CHAPTER 6
Extreme Weather Events

6.0 Extreme Weather Events: Key Findings

Climate change projections and exposure pathways

- Annual precipitation levels events are likely (66% to 100% probability) to increase in York Region by the 2050s, particularly in the winter and spring
- Extreme precipitation events are likely (66% to 100% probability) to increase in York Region by 2050s, particularly in the summer months
- York Region has experienced major rainfall and flooding events in recent years that have resulted in infrastructure damage and large recovery costs
- York Region floodplains are at an increased risk of flooding following heavy precipitation events. Current floodplain maps focus on riparian and lakeshore flooding but there is limited information on higher risk areas for urban flooding
- Due to limitations in climate models, there is insufficient evidence to suggest droughts and ice storms will increase in York Region by the 2050s

Population sensitivity

- Seniors are more vulnerable during and after extreme weather events due to chronic health conditions and medication use, greater risk of injury, limited mobility, difficulty managing during transportation and evacuations and limited capacity to recover following an event
- Residents living in floodplains are at an increased risk of injury and illness due to flooding, as well as property damage and loss. Low-income households may be more vulnerable to health impacts due to limited resources to recover from property damage or loss

Adaptive capacity

- Early warning and forecasting systems for extreme weather events from Conservation Authorities and Environment and Climate Change Canada provide critical information for emergency planning and response
- York Region Public Health has identified its primary emergency response roles and responsibilities within the Public Health Emergency Plan and the Regional Emergency Plan
- Emergency and business continuity plans need to adequately address climate and health risks at all levels
- In 2018, more than half of York Region households surveyed had taken measures for emergency preparedness and half have plans to check on family and friends during an emergency. However, additional research is still needed to understand the existing level of resilience to climate change

Health impacts

- Future health impacts in York Region from extreme weather events are difficult to predict. Impacts will vary depending on the magnitude, frequency and affected areas of extreme weather events, the local population exposed and the critical infrastructure impacted
- The health impacts of extreme weather events can be severe. They can include injury, death, mental health effects, population displacement and food- and waterborne illness
- Extreme weather events also impact human health through changes in service demand and operation of health services
- Health impacts can occur during an extreme weather event or can last for many years following an event, such as with mental health outcomes

Recent Trends:

- There is limited hospital data relating to past extreme weather events in York Region. However, a study observed an increased number of injury-related Emergency Department visits in Toronto following the 2013 ice storm

Extreme weather events can result in major health impacts such as traumatic injury and death and can also impact health after the event takes place, including ongoing mental health troubles and stress, or damage to home environments. Considering the severe impacts that can result from such events, it is important to assess how climate change can impact human health through extreme weather events.

This chapter provides an overview of the health outcomes and impacts specific to extreme weather events and their implications for emergency planning and preparedness in York Region. Impacts related to coastal flooding or hurricanes are out of scope. The following impacts are most relevant to the York Region context with respect to extreme weather events and the links to climate change:

- York Region has experienced a wide range of extreme weather events such as intensive storms and flooding with large impacts on the community. Recent events such as the December 2013 ice storm resulted in loss of power to 92,000 homes in York Region and over 35 million dollars in cleaning and repair costs[10]
- Climate change is expected to increase the frequency and intensity of extreme weather events, such as heavy precipitation, flooding and possibly droughts and ice storms[4,80-83]
- Extreme weather events, including floods, rainstorms, ice storms and droughts, can cause significant damage to local communities. This may result in the disruption of transportation networks, impacts on water and wastewater treatment activities, power outages and damage to residential homes[40,81,84-86]

6.1 HEALTH IMPACTS

The relationship between health and extreme weather events is complex and depends on the physical impacts from an event, as well as mediating factors in communities that can reduce or increase risks. Predicting the health impacts from climate change-mediated extreme weather events is challenging due to the number of factors to be considered and existing limitations in forecasting complex weather patterns. For instance, there is currently no consensus on the impact of climate change on tornadoes or high winds associated with thunderstorms.[25] Similarly, research is still emerging on the impacts of climate change on the frequency and intensity of storms.[80] There is also less emphasis in literature on how extreme weather events alter the sensitivity and coping capacity of human systems to future events.[82]

Health impacts can occur during extreme weather events but can also last for many years following an event, particularly with respect to mental health outcomes. The health impacts of extreme weather events can be severe and include injuries, death, mental health impacts (e.g., anxiety, depression, Post-Traumatic Stress Disorder (PTSD)) and food- and waterborne illnesses. Mental health outcomes have consistently been associated with extreme weather events.[45,47,87] From reviewing the aftermath of disasters, researchers have strong evidence that extreme events have been associated with acute stress, PTSD, higher depression rates and suicide.[45] With advanced warning and preparation, many of the health impacts from extreme weather events can

be decreased. While insufficient data exists to link impacts and specific events in York Region, Table 6.1. provides a general overview of health impacts associated with extreme weather events.

Extreme weather events also impact human health in other ways, through changes in service demand and operation of health services. In addition to having a direct impact on health, extreme weather events strain health and social care systems and reduce the adaptive capacity of public services to address the challenges faced by residents. This is due to the effects on built, social and institutional infrastructure and communication networks being compromised.[88] For example, cuts in the electrical power supply due to flooding may lead to the loss of refrigeration for medicines, reduced mobility through disruption to various types of mobility aid devices that are designed to assist walking or otherwise improve the mobility of people with a mobility impairment, loss of heating and cooking equipment and the loss of telecommunication technology services.[40]

The United States climate change and human health assessment indicate with high confidence that climate-related changes in extreme weather are associated with health impacts such as death, injury, or illness, exacerbation of underlying medical conditions and adverse effects on mental health.[45] However, there is limited evidence on increases in exposure to health hazards associated with increases in the frequency and intensity of extreme weather events. Qualitative studies have examined potential health hazards from these events,[80] but few draw strong or definitive conclusions that exposure to these hazards will increase due to climate change. However, due to the likely increase in the frequency and severity of extreme weather events, York Region residents might be at increased health risks in the future.

Table 6.1. Health Impacts of Extreme Weather Events.

Event Type	Health Risks and Impacts	Supporting Evidence
Heavy Precipitation and Severe Thunder-Storms	• Increased risk for injury, illness and mortality • Health risks related to infrastructure damages • Water quality impacts • Respiratory impacts • Mental health impacts	• Exposure to storm hazards, including falling trees, sheltering in inadequate conditions, utility outages and discharge of hazardous substances may result in injury, illness, electrocution and death[89] • Asthma cases have been significantly associated with thunderstorms during the pollen season due to the high levels of airborne pollen grain[90] • Extreme summertime precipitation events increased risk of hospitalization for asthma by 11% in Maryland, U.S. Risk was slightly more pronounced for those under four years of age[91]
Flooding	• Increased risk for injury, illness and mortality • Indoor air quality impacts and potential illnesses due to mould and sewage backflows in basements • Carbon monoxide poisoning related to power outages • Vector-borne disease risks arising from new mosquito breeding grounds • Mental health impacts • Water quality impacts	• The rate of injury increased by 28% up to six weeks following the 2013 Alberta flood that affected 100,000 people. There was a 1.64- and 2.34-fold increase in new prescriptions for anti-anxiety medications and sleep aids, respectively, for females[48]
Ice and Winter Storms	• Injuries, isolation, mental health impacts, potential disruption of health/social services • Elevated risk of carbon monoxide exposure from the improper use of combustion generators and stoves due to power outages	• During the 2013 ice storm in Toronto, emergency department hospitalizations increased by 10% compared to the previous five years, with hospitalization rates for environmental conditions being 2.6 times higher[85]
Droughts	• Food safety and security impacts • Water quality and quantity impacts • Vector-borne disease risks	• Outbreaks of waterborne disease have been observed following heavy precipitation events after a dry spell [92] • Hot and dry conditions often associated with drought may support the proliferation of some food-borne pathogens (e.g., *C. perfringens*, Campylobacteriosis)[84] • Drought has been strongly associated with increased risk from mosquito-borne infections, such as West Nile virus, in the Canadian prairies where crop irrigation creates new mosquito breeding grounds.[84] • Drought often causes dry, dusty conditions that increase the concentration of particulates in the air and increases risk of wildfires. Increases in particulate matter and wildfire smoke can exacerbate respiratory and cardiovascular conditions[90]
Wildfires	• Mental health impacts • Air quality and respiratory impacts • Fire safety impacts	• Wildfires have been associated with premature mortality and low infant birth weight, but the strongest evidence is for acute respiratory illnesses[80]

Vulnerable populations

Certain populations are likely to be disproportionally affected by extreme weather events. Those most vulnerable include seniors, children, people who are socially isolated, individuals with pre-existing chronic disease, low-income individuals, people who are experiencing homelessness or mental illness, outdoor workers, emergency workers and those with mobility issues. See Chapter 4 for more information on vulnerable populations within York Region.

Seniors are more vulnerable during and after extreme weather events. This is due to chronic health conditions and medication needs, greater risk of injury, limited mobility, difficulty transporting and limited capacity to recover following an event. Mortality rates have been shown to be higher for seniors, particularly males, following disaster events such Hurricane Katrina.[80] Emergency response efforts may have also unintended harms on vulnerable populations such as seniors. For example, response efforts for the 2011 tsunami in Fukushima, Japan, observed an increase in mortality with seniors evacuated compared to seniors that remained in their homes. This could be related to mental health impacts and stress from relocation or limited access to health care during the evacuation process.[93]

Low-income households and renters are also more vulnerable to extreme weather events. Homes in need of repair are vulnerable to damage from extreme weather events. As such, individuals and families living in substandard housing are at greater risk of illness or injury due to climate-related hazards.[45] Based on past extreme weather events, low-income populations tend to experience greater impacts with more adverse health outcomes and have more difficulty recovering after an event. Individuals residing and working in floodplains are more vulnerable to extreme rainfall and flooding events.[86] Those who rent may have a reduced adaptive capacity even if they have the money for repairs or upgrades as they often cannot make the changes to their homes.

While extreme weather events can have a large impact on mental health on the general population, individuals with existing mental illness or stress-related disorders (e.g., depression, anxiety, PTSD, drug and alcohol abuse) can experience worsening symptoms soon after extreme weather events.[45] Additionally, damaged infrastructure can impact communication systems, services and availability of mental health support networks, which can further contribute to the mental health impacts of individuals during, or soon after an extreme weather event.[45]

6.2 HEAVY PRECIPITATION AND FLOODING EVENTS

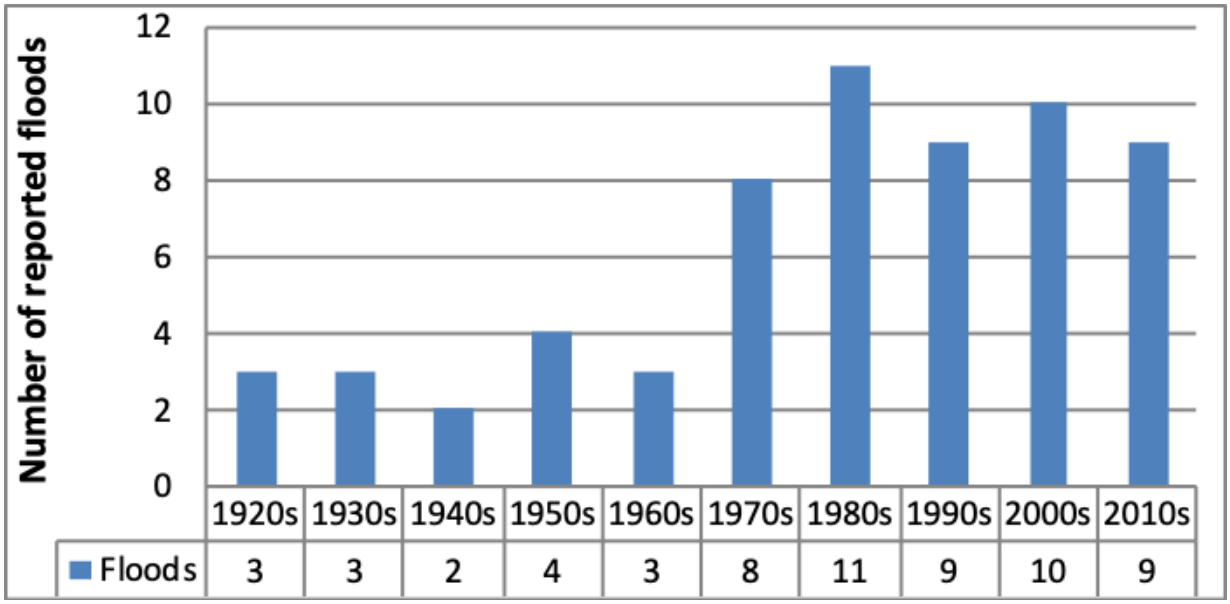
Flooding resulting from heavy precipitation events can create serious health and safety risks. Heavy rains, spring thaw, and quickly melting snow can cause rivers, creeks or streams to overflow and flood. Changing rainfall patterns and extreme weather can also increase the risk of flooding. Some floods develop slowly, while others develop in minutes. Floodwater can be exposed to many sources of pollution and it can carry diseases that impact human health. Floodwater can contaminate drinking water supplies, private wells, surface water, recreational water and public and private properties. People who live in low-lying areas tend to be at a greater

risk from damage caused by flooding.[86] Extreme precipitation and flooding events can influence cyanobacterial bloom development, toxin production and distribution within waterbodies due to altered water quality and nutrient concentrations.[94] Cyanobacterial blooms are a concern to human health due to the potential impacts on recreational and drinking water systems.

The frequency and severity of flood events have been increasing in Canada, and are often associated with spring snowmelt or severe precipitation. The Canadian Disaster Database has recorded more than 60 flooding events in Ontario since the beginning of the twentieth century.[95] The number of flood events appears to have increased since the 1920s. However, this frequency could be due to improved technology for communicating and detecting floods and changes in the built environment (Figure 6.1).

While climate change makes these events more likely, land-use change associated with urbanization adds to the issue. As the population in the Greater Golden Horseshoe continues to grow (estimated to increase by greater than four million people by 2040), associated development could exacerbate the frequency and intensity of urban flooding.[96]

Figure 6.1. The number of reported floods by decade in Ontario between the 1920s and 2010s.



Source: Public Safety Canada. Canadian Disaster Database. Reported floods in Ontario [data file]. Ottawa: Government of Canada; 2017.

6.2.1 Climate change impacts on heavy precipitation in York Region

Extreme precipitation events are likely to increase in York Region in terms of frequency and magnitude. By the 2050s, the annual one-day and five-day maximum precipitation amounts are expected to increase from 39.3 mm to 50.9 mm, and 61.4 mm to 78.4 mm, respectively in York Region.[10] The annual number of heavy and very heavy precipitation days (where

precipitation is greater than 10 mm and 20 mm respectively), is expected to increase by two or three days by the 2050s, particularly in the summer months.[10]

Precipitation changes are not expected to occur uniformly across the year. The amount of precipitation in the summer is expected to remain similar to historical levels, while precipitation in the spring and winter months will increase in the 2050s.[10] Precipitation events occurring over consecutive days are also expected to increase from 6.9 to approximately 7.4 days annually, which may continue to impact urban infrastructure.[10] More frequent rain events can saturate the soil and result in less area for water from subsequent storms to absorb, which leads to flooding.

6.2.2 Climate change impacts on flooding in York Region

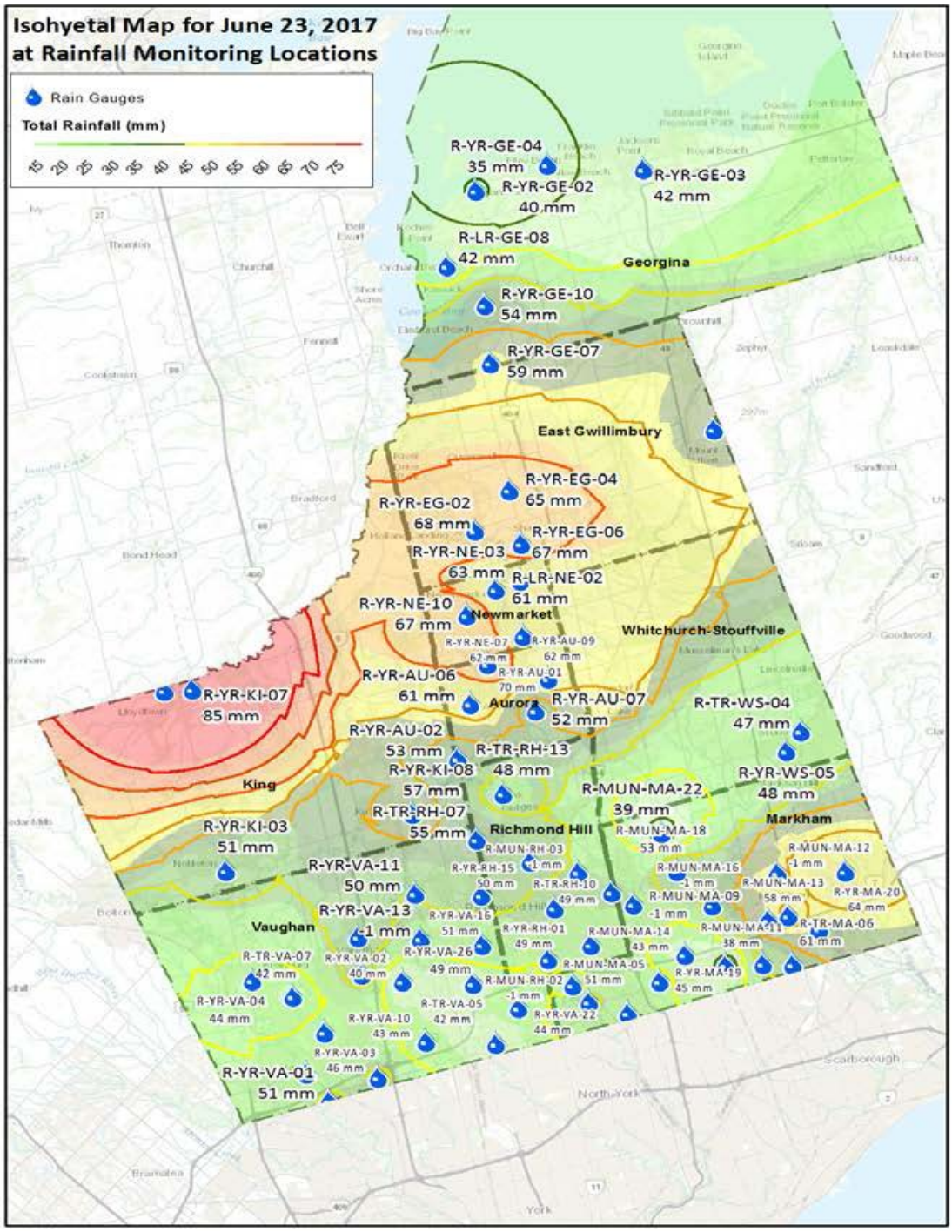
York Region has experienced major rainfall and flooding events in recent years that have resulted in infrastructure damage and large recovery costs. In August 2005, a three-hour extreme rainfall event resulted in as much as 175 mm of rain in the area of Yonge and Steeles, causing severe flooding, power outages and infrastructure damage. Numerous other areas in the City of Vaughan experienced flooding and sewer back-ups during the storm.[10]

An extreme rainfall event on June 23, 2017 caused severe flooding and affected a number of water and wastewater sites (pumping stations and wastewater treatment facilities) across the Region (Figure 6.2).[97] Although the storm was classified as a less than two-year event, certain areas experienced more substantial rainfall (Figure 6.3).[97] Areas greatly affected included Schomberg in the Township of King, which experienced rainfall levels comparable to a 1 in 100 year event. The Towns of Newmarket, Aurora, and East Gwillimbury experienced rainfall levels comparable to a 1 in 50 year event.[97] As part of the monitoring program following this major rainfall event, a map was produced to visualize the real-time data collected from rain gauges installed throughout the Region.[97]

Figure 6.2. Down-looking Ultrasonic Level Sensor Monitoring Creek Levels at Aurora Sewage Pumping Station on May (Left) and June 23, 2017 (Right) Extreme Rainfall Event.

Source: York Region. York Region inflow and infiltration reduction strategy annual report, March 31, 2018 [Internet]. Newmarket: Regional Municipality of York; 2018. Figure 17 – Down-looking ultrasonic level sensor monitoring creek levels at Aurora sewage pumping station in June 23, 2017; p. 31. Available from: https://www.york.ca/wps/wcm/connect/yorkpublic/b22ae2f3-5140-48f2-869e-a803d2552893/2017+Inflow+and+Infiltration+Reduction+Strategy+Annual+Report.pdf?MOD=AJPERES. Reproduced with permission from the copyright owner.

Figure 6.3. Isohyetal Map showing different localized precipitation amounts recorded on the June 23, 2017 extreme rainfall event.



Note**:** Isohyetal maps are used to estimate the mean precipitation across an area.

Source: York Region. York Region inflow and infiltration reduction strategy annual report, March 31, 2018 [Internet]. Newmarket: Regional Municipality of York; 2018. Figure 7, Isohyetal map for June 23 2017; p. 20. Available from: https://www.york.ca/wps/wcm/connect/yorkpublic/b22ae2f3-5140-48f2-869e-a803d2552893/2017+Inflow+and+Infiltration+Reduction+Strategy+Annual+Report.pdf?MOD=AJPERES.

York Region may experience more flooding due to an increase in daily precipitation levels, as well as an increase in the number of consecutive days with precipitation. Heavy rainfall can increase flood risk in floodplain areas, urban areas with impermeable surfaces and areas where stormwater management systems are overwhelmed. Areas at risk of sewage overflows and aging infrastructure are particularly vulnerable to adverse water quality impacts from increased precipitation events.[81]

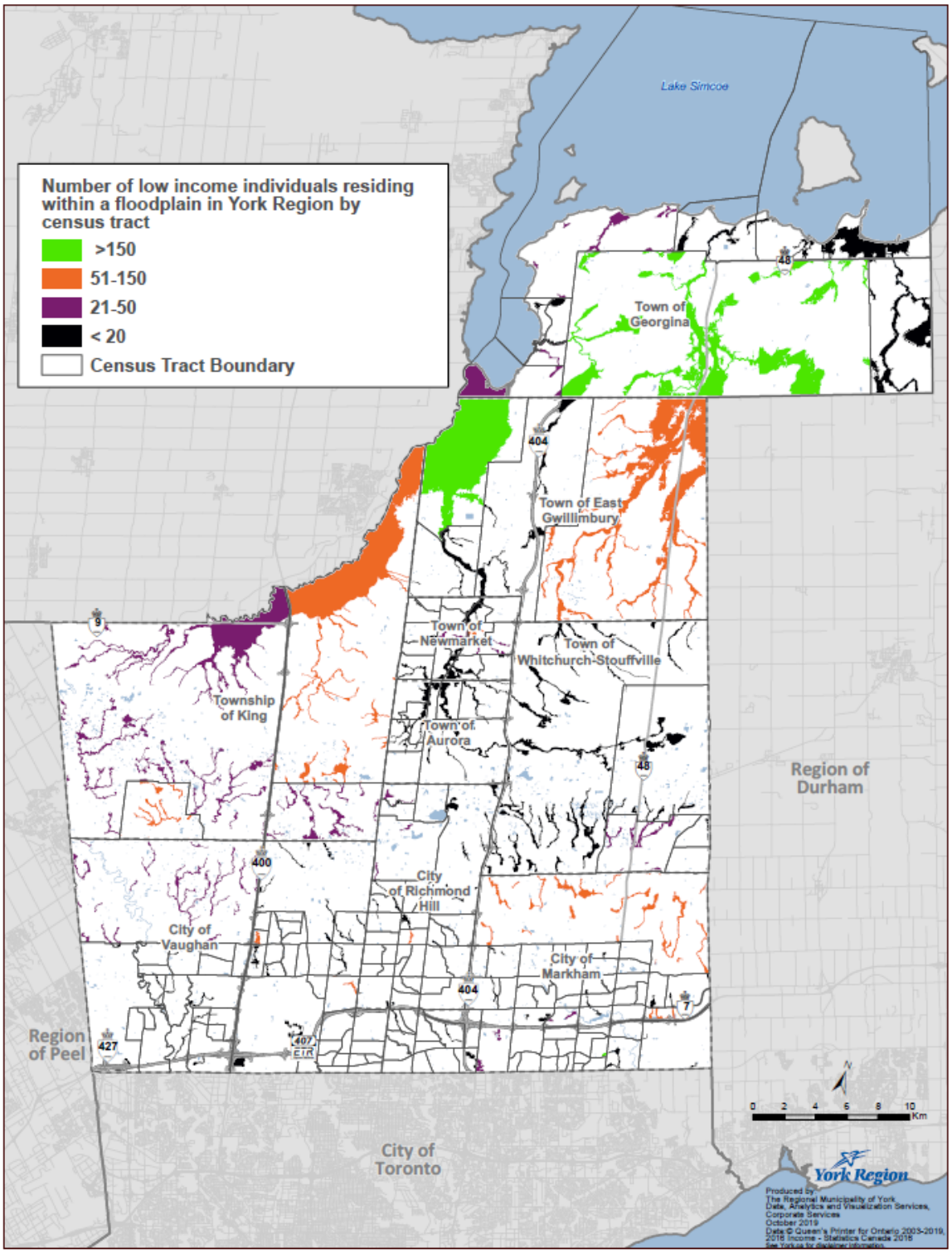
Increases in frequency and intensity of precipitation are likely to result in greater surface water run-off and sewage overflows, contributing to contamination of surface water, recreational water and drinking water supplies. York Region's sanitary sewers are affected by heavy rainfall and snowmelt.[98] Excess flow entering the sewers from household connections, footing drains and deteriorated sections of the sewer system can overwhelm the capacity of the sanitary sewer, causing basement flooding and sewage overflows.[98] Flooding of basements can lead to mould growth in homes, affecting indoor air quality, and sewage overflows can increase the risk of exposure to pathogens.

The York Region wastewater system was designed to handle wet weather flow from a 25-year storm event. The 2016 York Region Water and Wastewater Master Plan[98] modelled the 25-year storm based on an actual York Region rainfall event to provide an accurate picture of rainfall impacts on wastewater flow rates. The Plan indicates that as severe storms become more frequent, further adjustments to the model will likely be required.[98]

Residents living in floodplains are at an increased risk of injury and illness due to flooding, as well as property damage and loss. In Canada, the cost of insured losses from extreme weather events was approximately $1.8 billion per year between 2009 and 2017. Most of these losses were due to flooding.[99] The number of insurance claims and incurred economic losses due to flooding is predicted to increase 20% to 30% by 2065.[100]

Low-income individuals may be more vulnerable to flooding events due to limited resources and substandard housing conditions. Northern York Region, specifically Georgina and East Gwillimbury, have the largest number of low-income individuals who reside within a flood plain (Figure 6.4). However, it is important to note that existing floodplain maps only cover riparian and lakeshore flooding events and do not take urban flooding risks into account. Certain areas of the York Region watershed may also not be up-to-date as some flow hydrology and hydraulic models were completed before 2010. More research is needed to understand river system flooding and risks posed to urban and suburban areas, which represents a large proportion of York Region's population.

Figure 6.4. Number of low-income individuals residing within a floodplain in York Region by census tract.



Note: This map only includes riparian and lakeshore flooding scenarios

6.2.3 Adaptive capacity: Early warning and response to flood events

Municipalities, Conservation Authorities (CAs) and the Ministry of Natural Resources and Forestry (MNRF) share the responsibility for flood contingency planning in Ontario. Municipalities have the primary responsibility and authority for response to flooding and flood emergencies, and for the welfare of residents and protection of property. If a local emergency is declared, MNRF will work directly with the municipality in consultation with the Conservation Authority.

The Government of Canada also plays a role with respect to flooding. The Government Operations Centre monitors the flood situation across the country, coordinates the federal government's response to floods (should the province request assistance to deal with a flood) and has disaster assistance programs.[101] Environment and Climate Change Canada also issues public weather alerts to notify those in affected areas in the event of impending severe weather in order to take steps to protect themselves.

The MNRF and CAs are primarily responsible for operating a forecasting and warning system. The MNRF issues two types of provincial flood messages for areas not serviced by a CA: [102]

- Provincial Flood Watch: Provides consistent and timely technical information about the potential for flooding
- Provincial Watershed Conditions Statement: Provides information on provincial watershed conditions as they relate to flood potential and an outlook on expected spring flood conditions

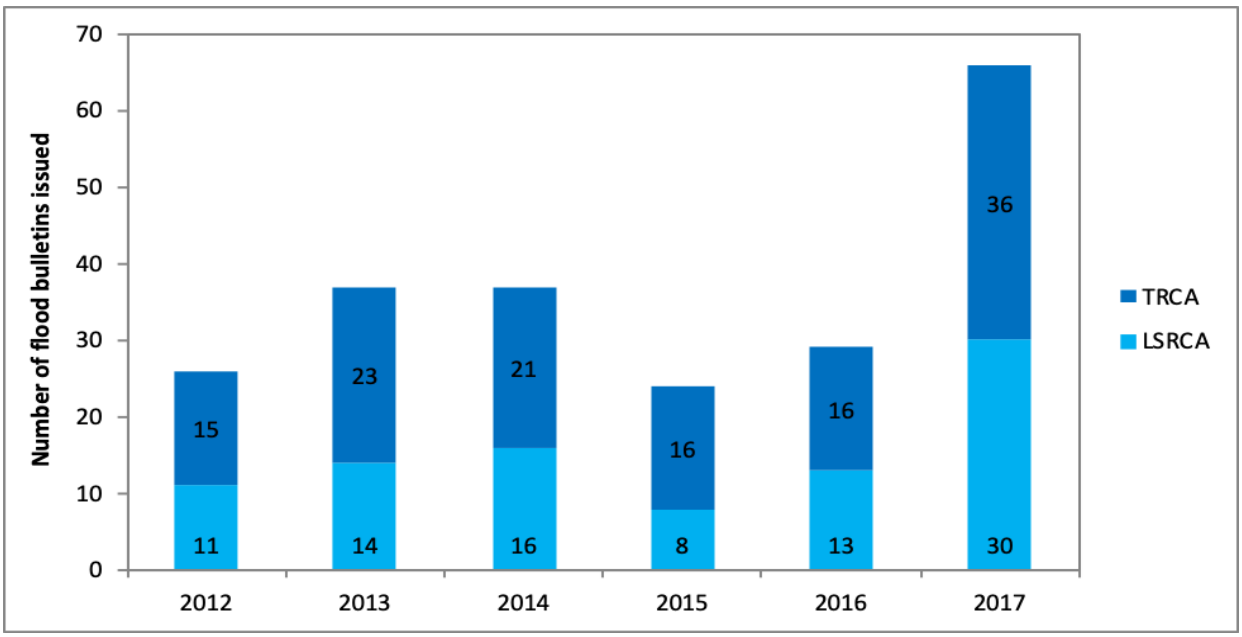
The CAs of the Greater Toronto Area (GTA) have developed a coordinated **Flood Forecasting and Warning Service** for municipalities and residents within their collective watersheds and the shoreline of Lake Ontario. Each CA monitors weather forecasts and watershed conditions, and uses this information to assess the potential for flooding. The two Conservation Authorities who provide Flood Forecasting and Warning Services within the collective watersheds of York Region are the Lake Simcoe Region Conservation Authority (LSRCA) and the Toronto and Region Conservation Authority (TRCA) (Figure 6.5).

When spring melts or severe storms are anticipated, the CAs estimate the severity, location and timing of possible flooding and provide these forecasts to local agencies.[103]

The LSRCA and TRCA communicate local flood messaging through a Flood Bulletin including:

1. Flood Warning: Flooding is imminent or already occurring
2. Flood Watch: Potential for flooding
3. Watershed Condition Statement (Flood Outlook): Early notice of potential flooding

Figure 6.5. Number of flood bulletins issued from 2012 to 2017 by the LSRCA and TRCA.



Sources: Toronto and Region Conservation Authority (TRCA). TRCA Flood bulleting data. TRCA annual reports from 2012 to 2017. Toronto: TRCA, 2017.
Lake Simcoe Region Conservation Authority (LSRCA). Flood Bulletin data from LSCRA Annual Reports from 2012 to 2017. Newmarket: LSRCA, 2016.

In addition to flood forecasts, other measures exist to prevent basement flooding in residential homes such as the installation of backwater valves. Currently, there are a variety of subsidy programs offered by local municipalities and York Region to support the installation of backwater valves.

6.3 DROUGHTS

In addition to increased flood risks, the risk of drought in Ontario is also expected to increase as a result of climate change.[96] There is no clear definition or criteria for droughts, generally described as long periods of abnormally dry conditions that stress water and environmental conditions.[84] Consecutive dry days[o] are used as a proxy measure of drought conditions. Historically, York Region has experienced an annual average of 14.4 consecutive dry days between 1981 and 2010.[10]

Droughts can contribute to a wide range of health impacts including poor air quality, food and waterborne diseases, food and water insecurity and vector-borne diseases. As identified in Table 6.1, droughts can potentially contribute to a wide range of health impacts. However, the relationship between droughts and health outcomes depends on multiple mediating factors, including: Local soil, vegetation and water sources, vulnerable populations and existing

[o] Consecutive dry days are considered to have less than 1 mm of rainfall during the period.

vector populations. Many correlational studies have shown an association between droughts and enteric diseases but there is limited evidence on the pathways in which droughts impact health.[84]

6.3.1 Potential impacts from climate change on droughts in York Region

The number of future consecutive dry days is not expected to change significantly in the 2050s[10]; however, studies conducted for the areas surrounding York Region have suggested there would be a drier growing season.[104] This increased risk of drought is based on temperatures that are expected to increase and summertime precipitation predicted to remain the same, which makes drier conditions more likely. However, additional data to project drought conditions, such as solar radiation and moisture index to project drought conditions, would be required and would need to be validated through comprehensive analysis.

Future drought scenarios on groundwater levels have also been modelled for a 10-year drought in York Region as part of the Source Water Protection work required under the *Clean Water Act 2006*.[105] The model found that while water levels stayed at sustainable levels, supply declined in four municipal production wells. The model also showed moderate impacts on some streams near municipal wells.

However, there are currently limited assessments that assess the wide range of health impacts from droughts in York Region, such as food and waterborne illnesses or air quality impacts.[106] Impacts on drinking water quality and quantity in York Region are discussed further in the water impacts chapter.

6.3.2 Adaptive Capacity: Addressing potential future drought impacts

There have been limited measures taken in York Region that focus on the potential health impacts of droughts. As droughts have a wide range of potential health impacts that depend on multiple local factors that impact risk - land use, existing infrastructure, vulnerable populations - adaptation planning will need to consider the health impact pathways that are of greater significance in York Region. Emerging research highlighting drought impacts relevant to York Region will also be important to inform disease surveillance activities.

Currently, Agriculture and Agri-food Canada monitors drought conditions across Canada. Using data from academic government sources, the Canadian Drought Monitor provides monthly maps showing drought ratings across Canada.[107] Adaptation planning can consider using this tool to monitor drought conditions. Additionally if possible, future assessments can explore any potential relationships between the drought measures with health outcomes, which can be used for surveillance planning.

Most adaptation measures identified in the research relate to ensuring water security.[84] While water quantity impacts have been modelled in York Region, the potential declines in water supply can be mitigated by adjusting the amount of water taken from those vulnerable locations and increasing water supply from other municipal wells in the area. Another factor that needs to be

considered is the increased pressure on water resources as a result of increased population growth.

6.4 WILDFIRES

Wildfires, such as forest or grass fires, are closely associated with droughts and thunderstorms. Droughts influence the amount of dry plant materials that burn easily and can serve as starter material for wildfires. Wildfires may occur in grass, peat, shrub and forest regions, but they tend to become large and more persistent in forests. It is estimated that lightning strikes associated with thunderstorms cause 45% of all forest fires.[108] On average, there are more than 8,000 forest fires in Canada annually that burn 0.7 million to 7.6 million hectares[4] of land.

Experts predict the fire season and the frequency and intensity of forest fires will increase if climate change continues to increase temperatures in North America. Higher temperatures can cause:

- Forests to be drier
- Fires that start easily and are harder to put out

6.4.1 Potential impacts from wildfires in York Region

York Region may be susceptible to periodic episodes of plumes from wildfire/forest fire smoke from neighbouring jurisdictions or out-of-province, but there is limited evidence to suggest forest fire risks within York Region. Factors affecting the plume and direction include the size of the fire, the amount of smoke produced and atmospheric conditions and wind direction. In August 2018, British Columbia's wildfire smoke plume travelled thousands of kilometres to the east and reached parts of Northern Ontario, Quebec and parts of the Maritimes.[110]

Forests in York Region include more than 29 million trees, contributing a total canopy cover of 31% and woodland cover of 23.2%.[112] Woodlands are heavily treed areas at least 0.2 hectares in size.[112] Canopy cover includes all woodlands, individual trees and small treed areas.[112] The York Regional Forest is made up of approximately 2,400 hectares of protected land located in different parts of the Region. York Region Forestry actively manages 23 tracts of the York Regional Forest for recreational use by the public.[113] Wildfire events are not likely to occur in York Region due to climate factors as fire is not the predominate process by which forests regenerate in the Region.

There is increasing research looking at the relationship of wildfires and water quality.[111] Emerging research is needed to study the relationship between drinking water safety and wildland-urban interface fires. This might include an examination of what gets released from industrial and commercial substances when exposed to extreme heat and how it impacts water quality, which has not yet been well researched.

6.4.2 Adaptive capacity: Responding to wildfire events

To help plan for potential wildfire impacts, York Region has provided local fire departments with forest firefighting equipment and Regional forestry staff has received formal training in firefighting. A fire escalation protocol is in place between Forestry and the local Fire Departments to identify and inform appropriate emergency fire response. As part of its Forest Management Plan, York Region is committed to assessing the York Regional Forest's vulnerability to climate change and developing an adaptation plan.[113]

Wildfire forecasting systems: Smoke forecasts are published during the Canadian wildland fire season (April to September) by the BlueSky Canada Smoke Forecasting System operating at the University of British Columbia. This system produces forecasts of hourly ground-level concentrations of smoke particles ($PM_{2.5}$) from wildfires up to 48 hours into the future. The forecast output is experimental and is subject to uncertainties that are inherent in weather forecasts, wildfire detection/emissions and smoke predictions. This system may be useful in the event of plumes of wildfire or forest fire smoke from neighbouring jurisdictions or out-of-province.

6.5 ICE STORMS

Ice storms have the potential to directly affect health through injuries and fatalities due to icy surface conditions, and indirectly through impacts to food safety from loss of power or carbon monoxide poisoning. Ice storms can also cause substantial damage resulting in power outages, leading to health impacts for those requiring electricity for medical devices.[4,85]

On December 21 and 22, 2013, a significant ice storm event in York Region resulted in loss of power to more than 92,000 homes, road closures and tree damage. During the ice storm, 20 mm to 25 mm of ice accumulated and resulted in downed branches, trees and power lines. York Region residents lost power, predominantly in Aurora, Markham, Richmond Hill and Vaughan.[10] Response to this event was estimated to have cost York Region $2.2 million, and an additional $35 million for local municipalities in southern York Region.[114]

Rajaram and colleagues[85] research assessed the acute health impacts of the 2013 ice storm in Toronto, Ontario. The study used a population-level database and regression modelling of emergency visit codes to evaluate emergency department (ED) visits during the storm period, comparing the data to rates occurring on the same dates in the previous five years, and to a major unaffected city (Ottawa, Ontario).[85] Results showed an increase in Toronto ED visits with the greatest number of health impacts from injuries. The authors recommended that municipal cold weather plans take into account the health impacts of ice storms, including physical and environmental injuries.[85] Future studies may benefit from taking a similar approach that uses population-level databases and regression modelling of emergency visit codes to assess health impacts from these large-scale events.[85]

6.5.1 Potential impacts from climate change on ice storms in York Region

Ice storm risk in York Region was evaluated using ice potential[p], a proxy indicator for favourable conditions for ice storms to occur.[10] Model results showed little expected change in ice potential in York Region, but Fausto et al.[10] note the projections are limited as ice potential does not capture all relevant weather variables for ice storms.

6.5.2 Adaptive capacity: Responding to ice storm events

York Region Public Health's involvement in the December 2013 ice storm event included sharing power outage information for food premise operators and the public on the York Region website and social media, disseminating extreme cold messages, conducting public health inspections of the warming centres and communicating warming centre information to the broader health sector and other agencies. Following the ice storm, Public Health conducted a debrief to increase the understanding of community needs and barriers and assess the public health response during the event. This information has been used to prepare and plan for future ice storm events.

The 2013 Southern Ontario Ice Storm Ontario After Action Report from the Office of the Fire Marshal and Emergency Management evaluated information from the ice storm event. It identified gaps and made recommendations for improvement in a number of areas to ensure that Ontario is better prepared for, and able to mitigate, the consequences of future emergencies.[115] The report identified the need to further utilize the Hazard Identification and Risk Assessment (HIRA) process for mitigation and preparedness, especially as they relate to climate change. The assignment of a lead Ministry responsible for planning for the needs of vulnerable populations was also highlighted. This would include leading the revision of the Emergency Preparedness Guide for People with Disabilities and Special Needs; developing tools, templates, policies and procedures that municipal emergency management programs can use to create a voluntary registry of vulnerable persons; and embedding wellness checks as part of the emergency management program.[115]

6.6 RESPONDING TO EXTREME WEATHER EVENT EMERGENCIES

Not all extreme weather events will result in an emergency. An emergency, as defined under the *Emergency Management and Civil Protection Act*, R.S.O.1990, c.E.9 (EMCPA or the Act), is "a situation or an impending situation that constitutes a danger of major proportions that could result in serious harm to persons or substantial damage to property, and that is caused by the forces of nature, a disease or a health risk, an accident or an act whether intentional or otherwise."[116] For an event to become an emergency, the day-to-day response capacity and the ability to access resources must be exceeded, hence requiring additional support.

[p] Ice potential is measured as total number of days where maximum temperature is less than 2°C, minimum temperature is greater than -2°C, and precipitation is more than 1mm.

Emergencies can only be declared by authorized governing authorities as outlined in the EMCPA (e.g., Mayor, Regional Chair, Federal or Provincial Minister). In York Region, the Chair of Regional Council, under the advisement of the Regional Emergency Control Group (RECG), has the authority to declare an emergency as do Mayors of the municipalities.

Climate change will result in more extreme weather events, increasing the likelihood of weather-related emergencies. Such events can require a wide range of emergency response activities, including the potential for evacuation or shelter in place orders and subsequent need for reception centres and other emergency social services.

6.6.1 Local residents' emergency preparedness

Survey data from the 2018 Rapid Risk Factor Surveillance System (RRFSS) suggests that some York Region residents have made emergency preparedness efforts. Overall, 62% of households reported taking at least some measures at home to prepare for an emergency situation.[117] Many households reported they felt they had adequate non-perishable food (78%) and water (65%) supplies for the recommended three days in case of emergency.[117] Approximately half of households noted that they have a plan to contact friends and family in an emergency situation. This survey finding is similar to RRFSS data on extreme heat,[16,69] which found a low proportion of residents who call senior family members and friends during heat waves.

Recent studies have highlighted the importance of social networks and communities in creating adaptive capacity, particularly for more vulnerable individuals.[86] Future climate change adaptation planning should consider opportunities for supporting community and family networks in responding to extreme weather events and emergencies.

6.6.2 Regional emergency response

Emergency management is one of the Ontario Public Health Standards' (OPHS) Foundational Standards. The OPHS specifies that "boards of health shall effectively prepare for emergencies to ensure 24/7 timely, integrated, safe and effective response to, and recovery from emergencies with public health impacts, in accordance with ministry policy and guidelines".[118]

York Region Public Health has identified its primary response roles and responsibilities within the Public Health Emergency Response Plan[119] as well as Annex 8 of the Regional Emergency Plan available at york.ca/emergencymanagement. The plans provide all hazards frameworks for strategic actions in partnership with the other Regional stakeholders to mitigate, prevent, prepare for, respond to and recover from emergencies.

As a member of the RECG, the Medical Officer of Health advises on public health issues and recommends specific responses to events impacting the health of the community.

In the event of an extreme weather emergency, York Region Public Health may implement measures such as population health surveillance, environmental health risk assessments, adverse drinking water response and health risk communication, and provide support through

inspections of emergency reception centres and broader multi-community emergency response efforts.

Each year, in collaboration with Regional stakeholders and subject matter experts, Public Health reviews and assesses locally relevant hazards to determine their potential significance as a community risk and identify emergency planning priorities. The 2019 Regional HIRA process identified extreme weather events, such as winter weather (ice storms), tornadoes, extreme heat, flooding and high wind as significant local hazards.

It is critical that emergency and business continuity plans adequately address climate and health risks at all levels. The increased risk of extreme weather emergencies will require the emergency management sector (Public Health, Emergency Social Services, Paramedics, long-term care, Regional Emergency Management, Community Emergency Management Coordinators (CEMCs), hospitals, Ontario Health, local nongovernmental organizations and Ministry of Health) to work collaboratively. This collaboration should focus on integrating climate change health impact considerations to build adaptive capacity and climate resiliency. This includes the understanding of what is required to adapt to the consequences of climate change, as well as acknowledgement of and preparation for the impact of climate change in all aspects of emergency management. This is particularly important for the impacts related to extreme weather events that require effective stakeholder collaboration, disaster response and contingency planning for vulnerable populations.

6.7 CONCLUSION

With the likely increase in the frequency and severity of extreme weather events, York Region will be faced with addressing extreme weather and health risks mediated by climate change. Annual precipitation levels and extreme precipitation events are likely to increase, leading to increased flooding concerns for some areas of York Region.

It is difficult to quantify all of the health impacts associated with extreme weather due to multiple risk factors. It is important to address climate and human health impacts as extreme weather events could potentially increase the vulnerability of individuals, communities and regions. Assessing how the population's health would be negatively affected by extreme weather requires an understanding of the vulnerability of the populations affected. There is sufficient literature on factors that increase vulnerability to extreme weather and climate events. However, the understanding of the potential impacts of recurring extreme weather and climate events on health vulnerability is limited.

Further research is critical to inform adaptation planning to reduce future extreme weather-related risks to health. Less attention has been paid to the impact of climate change on infrastructure that supports health and social service delivery, including health and social care facilities, private homes, communications, utilities and road networks**.**

Gaps exist in our knowledge and understanding of the impacts of extreme weather events. There are opportunities to conduct additional research to better assess extreme weather impacts on health. For example, psychosocial aspects need to be assessed to better understand risk perception, behaviour and mental health issues. Further research will be critical to informing adaptation planning to reduce future extreme weather-related risks to health.

Enhanced surveillance activities, strong social networks and the involvement of the community in emergency planning will also be critical adaptation measures to build community resilience. Extreme weather events have wide-ranging implications for the emergency management sector. Adaptation planning requires a multi-sector approach that integrates the increased risk of extreme weather emergencies across emergency management to build adaptive capacity and climate resiliency. Moving forward, emergency response, business continuity plans, exercises and the HIRA processes must factor extreme weather emergencies in the planning process to address climate and health risks at all levels. Table 6.2 provides an overview of existing activities and future adaptation planning opportunities.

Table 6.2. Summary of extreme weather-related activities and adaptation planning opportunities.

	Ongoing and Completed Activities	Opportunities
Population Health Assessment and Surveillance	**Environmental Monitoring:** Utilize extreme weather event monitoring conducted by ECCC (e.g., storms, tornadoes, wildfires, ice storms, etc.) through the EC Alert Me notifications and Conservation Authorities (e.g., flood bulletins).	**Emergency Preparedness and Response:** Engage other York Region departments on coordinated extreme weather monitoring and stakeholder notification. Explore other datasets such as the Canadian Drought Monitor and BlueSky forecasting for environmental surveillance planning. Explore the use of Public Health Information Management System technology to enhance real-time situational awareness and assist with evidence informed decision-making.
	Health Equity: Creation of maps of vulnerable populations such as seniors, children, low-income, etc.	**Health outcome surveillance:** Consider opportunities to utilize Paramedics' data and ACES data during, and soon after, extreme weather events/power outages. Consider future ACES use for mental health outcomes following events. Consider developing a plan to review health-related data following extreme weather events (e.g., carbon monoxide poisoning, injuries, mortality and mental health).
	Population survey: Conducted 2018 RRFSS survey on emergency preparedness of York Region residents.	**Health Equity and Emergency Preparedness and Response:** Assess emergency preparedness of different vulnerable populations within York Region. Consider including mental health as part of RRFSS modules on emergency preparedness. **Emergency Preparedness and Response:** Consider other survey tools to assess impacts and inform emergency response (e.g., Centers for Disease Control and Prevention Community Assessment for Public Health Emergency Response tool).

Program and Policy	**Emergency Preparedness and Response:** Annual HIRA process to inform top health risks for York Region.	**Emergency Preparedness and Response*:*** Provide climate change vulnerability assessment to help inform future HIRA processes. Consider how data and surveillance planning can inform HIRA process.
	The York Region Public Health Emergency Plan (an annex to the York Region Emergency Plan), with appendices addressing unique hazards that can impact the health of the population.	Consider incorporating climate change health impacts into the next revision of the York Region Public Health Emergency Plan. Review available resources developed from other jurisdictions for key messages and adaptation measures (e.g., wildfire resources from ECCC, National Collaborating Centre for Environmental Health, Oregon State). **Health Equity:** Consider mental health impacts in emergency planning and response plans.
	Emergency Preparedness and Response: Conducted extreme weather emergency event response debriefs including lessons learned on what did and did not work well. Participate in and conduct training and exercises on extreme weather-related emergencies.	**Emergency Preparedness and Response:** Continue debriefs and lessons learned following extreme weather events. Include climate change scenarios for future emergency response training.
	Emergency Preparedness and Response: Inspect emergency reception centres to ensure they meet food, water, sanitation, indoor air quality, sewage, garbage disposal and infection control standards.	**Health Equity:** Consult with mental health stakeholders on the impacts of extreme weather events and determine what support can be provided from public health (e.g., mental health messaging, communication to stakeholders during events). Consult with community organizations involved in extreme weather-related emergencies (e.g., Canadian Red Cross, Salvation Army) regarding potential public health support.

Health Promotion	Developed messaging for the public and stakeholders regarding power outages, the dangers of carbon monoxide poisoning, sewage back-ups and flooding, particularly during extreme weather events.	Consider incorporating health messaging to support coping with psychological impacts (e.g., emergency plans and kits for homes to support mental health including spiritual objects, blankets, toys, treats, recreational items). Support promotional activities from York Region and local municipalities for homeowners to take action to protect their home from flood events (e.g., disconnecting downspouts, fixing cracks in the foundation and installing window wells). **Health Equity:** Target landowner and rate-payers associations to communicate flood risks.
Key Stakeholder Activities (outside of Public Health)	Strategies and activities for existing water and wastewater systems for addressing extreme weather events (e.g., enhanced treatment options before a forecast event and building redundancy into water supply systems, including back-up power generators). York Region Water and Wastewater Master Plan which provides an overview of needs for 2041, including population growth and climate change impacts.	Consult stakeholders (e.g., York Region water and wastewater, Conservation Authorities) regarding residential flooding impacts to better understand mediating factors and the role of weather factors (e.g., prevalence of back-water valves to reduce flood risk in homes).
	York Region Forestry Fire Escalation Protocol for Responding to Wildfire events.	Consider supporting York Region Forestry on public health measures to reduce air quality impacts to local residents from wildfire events.
	York Region Data Analytics and Visualization development of maps for floodplains and potential vulnerable populations (e.g., location of community centres, shelters, schools, child care centres, long-term care homes).	**Emergency Preparedness and Response:** Review available GIS datasets and determine which information can be utilized to inform future extreme weather risk and emergency response. **Health Equity:** Review future urban flood risk maps created to better understand potential populations vulnerable to flooding in urban areas.
	Land use planning and building code policies (e.g., installation of mainline sanitary sewer backwater valve at homes, sump pumps, moisture resistant flooring and wall finishes, discouraging reverse slope driveways).	Review land use planning best practices to reduce climate change health impacts. Consider best practices for flood prevention and advocate for provincial building code and other regulations.
	Emergency Preparedness and Response: Using the Incident Management System (IMS) at the Regional and Departmental levels to ensure a standardized approach to emergency response.	Encourage strong social networks and involvement of the community in emergency planning (e.g., community emergency preparedness groups or resource teams to respond soon after an emergency).

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