Health Impacts of Climate Change: A Vulnerability Assessment

Peterborough Public Health

TECHNICAL REPORT | 2023

Peterborough Public Health

Land Acknowledgement

We respectfully acknowledge that we are on the Treaty 20 and traditional territory of the Mississauga Anishnaabeg. We offer our gratitude to the First Nations for their care for, and teachings about, our earth and our relations. May we honour those teachings.

Positionality Statement

In this assessment we refer to people who are experiencing poverty/low socioeconomic status, those with health conditions/mental health issues, Indigenous peoples, etc. as "vulnerable". It is important to recognize that these individuals have unique experiences and perspectives, possibly different than our own. As individuals working on this paper, we are aware of the power dynamics that exist between ourselves and those vulnerable populations. We recognize that our privileges and power may impact our work. We acknowledge that our education, socioeconomic status, and other social identities may give us advantage in certain situations. To address this, we will continually reflect on our own positionality and biases, and use our privilege to advocate for the needs and rights of those we are working with.

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Message From the MOH

Dr. Thomas Piggott, Medical Officer of Health and Chief Executive Officer

In 2009 the world's largest Medical Journal, The Lancet, wrote: "Climate change is the greatest global health threat facing the world in the 21st century, but it is also the greatest opportunity to redefine the social and environmental determinants of health."

This came as I was starting my career in public health, and I knew then that climate change would not be a future uncertainty to ponder, but an emergency that would require collective action and a whole-of-society response.

Fast forward more than a decade and we are now seeing in real-time how human behaviour is changing our environment in profound and irreversible ways. In my previous role as Medical Officer of Health in Labrador there have been profound changes to arctic sea ice impacting health over the past decade. Now even in Peterborough these impacts are here with record high temperatures, droughts, windstorms, flooding, and forest fires and smoke, all happening with increasing frequency and severity.

The detrimental health effects of these events are significant, and just as serious as the physical damage they cause. Yet, as the Lancet rightly noted more than a decade ago, responding to climate change should not be a burden, but an opportunity to reshape society to be healthier, happier, fairer, and more equitable.

Adaptation will be a journey, and reducing the negative health outcomes brought about by the climate emergency will require all of us to adapt. But, if necessity truly is the mother of invention, then it is time we also seize this opportunity to build a better, healthier, world.

This Climate Change Vulnerability Assessment is the first step in the journey towards adaptation at a local level. Our starting point in this journey is health equity, beginning with a detailed look at the factors that create and increase vulnerability to a range of climate hazards.

As our next step, we will look at what we – as a community – can do together to adapt to the impacts of a changing climate and warming world.

Executive Summary

Climate change is a threat to everyone and the health of our planet. People's health and well-being can be impacted by the changes to the climate and the environment, including locally in the Peterborough Public Health (PPH) region, which includes the County and City of Peterborough, Curve Lake First Nation, and Hiawatha First Nation.

PPH is required by Ontario's Ministry of Health to consider the health impacts of climate change and to assess the vulnerability of the populations served (Ontario Public Health Standards [OPHS], 2018). PPH has conducted this vulnerability assessment to understand the present and potential future impacts of climate change on the health of the people in the PPH region. The report also identifies vulnerable populations and the factors that can contribute to increasing a person's risk.

This assessment serves as a foundation to support further work that aims to reduce the health impacts of climate change in the community, helping to achieve other OPHS requirements that relate to reducing exposure to health hazards. This is referred to as climate change adaptation. Further, PPH's Strategic Plan for 2022 to 2025 identifies adaptation work related to climate change as a priority, with an emphasis on ensuring that those who are most vulnerable are supported in adapting to and reducing the negative health impacts of climate change.

Climate change refers to the long-term shift in the usual weather patterns of a region. The following climate-related health hazards (climate hazards) and health impacts were assessed:

- Extreme temperatures
- Extreme weather
- Food and water security and safety
- Vector-borne diseases
- Air quality
- Ultraviolet radiation

Climate hazards can be impacted by long-term shifts in weather patterns (i.e., temperature, precipitation, wind), increases in extreme weather, or both.

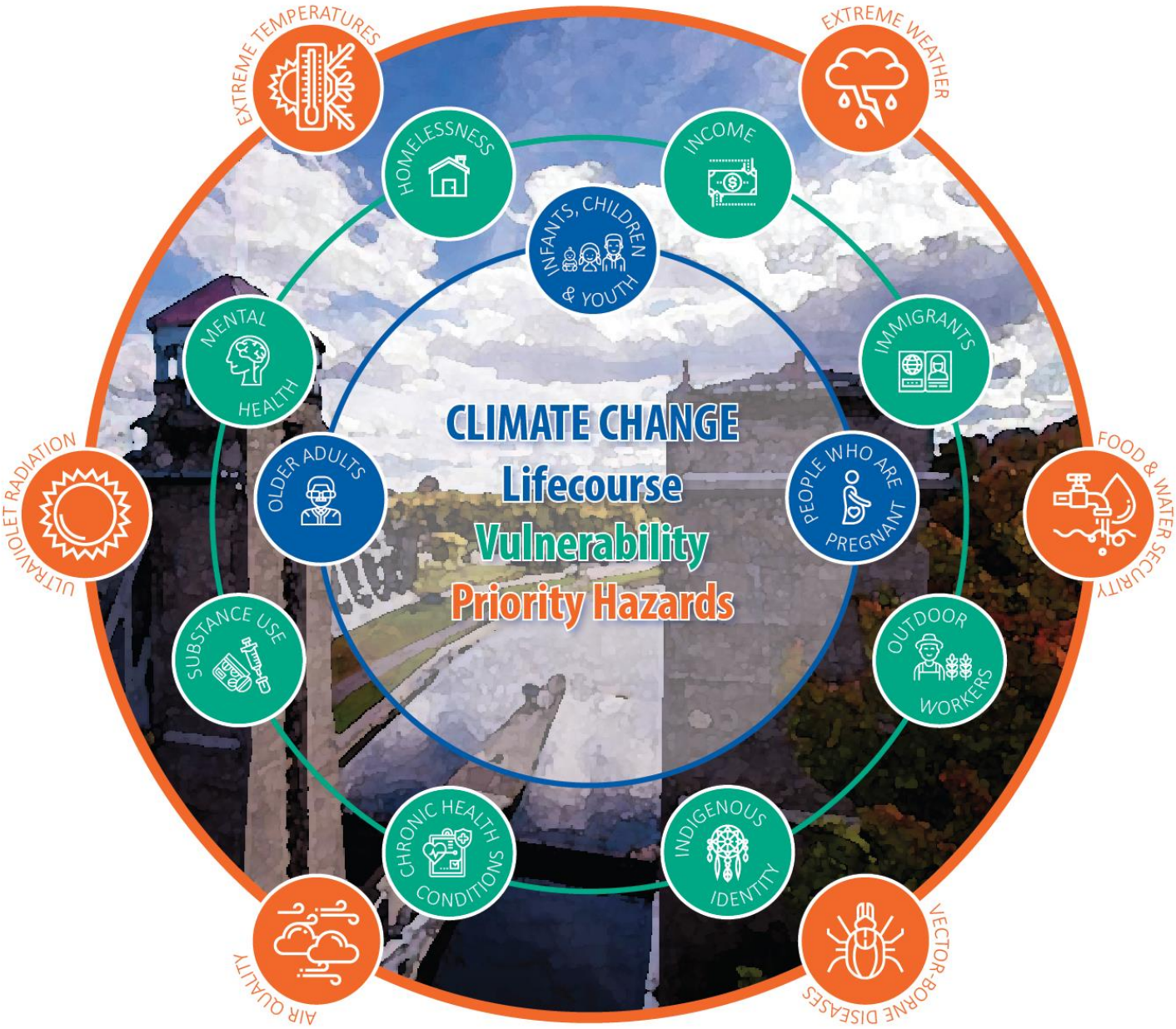
Vulnerability and Populations at Increased Risk of Adverse Health Impacts

While all people can be impacted by climate hazards, certain population groups are at increased risk (i.e., more vulnerable). Vulnerability may be experienced across the lifespan, where infants, children and youth, older adults and pregnant people may be more vulnerable to climate hazards. These vulnerable populations may be even more at risk if they are experiencing chronic health conditions, or life circumstances that limit their ability to prepare or respond to a climate hazard. These factors can be influenced by the social determinants of health (e.g., income, education, race/culture, stable housing, social connectedness, etc.).

Throughout this assessment vulnerable populations have been identified, with some notable populations highlighted in the blue and green icons in the diagram below. Vulnerability can depend on the specific climate hazard, but overall, some of the greatest vulnerability exists for those experiencing a combination of risk factors such as:

- Being very old or very young
- Living on a low income or not having enough money to adapt to climate hazards

- Living without safe, stable, or adequate housing
- Experiencing health conditions, including mental illness
- Facing barriers to social connection or access to appropriate supports and services



PPH recognizes that the concept of vulnerability may seem stigmatizing for those identified as vulnerable. The purpose of highlighting vulnerable groups is to prioritize adaptive actions and ensure that no one in our community gets left behind. Many of the groups mentioned in the report have the skills, knowledge, and ability to adapt to climate hazards in their own way.

Key Findings for Climate Hazards Presented in this Report:

Extreme Temperatures

- Projections show that the PPH region will experience significant increases in the number of days above 30˚C: increasing by four-fold by the 2050s (averaging 38 days per year) and increasing by almost eight-fold by the 2080s (averaging 71 days per year), under the fossil-fueled development scenario.[21]
- Health outcomes from this include heat-related illnesses and deaths, as well as exacerbation of health conditions such as heart and lung diseases, and mental illness.

Extreme Weather

- Climate change may lead to more extreme weather in the PPH region, such as extreme precipitation events, severe storms, and wildfires.
- Health outcomes from extreme weather (and/or related power outages) vary, but can include injuries, food and waterborne illnesses, mental health impacts, and can also impact mobility and access to health care.

Food and Water Security

- Climate change may negatively impact food systems, food safety and food security, through its impact on food production, processing, distribution, and consumption of food.
- Climate change contributes to increased food costs, which will have the greatest impact on people already worrying about running out of money for food. Household food insecurity is associated with poorer physical and mental health.
- Increasing temperatures and heavy precipitation events may adversely affect food and water safety by increasing the risk of exposure to pathogens.
- Health outcomes from exposure to contaminated food and water may include an increase in food and waterborne illnesses throughout the exposed population which may lead to the development of chronic conditions or death in some instances.

Vector-borne Disease

- Increasing temperatures, longer warm seasons, and changing precipitation patterns may lead to an increased risk of exposure to vector-borne diseases such as West Nile virus and Lyme disease. Emerging diseases may also be experienced locally due to expansions in tick and mosquito species geographic ranges.
- Health outcomes vary depending on the disease acquired and vulnerability factors. The risk of adverse health outcomes from emerging vector-borne diseases may be heightened due to more limited knowledge and understanding of these diseases, which can lead to delays in diagnosis and appropriate treatment or follow-up.

Air Quality

- PPH region may experience more instances of poor air quality due to extreme heat and extreme weather events (e.g., droughts and wildfires), and worsened allergy seasons.
- Health outcomes from this include exacerbation of asthma and other respiratory diseases, impacts on child development, increased respiratory and cardiovascular diseases, and premature death.

Ultraviolet Radiation (UVR)

- Extended warm seasons and warmer days are factors that may lead to people spending more time outdoors which increases their exposure to solar UVR.
- Health outcomes from excess exposure may include skin and eye cancers and cataracts.
- Skin cancers are caused mainly by exposure to UVR and are the most preventable cancers especially if protective measures (e.g., protective clothing, sunscreen, hat, sunglasses) are taken.

Mental Health

- Climate change is likely to have negative effects on the mental health and well-being of individuals and communities.
- Mental health outcomes can include the worsening of existing mental illnesses (e.g., depression), new mental illnesses such as post-traumatic stress disorder and mental health stressors (e.g., grief, worry, anxiety).

Climate Change Adaptation

Climate change cannot be halted in the near future, even if greenhouse gas emissions are significantly reduced. As such, it is vital that actions are taken to prevent the negative health impacts of climate hazards, especially of those who are most vulnerable. These actions are components of climate change adaptation and may be taken by all levels of society. Various PPH programs and services support adaptation to the health impacts of climate change, but collaboration is required to assess and support climate change adaptation across the community.

Next Steps:

- Share the report with key partners working in health and the environment and engage in activities to increase public and partner awareness.
- Conduct community and partner consultations to inform adaptation, programming, and policy.
- Continue to gather and report on relevant climate change and health information on an ongoing basis to improve our understanding of local health impacts.
- Work collaboratively with community partners to develop a community adaptation plan, with a goal of reducing the negative health impacts of climate change for the priority populations that we describe.
- Work with Indigenous communities, utilizing a two-eyed seeing approach.

Two-Eyed Seeing or Two-Eyed Knowing is learning to see the strengths of Indigenous knowledge and ways of knowing from one eye and the strengths of Western knowledge and ways of knowing from the other eye. Bringing together both ways of knowing will help to benefit everyone.

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Introduction

Climate Change and Health

Climate refers to the average weather patterns of a region over a long period of time (i.e., 30+ years).[1] Climate change is the long-term shift in the usual weather patterns of a region.[2] Over the last 100-150 years, the Earth's climate has been changing because of human and naturally caused warming, often described as global warming. A major human-caused contributor to global warming is the burning of fossil fuels (i.e., coal, oil and gas), which releases carbon dioxide into the atmosphere.[3] Carbon dioxide and other greenhouse gases such as methane and nitrous oxide trap heat in the atmosphere, which has resulted in unprecedented increases in average temperatures.[3] Subsequently this warming has intensified weather systems including the frequency of storms, seasonal variability, rising sea levels, changes to precipitation and more.[3]

These changes in temperature and precipitation, as well as levels of greenhouse gases in the air, are associated with various threats or "hazards" to human health. Climate-related health hazards (herein called "climate hazards") are often categorized as: extreme temperatures, particularly heat and heat waves, extreme weather events (e.g., intense rain or windstorms), food and water contamination, changes to food and water security, increased infectious diseases such as those carried by ticks and mosquitoes, reduced air quality and changes to ultraviolet (UV) radiation exposure.

Impacts on health due to climate change are variable and an individual or group's vulnerability is dependent on their exposure, sensitivity, and ability to adapt to a climate hazard:

- Exposure refers to contact between a person or group with a climate hazard.[3-5]
- Sensitivity refers to how individuals or population groups are more susceptible to the health impacts of a climate hazard. Sensitivity is impacted by physiology, biology, genetic endowment, gender, and age.[4,5]
- Adaptive capacity refers to the ability of individuals or population groups to prepare for, cope with, and recover from the consequences of climate hazards.[3-6]

Health-related impacts to climate change can include: dehydration and heat stroke, injuries from extreme weather events, food- and water-borne illnesses, issues with safety and access to food and water, illness from Lyme disease and West Nile virus, as well as other vector-borne diseases, exacerbation of lung diseases, heart disease and allergies, increased risk of skin cancer and mental health impacts from any of the challenges above.[3,7]

Climate change has been identified as the "the biggest global health threat of the 21st century",[27(p.1693)] and it is recognized that "the effects of climate change are being felt today and future projections represent an unacceptably high and potentially catastrophic risk to human health".[32(p.1861)] Our collective response to climate change has the potential to significantly impact human health as much of the work and policies needed to fight climate change will also improve health, lower healthcare costs and improve equity and community connectedness.[8]

Peterborough Public Health (PPH) is required by Ontario's Ministry of Health to consider the health impacts of climate change and to assess the local needs of the populations served.[9] In addition, as outlined in PPH's 2022-

2025 Strategic Plan, climate change was identified as an issue of public health importance with a goal that, "People most vulnerable to the health impacts of climate change are supported in adapting to and reducing negative health impacts".[10(p.6)]

To adequately address climate change, two approaches are required – mitigation and adaptation. Mitigation refers to approaches aimed at reducing the levels of greenhouse gases in the atmosphere, often by way of reducing greenhouse gas emissions.[11] Adaptation refers to approaches aimed at reducing the negative impacts of climate change.[11] While both are important to consider, PPH, in collaboration with relevant stakeholders, is focused on supporting community adaptation planning over the next several years, beginning with this vulnerability assessment report. Subsequent adaptation work will incorporate both a two-eyed seeing approach to include an Indigenous lens and a One Health or Planetary Health approach, in which cross-sector action, communication and partners work together to achieve better public health outcomes by optimizing the health of humans, animals, plants, and ecosystems.[3,12]
The main objectives of this vulnerability assessment were to:

1. Determine who in the community is most vulnerable to the health impacts of climate change;
2. Provide relevant baseline health data; and
3. Present information that can be used to develop climate change adaptation strategies for the PPH region based on local need.

PPH viewed this work as a great opportunity to assess the need and enhance public health capacity to address local risk factors associated with climate change and protect the health of PPH residents. The assessment is intended to assist the health unit and community partners to create effective and meaningful climate change adaptation measures for the PPH region which includes Curve Lake and Hiawatha First Nations and the County and City of Peterborough. Exploring climate change impacts and opportunities to adapt for Indigenous Communities is important, and beyond the scope of this report. Indigenous-led and two-eyed seeing approaches are needed to learn about impacts and potential adaptive actions for Curve Lake and Hiawatha First Nations, and Indigenous people living in the County and City of Peterborough. Based on recommendations from PPH's Indigenous Health Advisory Circle, PPH is currently exploring opportunities for engagement with local Indigenous communities and learnings will be incorporated into future adaptation assessments.

Two-Eyed Seeing or Two-Eyed Knowing is learning to see the strengths of Indigenous knowledge and ways of knowing from one eye and the strengths of Western knowledge and ways of knowing from the other eye. Bringing together both ways of knowing will help to benefit everyone.[55]

Methodology

Peterborough Public Health (PPH) referred to the 2016 Ontario Climate Change and Health Toolkit, particularly the Vulnerability and Adaptation Assessment Guidelines[13] for completion of this report. These guidelines were developed by the Ministry of Health and Long-Term Care to support public health units in Ontario with the completion of local climate change and health vulnerability and adaptation assessments. This report focuses on the first three steps of conducting a vulnerability and adaptation assessment, including:

1. Frame and Scope of the Assessment
2. Describe Current Risks Including Vulnerabilities and Capacities
3. Project Future Health Risks

The work on the PPH climate change and health vulnerability assessment began in 2019. However, the work was put on hold between March 2020 and August 2022, during PPH's response to the COVID-19 pandemic. The resumption of the work in September 2022 was supported by the requirement to conduct a vulnerability assessment according to the Ontario Public Health Standards, as well as the inclusion of relevant climate change adaptation goals and objectives in PPH's 2022-2025 Strategic Plan.[10] An internal multidisciplinary team was relied upon to bring insight, expertise, and links to community partnerships for the completion of the assessment, including representation from health promoters, public health nurses, public health inspectors, and registered dietitians, with support from epidemiologists, communications/graphics design, and administrative assistants. A workplan and communications/engagement plan were developed to support the project.

Assessment Scope and Process

The vulnerability assessment was centralized around six climate hazards identified based on the Ontario toolkit, literature, and local needs: extreme temperatures, extreme weather events, food and water security and safety, vector-borne disease, air quality, and ultraviolet radiation.
This report describes climate hazards that have the potential to impact health outcomes in our community through analysis of:

- Historical climate trends and the occurrence of climate hazards and health impacts,
- Future climate change projections,
- Populations at increased risk (i.e., vulnerable) to current and future health impacts, and,
- Current adaptive capacity actions undertaken by PPH, which contribute to protecting health.

Geographic Scope

This report focuses on the geographic region served by Peterborough Public Health (PPH), which encompasses the City of Peterborough, Peterborough County (including eight lower-tier municipalities), and two First Nation communities: Curve Lake First Nation and Hiawatha First Nation. When data is presented, the applicable geography will be outlined, where "PPH region" includes the full geographic region served by PPH (where possible; data from First Nation communities is not available from all data sources), and "Peterborough Census Metropolitan Area (CMA)" includes the City of Peterborough, the municipalities of Selwyn, Cavan-Monaghan, Douro-Dummer, and Otonabee-South Monaghan, and Curve Lake and Hiawatha First Nations.

Hazard and Health Outcomes Scope

This assessment focuses on the impacts of local climate hazards on community health outcomes. While climate change may cause global issues that can impact local communities (e.g., conflict and mass migration), this is outside of the scope of the report. The potential for climate change to negatively impact certain industries (e.g., snow-based recreation, campgrounds) and the livelihoods of owners/operators is also outside of the scope of this assessment.

Climate Timeframes and Scenarios

It is important to consider 30 years of climate data for describing trends or changes. The indicators of climate change in this report will be described, where applicable, using the following time frames for current and future local climate conditions:

- Baseline (historical reference): 1981 to 2010
- 2050s: 2041 to 2070
- 2080s: 2071 to 2100

The climate scenarios used for this assessment are based on a set of Shared Socio-economic Pathways (SSPs), which were used in the latest assessment reports (AR6) released by the Intergovernmental Panel on Climate Change (IPCC).[14] The report team considered both the SSP2-4.5 ("Middle of the Road") scenario and SSP5-8.5 ("Fossil-fueled Development") scenario, though SSP5-8.5 may be highlighted in some instances to simplify the amount of information presented.

Indicators

Climate, health, and population indicators were determined based on suggestions from the Ontario toolkit, as well as from looking at similar assessments completed in other regions in Ontario. Decisions to access and analyze data required consideration of project timelines, allocated resources, and assigned priority level of each indicator.

Several data sources were used for this report:

Climate and Hazard-Related Data

Historical and Projected - ClimateData.ca

- ClimateData.ca was relied upon for much of the climate indicators relating to temperatures and precipitation. The platform makes it possible to visualize and download climate data for health regions (e.g., PPH) according to the selected timeframes of this report. More information can be found at climatedata.ca/about/

Other Historical

- Hazard-related surveillance and alert data was accessible:
    - Internally at PPH:
        - heat warnings and frostbite alert data
        - beach testing
        - vector (tick and mosquito) surveillance
    - Externally (publicly available or via consultation):
        - Otonabee Regional Conservation Authority (ORCA) (flood and low water warnings)
        - Air Quality Ontario (Ministry of the Environment, Conservation and Parks)
- Other historical climate data was compiled by accessing records of extreme weather events from sources like the Canadian Disaster Database and local sources, including newspaper articles.

Mapped climate hazards for PPH region were accessed from external sources (See their website for more information on methodology and data sources):

- Université Laval (extreme heat, vaguesdechaleur.ffgg.ulaval.ca)
- HealthyPlan.city (canopy cover (relates to extreme heat), healthyplan.city)
- ORCA (floodplain, www.otonabeeconservation.com/programs/floodplain-mapping/)

Other Projected

- Any other projected climate-related data came from peer-reviewed literature or government reports.

Population and Health-Related Data

Local population data provides community context and was also included for the purpose of highlighting and quantifying vulnerability-related factors in the PPH region. Health data was used to highlight vulnerability as well as representing the health burden of a climate hazard in the PPH region.

Local population and health data were sourced from:

- Statistics Canada
  - Census of Population
  - Census of Agriculture (via Ontario Ministry of Agriculture, Food and Rural Affairs – business, agri-food, and farm data profile for Central - Peterborough)
  - Population Estimates and Projections (with Ontario Ministry of Finance)
- Population-based surveys (e.g., the Rapid Risk Factor Surveillance System, Canadian Community Health Survey, Households and the Environment Survey)
- Institute for Clinical Evaluative Sciences (ICES)
  - Chronic disease cohorts
  - Estimating the size of the population at increased risk for health-related problems due to poor air quality
- Better Outcomes Registry & Network (BORN) Ontario
- Office of the Chief Coroner, Ontario
- Peterborough County-City Paramedics - Paramedic calls for service
- Ontario Health (Cancer Care Ontario), Surveillance and Cancer Registry - Ontario Cancer Registry SEER*Stat package
- Peterborough Public Health - Ontario Nutritious Food Basket data
- Integrated Public Health Information System (iPHIS)
- National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI) - Emergency department visits
- Ontario Climate Change and Health Modelling Study: Report

The project team also relied on information collected by other local community partners (e.g. Peterborough Community Safety and Well-being Plan, United Way Point in Time count) and government reports.

Mapped population data utilizes census data by dissemination area. The data can be presented on its own (individual variable or a multi-variable “index”), or overlaid with climate hazard-related data. This assessment includes mapped population data from the following sources:

- Public Health Ontario, Ontario Marginalization Index (www.publichealthontario.ca/en/Data-and-Analysis/Health-Equity/Ontario-Marginalization-Index)
- Université Laval (vaguesdechaleur.ffgg.ulaval.ca)
- HealthyPlan.city (healthyplan.city)
- Public Health Ontario - Per cent of the population exposure to Traffic Related Air Pollution by public health unit, Ontario, 2011 (data is not presented in a mapped format but was prepared using census data)

See the source for more information on methodology and data source(s).

Data Extraction Process and Limitations to Data

More information on these data sources and extraction processes is available in Appendix A. Additional details are available upon request.

There are limitations to all data sources. Some limitations are outlined in Appendix A.

External Engagement

An External Advisory Group was convened to provide subject matter expertise and overall guidance and advice in the development of this first assessment report. The Group includes representatives from the City of Peterborough, the County of Peterborough, Selwyn Township, Curve Lake First Nation, Hiawatha First Nation, Métis Nation of Ontario – Peterborough & District, Otonabee Region Conservation Authority, Sustainable Peterborough, Trent University, Fleming College, Sustainable Peterborough, Peterborough Regional Health Centre, and a youth representative.

Additional external engagement was conducted to inform content related to food security and food systems. A Masters of Public Health nutrition student and PPH Registered Dietitian co-facilitated a *Food and Climate Change Consultation Meeting* on May 25, 2023, with interested members from the Peterborough Food Action Network and Peterborough Alliance for Food and Farming.

Internal Assessment of PPH Programs Contributing to Adaptation

An internal process engaging PPH management was conducted to identify the current PPH program activities that contribute to climate change adaptation. A summary of these actions are listed at the end of each hazard chapter, organized under categories of core public health functions.

Community Context

Geography and Population Demographics

The PPH region is located in central east Ontario, covering an area of 3,779 square kilometres.[15] The city of Peterborough is located centrally within the region, surrounded by eight townships that make up the County of Peterborough. Two First Nations communities are also located in the PPH region.

Figure 3-1. *Map of Peterborough Public Health Region Showing Single- and Lower-Tier Municipalities and First Nations Communities.*

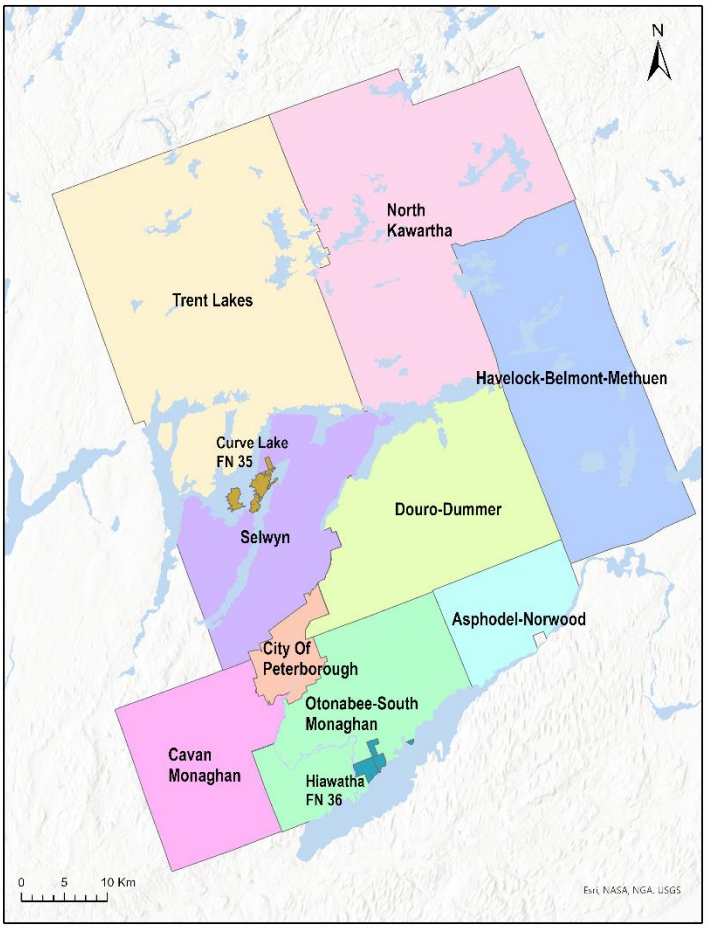


Figure author: Peterborough County, 2023 (Created for this report).

The region's geography has several interesting features. The northernmost section is located on the Canadian Shield and is quite forested, with many lakes dotting the region. This area is more sparsely populated than the southern two-thirds of the region, which includes the City of Peterborough as well as numerous rural communities of various sizes.[16] Outside of the City of Peterborough, farms are common, taking up much of the landscape.[16]

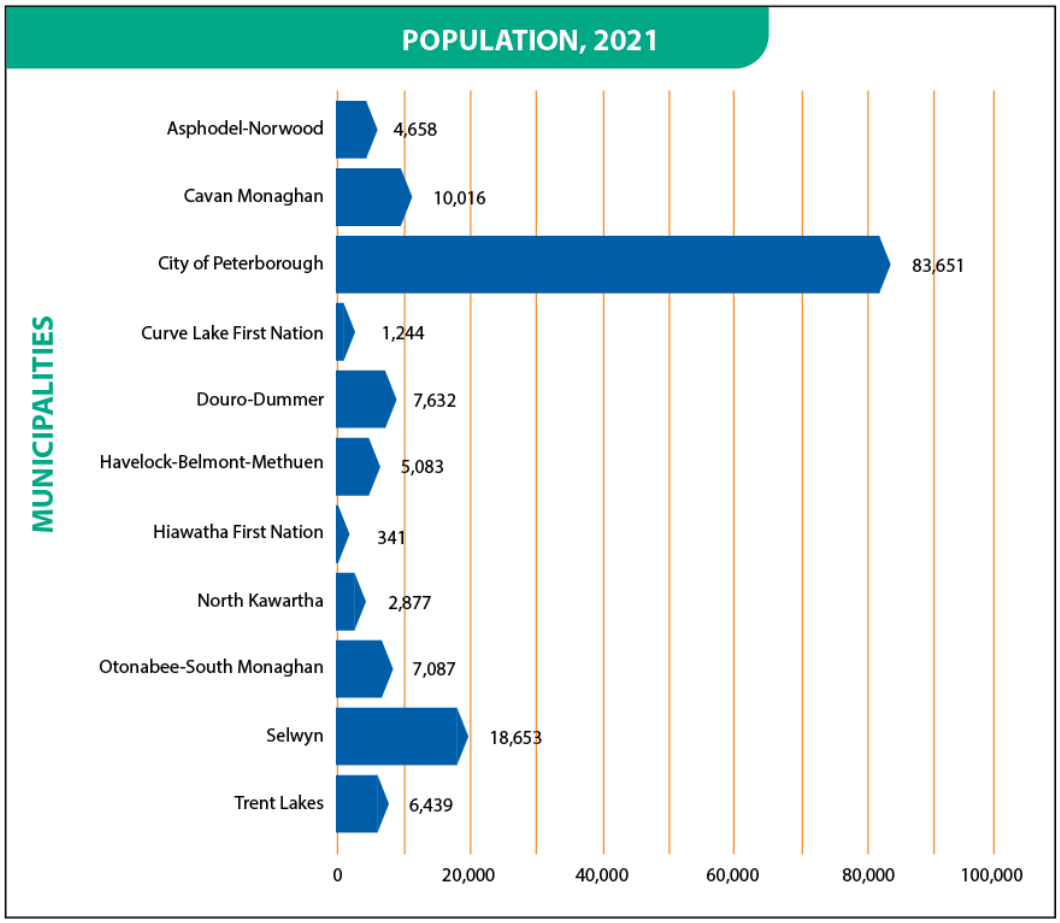
Based on 2021 census data, the City of Peterborough is 65 square kilometres, with a population density of 1,292 people/km^2, as compared to 17 people/km^2 in the County of Peterborough[a].[15] The populations of the City and County[a] are 83,651 and 64,030, respectively.[15] The County has five population centres (i.e., areas that have a population of at least 1,000 individuals, and a population density of 400 persons or more per square kilometer). These include Bridgenorth-Chemong Park, Lakefield, Millbrook, Norwood, and Havelock.[17] Of the

[a] This statistic includes Curve Lake and Hiawatha First Nations for ease of comparison

total PPH population, 64.5% live in urban areas (i.e., within a population centre) and 35.5% live in rural areas.[17] PPH serves an estimated seasonal population size of over 20,000 individuals with over 90% of the seasonal population residing within five municipalities (Trent Lakes, North Kawartha, Havelock-Belmont-Methuen, Selwyn and Douro-Dummer).[a]

Peterborough is considered a mid-sized city.[18] Unlike other cities west of Peterborough including Oshawa and Bowmanville, Peterborough has not historically experienced the sprawl from the Greater Toronto Area.[19] Population growth has been moderate, though Peterborough has established itself as a great place to call home for recreationists, families, students, professionals in various industries, and for older adults.[18]

Figure 3-2. *Population Sizes of Municipalities and First Nations Communities in PPH Region.*

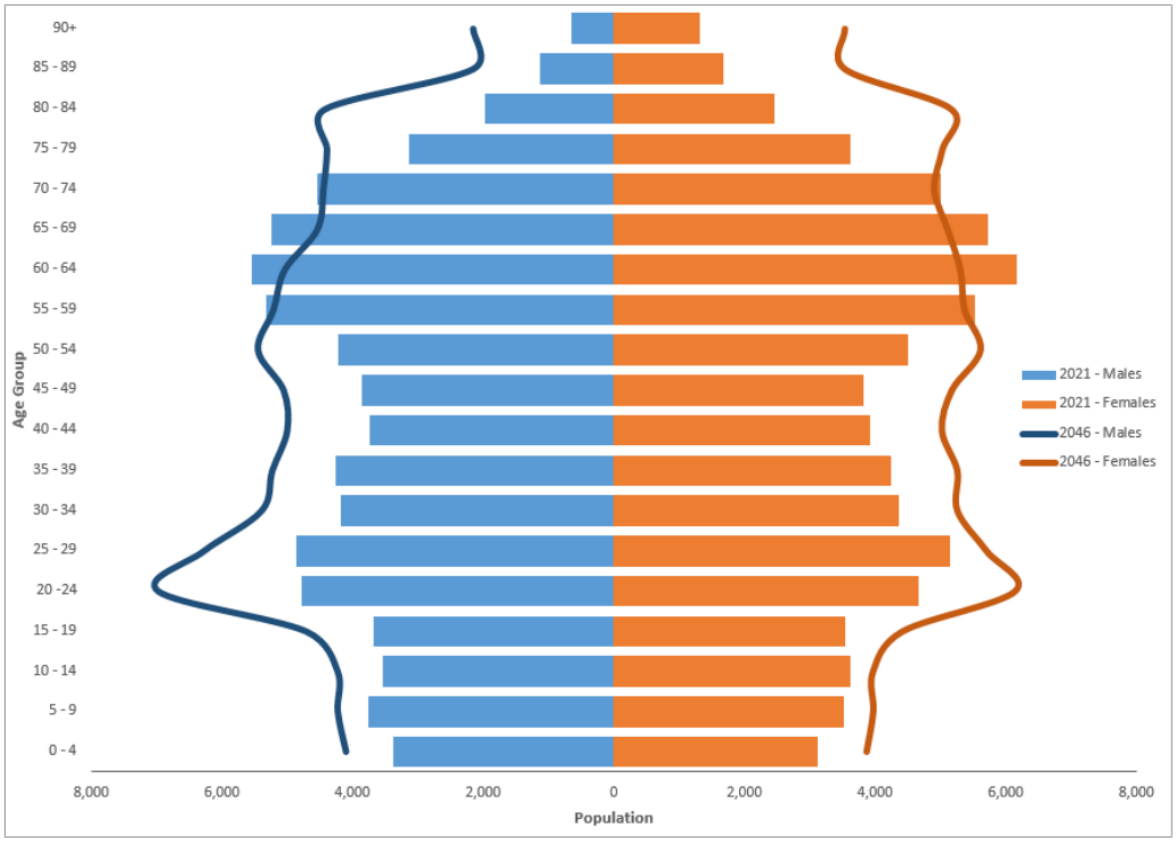


Source: Census of Population, 2021 (Statistics Canada).

PPH's 2021 population by age and gender is shown in the population pyramid below. The bars represent the 2021 population and the number of people in each 5-year age group, where there are notable bulges for the "baby boomer" generation aged late-50s to early 70s, as well as a smaller bulge coinciding with their children. The lines represent the projections for the age groups in the year 2046. Peterborough is known for having a high percentage of older adults with 24.7% of the population aged 65 years or older, compared to the Ontario average of 18.1%.[15] Over the next 25 years, we will see greater numbers of residents aged 75 years or older as the "baby boomer" generation continues to age. The 65+ age group is projected to increase by 13% by 2046, reaching 27.9% of the PPH population. In addition to shifts in age trends, the overall population of the PPH region is expected to grow by 24% between 2021 and 2046, increasing to over 183,000 people.

[a] Seasonal population is calculated from census data, based on the number of private dwellings that are not occupied by usual residents, and the average household size of private dwellings occupied by usual residents.

Figure 3-3. *Population Pyramid for the PPH Region in 2021 (Bars) and Projected for 2046 (Lines).*



Sources: 2021 population: Population Estimates County/Municipality (Statistics Canada), Ontario Ministry of Health: IntelliHealth Ontario. Extracted: April 2023.
2046 population: Population Projections County (Statistics Canada & Ontario Ministry of Finance), Ontario Ministry of Health: IntelliHeath Ontario. Extracted: April 2023.

Additional population demographics for PPH region, compared to the Ontario average, are presented in Table 3-1.

Table 3-1. *Population Demographics for PPH Region vs Ontario in 2021.*

Population Demographic	PPH Region	Ontario
English- or English and French-speaking population	99.7%	97.3%
Neither English nor French	0.3%	2.4%
Indigenous identity	4.9%	2.9%
First Nation	3.3%	1.8%
Métis	1.3%	1.0%
Visible minority	6.6%	34.3%
Immigrant	8.7%	30.0%
Immigrant since 2011	1.5%	7.5%
Median after-tax household income ($)	70,500	79,500

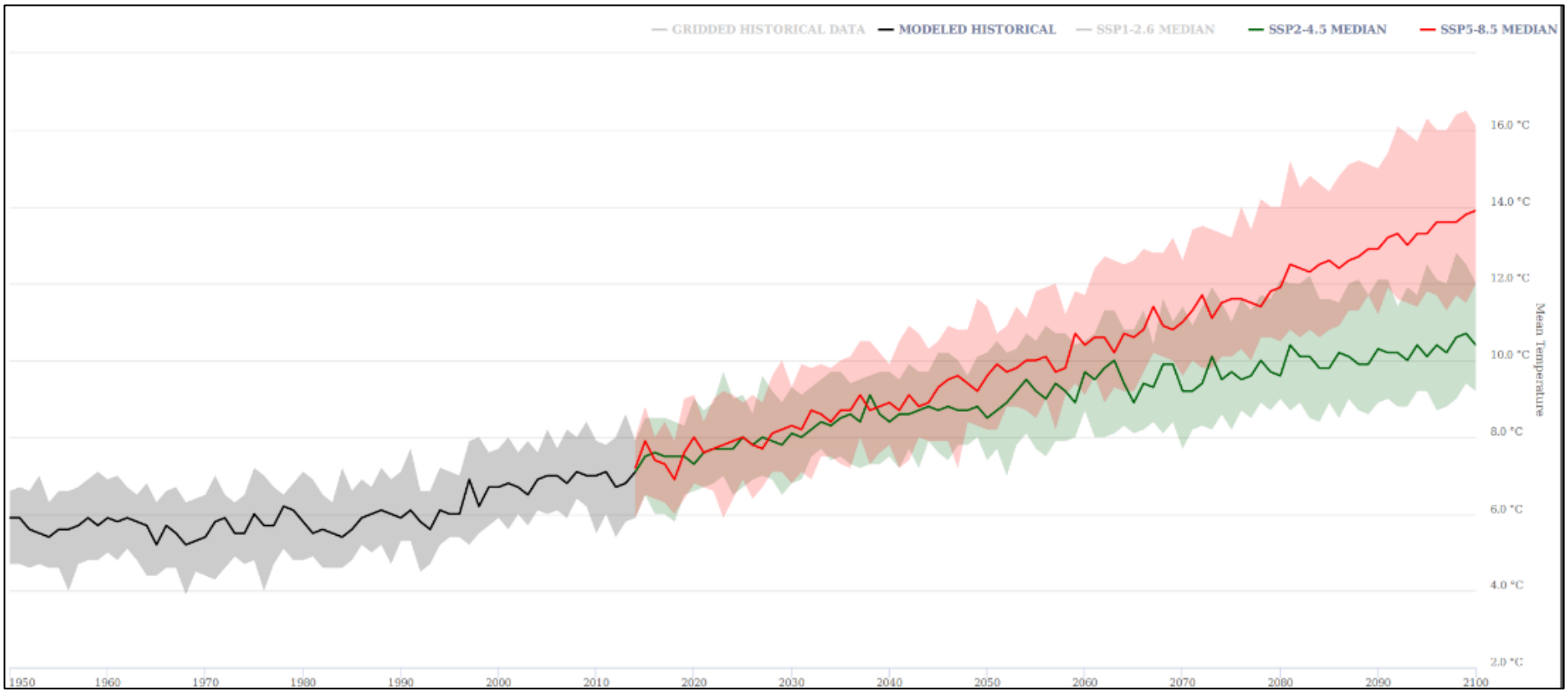
Source: Census of Population, 2021 (Statistics Canada).[15]

Climate

The PPH region has a moderate humid continental climate.[20] PPH's region experiences all four distinct seasons with large seasonal temperature differences which result in warm to hot, often humid summers and cold winters.

The climate of the PPH region has shifted in recent decades and is projected to change even more in the coming decades. As an example, the annual mean temperatures for the PPH region over time are shown in Figure 3-4. The black line represents historical mean temperatures (ensemble mean, modelled from historical values) from 1950 to 2013, and an increase over time can be seen. From 2014 to 2100, projections for annual mean temperature are modelled according to two climate scenarios shown with different coloured lines. The annual mean temperature is projected to increase above historical averages under both scenarios. Additional information about climate scenarios is provided in the text box on the following page.

Figure 3-4. *Annual Mean Temperature (°C) for PPH Region from 1950 to 2100 (1950-2013: Modelled Historical Values, 2014-2100: Two Climate Scenarios (SSP2-4.5, SSP5-8.5)).*



Source: ClimateData.ca, 2023.[21] Shaded areas show the range in values of the climate model ensemble (defined as the 10th and 90th percentile).

Climate Scenarios

Climate modelling is an important part of climate science and images like those in Figure 3-4 have become a common way of communicating the potential changes to climate variables like temperature and precipitation (i.e., rain and snow) over time. The best practice is for multiple climate models to be considered, where an ensemble mean is presented, and not use one model in isolation.[22]

In 2023, ClimateData.ca incorporated updated model data to CMIP-6, which are based on Shared Socio-economic Pathways (SSPs). According to ClimateData.ca, "[t]hese models make assumptions of how population, education, energy use, technology – and more – may change over the next century, and couple them with assumptions about the level of ambition for mitigating climate change" and "SSP-based scenarios further refine the previous greenhouse gas concentration scenarios known as Representative Concentration Pathways(RCPs)." [14]

While there are five "families" of SSPs with multiple emissions scenarios in each, ClimateData.ca currently hosts projections based on three scenarios: SSP1-2.6, SSP2-4.5, and SSP5-8.5.

SSP5-8.5

5 = SSP Family

8.5 = Radiative Forcing Value (relates to greenhouse gas emissions)

Briefly, these scenarios represent the following:[14,23,24]

- **SSP1-2.6** - This is a "Sustainability" scenario where global greenhouse gas emissions are cut severely. *This scenario is not a focus in this report.*
- **SSP2-4.5** - This is a "**Middle of the Road**" scenario where global carbon dioxide (CO_2) emissions remain about the same as they are currently before starting to drop mid-century.
- **SSP5-8.5** - This is a "**Fossil-fueled Development**" scenario where we see development continue to be fueled by fossil fuels, leading to a doubling of current CO_2 emissions by 2050 (SSP5-8.5).
  ~ These scenarios are an ensemble of 26 or more individual climate models.[25]

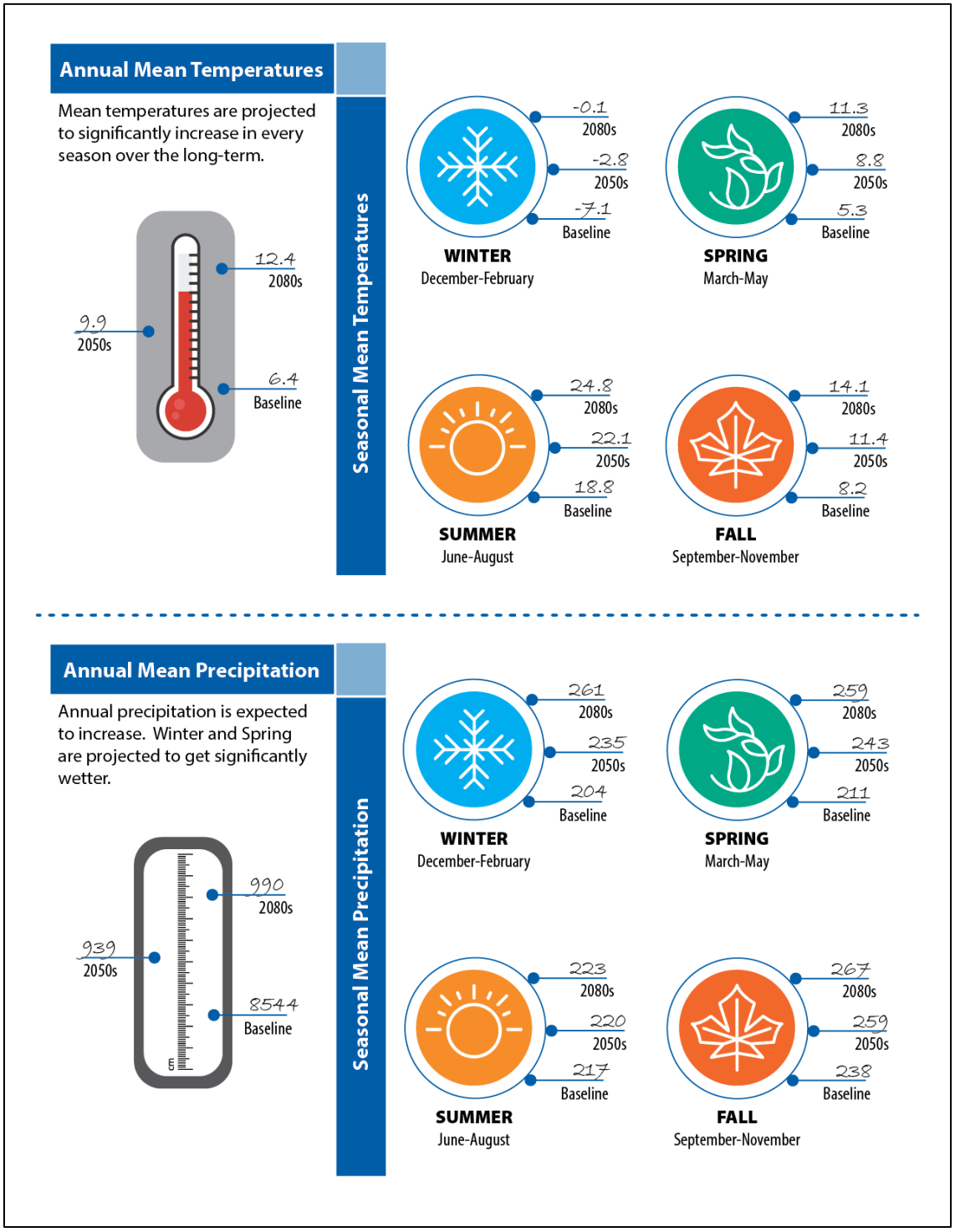
As described in the Methodology, the scope of this report will focus on comparing projections of select climate variables using SSP2-4.5[a] and/or SSP5-8.5 during the time periods:

- "2050s" = 30-year average between 2041-2070 and
- "2080s" = 30-year average between 2071-2100, and comparing them to the
- "Baseline" values = 30-year average between 1981-2010

[a] In order to simplify some information presented, the SSP2-4.5 scenario is not always fully outlined or shown visually, but details can be found in Appendix B.

Changes to the temperature and precipitation levels throughout the year are related to the climate hazards that will be presented in this report. Climate hazards can be impacted by long-term shifts in weather patterns (i.e. temperature, precipitation, wind), increases in extreme weather, or both. While projected shifts in the frequency of climate "extremes" are presented in the relevant subsequent chapters, projections for select climate variables relating to shifts in average temperatures and precipitation levels are shown below.

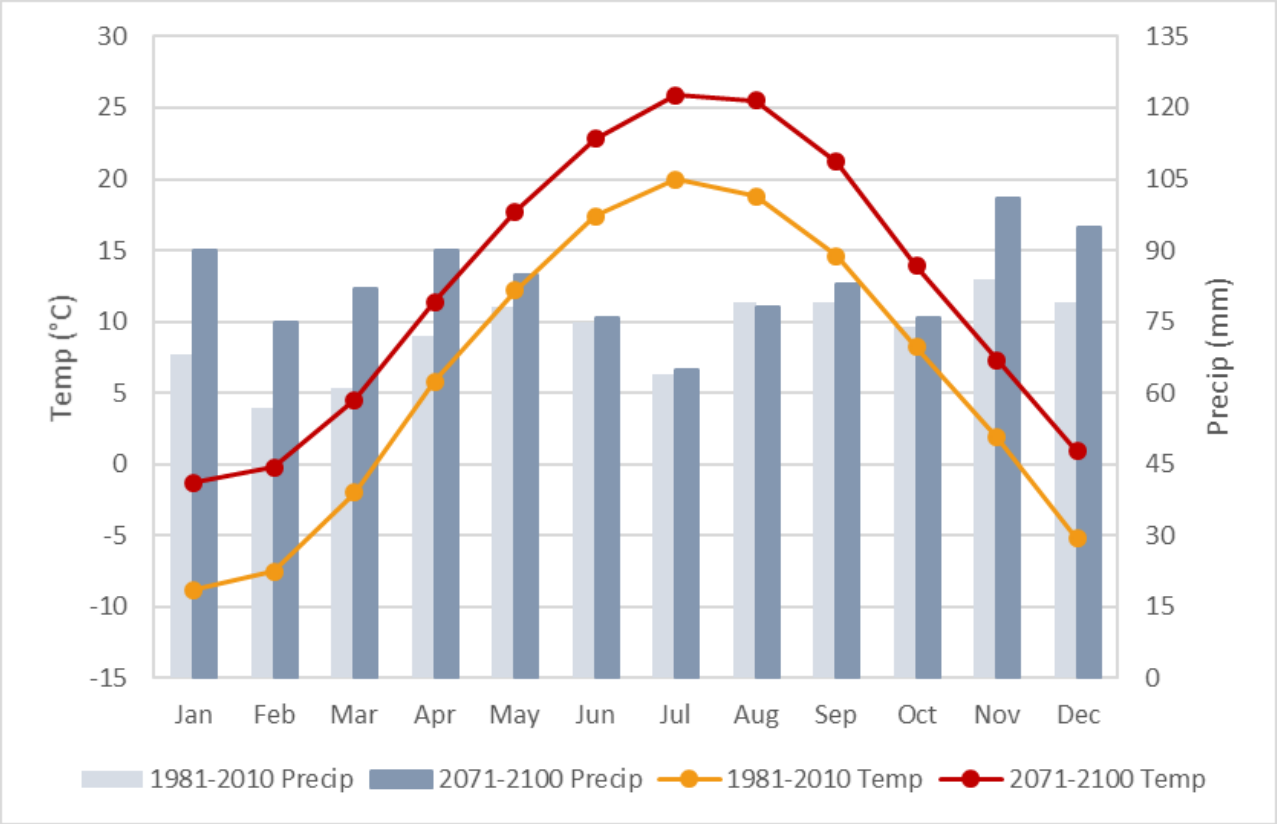
Figure 3-5. *PPH Region Mean Annual and Seasonal[a] Temperature (°C) and Precipitation (mm), from Baseline (1981-2010) to the 2050s (2041-2070) and 2080s (2071-2100) Under the Fossil-Fueled Development Scenario (SSP5-8.5).*



Source: ClimateData.ca, 2023.[21]

[a] Here and in rest of the report, seasonal data uses the standard climatological definitions for seasons: Winter = December / January / February; Spring = March / April / May; Summer = June / July / August; Fall = September / October / November

Figure 3-6. *PPH Region Climograph (Monthly Mean Temperature °C (Lines) and Total Precipitation (mm) (Columns)), Displaying Median Values for Baseline (1981-2010) and 2080s (2071-2100) Under the Fossil-Fueled Development Scenario (SSP5-8.5).*



Source: ClimateData.ca, 2023.[21] Temp=temperature, Precip=precipitation.

It is projected that the average seasonal temperatures will be 2.4-3.5°C warmer by the 2050s. By the 2080s, average temperatures may be 3.6°C warmer based on the Middle of the Road scenario, or 6°C warmer based on the Fossil-fueled Development scenario. Annual precipitation is anticipated to increase, most notably in winter, spring and fall between November and April.[21]

The 2080s are only about 60 years away. Children today may be grandparents. The children of today will be seniors in the 2080s, coping with the health impacts of changes to the climate outlined in this report.

The warming temperatures coincide with a longer frost-free season and a shorter winter season. By the 2080s, under the Fossil-fueled Development scenario it is expected the last spring frost will occur 3 weeks earlier, in mid-April instead of the baseline average of May 7th. The first fall frost will come a full month later in early November instead of early October. In the winter, the number of "ice days" (where the temperature does not go above 0°C) will decrease from an average of 69 days to an average of 22 days each year under the Fossil-fueled Development scenario.[21]

Table 3-2. *Frost-Related Climate Variables for PPH Region Showing Baseline Values and Projections in the 2080s Based on a Fossil-Fueled Development Scenario.*

Variable	Baseline (1981-2010)	2080s under SSP5-8.5 scenario
Last spring frost date	May 7	April 14
First fall frost date	Oct 3	Nov 3
Ice days (# days temperature does not go above 0°C)	69 days	22 days

Source: ClimateData.ca, 2023.[21]

The bottom line is that in either of the considered scenarios, PPH's local climate will continue to change, which will have health impacts on our communities, specifically, those who are most vulnerable to the health impacts of climate change. This will be discussed in more detail throughout this report.

What are the opinions of PPH residents on climate change?

In 2019, a telephone survey was conducted exploring local public opinions on climate change. Respondents were residents of PPH region and aged 18 years or older. The results from the survey are presented below, with more details provided in Appendix C.

- 95% of respondents agree that the world's climate is changing.
- 90% of respondents think it is likely that climate change will cause more frequent and severe heat waves.
- 89% of respondents think it is likely that climate change will cause more extreme weather such as flooding, ice storms or heavy snowstorms.
- 86% of respondents think it is likely that climate change will cause more days with poor air quality or smog.
- 80% of respondents think it is likely that climate change will result in more insects carrying diseases such as West Nile virus and Lyme disease.
- 19% of respondents think the overall health impacts of climate change on human health will be positive, 64% think the health impacts will be negative, 12% said both positive and negative, and 5% were unsure.
- 91% of respondents are concerned about climate change.

Source: Rapid Risk Factor Surveillance System (RRFSS), 2019.

Vulnerability

Everyone in the PPH region is vulnerable to the health risks of climate change. However, climate change hazards are not experienced equally as some individuals, populations and communities may be affected more than others and the ability to adapt varies. Understanding vulnerability can help identify the resources needed and the adaptation strategies necessary currently and in the future.[26]

Vulnerability to climate change can be considered at various levels. For the purpose of this report, vulnerability will be considered at the individual and population group level, as opposed to systems or organizational levels. The working definitions used for considering vulnerability and components of vulnerability in this report are listed below:

> **Vulnerability** refers to the increased risk of health impacts on individuals, populations and communities relating to their ability to cope or adapt to a changing climate. It is influenced by the degree of exposure, sensitivity, and adaptive capacity.[3-5]
>
> **Exposure** is contact between an individual or population group with a climate hazard such as a very hot day or a flood.[3-5] Exposure can be random, but it can also relate to factors like occupation, geographic location, housing circumstances, and other social determinants of health (SDOH).[3,5]
>
> **Sensitivity** is how individuals or population groups are more susceptible to the health impacts of a climate hazard. Sensitivity is impacted by physiology, biology, genetic endowment, gender, and age.[4,5]
>
> **Adaptive capacity** is the ability of individuals or population groups to prepare for, cope with, and recover from the consequences of climate hazards.[3-6] Adaptive capacity can be impacted by factors such as income, education, knowledge of official languages, community connectedness, and relevant policies and programs.[3,5,6]

Identifying Populations at Increased Risk of Health Impacts

PPH recognizes that the concept of vulnerability in this report may be stigmatizing. Identifying individuals and population groups who may be at increased risk or factors that may increase vulnerability does not mean that they do not have the skills, knowledge, and the ability to contribute to adaptation or that they have not been adapting already. Many people and populations experiencing climate hazards have been and continue to demonstrate adaptive capacity and resilience despite experiencing unequal distribution of resources and capacity.[28] Though this report is a vulnerability assessment for the community, subsequent chapters will refer to populations at increased risk of health impacts from specific climate hazards. PPH is specifically highlighting these groups to inform adaptive actions and ensure that no one in our community gets left behind. Climate vulnerability can occur when **inequity** influences adaptive capacity to climate hazards, and ultimately health.[3,29] Health inequities refer to the differences in health because of social, economic and environmental conditions; and power imbalances which are systemic, modifiable and unfair.[30,31] When assessing climate change and health, it is important to understand how multiple inequities can interact and may compound experiences and reactions to climate change.[5] Recognizing multiple inequities is an intersectional approach which can help with understanding vulnerability.[28] Vulnerability can also be influenced by social determinants of health (SDOH)[3,33] which are major drivers of health inequities. SDOH are the circumstances in which people are born, grow up, live, and work.

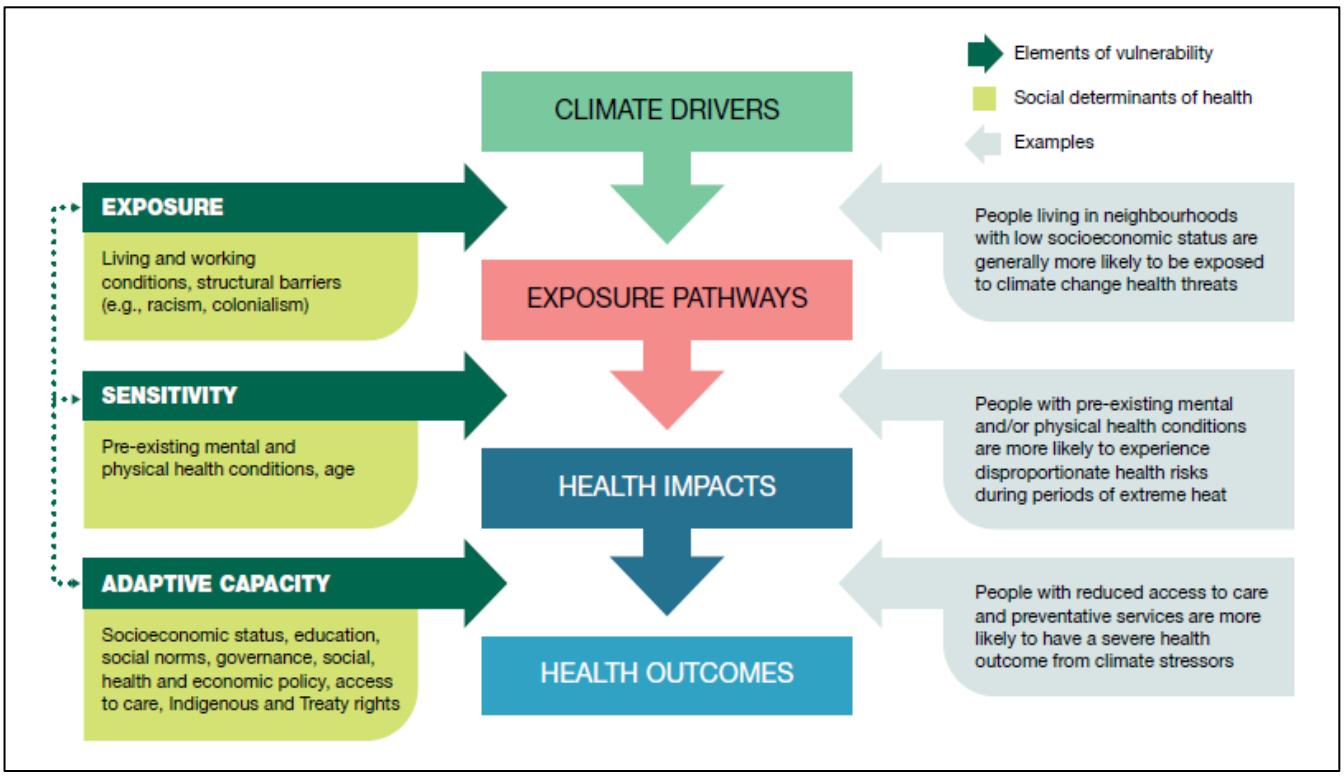
PPH is specifically highlighting these groups to inform adaptive actions and ensure that no one in our community gets left behind.

Examples of SDOH are:

- Geography
- Age
- Personal health practices and resiliency
- Early child development
- Household food insecurity
- Access to health services
- Housing
- Immigration
- Sexual orientation; gender identity and expression
- Experience of colonization
- Education /literacy and skills
- Culture/ethnicity/race and experience of racism
- Social inclusion/exclusion/social support networks
- Disability
- Income
- Employment/job security and working conditions
- Built environments
- Living conditions

These determinants may positively or negatively influence health risks and the ability to adapt to the changing climate.[3,6,34]

Figure 4-1. *The Relationship of Social Determinants of Health and Climate Vulnerability.*



Source: Public Health Agency of Canada. Mobilizing Public Health Action on Climate Change in Canada: The Chief Public Health Officer of Canada's Report on the State of Public Health in Canada; 2022, p26 (Adapted from U.S. Global Change Research Program. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment; 2016).[3,35]

Other factors that can influence vulnerability include:

- Living in rural, urban, and suburban communities, with various risk factors for each geographical distribution
- Being underinsured or uninsured
- Living in high-risk geographic environments (e.g., floodplains)[3]

Adapting to climate change means identifying who may be at risk and addressing both the health impacts and the root causes of health inequities and vulnerabilities.

The table below highlights: **Populations at risk across the life span,**
Factors that can influence vulnerability and adaptive capacity, and
PPH underserved populations at risk of climate hazards.[3,35–38]

Included in the table are PPH regional trends. In subsequent chapters, we will highlight population groups that are particularly at risk of the health impacts of the specific climate hazards**.**

Table 4-1. *Vulnerability to Climate Hazards*

Populations at Risk Across the Life Span	Vulnerability to Climate Hazards	PPH Regional Trends
Infants, Toddlers, Children & Youth 	Infants and toddlers have high sensitivity to climate change hazards due to developing immune systems, and dependence on others to adjust to these hazards (e.g., heat, infectious diseases and food or waterborne illnesses). The direct and indirect impacts on children and their caregivers can lead to toxic stress which impacts health.[39] Children and youth may have greater exposure to climate hazards due to more time spent outside, leading to respiratory issues due to low air quality, heat-related illness and vector-borne diseases. They also have a higher risk of mental health impacts due to climate change.[3]	In the PPH region in 2021: • Children (0-14 years of age) represented **14.4%** of the population compared to Ontario at **15.8%** • There were **6,875** lone parent led families (**4,680** in the city and **2,195** in the county)[15] In the PPH region in 2015 and 2018: • Data from the Early Development Instrument (EDI) noted the region had the **3rd highest** number in Ontario for SK students with vulnerability in the physical health and well-being domain.[40]
Older Adults 	Older adults may have a higher sensitivity to the health impacts of climate hazards because of age, chronic health conditions, limited mobility, medications, compromised immune systems and the need for medical care and assistance.[41,42] Some older adults may be less able to physiologically adapt to hazards such as wildfire smoke and extreme heat. Some may also face challenges with preparing for and responding to climate change emergencies such as extreme weather events. This can be due to	In the PPH region in 2021: • Older adults (65+) represented **25.2%** of the population compared to Ontario at **18.5%** • Older adults made up **24.2%** of the population in the City of Peterborough and **26.6%** in the County, with the highest median ages in townships of North Kawartha, Trent Lakes and Havelock-Belmont-Methuen[15]

	low income, social isolation, and/or reliance on others to meet basic needs.[3] For example, when adapting to extreme heat, having access to air conditioning, cooling spaces, tree canopies, and green spaces can help to mitigate health risks. However, those living with low income tend not to have these options available or they are limited.[28,41]	By 2041, the population of older adults is expected to grow to **26%** in the City and **30%** in the County.[43,44] Of the total population of older adults in PPH region in 2020 (approximately **35,000** people), close to **4,000** (**11.3%**) were low income (i.e. income below the low-income measure, after tax (LIM-AT)). This was **higher** than the low-income rate of **working age adults** (aged 18-64), which was **10.5%**.[15]
Pregnant People 	Pregnant people may face increased health risks from climate hazards. Potential impacts include infections, heat-related illness, respiratory disease, mental health impacts, socioeconomic challenges, and issues with meeting nutritional needs. These impacts can result from high temperatures, flooding, infectious agents, and low air quality. Such conditions can also impact fetal health, increasing the risk of low-birth weights, and premature births.[3]	In the PPH region: • Approximately **1,200** pregnant people gave birth each year, between 2012 and 2023. (Source: Better Outcome Registry & Network, 2023) • Of PPH residents giving birth in 2019, **37.4%** reported a mental health concern, which was significantly higher than the Ontario rate of **20.5%**.[45]
Factors that can influence Vulnerability and Adaptative Capacity	**Vulnerability to Climate Hazards**	**PPH Regional Trends**
Socioeconomic Status (SES)  • influenced by income, education, social status and connectedness with communities	People impacted by low SES may face many factors that increase their vulnerability to the health risks of climate change. People with limited financial resources may struggle to have basic needs met such as adequate and affordable housing and food security. They may not have extra money to spend on climate change protective actions such as: • seeking shade, accessing cooler spaces, buying and running air conditioners and/or fans, making necessary repairs to housing • preparing for climate change related emergency events (e.g., emergency preparedness kits)[46] People experiencing low-income tend to live in areas with older infrastructure, poorer housing conditions and increased exposure to urban heat islands.[35,47] People experiencing low SES are more likely to have poorer health and are disproportionately affected by chronic health	**Income**: The prevalence of low income[a] in 2020 was: • **10.9%** in the PPH region • **12.8%** in the City of Peterborough • **8.3%** in the County • **10.1%** in Ontario[15] The number of people living on low incomes[a] in the PPH region in 2020 included: • **2,895** children and youth aged 17 and younger • **8,865** adults aged 18-64 • **3,965** older adults aged 65+[15] [a] Using Low-income measure, after tax (LIM-AT). Unemployment rates in 2021 were: • **12.8%** in the PPH region • **14.7%** in the City of Peterborough • **10.4%** in the County

	conditions, such as mental health illnesses, asthma, diabetes and cardiovascular diseases.[5,48] They are also more likely to experience and receive worse health care and to die earlier. [46,49] Peoples' health can be impacted when their basic needs are not met and this toxic stress can also impact the health of their next generation.[50]	• **12.2%** in Ontario[15] Education: In 2021, **83%** of the population in the PPH region had a secondary school diploma or equivalency (similar to Ontario rates).[15] Housing: In the PPH region in 2021, there were: • **61,745** occupied private dwellings • **3,935** or approximately **6%** of private dwellings need major repairs[15] The PPH region has high rates of dependency on social assistance. In October 2021, the region had an Ontario Disability Support Program (ODSP) case rate of **3.74%**, which is **43.2%** higher than the provincial rate. The Ontario Works (OW) case rate of **1.26%** is **33.3%** higher than the provincial rate.[43,51] **Health Care Access**: As of June 2023, there were over **18,000** people in the PPH region who did not have a family doctor (Source: communication with Peterborough Family Health Team, June 2023) • The Ontario College of Family Physicians estimate that **2.2 million Ontarians** are without a family doctor. People who live in poorer communities have higher rates of being without a family doctor.[52] • In May of 2023, Emergency Department patients at Peterborough Regional Health Centre waited an average of **3.4 hours** before being assessed by a physician.[53] The Material Resources dimension of the Ontario Marginalization Index incorporates some of the above SES factors. Mapping of this dimension across PPH region, is shown in **Figure 4-2** below.

Immigration 	Recent immigrants may speak limited English and therefore may have more obstacles accessing community services related to climate change.[54] Language barriers may prevent the understanding of alerts related to hazards.[4]	Number of recent immigrants (2016-2021): • **1,355** in the PPH region • The majority (**86%**) of recent immigrants in the PPH region reside in the City of Peterborough. • The number of recent immigrants to PPH increased by **63%**, compared to the 2011-2015 time period.[15] **5.1%** of recent immigrants in Peterborough CMA speak neither English nor French.[56] The median after-tax income of recent immigrants in Peterborough CMA was $29,000 in 2021, which was **19%** lower than the median after-tax income of non-immigrants in the Peterborough CMA.[56] In Canada, it was found that among recent immigrants (≤10 years in Canada), the proportion of children living in low-income families was **2.2 times higher** than that of non-immigrants.[57]
Outdoor work (workers are at risk due to where they work and/or their job duties) 	People who work outdoors are more exposed to climate hazards such as extreme temperatures, air pollution, UV radiation, extreme weather events and vector-borne diseases. Farmers are one example of a population of outdoor workers disproportionately impacted by climate change health impacts (Source: Peterborough Public Health, Food and Climate Change Consultation Meeting, May 25, 2023).	In the PPH region in 2021, the number of people working in sectors involving outdoor work included: • **1,560** in agriculture, forestry, fishing and hunting • **320** in mining, quarrying, and oil and gas extraction • **6,570** in construction[15]
Chronic Health Conditions 	Chronic health conditions can increase the vulnerability of people to the health impacts of climate change. Chronic health conditions and some medications can make people physiologically more sensitive to many of the climate hazards.[59] For example, people with chronic conditions may have a higher risk of dying or becoming ill due to extreme heat.[35]	According to the "Burden of Chronic Diseases in Ontario" in 2015, three-quarters of deaths in Ontario were a result of chronic diseases.[60] People in Ontario who had the lowest SES were significantly more likely to die and have more hospitalizations due to chronic health conditions.[60] It is estimated that about **69%** of Ontarians live with one or more chronic health conditions, and **45.6%** live with two or more chronic conditions (this is inclusive of minor physical and mental health conditions).[61] In the PPH region in 2019, the prevalence and age-standardized rate of the following chronic diseases[62] was: Asthma • **18.7%** of population • 19,235 per 100,000*

		COPD • **12.7%** of those aged 20+ • 10,197 per 100,000* aged 20+ Hypertension • **30.6%** of those aged 20+ • 24,686 per 100,000º aged 20+ Diabetes • **13.0%** of those aged 20+ • 10,776 per 100,000º aged 20+[62] *denotes rate is significantly higher than Ontario rate ºdenotes rate is significantly lower than the Ontario rate Approximately **1 in 2 people** will be diagnosed with cancer in their lifetime. [63] The greatest number of new cancer cases will occur in people ages 60 to 79.[63,64]
Mental Health 	People with mental health conditions are more vulnerable to the health impacts of climate change. Extreme weather events may increase the risk of new cases of mental health conditions.[54] The mental health impacts of climate change may include: • worsening of existing mental health conditions such as schizophrenia, substance use disorder and dementia [65] • new mental health conditions including; "post-traumatic stress disorder; mental health stressors such as grief, worry, anxiety, and vicarious trauma; and a lost sense of place, which refers to the perceived or actual detachment from community, environment, or homeland." [65] **See the Mental Health section below.**	**See the Mental Health section below**.
Underserved Populations	**Vulnerability to Climate Hazards**	**PPH Regional Trends**
Homelessness (living rough, unhoused)	People who are homeless and/or living rough may be experiencing multiple vulnerabilities and are at increased risk of climate hazards when living outdoors and rough. They may have increased exposure and reduced ability to adapt to or cope with extreme temperatures, extreme weather events, poor air	According to the Peterborough Community Safety and Well-being Plan (2022): • A monthly average of **266 individuals experienced** homelessness in the City and County in 2021.[51]

 Examples of homelessness could be individuals or families who are living: • or staying in an emergency shelter • outdoors, camping at night, sleeping rough, living in their vehicle or in other spaces that are not intended for permanent living • in transitional housing, hotel, motel, hospital, jail or another program or institution where if released or discharged, they would not have a permanent, safe place to go or are couch surfing, staying with friends or living with others where they cannot stay Many of these people are also experiencing chronic health and mental health conditions, and substance use.[66]	quality, vector-borne diseases and ultraviolet radiation.[46,66] They may be more physiologically sensitive to climate-related hazards due to chronic diseases or drug/medication usage.[66]	• As of April 2022, there were at least **317 people** on the By-Name Priority List of those experiencing homelessness to be housed (153 of those people experiencing chronic homelessness).[51] • In 2020, there were **1,563 households** on the social housing waitlist; in 2021 it was increased to **1,699 households.**[51]
People who use Substances 	People who use substances may be less able to respond to climate hazards due to the impacts of substances on their cognitive function. For example, excessive alcohol or drug use can make people more sensitive to the effects of heat.[41]	Opioid Use: In the PPH region in 2022 there were **262** emergency department (ED) visits related to opioid overdoses. The rate of opioid-related ED visits for residents (178.6 per 100,000 population) was **2.2 times higher** than the provincial rate (Source: Ontario Ministry of Health; Acute Care Enhanced Surveillance (ACES); National Ambulatory Care Reporting System (NACRS)). In 2022 there were **47**

		opioid related deaths in the region (Source: Office of the Chief Coroner: Peterborough Police Services). In 2022, Paramedics responded to **358,911** calls for someone experiencing an opioid poisoning (Source: Peterborough County-City Paramedics iMedic database). Alcohol Use: In the PPH region: • **25.3%** of people self-reported exceeding the low-risk drinking guidelines for chronic diseases in 2019-2020 (age-standardized rate for both sexes; significantly higher than the provincial rate) • **22.5%** of people self-reported heavy drinking from 2015-2020 (age-standardized for both sexes)[67,68]
Indigenous Peoples 	"Since time immemorial, Indigenous peoples have respectfully lived with the natural world, and have a deep connection to the land, water, and ecosystems that are central to their cultures, languages, and livelihoods. Through this intergenerational experience and observation, Indigenous peoples were amongst the first to notice climate change and also have critical knowledges for navigating and adapting to it."[69] Indigenous peoples may experience greater challenges from climate change because of existing disparities such as: shorter lifespans, higher rates of chronic health conditions and greater food and water insecurity in many communities.[59] The climate hazards may influence Indigenous peoples' access to traditional cultural practices, safe water, and availability of traditional food sources.[46] Indigenous health inequities are complex and deeply rooted in historical and ongoing acts of colonization. Allyship and support of indigenous self-determination and health equity are needed to move forward.[10,70]	In the PPH region**, 4.9%** of the population in private households reported indigenous identity in the 2021 Census (vs. **2.9%** in Ontario). (According to Statistics Canada, "[t]his category includes persons who identify as First Nations (North American Indian), Métis and/or Inuk (Inuit) and/or those who report being Registered or Treaty Indians (that is, registered under the *Indian Act* of Canada), and/or those who report having membership in a First Nation or Indian band.")[15] NOTE: Exploring climate change impacts and opportunities to adapt for Indigenous Communities is important, and beyond the scope of this report. Indigenous-led and two-eyed seeing approaches are needed to learn about impacts and potential adaptive actions for Curve Lake and Hiawatha First Nations, and Indigenous people living in the County and City of Peterborough. A separate assessment will be conducted, incorporating these approaches, as recommended by PPH's Indigenous Health Advisory Circle.

Socioeconomic Status (SES) and Material Resources

According to the Ontario Marginalization Index User Guide, "[t]he material resources dimension is closely connected to poverty and refers to the inability for individuals and communities to access and attain basic material needs relating to housing, food, clothing, and education".[71(p.7)]

***Figure 4-2**. Ontario Marginalization Index: Material Resources Quintile for Peterborough City and County Dissemination Areas.*[72]

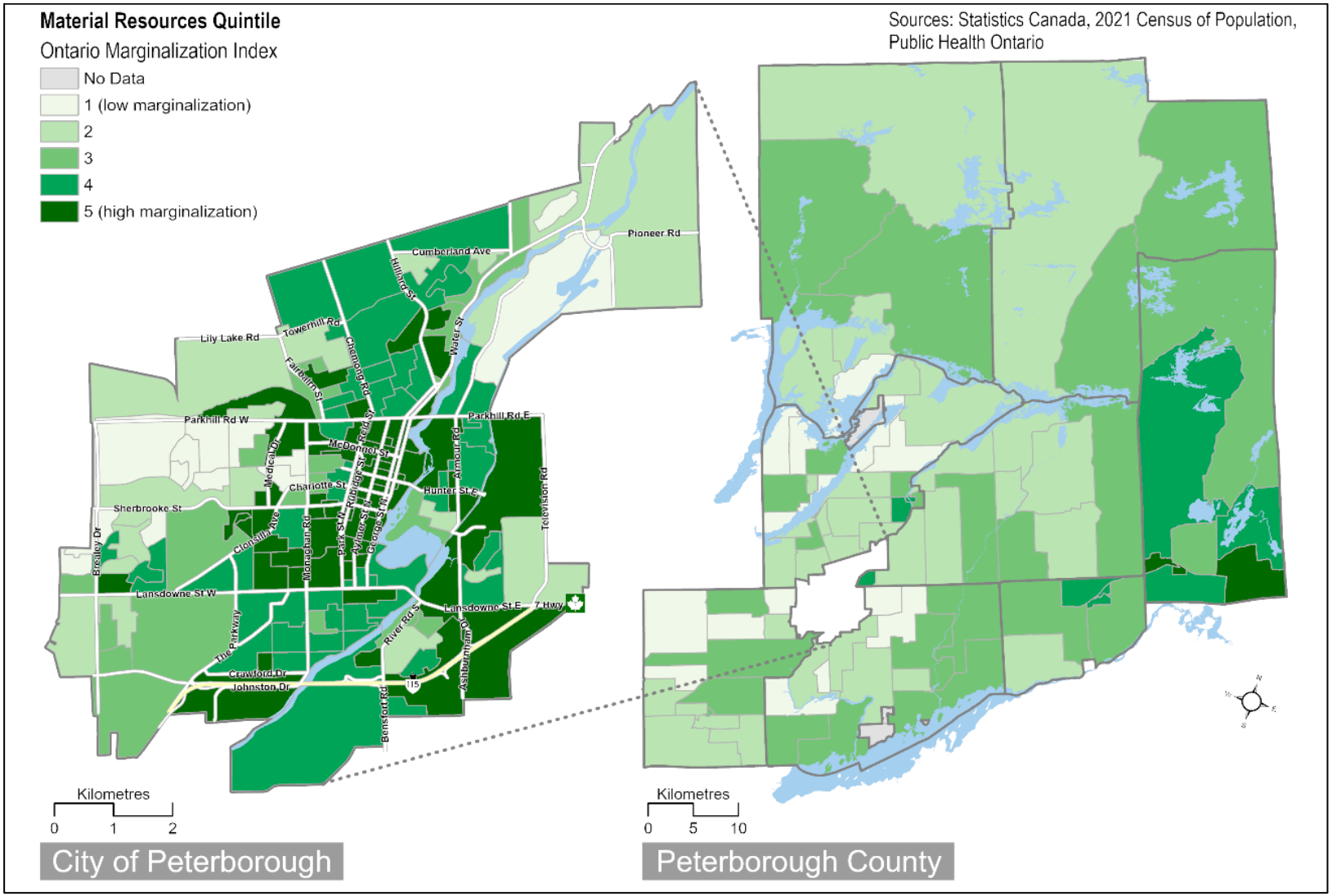


Figure author: City of Peterborough Geomatics/Mapping Division, 2023 (Created for this report). Sources are denoted in the Figure.

Mental Health

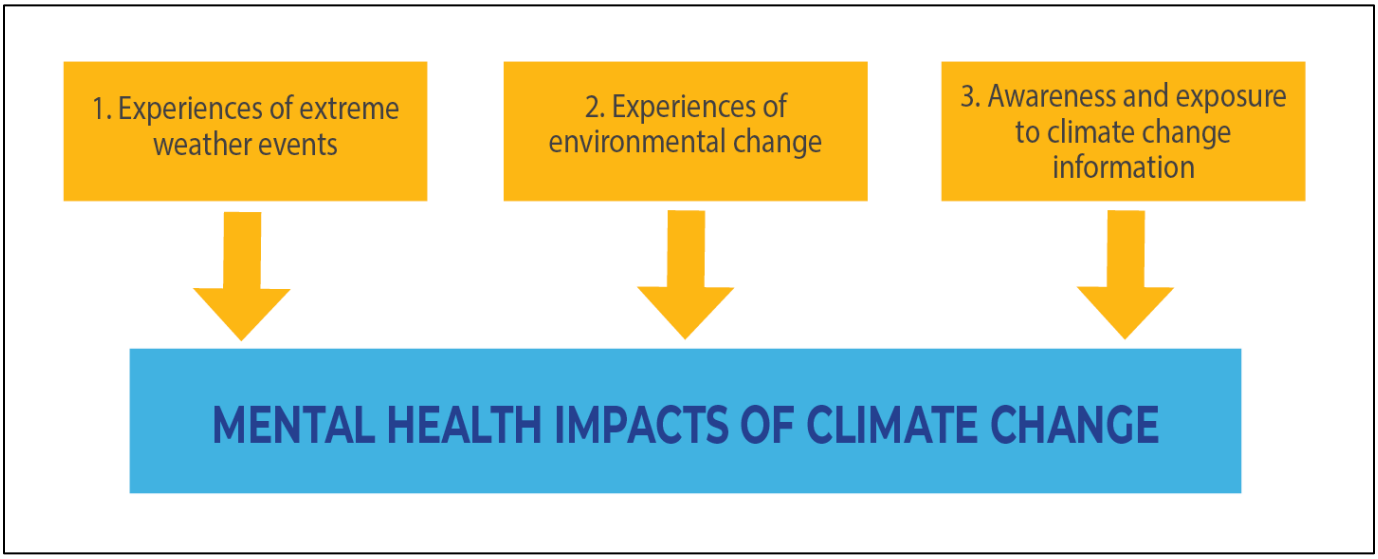
Many factors can influence vulnerability; however, it is important to highlight mental health, both as a component of vulnerability and as a health outcome influenced by climate change as a whole. Climate change is currently having an impact on the mental health of our communities. In the years ahead, the changing climate will increase the risk of mental health conditions for many people, negatively impact well-being and inflict extensive costs on individuals and society.[73] Presently about 12 percent of adults in Canada self-report having a mood or anxiety disorder.[73] Not including climate change, the cost of mental illness in Canada is expected to grow to 291 billion dollars per year by 2041.[73] Approximately two million Ontarians are affected by mental illnesses and addictions each year.[74]

While the mental health impacts of specific climate hazards are expanded on in subsequent chapters, mental health impacts can be categorized into three pathways.

A person or population may experience all the pathways at once, just two or one. The pathways are (see Figure 4-3):[75]

- **Extreme weather events** may be sudden and severe and can cause stress and trauma (i.e. extreme heat events, floods, wildfires)
- **Experiences of environmental change over time,** such as overall temperature increases and local losses of species, loss of food and water quality, increase in vector-borne diseases, etc.[76]
- **Exposure to information** about the climate changing/crisis (e.g., social media, news, classroom)

Figure 4-3. *Three Pathways of Climate Mental Health Impacts.*



Source: Climate Atlas of Canada. Mental Health and Climate Change. Accessed September 21, 2023. https://climateatlas.ca/mental-health-and-climate-change [75]

Populations at Increased Risk of Mental Health Impacts of Climate Change

- **People who spend more time outdoors** and/or have a stronger connection to the natural environment (e.g., children, farmers, hunters, outdoor enthusiasts) [75]
- **People with pre-existing health conditions** including mental health conditions.[77,78] For example, some mental health conditions inhibit body temperature regulation. Schizophrenia is one example and was most strongly associated with higher risk of death during extreme heat events.[79]
- **Young people** with increased climate change knowledge and awareness may experience high levels of grief, anxiety and distress.[80] A recent study of young Canadians (age 16-25) found that, "78% of [survey

respondents] reported that climate change impacts their overall mental health and 37% reported that their feelings about climate change negatively impacted daily functioning."[81]

- **People experiencing low SES** tend to have fewer resources and less access to health and social services, and higher stress. These individuals are also less likely to have access to supports to help address mental health issues, which can lead to more social and health inequities.[76,82,83]

Currently, there is limited information connecting climate change to local mental health data. However, in a local survey, **91.2**% of respondents indicated concern about climate change (Source: RRFSS, 2019).

The following information helps demonstrate the vulnerability of the PPH region to mental health impacts associated with climate change, as well as providing a baseline for comparison in the future. While it is not possible at this time to know how much climate change contributes to these outcomes, perhaps there will be advances in the future to estimate this.

Self-reported Mental Health

In Table 4-2, several self-reported mental health statistics for PPH and Ontario are presented from the 2017-2018 Canadian Community Health Survey (CCHS).[67] In the PPH region 70% of respondents perceived their mental health as very good or excellent; self-reported prevalence of mood disorders was 14% and anxiety disorders was 14%. [84,85] The latter two values were statistically significantly higher when compared to Ontario.

Table 4-2. *Proportion of PPH and Ontario Population with Select Mental Health-Related Responses (Self-Reported) in the CCHS, 2017-2018.*

	PPH	Ontario
Perceived mental health is very good or excellent (self-reported)	70.0% (95%CI:64.8-74.3)	69.0% (95%CI:68.1-69.9)
Self-reported prevalence of mood disorders	14.0%* (95%CI:10.5-17.3)	9.0% (95%CI:8.8-9.9)
Self-reported prevalence of anxiety disorders	14.0%* (95%CI:10.3-18.1)	10.0% (95%CI:9.1-10.2)

*denotes significant difference

Source: Public Health Ontario, Canadian Community Health Survey, 2017-2018.[84,85]

Mental Health-related Emergency Department (ED) Visits

Mental health-related ED visit data demonstrates how the mental health needs of PPH residents have increased over the past fifteen years. Crude incidence rate over 5-year time periods is presented in Table 4-3. Over this time period, those aged 18-44 years old have the highest rate, making up 57% of all mental health-related ED visits.

Table 4-3. *5-Year Average Crude Incidence Rate (Cases per 100,000 Population per Year) of Mental Health-Related[a] Emergency Department Visits by PPH Residents from 2008 to 2022.*

	2008-2012	2013-2017	2018-2022
Crude incidence rate per 100,000 population	2,081 (95%CI:2,070-2,116)	2,851 (95%CI:2,837-2,891)	2,981 (95%CI:2,967-3,021)

Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: August 2023.

[a] ICD 10 Codes included those for mood/affective disorders, anxiety disorders, substance-related disorders, schizophrenia, delusional and non-organic psychotic disorders, and selected disorders of adult personality and behaviour (specific codes available in Appendix D).

Mental health is a rising concern in our communities. For example, healthcare and mental health has been identified as a priority in the Peterborough Community Safety and Wellbeing Plan.[43] PPH's Strategic Plan also identifies the importance of working with partners to address health inequities and barriers to services, in particular in relation to housing and mental health.[10] As the climate warms, this will be critical to adapt and address the breadth of mental health impacts related to climate change.[65]

In the chapters to follow climate hazards and the possible health impacts of climate change in the PPH region will be discussed with a focus on those who are most vulnerable.

Extreme Temperatures

Extreme temperatures are one of the most noticeable impacts of climate change. The following chapter outlines the projections for extreme temperatures for both heat and cold in the PPH region and summarizes the health impacts. It will also highlight the populations most at risk of experiencing negative health impacts because of extreme weather currently and into the future.

Extreme Heat

Extreme heat is defined as temperatures - generally experienced in the summer - that are much hotter and/or humid than average.[86] The temperature value considered extreme may vary depending on the location and typical seasonal temperatures. Locally, temperatures above 30°C are often considered more extreme. Extreme heat is of particular concern when the elevated temperatures are maintained for 2 or more days, often called a "heat wave". See the section below for more information about heat waves/heat warnings.

Climate change is very much connected with extreme heat. With a warming climate, heat waves are likely to become more frequent and more intense.[87] Not only do the warming average temperatures lead to more extreme heat, but climate change may also cause atmospheric changes such as high-pressure systems leading to "heat domes" like Western Canada experienced in 2021.[88]

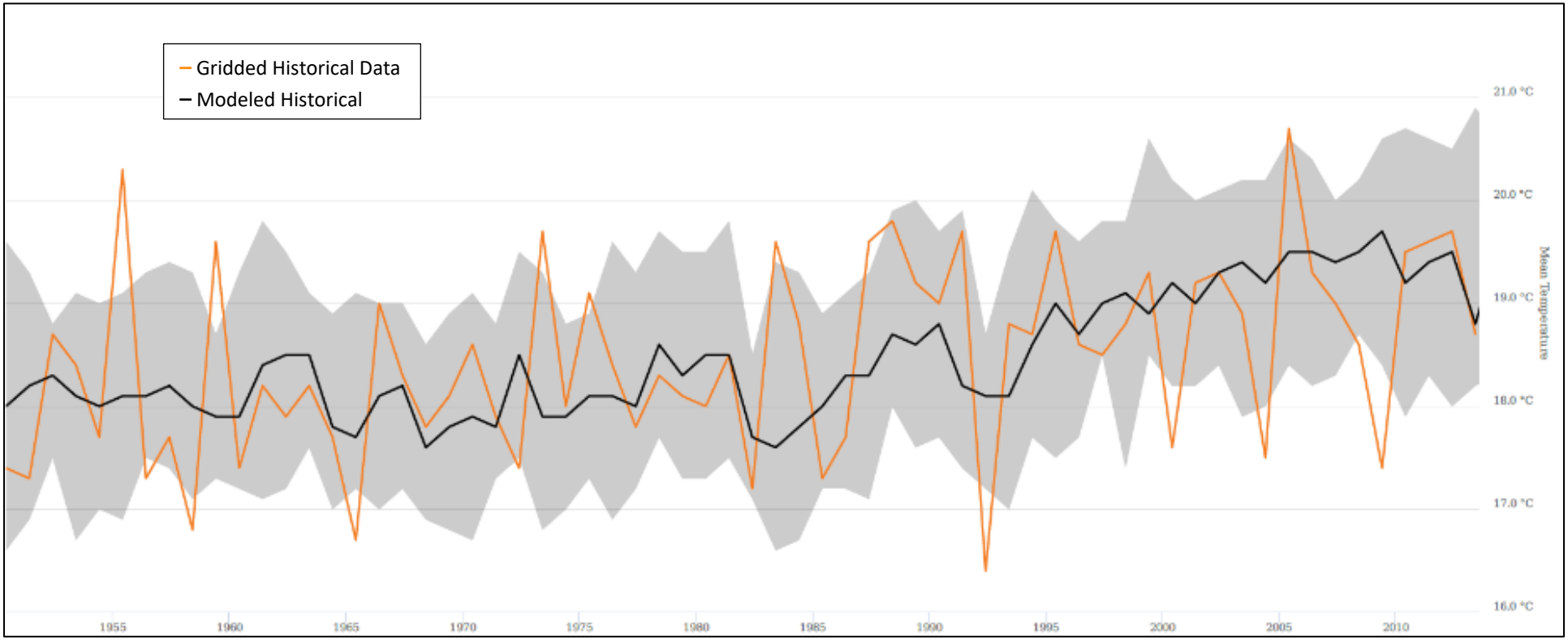
Extreme heat can be extremely harmful to health. It is associated with a variety of physical and mental health symptoms that can result in increased morbidity and mortality, perinatal effects, and even crime within the affected community.[41]

Hazard Trends and Projections

Average Summer Temperature Trends and Projections

As presented in Figure 3-4 (Chapter 3: Community Context), the average temperature in PPH region has shown an increasing trend between the 1960s (1950-1980) and the 1990s (1981-2010). Summer temperatures have shown an increasing trend as well. Figures 5-1 and 5-2 below show how the mean summer temperature (average of daily average temperature), and the average daily high temperatures in summer, respectively, have gradually increased in the PPH region. Both the actual historical values and the ensemble means/modelled data are included, which highlights how actual historical values show greater fluctuation.

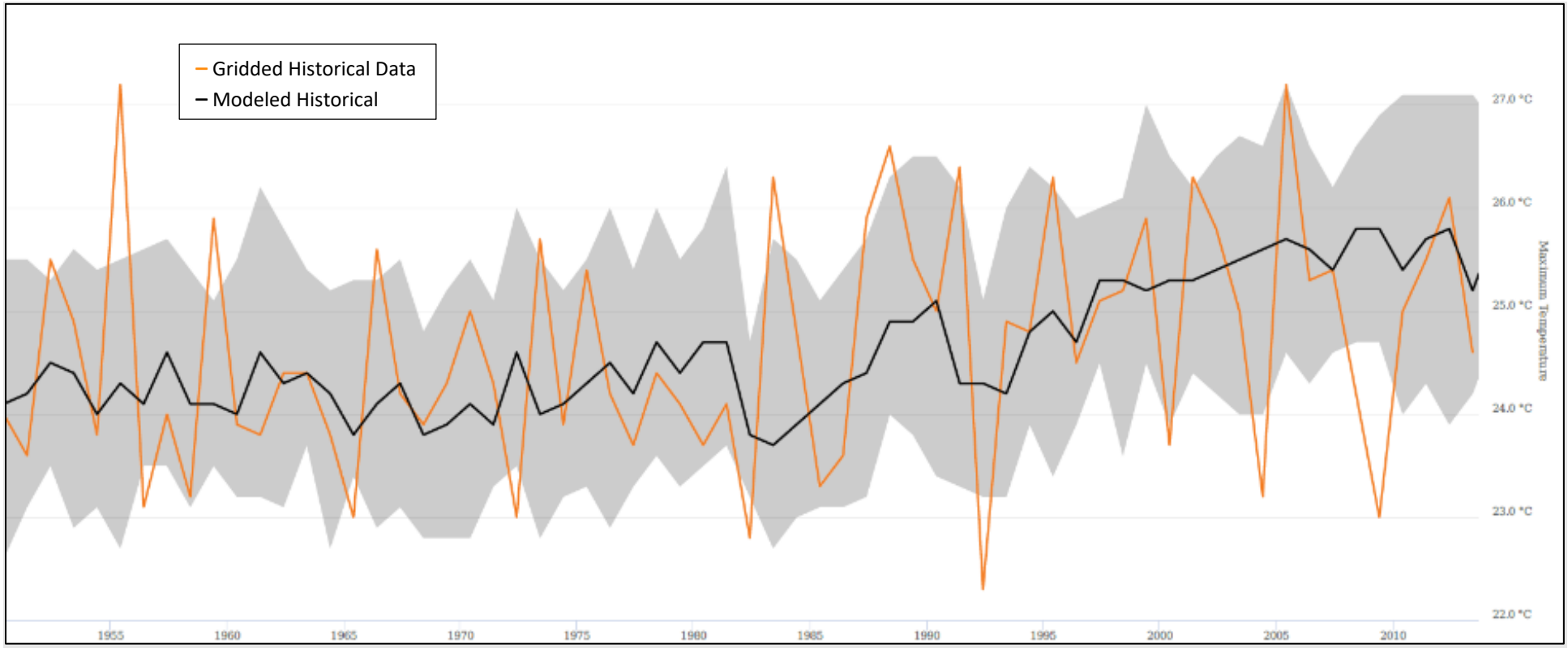
Figure 5-1. *Mean Summer Temperature (Average of Daily Mean Temperature[a]) for PPH Region, 1950-2013.*



Source: ClimateData.ca, 2023.[21] Shaded areas show the range in values of the climate model ensemble (defined as the 10th and 90th percentile).

[a] The "daily mean temperature" is the average of the daily maximum and daily minimum temperatures.

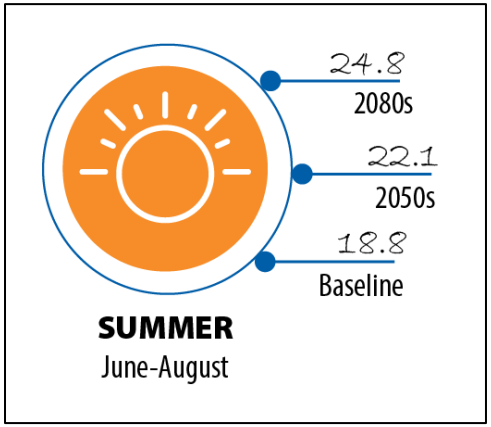
Figure 5-2. *Average Summer Maximum Temperature for PPH Region, 1950-2013.*



Source: ClimateData.ca, 2023.[21] Shaded areas show the range in values of the climate model ensemble (defined as the 10th and 90th percentile).

With regards to summer temperature projections, as presented in Chapter 3: Community Context and highlighted in Figure 5-3, the mean summer temperature is projected to increase this century. By the 2080s, this increase will be about 6°C under a Fossil-fueled Development scenario, or about 3.4°C under a Middle of the Road scenario (*data not shown).*

Figure 5-3. *Projected Changes to Mean Summer Temperature under a Fossil-Fueled Development Scenario (Excerpt from Figure 3-5).*



Source: ClimateData.ca, 2023.[21]

"Due to climate change, heat events are expected to become increasingly frequent, prolonged and severe."[89(p.2)]

Extreme Heat Trends and Projections

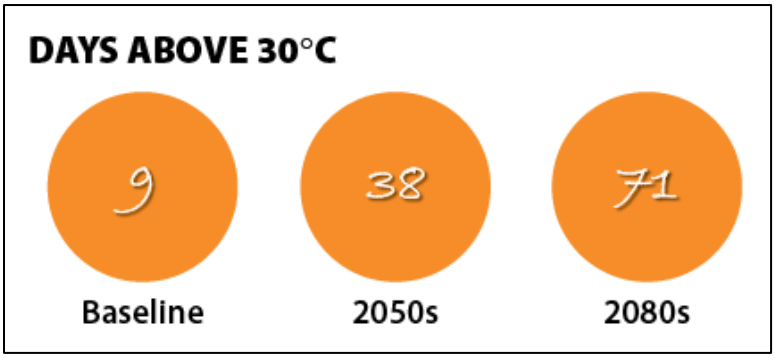
There are many extreme heat variables based on different thresholds and considerations (e.g. daily maximum (Tmax) or daily minimum (Tmin) temperatures). Various extreme heat variables are shown in Table 5-3, and changes in the first variable in the table over time are highlighted in Figure 5-4.

Table 5-1. *Extreme Heat Variables for PPH Region for Baseline Time Period and Projected for 2050s and 2080s Under Middle of the Road (SSP2-4.5) and Fossil-Fueled Development Scenarios (SSP5-8.5).*

Variable	Baseline	2050s		2080s	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Very hot days (days with Tmax>30°C)	9	28	38	40	71
Very hot days (days with Tmax>32°C)	3	13	20	21	45
Days with humidex>40°C	0	5	9	8	28
Tropical nights (Tmin>20°C)	2	10	16	15	41
Hottest maximum temperature	32.8°C	35.7°C	36.4°C	36.6°C	39°C

Source: ClimateData.ca, 2023.[21]

Figure 5-4. *Number of Very Hot Days (Tmax>30°C) for PPH Region During the Baseline and Projected in the 2050s and 2080s Under the Fossil-Fueled Development Scenario.*

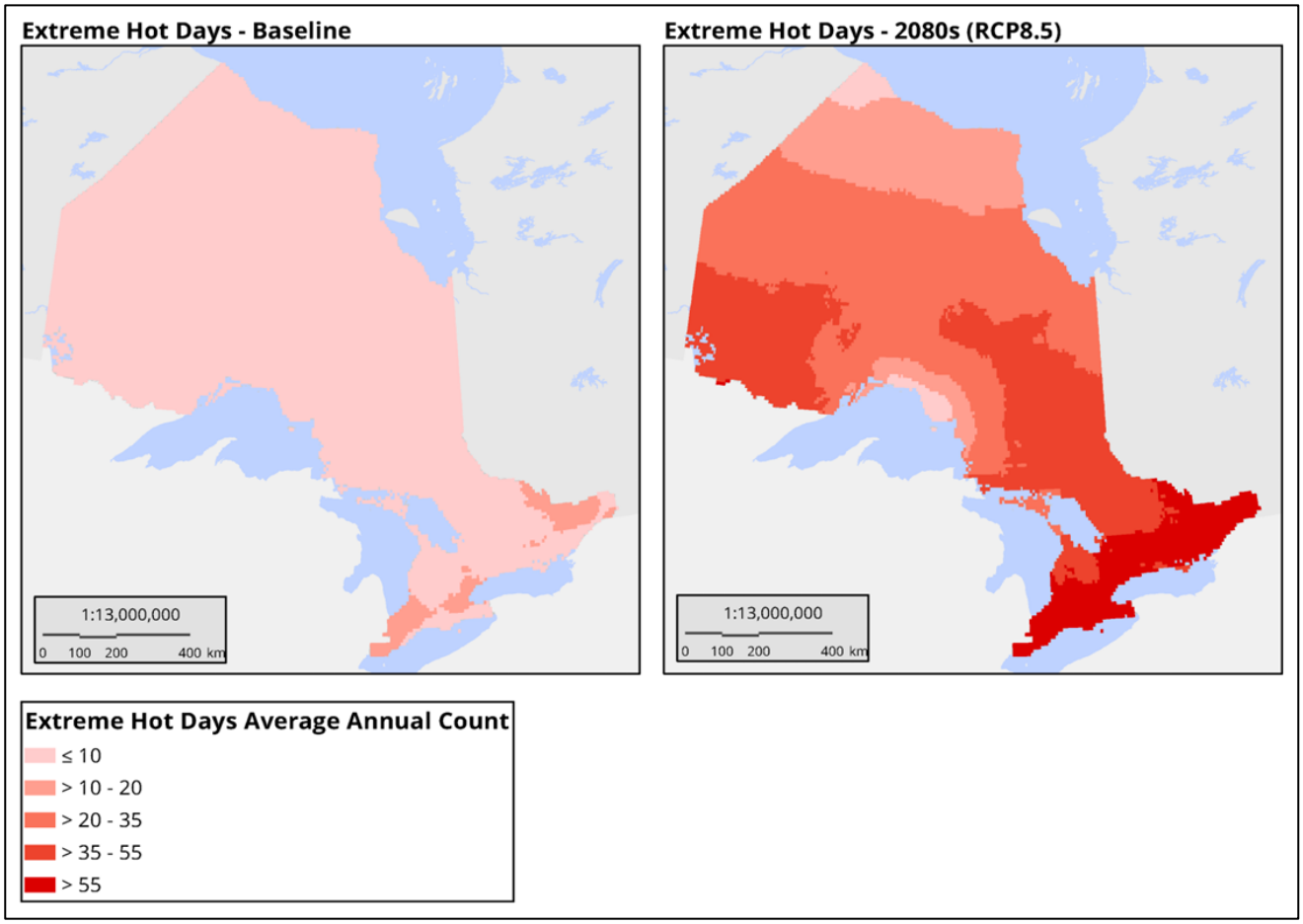


Source: ClimateData.ca, 2023.[21]

The PPH region can anticipate an increase in very hot days by the 2050s, and even more by the 2080s. In the 2050s we may see a three- to four-fold increase in the number of days with temperatures higher than 30°C, where the average during the baseline time period was 9 days per year. There will be more extreme heat in May and September than seen during the baseline time period. Extreme heat days in June will increase from the baseline average of 2 days per year, to an average of 6 or 7 days per year, which is something particularly relevant for schools that don't have air conditioning. By the 2080s, the Middle of the Road scenario shows days over 30°C increasing to about 40 per year and 21 of these days being over 32°C. The Fossil-fueled Development scenario has extremely concerning projections where temperatures may exceed 30°C for, on average, 71 days per year, nearly 20% of the year! It also projects an average of 41 tropical nights (i.e., nighttime temperatures staying above 20°C) each year - which was experienced, on average, only 2 times per year during the baseline time period. The hottest maximum temperature (30-year average the of yearly maximum temperature) will rise into the high 30s by the 2080s, compared to 32.8°C during the 1990s baseline time period.

The projections for number of very hot days across the province are also demonstrated in the 2023 Ontario Provincial Climate Change Impact Assessment Technical Report.[90] Shown in Figure 5-5, the number of days are projected to increase substantially across the province by the 2080s under a high emissions scenario.

Figure 5-5. *Average Annual Number of Very Hot Days (>30°C) Across Ontario (Left: Baseline Time Period (1981-2010); Right: Projections for 2080s Under RCP8.5[a]).*



Source: Climate Risk Institute, Dillon Consulting Limited. Ontario Provincial Climate Change Impact Assessment Technical Report.; 2023. Accessed September 17, 2023. https://www.ontario.ca/files/2023-08/mecp-ontario-provincial-climate-change-impact-assessment-en-2023-08-17.pdf, p44.[90]

[a] RCP scenarios were used for the Ontario assessment, where RCP8.5 would be comparable to the SSP5-8.5 scenario used in this report.

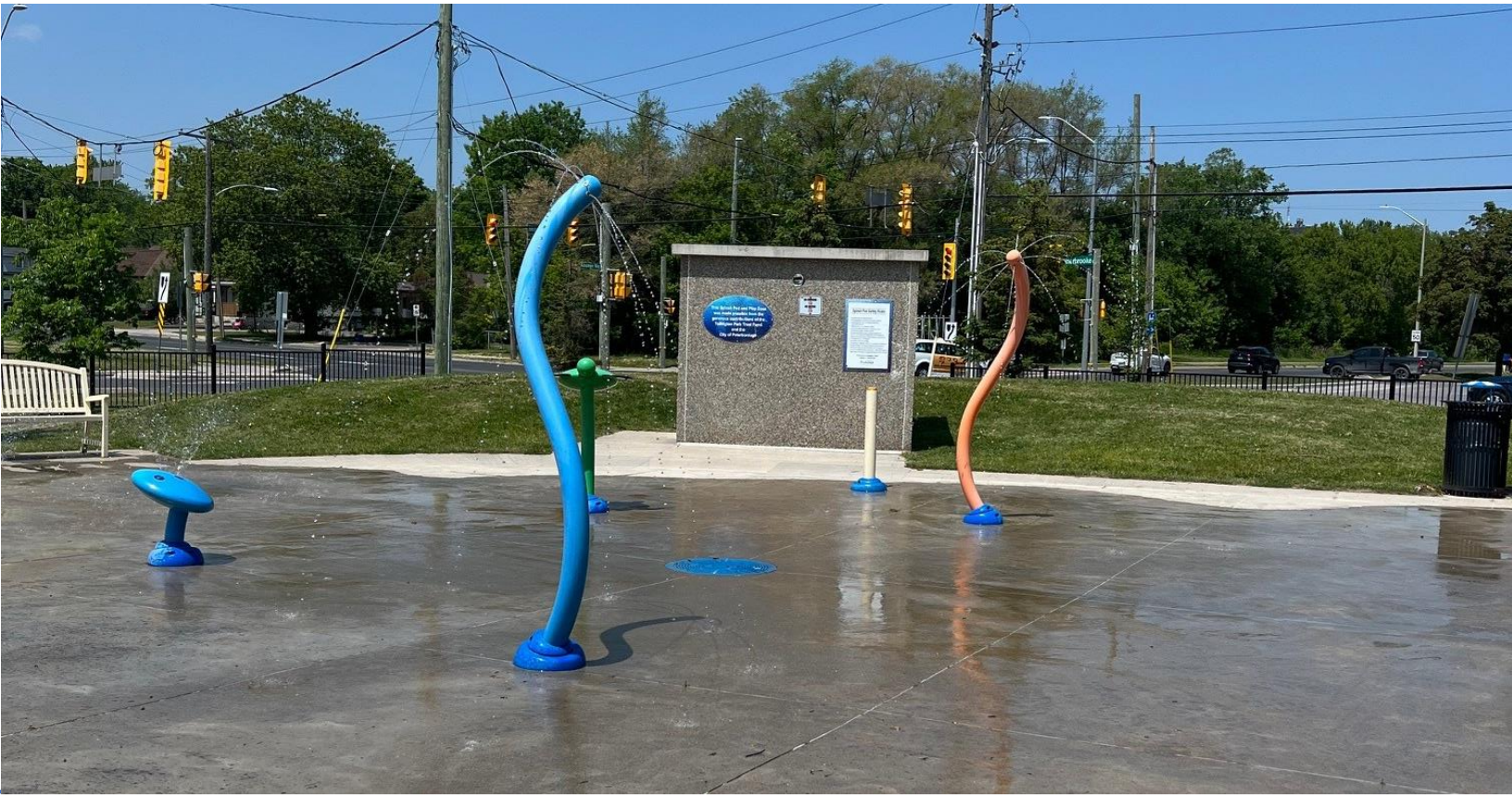
Heat Warnings

Due in large part to the potential health impacts from extreme heat, **heat warning systems** have been implemented in parts of Ontario since the late 1990s.[91] Since 2016, a Harmonized Heat Warning and Information System (HWIS), has been implemented in Ontario. Heat warnings are issued based on forecasted weather by Environment and Climate Change Canada.

For southern Ontario, the thresholds for heat warnings are as follows:

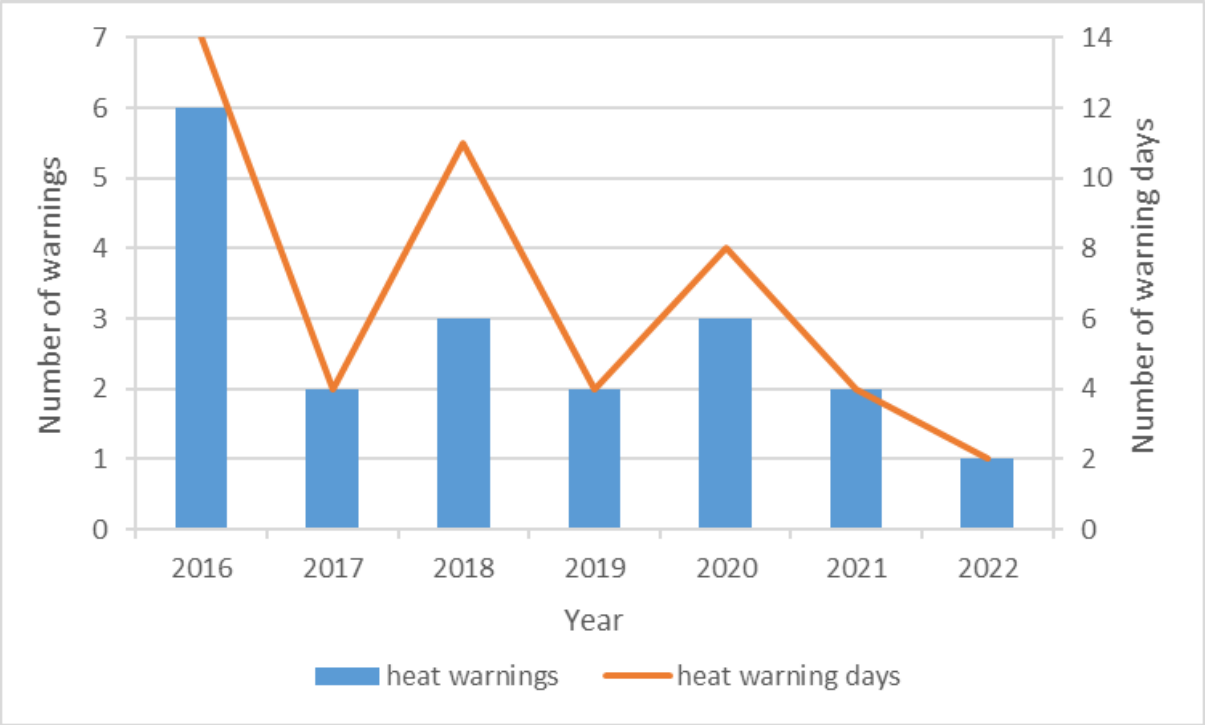
- **Heat warnings** are released when it is forecasted that one or both of the following criteria will be met for two days in a row:
  - Maximum daily temperature equal to or greater than 31°C and minimum daily temperature equal to or greater than 20°C
  - Humidex temperature equal to or greater than 40°C
- **Extended heat warnings** are released if these temperatures are forecasted for three or more days in a row.[92]

Environment and Climate Change Canada issues Heat Warnings 18 to 24 hours in advance of the heat event.



The number of heat warnings and number of heat warning days each year between 2016 and 2022 issued by PPH for the region is presented in Figure 5-6. This is a short time period so it is not possible to comment on trends; however, the data for this time period may be used as a baseline as heat events are monitored moving forward. The average number of heat alerts each year was 2.7 and for the number of heat alert days each year, the mean and median were 6.7 days and 4 days, respectively.

Figure 5-6. *Number of Heat Warnings and Number of Days with Heat Warnings from 2016 to 2022 in PPH Region.*

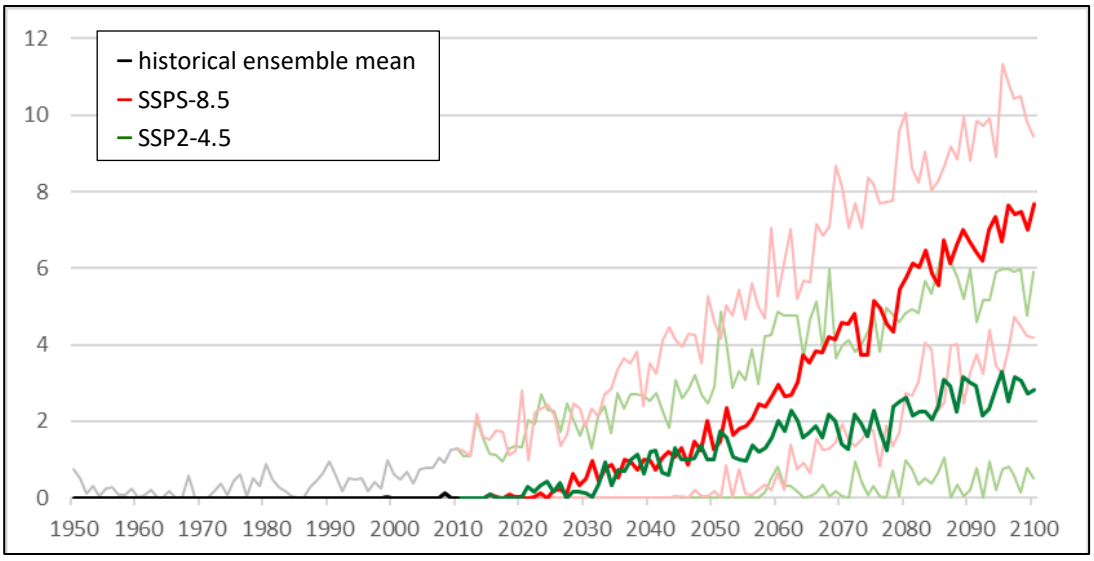


Source: Peterborough Public Health records, 2023.

ClimateData.ca makes it possible to project frequency of heat waves based on the specific temperature thresholds that trigger heat warnings locally. The following Figure 5-7 shows projections using the requirements of having two or more days with a maximum temperature being higher than 30.99°C and the minimum temperature being higher than 19.99°C (Note: It is not possible to incorporate a humidex threshold in the same analysis at this time). The frequency of heat waves is projected to increase under both scenarios, with the median between 2 and 3 per year later this century under the SSP2-4.5 scenario (2080s average[a]: 2.4) and increasing higher under the SSP5-8.5 with median values between 4 and nearly 8 (2080s average[a]: 6.0).

[a] These averages were calculated from the mean of the medians over the 30-year time period. See Appendix E for additional information on this process.

Figure 5-7. *Frequency of Heat Waves (Median) for PPH Region with Ensemble Mean Modelled for 1950 to 2010, and Climate Modelling Projections for 2011 to 2100 Based on SSP2-4.5 and SSP5-8.5 Scenarios.*



Source: ClimateData.ca, 2023, Custom analysis. Lighter coloured lines show the range in values of the climate model ensemble (lower and upper limits, defined as the 10th and 90th percentile).

Comparing Figure 5-6 and 5-7 above, it is noticeable that the frequency of heat waves modelled between 2016 and 2022 does not appear to match with the number of heat warnings issued for our area. For example, the 90th percentile for frequency of heat waves doesn't exceed 3 until the mid-2030s in either scenario, yet we saw 3 or more heat warnings in three of the past seven summers. There may be different reasons for this (e.g., one example may be because heat warnings are released in advance of a heat event, so it may be possible that actual temperatures didn't meet the thresholds for the heat warning). In any case, it may be useful to consider and refer to both types of data into the future.

Health Impacts

When temperatures increase, the human body can typically regulate its internal temperature to cool itself.[93–95] However, extreme heat can overwhelm this regulatory system, resulting in **heat-related illness** (HRI). HRI can range from minor symptoms, such as heat rash and cramps, to more severe conditions like heat exhaustion and heatstroke.[95] HRIs usually result from exposure to high temperatures, high humidity, lack of shade and minimal air movement both indoors and outdoors.[54,95] Extreme heat is also associated with other health outcomes and can exacerbate existing medical conditions such as cardiovascular disease, respiratory/lung diseases, diabetes, renal/kidney illnesses, hypertension, mental illness and more.[95,96]

These impacts result in extreme temperature contributing to increased hospital admissions and mortality such as respiratory-related hospitalization and mortality, cardiovascular-related hospitalization and mortality, and all-cause mortality.[41,96] Even moderate changes in temperature can impact mortality.[96] The effect of a heat wave on cardiovascular mortality may potentially persist for a week after the event, though further research is needed.[41]

There is an indication that tolerance for extreme heat can increase after regular exposure. This is known as acclimatization.[96] This means that communities in cooler climates are at higher risk of the health outcomes of extreme temperatures to which they are not acclimatized.[96] It may also mean that tolerance to extreme heat for the PPH population will increase over time and help to temper some of the potential health outcomes.[54,97] However, there are limits to temperatures that the human body can withstand and function optimally.[98,99] Extreme heat has also been associated with additional health impacts that include difficulty sleeping, increases in unintentional accidents and injuries,[100] and perinatal effects.[41,96]

Many studies have explored the connections between extreme heat and mental health. High temperatures have been found to increase stress and contribute to the development of psychological and behavioural problems,[41,65] and exacerbate mental illness.[65,101] Both of these impacts can result in a higher risk of mental health–related ED visits and possibly self-harm or self-inflicted mortality.[101–105] Higher temperatures have also been linked with increases in crime and violence, possibly because stress increases people's propensity for aggressive behaviour.[65,106] And finally, extreme heat can impact mental health potentially contributing to isolation when outdoor activities are discouraged.[41,107]

Populations at Increased Risk

> While the "Populations at Increased Risk" are presented here and in subsequent chapters as fairly discrete groups, the **highest risk for vulnerability** exists for the people that have multiple risk factors.

Children

Children, especially young children and infants have increased sensitivity to extreme heat as they are less able to regulate their body temperature and adjust physically to extreme heat[41,96] as outlined in Chapter 4: Vulnerability. A study in Montreal found that outdoor temperatures above 29°C increased risk of Sudden Infant Death Syndrome (SIDS).[108] Children can also be vulnerable due to lower adaptive capacity and higher exposure; they depend on parents/caregivers to keep them safe, and they may spend more time outdoors depending on their age.[82,96] To illustrate exposure considerations, a Canadian study of sun- and heat-related illnesses (HRIs) at 20 hospitals where 72% of cases were aged 19 years and younger found that the top three event circumstances associated with HRIs were sports and recreational activities (33.1%), playing outside (14.8%), and working (14.8%).[109] This information highlights the importance of having adequate built environment and precautions to respond to extreme heat for children's summer programs or sporting events, especially. Children living in urban areas are at increased risk of extreme heat due to increased exposure to urban heat islands[110] (See more information on urban heat islands below).

Older Adults

Older adults are more sensitive to extreme heat because they may be less able to adapt physically, have pre-existing chronic diseases and use medications that may affect their thermoregulation, as outlined in Chapter 4: Vulnerability.[41,96,111] Those who experience higher levels of social isolation or dependence, low socioeconomic status (SES), live in an urban heat island and/or have mobility issues may have limited ability to adapt to extreme heat.[112,113] In the PPH region older adults (65 and older) represent 25.2% of the population compared to Ontario at 18.5% in 2021.

Pregnant People

Extreme heat may lead to pregnancy and labour complications, and impact prenatal development. Depending on timing of the exposure to extreme heat events, exposure has been associated with outcomes such as miscarriage and congenital complications (e.g., heart or neural tube defects) premature birth and stillbirth, and severe labour complications.[114–118] The causes and pathways of these impacts are not fully understood but research is growing.[96] In the PPH region, on average about 1,200 pregnant people give birth each year. (Source: BORN Ontario, 2023)

Socioeconomic Status

Individuals experiencing low SES are often affected by low income and limited finances. They are more likely to experience housing that is poorly insulated and ventilated, and lacking air conditioning.[41,119–121] Finances can be a barrier to taking protective actions against extreme heat events, which can be referred to as "energy poverty".[94] Examples of protective actions include the ability to purchase an air conditioner (including the ongoing expenses to operate it), accessing cool or shaded spaces, undertaking necessary housing repairs, and avoiding sources of air pollution such as high traffic areas.[82,122,123] Low SES and a lack of air conditioning are two of the greatest combined risk factors for heat related illnesses.[95] People with low SES have been found to be more likely to see a doctor during extreme heat events because of health impacts[41,120] and low SES seniors were three times more likely to go the emergency department, be hospitalized or die from heat when temperatures were above 30°C.[41,112]

Individuals with low SES are often found to inhabit single rooms or upper floors of apartment buildings where heat can reach extreme levels without proper ventilation or air.[95] While accessing cooler environments - like cooling rooms or public spaces in urban centers - may be an option, it is important that barriers to access them are considered as part of adaptation planning and implementation.[95]

The unemployment rate within the PPH region in 2021 was 12.8%, slightly higher than the Ontario rate (12.2%). The rate is notably higher in the city of Peterborough (14.7%) compared to in the county. Maps such as shown in Figure 4-2 in the Vulnerability chapter (Material Resources Quintiles of the Ontario Marginalization Index) can show areas of the PPH region that may be vulnerable due to SES. New immigrants are a specific population that may also face barriers to adapting to extreme heat events, largely due to SES factors and the challenges described above.[5]

People Without Fans or Air Conditioning

As described above, cooling equipment like fans and air conditioning can be important during an extreme heat event. Quinn et al.[124] found that during heat waves homes without air conditioning often reach levels that are hazardous to human health. This can be particularly true in upper stories of high-rise buildings, and in areas where urban design characteristics result in heat retention, limited airflow, and/or reduced shade,[54] which can characterize urban heat islands (further described below).

A report on the 2021 Heat Dome in BC, where over 600 people died because of the heat found the following:

"High indoor temperature was the primary cause of injury and death during the extreme heat event. During this time, hot air became trapped indoors and continued to rise over time. Although outdoor temperatures decreased overnight, residences did not cool off, exposing people to harmful high temperatures for extended periods of time."[125 (p.22)]

In 2021, it was found that **22%** of households in the Peterborough CMA did not have any kind of an air conditioner as part of the Statistics Canada's voluntary Household and Environment Survey. This is higher than the provincial average of 16%.[126]

Outdoor Workers

Outdoor workers, for example those involved in agriculture, forestry, and construction, are at an increased health risk due to exposure to extreme heat. This exposure may increase the risk of injury and illness and

worker productivity may decrease.[41] As stated in, Health of Canadians in a Changing Climate, Fortune et al.[127] found that, "in Ontario, from 2004 to 2010, every degree above 22°C increased the median number of hospitalizations for heat-related occupational illnesses and diseases by 75%". [425] Heat related injuries are more frequent for men and younger workers.[128] In the PPH region in 2021 the number of people working in the following sectors were:[15]

- Agriculture, forestry, fishing, and hunting - 1,560
- Mining, quarrying, and oil and gas extraction - 320
- Construction - 6,570

People with Chronic Health Conditions

"Temperature extremes can also worsen chronic conditions such as cardiovascular disease, respiratory disease, cerebrovascular disease, and diabetes-related conditions. Prolonged exposure to high temperatures is associated with increased hospital admissions for cardiovascular, kidney, and respiratory disorders." [96] Medication usage may also be required to manage chronic health conditions, which can increase vulnerability to heat (See People who use Substances section below).

Estimated prevalence (and age-standardized prevalence rate) of a few chronic diseases in PPH region in 2019 were as follows:

- Asthma - **18.7%** of population (19,235 per 100,000)*
- COPD - **12.7%** of those aged 20+ (10,197 per 100,000 aged 20+)*
- Hypertension - **30.6%** of those aged 20+ (24,686 per 100,000 aged 20)ᵒ
- Diabetes - **13.0%** of those aged 20+ (10,776 per 100,000 aged 20)ᵒ

*denotes rate is significantly higher than Ontario rate
ᵒdenotes rate is significantly lower than the Ontario rate

Source: Public Health Ontario, Institute for Clinical Evaluative Sciences (ICES) chronic disease cohorts 2019.[62]

The age-standardized prevalence of Ischemic heart disease in Ontario in 2019-2020 was **7.55%** of those aged 20+.[129] Prevalence increases with age, therefore PPH region likely has a higher crude prevalence rate due to the higher proportion of older adults in the region.

Mobility limitations can lead to exacerbated effects of extreme heat. Being confined to a bed is strongly associated with heat-related illnesses.[95] Individuals who require assistance for daily care are also at an increased risk of morbidity and mortality from extreme heat events. People with disabilities can also experience disproportionately higher rates of social risk factors, such as poverty and low SES.[5]

People with Mental Health Problems

Extreme heat can worsen health and increase hospitalizations of people with pre-existing mental illnesses such as schizophrenia, mood disorders, substance use disorder and dementia.[83] Some medications used to treat mental illnesses make it difficult to control body temperature and cool down.[65,78] People with schizophrenia are at higher risk of death during extreme heat events.[130,131] People with mental illness also often live in chronic poverty,[132] which further limits their ability to adapt and cope with extreme heat events.

People who use Substances

Alcohol or drug use and certain medications can make people more susceptible to the effects of heat.[41,78,95] These substances can interfere with the body's thermoregulatory mechanisms contributing to an increased risk of HRI. Some examples of medications which can make people more susceptible are diuretics, antidepressants, antihypertensives and psychotropic drugs.[95] Methamphetamines are an example of a drug which can cause the body temperature to increase and put individuals at a higher risk for HRI.[133] People under the influence of substances may have a reduced level of awareness and reaction time to initiate protective behaviours during extreme heat events.[95]

People Experiencing Homelessness

People experiencing homelessness can be at increased risk to the health impacts of extreme heat due to various vulnerability factors. This population faces increased risks as they are directly exposed to outdoor heat and excess humidity with decreased respite from these conditions.[95] This is often coupled with living in urban areas which increases their exposure to urban heat island effects. They face multiple risk factors which can increase their sensitivity to extreme heat events, as described in Chapter 4: Vulnerability, but include factors such as social isolation, substance use, mental illness and other chronic health conditions.[41,66,78] Their ability to adapt to extreme heat events is limited, and there can be barriers to accessing cooling centres, which could include lack of transportation, and fear of leaving belongings or pets unattended.[134] In Peterborough City and County in 2021, a monthly average of **266 individuals experienced** homelessness.[51] The most common health conditions reported by those experiencing homelessness were substance use (78%), mental health concerns (61%), followed by medical conditions/illness (52%).[441]

Indigenous Peoples

For Indigenous peoples, the indirect effects of rising temperatures on the environment and the direct and indirect effects of extreme heat may cause major health impacts.[41,135] There are multiple factors that may influence health, including existing disparities of shorter lifespans, higher rates of chronic health conditions and greater food and water insecurity in many communities.[59] The increased risks are largely the result of the health and social inequities experienced by Indigenous peoples, that are underpinned by systemic racism and colonialism. However, it is important to emphasize that these findings are broad, and it may not be appropriate to generalize findings to the Indigenous peoples that we share space with in the PPH region. In 2021, the percentage of PPH region population who identified as Indigenous in private households was 4.9% vs 2.9% in Ontario.[15]

Mapping Vulnerability in the Peterborough CMA

Sensitivity and Adaptive Capacity

In 2023, Université Laval launched a website with heat vulnerability maps for many of the Census Metropolitan Areas across Canada.[136] One of their map layers is a "sensitivity index". The variables used for this index include factors that match the definition of sensitivity used in this report, but also relate to factors that would relate to adaptive capacity (many of these described above). The variables are listed in the Figure 5-8 below.

Figure 5-8. *Variables Used to Create the Sensitivity Index by Université Laval.*[137]

Proportion of elderly (≥ 65 years old) and children (≤ 4 years old) (%)
Proportion of people with no certificate, diploma, or degree (%)
Proportion of recent immigrants (%)
Proportion of people who don't know either official language (%)
Proportion of people living alone (%)
Proportion of single-parent families (%)
Proportion of rented dwellings (%)
Proportion of dwellings in need of major repairs (%)
Proportion of apartments in a building that has five or more storeys (%)
Proportion of dwellings built before 1980 (%)
Proportion of low income based on the Low-Income Measure after tax (%)
Proportion of renter households spending 30% or more of income on shelter costs (%)

In Figure 5-9, it is possible to see how vulnerability to heat waves varies across the Peterborough CMA, being very high (dark maroon) in some areas of the City, as well as some areas of the broader CMA region. One limitation in this map is that it is not possible to delineate which variables from the list above are contributing most to the high sensitivity in different areas. This specific information could be useful to inform targeted initiatives or programs to support the communities with adaptation.

Figure 5-9. *Map of Sensitivity to Heat Waves for the Peterborough CMA.*[138]

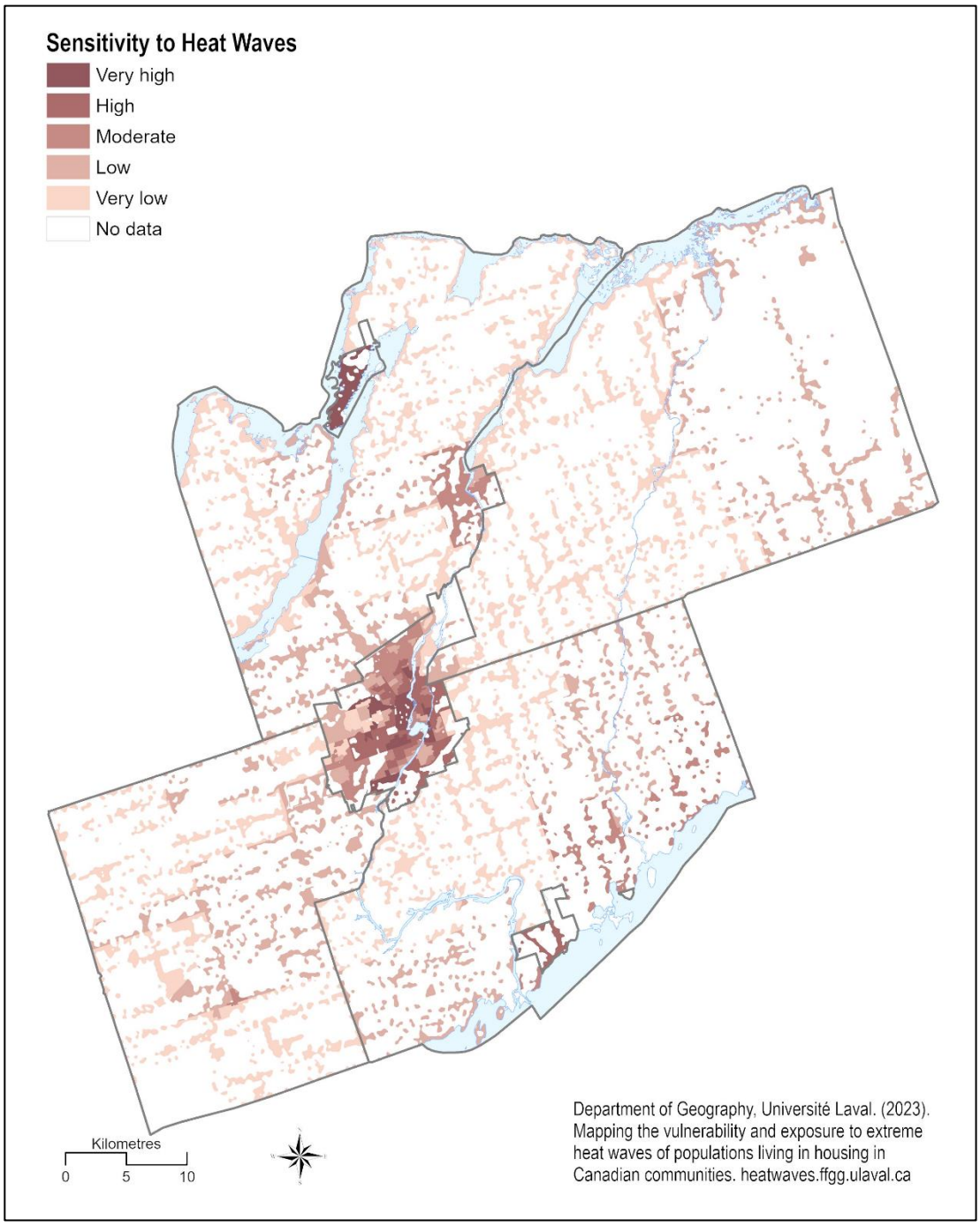
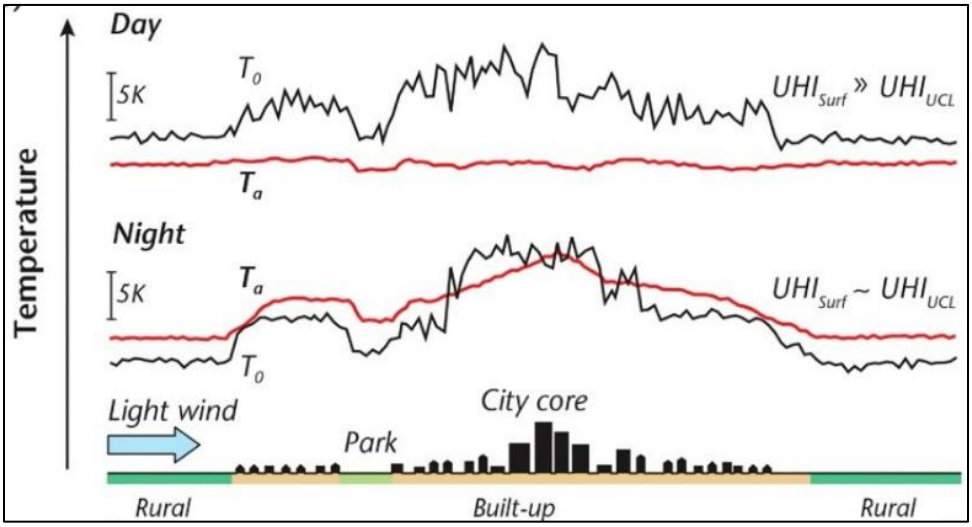


Figure author: City of Peterborough Geomatics/Mapping Division, 2023 (Created for this report). Source is denoted in the Figure.

Exposure - Urban Heat Islands

An urban heat island is a phenomenon that occurs when urban areas are warmer than surrounding rural areas.[139–141] These are primarily caused by the built environment in urban areas, as natural resources (i.e., trees) get replaced by structures that absorb solar radiation (e.g., buildings, factories, asphalt, roads). This creates less shade and moisture causing an increase in heat production.[140,141] Health Canada[142] reports that in some cities, the temperature can be 1-3°C warmer than surrounding urban areas and sometimes up to 12°C warmer if certain weather conditions (calm winds and clear skies) are present. This in turn intensifies the impact and adverse health effects of an extreme heat event, especially for those most vulnerable.

Figure 5-10. *Two-Dimensional Cross-Section of a Typical Urban Area Showing Both Day-Time and Night-Time Surface Temperature (T_0) and Air Temperature (T_a).*



Source: Health Canada. Reducing Urban Heat islands to Protect Health in Canada: An Introduction for Public Health Professionals.; 2020.[142]

Urban heat island mapping can be conducted for communities, and is another product made available for the Peterborough CMA in 2023 by the Department of Geography at the Université Laval. The map (see Figure 5-11), was created using ten indicators including ground temperature (taken on days when temperatures exceeded 30°C), the vegetation index (NDVI) and the built-up index (NDBI). Other variables included percentage of soil imperviousness, latitude, longitude, altitude, and proximity to bodies of water.[143] On the map, dark red areas represent the hottest areas in the region, while dark green represents the coolest areas of the region. The map shows that the urban core of the City of Peterborough is hotter than the more rural and forested areas in the northern and surrounding portions of the CMA.

Figure 5-11. *Urban Heat Island Mapping for the Peterborough CMA.*[144]

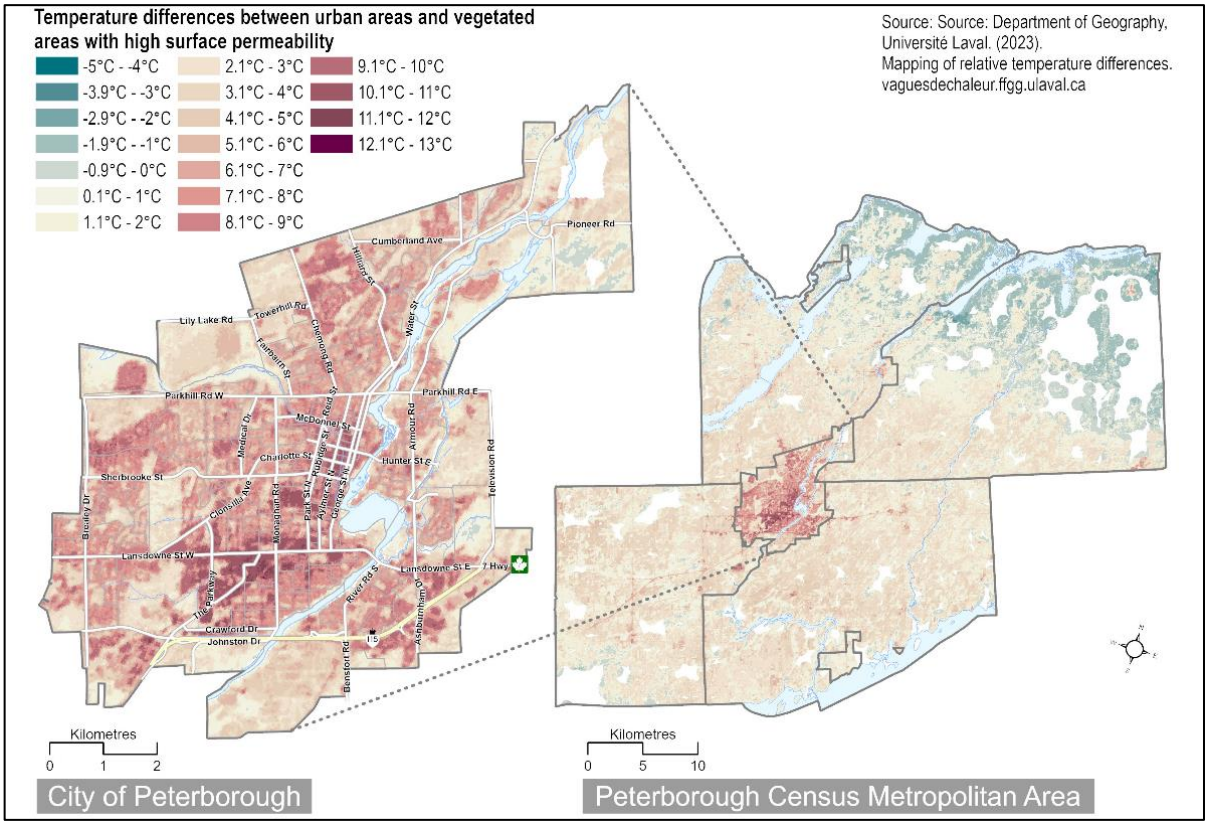


Figure author: City of Peterborough Geomatics/Mapping Division, 2023 (Created for this report). Source is denoted in the Figure.

Mapping Vulnerability and Exposure in the City of Peterborough

The heat mapping program from Université Laval makes one multivariable map available, combining their **vulnerability** and **exposure** indices, which is shown for the City of Peterborough[a] in Figure 5-12.

- The **vulnerability index** is shown on the map with the purple gradient. The index can be used to identify groups of people and areas most vulnerable to extreme heat and combines their *sensitivity index* and *coping capacity index*.
  - The *sensitivity index* groups together several demographic and socio-economic factors (presented and described above)
  - The *coping capacity index* is estimated by determining proximity to places and services that provide shelter and relief from extreme heat, like shopping centers, parks and public swimming pools.
- The **exposure index** is shown on the map with the orange gradient. It was calculated using satellite imagery data including temperature and impermeability data for soil, plant cover, and the built environment. It also incorporated factors such as water proximity, altitude, and location data.[136] This index is comparable to the urban heat island map.

On the map in Figure 5-12, dark brown areas (purple and orange combined) are places that are most vulnerable and exposed to extreme heat in the region, while the light beige areas represent places that are least vulnerable and least exposed. As indicated on the map, the areas where both indices are considered high or very high are located in the central area of the downtown core of the City of Peterborough. In the

[a] The County portion of the CMA was not presented because exposure is relatively low throughout the whole region as shown in Figure 5-11. See Sensitivity Index and Urban Heat Island maps above to consider vulnerability factors for the County portion of the Peterborough CMA.

occurrence of a heat wave, these areas should be prioritized for adaptation supports. Other areas that show slightly lighter brown/purple shades may also be areas to consider.

Figure 5-12. *Vulnerability and Exposure to Heat Waves in the City of Peterborough.*[138]

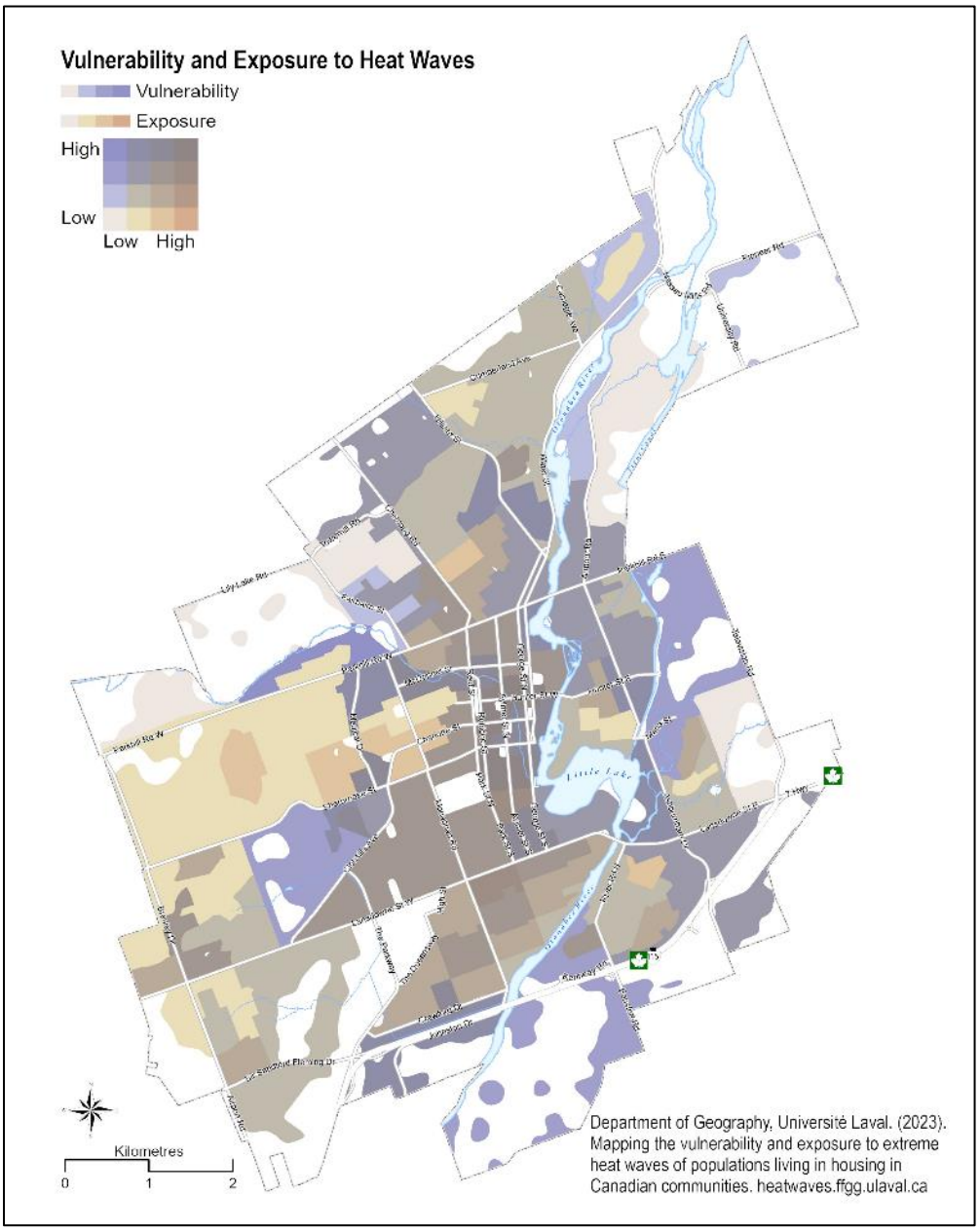


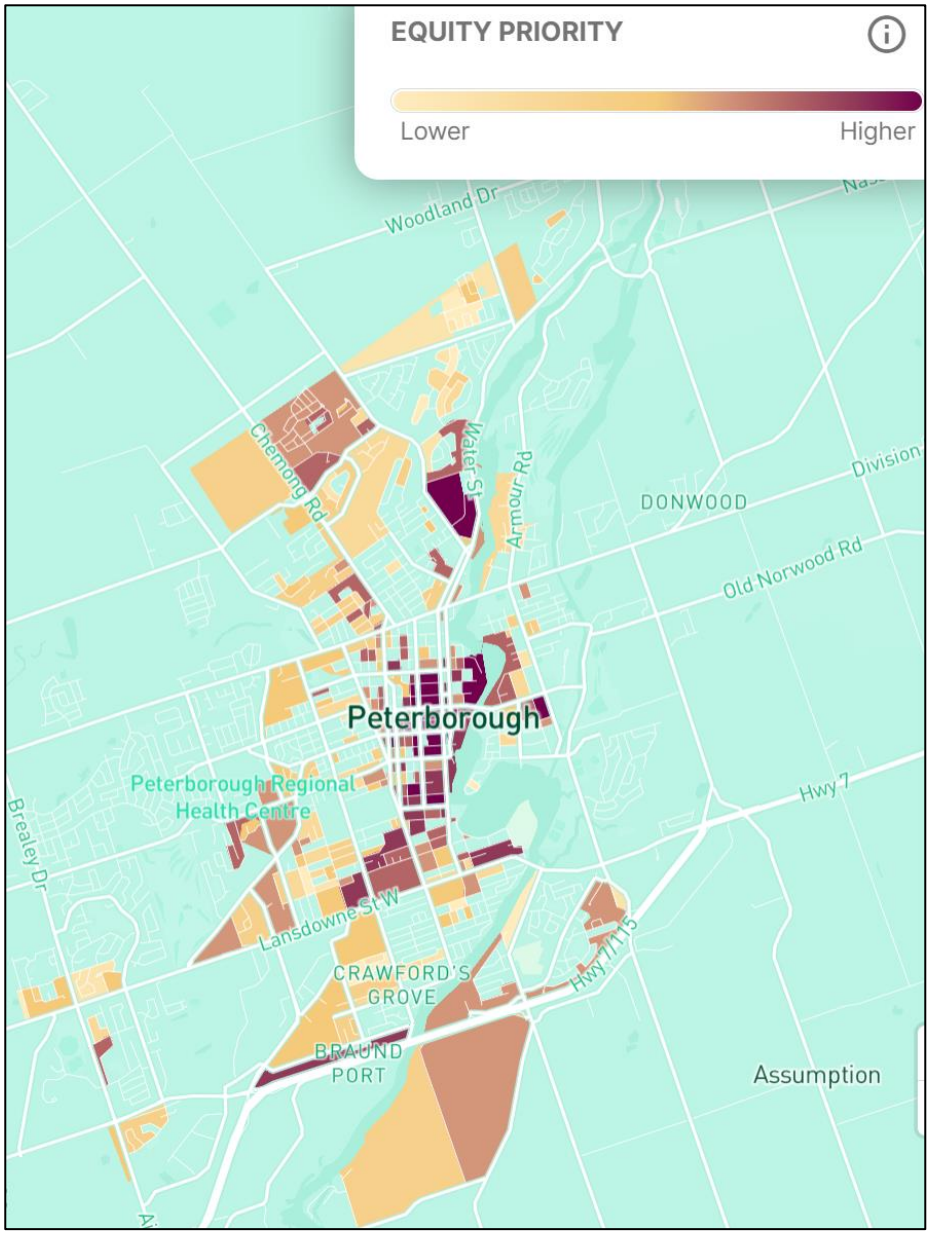
Figure author: City of Peterborough Geomatics/Mapping Division, 2023 (Created for this report). Source is denoted in the Figure.

Mapping of Tree Canopy and Income in the Peterborough CMA

Tree canopy cover is another factor that influences urban heat and can be mapped. The tree canopy can protect against the urban heat island effect by providing shade and cooling through evaporation and transpiration.[145] It is possible to assess tree canopy with satellite data. HealthyPlan.City presents this information and combines it with demographic data from the census for many cities across the country, including the Peterborough CMA. Figure 5-13 presents a subset of the map for the Peterborough CMA combining tree canopy data (from 2015) with low-income data. The dark maroon areas have the highest inequities, where there is a higher proportion of low-income individuals and a lower level of tree canopy cover. HealthyPlan.City presents several statistics alongside the map, including the following:

- There are 5,973 low-income individuals living in unfavourable tree canopy cover areas in Peterborough. This is 61% of the population of low-income individuals in Peterborough, compared to 57% in Canada.[146]

Figure 5-13. *Mapping of Tree Canopy and Low Income in the City of Peterborough.*



Source: HealthyPlan.City, 2023.[146]

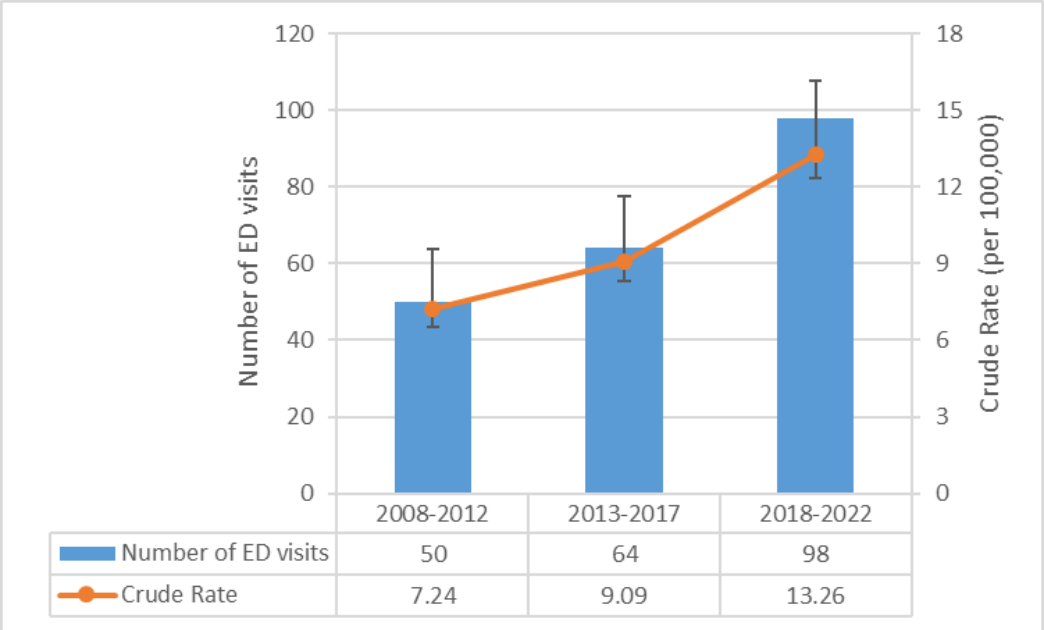
The City of Peterborough has an Urban Forest Strategic Plan, and more recently implemented a Tree Bylaw to support achieving their commitment to preserve and expand their urban forest canopy to 35% by 2041.[147,148]

Health Outcomes

Heat-related Emergency Department (ED) visits

Emergency department visits due to extreme heat have ranged in incidence from 4 to 25 cases per year during the 2008 to 2022 time period. Five-year totals and average rates are shown in Figure 5-14 below, and these totals and rates have increased over time. Increasing rates may correspond to increasing temperatures as well as increasing vulnerability in our community.

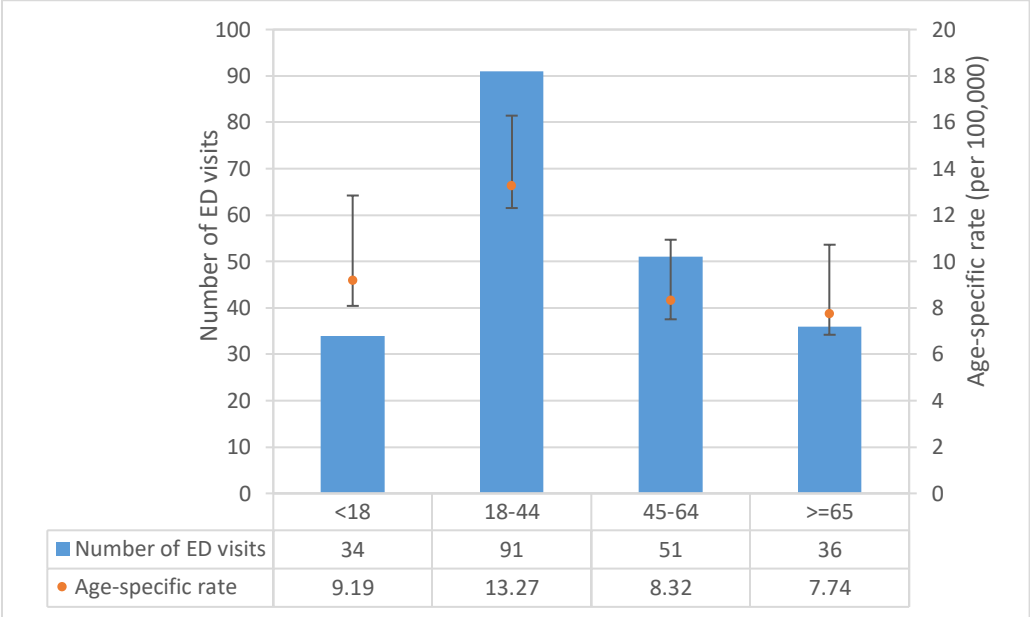
Figure 5-14. *5-Year Totals and Average Crude Incidence Rate (Cases per 100,000 Population per Year) of Heat-Related Emergency Department Visits by PPH Residents From 2008 to 2022.*



Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: July 2023.

The rates per age group are shown in Figure 5-15. Those in the 18-44 age group have the highest rate and contribute about 43% of these ED visits. This age group falls outside of some of the populations at increased risk due to sensitivity to heat listed above, such as children, older adults, and those with chronic health conditions. This suggests that other characteristics of this age group may relate to vulnerability due to higher exposure and/or lower adaptive capacity, which could contribute to these negative health outcomes. This age group is a fairly broad age group but includes young adults, post-secondary students, and young to middle-aged workers.

Figure 5-15. *Number of Heat-Related ED Visits and Age-Specific Rate (per 100,000 Population) by PPH Residents for the Time Period 2008 to 2022.*



Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: July 2023.

Finally, males make up 66% of these ED visits, suggesting a gender difference in vulnerability factors, likely relating to exposure and/or adaptive capacity factors. Various outdoor-based industries tend to have a male-dominated workforce, including construction and agriculture,[149] which relates to exposure. Gendered social norms relating to behaviours that might increase exposure or reduce preventative actions may also contribute to increased vulnerability of males.[150] It is important that continued adaptation strategies to mitigate against the harms of extreme heat consider these vulnerability factors.

It would be valuable to explore heat-related ED visit data more thoroughly to determine if there are noticeable patterns. For example, are visits more likely to happen:

- When temperature exceeds a certain daily high temperature? (What temperature?)
- During a heat warning or extended heat warning (i.e., during a multi-day heat event)?
- On the weekend vs. on a weekday/night?

This information could support tailoring adaptation strategies to when risk is highest.

Other Health Outcomes

The impacts of extreme heat events on other health outcomes such as mental health, exacerbation of chronic physical or mental illnesses, and contributions to mortality, were not explored for the current report. If there was demand to explore this locally, the outcomes would need to be compared to daily temperatures to support drawing any connections with extreme heat.

Extreme Cold

Extreme cold refers to times where temperatures drop below a certain temperature. The specific temperature value considered extreme may vary depending on the location and what typical seasonal temperatures are. Locally, temperatures below -27°C are often considered extreme. Similar to extreme heat, the impact may be more significant if extreme cold persists for more than one day. See the next section below for more information about extreme cold alerts.

While climate change is projected to reduce the frequency and intensity of extreme cold, extreme cold events are still going to occur.[41] Beyond natural temperature variability, the impact of climate change on the arctic polar vortex is important to note. A changing climate could disrupt the polar vortex leading to cold air moving more south into mid-latitudes than is typical, and instances of extreme cold events.[151]

Extreme cold can be harmful to health by causing cold weather injuries, such as frostbite and hypothermia. Exposed skin can freeze in less than half an hour, potentially in as little as 5 minutes, depending on the temperature.[152]

Hazard Trends and Projections

Extreme Cold Trends and Projections

"Warmer temperatures will reduce the length of the cold season across Canada and the intensity and frequency of extreme cold."[41(p.152)]

Table 5-2 shows the projected changes in the number of very cold days (Tmin<-25°C) and cold days (Tmin<-15°C) in the future according to two climate scenarios.

Table 5-2. *Extreme Cold Variables for Baseline Time Period and Projected for 2050s and 2080s under Middle of the Road (SSP2-4.5) and Fossil-Fueled Development Scenarios (SSP5-8.5).*

variable	Baseline (1981-2010)	2050s		2080s	
		SSP4.5	SSP8.5	SSP4.5	SSP8.5
Very cold days (days with Tmin<-25°C)	6	1	1	1	0
Cold days (Days with Tmin<-15°C)	37	19	13	14	4

Source: ClimateData.ca, 2023.[21]

By 2050, the PPH region can anticipate a decrease in very cold days. The number of these days in the baseline time period (6) is already 2 days less than the 1951-1980 average (*data not shown*), and the number of days will continue to decrease to an average of 1 each year by the 2050s under both scenarios.

To expand on this picture of PPH region winters, the number of cold days (Tmin<-15°C) is also presented. Likewise, these days are projected to decrease significantly under these two scenarios throughout the century.

Frostbite Alerts

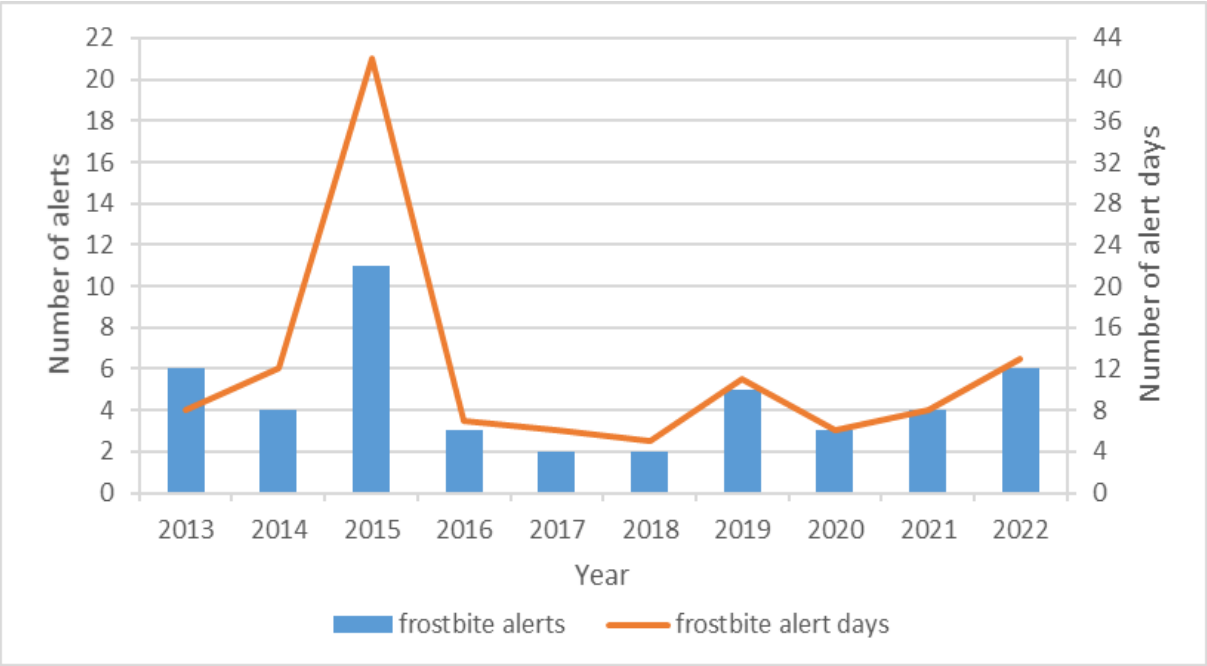
Extreme Cold Alerts

Similar to extreme heat, weather forecasts (meteorology) make it possible to forecast instances of extreme cold, which can be helpful for communicating risks via extreme cold alerts. PPH has three levels of extreme cold alerts:

1. Frostbite Alerts are the most common and are issued when temperatures are forecasted to be from -27°C to -38°C or a wind chill of -27°C to -38°C.[152]
2. Frostbite Warnings are issued when temperatures are forecasted to be from -39°C to -47°C or a wind chill of -39°C to -47°C.[152]
3. Cold Weather Emergencies are issued when temperatures are forecasted to be -48°C or colder or a wind chill of -48°C or colder (OR when the temperature is below -27°C or a wind chill below -27°C accompanied by a contributing risk factor such as a power outage, or critical infrastructure failure).[152]

Figure 5-16 presents the number of frostbite alerts and number of frostbite alert days each year between 2013 and 2022 for the PPH region. The number of frostbite alerts each year is typically between 2 and 6, but in 2015, there was a noticeable peak with 11 frostbite alerts. Frostbite alerts are often implemented for an overnight period, which is counted as two days, though sometimes alerts are enacted for one day or for more than two days. Again, 2015 is noticeably higher than the other years, with 42 frostbite alert days. The winter of 2015 was an example of how movement of the polar vortex can lead to instances of persistent, extreme cold, compared to typical years.[153]

Figure 5-16. *Number of Frostbite Alerts and Frostbite Alert Days Issued by PPH from 2013 to 2022.*



Source: Peterborough Public Health records, 2023.

Health Impacts

Exposure to cold weather and extreme cold can result in a variety of health impacts such as windburn, hypothermia (body loses heat faster than it can be produced, which is a medical emergency), frostnip (mild form of frostbite), frostbite and trench foot (feet exposed to wet and cold conditions for prolonged periods).[154,155] A person's body responds to the cold weather by increasing the heart rate and pumping blood faster to maintain warmth. A high heart rate and blood pressure can increase the risk of heart attacks. Cold weather can worsen heart disease, respiratory illness and stroke-related illness and mortality, as well as general mortality.[41] Cold temperatures can reduce blood supply to extremities which means the immune system is compromised and a person can be more susceptible to infections such as rhinovirus and influenza.[155] The health effects related to the time of the cold exposure are not well known and the effects can be seen up to two weeks or longer following the exposure.[156] Other possible risks include falls and injuries related to hazardous icy conditions caused by extreme cold.[155] This is further explored in Chapter 6: Extreme Weather Events. During extreme cold events people may increase their time indoors which can facilitate the spread of influenza and respiratory infections.[41]

The projected global warming may mitigate some of the adverse health effects from cold in Canada.[41]

Populations at Increased Risk

Any person who does not dress appropriately for cold weather conditions is at risk for negative health impacts, however some populations are at greater risk than others.

Children

Children and infants are at greater risk for frost bite and hypothermia[154] and those with respiratory conditions such as asthma are at increased risk for cold related morbidities.[157,158]

Older Adults

Individuals over the age of 65 are at increased risk of cold related illnesses as their ability to regulate their temperature decreases with age.[157,94] This age group also experiences higher rates of pre-existing chronic health conditions making them sensitive to extreme cold and further increasing their risk for illness. Some medications may also increase their susceptibility to hypothermia.[155] The rate of hospitalization among the elderly for cold injuries from slips and falls increases during cold weather events.[159]

Pregnant People

Exposure to cold during pregnancy may increase the risk of adverse effects such as eclampsia, low birth weight and premature birth.[41,116,160]

Socioeconomic Status

Individuals who experience low SES are often affected by low income and limited financial resources. However, there is limited research on the impact of cold on this group.[41] They may not be able to afford necessary repairs to their homes or afford utilities to keep their homes heated comfortably, which can be referred to as "energy poverty".[94] In order for individuals to afford other needs such as rent and food, they may lower the heat in an effort to save money.[161,162,163] A cold home negatively affects the mental health of all age groups.[164,165]

Outdoor Workers

Workers who are exposed to cold weather may experience thermal discomfort and, in some cases, even severe injuries, illnesses, or death.[166] Outdoor workers may have higher exposure and be at increased risk of cold related health impacts. Examples of outdoor workers are those that are involved in agriculture, forestry and construction, though many other job types require varied amounts of time spent outdoors. Indoor work in an unheated space could also put indoor workers at risk of negative health impacts. Workers who have had frostbite, perform sedentary work and those with poor circulation may be more at risk.[166] Prolonged exposure to cold can lead to extreme cooling of the extremities and the lungs. Workers who have decreased sensation or pain in the extremities due to cold are more likely to suffer from injuries and accidents. Individuals can also have adverse health effects from pre-existing health conditions and respiratory tract cooling.[167]

People with Chronic Health Conditions

People with illnesses such as diabetes, peripheral neuropathy and diseases affecting the blood vessels are at greater risk for frostbite and hypothermia.[155,94] Those with pre-existing health conditions such as thyroid problems,[168] asthma, and cardiovascular disease may be more susceptible to cold exposure.[155,41] According to the Health of Canadians in a Changing Climate report, a study in Toronto found that, "people with pre-existing kidney or cardiac conditions had a higher probability of being admitted to the emergency department for cardiovascular reasons in extreme cold compared to those without this type of problem."[169, 425] found that people with pre-existing kidney or cardiac conditions had a higher probability of being admitted to the emergency department for cardiovascular reasons in extreme cold compared to those without this type of problem.[169]

People with Mental Health Conditions

People with dementia (e.g., Alzheimer's, vascular dementia) or who are mentally impaired may not fully understand the dangers of going outside in cold weather and consequently may experience negative health impacts due to exposure.[155]

People who use Substances

Alcohol or drug use and certain medications can make people more susceptible to the effects of cold.[168,94] Substances can lower the body's ability to retain heat and can impair judgment to initiate protective behaviours.[155]

People Experiencing Homelessness

Many people experiencing homelessness or living in homes with inadequate heating are exposed to cold weather.[155,94] They may experience social isolation, substance use, mental illness and other chronic health conditions.[41,96,170,171,172] According to the Health of Canadians in a Changing Climate report, "[a] study in Paris, France, estimated that people experiencing homelessness accounted for 62% of those admitted to emergency departments for hypothermia or frostbite in winter from 2005 to 2009."[173, 425]

Indigenous Peoples

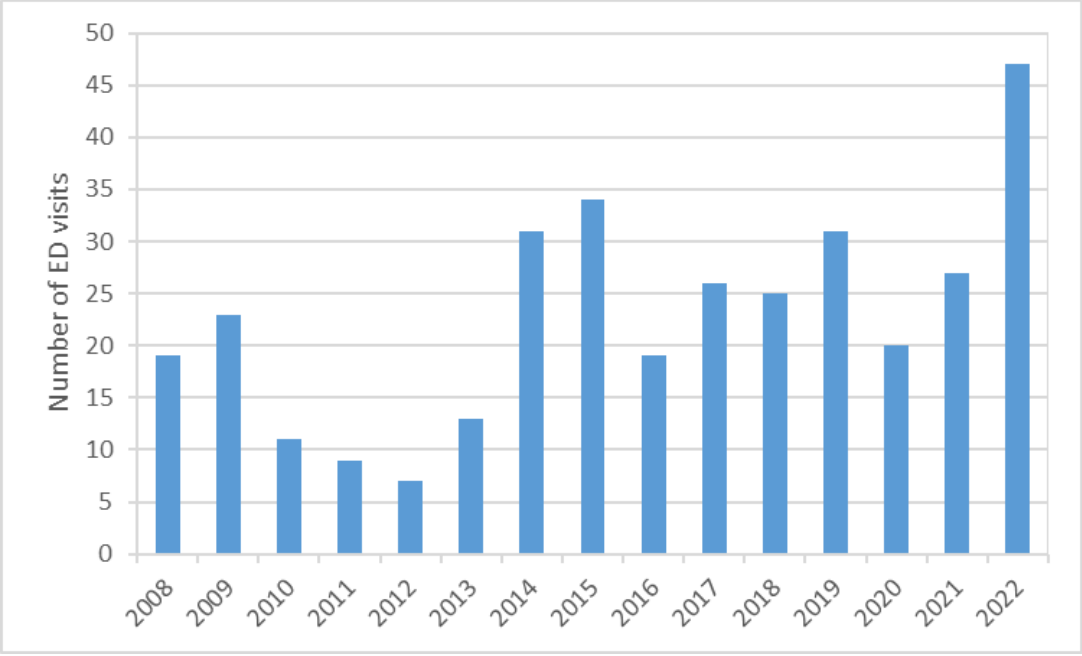
Indigenous peoples may be more vulnerable to extreme cold. Research literature notes a higher prevalence of living in inadequate housing that require minor to major repairs,[41] which may not be protective of cold temperatures. Indigenous peoples have higher rates of chronic health conditions and have also been found to be disproportionately represented in the homelessness population,[174,59] which contribute to being at increased risk. Again, it is important to acknowledge that 1) the increased risks are largely the result of the health and social inequities experienced by Indigenous peoples that are underpinned by systemic racism and colonialism, and 2) these findings are broad, and it may not be appropriate to generalize findings to the Indigenous peoples that we share space with in the PPH region.

Health Outcomes

Cold-related Emergency Department (ED) visits

Cold-related emergency department visits by PPH residents have ranged in incidence from 7 to 47 cases per year during the 2008 to 2022 time period. Yearly totals seem to fluctuate somewhat, as shown in Figure 5-17. Looking at 5-year average rates of these ED visits (see Table 5-3), there has been an increase in the average since 2008-2012. These rates may be useful for comparison purposes in the future.

Figure 5-17. *Number of Cold-Related Emergency Department Visits by PPH Residents Between 2008 and 2022.*



Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: July 2023.

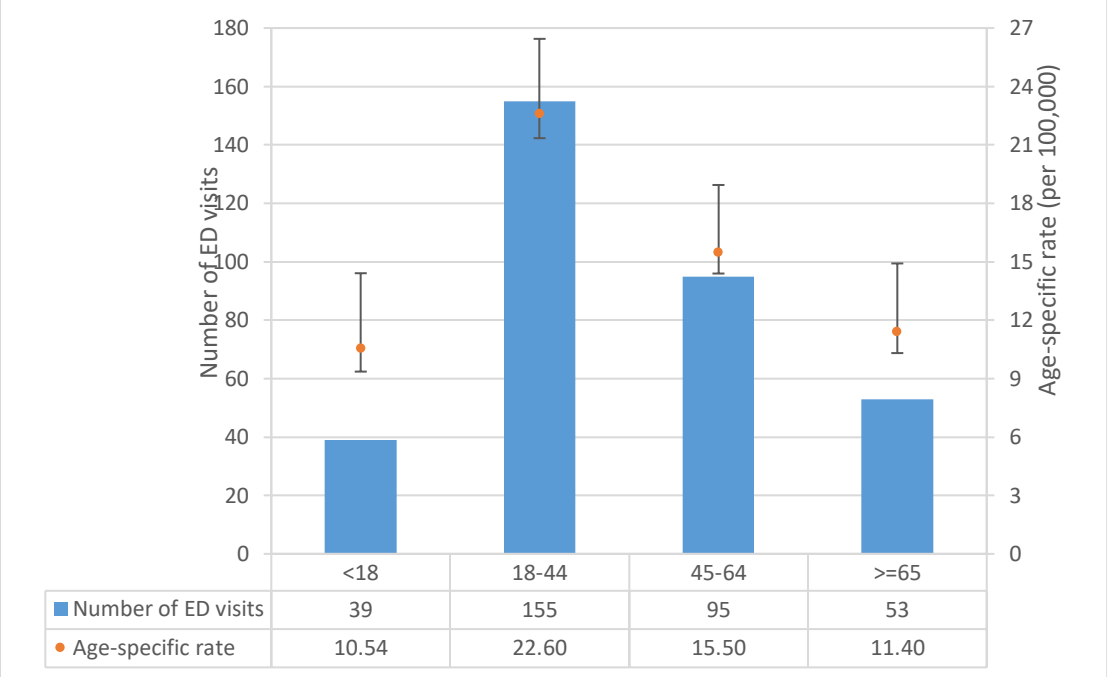
Table 5-3. *5-Year Average Crude Incidence Rate (Cases per 100,000 Population per Year) of Cold-Related Emergency Department Visits by PPH Residents from 2008 to 2022.*

	2008-2012	2013-2017	2018-2022
Crude incidence rate per 100,000 population	9.99 (95%CI:9.16-12.64)	17.47 (95%CI:16.38-20.84)	20.29 (95%CI:19.15-23.81)

Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: July 2023.

The rates per age group are shown in Figure 5-18. Like heat-related ED visits, those in the 18-44 age group have the highest rate (22.60 ED visits per 100,000 population in this age group) and contribute about 45% of these ED visits. By narrowing to 10-year age groups, the 20-29 year old age group stands out with the highest age-specific rate: 25.78 cases per 100,000 of the population), followed by the 30-39 year-old age group (*data not shown*). As mentioned with heat-related ED visits, this age group falls outside of some of the populations at increased risk due to sensitivity to cold. This suggests that other characteristics of this age group may relate to vulnerability due to higher exposure and/or lower adaptive capacity, which could contribute to these negative health outcomes. This age group is a fairly broad age group but includes young adults, post-secondary students, and young to middle-aged workers.

Figure 5-18. *Number of Cold-Related Emergency Department Visits and Age-Specific Rate (per 100,000 Population) by PPH Residents for the Time Period 2008 to 2022.*



Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: July 2023.

Finally, males make up 73% of these ED visits, suggesting a gender difference in vulnerability factors, likely relating to exposure and/or adaptive capacity factors. These differences are not documented in the literature, but potential differences may relate to occupational or recreational exposure, or gendered social norms relating to behaviours that might increase exposure or reduce preventative actions in extreme cold. It is important that continued adaptation strategies to mitigate against the harms of extreme cold consider these vulnerability factors.

It would be valuable to explore cold-related ED visit data more thoroughly to determine if there are noticeable patterns. For example, are visits more likely to happen:

- At night vs. during the day?
- During extreme cold (frostbite alert in effect) or during moderate cold (no alert in effect)?
- On the weekend vs. on a weekday/night?

This information could support tailoring adaptation strategies to when risk is highest.

Peterborough Public Health Adaptation Efforts

The following are examples of Peterborough Public Health's current work that is contributing to climate change adaptation and supporting those most vulnerable to the health impacts of climate change related to extreme temperatures (heat and cold):

Population Assessment & Surveillance

- Monitoring extreme cold and extreme heat data.
- Conducting analysis on Rapid Risk Factor Surveillance System public surveys including general attitudes about climate change and extreme temperatures.

Health Promotion

- Educating, information sharing, and health teaching related to the health risks of extreme temperatures during routine activities such as family home visits, parenting groups, clinics, prenatal classes, and general contacts with clients and families.
- Supporting community partners with the establishment of centres for warming, cooling, and publicly accessible bathrooms.
- Sharing information regarding access to drinking water stations.
- Municipal engagement and advocacy for healthy municipal policies to reduce the health-impacts of extreme temperatures (e.g., land-use, shade, and "green" community design), as required.
- Partnering with agencies who work with vulnerable people to disseminate information that is practical and useful.
- Providing support to school boards, as requested, on policies and procedures related to extreme temperatures and health.

Health Protection

- Maintaining and implementing the Heat Alert Response Program based on the provincial Health Warning and Information System, including public alerts and notifications.
- Maintaining and implementing the Extreme Cold Response Plan, including public alerts and notifications.
- Providing recommendations and advice to vulnerable populations, for example, childcare settings and outdoor workers, related to exposure to extreme temperatures; facilitating referrals and connections with appropriate Ministries for legislative purposes.
- Providing enhanced inspections of recreational water facilities to ensure safe operation, particularly public beaches and splash pads, during periods of extreme heat.
- Providing guidance to special event organizers on the management and precautions related to anticipated extreme temperature events.
- Activating local protocols to open warming and cooling centres during extreme temperature events.
- Conducting compliance inspections of warming and cooling centres, as necessary.
- Contributing health expertise during periods of temperature emergencies and participating in coordinated emergency response efforts.

Extreme Weather Events

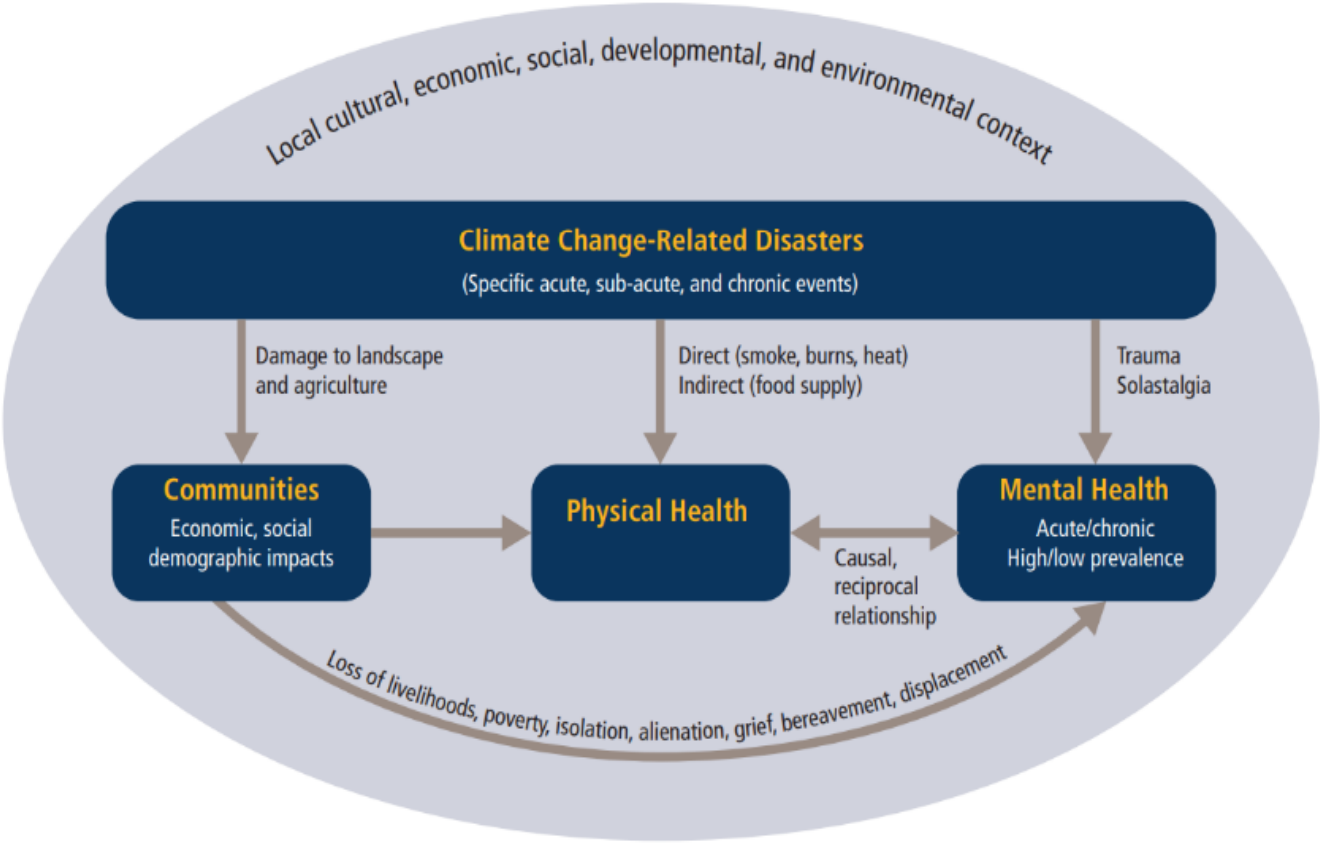
Extreme weather refers to "infrequent, but significant, departures from a location's normal weather conditions".[175(p.4)] There are many types of extreme weather events that may impact the PPH region including extreme windstorms (hurricanes and tornadoes), severe thunderstorms and heavy precipitation events (flooding), and winter storms (ice storms and blizzards). These events are often destructive and can have significant impacts on the communities affected.[176] Health impacts can include injury, illness, and death as a direct result of the event, as well as those caused by power outages, property damage, evacuations, and associated displacement from homes, jobs, and school.[3]

Climate change is expected to cause increased frequency and duration of extreme weather events.[177,87,36] Changes to temperatures and precipitation patterns throughout the year, as well as snowmelt, may contribute to things like increased risk for drought, wildfires (across Canada), winter precipitation/storms, heavy rain precipitation events, and potential flooding.[87] The effect of climate change on windstorms is more uncertain.[178] Attributing extreme weather events to climate change is a growing field of research, and continued work in this area should strengthen scientific claims connecting climate change to extreme weather.[87]

Health Impacts and Trends

Extreme weather events present threats to individual's lives, health and well-being in a variety of ways which vary depending on the individual, type of extreme weather event and adaptive capacity factors.[179] For some extreme weather events, health effects may be more direct and acute such as injury, illness, stress, exacerbation of chronic diseases, or death. Other health impacts may be less direct and/or long-term, contributing to the development of a chronic physical or mental illness (e.g., depression and post-traumatic stress disorder) or perinatal effects.[36] Research arising from extreme weather events indicates that the harm to an individual's mental health may be the greatest adverse effect on health. This can arise from emergency evacuations, displacement, compromised food security, lack of housing, trauma, and financial burdens.[8] The potential health impacts that relate to extreme weather generally are summarized below in Figure 6-1.

Figure 6-1. *Linkages Between Climate Change-Related Disasters and Community Impacts, Physical and Mental Health.*



Source: Council of Canadian Academies. Canada's Top Climate Change Risks, Ottawa (ON): The Expert Panel on Climate Change Risks and Adaptation Potential.; 2019, p21 (Adapted from Berry HL, Bowen K, Kjellstrom T. Climate change and mental health: a causal pathways framework. Int J Public Health. 2010;55(2):123-132. doi:10.1007/s00038-009-0112-0).[180,181]

Trends for extreme weather events are not easy to identify as there is limited reliable and comprehensive data about natural disasters and extreme weather events in Canada.[179] The most comprehensive database is the Canadian Disaster Database maintained by the Government of Canada.[179] However, in order to be included in the database, certain criteria (i.e., one or more of the following: ≥10 people killed, ≥100 people affected, injured, evacuated or homeless, an appeal for national assistance, historical significance, or significant interruption or damage to normal processes)[235] must be met, meaning that not all extreme weather events are captured.[179] Public Health Ontario used this database to identify 23 disaster level extreme weather events in Ontario between 2003-2012. These included 9 floods, 4 tornadoes, 4 storms and severe thunderstorms, 4 wildfires and 2 winter storms.[182]

The health impacts and trends of specific types of extreme weather events are outlined below.

Flooding

Floods are considered the most common and significant natural disaster in Ontario in terms of death, damage, and civil disruption.[41,183] Flooding is one of the most important concerns for the PPH region. The PPH region contains many streams, rivers, and lakes. Flooding can happen due to intense rainfall resulting in flash flooding, and from river flooding where water levels rise over the tops of river banks.[184] Risks due to both types of flooding could increase due to warming temperatures, more precipitation falling as rain rather than snow, and more frequent and intense extreme precipitation events. In urban settings, overflow and flash flooding are of particular risk.[41]

Health Impacts

Potential health effects of extreme precipitation events and flooding include physical and mental health impacts.

Physical risks from floods include injuries, infection of wounds, and electrocution. Other risks include drowning and hypothermia.[185] Flooding has also been associated with infectious diseases like water-borne, food-borne, and vector-borne diseases (see Chapter 7 and 8 for more information). Finally, in the aftermath of a flood, water damage from flooding can lead to additional health risks, particularly relating to growth of mold, bacteria and fungi, which can increase risk of developing or exacerbating skin, allergy and respiratory/lung problems.[41]

The mental and social health impacts of major floods are significant. Flooding can destroy contents in homes that may be costly or sentimental. People may have to evacuate their homes for a time or undertake significant renovations to their home. The disruption of life and financial uncertainties can often cause stress for months. These impacts include increased symptoms of PTSD, depression, anxiety, and suicidal ideation, as well as worsened quality of life.[41] Impacts can lead to increased use of substances and stress can also in turn impact physical health (e.g., cardiovascular health).[186]

Trends and Projections

Flooding History

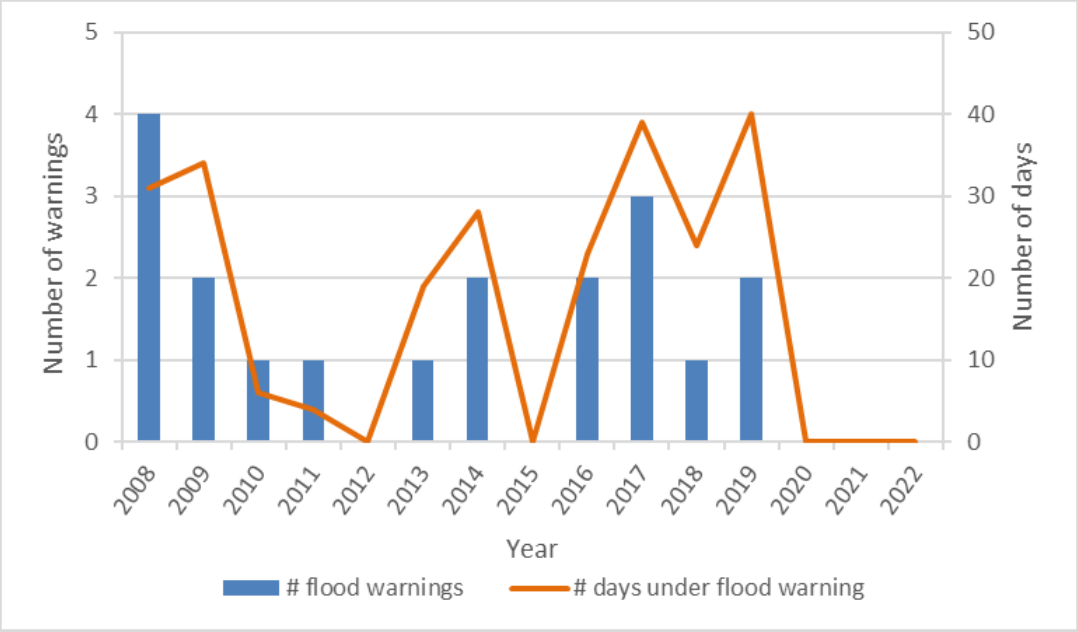
The City of Peterborough and other regions of the community have experienced flooding from time to time. For many, especially those in the City of Peterborough, the flood of July 2004, will stand out as an extreme flood event with immense impacts. The storm produced the largest 24-hour total rainfall depth on record for southern Ontario – over 220 mm at one of Peterborough's weather stations. The likelihood of this 24-hour rainfall amount (approximately 9.1 mm per hour for 24hours) is extremely rare. Roads, homes, and businesses were flooded. A state of emergency was declared, staying in effect for two weeks. The City issued emergency clothing to more than 1,300 people and emergency food to more than 1,000 households. The cost relating to insured losses, repairs and restoration to community infrastructure was estimated to be $140 million.[187] Shortly after the 2004 flood, the City of Peterborough prepared a Flood Reduction Master Plan which helped guide further assessments and actions to protect the city from future flooding damage.[187]

Flood Warnings by Conservation Authorities

Conservation Authorities are responsible for forecasting where and when flooding is likely to occur and issuing appropriate messages. [188] The flood messages are issued to municipal emergency management officials and the media. [188] Municipal officials can then take action to warn local residents.[188]

Much of the PPH Region is located within the Otonabee Region Conservation Authority (ORCA) district. ORCA tracks flood warnings by date and number of days in effect. The flood warnings issued by ORCA between 2008 and 2022 are presented in Figure 6-2. There were nineteen flood warnings during this time, with between zero and four flood warnings issued each year. Flood warnings lasted between four and forty days and ten of the nineteen warnings were issued in April. Warnings apply to specific geographic areas; sometimes the warning is for all watercourses and waterbodies, others are for a few waterways, and others are issued for a specific waterway. Most of these flood warnings related to "spring freshet" (i.e., snowmelt), but the warnings in January and February related to "frazil ice generation and jamming impeding flow, causing back-up". Only one warning was made due to "significant regional-scale rainfall".

Figure 6-2. *The Number of Flood Warning and the Number of Days of the Year Under Flood Warning Issued by ORCA Between 2008 and 2022.*



Source: Otonabee Region Conservation Authority, 2023. Overlapping days counted once.

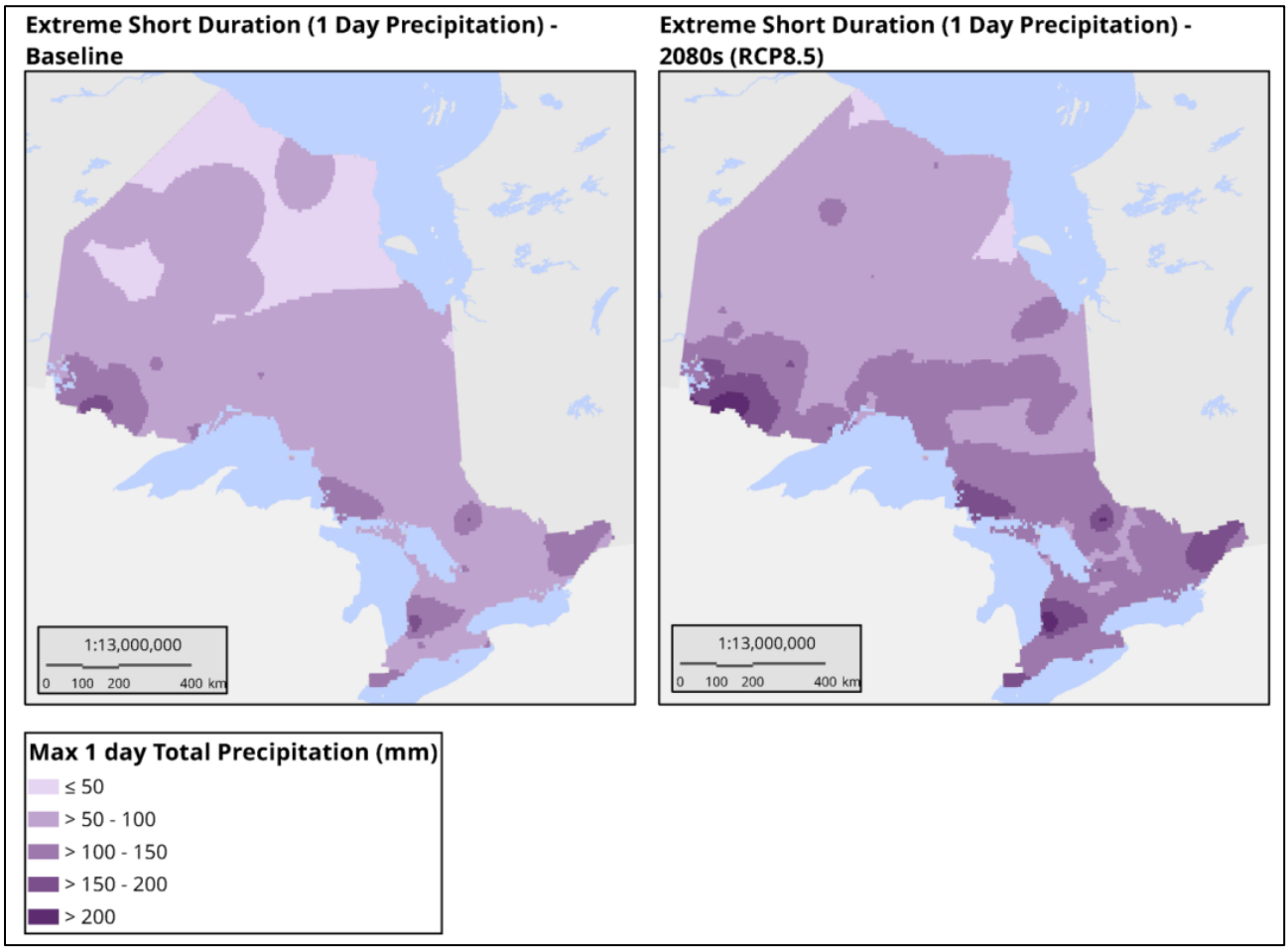
Smaller areas of the PPH region are covered by two other conservation authorities, other than ORCA. Part of the most northern area of the PPH region is not covered by a conservation authority, so the Ministry of Natural Resources and Forestry (MNRF) are responsible for flood warnings in this area. No flood warning data was available for these areas of the PPH region.

Extreme Precipitation

Climate modelling makes it possible to model various historical and projected extreme precipitation variables. Modelling an indicator such as maximum 1-day precipitation into the future shows an increasing shift in the 30-year average for PPH region, but the actual maximum amount of precipitation that may fall in future years is not known with certainty. The province reported on projected shifts in the max 1-day precipitation across the province in their recent Ontario Provincial Climate Change Impact Assessment Technical Report (2023), displayed in Figure 6-3. Much of the province, including the PPH region shows increases in the average 1-day maximum precipitation from the baseline time period to the 2080s under the high emissions RCP8.5 scenario.[a]

[a] RCP8.5 scenario is referred to above and in Figures 6-3, 6-7 and 6-8. RCP scenarios were used for the Ontario Provincial Climate Change Impact Assessment, where RCP8.5 would be comparable to the SSP5-8.5 scenario used in this report.

Figure 6-3. *Maximum Short Duration (1 day) Precipitation Across Ontario (Left: Baseline Time Period (1981-2010); Right: Projections for 2080s under RCP8.5).*



Source: Climate Risk Institute, Dillon Consulting Limited. Ontario Provincial Climate Change Impact Assessment Technical Report.; 2023. Accessed September 17, 2023. www.ontario.ca/files/2023-08/mecp-ontario-provincial-climate-change-impact-assessment-en-2023-08-17.pdf, p60.[90]

Another indicator that can be considered is "number of wet days" per year. Table 6-1 shows how the number of wet days (≥10mm) will increase in the future. The majority of the increase is projected to be experienced from December to May.

Table 6-1. *Mean Number of "Wet Days ≥10mm" per Year (for 30-year Time Period) with Precipitation[a] ≥10mm According to SSP2-4.5 and SSP5-8.5 for the PPH Region.*

Variable	Baseline (1981-2010)	2050s		2080s	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Number of days with precipitation ≥10mm	25.2	29.0	28.9	29.2	30.9

Source: Climatedata.ca, 2023.[189]

[a] Precipitation includes rain and snow combined.

Short duration rainfall Intensity-Duration-Frequency (IDF) charts are another way of showing rainfall data, and the frequency one might expect to experience a certain intensity and duration of precipitation at the weather station.

By comparing the IDF data for the Peterborough Airport weather station for 1971-2006, to projections of this data in the 2080s under a Fossil-fueled Development scenario (SSP5-8.5), the following findings were made:

- For two-hour long precipitation events (medium duration)
  - Precipitation intensities that have a 1 in 100 chance of occurring (i.e., a 100-year return period) during the baseline time period are projected to have a one in ten chance of occurring each year.
- For twelve-hour long precipitation events (longer duration)
  - Precipitation intensities that have a 1 in 100 chance of occurring (i.e., a 100-year return period) during the baseline time period are projected to have somewhere between a one in five and a one in ten chance of occurring each year.

Source: Short Duration Rainfall IDF Data, accessed from ClimateData.ca, 2023.[190]

Two storm duration periods are being highlighted because these intervals can often be associated with different community impacts. Storms that tend to cause damaging urban overland flooding are often shorter, more extreme events (e.g., up to two hours in duration). In contrast, soil saturation and stability may be most impacted by lower intensity, longer duration storm events (e.g., 12 to 24 hour events).[191] As such, users of the data should look at the data that is most appropriate to their project or concern. Additional IDF analysis and charts are available upon request.

These findings demonstrate that climate models indicate that there will be higher chances of what would be historically considered more rare, high-intensity precipitation events.

Windstorms

Another type of severe weather event that the Peterborough region may experience more frequently in the future is severe windstorms such as tornadoes and derechos, though the impact of climate change on windstorms is more uncertain than other aspects of extreme weather.[36] Tornadoes are violent and destructive windstorms with varying wind speeds, size and damage potential.[179] A derecho is defined as "a widespread, convectively induced straight-line windstorm, more specifically, any family of downburst clusters produced by an extratropical mesoscale convective system"[192(p.935)] or, in other words, an organized cluster of thunderstorms.

Health Impacts

Potential health effects from windstorms include death, physical injury (e.g., from building collapse or flying debris), loss of property, financial hardship and stress.[179] Associated power outages can also contribute to injuries as the use of gasoline powered generators can result in fires, burns, electrocution and carbon monoxide poisoning.[193,194] Infrastructure damage, staff shortages and other effects of a severe storm can also restrict an individual's access to medical care or medication resulting in exacerbation of chronic illnesses.[195]

Trends

Tornadoes

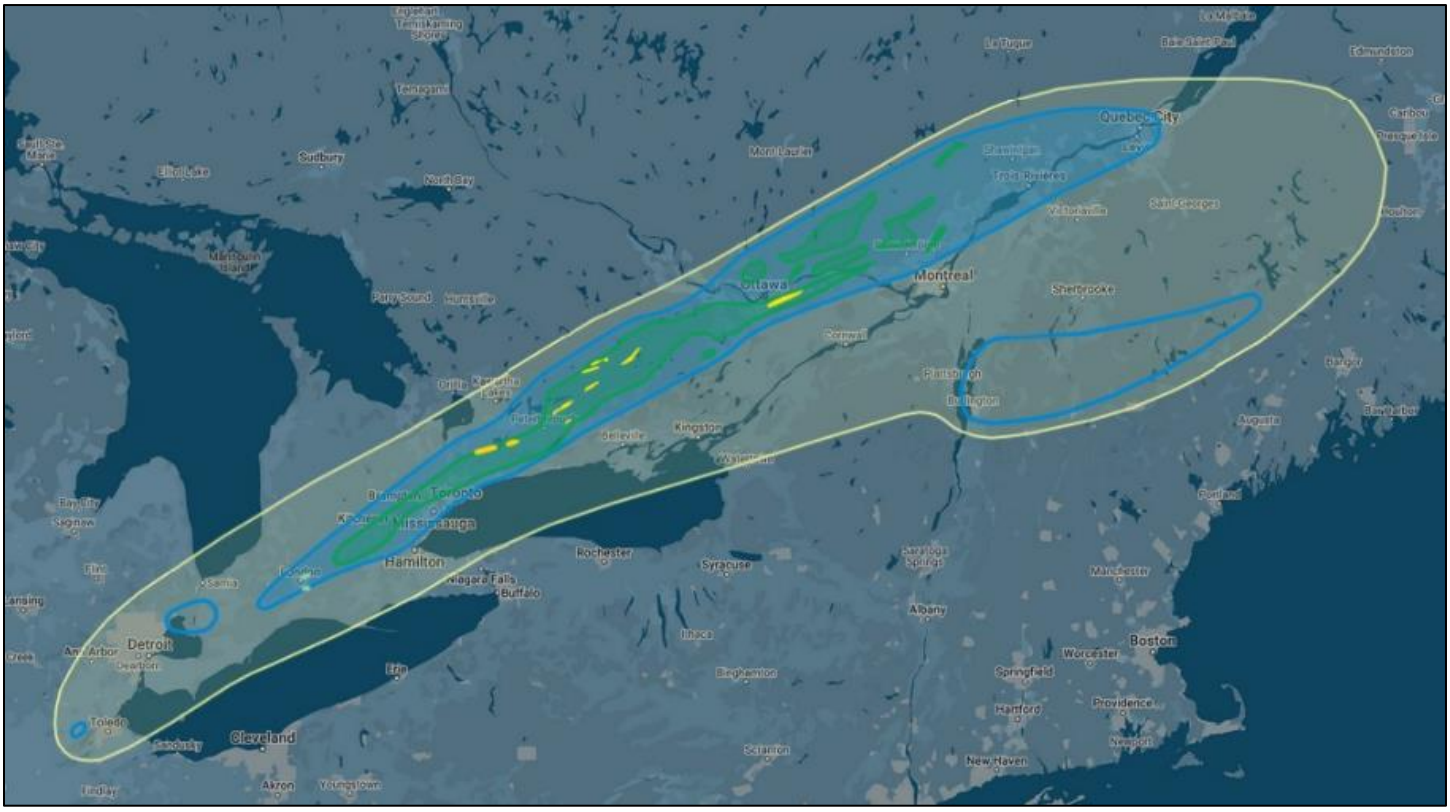
The effect of climate change on severe winds and tornadoes remains uncertain.[196,41] According to Sills et al., [196] more than a dozen tornadoes occur on average every year in Ontario. Generally, they are weak in nature (i.e., rated F/EF0-1), however more intense tornadoes have occurred in the past (1946, 1970 and 1985) and were responsible for 31 deaths and hundreds of injuries. [196]

For the PPH region, Public Health Ontario reported that 4 tornadoes occurred between 2003 – 2012.[197] More recently, in July 2022, a tornado developed in the community of Rockdale in the Township of Havelock-Belmont-Methuen.[198] According to Western University's Northern Tornado Project (NTP) [198], a multi-vortex supercell tornado developed at Rockdale and continued for 55.8 kilometers East-North-East into the neighbouring region. Extensive tree damage and widespread structural damage was reported.

Derechos

Although derechos are rare, the PPH region has experienced these notable storms.[199] The most recent encounter with a derecho storm in the PPH region occurred in May 2022. According to Western University's Northern Tornado Project [200], on May 21, 2022, this historic storm was documented to be 1,000 km in length and 100 km in width and is considered one of the costliest weather events in Canadian history with over $1 billion in insured losses (see Figure 6-4). The storm included four tornadoes, nine downbursts and resulted in 12 deaths across Ontario and Quebec.[200] Two deaths occurred in the PPH region (Lakefield and Apsley).[201] The City of Peterborough called a state of emergency due to the extensive damage to structures, trees and power poles. Power outages affected the entire City of Peterborough and much of Peterborough County. These lasted days and in some cases, weeks following the storm.[201] (See the "Impacts of the 2022 Derecho Storm on Vulnerable Populations" textbox in the "Populations at Increased Risk" section below for more impacts). The cost of local recovery efforts was estimated to have reached $3.3 million.[202]

***Figure 6-4**. Map Showing the Damage Areas and Intensity (via Enhanced Fujita Scale) of the May 21, 2022 Derecho.*



Source: The Northern Tornadoes Project. May 21 derecho update #2 of 2: EF-scale contour map - May 21 derecho update #2 of 2: EF-scale contour map - Western University. Published 2022. Accessed September 26, 2023. uwo.ca/ntp/blog/2022/may_21_derecho_update_2_of_2_efscale_contour_map.html.[203]

A fallen hydro pole and its wires block Monaghan Road near Sherbrooke Street. Credit: Peterborough Examiner.[202]

The PPH region was also impacted by a severe derecho windstorm in July 1995.[204] While most of the damage associated with the storm that swept across Central Ontario was from intense straight-winds due to the derecho, several brief tornadoes also occurred, one of which took place in the community of Bridgenorth.[204] There, a tornado came ashore and destroyed a marina, leveled buildings, sunk boats and severely damaged several houses. One death was reported.[204]

Winter Storms

Winter weather that the PPH region typically experiences is often in the form of blizzards, ice storms and freezing rain.

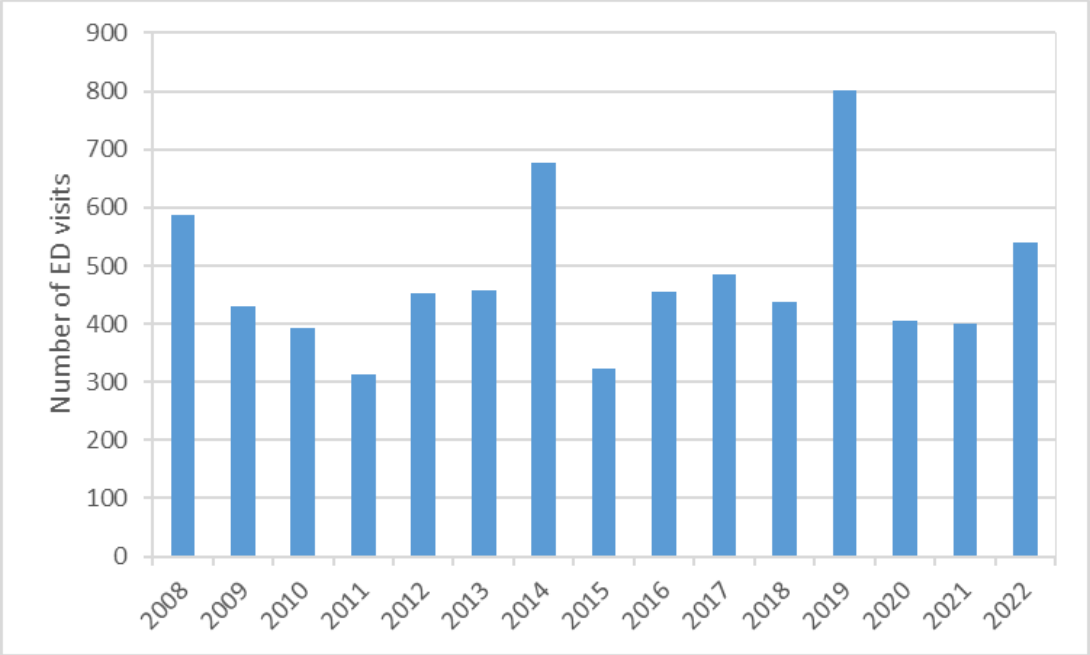
Health Impacts

Potential health effects from extreme winter storms include increases in motor vehicle collisions and physical injury from slips and falls.[205] According to Huynh et al., [206] unintentional falls are a leading cause of injury-related hospital visits among Canadians, and slippery environments due to ice and snow are one of the main risk factors for outdoor falls. While various weather conditions can contribute to fall-related injuries, this study demonstrated that, "snowfall and warmer winter temperatures were associated with an increased risk of fall-related ED visits during Ontario winters.[206]

Emergency department visits for falls due to ice and snow by PPH residents have ranged from 314 to 802 cases per year during the 2008 to 2022 time period. Yearly totals seem to fluctuate year-to-year, as shown in

Figure 6-5. Looking at the 5-year average rates of these ED visits (see Table 6.2), there has been a slight increase in the average since 2008-2012.

Figure 6-5. *Number of Emergency Department Visits by PPH Residents for Falls Due to Ice and Snow Between 2008 and 2022.*



Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: July 2023.

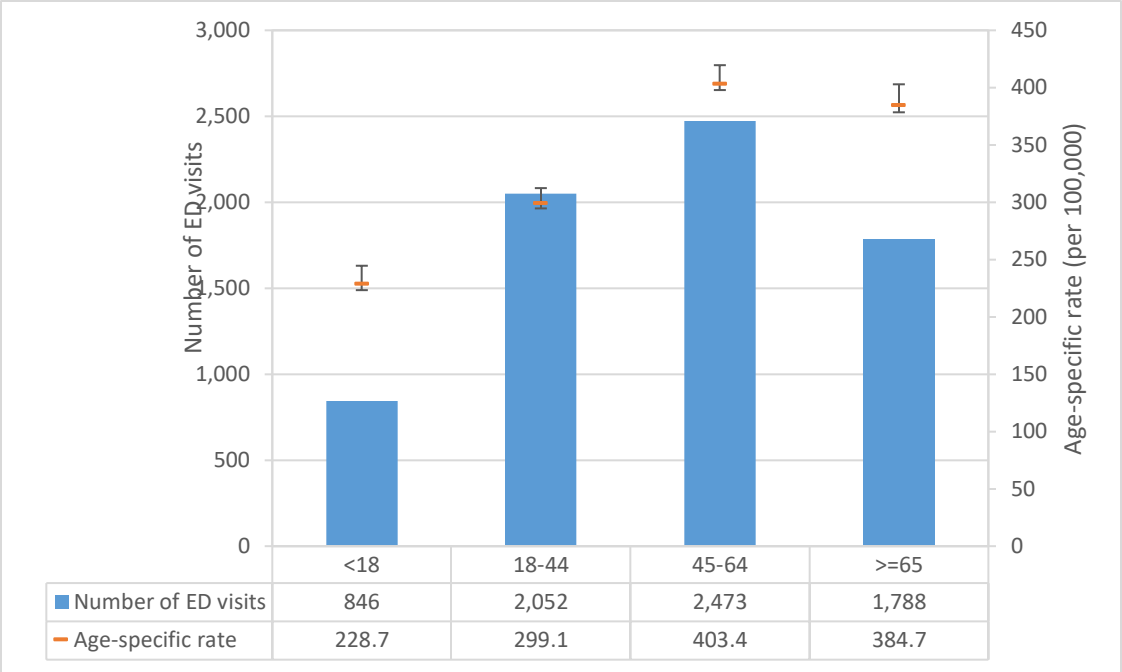
Table 6-2. *5-Year Average Crude Incidence Rate (Cases per 100,000 Population per Year) of Emergency Department Visits for Falls Due to Ice and Snow by PPH Residents from 2008 to 2022.*

	2008-2012	2013-2017	2018-2022
Crude incidence rate per 100,000 population	315 (95%CI:310-328)	341 (95%CI:336-355)	350 (95%CI:345-364)

Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: July 2023.

The number of visits and rates per age group from 2008 to 2022 are shown in Figure 6-6. Those aged 45 years and older have the highest rates and comprise about 60% of these ED visits. Gender does not seem to be a major factor, with females making up 52% of these ED visits.

Figure 6-6. *Number of Emergency Department Visits and Age-Specific Rate (per 100,000 Population) for Falls Due to Ice and Snow by PPH Residents for the Time Period 2008 to 2022.*



Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: July 2023.

Trends and Projections

Winter Precipitation

The Ontario Provincial Climate Change Impact Assessment Technical Report (2023) presented changes to mean winter precipitation (rain and snow) across the province.[90] Much of the province, including the PPH region shows increases in the winter precipitation from the baseline time period to the 2080s under the high emissions RCP8.5 scenario (see Figure 6-7).[90]

A second indicator, known as the Rain to Snow Ratio (percent of rain falling in the wintertime) revealed that increases in rain fall amounts during the winter season are projected for the PPH region (see Figure 6-8).[90]

Figure 6-7. *Mean Winter Precipitation Across Ontario. (Left: Baseline Time Period (1981-2010); Right: Projections for 2080s Under RCP8.5).*

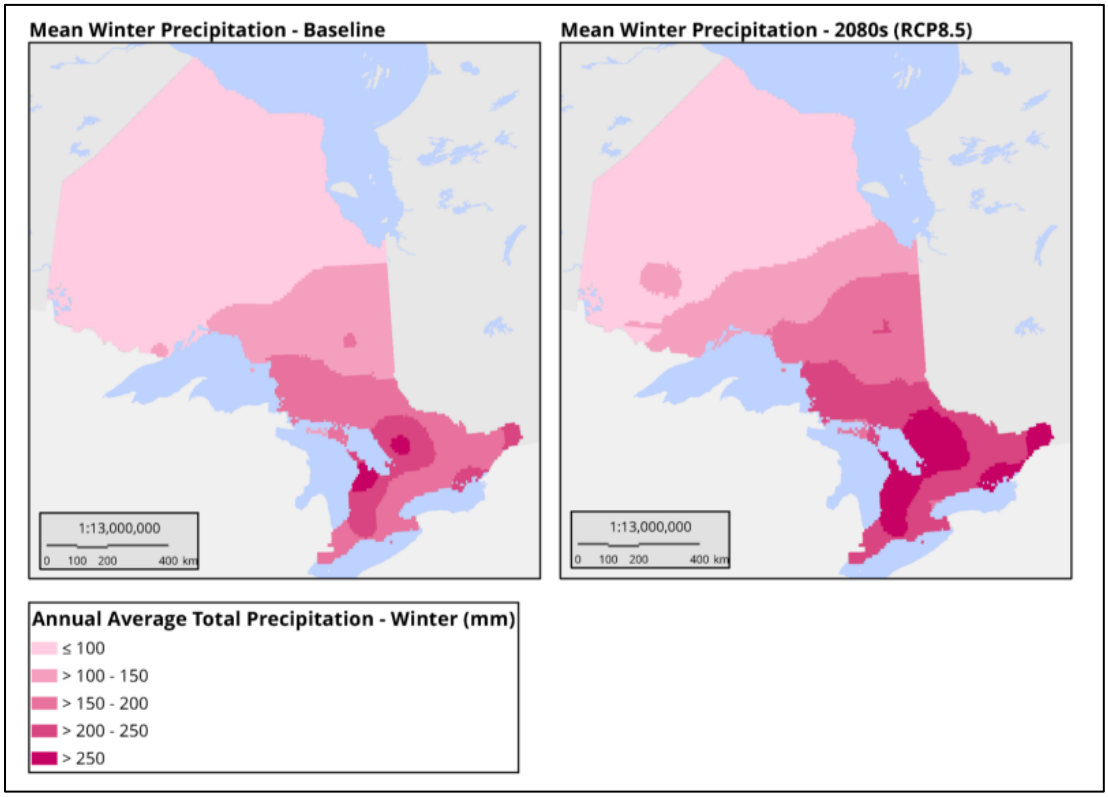
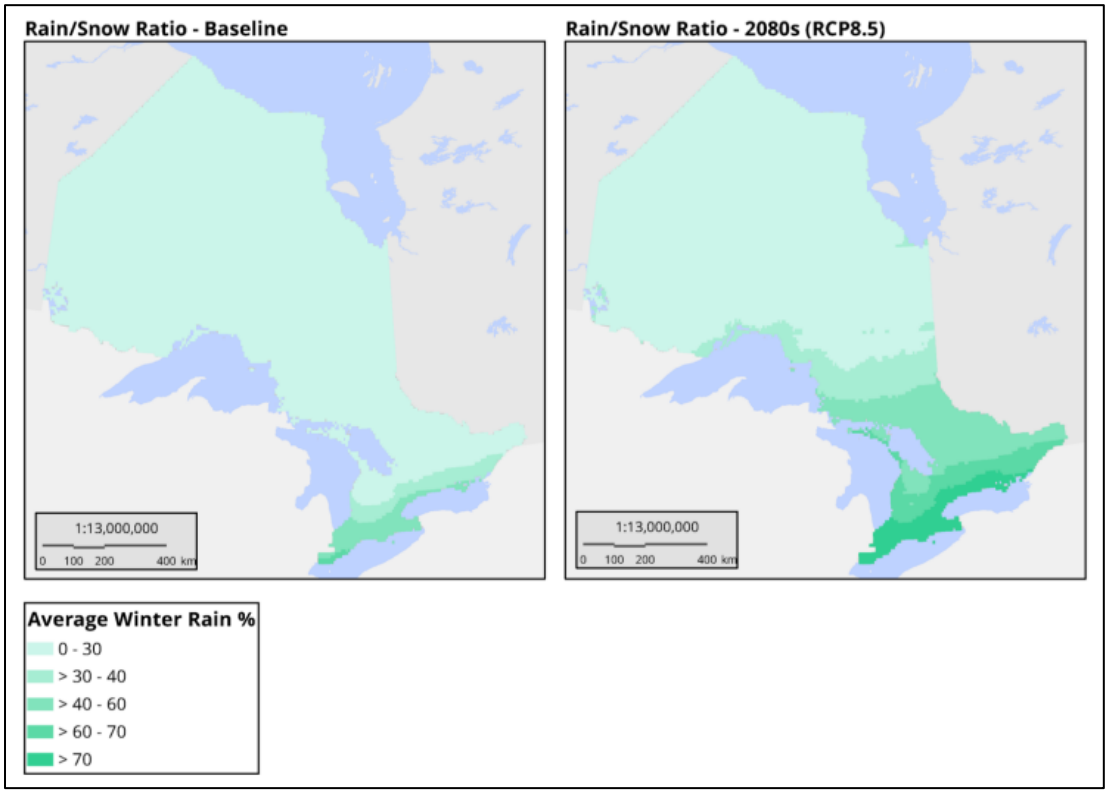


Figure 6-8. *Rain:Snow Ratio Across Ontario. (Left: Baseline Time Period (1981-2010); Right: Projections for 2080s Under RCP8.5).*



Source: Climate Risk Institute, Dillon Consulting Limited. Ontario Provincial Climate Change Impact Assessment Technical Report.; 2023. Accessed September 17, 2023. www.ontario.ca/files/2023-08/mecp-ontario-provincial-climate-change-impact-assessment-en-2023-08-17.pdf, p57,58.[90]

Freezing Rain

The most notable and hazardous winter storms for Ontario are in the form of freezing rain events however, major freezing rain events in Ontario are rare.[207] The costliest weather disaster to ever occur was in 1998 when 95 mm of freezing rain fell in Ontario. It caused major electrical and power outages as well as 25 deaths and over 900 injuries.[207] A significant ice storm that affected the PPH region occurred on April 12, 2013. This storm took out power lines and downed trees affecting 18,000 homes.[208]

Although freezing rain and ice precipitation cannot be reliably projected and are difficult to estimate for current conditions due to climate data insufficiency, climate change is expected to increase the frequency and intensity of extreme weather events such as ice storms in the future.[209]

A study by Cheng et al. (2011) used models[a] to project changes in frequency of freezing rain events, focusing on different severity levels. The PPH region experiences the most amount of freezing rain days in December, February, and March.[210] Results indicated that compared to the baseline time period (1958-2007) the PPH region may experience an increase in freezing rain during these months - around 20% by 2081-2100. Freezing rain in January is less common but projected increases are more significant, so these events will become more common. Finally, freezing rain in November and April is not very common, and it is projected to decrease by 2081–2100.[210]

[a] Three climate scenarios were used, ranging from low emissions to "business as usual". See Cheng et. al, 2011 for more information.

Wildfires

Wildfires are another example of extreme weather events that make headlines in Canada every summer. Wildfires occur across the country, particularly within the boreal forest and they are a natural part of the boreal forest life cycle.[211] However, when fires are out of control and they approach human settlements, they become a dangerous or catastrophic threat.[211]

Health Impacts

Adverse health effects from forest fires on communities most affected (i.e., community is in close geographical proximity or directly engulfed) include both physical and mental health impacts. The immediate physical health consequences are often due to fire, smoke, and heat, and can include detrimental effects from smoke inhalation, respiratory tract burns and injury, and reduced levels of oxygen. Other health impacts include dehydration and heat exhaustion.[212,213] Mental health issues can also occur or be exacerbated by wildfire events. This includes mental exhaustion, anxiety, depression and post-traumatic stress disorder (PTSD) related to loss of property, relatives or friends and economic hardship from lost or impacted livelihoods.[213]

The health impacts from wildfire smoke are further explored in Chapter 9: Air Quality.

Trends

In Ontario, most fire activity takes place in the northwest and northeast regions of the province. While the City of Peterborough is outside of the Fire Region, other areas of the PPH region are within Ontario's Fire Region (See Figure 6-9 showing affected areas).

Figure 6-9. *The Ontario Fire Region (as Set Out in Regulation O. Reg. 332/15, s. 7, Under the Forest Fires Prevention Act), with PPH Region Inset.*

Source: Ontario Ministry of Natural Resources and Forestry. Forest Fire Info Map. Published 2023. Accessed September 28, 2023. www.lioapplications.lrc.gov.on.ca/ForestFireInformationMap/index.html?viewer=FFIM.FFIM.[214]

While the PPH region does not often have wildfires like the ones that cause widescale destruction and evacuations that are highlighted in national and international news, significant fires occasionally occur. For example, in 2018 a 12-hectare fire occurred in Trent Lakes township.[215] Residents and seasonal residents of the PPH region in Ontario's Fire Region should particularly be aware of the risks.

Natural Resources Canada has Fire Danger maps available. The Fire Danger index reflects three factors: "how easy it is to ignite vegetation, how difficult a fire may be to control, and how much damage a fire may do."[216] While the fire risk in the PPH region is usually low, the Fire Danger index moved to the highest level (Extreme) for most of the PPH region on June 7th of 2023.[217] This is a tool that can support communities in implementing protective actions such as burn bans.

Wildfires Across Canada – Trends and Climate Change Impacts

Northern areas of Canada located within the boreal forest have been the most impacted by wildfire over the past 100 years.[218] Across Canada, wildfire characteristics have shifted over time, including the number of fires and hectares burned each year. The number of hectares burned fluctuates from less than 1 million hectares some years, to up to 5 to 7 million hectares other years. However, in 2023, Canada experienced what many have called the worst wildfire season in record with over 18 million hectares burned so far (up to October 6, 2023).[219]

Climate change may increase the risk of more severe wildfire seasons in Canada. While the spread and severity of fires can also be impacted by factors such as fire management/suppression practices and population growth in forested areas, warming of Canada's climate is associated with escalating three important wildfire factors:

- Longer fire seasons and more "fire weather" - Warmer conditions earlier in the year and extending later in the year can extend the fire season.[220] Warming can also increase fire weather (i.e., hot, dry, windy weather).[221,211]
- Ignition - Warmer temperatures increase the likelihood of ignition from lightning strikes as thunderstorms develop in warm/humid conditions.[211,222]
- Fuel source – Warmer temperatures and extreme heat can dry out landscapes and vegetation (i.e., wildfire fuel), making forests more flammable unless precipitation counteracts these effects, which is unlikely based on climate projection scenarios.[223,211]

It has been projected that some regions of Canada will experience increased burning or more uncontrolled burning by the end of the century, including the Arctic[224] and British Columbia.[225]

Droughts

As defined in the Health of Canadians in a Changing Climate Report, a drought is, "a period of abnormally dry weather long enough to cause a serious hydrological (water) imbalance."[226 pg 759] It can be caused by lack of rain, warmer temperatures, increased evaporation and increased human water use.[227] Climate change may increase the likelihood of droughts across Canada, though impacts will vary by region.[41,228] While the PPH region may experience more annual precipitation over the course of this century, summer precipitation is not projected to increase much, while temperatures will be increasing. Warming temperatures in the summer months may lead to more water evaporation, and also increase water demands of plants, agriculture crops and animals.[41]

Health Impacts

Potential health impacts of drought include increases in respiratory (lung) illness as drought conditions have a negative effect on air quality by boosting the concentration of pollutants in the air (e.g., fine particulate matter).[229] Health impacts of pollutants are further expanded in the Chapter 9: Air Quality.

Droughts can decrease agricultural production which can negatively impact community food security. They can also affect water quality, lead to a rise in infectious diseases, and conditions can increase the spread of vector-borne diseases.[213] This is expanded on in Chapter 7: Food and Water Security and Safety, and Chapter 8: Vector-borne diseases.

Finally, drought conditions can cause stress and contribute to anxiety, emotional and psychological distress, loss and grief, as well as economic hardship for those relying on impacted water sources for livelihoods (e.g., agriculture and horticulture), or their personal consumption.[230]

Trends

Droughts are highly variable from one location to the next and have varying effects in each area where they occur. In southern Ontario, droughts that occur tend to be shorter, smaller in area and less frequent and intense than other areas in Canada.[230]

The last major droughts in southern Ontario occurred in 1998, 1999, 2001 and 2002.[230,231] Like flood alerts, conservation authorities (or the MNRF) have a role in monitoring precipitation, stream flow and water levels regularly to gauge water conditions as part of Ontario's Low Water Program.[227,231]
There are three levels for these warnings: [231]

- Level 1 – the potential for water supply problems iso identified
- Level 2 – minor water supply issues are encountered
- Level 3 – supply may no longer meet demand; social and economic impacts are anticipated

ORCA again has a role in this locally, as part of a collaborative Otonabee Region Water Response Team. Local data is reviewed monthly to determine if a low water warning is warranted.

Low water warnings are tracked by identifying the months that the warning declaration was made, upgraded, downgraded or cancelled, and show the number of months that the declaration was in effect. Between 2000 and 2022, there were 20 low water declarations in the ORCA region. The number of declarations per year ranged from zero (11 of 23 years) to three. Multiple declarations in one year typically related to upgrades or downgrades in the level of a low water warning. All warnings were either Level 1 (24 months total) or Level 2 (17 months total), though there was no authority to declare Level 3 warnings until 2017.

One notable period was between 2016-2017, when a low water warning was in effect for ten months (June 2016 to March 2017) and which remained at Level 2 for nine of those months. The drought peaked between May to August 2016, where only 83.5 mm of rain fell compared to the average of 241.02 mm.[232] Local businesses and residents were encouraged to reduce their daily water use by 20 per cent.[233] This was noted to be the second driest year on record.[234]

Populations at Increased Risk

For each different type of extreme weather, there are unique populations at increased risk for health impacts. However, there are commonalities across many of the types. These groups of individuals tend to have fewer resources to deal with the aftereffects of extreme weather events including older adults, the very young, individuals experiencing low SES and certain sectors of the population who may use natural resources for their source of income. Presented below are the common categories of populations where vulnerabilities to specific types of extreme weather are further explained. The section finishes with geographic vulnerability relating to living in the floodplain.

Older Adults

As individuals age there is a correlation with increased use of medications, chronic illness, and physical mobility issues.[5,179] These issues may dictate that some older individuals need to rely on regular medical attention and assistance from caregivers for mobility and daily activities. Such requirements can be hindered by any type of extreme weather event, leaving them vulnerable to adverse health effects.[179] Older adults can also have lower bone density which can make them more susceptible to bone fracture injuries.[236] However, those that are more senior (i.e., aged 75+) have been found to have lower rates of injury due to precipitation than those aged 40-74, which may be due to protective measures like reducing their outdoor travelling time.[237,238] Older individuals may also be on a fixed income, which can make it challenging to afford increases to home insurance, which is being experienced across Canada.[239] According to Gifford, [240] older adults may also face untreated illnesses such as depression and they tend to employ fewer coping strategies during extreme weather events such as flooding. This sensitivity therefore leaves them more at risk for mental health concerns.[241,242]

Children

Children are at an increased risk for adverse effects of extreme weather events since they do not have the capabilities and resources to change their circumstances independently. They must rely on others for protection during and after an extreme weather event. Children are also growing and developing at fast rates requiring lots of food/water and in turn may have more hand to mouth behaviors.[179] This can expose them to adverse health effects from loss of food resources and/or exposure to food- or water-borne illnesses arising from events such as flooding.[179] They are also at risk of sustaining an injury on rainy days.[237]
Wildfires and floods have the potential to cause PTSD for children, as they struggle to cope with the changes and losses brought by disaster, which could have impacts on a child's long-term development.[243,244,240]
Research has shown that children who have caregivers that are of low SES may suffer even more from increased stress after an extreme weather event as the family system was already experiencing limited financial resources and stress.[179] Natural disasters can be considered a source of toxic stress, contributing to adverse childhood experiences (ACEs), which is another priority area in the PPH 2022-2025 Strategic Plan.[245]

Pregnant People

Evidence suggests that prenatal maternal stress related to extreme weather events significantly influences child development.[246,247] Issues such as compromised food security, water scarcity, infection, malnutrition, stress related to the event plus displacement and lack of access to health services and resources can lead to gestational complications including low birthrate, restricted fetal growth, preterm birth or infant mortality[229,248], as well as developmental impacts for the child.[247,249,250]

Gender

Men are more likely to have a cardiac event in the aftermath of a flood[251] and following snowstorms.[252] The snowstorm impact may be due to gendered roles in snow shoveling.[252] Women are more likely to have mental health impacts from wildfires and flooding events.[251]

Socioeconomic Status

Individuals with low SES may be at increased risk for adverse health effects from extreme weather events. Individuals with low SES already have limited financial resources and may struggle to cope with increased levels of stress from extreme events.[179]

Further, people who are more economically deprived are more likely to be without flood insurance or are challenged to afford their deductible.[253,254]

New Immigrants are a specific group that (on average) experience incomes that are lower than the general population, as outlined in Chapter 4: Vulnerability. They are also more likely to not have knowledge of either official language which can be another barrier to coping with and adapting to an extreme weather event.[4,35]

People Experiencing Homelessness

Individuals who are facing homelessness or precarious housing are disproportionately exposed to extreme weather, have difficulty protecting themselves, and thus, face increased risk of negative health effects.[255] In the event of extreme precipitation (rainfall) and winter precipitation, people experiencing homelessness may experience higher risk of infectious diseases. They may occupy more marginal areas of a community that are more vulnerable to environmental hazards.[170] Impacts such as shelter damage and loss of property may result, possibly leading to evacuation or relocation, all of which can exacerbate mental health issues.[66,172] With flash flooding, recreational water or safe drinking water sources may be compromised due to run off, which can limit access to potable water.[256] These circumstances can increase the risk of health impacts for people who are unhoused.

People with Chronic Health Conditions

Individuals with chronic conditions can be affected by extreme weather events in multiple ways. Access to medical infrastructure or medication can be compromised or inaccessible, leaving conditions untreated.[257] This in addition to the stress of the weather event can result in the disease worsening over time or may cause an acute exacerbation of the condition leading to impairment or death.[179,258] Power outages can also detrimentally affect proper storage of medication and the operation of critical medical equipment or other life saving devices for the maintenance or treatment of certain chronic conditions.[259] Finally, flooding and runoff can lead to water contamination, where certain risk factors (e.g. health conditions, age, SES) can make a person at higher risk of water-borne illnesses. (See Chapter 7: Food and Water Security and Safety)

Having disabilities is another challenge when extreme weather events occur. Disabilities are diverse and can include limitations relating to mobility, vision, hearing and cognition. Plans and communication about extreme weather may not be designed with accessibility in mind.[260]

Also "[i]n multi-story residential buildings in which residents rely on elevators, electricity loss makes it difficult, if not impossible, for elderly residents and those with disabilities to leave the building to obtain food, medicine, and other needed services".[5(p.258)]

Indigenous Peoples

Indigenous peoples may be at increased risk to health impacts of extreme weather. Again, we would like to emphasize that these findings are broad, and it may not be appropriate to generalize findings to the Indigenous peoples that we share space with in the PPH region.

According to the National Collaborating Centre for Indigenous Health, [261] displacement and/or evacuations due to severe weather disproportionally affects Indigenous peoples living on reserve. Extreme weather events can also "destabilize housing, pipelines, and local civic water, wastewater, and transportation infrastructure and systems, increasing the risk of injury, water-borne illnesses, and environmental contamination, as well as causing disruptions in supply chains".[261(p.21)] Indigenous communities' water management infrastructure is often considered at moderate or higher risk to the impacts of heavy precipitation.[262] Communities may experience boil water advisories which increases the risks from extreme rainfall events.[263] Finally, increased exposure to extreme weather can result in the destruction of places that have cultural significance, which in turn impacts mental health.[261]

Rural Populations

In general, rural areas are more physically isolated and have reduced access to health care and other goods and services compared to urban areas.[264] They may also have substandard housing, untreated drinking water sources and less robust electrical and transportation infrastructure.[265] The effects of extreme weather events therefore are often more severe and felt immediately compared to their urban counterparts.[265]

When power outages occur, access to water is limited in rural populations, except where back-up generators are installed. This can limit sanitation and can have health and wellbeing impacts. Rural populations often rely on ground or surface sources of water, which may be more vulnerable to contamination following drought,

extreme precipitation events or extended power outages.[266,267] Wells in rural communities may also run dry more frequently if the PPH region experiences more severe droughts in the future.

Dwellings and facilities in rural areas are often serviced by onsite sewage systems, rather than municipal sewers. Flooding is a risk factor for the malfunction of onsite sewage systems, resulting in untreated sewage leaching from the system or backup into a building. This increases the contamination of floodwaters and puts surface and groundwater at further risk for contamination. If sewage enters a building, it can result in increased risk of illness for occupants and can require specialized remediation.

Occupational Exposure and Impacts

Outdoor workers experience the effects of climate change firsthand. Depending on the nature of the work, they may be exposed to climate-related hazards for extended periods and at greater intensities. Occupations and volunteers that directly respond to extreme weather events may be at particular risk, potentially being exposed to hazards such as extreme weather, wildfire smoke, contaminated flood waters, etc.[268–270]
Beyond exposure, people who rely on natural resources for their sources of income and/or food, can be particularly impacted by extreme weather events. Droughts, storms and power outages can contribute to agricultural damage and loss, ongoing stress, and can have income and livelihood impacts.[179,271]

Recreational Exposure

Individuals who are participating in outdoor activities such as camping, hiking or attending events such as fairs or festivals are most at risk during windstorms such as tornadoes or derechos as they are more vulnerable to being injured or killed by falling trees, collapsing structures, or flying debris.[272] People on the water are also at risk of drowning due to storm winds and waves that can overturn boats.[272,273]

Impacts of the 2022 Derecho Storm on Vulnerable Populations

The May 2022 derecho storm was an extreme weather event that impacted the Peterborough region. While this sudden extreme weather event disrupted the whole community, some people faced unique vulnerabilities to health impacts.

During the power outages caused by the derecho, those with mobility issues were isolated in apartment buildings and unable to leave to meet basic needs, such as accessing food and medication, or going to work to earn income. Some people requiring electric lifts were unable to leave their beds. Community members requiring electrically powered assistive devices for activities of daily living were without power. The inability to charge electronic devices caused further isolation for some people trapped in buildings, unable to leave apartments or use elevators.[274]

Community members also had to discard significant amounts of fresh and frozen food that had spoiled during wide-spread power outages due to the inability to keep it at safe temperatures. Replacing food lost at a time with high food prices was a struggle for community members living on low incomes, and for those already facing food insecurity.[274,275]

Populations at Increased Risk to Specific Types of Extreme Weather

Flooding

Living in the Floodplain

Floodplain mapping is conducted by local conservation authorities to help predict the path of floodwaters and assess flooding risk and hazards.[276] In the PPH region, this can help predict potential flooding from snow melt, rain or snow (typically March-April) and rainfall flood peaks (typically July, August, September).[277] Living in the floodplain may increase the chance of exposure to flooding.

Figure 6-10 shows the ORCA region highlighting the population centres and the mapped floodplain. It is possible to estimate the number of dwellings and population living in the floodplain, which is shown in Table 6-3. The process is described in more detail in Appendix E.

Figure 6-10. *ORCA Floodplain Map, with Populations Centres Shaded Brown.*

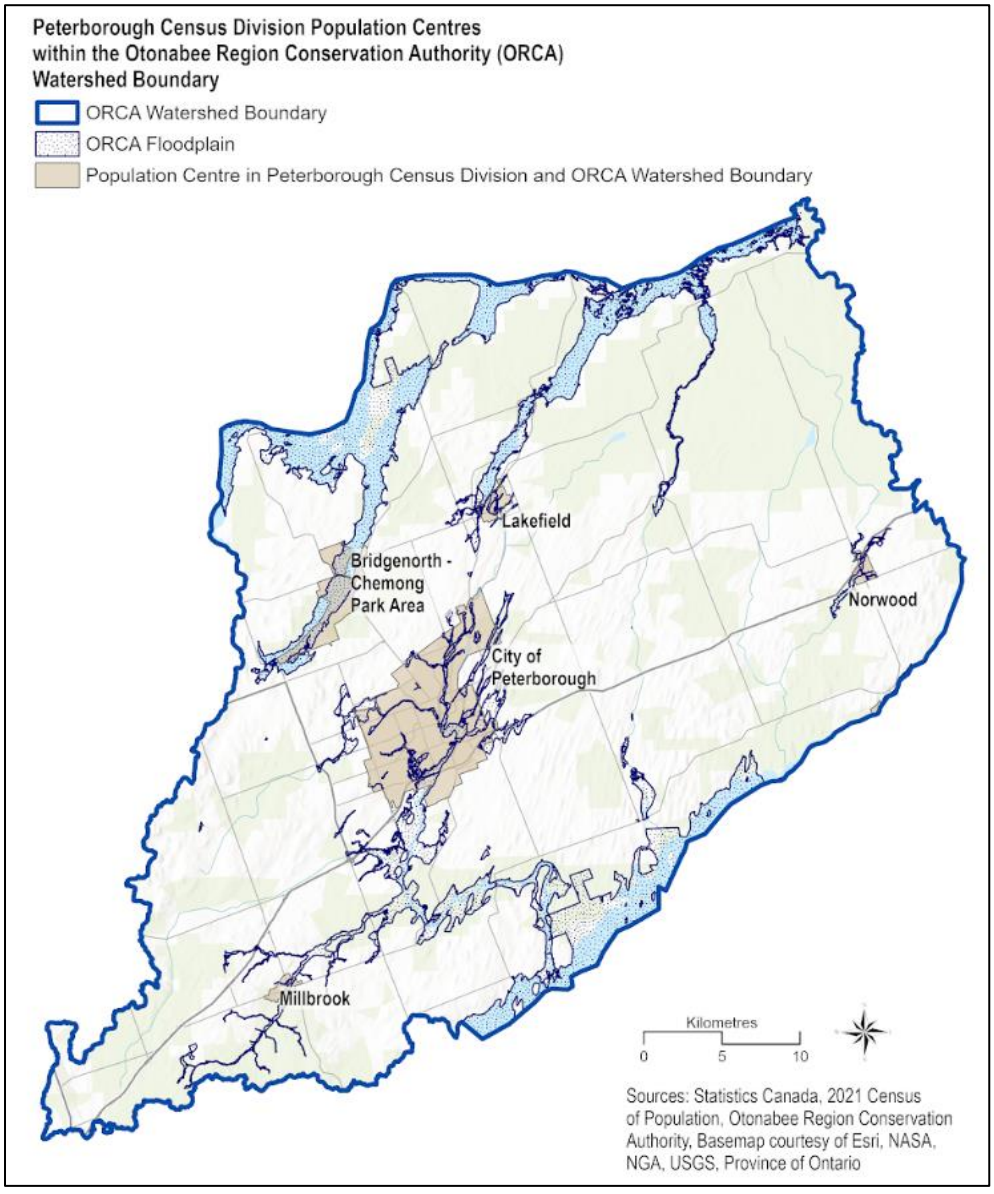


Figure author: City of Peterborough Geomatics/Mapping Division, 2023 (Created for this report). Sources are denoted in the Figure.

Table 6-3. *Estimated Number of Occupied Dwellings and Percentage of Population Living in the Floodplain in Population Centres in the ORCA region, 2021.*

Population Centre	Number of occupied dwellings in the floodplain	Population living in the floodplain	% of population living in the floodplain
City of Peterborough	832	1903	2%
Bridgenorth - Chemong Park Area	24	58	2%
Lakefield	120	238	8%
Millbrook	57	125	7%
Norwood	64	154	10%
Total	**1,097 dwellings**	**2,478 persons**	

Sources: Census of Population, 2021 (Statistics Canada)[15], Otonabee Region Conservation Authority floodplain GIS (geographic information system) data.
Data analysis by: City of Peterborough Geomatics/Mapping Division, 2023 (Created for this report).

There are an estimated 2,478 people living in the floodplains of these population centres, with 77% of these people in the City of Peterborough. There would be additional people living in floodplains outside of population centres, as well as in the floodplain of the other two conservation authorities that overlap with parts of the PPH region: Crowe Valley and Kawartha Conservation Authorities.
Detailed floodplain maps for ORCA region can be found at their website.

Living in the Floodplain and Experiencing Marginalization

Experiencing flooding can be particularly challenging for people who are having challenges in meeting their basic needs or those experiencing social isolation.[71]

In the City of Peterborough, it is possible with maps to highlight areas where increased risk for flooding overlaps with areas experiencing higher marginalization. In Figure 6-11, the dark green areas highlight overlap between census dissemination areas with a high percentage of occupied dwellings in the floodplain, and high marginalization with regards to "material resources" (described in Chapter 4: Vulnerability). Three regions stand out: parts of the downtown core, extending up McDonnel Street towards Jackson Park, the Talwood area off Sherbrooke

Figure 6-11. *Multivariate Map of the City of Peterborough Combining the ORCA Floodplain Map, the Percentage of Occupied Dwellings in the Floodplain (by Dissemination Area), and the ON-MARG Material Resources Marginalization Index.*

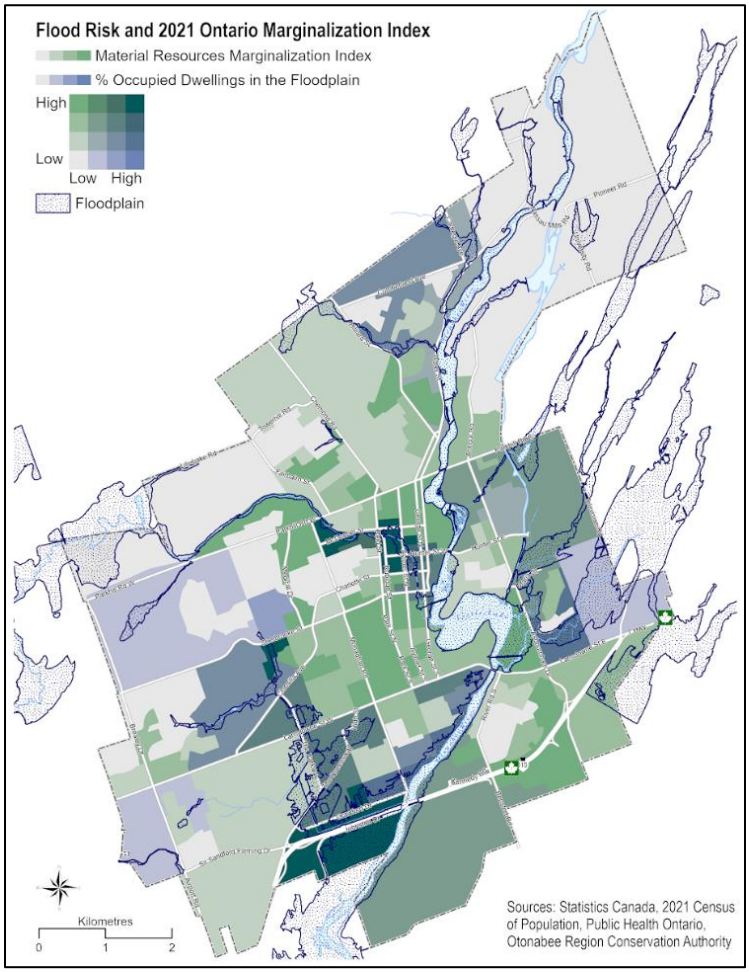


Figure author: City of Peterborough Geomatics/Mapping Division, 2023 (Created for this report). Sources are denoted in the Figure.

Street, and in the south end, the area around Crawford Drive and Johnson Drive. These inequities should be considered when developing and offering adaptation support to community members.

Another aspect of marginalization is household and dwelling factors. This ON-Marg dimension relates to family and neighbourhood stability and cohesiveness, including but not limited to:[71]

- higher proportion of dwellings that are not owned,
- higher proportion of population living alone, and
- higher proportion of population who moved during the past 5 years

It is particularly relevant to extreme weather because it can highlight areas that may experience more social isolation. The map shown in Figure 6-12 is quite similar to the previous Material Resources map with darkest purple areas including the downtown core and the Talwood area, but not as much marginalization in the area around Crawford Drive. No additional areas achieve the darkest colour, but the area between Clonsilla Drive and Lansdowne Street presents high marginalization but a slightly lower percentage of occupied dwellings in the floodplain than the aforementioned areas. These inequities should be considered when developing and offering adaptation support to community members.

***Figure 6-12**. Multivariate Map of the City of Peterborough Combining the ORCA Floodplain Map, the Percentage of Occupied Dwellings in the Floodplain (by Dissemination Area), and the ON-MARG Households and Dwellings Marginalization Index.*

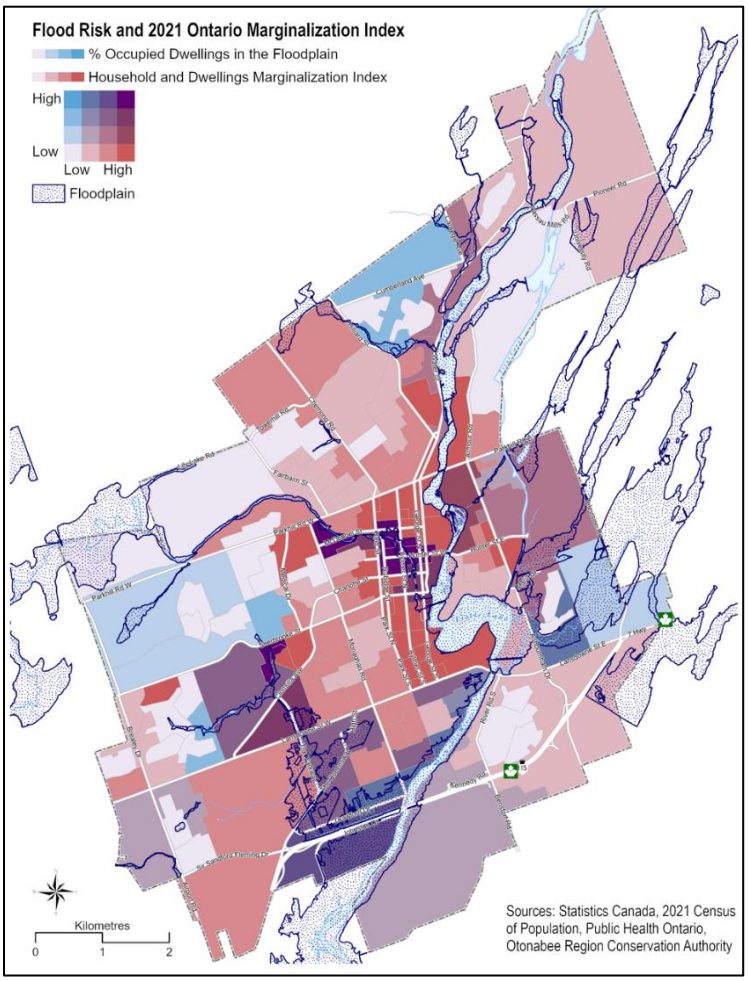


Figure author: City of Peterborough Geomatics/Mapping Division, 2023 (Created for this report). Sources are denoted in the Figure.

Peterborough Public Health Adaptation Efforts

The following are examples of Peterborough Public Health's current work that is contributing to climate change adaptation and supporting those most vulnerable to health impacts of climate change as it relates to extreme weather:

Population Assessment & Surveillance

- Providing consultations to local municipalities on outdoor public spaces, as required.

Health Promotion

- Strategically connecting with clients, for example, community workers connecting with clients during programming to enable real time preparation for extreme weather events.
- Providing targeted communication efforts including traditional media, social media and working with partner agencies to provide information and health guidance that is practical and useful in a timely manner.
- Providing training and education related to food literacy and food skills training, including food safety during emergencies, and emergency planning.

- Providing public education on the health risks of extreme weather and floods, including prevention and personal protection techniques, via websites, web pages, social media and media releases including information related to food safety, safe drinking water, and environmental protection.

Health Protection

- Communicating and enhancing communication of extreme weather notifications and appropriate health-related precautions.
- Collaborating with local municipalities to ensure the establishment of emergency shelters during weather-related emergencies and conducting inspections of emergency shelters to confirm public health and safety precautions are maintained.
- Modifying service delivery with respect to clinical services and immunization to ensure members of the public are protected in the event of extreme weather events.
- Participating on municipal emergency control groups and contributing to discussions on Hazard Identification and Risk Assessment priorities. Raising awareness of health impacts and the role of public health during extreme weather events.
- Providing enhanced inspections of high-risk facilities impacted by extreme weather events.

Food and Water Security and Safety

Climate change has widespread implications for food and water systems with important health consequences both globally and locally in the PPH region.[278] Impacts of climate change on food and water security and safety may affect all residents, although certain populations face greater health impacts.

Food Systems and Food Security

Impacts of Climate Change

Climate change is expected to impact all parts of the food system.[279] According to the Health of Canadians in a Changing Climate Report, "[w]arming temperatures, changing precipitation patterns, and more frequent and severe extreme weather events will increase risks to key components of food systems in Canada, such as the production, processing, distribution, preparation, and consumption of food."[278] As a result, such disruptions to the food system can impact community food security, household food insecurity, and ultimately, human health.[278]

Community food security means that "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."[58(p.3)] This includes access to food that is culturally appropriate. Ingram et al[281] describe food security to be made up of three elements in the context of climate change: availability, accessibility, and utilization of food. When one of these elements is missing or compromised, food security is not met.[278] Connected to but distinct from this, the term **household food insecurity** which is referred to as, "inadequate or insecure access to food due to financial constraints."[282(p.1)]

Locally, the Peterborough food charter envisions a food system that provides "healthy, sustainable, and just food for all."[283(p.1)] Its pillars include the value of the local food system, health, social justice, culture and community, education, economic sustainability, and the environment.

Table 7-1 outlines pathways through which climate change impacts our local and global food systems and food security, and populations in the PPH region that may be disproportionately impacted.

Table 7-1. *Impacts of Climate Change on Global and Local Food Systems and Vulnerable Populations.*

Changes to Food Production

- Predicted net-decrease in agricultural productivity in Ontario.[90]
- Opportunities for agriculture include warmer weather and longer growing seasons.[90]
- Extreme weather events, rising temperatures and changes in precipitation patterns may cause damage to crops, reduce agricultural productivity, increase losses due to decrease in production yields, and reduce land available for livestock pasture and foraging.[278]
- Increases in temperatures and changes to precipitation patterns may create more favourable conditions for pests and invasive species, resulting in reduced crop productivity.[278]
- Extreme weather events may result in chemical and bacterial contamination of food production sites leading to increased risk of food contamination.[278]
- Temperature extremes can adversely affect livestock health, decreasing productivity.[278]
- Rising temperatures may create favourable conditions for increased growth of aquatic diseases and invasive species, reducing the quantity and quality of fish and marine animals.[278]
- Climate change is likely to have compounding impacts on food systems workers' physical and mental health. This could further impact food production and thus the food system.[284]

Barriers to Food Processing and Distribution

- There may be a greater risk of food spoilage and contamination from processing facilities as temperatures rise and extreme heat events become more prominent.[278]
- Extreme weather events, changes in precipitation patterns and temperature extremes may cause damage to transportation infrastructure and distribution routes and disrupt critical energy supplies (e.g., power outages).[278]

Challenges for Food Preparation and Consumption

- Reduced nutritional value of food: Increased concentration of atmospheric CO_2 levels can alter the nutritional content of certain agricultural crops such as grains and legumes, decreasing concentration of protein, iron, zinc, and other key minerals.[278]
- Food consumption patterns may be negatively impacted due to reduced accessibility, availability, and increasing food prices influenced by factors including climate change.[278]

Changes to Availability[278] (food production, distribution and exchange)	**Changes to Accessibility[278] (food affordability, allocation, and preference)**	**Changes to Utilization[278] (food safety, social and nutritional value of food)**

Impact on Food Safety, Security and Human Health

Greater Physical and Mental Health Impacts Faced by:

- Farm operators and workers.[284]
- Pregnant people, children, and older adults.[278, 331]
- People who are already facing household food insecurity. Groups disproportionately impacted by household food insecurity include (but are not limited to): female led lone-parent households, people living on low incomes, people on social assistance, families with children, and home renters.[282]
- People facing household food insecurity on top of health conditions, including mental health.

Vulnerability of Peterborough's Food System to Climate Change Impacts

A basic understanding of the impacts of climate change on food systems is necessary to discuss the food related impact of climate change on vulnerable populations. Climate change is expected to impact availability and accessibility of food in the PPH region. Although warmer weather and longer growing seasons could allow for more and different types of crops to be grown in the PPH region, climate change is associated with increased risks of agricultural losses from invasive pests, heat waves, flooding and other extreme events.[286,287] Livestock feeding,[288] fertility, and reproductive capacity can be negatively impacted by higher temperatures and can result in lower weight gains in livestock, reduced milk and egg production, and in extreme cases, livestock mortality.[289] For a detailed analysis of projected impacts of climate change on agriculture in Ontario, review the Ontario Provincial Climate Change Impact Assessment,[90] and explore the "Agriculture" Sector section of ClimateData.ca.

It is critical to note that availability, accessibility, and utilization of food in the PPH region relies heavily on global food systems, as is the case provincially and nationally. Ontario imports $20 billion worth of food annually.[290] While certain regions may see an increase in productivity in the short term, a general decrease in food production at a global scale is predicted.[278] Both locally and globally, extreme weather events have become increasingly frequent and severe over the past few years and have impacted the supply, production storage, and overall availability of food and products.[285] Reduced supplies, along with rising input costs for food producers, leads to higher consumer prices.[285] Between September 2021 and 2022 Canada experienced the fastest increase in the cost of food since the early 1980s: roughly 11%.[285] The cost of food increased an additional 6% from September 2022 to September 2023.[280]

The May 2022 derecho storm was an extreme weather event that impacted Peterborough's food system, including temporarily reduced food availability for local residents. Due to power outages, grocery stores were forced to temporarily close, discard food, and may have had to turn away some deliveries. Community members shared reports of sparsely stocked grocery store shelves in the days following the storm and power outages. PPH's annual food costing and food availability tracking started one week after the storm. In the 8 grocery stores surveyed 1-3 weeks after the storm, the frozen food items on the Ontario Nutritious Food Basket list were missing from shelves 11% of the time.[291] In contrast, when food costing and availability tracking was conducted in the same stores in May of 2023, (a time period that did not correspond with an extreme weather event), there were no missing frozen items in any of the 8 stores surveyed.[292] This is a local example of potential impacts of extreme weather and other factors, on food availability, and the food system's ability to recover. See Chapter 6: Extreme Weather Events, to learn about impacts of the May 2022 derecho.

Adaptive Capacity of the Local Food System

Climate resiliency of all parts of our local and national food system will be essential to support our community's adaptation to health impacts of climate change.[278] Overall, the food systems that support our local communities are strong and resilient, but they do face challenges.[293] Adaptive capacity for the agricultural sector includes technological advancements, infrastructure adaptation, resource availability of finances, labour, and support for farmers.[90] Protecting agricultural land and strengthening our local food system and agricultural workforce may also enhance our community's adaptive capacity to health impacts of climate change for all residents, including vulnerable populations.

For example, local farmland available for food production is necessary for our food system to adapt to impacts of climate change, and the protection of farmland is thus important for adaptation. The table below shows the change in agricultural land area in the PPH region from 2011 to 2021. There has been a 21% decrease in agricultural land over time in the PPH region from 2011 to 2021.[294]

Table 7-2. *Agricultural Land Area in the PPH region (Total Area of Farms in Acres).*

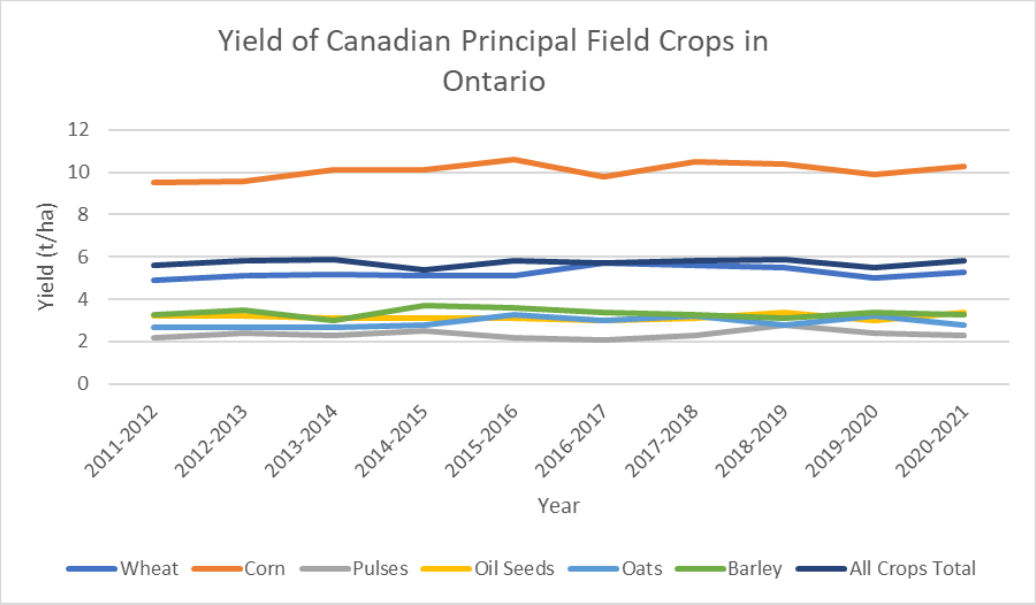
2011	2016	2021	Percentage change from 2011 to 2021
228,936	202,240	180,372	**-21 %**

Source: Census of Agriculture (via Ontario Ministry of Agriculture, Food and Rural Affairs), 2022.

Reductions in available farmland and agricultural capacity may happen due to intersecting factors, which may include aging of farm operators, stress, expense and profitability of farming, barriers to entry for new prospective farmers, abandonment of marginal land, and land use planning policies that promote urban expansion and use of farmland to build housing.[295]

Figure 7-1 shows the change in annual yields of the Canadian principal field crops grown in Ontario from 2011 to 2021. Yields have been relatively stable in the past decade with a slight decrease in 2019-2020. While assessing the impacts of climate change on crop yields is complex, the overall stability in yield speaks to the agricultural sector's ability to adapt to climate change.[296]

Figure 7-1. *Yield of Canadian Principal Field Crops in Ontario.*



Source: Government of Canada, Agriculture and Agri-food Canada, 2021.[296]

There has been a serious decline in the agricultural workforce in the PPH region over the last decade as demonstrated in table 7-3 below. There has been a 26% decrease in total number of farm workers from 2011 to 2021.[294] This also influences adaptive capacity of the food system.

Table 7-3. *Changes in the Agricultural Workforce between 2011 and 2021.*

	2011	2016	2021	Change Over Time (from 2011 to 2021)
Number of Farm Operators in the PPH region	1,460	1,360	1,215	-16.8%
Number of Paid Agricultural Workers in the PPH region	571	603	283	-50.4%
Total Number of Farm Workers in the PPH region	2,031	1,963	1,498	**-26.2 %**

Source: Census of Agriculture (via Ontario Ministry of Agriculture, Food and Rural Affairs), 2022.

During a consultation in May 2023, local food systems stakeholders shared that the local farming community is an important group with disproportionate health impacts resulting from climate change (Peterborough Public Health, Food and Climate Change Consultation Meeting, May 25, 2023).

Farm workers are one population that is disproportionately affected by the compounding physical and mental health impacts of climate change. Farm workers are predominantly outdoor workers and are often exposed to climate hazards as described in Chapter 6: Extreme Weather Events. Farm workers' livelihoods heavily depend on agricultural yield and production and are greatly influenced by climate change which in turn impacts farm workers' incomes, job security, physical health, and mental wellness.[284] From 2015 to 2016, a national survey on Canadian farmers' mental health was conducted. This survey found that roughly 45% of farmers reported stress, 58% met the classifications for anxiety and 35% for depression.[297] In 2021, the survey was conducted again and showed that 1 in 4 farmers reported suicide ideation and 76% reported experiencing stress.[298]

Despite facing challenges, it is important to highlight the remarkable resiliency and adaptability that farmers have demonstrated in the face of climate change over the years. Their determination is evident by their responses to climate change as they continuously and proactively embrace new technologies and various strategies to adapt their practices.[299]

Community gardens in the PPH region may also support adaptive capacity of the food system. In 2022, there were 44 community gardens in the PPH region. Of these, 33 were open to the public, offering 595 plots to 830 gardeners (email communication, *Nourish Project,* Sept 26, 2023). The City of Peterborough's community garden policy expresses support for community gardens, and acknowledges their contribution to local food production, health and well-being, and strong neighbourhoods.[300] Community gardens offer families and individuals the chance to grow fresh, healthy produce, green previously underused areas, and may also support local food programs.[301]

Climate Change, Food Systems and Security, and Vulnerable Populations

Climate change will have broad impacts on food systems and food security. These impacts will be unequally distributed and some populations may experience greater barriers to adaptation.[278]

Nutrition Impacts and Populations with Unique Nutritional Needs

In 2017, only 32% of residents in the PPH region reported eating 5 or more fruits and vegetables each day,[302] a smaller percentage than 2013, when 36% of residents reported eating 5 or more fruits and vegetables daily.[302] Climate change models project decreased fruit and vegetable consumption, which could contribute to between 25 and 33 deaths per million in 2050.[278]

In addition, rising atmospheric carbon dioxide levels may impact the nutritional value of important crops such as wheat, corn and rice. These crops, as well as many other plant species produce lower concentrations of protein and essential minerals like iron and zinc when grown at elevated carbon dioxide (CO_2) levels.[303] Crops such as rice, soybeans, wheat and barley are expected to have 6% to 15% lower protein concentrations by the year 2100.[303]

Climate change impacts on nutrition can impact all residents, and unique nutritional needs can occur at all ages and life stages. This said, reduced intake of nutritious foods, as well as decreased nutrient value of staple foods could disproportionately impact those who are at a critical life stage periods for development, or who have higher nutritional needs. These populations include (but are not limited to) the following:

- ***Infants, children and youth*** are vulnerable to health impacts of malnutrition. Lack of proper nutrition can impair brain development which can have long-term consequences on educational attainment and income as adults.[304] Malnutrition in children is also associated with increased risk of developing chronic disease in adult-life.[304, 305]
- ***Pregnant people*** who rely primarily on staple crops such as wheat and rice for nutrition may be particularly vulnerable to the decrease in nutritional value. During pregnancy, nutritional deficiencies such as iron deficiency anemia, can result in severe and irreversible cognitive and developmental impairments in children.[306] Poor nutrition during pregnancy can increase risk of problems during delivery, low birth weight, difficulty with breastfeeding and newborn death.[307]

- ***Older adults*** are already more susceptible to malnutrition than the general population due to biological changes that can happen in the body with age.[308] These can include reduced appetite, poor oral health, digestive changes that can result in decreased nutrient absorption from food, and increase in chronic health conditions that can raise risk of malnutrition and muscle mass loss. Malnutrition in older adults is associated with weakened immune system, weakness, increased frailty, impaired wound healing, and increased mortality.[308]

Climate Change Vulnerability and Household Food Insecurity

Rising food prices due in part to climate change, can amplify existing health inequities. Those already facing food insecurity will be disproportionately affected by the impact of climate change on food systems.[309] Increasing food costs are likely to worsen food insecurity and financial access to food for people who are already struggling to buy food.

Household food insecurity is inadequate or insecure access to food due to financial constraints.[282] Someone who is food insecure worries about running out of money for food. People experiencing household food insecurity are more likely to have chronic illnesses such as type 2 diabetes, heart disease, high blood pressure along with mental health issues. Household food insecurity and poor mental health are strongly linked.[310] Adults in food insecure households have a higher risk of mental health conditions such as depression and anxiety disorders.[310] Facing food insecurity makes it very difficult to meet nutrition needs, or to manage chronic health conditions. In addition, household food insecurity is associated with increased risk of birth defects among pregnant people, and with poorer health and development in children.[278]

The most recent local data for the County and City of Peterborough shows that approximately 19% of households were food insecure between 2020 and 2022.[311] This estimate needs to be interpreted with caution due to a small sample size and variability in the sample.

Populations disproportionately impacted by food insecurity are predicted to be hardest hit by increased food prices, and reduced availability and accessibility of food caused by climate change. Some of these groups include (but are not limited to) the following:

Nearly 1 in 5 households faced food insecurity between 2020-2022. This is the highest number ever recorded in Peterborough.

- **People living on low incomes:** Data for the Peterborough Census Metropolitan Area in 2020, shows that 10.9% of residents live on low income based on low-income measure after tax.[312] In Canada in 2022, 70% of households reliant on social assistance faced food insecurity: the highest prevalence by household type.[282] In the County and City of Peterborough in 2021, the Ontario Disability Support Program case rate and Ontario Works case rate were 3.74% and 1.26% respectively. These rates are 43.2% and 33.3% higher than Ontario's case rates.[43]
- **Households that rent versus own:** Homeownership is often an indicator of wealth and can be used to access funds during times of unexpected income loss.[282] In 2022, 28% of renters compared with 16% of homeowners with mortgages and 8% without mortgages were food insecure in Canada.[282] In the PPH region, approximately 40% of residents rented their home in 2021.[15]
- **Female led lone-parent households and children:** Between 2019 and 2022, 24.6% of children under the age of 18 years old were living in food insecure households in Ontario. This is almost 1 in 4 households.[313]

In 2022, female lone-parent households had the highest rate of food insecurity by household type in Canada at 41%: roughly 2 in 5.[282]

Food Affordability in Peterborough

When basic needs such as housing and enough money to buy food and clothing are not met, this can be a significant barrier for individuals to survive, let alone thrive, or make meaningful contributions to society.[4] **It is not feasible for some community members to prepare for climate emergencies when every-day life is an emergency due to unmet basic needs.**

The Nutritious Food Basket Survey measures the cost of healthy eating based on Canada's Food Guide.[70] Results from the PPH region in 2023 indicate that low-income households often cannot afford nutritious food and housing and have very little income left (if any), to pay for other basic needs.[70] When comparing income to the cost of food and rent locally, an older adult receiving income from old age security in the PPH region would need to spend 70% of her income on food and rent alone, and a family of four receiving Ontario Works assistance would need to spend 98% of their income before any other expenses.[70] Rent and food costs alone exceed income for a single pregnant person in the PPH region receiving income from the Ontario Disability Support Program or Ontario Works with a deficit before paying for any other expenses.[70] Rising food costs stemming in part from climate change impacts, may exacerbate this problem and may even cause food-secure households to become food insecure in the future, if incomes are not sufficient to meet the cost of basic needs.

Food banks and pantries across the County and City of Peterborough try to provide short-term, emergency support; however, food banks only support 1 in 5 people facing food insecurity.[314] Adequate incomes are needed to address the root cause of household food insecurity.[315] **Adaptive capacity can be strengthened through local, provincial and federal policies that support all community members to have incomes that meet the cost of living.**

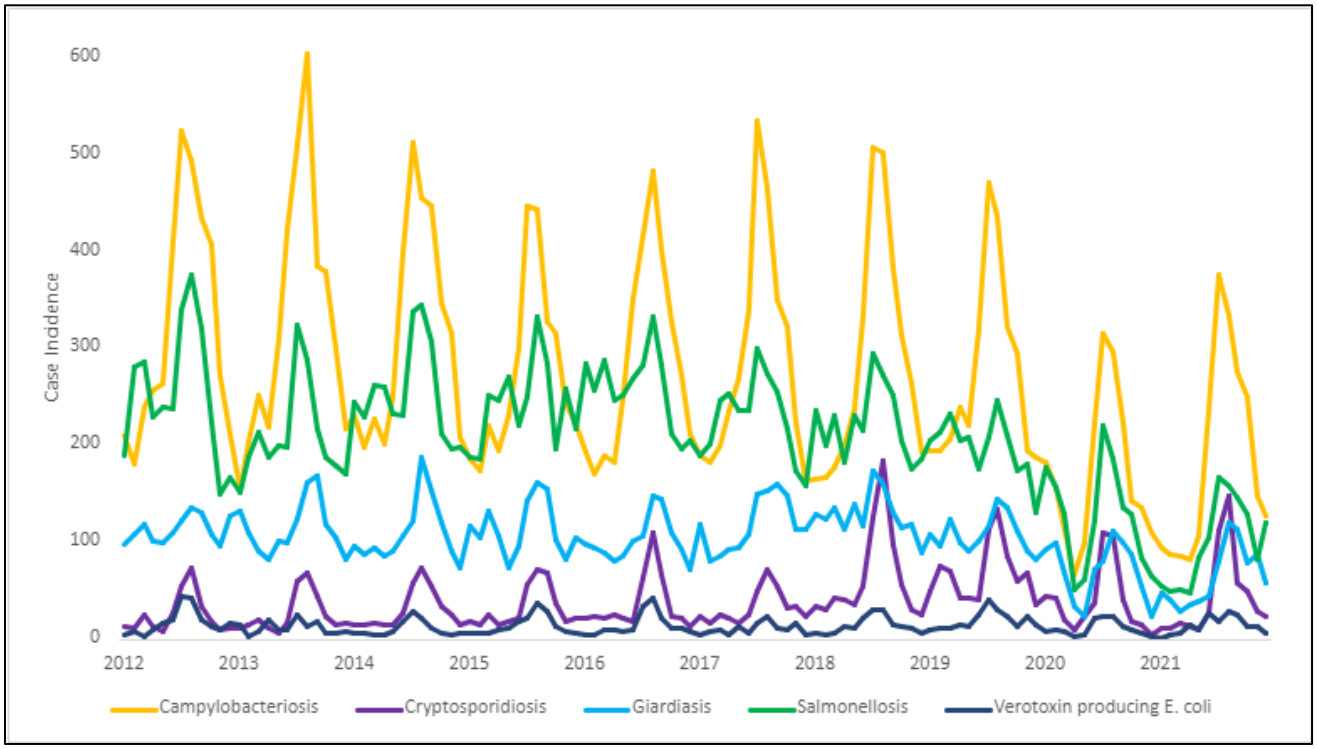
Food and Water Safety

Impacts of Climate Change

Safe food and safe water imply that these resources are not contaminated with pathogens or chemicals at levels that could lead to adverse health effects[278] to those who consume or recreate in them. Food and water safety are an essential component of the foundation of community food security and can be affected by a changing climate. Increases and changes in precipitation patterns, a warming climate, and extreme weather events are anticipated to increase the introduction and persistence of pathogens and chemicals to levels in food and water which could lead to an increased incidence of foodborne and waterborne illnesses in consumers.[278]

Warming temperatures can influence human behaviours related to outdoor recreation and food handling where individuals may choose to spend more time outdoors including barbequing, picnicking, and recreating. A potential lack of adequate handwashing and dishwashing facilities, less than optimal temperature control, the possibility for cross-contamination, and access to potable drinking water can negatively impact food and water safety. Studies in regions similar to Canada have linked food and waterborne contamination and disease incidence with seasonal trends; specifically, consistent summer peaks for food and waterborne illnesses caused by Cryptosporidium, Giardia, Campylobacter, Salmonella, and *Escherichia coli (E. coli)*.[316] Figure 7-2 illustrates the seasonality of the causes of food and waterborne illnesses. Microbial water and foodborne illness caused by these pathogens can lead to general gastrointestinal illness with symptoms of diarrhea and vomiting, to more severe illness such as Guillain-Barre syndrome and hemolytic uremic syndrome (HUS), and subsequently death.[278] The impacts of these food and waterborne diseases can be a burden on already stressed healthcare services.

Figure 7-2. *Monthly Incidence of Select Reportable Diseases in Ontario from 2012-2021.*



Source: Public Health Ontario (Infectious Disease Trends in Ontario), Integrated Public Health Information System. Extracted: September 2023.

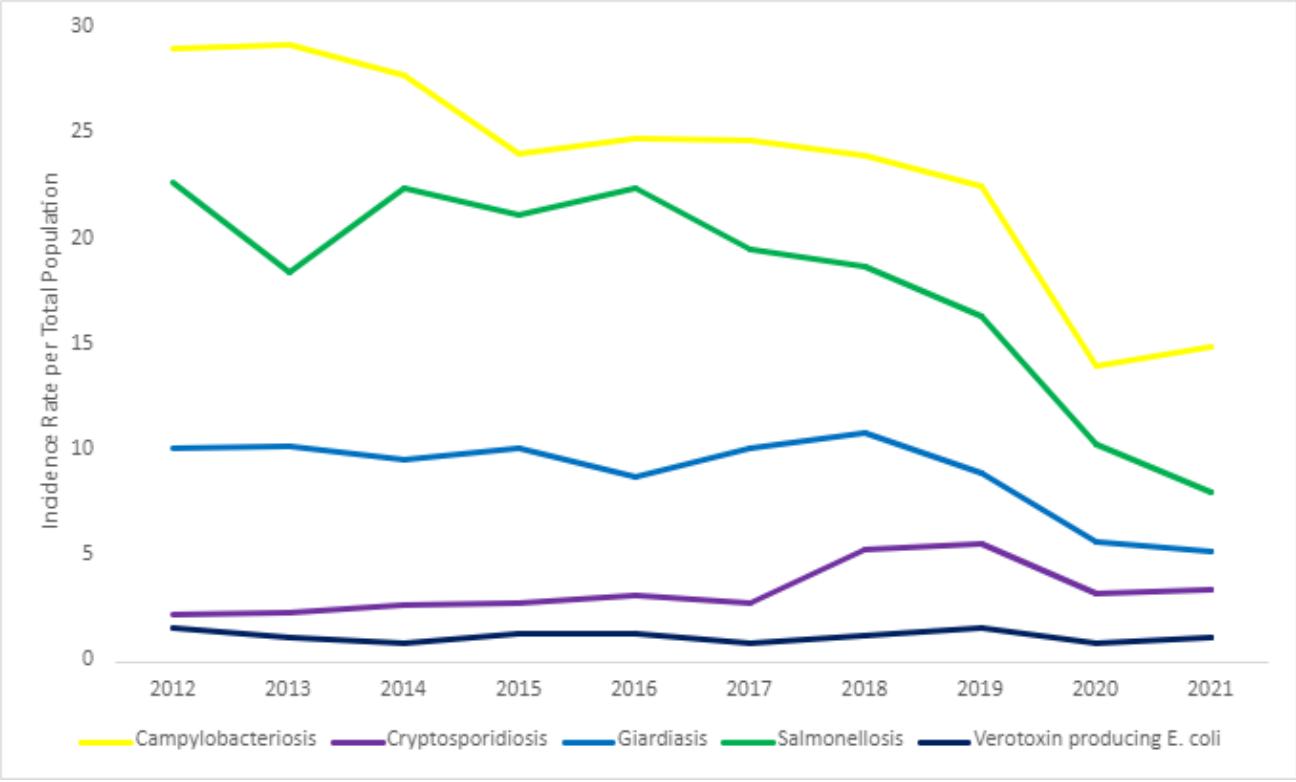
Foodborne and Waterborne Disease Trends

A seasonal increase in incidence of foodborne illnesses campylobacteriosis, salmonellosis and verotoxin producing *E. coli* (VTEC); and of waterborne illnesses cryptosporidiosis and giardiasis in Ontario between the period of 2012-2021 is depicted in Figure 7-2.[317] The incidence of these diseases is higher during the summer or warmer months, specifically July, August, and September; with a few exceptions. This suggests that incidences of illness may be linked to activities that correlate with warmer weather, such as more time spent outdoors recreating in water bodies or camping where parasites such as giardia and cryptosporidium may be accidentally ingested through swimming or inadequately treated drinking water, and more time spent cooking and/or eating outdoors where food can be affected by lack of adequate handwashing and dishwashing facilities, temperature abuse, and cross-contamination. Data from the PPH region showed similar trends; however due to a lack of data points, data from Ontario is displayed instead.

The consequences of a changing climate, specifically longer periods of warmer temperatures can therefore affect and increase public exposure to certain food and waterborne illnesses. Interventions, such the Canadian Food Inspection Agency's (CFIA) requirements for manufacturers to reduce Salmonella in frozen raw breaded chicken products which came into effect in 2019[318] in addition to public health messaging and education can have a positive impact on the incidence rates of food and waterborne diseases.

Cryptosporidiosis and VTEC have seen an increase in incidence rates as shown in Figure 7-3 below. An increase in incidence of Cryptosporidiosis can potentially be attributed to warmer temperatures leading to an increase in time spent outdoors. Increases in outdoor activities such as camping, hiking, and recreation in lakes and rivers where water may be accidentally ingested or used as drinking water without adequate disinfection are risk factors for Cryptosporidiosis. Cattle and other livestock are a source of cryptosporidium,[319] and agricultural runoff into bodies of water due to heavy precipitation can increase contamination of water bodies by cryptosporidium.

Figure 7-3. *Selected Food and Waterborne Disease Rates for Ontario from 2012 – 2021.*



Source: Public Health Ontario (Infectious Disease Trends in Ontario), Integrated Public Health Information System. Extracted: September 2023.

Between 2012-2021, a decrease in the incidence of Campylobacteriosis, Salmonellosis and Giardiasis infections was observed.[317] Over this same period, Cryptosporidiosis and VTEC infections have seen a steady increase or lack of a decrease in Ontario.[317] Data from the PPH region showed similar trends; however, due to a lack of data points, data from Ontario is displayed instead.

Studies have shown that cattle are able to shed greater numbers of enteric pathogens, particularly *E. coli* during periods of higher temperatures such as in summer months,[320] potentially affecting pathogen abundance in the surrounding environment. Pathogens that are released into the environment, particularly onto agricultural land can be transported by heavy precipitation to directly contaminate crops,[278] such as produce and salad greens. Recalls of romaine lettuce grown in California between 2018-2020 due to contamination by VTEC have impacted the Canadian market and included isolated cases within Canada as per the CFIA.[321] An increase in *E. coli* outbreaks linked to raw produce has been documented in the past few decades.[278] During 2003-2012 in the US, a total of 255 *E. coli* outbreaks related to food products were reported and resulting in 3,667 hospitalizations, 209 HUS cases and 25 deaths.[322] It was determined that food was the major mode of transmission for *E. coli* outbreaks; 76% of these outbreaks were attributed to leafy vegetables such as lettuce, spinach and salad greens.[322] The study also found that more outbreaks related to *E. coli* were reported during this period than during the previous 20 years.[322] Prior to recalls being declared, food items may already be available to consumers who may contract a foodborne illness after consumption of these products. Nearly 30% of food consumed in Canada is imported from other countries; therefore, any climate related changes to the occurrence and growth of pathogens during food production in other countries could affect the health of Canadians.[278]

Effects of Extreme Weather Events on Food and Water Safety

Extreme weather events associated with climate change can result in contamination or spoilage of food.[278] Power outages for example can disrupt temperature controls creating opportunities for the growth of pathogens and spoilage microorganisms resulting in impacts on food safety and foodborne illnesses.[323] Flooding can similarly impact food safety by contaminating food products with pathogens, chemicals, and physical contaminants as flood waters may carry raw sewage, chemicals, and other environmental contaminants into homes, establishments storing or serving food products and agricultural fields.

The impacts of flooding and warm temperatures can have a deleterious effect on stored food products such as grains, which are an important food source for humans.[324] Harvested grains are stored to ensure a continual supply throughout the year; improper storage can expose grains to ideal moisture and temperature levels that promote fungal growth, which can produce mycotoxins that are harmful to humans.[324] Flooding in major grain-producing states in the US in 2019 resulted in the destruction of a large volume of stored grains and crops[325] which impacted farmer livelihood and food security.

The effects of a changing climate can lead to risk of environmental contaminants including chemicals to enter the food supply chain, which can be, "introduced into plants and animals through environmentally mediated pathways such as atmospheric deposition, and uptake from contaminated soil, water, or other organisms."[323] Surveillance programs are in place in Canada to help ensure exposure to chemical contaminants in food are as low as possible.[323] According to the Health of Canadians in a Changing Climate report, "[m]ultiple factors contribute to the potential risk and severity of illness resulting from chemical contaminant exposure, including an individual's genetic predisposition and other health conditions, the contaminant type and concentration, and the extent of exposure over time." [323] Children and seniors are especially vulnerable due to their reduced ability to process and eliminate contaminants.[323]

Wildfires can increase the atmospheric deposition of chemicals such as persistent organic pollutants (e.g., industrial chemicals, pesticides), mercury/methylmercury, and polycyclic aromatic hydrocarbons in food.[323] Chemicals can travel long distances before they are deposited onto land or into water bodies which may be

used for irrigation,[323] drinking water or recreation. In the summer of 2023, smoke from wildfires in Northeastern Ontario and Quebec resulted in reduced air quality in the PPH region.

Heavy precipitation and flooding can also play a role in chemical contamination by transporting chemicals from contaminated soils to new locations where food may be produced or into water bodies through runoff. Studies have found high levels of certain chemicals in soil from flooded pastureland, in the milk of animals that grazed on that land, and high levels of certain chemicals in crops which may have an impact on public health.[323]

Water Safety Impacts – Drinking and Recreational Water

Impacts to Drinking Water

A changing climate may lead to health risks and threats associated with drinking and recreational water safety and availability, including to bodies of water, irrigation supplies, drinking water supply and increases in waterborne diseases such as Cryptosporidiosis and Giardiasis.[323] Risks can also include increases in the frequency of harmful, toxin-producing algal blooms and prevalence of waterborne pathogens, and the degradation of watersheds due to wildfires, flooding and droughts.[323]

In addition to municipal drinking water systems, Canadians, particularly those residing in rural areas may access their drinking water from private water systems supplying water through wells or surface water. Private drinking water systems may be more vulnerable to contamination than municipally managed systems due to a lack of adequate treatment or monitoring, operator knowledge, poor-quality source water, and lack of source water protection.[323] In the PPH region, approximately 39% of the population relies on private drinking water systems. Most residents of Curve Lake First Nation rely on private drinking water systems such as wells, whereas approximately 56 homes depend on a water treatment plant currently in need of repair or replacement and susceptible to frequent boil water advisories.[326] Hiawatha First Nation, in the latter half of 2023 opened their drinking water system with a distribution system currently serving 42 homes and anticipated to serve another 130 homes soon; the new system ensures potable water for its users ending drinking water advisories to those it now serves.[327] The remaining 61% of the population relies on one of the 11 municipal drinking water systems which supply both residents in the City of Peterborough and throughout the County, including residents in parts of Trent Lakes, Otonabee-South Monaghan, Asphodel-Norwood, Havelock-Belmont-Methuen, Selwyn, and Cavan-Monaghan.

Contamination of water can be categorized as biological or chemical. Biological contaminants include bacteria such as total coliforms, *E. coli* and cyanobacteria; protozoa such as Giardia and Cryptosporidium; and viruses. Biological contaminants are usually managed through filtration and disinfection treatment systems.[323] Chemical contaminants can include arsenic, lead, microplastics, pharmaceuticals, and radon which require specialized testing to detect and sophisticated treatment to remove.[323]

Heavy precipitation, particularly after a period of drought, can increase surface water contamination by increasing runoff of biological and chemical contaminants from land into water bodies or unprotected wells.[323] This runoff may carry high pathogen loads and particulate matter which can increase turbidity and the risk of waterborne diseases[323] in drinking water. Turbid water can strain and reduce the effectiveness of filtration and disinfection systems. Abandoned or poorly maintained wells can provide a pathway for contaminants to enter groundwater aquifers which may be used by adjacent, properly maintained wells.[323] Abandoned wells are required to be properly filled and sealed to prevent the potential for contamination of groundwater.[328]

Impacts to Recreational Water

Cyanobacteria, or blue-green algae are a concern in freshwaters, particularly surface waters used for recreation or drinking. The growth of cyanobacteria is influenced by warm temperatures, nutrient loading and high precipitation.[323] Extreme weather events such as wildfires can increase the deposition of ash on land and water; while heavy precipitation can increase surface run-off of nutrients into freshwater influencing the

growth of blue-green algae and the risk of blooms.[323] High water temperatures optimize growth rates and the presentation of blue-green algae blooms[329] in freshwater bodies which have the potential of producing cyanotoxins that may be harmful to health. Cyanotoxins can have various toxic effects depending on whether contaminated water was ingested or contacted the skin.[330] Over the past few years, reports of blue-green algae blooms have become increasingly common, specifically during the summer months when temperatures are warmer, and more light is available.[323] Due to the toxic nature of some cyanotoxins, the presence of blue-green algal blooms can lead to the closure of recreational waters and beaches, and lead to drinking water advisories rendering contaminated drinking and recreational water inaccessible for users.[330]

In the PPH region, the presence of a blue-green algae bloom in recreational water would lead to public notification and if present, closure of the associated public beach to protect public health. The beach would remain closed pending results of testing to confirm the presence of cyanobacteria and cyanotoxins or the dissipation of the bloom.

Peterborough Public Health's beach monitoring program tests two City of Peterborough beaches and 19 County beaches for *E. coli* levels throughout the summer months. Season length is variable but typically lasts between mid-June to the end of August. City of Peterborough beaches are tested daily from Monday to Friday, and County beaches are tested either once weekly or once monthly. Levels of *E. coli* can help to determine whether a beach is safe for swimming. Public beaches are to be posted as either closed due to significant risks to public health and safety including a blue-green algae bloom; unsafe if the geometric mean concentration of five samples is calculated to be greater than 200 *E. coli*/100mL or a single sample maximum concentration is determined to be greater than 400 *E. coli*/100mL; or as safe. If a public beach is posted as closed, access to recreational water is blocked to the public. If a public beach is posted as unsafe, the public can still access recreational water; however, at their own discretion.

Between the period of 2013-2022, the incidence of beach postings of 'unsafe' varied with no specific pattern (*data not shown*) and each posting was based on surface water levels of *E. coli.* The variation in beaches posted as unsafe could be due to multiple factors that influence the levels of *E. coli* in beach water including the incidence of extreme weather events such as high precipitation, the presence of animals and birds on the beach, and the average temperature. The two City of Peterborough beaches saw their first closures due to the presence of blue-green algae blooms in the summer of 2023.

Climate Change, Food and Water Safety, and Vulnerable Populations

Populations most vulnerable to food and waterborne illness include:[331]

- Pregnant people
- Older adults
- People with weakened immune systems
- Children aged 5 and under

Certain individuals may be at an increased risk of developing food or waterborne illnesses due to factors such as weakened or developing immune systems which may make it difficult for individuals to completely recover and instead potentially lead to serious long-term health effects.

Peterborough Public Health Adaptation Efforts

The following are examples of Peterborough Public Health's current work that is contributing to climate change adaptation and supporting those most vulnerable to health impacts of climate change as it relates to food systems and food and water safety and security:

Population Assessment & Surveillance

- Monitoring prevalence of household food insecurity.
- Monitoring food affordability and availability using the Ontario Nutritious Food Basket.
- Monitoring dietary patterns (i.e., vegetable and fruit consumption).
- Tracking, monitoring, and investigating diseases of public health significance, including those related to foodborne and waterborne illness.
- Monitoring potentially harmful algal blooms in collaboration with the Ministry of Environment, Conservation and Parks.
- Conducting water quality sampling and safety surveillance of local public beaches.

Health Promotion

- Participating in municipal engagement for healthy municipal policies (including land-use, food policy, and food systems). Collaborating with local municipalities to establish drinking water sample courier services.
- Collaborating on policy and partnership development to address health equity, the social determinants of health and prevent adverse childhood experiences. Priority issues include adequate incomes (e.g., living wage, basic income guarantee), housing, and food security.
- Promoting the Peterborough Food Charter and supporting food systems planning and policy development to work towards a sustainable food system.
- Collaborating with farmers and community partners to support gleaning initiatives, the JustFood box, and student nutrition programs.
- Promoting food literacy for underserved populations including lone parent led families, pregnant people, and people living on low incomes. Programs may include education on adapting to heat while cooking, access and use of local food, and emergency preparedness.
- Providing leadership and support for provincial adaptation related initiatives through the Ontario Dietitians in Public Health.
- Providing public information and outreach related to food and drinking water safety.
- Promoting breast/chest feeding as a safe, available, and affordable option.

Health Protection

- Conducting routine inspections of all food premises, prioritizing high-risk facilities serving vulnerable populations, and all public recreational water facilities.
- Providing interpretation, guidance and advice related to adverse water results for residents relying on private drinking water supplies.
- Responding to all reports of Adverse Water Quality Incidents for regulated drinking water systems and requiring appropriate corrective action.
- Issuing Boil Water Orders and Drinking Water Advisories, as necessary; ensuring orders and advisories are publicly disclosed.
- Inspecting small drinking water systems to ensure compliance with applicable regulations.
- Providing safe food handler training.
- Working with food operators to ensure food safety during and after power outages.
- Providing local communication campaigns during climate-related emergencies such as power outages, to educate residents on methods to maintain food safety and integrity to reduce food waste, where possible.
- Providing follow-up and public education on reportable food and water borne illness.
- Responding to confirmed harmful algal blooms where there is a potential public risk (e.g., beach closure, drinking water advisories, and enhanced monitoring).

Vector-borne Diseases

Changes in climate, including warmer seasonal temperatures, higher humidity, and increased precipitation are ideal conditions for certain vector-borne species to breed in areas they were not known to frequent in the past.[332] A warming climate is expected to enhance populations of vectors including mosquito and tick species, making southern Canada more suitable for the northward expansion of and emergence of new mosquito-borne and vector-borne diseases, particularly from the United States.[333]

Mosquito-borne Diseases

Over 80 species of mosquitos are endemic in Canada, only a few of which carry pathogens known to cause disease in humans.[334] Mosquito-borne diseases present in Ontario known to require medical attention in some infected individuals include West Nile Virus (WNV); Eastern Equine Encephalitis Virus (EEEV); and diseases within the California Serogroup Viruses (CSGV) including Jamestown Canyon Virus (JCV), Snowshoe Hare Virus (SSHV) and La Crosse Virus. WNV is a mosquito-borne disease considered medically important[334] and is the only notifiable mosquito-borne disease of public health significance in Ontario.

Mosquitos are most active in Ontario from late spring to early fall,[332] with most reported cases of mosquito-borne disease occurring from early June to mid-October.[335] Only adult female mosquitos take blood meals and are capable of transmitting pathogens.[333] Approximately 20% of individuals infected with mosquito-borne diseases are symptomatic and typically present with similar symptoms including, but not limited to: fever, headache, nausea and muscle aches.[333] Most infected individuals will recover fully; however, approximately 1% develop severe illnesses such as meningitis, encephalitis, or meningoencephalitis.[333] Encephalitis and meningitis, specifically of viral or unknown causes, are reportable diseases of public health significance in Ontario; however, it is up to healthcare professionals to pursue further testing to determine the underlying cause of those symptoms. Approximately 10% of human cases of WNV and CSGV are fatal,[333] compared to 30% of EEEV infections.[336]

Increases in precipitation brought on by climate change and extreme weather events during the mosquito season can increase pools of standing water and thus the availability of breeding habitats.[337] These conditions can lead to a longer mosquito season, support larval development and survival, extend the lifespan of adult mosquitos increasing their overall population size,[338] increase the diversity of mosquitos competent to serve as vectors for emerging diseases,[337] increase the diversity and population of reservoir host populations by increasing their abundance and geographic distribution[334] and increase the transmission risk of exposure to mosquito-borne diseases in humans.[337]

Populations at Increased Risk

Individuals most at risk for serious illness related to mosquito-borne diseases are those over the age of 70, individuals with underlying chronic conditions, and/or weakened immune systems;[334] this is particularly documented with individuals diagnosed with West Nile Virus. An increase in exposure to mosquitoes can also be expected due to warmer or more favourable temperatures over a longer period of the year where individuals may spend more time outdoors.[337] Those with increased risk include individuals spending time outdoors without personal protective measures against mosquito bites.

Surveillance and Disease Trends

Once considered an emerging mosquito-borne disease, human cases of WNV began to appear in the United States and Canada in the late 1990s and into the early 2000s. It is thought that the presence of WNV-infected mosquitos made their way to North America likely by importation on aircraft from endemic countries.[339] The existence of competent mosquito vectors and avian reservoir hosts in North America facilitated the

transmission of WNV allowing it to become an endemic mosquito-borne disease[333] not only in southern Ontario but in the rest of Canada as well. The introduction and establishment of WNV in Canada shows that Canada is not immune to the threat of invasive vector-borne pathogens.[339] WNV infection is transmitted through the bite of an infected Culex spp. mosquito, which in Ontario includes *Culex pipiens* and *Culex restuans* species,[333,332,334] which are endemic in eastern Canada.[338]

Peterborough Public Health (PPH) conducts surveillance activities during the months of June to August through mosquito trapping and testing to determine the presence of WNV and EEEV within the PPH region. Between 2013-2022, on average 92% of mosquitos collected yearly through PPH's WNV surveillance program were identified as species being able to carry WNV. During the same period, 8 WNV positive mosquito pools were identified, 3 of which were identified in 2020 and 1 identified in 2022.

Between 2012 to 2021, a total of 4 cases of WNV were reported in the PPH region, with the last case reported in 2018;[340] as opposed to a total of 887 cases reported in Ontario during the same period.[340] Higher risks of infection are usually located in urban-suburban areas with large, infective mosquito populations.[341] The proportion of cases in PPH, which is largely a rural area, is much lower than for the rest of Ontario.

Emerging Mosquito-borne Diseases – Eastern Equine Encephalitis Virus

Over the past few decades, the incidence of endemic mosquito-borne diseases including not only WNV, but the emerging mosquito-borne diseases Eastern Equine Encephalitis (EEEV) and the California Serogroup Viruses (CSGV) have increased by approximately 10%[334] in Canada. These viruses are classified as potentially emerging viruses threatening public health.[337]

EEEV is considered a medically important mosquito-borne disease which is emerging in Canada. The main mosquito vector for EEEV is *Culiseta melanura*, with a range of bird species serving as reservoirs, like WNV, including corvids, such as crows and blue jays and passerines, such as nuthatches and robins.[333] This species of mosquito is typically found in hardwood forests and swamps flooded with freshwater, with the disease most often seen in the horse family and most cases occurring in rural areas.[342] In addition to *Cs melanura*, mosquito-borne vectors including *Aedes vexans*, *Coquillettidia perturbans*[342] and *Culex spp* may act as bridge vectors between infected birds and uninfected mammals.[343]

To date, only one known human case of EEEV has been identified in Ontario in 2016, whereas many equine cases of EEEV have been identified. In early September 2023 the PPH region reported 1 confirmed equine case of EEEV and 2 suspect equine cases; the confirmed equine case died because of the EEEV infection. Equines can be protected from EEEV through vaccination, whereas there is no human vaccine for EEEV.[344] With no formal surveillance system in place, human cases of EEEV may go undetected or undiagnosed.[335] Human and equine infections are an indicator of EEEV positive mosquitos in the area.[342] EEEV surveillance is conducted in Ontario through the WNV mosquito surveillance program; any captured *Cs melanura* species of mosquitos may be tested for EEEV.[342] To date, no EEEV positive mosquito pools have been identified in the PPH region; however, the presence of equine cases of EEEV in the PPH region indicates that EEEV activity in mosquitos is present and a potential risk to public health exists.

During the period between 2013-2022, 4 out of 31,508 mosquitos collected tested as *Cs. melanura*. The proportion of total mosquitoes collected from mosquito surveillance activities represented by mosquito species that are EEEV vectors was approximately 25%. These vectors include: *Aedes, Coquillettidia, and Culex spp.*[345]

Emerging Mosquito-borne Diseases – California Serogroup Viruses

The Jamestown Canyon Virus (JCV) and Snowshoe Hare Virus (SSHV) are the most found CSGV in Canada; they have been identified throughout the country as medically important mosquito-borne diseases.[346] Although

most exposures to these viruses result in asymptomatic or mild infections, they have been known to cause febrile and neurological diseases, similar to West Nile Virus.[346] The SSHV specifically has been implicated in neurological cases mainly involving children;[346] whereas for JCV, neuroinvasive disease has been reported in children and adults.[337] As these mosquito-borne diseases are not reportable, relatively still emerging in Canada, and not routinely tested for, "these potential pathogens may be contributing to a higher burden of illness than previously recognized and should be considered as part of the differential diagnosis for febrile and neuroinvasive disease during the mosquito season."[334,346]

Approximately 21% of mosquitoes collected yearly during PPH WNV surveillance activities between 2013-2022 were identified as mosquito vectors for JCV and SSHV. These mosquito species included *Aedes spp, Culiseta spp*, and *Anopheles spp*. *Cq. perturbans* represented approximately 44% of mosquitos collected between 2013-2022. *An. punctipennis* represented approximately 2% of mosquitos collected during the same period; both species have demonstrated transmission of JCV.[337]

The emergence and seriousness of CSGV in Ontario was highlighted by a case of JCV in a young boy in early summer of 2023 as reported by Global News.[347] The boy was bitten by a mosquito while playing in his backyard in Oshawa, a city located in close proximity to the PPH region. The bite led to fever and lethargy, which continued to worsen over time. The boy was eventually hospitalized and diagnosed with life-threatening meningoencephalitis caused by JCV. The diagnosis was determined after healthcare practitioners ordered a multitude of tests to determine the underlying cause of the illness, causing delays in potential treatment. This case highlights the emerging nature of mosquito-borne diseases such as those caused by CSGVs and the need to educate health professionals of the health risks and significance of emerging mosquito-borne diseases.

Although CGSV cases are not notifiable in Ontario or throughout Canada, the Public Health Agency of Canada has been monitoring and collecting information on cases.[333] Since 2015, between 20-40 human cases of JCV and SSHV have been observed annually in Canada, apart from 2017 when 122 cases were reported – most of which were observed in Quebec.[334] It's believed this increase in the number of JCV and SSHV cases is attributed to enhanced testing of those who presented with WNV-like symptoms; however, tested negative for WNV.[334] Further testing may therefore have been requested to test for California serogroup viruses such as JCV and SSHV. The discovery and presence of JCV and SSHV cases throughout Canada, which present with similar symptoms to WNV, a medically important mosquito-borne disease highlight the need for education and awareness of symptoms, testing, and reporting of these diseases as they can be significant to public health. CSGV, JCV and SSHV cases may be under-diagnosed due to low-level awareness of these pathogens among physicians, health care practitioners and public health professionals as they are not currently nationally or provincially notifiable diseases in Canada.[334] [346] There are currently no surveillance programs to monitor JCV, SSHV or EEEV activity in mosquitos (with the exception of mosquito testing for EEEV), reservoirs or human populations,[334] and there is a lack of commercially available diagnostic assays.[346] The National Microbiology Lab (NML) in Winnipeg is the reference lab for EEEV and CSGV testing in Canada[334] and the only lab in Canada to perform testing for CGSVs.[346] Ongoing surveillance is needed to help target prevention and control efforts, and increase awareness among healthcare professionals, especially of CSGV and EEEV.[335]

The La Crosse virus is another California serogroup virus and,"is the primary cause of viral encephalitis in children in the United States (on average 80 to 100 cases per year) and the second leading cause of arbovirus-associated neuroinvasive disease in North America." [346] La Crosse virus associated cases have not yet been reported in Canada;[346] however, its vector mosquitos, *Ae. triseriatis* and *Ae. albopictus* have been discovered in limited numbers. Warming climate and increased precipitation may cause these vectors to expand further north into Canada.

Lyme Disease and Emerging Tick-Borne Diseases

The emergence and northward expansion of blacklegged ticks, specifically *I. scapularis,* into Ontario has been attributed to the effects of climate change. The effect of climate warming on the expansion of tick populations relates to higher average daily minimum temperatures at ground level positively correlated with tick abundance,[348] shifts in host animal migration patterns,[349] and human driven landscape changes.[350] Increasing temperature is the most important predictor of tick population establishment and suitability due to the influence of temperature on the life cycle and mortality of ticks.[351]

A warming climate provides an increased number of suitable habitats for ticks to survive and establish where they previously couldn't which increases the abundance and geographic range of vectors.[333] A warmer climate also increases the available time for ticks to seek and acquire a host, potentially leading to an increased incidence of tick-borne diseases. [351] Ticks require at least one bloodmeal for each part of their lifecycle to survive. Ticks are most active between spring and late autumn, being active throughout the day at temperatures above 4°C.[352] The geographic range of ticks is estimated to be expanding northwards at a rate of 35 to 55 kilometres each year.[353]

Lyme Disease cases have been increasing in Ontario and locally in the Peterborough Public Health (PPH) region year-over-year, with the highest number of cases reported annually between June and September[340] (see Figure 8-1). As a reportable disease of public health significance, Lyme Disease was once considered rare in Ontario; however, it has become the most reported vector-borne disease.[350] Most Lyme Disease cases in southern Ontario report exposure to blacklegged ticks, specifically *Ixodes scapularis* (*I. scapularis*) which carries the bacterium, *Borrelia burgdorferi* (*B. burgdorferi*), the microorganism responsible for causing Lyme Disease.[354]

The first population of blacklegged ticks capable of carrying *B. burgdorferi*, were identified at Long Point Provincial Park in Ontario in the early 1970s.[354] Blacklegged tick populations began to expand and establish further north into Canada from the United States[348] and into southern Ontario in the proceeding years, with cases of Lyme Disease becoming more frequent from the mid-1990s and into the 2000s.[354]

In addition to the increased risk for Lyme disease, the spread and establishment of *I. scapularis* into Ontario due to climate change poses a significant risk to public health as this species can transmit other pathogens resulting in vector-borne diseases such as Anaplasmosis caused by the *Anaplasma phagocytophilum* bacteria, Babesiosis caused by *Babesia spp.* parasites, and Powassan Virus, which have all been identified as diseases of public health significance as of July 1, 2023. Other species of ticks that can spread Powassan virus include *Ixodes cookei* and *Ixodes marxi,*[352]which have seen a slight increase in submissions to the health unit in the PPH region for identification. In September 2023, Maryland, USA's Department of Health identified a travel-related case of Powassan Virus with the individual having been bitten by an infected tick in Canada.[355] Although more information on the specific location of the tick bite in Canada is not provided, the individual unfortunately passed away due to the illness.[355]

An emerging condition spread by *I. scapularis* and *Amblyomma americanum* species of ticks is known as Alpha-gal syndrome or red meat allergy.[352] This allergic reaction can range from mild to life threatening and may require diet modification to avoid consuming mammalian products.[352] Evidence has shown that the range for *A. americanum* is spreading north from the United States[352] and the vector species has been detected in the PPH region in the past few years through passive surveillance.

The burden of illness posed by these vector-borne diseases ranges from asymptomatic infections and fever, to flu like symptoms. In some cases, infections can lead to serious complications such as cardiac and neurological symptoms; in the case of Lyme Disease, arthritis; and in the case of Powassan virus neurological issues in 50%

of infections and encephalitis and death in 10% of serious infections.[352] Complications and death are a possibility in all four tickborne diseases for immunocompromised or older populations.[352] Research has shown a link between negative mental health impacts relating tick-borne diseases, specifically symptoms of Lyme Disease that may last for months or years including fatigue, muscle aches, and difficulty with memory which can impact quality of life potentially leading to mental health issues such as anxiety or depression.[356]

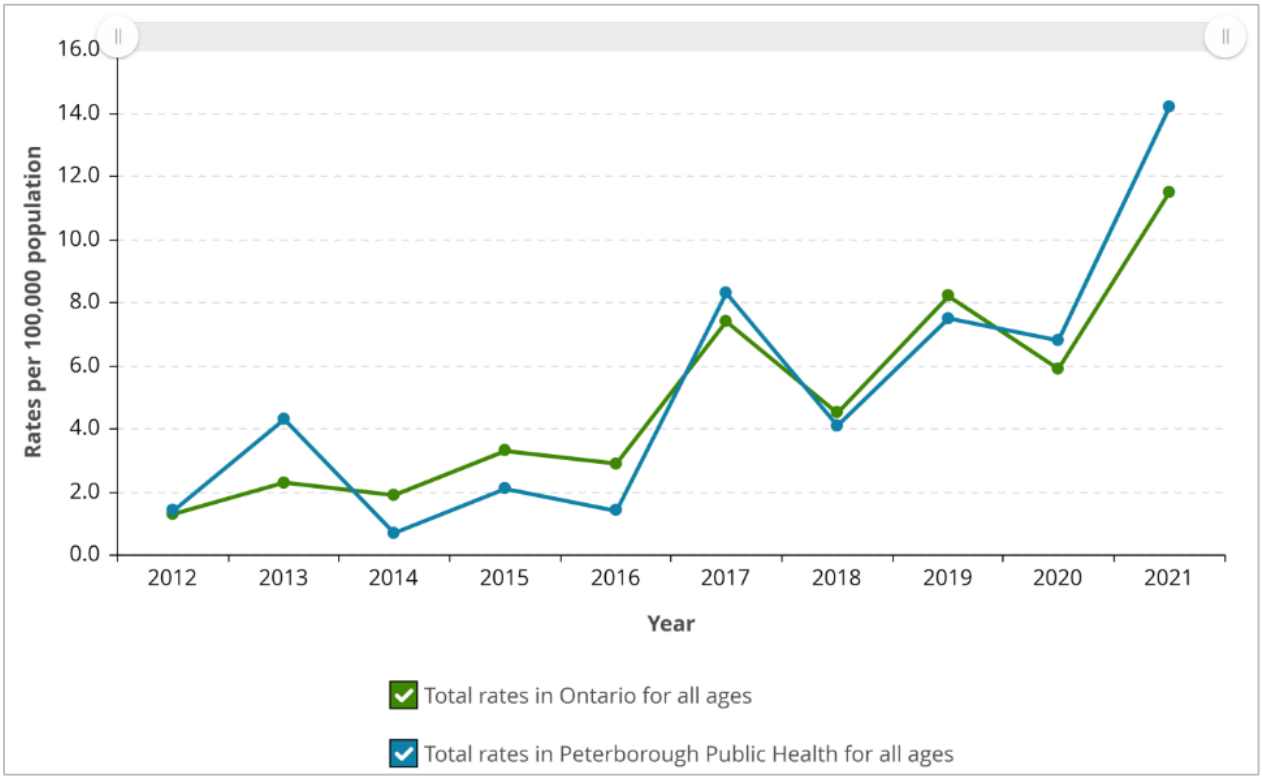
Populations at Increased Risk

Populations at greatest risk of tick-borne diseases are those that spend time outdoors, specifically individuals aged between 5-14 and 55-79 years; and those with greatest risk of complications are immunocompromised and older adults.[352] Human exposure to ticks correlates with the amount of time spent outdoors, particularly in high-risk areas such as tall grass, brush and leaf litter.[352] Activities that can increase chances of exposure to ticks include, but are not limited to hiking, fishing, hunting, camping, gardening, walking pets, outdoor labour, and golf.[352] Treatment options are limited for individuals who are pregnant and/or breast/chest feeding, increasing the risk of potential complications in this group.[352]

Surveillance and Disease Trends

The incidence rate for Lyme Disease has seen an increase in both the PPH Region and in Ontario between 2012-2021.[317] Increases in Lyme Disease incidence can be attributed to more time spent outdoors where there is a risk of exposure to ticks. More time spent outdoors can be correlated to warmer temperatures which may in turn increase the proportion of the year ticks are active. Infected tick species moving northwards into regions of Ontario not previously known as estimated risk areas for ticks is also considered a factor of exposure to ticks.

Figure 8-1. *Lyme Disease Rates in Ontario and the PPH Region from 2012-2021.*



Source: Public Health Ontario (Infectious Disease Trends in Ontario), Integrated Public Health Information System. Extracted: September 2023.

Impacts of Climate Change on Tick Habitat and Host Reservoirs

Ticks move only a few metres on their own during each life stage; relying on the movement of hosts including the white-tailed deer, small mammals, such as the white-footed mouse, and ground-dwelling birds for local range expansion.[357] The availability and abundance of host populations is considered the primary indirect influence on tick populations.[351] For ticks to establish, a suitable density of host species is required from which to take bloodmeals.[358] When reservoir hosts expand their habitats further north due to warming temperatures, they take with them vectors for diseases such as *I. scapularis* which can pose a threat to people residing, working, or recreating in those areas.[359]

The white-footed mouse, a widespread rodent native to North America is a common host for *I. scapularis* in the woodlands of southern Ontario and is also a highly efficient reservoir host for the bacterium *B. burgdorferi*, maintaining lifelong infection and infecting 75% to 90% of the tick larvae it feeds.[360] An important host for *I. scapularis* ticks are white-tailed deer[358] which have seen an increase in abundance with populations having exceeded historical records in recent years.[360] As the primary host for blacklegged ticks, white-tailed deer are essential for the establishment and maintenance of endemic *I. scapularis* populations; however as incompetent reservoirs, deer are unlikely to influence the rates of *B. burgdorferi* infection.[348]

Another common host species, migratory birds are thought to further add to the burden of ticks dispersed throughout Canada, including further north. It is estimated that migratory birds disperse between 50 and 175 million *I. scapularis* ticks across Canada each spring.[361] Migratory birds are also being observed further north due to warming temperatures with passerines, such as nuthatches and robins carrying ticks northward into Canada during spring migration.[361]

Ticks are typically killed in low winter temperatures however woodland habitats provide refuge for ticks to survive.[333] In addition, these woodland habitats also protect ticks from prolonged extreme temperatures, low humidity and intense rainfall which would otherwise adversely affect their survival.[333] The area between the soil and leaf litter (also called the duff layer) protects ticks from air temperatures reaching as low as -30°C, temperatures therefore have limited impact on where *I. scapularis* populations can establish.[362] Conversely, high relative humidity can increase tick survival rates at higher temperatures, increasing host-seeking activity.[363] There is a greater chance of tick survival in areas of good canopy cover and leaf litter which provides moisture at floor level and increased shade.[348]

Activities like urbanization and deforestation break up large forested areas into smaller patches of forest, creating more edge habitats where deer, a common host for ticks, thrive.[363] In addition, these conditions reduce species diversity, which can increase the population of white-footed mice, another important host for ticks.[363] Overall, this can lead to increased movement and density of ticks in these environments. Residential developments often border edge habitats, and there are commonly trails and other opportunities for people to interact with nature.[363] Given the natural increase in the tick population, this is a higher-risk environment for tick exposure.

Tick Surveillance Activities

Tick surveillance is used to determine areas in Ontario where tick species are expanding by investigating the level of establishment of *I. scapularis* populations and assessing the possible risk of exposure to infection.[364] Tick surveillance may be passive or active.

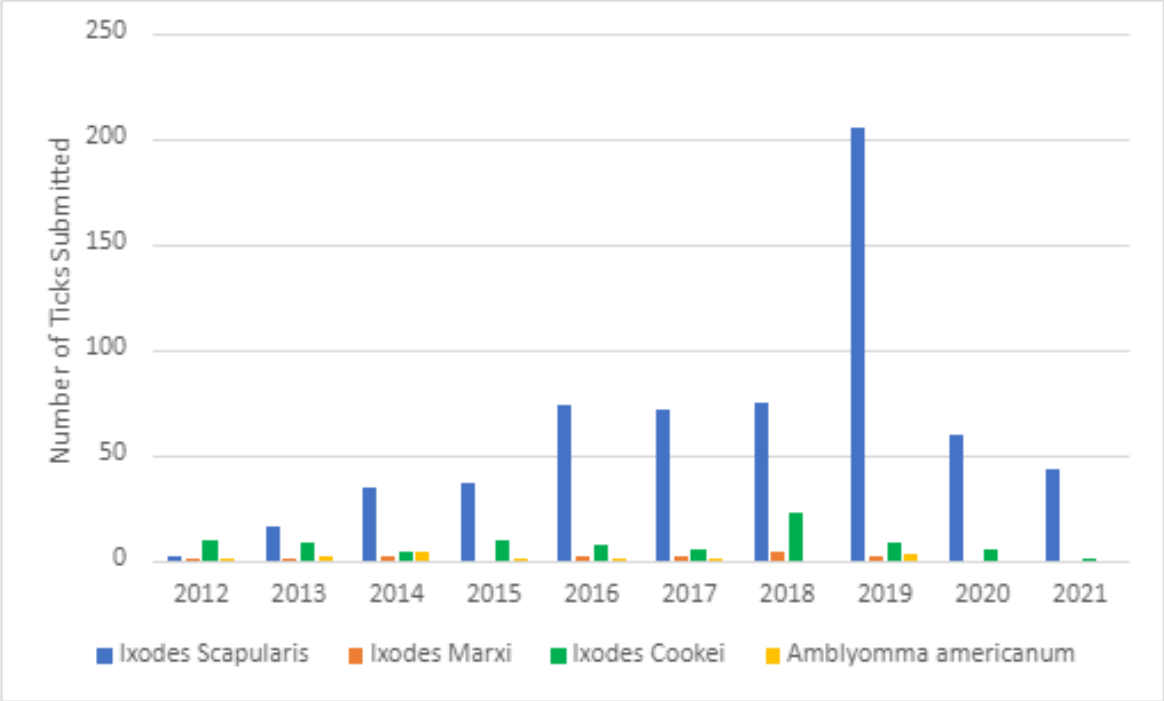
Passive tick surveillance involves examining ticks collected by the public and is used to identify areas where active tick surveillance should be performed to determine suitable tick habitats and where *I. scapularis* ticks may be expanding or establishing. Active tick surveillance involves collecting ticks from their natural habitat through tick dragging to identify established blacklegged tick populations and determine Lyme Disease risk

areas.[364] Ticks that are identified as *I. scapularis* are sent for further testing for *B. burgdorferi* and *A. phagocytophilum*.[364]

Passive surveillance was discontinued by most public health units in Ontario, including PPH in 2021. While PPH no longer accepts ticks for species identification, members of the public are encouraged to submit pictures of ticks using the eTick website for identification by a professional.[365] The identification results, combined with other data such as collection date and location are then mapped to visualize information related to species, date and/or geographic area.[365] This wide range of tick submission data provides information on the diversity of ticks on a large scale and complements provincial active surveillance programs.[365] Data from eTick has found that the most identified species of tick in Ontario is *I. scapularis* and there is an eastward increase in the proportion of *I. cookei* submissions.[366]

Figure 8-2 shows the number of a selection of 4 tick species submitted through passive surveillance to PPH from 2012-2021. The number of *I. scapularis* and *I. cookei* ticks submitted to PPH has shown an increase over time before decreasing in 2020. The passive surveillance program was discontinued by PPH in 2021 with the public encouraged to submit pictures of ticks through eTick.ca. PPH was conducting essential business only from early 2020 onwards, another factor which may contribute to the decrease in the number of ticks submitted for identification.

***Figure 8-2**. Tick Species Submitted Through Passive Surveillance to PPH from 2012-2021.*

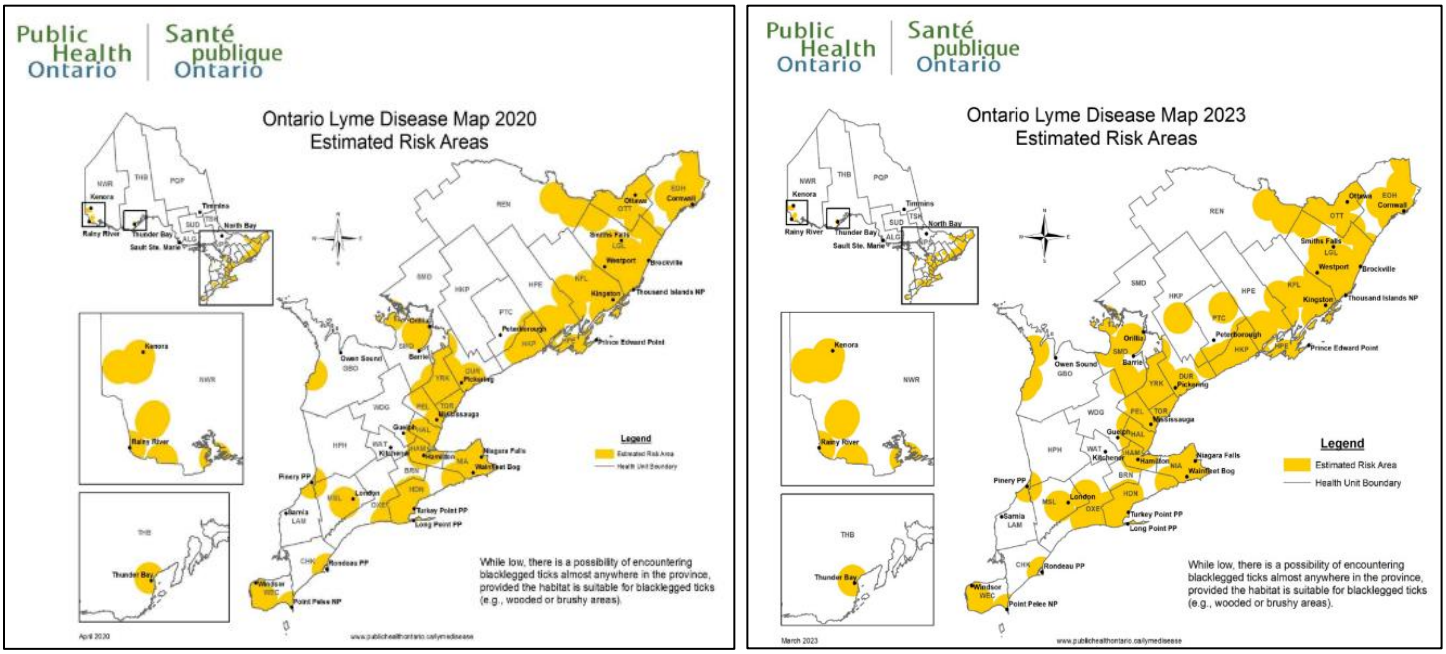


Source: Peterborough Public Health Records, 2023

In Ontario, emphasis is placed on active tick surveillance efforts to inform annual risk mapping. Estimated risk areas are determined when at least one blacklegged tick is found during tick dragging in both the spring and fall; an estimated risk area is a 20-kilometre radius from the centre of a location where the blacklegged ticks were found.[364] Established tick populations are defined as a tick species with locally reproducing populations where all tick life stages are found at the appropriate time of year for two consecutive calendar years.[367]

Estimated risk area maps provide information on the expansion and establishment of *I. scapularis* ticks. The maps also provide information related to case exposure locations representing new or emerging risk areas helping to inform public health messages raising awareness of disease risk areas in Ontario and the PPH

Figure 8-3. *Estimated Lyme Disease Risk Areas in 2020 and 2023.*



region.[364] Regardless of estimated risk areas, there is a possibility of acquiring a tick almost anywhere in Ontario since they are commonly transported by migratory birds. [368]

Sources: Ontario Agency for Health Protection and Promotion (Public Health Ontario). Ontario Lyme Disease Map 2023: Estimated Risk Areas.; 2023. Accessed October 5, 2023. www.publichealthontario.ca/-/media/Documents/L/2023/ontario-lyme-disease-risk-area-map-2023.pdf, Ontario Agency for Health Protection and Promotion (Public Health Ontario). Ontario Lyme Disease Map 2020: Estimated Risk Areas.; 2020. Accessed October 6, 2023. www.publichealthontario.ca/-/media/documents/l/2020/lyme-disease-risk-area-map-2020.pdf.[368,369]

The graphics compare the Ontario Estimated Lyme Disease Risk Areas in 2020 and 2023.[368,369] An increase in the estimated Lyme Disease risk area from 2020 to 2023 is shown in the PPH Region (denoted as PTC on the images) and its neighbouring public health unit Haliburton, Kawartha Lakes, Pine Ridge (HKPR). The estimated risk areas are determined through active surveillance activities conducted by public health units, which may not be consistent year-to-year. Further, active surveillance may not necessarily yield blacklegged ticks due to conditions such as weather, dragging technique, or the density of blacklegged ticks in an area; however, black legged ticks may be present inferring that the estimated risk areas for Lyme Disease may be greater than shown on the maps. Areas with a risk of Lyme Disease also carry a higher risk of Anaplasmosis.[370]

Peterborough Public Health Adaptation Efforts

The following are examples of Peterborough Public Health's current work that is contributing to climate change adaptation and supporting those most vulnerable to health impacts of climate change related to vector-borne disease:

Population Assessment & Surveillance

- Monitoring trends and reports of human cases of vector-borne diseases of public health significance including: Anaplasmosis, Babesiosis, Lyme Disease, Powassan Virus, and West Nile Virus.
- Monitoring changes to population health status over time, particularly related to confirmed human cases of vector-borne diseases.
- Providing active vector surveillance including: routine mosquito trapping, species identification and testing for West Nile Virus;
    - monitoring storm water management ponds for mosquito breeding; and
    - routine active tick surveillance through tick dragging.

Health Promotion

- Providing public education and outreach for vector-borne disease awareness at farmers' markets, children's camps, and local festivals.
- Providing presentations for public and worker health and safety, upon request.
- Conducting general social media campaigns about personal precautions for vector-borne disease protection; enhancing social media campaigns and issuing news releases in response to confirmed positive mosquito pools, or other concerning events related to vector-borne disease.

Health Protection

- Undertaking case investigation and support for diseases of public health significance related to vector-borne transmission, including reportable diseases such as: Anaplasmosis, Babesiosis, Lyme Disease, Powassan Virus, and West Nile Virus.
- Communicating with health care providers related to new and emerging trends to help ensure timely diagnosis and treatment.
- Providing targeted outreach, for example, door-to-door strategies implemented, in response to unique and significant threats of vector-borne disease.
- Providing public education and enforcement, when necessary, to eliminate sources of stagnant water and potential vector breeding sources.
- Collaborating with the City of Peterborough for a local vector-borne disease management strategy, including larvicide application to all catch basins as well as storm water management ponds, based on a risk assessment that incorporates geographical proximity to vulnerable populations and surveillance results.

Air Quality

Generally, when considering air pollutants, it is common to think of things like the emissions from coal-fueled industries and fossil-fueled vehicles. However, there are also natural sources of air pollution like wildfires and volcanoes. Due to the negative impacts on health, there have been efforts to reduce air pollution and enhance monitoring of pollution for decades. For many people, poor air quality can also be experienced due to airborne allergens, including pollens and mold. The focus of this section is primarily related to outdoor air quality; however, it is important to recognize that outdoor air quality can directly impact indoor air quality.

"*Health Canada estimates that above-background air pollution, including air pollution from human sources in North America, contributes to 15,300 premature deaths per year in Canada*."[372(p.4)]

Air quality is impacted by climate change in several ways and the complex relationships between climate and various air pollutants continue to be widely studied. Three factors most likely to have negative impacts on air quality in the PPH region are presented below.

Air Pollution

Air pollution can be made up of various substances that are harmful to health, including nitrogen oxides (NO_x), sulphur oxides (SO_x), and particulate matter (PM). Ground-level ozone (O_3) is another pollutant which is the main ingredient of "smog".[373] There are a few ways in which climate change could lead to increases in air pollution:

I. Ground-level ozone (O_3) is formed when two pollutants (nitrogen oxides and volatile organic compounds) combine in the presence of sunlight. There is a strong correlation between temperature and O_3.[374,375]
   "If air pollution emissions remain unchanged, a warming climate will likely increase ozone levels in heavily populated and industrialized areas, including Southern Ontario."[375(p.290)]
II. Heat waves are often associated with large, slow-moving high-pressure systems, which can concentrate air pollutants in one area.[375–377]
III. Furthermore, dry, dusty air during periods of hot weather or droughts also increases the amount of particulate matter pollution.[41,375,378]

Traffic-related air pollution (TRAP) is another type of pollution to consider. TRAP is a mixture of pollutants from vehicle exhaust and other particles such as road dust, evaporation of fuels, and tire and brake wear.[379] Concentrations of air pollutants are higher on and near major roads and highways.[380] As the population of the PPH region grows, we may see an increase in transportation and subsequent TRAP, at least until alternative fuel vehicles become more common. While climate change doesn't cause an increase in TRAP, transportation-related emissions do include ozone precursors, which may lead to creation of more ozone under a warming climate and may pose health risks particularly for residents who live close to major roads and highways.[380]

Wildfire Smoke

As described in Chapter 6: Extreme Weather Events, a warming climate may lead to an increase in wildfires across Canada. Wildfire smoke includes harmful pollutants like Fine Particulate Matter ($PM_{2.5}$) and while concentration of pollutants is highest closer to the fires, smoke plumes can spread over vast areas.[375] While spread of wildfire smoke to the PPH region has not been experienced regularly, the smoke experienced in the spring and summer of 2023 shows how distant fires can have a significant impact on local air quality.

"*Increasing wildfire emissions are one of the most significant climate-related risks to air quality in Canada*".[375(p.291)]

Particulate Matter

"Particulate matter" refers to very small solid exhaust particles that are emitted by fuel combustion. The particulates may consist of a wide variety of substances. Particulates that are of 2.5µm in diameter or less ($PM_{2.5}$) are of greatest concern to health.[226]

Particulate Matter

Allergens

Warmer temperatures will enable extended growing seasons in our province, with allergy seasons starting earlier and ending later.[375,378] It will also allow plant species to expand their geographic distribution. Increases in atmospheric carbon dioxide (CO_2) can also lead to increased production of pollen and may increase the allergenicity of the pollen as well.[375]

Legionella and Legionnaire's Disease

One additional air quality-related health impact that could be associated with climate change is Legionnaire's Disease and use of cooling towers. Legionella are bacteria which can establish and proliferate in potable water systems and cooling towers.[381] Cooling towers have been associated with outbreaks of Legionnaire's Disease, which is like a severe pneumonia, as they provide an ideal environment for Legionella bacteria to grow and they also release contaminated water droplets or mist into the air which can then be breathed in.[382] As the climate warms, use of air conditioners may increase, including cooling towers, which could increase opportunities for exposure.[381]

Hazard Trends

In Ontario, we have generally seen significant improvements to air quality since the 1960s[383], which can be attributed to things such as phasing out coal plants and tightening of pollution regulations and laws in Canada and across the border.[383,384] Air quality monitoring and alerts are conducted by the Ministry of the Environment, Conservation and Parks, in partnership with Environment and Climate Change Canada.

Air Quality Monitoring Capabilities

There are 39 outdoor air monitoring stations across Ontario that collect real-time air pollution data.[385] The PPH region has one station located in the City of Peterborough on Hospital Drive. The data is collected and posted on the Air Quality Ontario website every hour, 24 hours a day, seven days a week. More information about air monitoring can be found at airqualityontario.com.

The Peterborough ambient air monitoring station monitors Ozone (O_3), fine particulate matter ($PM_{2.5}$), and Nitrogen Dioxide (NO_3).

Peterborough Air Quality Monitoring Station. Credit: AirQualityOntario.com

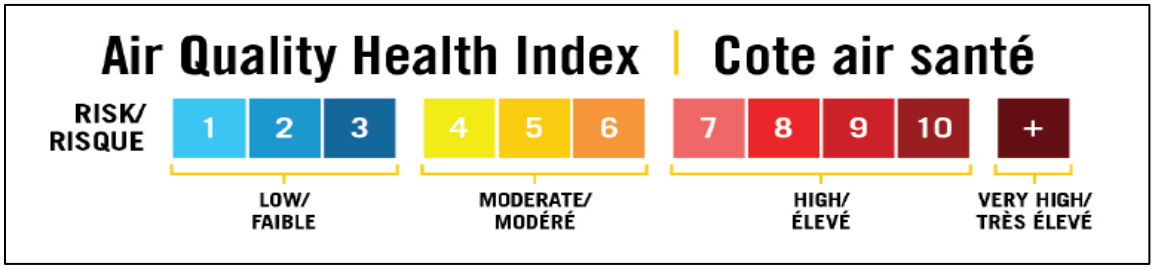
Air Quality Health Index (AQHI)

"The AQHI is calculated based on the relative risks of a combination of common air pollutants that are known to harm human health. These pollutants are:

- Ozone (O_3) at ground level,
- Particulate Matter ($PM_{2.5}$ / PM_{10}), and
- Nitrogen Dioxide (NO_2)" [386]

The index is a scale ranging from 1-10+ with values being grouped into health risk categories as shown below.[386] These categories are intended to help a person to easily and quickly identify their personal risk level.[386]

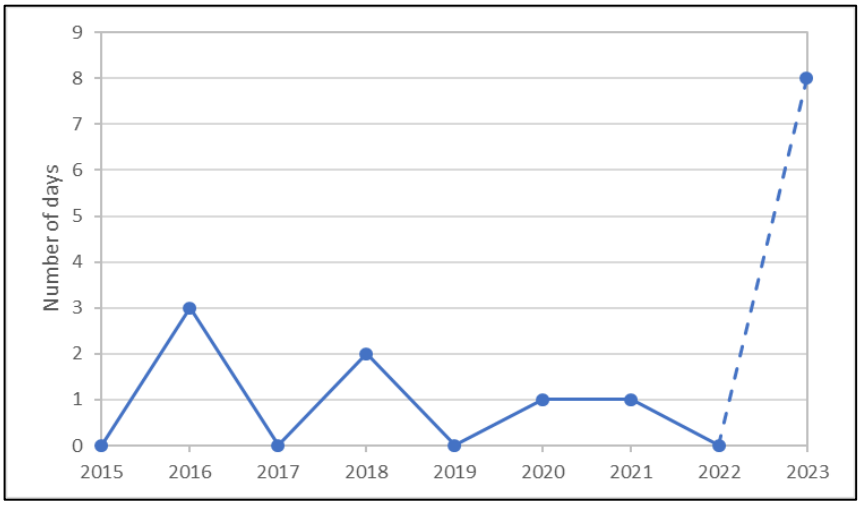
Figure 9-1. *Categories of the Air Quality Health Index.*



Source: Egyed M, Blagden P, Plummer D, et al. Air Quality (Chapter 5). In: Berry P, Schnitter R, eds. Health of Canadians in a Changing Climate: Advancing Our Knowledge for Action. Government of Canada; 2022:286-365, p333.[375]

Peterborough does not typically have many days or total hours where the AQHI is of High or Very High risk (AQHI>6).[387–392] However, in 2023, Peterborough recorded much more time where AQHI was High or Very High risk, both shown in the number of days and total number of hours where AQHI>6, shown in Figure 9-2 and 9-3, respectively. This was largely due to smoke travelling from wildfires in Ontario and Quebec starting in June.

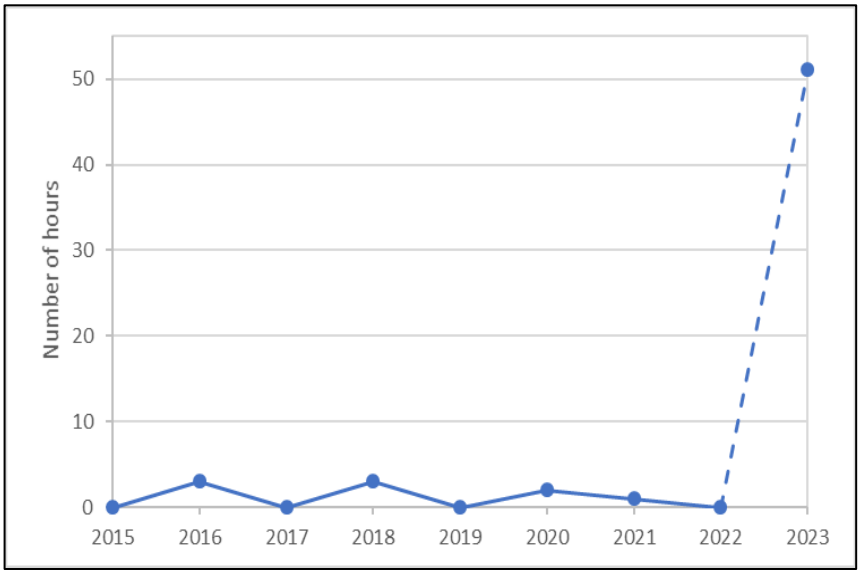
Figure 9-2*. Number of Days with at Least 1 Hour with a High or Very High Health Risk (AQHI>6), 2015-2023.*



Source: Data from 2015 to 2020 comes from Air Quality Ontario annual reports.[387–392]

[a]**Note:** Data from 2021, 2022, 2023 are automatically polled data, retrieved from the airqualityontario.ca webpage,[385] and have not undergone final verification. Data for 2023 is up to July 31, 2023.

Figure 9-3. *Number of Hours with AQHI>6 Each Year, 2015-2023.*[a]



Source: Data from 2015 to 2020 comes from Air Quality Ontario annual reports.[387–392]
[a]Note: Data from 2021, 2022, 2023 are automatically polled data, retrieved from the airqualityontario.ca webpage,[385] and have not undergone final verification. Data for 2023 is up to July 31, 2023.

Due to the connection between climate change and the pollutants ground level ozone and particulate matter, additional data relating to these pollutants is presented below.

Ground Level Ozone

The annual mean of ground level ozone levels for Peterborough is about 29 parts per billion (ppb), and did not significantly change between 2011 and 2020.[390] The mean ground level ozone level tends to be slightly higher in the summer months.

Ozone exceedances are noted when the one-hour concentration exceeds 80 ppb. Between 2015 and 2020, Peterborough had eight exceedances.[387–392] In 2020, Peterborough had two ozone exceedances.[390] Twelve of the other 38 monitoring stations also recorded ozone exceedances in 2020, while 26 stations recorded zero. Number of exceedances ranged from one to twelve exceedances, with the highest numbers recorded in Grand Bend and Toronto North.

Particulate Matter

The annual mean of $PM_{2.5}$ in Peterborough is about 6 µg/m^3, which is slightly lower than the mean from the early 2010s (approximately 7 µg/m^3).[390]

$PM_{2.5}$ exceedances are recorded when the 24-hour mean concentration exceeds 27 µg/m^3 ($PM_{2.5}$ AAQC). Between 2015 and 2020 Peterborough recorded zero days where there was an exceedance of the $PM_{2.5}$ AAQC.[387–392] In 2020, fourteen of the other monitoring stations did record PM2.5 exceedances, with a maximum of 3 recorded by Windsor West.[390] In 2023[a] (up to July 31st), there were 13 days in exceedance of the $PM_{2.5}$ AAQC in Peterborough.[393] There were also very high one-hour $PM_{2.5}$ concentrations in 2023. The one-hour maximum was 174 µg/m^3 in late June whereas the one-hour maximum in 2020 was 48 µg/m^3. These instances have largely coincided with smoke from wildfires and would have been main contributors to the high and very high risk AQHI in 2023.

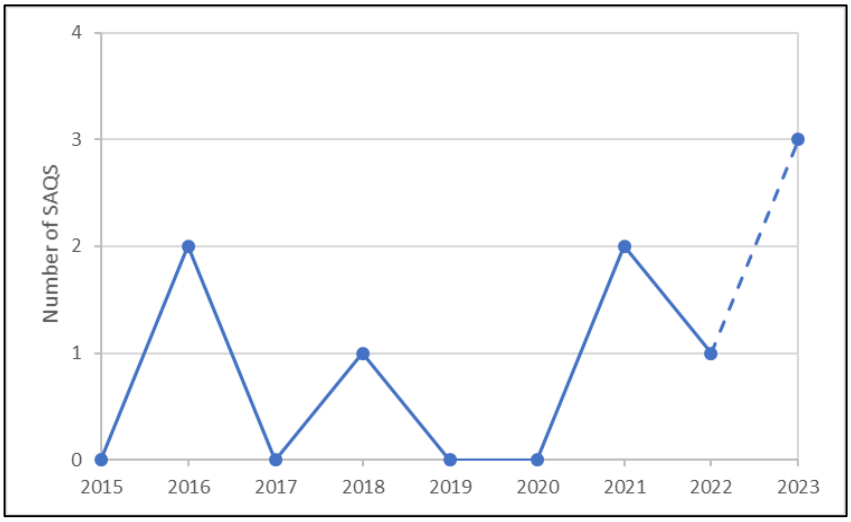
[a] Data referenced from 2023 is automatically polled data, pulled from the airqualityontario.ca webpage, and has not undergone final verification.

Air Quality Alerts - Special Air Quality Statements and Smog and Air Health Advisories

Special Air Quality Statements and Smog and Air Health Advisories are issued by the Ministry of the Environment, Conservation and Parks to inform the public when air quality is projected to be of concern.

A Special Air Quality Statement (SAQS) is issued when high risk air quality is forecasted for one to two hours.[390] A SAQS is also issued for areas where forest fire smoke is expected to cause deteriorating air quality.[390]

Figure 9-4. *Number of Special Air Quality Statements Each Year in the Peterborough - Kawartha Lakes Region, 2015-2023.*



Source: Air Quality Ontario, 2023.[394] Data for 2023 is up to July 31, 2023.

For the Peterborough - Kawartha Lakes region, there have been nine Special Air Quality Statements since 2015, with three of these occurring in 2023 (up to July 31, 2023). Two of the three statements in 2023 coincided with smoke from wildfires.[394]

A Smog and Air Health Advisory (SAHA) is the second level of air quality alert. A SAHA informs the public of the potential for degrading air quality and is issued when high risk air quality is forecasted for three or more hours.

The Peterborough region has had no Smog and Air Health Advisories issued since 2015.[394]

Health Impacts

Air pollutants have been and continue to be studied extensively for their health effects. Experiencing short-term symptoms from air pollution is typically dependent on a person's sensitivity, however, at elevated concentrations, impacts can be widespread and more people may experience symptoms. Common short-term symptoms[395] include:

- Eye, nose, and throat irritation
- Wheezing or difficulty breathing
- Irritation and inflammation of the respiratory tract (coughing)
- Shortness of breath, especially during physical activity
- Exacerbation of existing asthma, heart and lung conditions, and diabetes[396]

Aeroallergens, such as pollens and spores, can cause similar symptoms for people with Allergic Rhinitis (AR), including triggering asthma exacerbations.[397] AR allergies can have a significant impact on quality of life, especially if not properly managed.[398]

In addition to short-term symptoms, pollutants can increase the risk of longer-term health effects, which has been extensively studied, often focusing on specific pollutants, populations of interest, timing of exposure, and types of health outcomes. Poor air quality increases the risk of respiratory diseases (e.g., asthma and chronic obstructive pulmonary disease (COPD)), cardiovascular disease (e.g., heart attacks and strokes), and lung cancer. However, increased risk for other diseases such as diabetes, osteoporosis[399], and other types of cancer[400] have also been documented, as well as mental health impacts. All of these effects can lead to premature deaths. Exposure to poor air quality during pregnancy can also have long-term impacts by negatively impacting neurodevelopment in early life.[401]

Though knowledge gaps still exist, there is evidence associating poor air quality with mental health outcomes such as:

- Increases in psychiatric hospital visits by some populations, even from short-term exposure[402]
- Increase in depressive and anxiety symptoms and behaviours[403,404]
- Increased risk for dementia[405]

"Exposure to air pollutants can cause a range of adverse health effects, and even small increases in exposure are associated with an increase in risk".[375(p.304)]

Populations at Increased Risk

Children and Youth

Children and youth are at increased risk while their lungs and brains are developing. Their rate of breathing is also higher, which can lead to increased exposure.[406] Young children (i.e., infants and toddlers) are especially at risk.[375,407]

Pregnant People

Increased blood and plasma volumes and respiration rates can make pregnant people more vulnerable to pollutant exposure.[408] Exposure to air pollution during pregnancy has been associated with pregnancy outcomes such as low birth weight and preterm birth.[406] Prenatal exposure may lead to increased risk for asthma and AR in the child.[409]

Older Adults

Older adults are also at increased risk due to increased prevalence of chronic health conditions and weaker lungs, hearts and immune response.[410] This increases their sensitivity to poor air quality.

Socioeconomic Status and Homelessness

People who are of low SES can be at increased risk of the health impacts of air pollution due to various vulnerability factors. They may experience increased exposure due to factors such as:

- Relying on active transportation (e.g., walking, biking, walking to bus stops)[411]
- Employment less likely to have an option to work from home to limit exposure[412]
- Housing in low-income areas exposed to higher levels of air pollution[4,375,413,414]

People with low SES may have increased sensitivity to poor air quality as they are more likely to have health conditions, as described in Chapter 4: Vulnerability. People with low SES may have lower adaptive capacity to cope with poor air quality. For example, when there is poor outdoor air quality, advice is generally to keep windows closed. However, if poor air quality coincides with extreme heat, keeping windows closed may not be tolerable or safe for those that don't have or can't afford air conditioning.[415] These individuals may have increased exposure to poor air quality as a result of reducing their exposure to extreme heat. Finally, people with low SES may experience barriers to managing chronic health conditions. For example, prescription medication, home care, physiotherapy and other services are not consistently publicly insured and can lead to a financial burden.[416,417] These may put these individuals at increased risk of worse health outcomes from poor air quality.

People experiencing homelessness face increased risks to health impacts from poor air quality due to increased exposure, as well as sensitivity and adaptive capacity factors similar to those described for low SES and described generally in Chapter 4: Vulnerability.

People with Chronic Health Conditions

Pre-existing lung and heart conditions can increase a person's risk for experiencing the health effects associated with poor air quality.[375]

Population with Asthma

The PPH region has the highest age-standardized prevalence rate of asthma of all Ontario health units. The rate is significantly higher than the prevalence rate of Ontario as a whole as shown in Table 9-1. Over 28,000 PPH region residents have asthma. Prevalence is highest in those aged 20-44 years, where 1 in 4 people have asthma. Prevalence was higher for females than males; 20,370 and 17,980, per 100,000, respectively.

Table 9-1. *Prevalence of Asthma for Residents of PPH Region and Ontario, 2019.*

	PPH	Ontario
Age-standardized rate (per 100,000 population)	19,230*	15,000

*denotes significant difference

Source: Public Health Ontario, Institute for Clinical Evaluative Sciences (ICES) chronic disease cohorts 2019.[62] Prevalence rates have been rounded to the nearest 10.

Population with COPD

PPH region residents, aged 20+, have a significantly higher prevalence rate of COPD than the Ontario rate. Over 15,000 PPH region residents have COPD, with 61% of cases being those aged 65+. Prevalence was higher for males than females; 10,560 and 9,900 per 100,000 population aged 20+, respectively.

Table 9-2. *Prevalence of COPD of Adults Aged 20+ in PPH Region and Ontario, 2019.*

	PPH	Ontario
Age-standardized rate (per 100,000 population aged 20+)	10,200*	7,590

*denotes significant difference

Source: Public Health Ontario, Institute for Clinical Evaluative Sciences (ICES) chronic disease cohorts 2019.[62] Prevalence rates have been rounded to the nearest 10.

Population with Heart Disease

The age-standardized prevalence rate of ischemic heart disease for Ontarians aged 20 and older in 2019/2020 was 7.55%.[129] This rate would correspond with 9,260 people in PPH region in 2023, which is about 6.1% of the whole population. However, knowing that this rate increases with age and that PPH region has a higher proportion of older adults, the number of people and rate is likely higher.

Population with Environmental Allergies

Allergic rhinitis (AR) is highly prevalent, affecting approximately 20–25% of the Canadian population.[375,397] While there are no local statistics, it is documented that approximately two-thirds of people with asthma are allergic to aeroallergens.[397] As the prevalence of asthma in PPH is higher than average, it may be possible that the region also has a higher-than-average prevalence of environmental allergies.

A Community Estimate for Vulnerability

In response to the 2023 wildfires, a project was conducted in Ontario to estimate the size of the population at increased risk for health-related problems due to poor air quality across Ontario health units. The outcome of the project was to identify the total number of unique individuals who met one or more of the following conditions:

- age 65+,
- age 0-11,
- recent experience with homelessness,
- cancer,
- heart disease,
- respiratory disease,
- diabetes,
- currently pregnant in July 2023

For PPH, it was estimated that there are **87,223 individuals** at increased risk for health-related problems due to poor air quality. Based on a 2023 projected population of 151,394, this accounts for 57.6% of the population.[418]

A Note on Indoor Air Quality

Climate change factors can contribute to reduced indoor air quality:

- Infiltration of outdoor pollutants and allergens
- Extreme weather and flooding, as well as increased humidity can lead to issues like mold in buildings.[54,375]

It is important that settings and institutions that serve or house populations at increased risk of health impacts, consider and take actions to prevent these hazards and maintain systems that can help improve indoor air quality including heating, ventilation and air conditioning and filtration systems.

Populations Exposed to Traffic-Related Air Pollution (TRAP)

Concentrations of TRAP decrease at increased distance from traffic. Public Health Ontario (PHO) conducted a comprehensive review of population exposure to TRAP across Ontario in 2015-2016,[197] based on three TRAP zones:

- 50 m of a major road or highway[a]
- 100 m of a major road or 150 m of a highway
- 100 m of a major road or 500 m of a highway

It was found that about 23% of the 2011 PPH region population (over 30,000 people) resided in a TRAP zone, with 10% (14,000 people) residing within 50m of a major road or highway.[443]

[a] Public Health Ontario definition of major roads and highways can be found in Appendix E.

Indigenous Peoples

Indigenous peoples may be of increased risk to health impacts of poor air quality. Increased vulnerability may occur due to increased exposure as inadequate ventilation is more common.[419] Indigenous peoples may also have higher sensitivity due to the higher burden of chronic respiratory disease, including asthma and COPD in First Nations People and Métis People.[375] Another example is higher rates of lower respiratory tract infections reported in First Nations children. Housing factors that may contribute to this include use of wood burning stoves, and overcrowded housing, which may be more common in First Nation communities.[375] As noted in earlier chapters, this increased risk is largely the result of the health and social inequities experienced by Indigenous peoples, that are underpinned by systemic racism and colonialism. Also, the above findings are broad and it may not be appropriate to generalize findings to the Indigenous peoples with whom we share space in the PPH region.

> "People most at risk [to poor air quality] are those with pre-existing conditions (heart and lung diseases), seniors, young children, people with allergies […] and socially and economically disadvantaged populations."[176(p.4,40)] Social and economic disadvantages may limit a person's ability to reduce their exposure (e.g., due to occupational and socioeconomic/housing circumstances).[375]

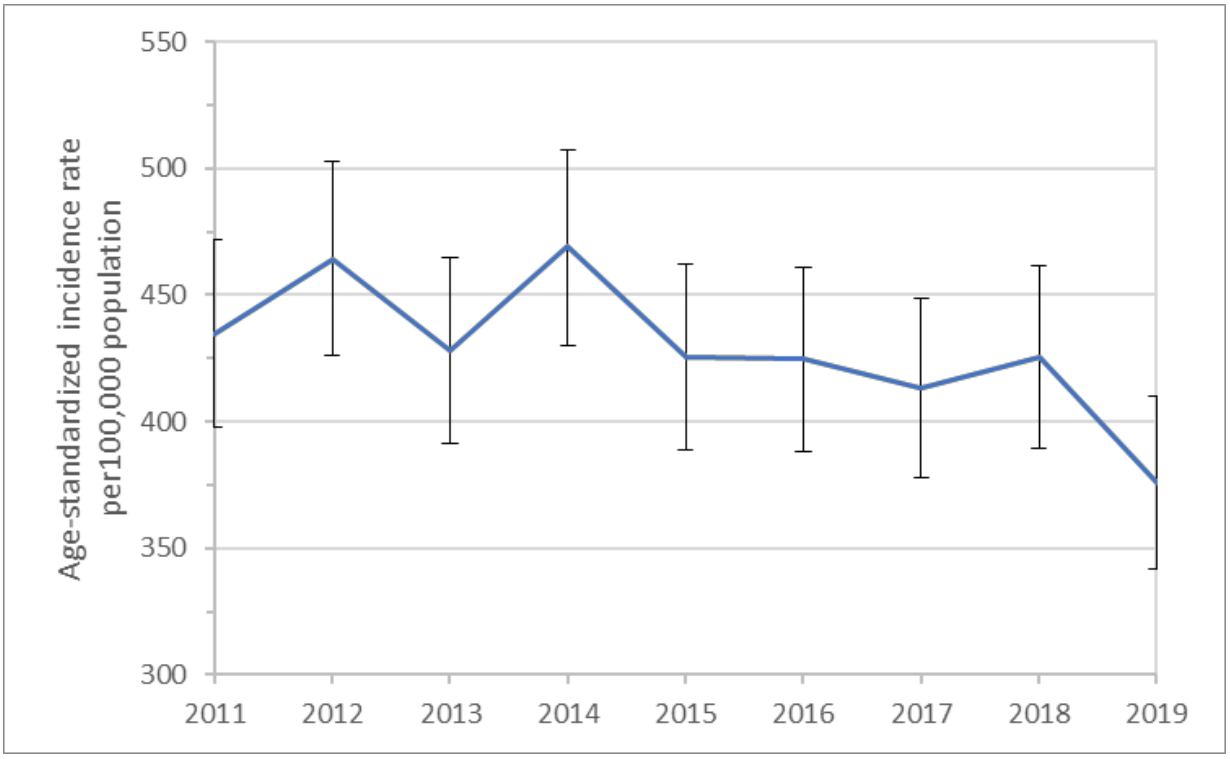
Health Outcomes

Health outcomes from poor air quality can range from increased incidence of diseases to increased morbidity and mortality. As air quality has been quite good in our region for the past few decades, the statistics presented below should be considered as baseline data, which can be compared to corresponding rates in the future. If poorer air quality is experienced in the future, the PPH region may experience increased rates of relevant diseases, and increased hospitalizations and mortality related to these illnesses.

Incidence of Asthma

Between 2011 and 2019, the incidence of asthma ranged from 502 to 587 cases per year in PPH region. The age-standardized incidence rate has not been significantly different from the Ontario rate from 2012 to 2019. As shown in Figure 9-5, the age-standardized incidence rate ranged from 413-469 persons per 100,000 population between 2011 and 2018, and then dropped in 2019 to 375 per 100,000.

Figure 9-5. *Age-Standardized Incidence Rate (per 100,000 Population) of Asthma in PPH Region from 2011 to 2019.*

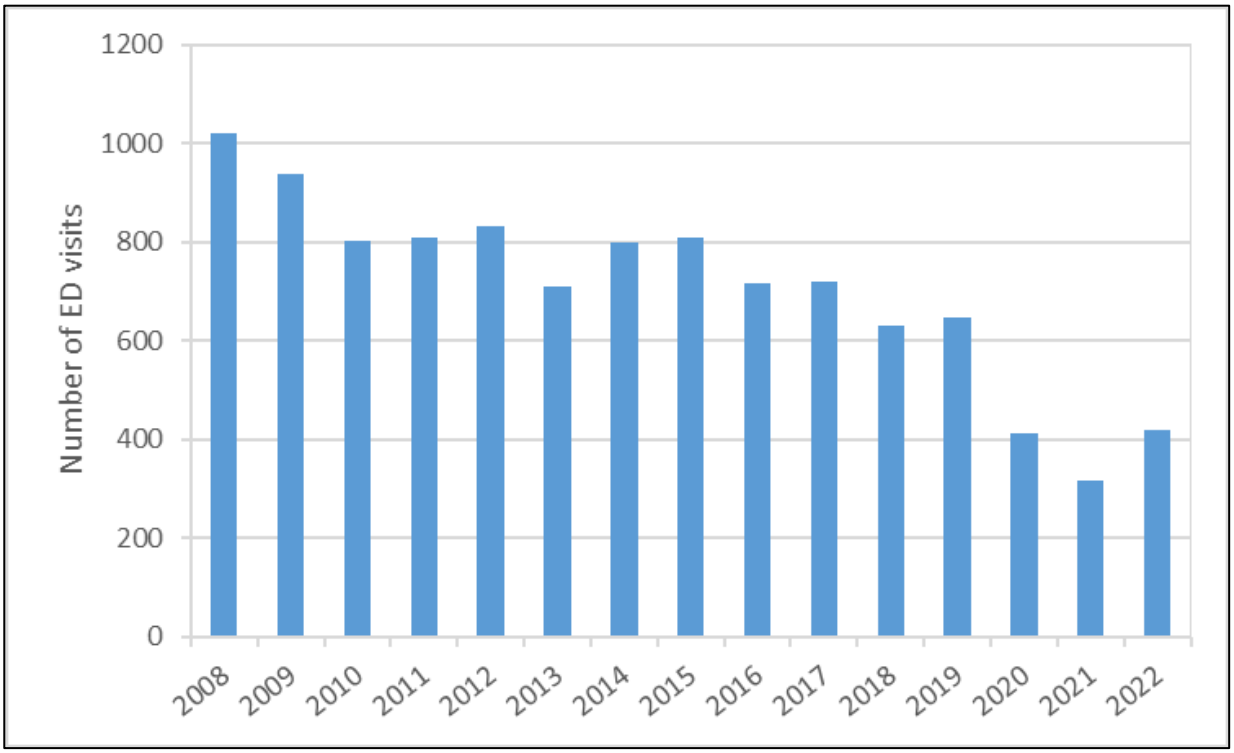


Source: Public Health Ontario, Institute for Clinical Evaluative Sciences (ICES) chronic disease cohorts 2019.[62] Bars show the 95% confidence interval.

Emergency Department (ED) Visits Related to Asthma

Emergency department visits for asthma by PPH residents have shown a declining trend from 2008 to 2022, ranging in incidence of 315 to 1,021 visits each year during this time period. Yearly totals are shown in Figure 9-6 below. The COVID-19 pandemic and shut-downs of many recreational spaces and programs likely contributed to the substantial declines in 2020 and 2021, though these reductions could also reflect additional factors (e.g., enhanced access to asthma medications, improved air quality, etc.).

Figure 9-6. *Number of Emergency Department Visits by PPH Residents for Asthma Between 2008 and 2022.*



Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: August 2023.

Table 9-3 presents the 5-year (average) incidence rates (per 100,000 population) for asthma from 2008 to 2022, which may be useful for comparison purposes in the future.

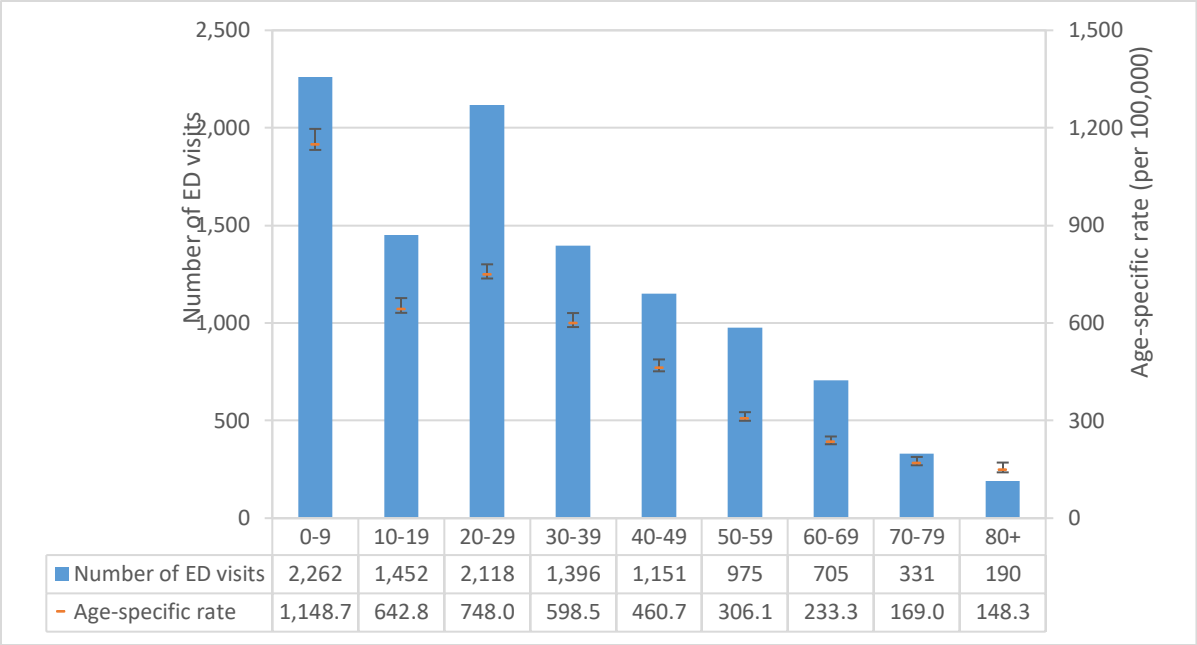
Table 9-3. *5-Year Average Crude Incidence Rate (Cases per 100,000 Population per Year) of Emergency Department Visits for Asthma by PPH Residents from 2008 to 2022.*

	2008-2012	2013-2017	2018-2022
ED visits; Crude rate per 100,000 population per year	637 (95%CI:631-657)	534 (95%CI:528-551)	327 (95%CI:323-341)

Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: August 2023.

The number of visits and rates per age group from 2008 to 2022 are shown in Figure 9-7. Those under the age of 10 have the highest rate, averaging 151 ED visits per year, demonstrating the vulnerability of this age group. ED visits by people under the age of 40 years account for 70% of the total number, while only making up 40% of the population.

Figure 9-7. *Number of Emergency Department visits and Age-Specific Rate (per 100,000 Population) for Asthma by PPH Residents for the Time Period 2008 to 2022, Shown with 10-year Age Groups.*



	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80+
Number of ED visits	2,262	1,452	2,118	1,396	1,151	975	705	331	190
Age-specific rate	1,148.7	642.8	748.0	598.5	460.7	306.1	233.3	169.0	148.3

Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: September 2023.

Emergency Department (ED) Visits Related to Seasonal Allergies

Emergency department visits for seasonal allergies are not common incidents among residents in the PPH region. Between 2008 and 2022, the number of visits ranged from 3 to 10 per year with a total of 105 over the 15-year time period. The 5-year totals and rates are shown in Table 9-4 below. Those under the age of 45 years have the highest rates and contribute to 63% of the seasonal allergy-related ED visits.

Table 9-4. *5-Year Totals and Average Crude Incidence Rate (Cases per 100,000 Population per Year) of Emergency Department Visits for Seasonal Allergies by PPH Residents from 2008 to 2022.*

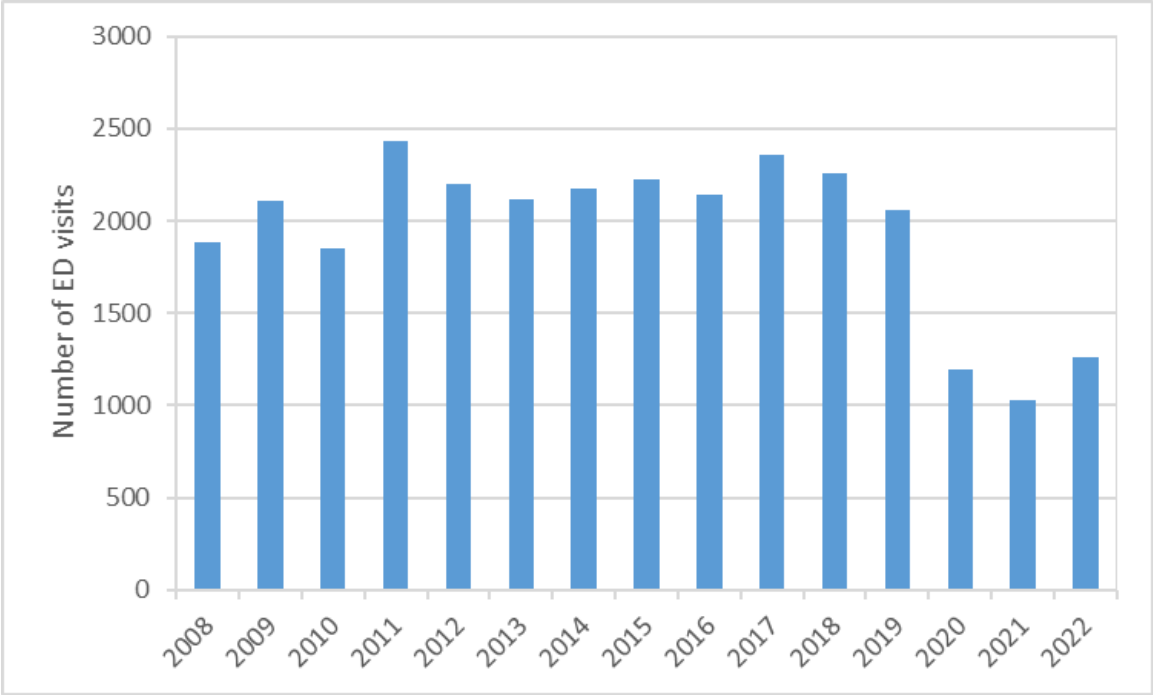
	2008-2012	2013-2017	2018-2022
Number of ED visits	39	25	41
ED visits; Crude rate per 100,000 population per year	5.65 (95%CI:5.01-7.72)	3.55 (95%CI:3.05-5.24)	5.55 (95%CI:4.94-7.53)

Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: August 2023.

Emergency Department (ED) Visits Related to Chronic Obstructive Pulmonary Disease (COPD)

Between 2008 and 2022, the number of COPD-related ED visits per year ranged from 1,027 to 2,434, where the yearly totals are shown in Figure 9-8 below. Again, we see a dramatic drop in visits starting in 2020, but no clear trend otherwise.

Figure 9-8. *Number of Emergency Department Visits by PPH Residents for COPD Between 2008 and 2022.*



Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: August 2023.

Table 9-5 presents the 5-year (average) incidence rates (per 100,000 population) for COPD ED visits from 2008 to 2022, which may be useful for comparison purposes in the future.

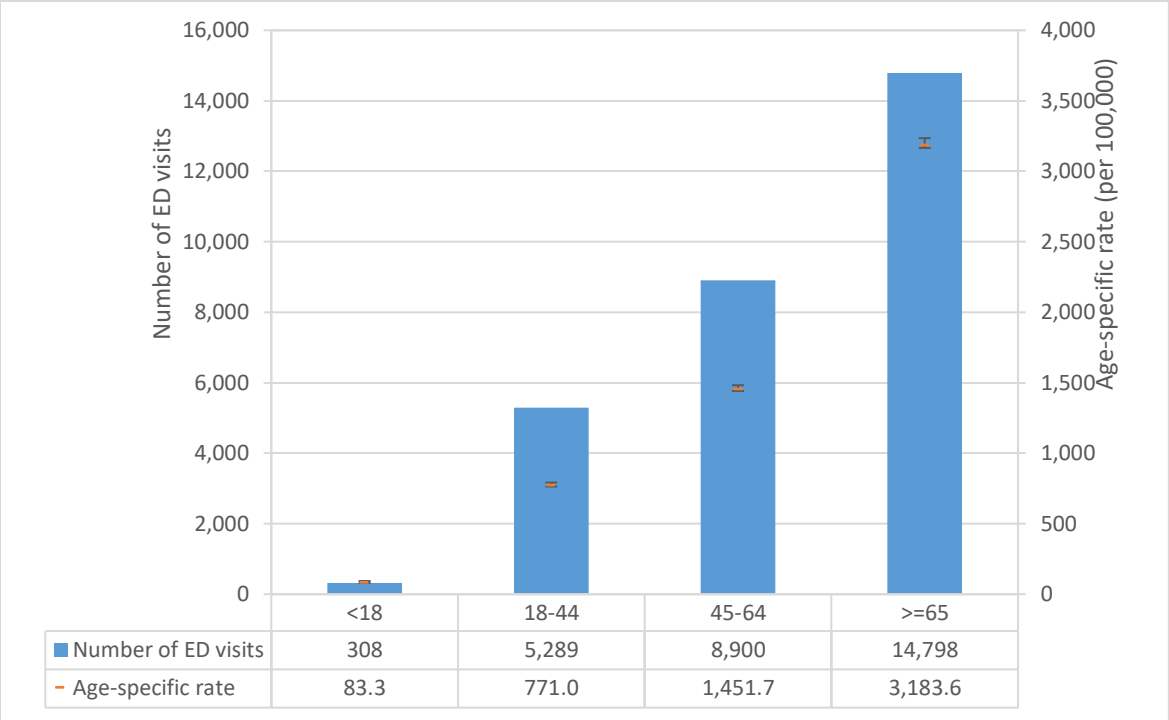
Table 9-5. *5-Year Average Crude Incidence Rate (Cases per 100,000 Population per Year) of Emergency Department Visits for COPD by PPH Residents from 2008 to 2022.*

	2008-2012	2013-2017	2018-2022
ED visits; Crude rate per 100,000 population per year	1,517 (95%CI:1,507-1,546)	1,566 (95%CI:1,556-1,595)	1,054 (95%CI:1,046-1,078)

Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: August 2023.

The rates per age group are shown in Figure 9-9. Those aged 65+ have the highest rate and make up 50% of all COPD-related ED visits.

Figure 9-9. *Number of Emergency Department Visits and Age-Specific Rate (per 100,000 Population) for COPD by PPH Residents for the Time Period 2008 to 2022.*



	<18	18-44	45-64	>=65
Number of ED visits	308	5,289	8,900	14,798
Age-specific rate	83.3	771.0	1,451.7	3,183.6

Source: National Ambulatory Care Reporting System (NACRS), Canadian Institute for Health Information (CIHI). Distributed by the Ontario Ministry of Health and Long-Term Care: IntelliHEALTH ONTARIO. Extracted: August 2023.

Lung Cancer

While smoking is the biggest risk factor for lung cancer, air pollution can also increase lung cancer risk.[420] The age-standardized rate of lung cancer diagnosis for PPH residents was 89.0 cases per 100,000 people during the 2014-2018 time period, compared to the Ontario average rate of 66.2 per 100,000.[a] During this time period, an average of 179 PPH residents were diagnosed each year.

[a] **Source:** Ontario Cancer Profiles - Ontario Cancer Registry SEER*Stat Package, 2021.

Mortality

Air pollution is a leading environmental cause of death in Canada.[375] Exposure to NO_2, O_3 and $PM_{2.5}$ air pollutants can be attributed to mortality and premature deaths. Studies have identified how exposure to certain pollutants contributes to all nonaccidental causes of death, and death from respiratory causes.

"It is estimated that current levels of three major air pollutants — fine particulate matter ($PM_{2.5}$), ozone, and nitrogen dioxide (NO_2) — together cause about 15,300 premature deaths in Canada annually."[375(p.295)]

For the PPH region, the rate of premature mortality associated with air pollution was determined to be 46-59 per 100,000 population in 2016. This rate applied to the 2021 population would equate to 57-87 people. At least 78% of Canadian census divisions have a rate that is lower than PPH.[372]

Specifically relating to wildfire smoke, it is estimated the wildfire smoke contributed to 620-2,700 deaths per year in Canada from 2013 to 2018.[372] It will be interesting to learn about the impacts of the 2023 wildfire smoke on morbidity or mortality, and what the local implications could be.

While a warming climate may negatively impact air quality in the future, changes to industrial practices and technological advances will hopefully lead to reductions in emissions of pollutants.[375] It is important to keep monitoring air quality and health outcomes over the coming years and decades.

Peterborough Public Health Adaptation Efforts

The following are examples of Peterborough Public Health's current work that is contributing to climate change adaptation and supporting those most vulnerable to health impacts of climate change related to air quality:

Population Assessment and Surveillance

- Identifying potentially vulnerable populations and monitoring health trends overtime.
- Monitoring the local Air Quality Health Index and air quality alerts.

Health Promotion

- Providing enhanced health teaching and education during poor air quality events for the general public with specific attention to vulnerable populations such as those who are not housed, the elderly and children; collaborating with agencies and organizations who work with vulnerable populations to help disseminate critical information related to poor air quality and health precautions.
- Providing support to school boards as requested on policies and procedures related to health and poor air quality.
- Participating in ongoing policy and partnership work to address the social determinants of health including issues related to housing, income, and transportation.

Health Protection

- Advocating for improved indoor air quality in public settings to help prepare for poor outdoor air quality events; providing education on indoor air quality adaptation during poor outdoor air quality events.
- Providing public alerts and news releases as well as media interviews during poor air quality events.
- Responding to questions and concerns from service providers, businesses, and organizations during poor air quality events.
- Responding to and investigating complaints about air quality, for example, mould due to flooding.

Ultraviolet Radiation

Ultraviolet Radiation (UVR) is an invisible form of radiation. UVR can come from both natural and artificial sources (e.g. tanning beds).[421,422] Sunlight is a natural source of UVR that all life on earth is exposed to. Small amounts of UVR are beneficial to health, playing an important role in the production of vitamin D, however excess exposure to UVR is associated with negative health outcomes.[423,424] The stratospheric ozone layer protects the earth's surface from solar UVR by absorbing much of it. Chemicals, particularly human-made chemicals, that are released into the atmosphere contribute to ozone depletion. [423] While the 1970s and 1980s faced the issue of a thinning ozone layer due to emissions of ozone-depleting substances and greenhouse gases (GHGs), the phasing out of these substances as part of international agreements, like the Montreal Protocol has allowed for some recovery of the ozone layer.[423] In addition to the state of the ozone layer, the level and intensity of UVR exposure reaching the Earth's surface varies as it is influenced by several factors such as: sun elevation (time of day), season, latitude, altitude, cloud cover, haze/pollution, and reflectivity of the Earth's surface (e.g. snow and waterbodies are more reflective than soil and plants).[47,423,424] Some of these factors are impacted by climate change as well as continued emissions of GHGs, specifically cloud cover, snow cover and reflectivity, and pollution-related haze. The potential impacts are complex and uncertain and likely to vary by region.[425] In the Health of Canadians in a Changing Climate report (2022), several considerations for Southern Canada are described where UVR intensity could increase or decrease over time.[425] As this is where PPH region is located, it is unknown at this time how climate change will impact levels of UVR reaching our region.

Hazard Trends and Projections

There are various types of solar radiation that do different things. When you feel the warmth of the sun, that is infrared radiation; you are able to see due to visible light; ultraviolet radiation can cause sunburns and other health impacts.[421] Even though there is no correlation between heat and UV radiation, the highest UV index is often found between the months of May to August due to the closeness of the sun.[4]

Levels of UVR

The UV Index is a tool that was developed to help people protect themselves from the sun's damaging UV (ultraviolet) rays.[422] The forecasting system provides hourly and longer-term (four days or more) forecasts, as well as regional and continental maps of UV radiation levels.[41] See Figure 10-1 that describes the exposure category and UV index by colours. The higher the UV Index, the stronger the UV rays, and hence the greater need for people to practice sun safety measures. The UV Index ranges from 0 to 11+.[422]

Figure 10-1. *UV Index Exposure Categories.*

Exposure Category	UV Index
LOW	0 - 2
MODERATE	3 - 5
HIGH	6 - 7
VERY HIGH	8 - 10
EXTREME	11 +

Source: Government of Canada. UV index and Sun Safety - Canada.ca. Published 2023. Accessed July 27, 2023. www.canada.ca/en/environment-climate-change/services/weather-health/uv-index-sun-safety.html.[422]

Behaviours that Impact Exposure to UVR

In the PPH region, we expect warmer than average weather across all seasons due to climate change. Consequently, with warmer days, and a longer warm season people may spend more time outdoors which would increase their exposure to UVR. If protective measures (e.g. protective clothing, sunscreen, hat, sunglasses) are not taken the exposure is increased. Local data on these behaviours is limited, but in 2019, a telephone survey known as the Rapid Risk Factor Surveillance System (RRFSS) was conducted in the PPH Region exploring some of these behaviours. The results from the "UVR exposure and protective behaviours" survey is presented below.

- 28% of Peterborough residents reported that they've experienced a sunburn in the last 12 months
- 39% of respondents always or often avoided the sun between 11 a.m. and 4 p.m. whereas 32% reported sometimes and 29% rarely or never
- 54% of respondents reported always or often wearing sun protective clothing, including a hat whereas 22% reported sometimes and 24% rarely or never
- 42% of respondents reported always or often using sunscreen whereas 20% reported sometimes and 38% rarely or never
- 66% of respondents reported always or often using sunglasses with UV protection whereas 17% reported sometimes and 17% rarely or never

Source: Rapid Risk Factor Surveillance System (RRFSS), 2019.

This data presents a point in time picture of some of these behaviours. The survey could be implemented in the future to assess changes over time, and possible inferences or connections could be made to a warming climate.

Health Impacts

As previously noted, small amounts of UVR are beneficial to health, due to its role in the production of vitamin D, which is important for bone health, blood pressure, and our moods.[41] Prolonged exposure to UVR, however, is linked with negative health impacts associated with the skin, eyes and the immune system.[41,424,426]

Effects on the Skin

UVR is a carcinogen and the most serious impact of UVR exposure on the skin is cancer. Sunburns can be harmful, though their most significant harm is increasing a person's risk of skin cancer.[424] The incidence of different types of skin cancer has been growing considerably over the past decades.[423,426] UVR exposure is associated with the development of non-melanoma skin cancers (such as basal cell carcinoma (BCC) and squamous cell carcinoma (SCC)), as well as melanoma, which is the most serious type of skin cancer.[41] BCC is a slow-growing skin cancer found mostly in older people and SCC is a malignant cancer and is less likely to cause death whereas melanoma is a life-threatening skin cancer.[41] The risk of melanoma is related to a history of sunburns and sun exposure, especially if exposure occurs during childhood and adolescence. According to Cancer Care Ontario about 80% of Ontario's melanoma cases are attributed to solar UVR exposure.[427]

Effects on the Eyes

Acute effects of UVR on the eyes can be inflammation of the cornea and conjunctiva which are reversible and easily prevented by protective eyewear.[41] These conditions are not usually associated with any long-term damage but can be painful and may require therapeutic interventions.[41] The long-term effects may be cataracts and cancers in and around the eye.[41] Age-related macular degeneration is another possible condition from UVR exposure. Worldwide, UVR exposure may account for 10% of the estimated 15 million people that are blind due to cataracts.[424]

Effects on the Immune System

UVR is absorbed by the skin and excessive exposure may reduce the body's ability to defend itself against bacteria, viruses and certain diseases.[428] In certain people solar UVR, "can reduce the incidence of autoimmune disease, such as multiple sclerosis, type 1 diabetes, chronic inflammatory bowel disease (e.g., Crohn's disease), arthritis, and allergies."[41]

Effects on Mental Health

People who experience any of the health impacts related to UVR such as cancer or loss of eyesight may also experience negative mental health impacts. People with chronic health conditions are at higher risk for mood and anxiety disorders, and major depression.[429]

Populations at Increased Risk

All people who spend time outdoors are at risk of UVR exposure and the potential negative health impacts described above. The vulnerable populations identified by PPH in the vulnerability chapter are also at risk of UVR exposure. However, some populations are more exposed to UVR as they may spend more time outdoors and/or they are less likely or less able to access sun protective measures.

Infants, Children, and Youth

Infants, children, and youth are more prone to the harmful effects of UVR exposure because of their skin and eye structure which can increase their cancer risk over the course of a lifetime.[424] They rely on parent/caregiver support to participate in sun safety behaviours for protection from UVR exposure.

Outdoor Workers and People who engage in Outdoor Activities

People who work outdoors or those who participate in physical activity outdoors may have a higher exposure to UVR and are at heightened risk for negative health impacts. Outdoor workers who have prolonged and high UV exposures are at higher risk of developing skin cancer.[41]

In 2021, there were 8,450 people in the PPH region whose work was primarily outdoors in sectors such as agriculture, forestry, fishing and hunting, mining, quarrying, oil and gas extraction and construction.[15] For those individuals, their UVR exposure would be varied, and it is unknown whether sun protective behaviours were implemented.

Canadian men tend to have higher exposure to UVR and therefore a greater risk of melanoma. They spend more time outdoors, and compared to women, are at 2.25 times greater risk of melanoma of the head or neck and trunk. Men were less likely than women to use sunscreen on the face and body or seek shade, but men were more likely than women to wear a hat or long pants.[430]

People who participate in activities outdoors during any season may be at increased risk of the harmful effects of UVR and if sweating occurs it can increase the photosensitivity of the skin which can result in sunburn.[431]

People Experiencing Homelessness

People experiencing homelessness may be exposed to harmful UVR due to spending a greater proportion of time outdoors. People who have limited material resources may not be able to protect themselves from UVR exposure. In the PPH region as of April 2022, there were at least 317 people experiencing homelessness.[51] People living outdoors are at increased risk of UVR exposure unless they are able to seek shelter inside or in shaded areas. In 2021, in the PPH region there were 1,699 households on the social housing waitlist.[51] People waiting for social housing are a potential group who may become homeless and be at risk of the negative health impacts of UVR exposure.

Other factors that can increase the risk of harmful health effects of UVR exposure are genetic predispositions (i.e. people with fair-skin, large number of moles) and the use of certain medications which cause people to be more sensitive to UVR exposure.[430,432]

Health Outcomes

According to the Environmental Burden of Cancer in Ontario report (2016) UVR is the leading environmental cause of skin cancer.[433] It is important to note that skin cancer is often diagnosed later in life after cumulative exposure to UVR over several decades.

Malignant melanoma is the deadliest form of skin cancer and has been associated with UVR.[41] People are at increased risk of melanoma based on total lifetime sun exposure especially early in life and the number of sunburns.[434–437]

From 2014 to 2018, there was an average of 3,800 cases of melanoma diagnosed each year in Ontario.[a] In 2016, it was reported that about 80% of melanoma cases (averaging 2,540 cases per year) in Ontario were due to UVR.[427] According to the World Health Organization, "[e]xcessive exposure to UVR caused around 1.2 million new cases of non-melanoma skin cancers (SCC and BCC) and 325 000 melanomas of the skin, and 64 000 premature deaths from non-melanoma and 57 000 melanomas of the skin in the year 2020."[424]

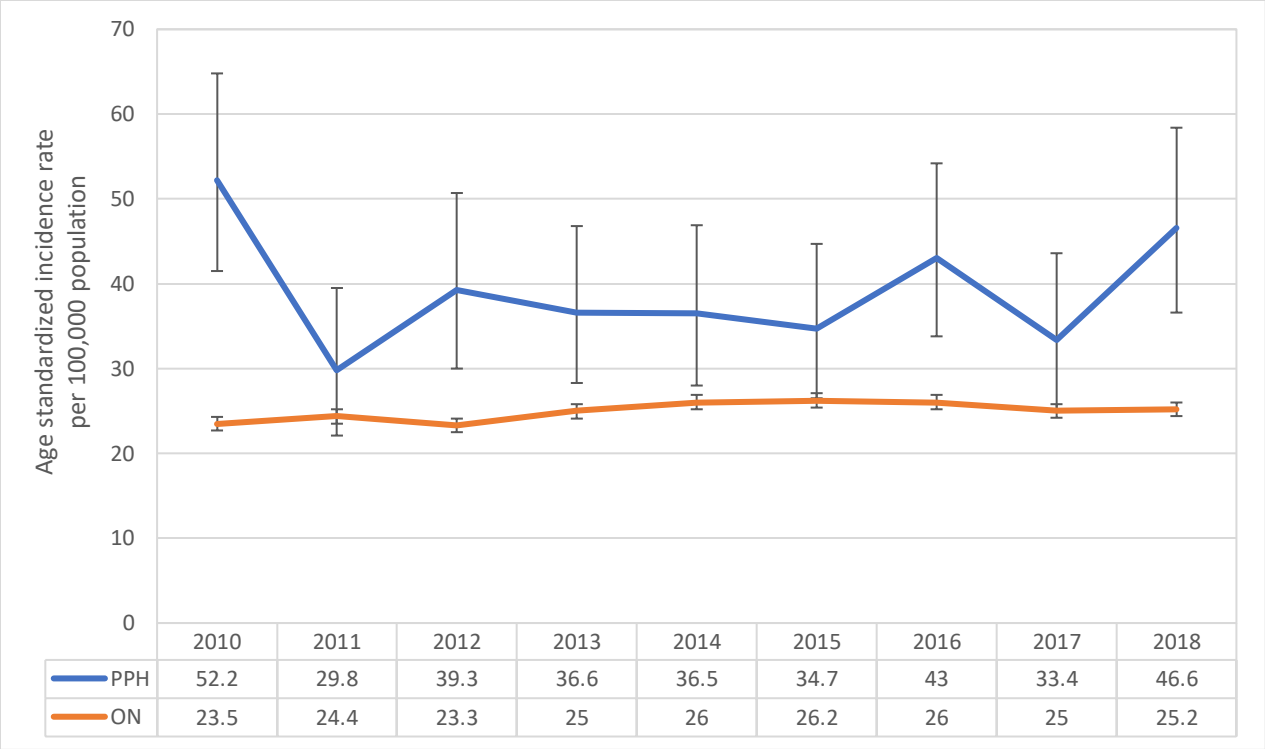
[a] **Source:** Ontario Cancer Profiles - Ontario Cancer Registry SEER*Stat Package, 2021.

Malignant Melanoma in PPH Region

The data below may be considered a baseline. It is important to note that outcomes from UVR exposure may not be observed in similar statistics for many decades.

The age-standardized incidence rates of malignant melanoma in PPH region from 2010 to 2018 are shown in Figure 10-2. The rates did not change significantly between the years in PPH or ON. PPH rates are higher than the province (significantly higher in some but not all years).

Figure 10-2. *Age-Standardized Incidence Rate of Malignant Melanoma in PPH Region and Ontariofrom 2010 to 2018*



	2010	2011	2012	2013	2014	2015	2016	2017	2018
PPH	52.2	29.8	39.3	36.6	36.5	34.7	43	33.4	46.6
ON	23.5	24.4	23.3	25	26	26.2	26	25	25.2

Source: Ontario Cancer Profiles - Ontario Cancer Registry SEER*Stat Package, 2021.

In Ontario, non-melanoma skin cancers (such as BCC and SCC) are not well documented since many cases are treated and not reported.[438] In Canada, non-melanoma skin cancers are estimated to be about 12 times as common as melanoma.[427]

The Ontario Climate Change and Health Modelling Study (2016),[439] compared the years of 1971-2000 baseline, during the 2050s and 2080s and the PPH region may expect an estimated increase of BCC by 7.8% and 13%, respectively, while SCC rates are projected to increase by 14.7% and 24.7%, respectively (See Table 10-1).

Table 10-1. *Projected Percentage Increase in Basal Cell and Squamous Cell Carcinoma in the PPH Region for 2050s and 2080s Over the Baseline Period (1971-2000).*

	2050s	2080s
Basal Cell Carcinoma	7.8%	13.0%
Squamous Cell Carcinoma	14.7%	24.7%

Source: Ontario Climate Change and Health Modelling Study (2016).[439]

Peterborough Public Health Adaptation Efforts

Population Assessment & Surveillance

- Conducting analysis on Rapid Risk Factor Surveillance System public surveys including attitudes about climate change and ultraviolet radiation.
- Completing community health status reports to monitor trends, as necessary.

Health Promotion

- Providing information and developing programs and communication strategies related to sun safety for childcare settings and schools, as requested.
- Providing education and health teaching regarding sun protection during family home visits and consultations with clients.
- Providing general messaging and communication during the summer months related to sun safety through social media.

Health Protection

- Recommending the provision of shade when reviewing plans and conducting inspections of public recreational facilities, such as splash pads and public beaches.

Conclusion and Next Steps

Climate change is a global and local issue that will require ongoing assessment and collaborative adaptation efforts to protect the health of the PPH area residents. Global warming and associated climate change cannot be halted in the near future, even if greenhouse gas emissions are strongly reduced.[440] As such it is vital that actions are taken to prevent the negative health impacts of climate hazards, especially for those who are most vulnerable. These actions are components of **climate change adaptation** and may be taken by all levels of society.

Vulnerability assessments, such as this report, are an integral part of understanding climate change health risks and vulnerabilities, which can help to prioritize adaptation efforts.

Next steps will include the development and implementation of regional, health-focused climate adaptation strategies with a focus on **health equity**.

PPH is dedicated to working with community partners to develop adaptation plans and strategies that will support those who are most at risk for severe health impacts, as identified in this vulnerability assessment. PPH is dedicated to engaging external stakeholders at a local, provincial and national level as well as the public in climate change adaptation plans. The goal is to create and implement adaptation plans and strategies that are relevant and supportive to the needs of the PPH area and residents to best protect their health in a changing climate.

A critical component of the engagement will be learning from local Indigenous communities to effectively integrate two-eyed seeing in adaptation planning.

There will be continued efforts to integrate climate change adaptation into current PPH activities and work towards attaining the goals outlined in PPH's 2022-2025 Strategic Plan, including:

- Updating our collaborative community emergency response plans to adapt to health risks of climate change, specifically including mechanisms to support vulnerable populations and mental health needs during severe climate events.
- Escalating communications and impactful messaging about anticipated health impacts of climate change in the local context.
- Re-launching and supporting community climate change engagement work with particular attention to Indigenous-led initiatives.

What is Health Equity? [442]

"Health equity means that all people can reach their full health potential and are not disadvantaged from attaining it because of their race, gender, age, socioeconomic status or other socially determined circumstances. Different people need different heights of steps to reach the apple tree, just as different people need different supports to reach health equity."[70]

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