Climate Leadership Plan

Appendix B

Baseline Vulnerability and Risk Assessment Report

December 13, 2021

KINGSTON

WSP Canada Inc.

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Executive Summary

Climate change is already affecting Kingston and will continue to do so in the future. Rising temperatures, increasing precipitation, and extreme weather will result in higher costs, more severe risks, and long lasting consequences for Kingston's infrastructure, ecosystems and communities.

Reducing greenhouse gas emissions is imperative in order to prevent long term, unmanageable impacts of climate change – but is still not enough due to continued atmospheric warming over the past century. Emissions can take decades or longer to fully impact the earth's atmosphere which means there is still significant climate changes that are already locked in to occur in the future even if all emissions were halted today. For this reason, adaptation to today's climate change risks is vital to ensure the City can continue to provide services and protect the health and safety of its residents

The Baseline Vulnerability and Risk Assessment Report accomplishes two strategic objectives of the Kingston Climate Leadership Plan. This Report provides the City of Kingston with a list of priority climate risks and vulnerabilities and next steps to build resilience of critical municipal infrastructure and services. The report also provides a framework and best practices that can be used by the City, businesses, and community organizations to assess their own risks and develop adaptation and resilience plans.

To determine priority climate impacts for the City and community, a Vulnerability and Risk Assessment was completed. The Vulnerability and Risk Assessment was supported by an Adaptation Technical Team made up of City staff and community stakeholders such as the KFL&A Public Health, Cataraqui Conservation Authority, and community support organizations. Local experiences with climate hazards and impacts were captured through an online survey which received hundreds of responses from residents.

The Vulnerability and Risk Assessment resulted in a list of 41 climate impacts and three opportunities. There are four impacts with a very high-risk level and eight impacts with a high risk level, which are discussed in detail in this report.

Priority adaptation measures for the City include protecting shoreline infrastructure from flooding and erosion, adapting transportation infrastructure to reduce flooding impacts, and integrating future climate projections into asset management planning and lifecycle management of infrastructure. Other best practices and recommendations for the community are also discussed in this report.

Lastly, an adaptation and resilience framework is included as a high level pathway for the City and other businesses or community organizations to advance risk and vulnerability assessments, identify adaptation measures, and create an adaptation strategy for their assets and services.

By taking measures to reduce risks to critical municipal infrastructure and services, and supporting the community in doing the same, Kingston will continue to proactively move towards a more climate resilient and low carbon community.

Key Terms

- Adaptation: Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.
- Adaptive Capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
- Anthropogenic: Originated or produced by human activity.
- Baseline: The historical starting point used for comparison.
- C40 Cities Climate Action Planning Framework: The Climate Action Planning Framework was developed in 2018 to support cities in developing climate action plans that are aligned with the objectives of the Paris Agreement. It provides a flexible and iterative framework that can be followed to ensure collaborative, inclusive and transformational strategies to reduce emissions and build resilience.
- Climate: Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years.
- Climate Change: Change in the mean or variability of the earth's climate over time.
- Climate Hazard: Climate or weather that has the potential to cause harm to humans, their environment, their livelihoods, or their property and resource.
- Climate Model: A type of computer program used to forecast future climate.
- Climate Time Horizon: A 30-year time period modelled for the future or based on historical observed data.
- Cooling Degree-Days: A measure of how hot a day's peak temperature is above 18°C. If a day reaches 22°C, it has four cooling degree-days. Annual cooling degree-days are the sum off all the daily cooling degree-days in a year. This is an indicator used to quantify future demands for energy to cool buildings.
- Downscaling: When the information from larger climate models, such as global climate models, is used to make predictions at smaller spatial scales.

- Emissions Scenario: Estimations of the concentration of greenhouse gases in the atmosphere in the future.
- Ensemble: A group of climate models used for climate projections.
- Frost Days: The number of days per year when the coldest temperature of the day is lower than 0°C.
- Freeze-Thaw Cycle: The number of days per year or winter when the air temperature fluctuates between freezing and non-freezing temperatures.
- Greenhouse Effect: The warming of the surface of the earth and troposphere caused by greenhouses gases.
- Greenhouse Gas: Any of the various gaseous compounds (such as carbon dioxide or methane) that absorb infrared radiation, trap heat in the atmosphere, and contribute to the greenhouse effect.
- Hazard: Something that has the potential to cause harm to humans, their environment, their livelihoods, or their property and resources.
- Heat Waves: When the temperature exceeds 30°C for at least three days in a row.
- Intensity Duration Frequency (IDF): Representations of the probability that a given average rainfall intensity will occur in a given period of time.
- Mitigation: Reducing and avoiding emissions of greenhouse gases into the atmosphere to limit the magnitude of future climate impacts.
- Precipitation: Any water falling from the sky to the ground and can include rain, snow, hail, mist, or sleet.
- Projection: A forecast of a future situation.
- Representative Concentration Pathways: A set of four emissions scenarios currently used by the Intergovernmental Panel on Climate Change.
- Tropical Nights: When the lowest temperature of the days does not go below 20°C.
- Uncertainty: A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable.
- Variability: The short term changes in climate that take place over months, seasons, and years, but do not influence the greater trends.

- Vulnerability: Propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
- Weather: The conditions in the air at a particular moment in time.
- Wind Gust: A brief increase in the speed of the wind, usually lasting less than 20 seconds.

Acronyms

- ACT: Adaptation to Climate Change Team.
- DMAF: Disaster Mitigation and Adaptation Fund.
- FCM: Federation of Canadian Municipalities.
- GCoM: Global Covenant of Mayors
- ICLEI: International Council for Local Environmental Initiatives (formerly, currently ‘Local Governments for Sustainability’).
- IPCC: Intergovernmental Panel on Climate Change.
- PIEVC: Public Infrastructure Engineering Vulnerability Committee.
- RCP: Representative Concentration Pathway.

Introduction

Climate change is one of the most complex challenges of our time, and will have long-lasting effects on our environment, infrastructure, and communities. The City of Kingston has been taking steps to assess and manage local climate impacts for more than a decade. The 2014 Climate Action Plan outlined priority future conditions, top climate risks and high-level adaptation measures for the City and community in addition to identifying mitigation strategies to reduce GHG emissions. Through this refreshed Climate Leadership Plan, the City of Kingston is advancing efforts to reduce greenhouse gas emissions and transition to a low carbon, climate resilient community.

As part of the Climate Leadership Plan project, a Baseline Vulnerability and Risk Assessment was completed. The purpose of the assessment was to identify priority vulnerabilities and risks to critical municipal infrastructure, services, and to the community more broadly. Based on the results, next steps and best practices were identified for the City and community to reduce risks and improve resilience of its critical systems. An adaptation and resilience framework is also provided to enable other stakeholders to undertake their own vulnerability and risk assessments and identify adaptation measures for their own sectors and systems.

Scope and Limitations

The Baseline Vulnerability and Risk Assessment is intended to provide the City with a high level picture of various types of climate impacts across its assets, services, and the community. The impacts that were assessed ranged from health and safety risks, ecological shifts, and impacts to built assets. This assessment was completed in alignment with the ISO Standard for Risk Management and ICLEI (International Council for Local Environmental Initiatives) Canada's Building Adaptive and Resilient Communities Framework, the leading climate adaptation processes for Canadian municipalities. These frameworks provide guidance on holistic risk assessments that cover multiple assets and systems, as opposed to detailed infrastructure risk assessments which tend to focus on a small number of assets or asset systems.

Climate risks were evaluated and prioritized based on future climate projections obtained from publicly available data sources, literature review and expertise from WSP Canada's project team. Local expertise and community knowledge were critical to the assessment and were gathered through the Adaptation Technical Team, made up of City and community stakeholders. This interdisciplinary team represents some of the most critical infrastructure, services and stakeholders within the community, allowing for diverse and experienced input. The outcomes of the Vulnerability and Risk Assessment provide a wide range of potential climate impacts in the City, but is not be an exhaustive list of all potential hazards, risks and consequences that may occur as a result of climate change. Factors such as climate variability, data uncertainty, and complex and interdependent systems within communities can make it hard to accurately predict when and how risks will occur. Further commentary on the scope and limitations of the methodology can be found in the Methodology section of this report. Regardless of the limitations above, climate adaptation is a priority and the results of the Baseline Vulnerability and Risk Assessment Report provide the City with key focus areas and potential next steps to address pressing risks to assets and systems.

Climate Change

What is climate change?

Climate change refers to any change in the mean or variability of the earth's climate over time. The global climate system of the earth is moderated by the Greenhouse Effect, which acts like the glass in a greenhouse to retain temperature and heat in the atmosphere. When the energy from the sun hits the earth, some of it is redirected to space, some of it is absorbed by the earth, and some is trapped by greenhouse gases in the atmosphere. Without these gases to trap that heat, it is estimated that the temperature of the earth would be -18°C and life would not be able to flourish. When the concentration of these gasses increases, too much heat is trapped in the atmosphere and the temperature of the earth begins to rise. This increase in concentration of greenhouse gases can be caused by human activities (known as 'anthropogenic') such as altering land use or emitting greenhouse gases, or earth processes such as volcanic eruptions and variations in solar cycles, or other natural processes in the climate system.

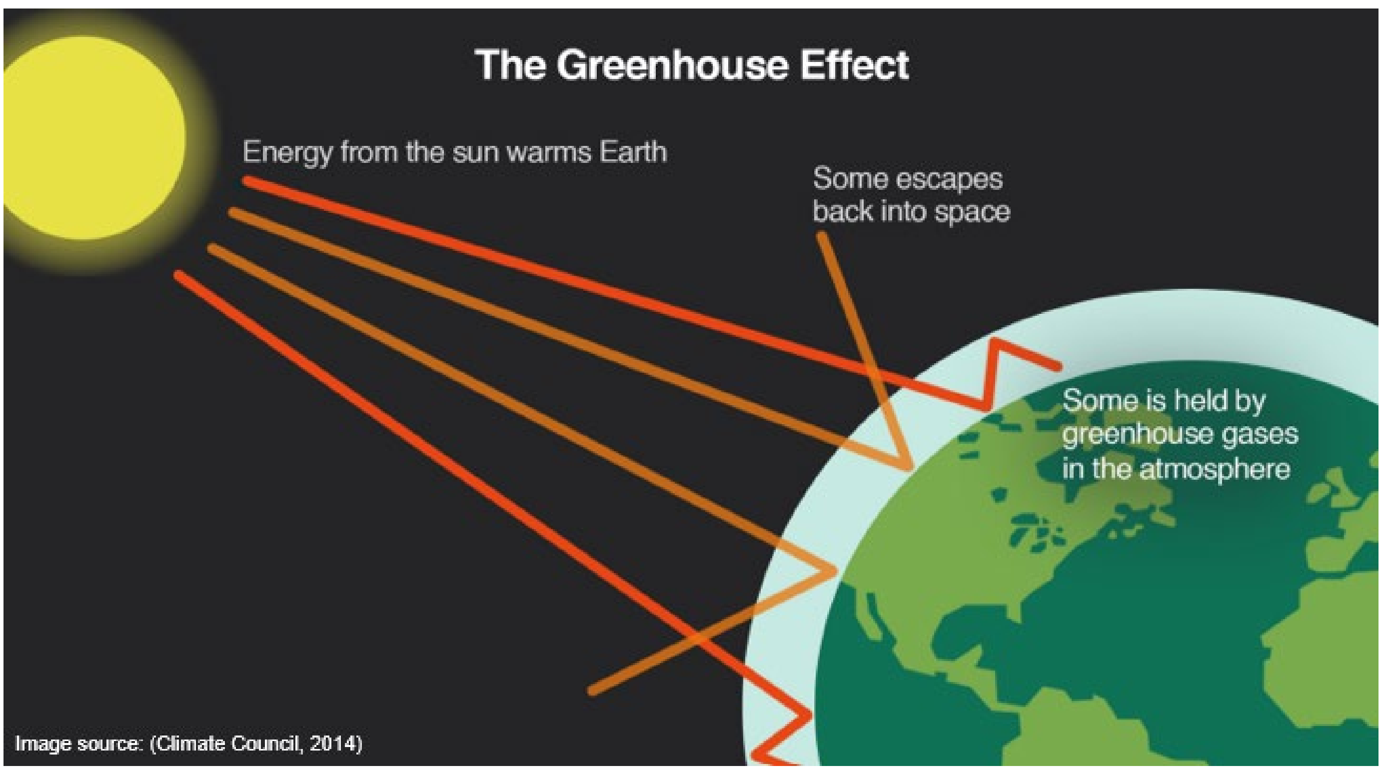


Figure 1: The Greenhouse Effect

What is the difference between climate and weather?

The terms climate and weather are often used interchangeably in daily discussions, but they do not mean the same thing. ‘Weather’ refers to the conditions in the air at a particular moment in time. If someone says that is it currently hot or raining, they are talking about the weather. Climate is the average weather conditions for an area over a long period of time. Typically, this period lasts a minimum of 30 years, but can span as long as thousands of years. If someone said that Kingston has hot humid summers, they are referring to the climate of the community because they are talking about the average conditions seen during that time.

What is the difference between adaptation and mitigation?

Adaptation is the process of adjustment to actual or expected climate and its effects. Adaptation can include moderating potential harm or exploiting the beneficial opportunities of a changing climate.

Mitigation is human intervention to reduce the sources or enhance the sinks of greenhouses gases, to reduce their concentration in the atmosphere

How do we project future climate?

Future climate is projected with the help of climate models. Climate models forecast future climate using equations that represent the physical processes and interactions that drive the Earth’s climate including considerations of the atmosphere, oceans, land surface, and ice. Models can range from smaller regional simulations to large scale global models, and often require the use of a supercomputer to run. As technology has advanced, these models have increased in complexity, growing from simple interactions of CO_2, rain, and temperature in the 1970s to include ice, oceans, volcanic activity, aerosols, the carbon cycle, river, and interactive vegetation today.

In order to project future conditions, climate models need inputs known as emissions scenarios which are estimations of the concentration of greenhouse gases in the atmosphere in the future. Emissions scenarios are based on storylines of how we think conditions will change in the upcoming decades. This includes estimations of how technology will advance, what kind of energy humans will rely on, how land use will change, and how large and affluent the global population will become. In modern modeling, four common emissions scenarios have been developed known as representative concentration pathways (RCPs). These RCPs range from the most optimistic scenario, RCP2.6, known as “peak and decline” which assumes stringent and immediate reductions in greenhouse gas emissions, to RCP8.5, known as “business-as-usual” which assumes limited mitigative effort, rapid population growth, and high fossil-fuel energy demand. For the purposes of this assessment, wherever possible, future climate projections based on RCP8.5 have been used to maintain a conservative approach to risk management.

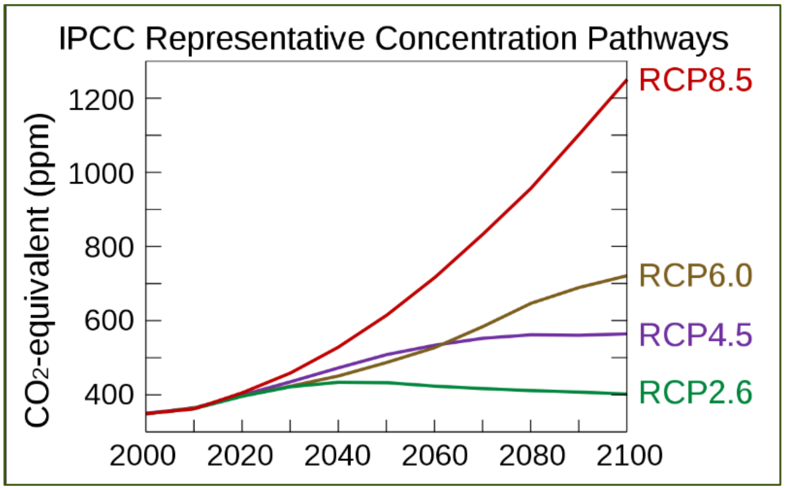


Figure 2: RCP pathways

Data from climate models is often downscaled. Downscaling is when the information from larger climate models, such as global climate models, is used to make predictions at smaller spatial scales. Downscaling helps take into account regional features that affect local climate such as rivers, lakes, and mountains. When modeling future climate there will always be a degree of uncertainty. Uncertainty is the idea that there is an incomplete amount of knowledge for a topic. This may be the result of a lack of information, disagreement, imprecise data, or if a system is too complex or unknown to perfectly understand. When considering future projections, there will always be a certain level of uncertainty for several reasons: global climate systems are incredibly complex, there isn't enough historical data, lack of computing power, and limitations of human understanding and assumptions.

What are climate ensembles, trends, and variability?

Often, several different climate models are run together to create an ensemble. An ensemble is a group of climate models used for climate projections. This method produces a larger range of possibilities and can help estimate the certainty of the results. Climate trends are the directions in which the climate is projected to change. For example, a climate trend could include an increase in temperature or decrease in precipitation.

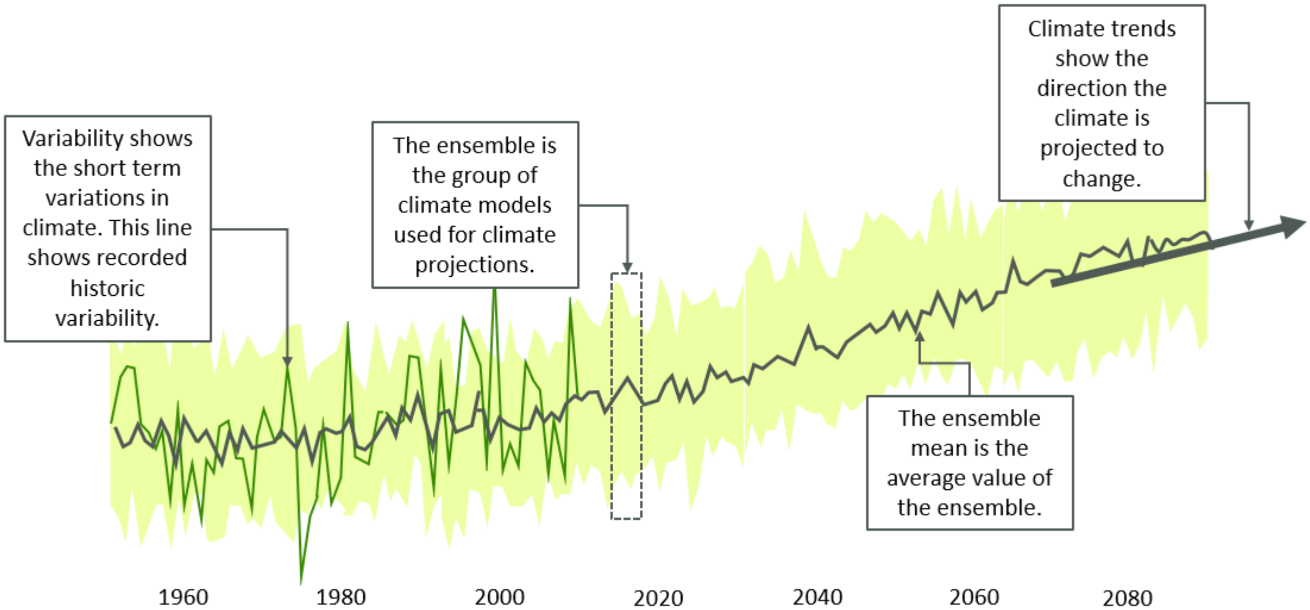


Figure 3 Descriptor of climate ensembles, variability, and trends

Climate variability represents the short-term changes in climate that take place over months, seasons, and years, but do not influence the greater trends. For example, an area which is accustomed to very cold winters may experience a series of mild winters, or a mild winter followed by an unusually severe winter. Variability is the result of natural, large scale features of climate and, in isolation, does not reflect longer term climate change.

What climate data was used for this assessment?

International climatology practices typically use 30-year averaging periods when reporting or modelling climate data. Historical data sets of observed conditions are used to provide a baseline to assess future trends such as 1961 – 1990, 1976-2005 or 1981 – 2010. For modelling future conditions, the “2050s” indicate the average of the 2041-2070 period. In this period, it is likely that many infrastructure, land use and urban design decisions will still be in place.

Future climate projections for 2050s are based on the output of climate models, using the RCP8.5 scenario (a high emissions scenario that projects a high-risk future). This scenario was selected based on global emission trends identified by the IPCC over the past several decades up to the most recent reporting year of many nations around the world (2019). Additional data sources included historical weather and climate records, scientific literature, City documentation, news articles, and workshop and public input. More information is available in the Appendix.

Temperature Trends

Between 1948 and 2008, the average annual temperature in Ontario increased by approximately 1.5 °C. By the 2050s, the City of Kingston is projected to see an increase in average annual temperature of 2.2°C as compared to historical baseline (1976-2005). By the 2080s, this increase is projected to be 4.4°C, with the greatest changes happening during the winter season. Future projections show increases in all temperature-related variables including the number of days above 30°C per year, the number and length of heat waves per year, the longest spell of days above 30°C, and the number of annual cooling degree-days. In upcoming decades, the City of Kingston is likely going to see hotter conditions happening more frequently and at greater magnitudes.

Average winter temperatures are projected to increase from -6.0°C to -3.7°C in the 2050s and -1.2°C in the 2080s. In winter, there is a projected decrease in the number of days colder than -15°C and frost days, and an increase in the length of the frost-free seasons and winter thaw days. The number of freeze-thaw cycles is projected to decrease annually but become more concentrated in the winter months, and may occur more rapidly over shorter periods of time. Kingston can expect to see warmer and shorter winters in the upcoming decades, however annual variability can still occur, and cold conditions will not disappear entirely. A full list of climate projections can be found in the Appendix.

A freeze-thaw cycle is when a day's highest temperature is above 0°C, and its lowest temperature is below 0°C. Freeze-thawing can be very destructive to infrastructure and buildings because if water infiltrates a crack in liquid form, and then freezes, the expansion into ice can push the crack apart, making it a little bit larger. When this happens continuously there can be significant damage, such as potholes in roads and degraded bridges.

Winter thaw days are the number of days in which the four warmest hours of the day are above 0°C.

Cooling degree-days are a measure of how hot a day's peak temperature is above 18°C. If a day reaches 22°C, it has four cooling degree-days. Annual cooling degree-days are the sum off all the daily cooling degree-days in a year. This is an indicator used to quantify future demands for energy to cool buildings.

Heats waves are when at least three days in a row the temperature reaches t 30°C.

Precipitation Trends

What is precipitation?

Precipitation is any water falling from the sky to the ground and can include rain, snow, hail, mist, or sleet.

Precipitation in Kingston is projected to increase in amount, be more intense, and more variable. The average annual precipitation in the City of Kingston is projected to increase by 10% by the 2080s. This could mean the City will receive an additional 96 mm of precipitation per year. Individual rain events will likely increase in intensity, which means more precipitation falling in a shorter time period. For example, 1-hour storms that historically saw 42 mm of water are projected to increase to 52 mm of water by the 2080s.

There is also an anticipated increase in drought conditions for the summer months. While summer precipitation is projected to increase slightly by 2 mm by the 2080s, summer temperatures are also projected to increase by 4.3°C during that same time period. This combination is projected to lead to a decrease in the amount of moisture staying on or in the ground, which may lead to more drought conditions.

As winter temperatures get warmer it is likely that winter precipitation will begin to shift from snow to rain. Snow will likely start later in the year, end earlier in spring, and more often occur as rain during winter. It could also mean that snow may be wetter and heavier. Future projections used for the Vulnerability and Risk Assessment only show the changes in average conditions. It is still possible that there could be intense snowfall events and years with significant snow accumulation.

The amount of freezing rain that the City experiences annually is projected to increase significantly into the future. The City has historically experienced one point five freezing rain events lasting over six hours per year and this is projected to increased by up to 60% by the end of the century.

Storm Activity Trends

As atmospheric conditions change and the air temperature rises, storm activity is likely to increase. Strong wind gusts (90 km/hr), which historically occur <1 times per year, are projected to increase by 15% by the 2080s. Lightning events, which can also be correlated with temperatures, are projected to increase by up to 50% by the 2080s. Storm activity is one of the more challenging climate change impacts to model and estimate, due to the complex nature of the climate variables involved. Rain, thunder, and snowstorms are all also likely to increase in frequency and intensity, although the projection data is more uncertain.

Forest Fire Trends

While Kingston is largely an urbanized area, it is surrounded by forests to the north, east, and west within south eastern Ontario. Large wildfires in other parts of the province or neighbouring provinces such as Manitoba and Quebec can bring smoke from hundreds of kilometers away, impacting the health and safety of residents. As summer conditions get hotter and drier, the likelihood of forest fires in Ontario are projected to increase by 2.5 by the 2050s.

Additional projection and trend data are available in the Appendix.

Summary of Prioritized Risks

The Vulnerability and Risk Assessment resulted in a list of 41 prioritized climate impacts and three opportunities relevant to the City and community. Four impacts scored very high and eight scored high (overall prioritized risk score). The very high and high risk impacts are described below.

Impact 1: Increase in vector-borne diseases

Shifts in temperature and precipitation regimes are already causing the habitats of disease vectors, such as ticks, to migrate north. This is anticipated to worsen in the future as temperatures continue to rise. The Kingston, Frontenac and Lennox Addington (KFL&A) Public Health region is already sensitive to vector-borne disease risks. In 2017 the region had the highest confirmed number of human Lyme disease cases across the province. Vector-borne diseases can pose a serious threat to the health and safety of the community if not addressed. Increasing cases can also cause a decline in the use of parks and recreational areas and lost productivity amongst the affected labour force.

There are several awareness and prevention measures already in place in the region, which can be extended in the community including education, pesticide use, and treatment supplies and awareness.

Impact 2: Increase in frequency and magnitude of combined sewer overflows (CSO), infiltration of storm systems, and sanitary sewer overcapacity causing overcapacity of wastewater treatment plants, pumping stations, and localized flooding

Precipitation is increasing in frequency and intensity, which may worsen the City’s existing challenges with combined sewer overflows in Kingston. The sewer system was designed using historical climate information, and some infrastructure is over 50 years old, which can mean it was not designed to withstand future conditions. The City has already experienced extensive CSO impacts, road washouts and flooding, particularly in older areas of the downtown core, and waterfront roads such as King Street and Bath Road. This impact is compounded by earlier thaw, melting snow or other storm events which put greater demand on the drainage system. Overcapacity storm/sanitary and water treatment infrastructure is a costly problem that can also interrupt service to the community and block access for emergency respondents in cases of severe road washouts. This impact can also affect water quality particularly in receiving water bodies.

The City is undertaking projects to separate combined sewers and reduce flood risk for older assets. However, the impact is expected to increase under climate change and additional monitoring, upgrades or flood mitigation measures may be needed as precipitation and storms intensify.

Impact 3: Increased erosion and destabilization of riverbanks causing damage to City and community infrastructure

Increasing storm activity, high water levels, and high intensity rain events are increasing erosion and infrastructure damage along the Lake Ontario shoreline. Critical City assets and infrastructure, marina infrastructure, and homes located near the shoreline have been damaged by erosion, including a significant older trunk sewer that serves downtown Kingston. The City's water and wastewater treatment plants situated on the shoreline have also been damaged by erosion, which could result in increased risks and high costs if not addressed. Projects have been initiated to protect vulnerable areas of shoreline, but consistent monitoring and management of erosion impacts will be important.

Impact 4: Increase in interruptions to energy and power supply

Extreme heat, storms, icing, and freezing rain all increase the likelihood of brownouts and blackouts. Power outages have disrupted critical infrastructure in the past, such as pumping stations and water treatment plants, which can have high repair costs and cause environmental and social risks to the community. Residential power outages can have dangerous consequences for public health and safety, particularly if compounded by extreme heat or a winter storm. The City should continue to ensure adequate back up power at critical infrastructure (planning for multiple compounding events), buildings and communications networks, and support residents who are vulnerable to dangerous conditions caused by power outages.

Impact 5: Increase in invasive species

Shifts in temperature and precipitation regimes, along with human activities, have already caused thousands of types of invasive species to spread north. Public survey participants noted that they had observed the spread of invasive species as well as tree and plant diseases in the past. Invasive species can cause severe damage to local ecosystems and biodiversity by outcompeting or killing native plants. Preventative measures such as public education and conservation work can help reduce the risk early.

Impact 6: Increased demand for cooling in the summer months

As average and extreme summer temperatures increase, so does the need for cooling. Residents who are low income, elderly, or living in older homes or rural areas may not be able to access adequate cooling in future temperatures. The City has already begun to improve cooling capacity in facilities to mitigate this risk, however older buildings and homes will face challenges as temperatures rise. This risk exemplifies the complex relationship between emissions reduction and adaptation. As more buildings move away from fossil fuels for heating and cooling, grid demand may increase. More grid capacity is needed to accommodate both the increased cooling demand and the transition to a low carbon society.

Impact 7: Increased heat stress or damage to agricultural crops and livestock and rural water services

Local agriculture provides economic and cultural benefits to the community in Kingston. Southeastern Ontario has already experienced crop stress and crop loss due to heat, drought, fluctuating temperatures, and severe weather in recent years. Projections indicate these trends will worsen in upcoming decades. While they are considered an inherently adaptive sector, the agricultural community is still sensitive to climate change as much of their livelihood depends on healthy crops and livestock. Increased heat stress on crops can also hamper Kingston's ongoing efforts to increase local food production and urban agriculture.

In addition, more pronounced drought conditions can limit the water supply available for rural communities and residents who rely on water for private wells. These communities may also be more vulnerable to this impact as a result of the dependence on well water and proximity to municipal infrastructure and resources.

Impact 8: Increase in damage and/or disruption of businesses, offices, and industrial and commercial properties and operations

As storm activity and precipitation become more frequent and intense, more businesses may experience flooding, damage or disruption to property or supply chains. Businesses that are particularly sensitive are those by the waterfront, in areas prone to flooding, or those with less resilient supply chains. During past storm and flood events, City staff and community stakeholders observed that adaptive capacity was low – suggesting that climate risks are not consistently or comprehensively considered in operations or business continuity planning.

Impact 9: Increase in temperature and water-related stress on parks, trees, vegetation, and personal gardens

Summers are expected to become hotter and drier, which can put stress on natural assets such as trees, vegetation, wetlands, parks, and watercourses. Heat and water stress on natural assets can diminish their overall health and make them less resilient to severe storms, flooding, drought, or high temperatures. Areas particularly sensitive include wetlands, creeks, and streams. Groundwater levels may also diminish, having a compounding effect on water supply for those who rely on wells, located in rural areas.

The majority of public survey respondents said that they had experienced stress on vegetation, or seen it in parks. Many residents even cited loss of crops, plantings or home gardens due to poor conditions. Sports fields, public parks, and the overall tree canopy within Kingston may require additional watering – which can be costly, negatively impact emissions reduction, and may exacerbate risks if water restrictions are put in place.

Impact 10: Increase in basement flooding and associated damage to homes and properties

Damage caused by flooding and severe weather is becoming more frequent and costly across Canada. From 2010 to 2019, insurance payouts in Canada for catastrophic losses from natural disasters exceeded $1 billion per year. In the public survey, a high percentage of respondents noted that they had experienced damage to their property because of storms and flooding. About one in five respondents noted that they had had difficulty obtaining flood insurance. As climate hazards intensify, homeowners in high-risk zones (e.g. neighbourhoods with older stormwater infrastructure) who endure repeated damages may be priced out of affordable and effective insurance or have to pay more for repairs.

Impact 11: Higher demand for emergency response and community support services

Increases in severe weather events such as storms, strong winds, extreme heat, or fire will put additional stress on emergency response providers and community services. Climate impacts can be complex and interdependent, occurring at the same time in different parts of the city. Damage or failure of critical infrastructure in one place can cause cascading health and safety risks across the community, especially if emergency response efforts are strained. Responding to emergencies in rural areas of Kingston may exacerbate demand. There is also a long term need for community support services to assist the growing number of residents who will be exposed to climate hazards as they intensify.

Impact 12: Increase in frequency and magnitude of road and culvert washouts and blockages

Changing precipitation intensities and storm events is likely to increase the magnitude of road and culvert washouts. Areas with combined storm and sanitary sewers or older below ground infrastructure are especially vulnerable. Certain roads, such as King Street and Bath Road, have already experienced road washouts driven by heavy rainfall events and early thaws. Overland flooding has also impacted other roadways, bridges, and culvert infrastructure in Kingston, causing disruptions to the transportation systems, additional costs of repair, and health and safety hazards.

Note: The full list of risks scores for all climate change impacts are available in the Appendix. For each climate impact (i.e. sensitivity, adaptive capacity, etc.) there is an accompanying rationale.

Compounding Impacts and Risks

Compounding risks is when two or more risks occur simultaneously after the other, often increasing the impact. While climate data and the risk assessment process are geared towards single risks, it is important to consider the impact of multiple hazards at one time. For example:

- A power outage followed by a heat wave could significantly increase the percentage of the community that is vulnerable to heat-related health impacts;
- A large flooding, storm, or fire event during a pandemic could greatly limit evacuation and temporary shelter options; and
- A snowstorm followed by sudden high temperatures may overload both the storm capacity of the infrastructure and the resources available to help.

Climate Change Adaptation and Resilience

The Vulnerability and Risk Assessment helped identify priority climate impacts and focus areas in the City and community. Preliminary recommendations and best practices to address top risks and vulnerabilities are discussed below.

Climate adaptation takes many forms, ranging from operational and procedural changes, to policies and regulations, assessments or studies, and physical interventions. Well-rounded adaptation requires a blend of all types of actions, with various departments and community organizations taking the lead on implementation.

Types of adaptation actions can include:

- Studies and assessments: Projects that investigate climate change risks and/or potential adaptation measures. Examples include climate vulnerability and risk assessments, risk mapping projects, policy review studies, financing studies, etc.
- Policy and plans: Plans and strategies set forward thinking adaptation goals and identify actions to address climate risks. Policy can set regulatory requirements for climate adaptation and risk management within municipal processes and decision-making.
- Physical / technical solutions: Targeted, asset-specific measures that reduce climate risks and adapt built assets or natural systems to climate risks. Examples include improving cooling capacity in a facility, installing a sump pump to prevent flooding, or raising a bridge deck elevation to minimize flood exposure.

- Mainstreaming and enabling actions: Enabling actions are measures that build capacity and foster continued integration and monitoring of adaptation in city business and decision-making (ICLEI Canada, 2020). Enabling actions help to institutionalize the process of adaptation and climate risk management.

The following considerations can support the City and community in addressing top climate risks.

Critical Municipal Infrastructure

Reduce climate risks and vulnerabilities to critical municipal infrastructure.

Recommendation: Conduct a detailed vulnerability and risk assessment on critical municipal assets. Identify risk interdependencies within critical infrastructure and service delivery.

Potential focus area (if applicable):

- Water and wastewater treatment facilities, shoreline and marine infrastructure, heritage facilities, major roadways, and transportation corridors such as Bath Road, King Street and Princess Street. Consider interdependent risks such as power outages, flooding, and blocked access for emergency services. One particularly vulnerable asset is a major trunk sewer through the oldest part of the city. The trunk sewer handles 60-80% of the sewer volume from the downtown core. It was installed in the 1950s and is very close to the lake. Erosion in this area has previously caused some major damage. Major issues have been avoided to date, although there are ongoing concerns.

Resources and/or implementation tools:

- Detailed infrastructure risk assessment frameworks such as Infrastructure Canada Climate Lens (based on principles from ISO 31 000 for risk management).
- The PIEVC (Public Infrastructure Engineering Vulnerability Committee) Protocol developed by Engineers Canada may be used for asset-specific assessments.

Recommendation: Create a geospatial risk database and map of current and future climate risks across Kingston.

Potential focus area (if applicable):

- Citywide maps can display a wide range of data and identify hotspots such as vulnerable rural populations, shoreline and waterfront parks, recreation areas, and critical infrastructure.

Resources and/or implementation tools:

- Observe best practices in risk mapping such as Vancouver Coastal Health, City of Calgary, City of Montreal.
- Consider data visualization tools such as ESRI and Power BI.
- Leverage existing resources including Census data, asset condition data, and flood mapping to identify hot spots that are more vulnerable to current and future climate change risks.

Recommendation: Continue to implement flood mitigation measures for critical infrastructure and roadways.

Potential focus area (if applicable):

- Vulnerable areas noted by City staff include Bath Road, King Street, Princess Street, waterfront parks, and other facilities adjacent to the water including above and below ground infrastructure. The infrastructure was designed with precipitation threshold standards (as per code) and the majority of Kingston's water treatment plants were upgraded (or are currently being upgraded) in recent years; however increasing impacts such as erosion, wind, heavy precipitation and flooding will accelerate the weathering of the infrastructure; breaks and bypasses have increased in some areas in recent years due to severe weather. The interrelated nature of flood causes can lead to compounding flood risks such as combined sewer overflow and over-capacity storm water infrastructure at the site (e.g. King Street).

Resources and/or implementation tools:

- Utilize existing flood incident logs to identify hotspots, consider future flood risk mapping.

Recommendation: Protect shoreline assets from erosion and flooding.

Potential focus area (if applicable):

- Vulnerable areas include King Street, Princess Street, waterfront parks and trails, marinas, and City facilities (e.g. water and wastewater treatment plants) along the shoreline. The Adaptation Team noted that there are a number of assets right next to the shoreline which have been impacted by high water levels or erosion.

Resources and/or implementation tools:

- Leverage City staff knowledge.

Recommendation: Improve inspection procedures for high-risk infrastructure to monitor damage from changing temperatures, freeze-thaw patterns, and extreme events.

Potential focus area (if applicable):

- Prioritize older transportation infrastructure (i.e. East and West entrances to the City, older downtown roads), water mains, etc. Water and wastewater treatment plants along the waterfront could also be prioritized for more detailed climate risk monitoring.

Resources and/or implementation tools:

- Leverage City staff knowledge.

Recommendation: Update operations, maintenance, monitoring and long-term planning to proactively address changing freeze-thaw cycles, erosion and flooding impacts.

Potential focus area (if applicable):

- Prioritize older transportation infrastructure, major roadways, and critical water and wastewater treatment infrastructure. Include green infrastructure such as parks, trees, and natural areas.

Resources and/or implementation tools:

- Leverage City staff knowledge.

Recommendation: Continue to update asset management plan and lifecycle plans to account for future climate change projections and accelerated degradation of assets, ensuring maintenance programs include climate adaptation.

Potential focus area (if applicable):

- All City assets, including green infrastructure so that the City can consider future climate impacts on its natural assets.

Resources and/or implementation tools:

- Climate Change and Asset Management resources from Federation of Canadian Municipalities (FCM) and Asset Management Ontario.
- Natural Asset Management resources from Federation of Canadian Municipalities and Municipal Natural Assets Initiative.

Recommendation: Pursue zero-emissions or low-carbon back-up power in critical infrastructure.

Potential focus area (if applicable):

- Most critical infrastructure is already equipped with back up power. The City could prioritize additional back up power for sites that frequently experience power outages, as well as upgrading sites with existing fossil fuel back up power, and facilities without any back up power.

Resources and/or implementation tools:

- Leverage City staff and local utilities knowledge.

Other City and Community Infrastructure

Protect community infrastructure and its users from climate impacts caused by extreme heat, severe storms, heavy precipitation, and flooding.

Recommendation: Reduce risks to active transportation infrastructure (and users) caused by extreme heat, flooding, and severe weather damage.

Focus areas:

- The Adaptation Technical Team and community stakeholders flagged waterfront parks and trails as priority areas where trails have been previously damaged or closed due to storm damage and flooding. Priority areas could include Lake Ontario Park or Breakwater Park.

Resources and/or implementation tools:

- Leverage City staff knowledge.

Recommendation: Prepare for increased demand for outdoor and waterfront recreation. Protect users from health and safety risks due to higher temperatures, flooding, and severe weather.

Focus areas:

- Monitor and educate community on health and safety risks at waterfront and beach areas (such as algae and bacteria).
- Increase access to cooling (i.e. shade trees, covered structures, water fountains) in existing parks.

Resources and/or implementation tools:

- Leverage partnerships with KFL&A Public Health.

Recommendation: Continue to monitor and remove hazard trees/branches damaged by Emerald Ash Borer or other pests.

Focus areas:

- Prioritize known infested ash tree hotspots such as City Park, Collins Bay, etc.

Resources and/or implementation tools:

- Utilize existing City Ash Tree - Treatment and Removal Mapping.

Recommendation: Build capacity of residents to reduce basement flood risk

Focus areas:

- Prioritize residential streets or neighborhoods that have flooded more than once in the past and neighborhoods with older stormwater infrastructure.

Resources and/or implementation tools:

- Intact Centre Home Flood Protection Program.

Recommendation: Identify water conservation and drought management strategies

Focus areas:

- Target rural and hamlet residents and residents who are dependent on well water. Residents living in northern Kingston were identified as having potentially heightened vulnerability due to demographic factors like age and income.

Resources and/or implementation tools:

- Leverage knowledge of Cataraqui Region Conservation Authority and neighboring communities.

Mainstreaming and Enabling Climate Adaptation

Improve City staff understanding of climate risks and resilience priorities and mainstream climate change adaptation into City decision-making.

Recommendation: Consider developing a Climate Adaptation and Resilience Strategy and Implementation Plan.

Focus areas:

- Utilize the results of the Vulnerability and Risk Assessment to identify short, medium, and long-term adaptation actions to adapt City infrastructure and services. Prioritize top risk areas such as flooding and road washouts, combined sewer overflow, heat-related risks, shoreline erosion, etc.

Resources and/or implementation tools:

- ICLEI Canada programs and resources such as the Building Adaptive and Resilient Communities Network, C40 Climate Action Planning.

Recommendation: Ensure emergency response plans and continuity plans include current and future climate-related risks.

Focus areas:

- Ensure emergency plans for critical infrastructure and operations consider climate hazards. Plan for scenarios where interdependent risks occur, such as concurrent flooding, heat and storm damage, or hazards occurring in multiple areas of the city at once. Develop specific response plans for vulnerable populations such as rural communities or aging population. Northern and rural areas of Kingston have been identified as vulnerable.

Resources and/or implementation tools:

- Make use of incident registries to document climate impacts, including interconnected and cascading climate impacts (e.g. where one event such as a power outage or ice storm triggered other related issues).
- Engage the emergency management community on understanding and preparing for climate risks.
- Build on existing emergency management routes and maps to ensure response plans are effective in scenarios with heavy precipitation and potential flooding.

Recommendation: Educate City staff on climate change impacts and adaptation measures.

Focus areas:

- Educate staff in all departments to increase understanding of climate change impacts to facilities, infrastructure, planning, environment, etc.

Resources and/or implementation tools:

- Natural Resources Canada, ICLEI Canada, the Adaptation to Climate Change Team (ACT at Simon Fraser University), and Federation of Canadian Municipalities provide several resources on climate change adaptation planning available for free on their websites (hyperlinks not provided as to prevent broken links within this document).

Recommendation: Develop a municipal “Climate Lens” to formalize how climate risks and resilience are embedded into municipal decision making. For example, the Climate Lens could require that climate risks and resilience measures are documented in planning policy, master plans, and planning and development decisions.

Focus areas:

- Prioritize the application of a Climate Lens on large scale and long lasting municipal investments and planning decisions to avoid lock in of climate vulnerabilities. For example, climate risk assessments could be required for large capital projects or development approvals.

Resources and/or implementation tools:

- Investigate municipal best practices in climate lenses for decision making such as the Cities of Ottawa, Windsor, Victoria, and Calgary.
- Consider lessons learned from the City’s recent use of Infrastructure Canada’s Climate Lens for Disaster Mitigation and Adaptation Fund applications and for the new Kingston East Community Centre.

Recommendation: Disclose financial risk and adaptation return on investment. Consider calculating ‘cost of doing nothing’ for critical infrastructure adaptation investments.

Focus areas:

- Prioritize exercises to cost climate risks and adaptation return on investment for critical municipal infrastructure and risk hotspots in Kingston such as water and wastewater treatment facilities, flood-prone roadways, heritage assets, and shoreline and waterfront infrastructure.

Resources and/or implementation tools:

- Investigate municipal best practices in climate risk valuation and disclosure. The Cities of Windsor, Toronto, Montreal, Vancouver, and Calgary are pursuing similar programs.

Consult publications and resources such as:

- Essential Guide to Valuations and Climate Change: a framework to assess the impact of climate change on business valuations released by the Accounting for Sustainability CFO leadership network (A4S);
- Investing in Canada’s Future: The Cost of Climate Adaptation at the Local Level (FCM and Insurance Bureau of Canada);

- Credit Valley Conservation's Risk and Return on Investment Tool; and
- Resources on Task Force for Climate-related Financial Disclosure for cities (Chartered Professional Accountants of Canada, Canadian Urban Sustainability Practitioners: CUSP Network).

Communitywide Priorities

Support measures to enhance resilience across the whole community.

Recommendation: Continue to educate students, residents, and tourists on increasing risk of pests and vector-borne illnesses.

Focus Area:

- Prioritize locally relevant issues such as Lyme disease.

Resources and/or implementation tools:

- Leverage partnerships with KFL&A Public Health.

Recommendation: Support the agricultural community in adapting to climate change and increase equitable access to local food in Kingston.

Focus Area:

- Community stakeholders identified the need to prioritize local food producers from Kingston and surrounding growers in Ontario.
- Focus areas include supporting businesses and institutions in increasing and tracking local food purchases. Identify ways to support young farmers in entering the local food system in Kingston.

Resources and/or implementation tools:

- Leverage partnerships with Ontario Federation of Agriculture, local businesses, Tourism Kingston, and community food organizations such as Sun Harvest and Loving Spoonful.

Recommendation: Explore the creation of resilience hubs that provide resources and support during climate-related events such as heat waves, power outages, and floods.

Focus Area:

- Leverage existing facilities and community centres. Consider locating hubs in communities and neighbourhoods where vulnerable populations live.

Resources and/or implementation tools:

- Look to municipal best practices such as Victoria and Vancouver.

Recommendation: Encourage businesses and community organizations to complete climate vulnerability and risk assessments.

Focus Area:

- Prioritize organizations and sectors that may be adversely impacted by changing climate or severe weather, including the agriculture sector, transportation service providers (e.g. ferry), post-secondary education institutions and school boards, tourism-dependent organizations, local restaurants, etc.

Resources and/or implementation tools:

- Publicly available climate data sources such as Climate Atlas of Canada and Canada's Changing Climate Report.
- Free climate adaptation frameworks which can be tailored to the organizational context, such as ICLEI's Building Adaptive and Resilient Communities Framework, C40 Cities, community case studies.

Recommendation: Encourage businesses/community organizations to develop business continuity and/or climate adaptation plans.

Focus Area:

- Prioritize organizations and sectors that may be adversely impacted by changing climate or severe weather, including agriculture sector, transportation service providers (e.g. ferry), school boards, tourism-dependent organizations, local restaurants, etc.

Resources and/or implementation tools:

- Publicly available climate data sources such as Climate Atlas of Canada and Canada's Changing Climate Report.

- Free climate adaptation frameworks which can be tailored to the organizational context, such as ICLEI's Building Adaptive and Resilient Communities Framework, C40 Cities, community case studies.

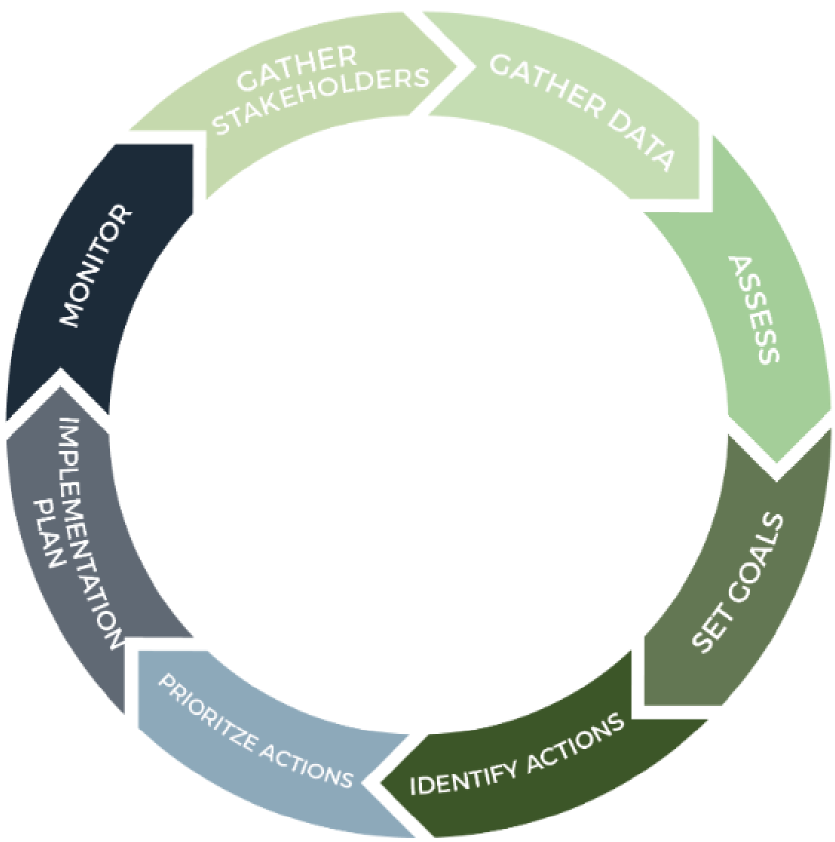
Existing Community Action

The City of Kingston has been working to adapt natural assets and infrastructure to the impacts of climate change and extreme weather. Highlights of recent or ongoing climate resilience initiatives include:

- Prioritizing sewer separation in areas susceptible to combined sewer overflow, with several sewer separation projects planned for the coming years;
- Improving cooling capacity in facilities and added redundancy in cooling systems to public facilities for public cooling centres;
- Monitoring and managing erosion in vulnerable areas of shoreline, including a project to protect the Lake Ontario/Cataraqui River shoreline from erosion;
- Supporting basement flood protection through Utilities Kingston;
- Monitoring and raising awareness on vector borne illnesses such as Lyme disease; and
- Monitoring Emerald Ash Borer and hazard trees.

Community Climate Adaptation and Resilience Framework

Climate resilience is a collaborative effort that requires community organizations and businesses to understand and manage their climate risks. To support Kingston's organizations and businesses in measuring and managing climate impacts, a simple framework for Vulnerability and Risk Assessments and adaptation planning has been provided below. The framework is consistent with ICLEI Canada's Building Adaptive and Resilient Communities (BARC) Program and the C40 Climate Change Risks Assessment Guidance, both leading frameworks for adaptation in North American communities. The framework is also consistent with the climate risk assessment steps outlined in ISO Standard 31000 for Risk Management, can be aligned with Hazard Identification and Risk Assessment (HIRA), and can meet the requirements of the Global Covenant of Mayors (GCoM). Potential questions to consider, resources, and data sources are also highlighted.



Principles of Climate Adaptation and Resilience Planning

- Grounded in Equity: Climate change impacts different people, places and sectors unequally. Those that are disadvantaged by institutions and systems due to mobility status, gender, race, identity, location, etc. tend to be most vulnerable to climate change impacts. Identifying and including the voices that are most vulnerable to climate change impacts will help make sure that resilience measures are targeted where support is most needed.
- Iterative: Climate change impacts and future climate conditions will continue to change. Our resilience will evolve as the economy shifts and as communities grow and change. It is important to re-evaluate risks and measure progress on adaptation every few years to determine what has changed, what has been successful and where improvement is needed.
- Low carbon resilience: Where possible take a Low Carbon Resilience approach, positioning climate vulnerabilities and risks in the context of the societal transition away from fossil fuels. Doing so helps identify risks that could result from GHG reduction actions, and helps ensure that your adaptation solutions do not work against your emissions reductions efforts.
- Collaborative: Climate change affects infrastructure, people, financial systems and the natural environment. Including perspectives from all facets of an organization and representatives from different components of the business and community ensures that climate risks are captured holistically.

Community Adaptation and Resilience Framework

Step: Identify stakeholders to be involved in the process.

Description:

- Identify the stakeholders that may be affected by climate impacts. Also identify those who have a role in reducing climate risks and adaptation decision making, and invite them to be part of the adaptation planning process.

Questions to consider:

- What expertise is needed for me to understand the risks and vulnerabilities to my organization, assets or business?
- Who represents and understands the communities or customers that you work with?
- What leadership is needed to approve the process and give feedback on decisions and strategy?
- Are there any gaps in knowledge or perspectives missing such that we need to bring in experts?

Resources:

- Varies depending on the organization. Consider consulting business registries, company staff directories, or conducting a search of community organizations.

Step: Gather climate projections and other relevant data.

Description:

- Determine what information you need to inform your vulnerability and risk assessment. Data needs will depend on the level of detail intended to be addressed within your assessment. At a minimum, you can find future climate projections and historical data in your region online (resources shared in the Baseline Vulnerability and Risk Assessment Report). Other helpful data can include flood maps, asset maps, information on the condition, location and age of assets, operations and maintenance logs, records from past weather events.

Questions to consider:

- What kind of information will help you understand climate risks and vulnerabilities for your context? (including climate data and internal information about including about operations and processes, infrastructure condition, etc.).
- What geographic location and time scale do you want to evaluate? (This will help you determine what climate data is needed to complete your assessment).

Resources: For a high level assessment, there are several climate data platforms that provide free climate change projections:

- Climate Atlas of Canada;
- Climatedata.ca portal and sector modules;
- Ontario Climate Data Portal; and
- Canadian Climate Normals (for historical data).

Step: Assess vulnerabilities and risks.

Description:

- Determine whether a high level or detailed vulnerability and risk assessment would be most productive for you. If you have never assessed climate risks, begin with a high level assessment to help you prioritize. If you have completed a risk assessment and have an understanding of your vulnerabilities, consider a more detailed assessment on an asset or system.
- Best practice for a holistic assessment is to complete the vulnerability and risk assessment using a blend of research, expert knowledge, and stakeholder input.
- The results of the vulnerability and risk assessment should be a list of priority climate risks or impacts.

Questions to consider:

- How is the climate changing in your region? What climate-related impacts that could occur?
- Who and what may be affected by climate impacts (climate exposure)?
- How often might the climate impacts occur, now and in the future?
- How sensitive is the organization/asset/system to harm or damage from the climate impact?;

- What is the current capacity to cope or adapt?
- How severe would the consequences be if the impact were to occur today?

Resources:

- There are several tools available to assess vulnerability and risks depending on the level of detail (best practices, tools, and resources are identified in the Baseline Vulnerability and Risk Assessment Report).
- ICLEI's Building Adaptive Resilient Communities framework provides a holistic, qualitative approach. ISO Standards 31000, 14090 also provide high level, flexible guidelines for vulnerability and risk assessments. For more detailed infrastructure assessments on a singular piece of infrastructure, methods such as the PIEVC Protocol, developed by Engineers Canada, assess climate-infrastructure interactions throughout every component of an asset (i.e. all interior and exterior parts of a building or tangible process).

Step: Identify adaptation and resilience goals and objectives.

Description:

- Set overarching goals for climate resilience and adaptation. Set more specific objectives focused on priority risks and building the resilience of vulnerable systems.

Questions to consider:

- What is the desired outcome of the adaptation process?
- What does a resilient organization look like? What would it look like if climate risks and vulnerabilities were managed proactively?

Resources:

- Consult other adaptation strategies for high level goals and objectives. Sector specific resources are available, such as the Principles of Climate Change Adaptation for Engineers by Engineers Canada or resources created by Adaptation to Climate Change Team (ACT).

Step: Identify and prioritize adaptation actions.

Description:

- Identify a variety of actions and solutions that can reduce priority risks and vulnerabilities. There may also be opportunities (positive impacts) that require planning to fully realize. Actions range from policy or regulation, physical or technical solutions, or changes to operational or procedural processes. There are several resources available to help you identify adaptation actions depending on your context and your top risks (see the Baseline Vulnerability and Risk Assessment Report for more details).

- You may consider a set of criteria to help with prioritizing actions. Use criteria such as feasibility, cost, human resources, emissions reduction co-benefits, alignment with other policy or plans, number of climate impacts addressed, and urgency of decision (e.g. if action is required immediately to prevent lock-in of a long-lasting decision such as land use or infrastructure design).

Questions to consider:

- What can be done in day to day work to prepare for climate impacts?
- What processes should be in place to respond if a climate impact occurs?

Questions to consider:

- How could we integrate climate resilience thinking into our current systems and processes?

Resources:

- There several resources available to help you identify adaptation actions depending on your context, sector and your top risks.
- Consult publications by the Intact Center for Climate Adaptation, Federation of Canadian Municipalities, ICLEI Canada, Adaptation to Climate Change Team, Climate Risk Institute.
- Leading resources for adaptation are also collated on the Government of Canada website. Natural Resources Canada recently launched a map of adaptation actions.
- The US Climate Resilience Toolkit also has dozens of resources on climate risk assessments and adaptation planning.

Step: Establish monitoring and implementation plans.

Description:

- Assign a lead department or individual for each action and identify supporting partners. Create an implementation table which includes key information for each action such as estimated cost, roles and responsibilities, timing of the action, and priority level. For each action, consider how you will measure progress. Identify indicators that will help you measure the change in risk and/or resilience resulting from your actions.

Questions to consider:

- What needs to happen for this action to be implemented effectively?
- Who is going to lead the action and who else needs to be involved?
- How much will the action cost and how will it be funded?
- What approvals or groundwork is needed before starting with implementation?
- When should work start on this action and how long will it take?
- What key progress indicators (KPIs) will help measure effectiveness of implementation?

Resources:

- Consult best practices in adaptation indicators such as “Measuring progress on adaptation and climate resilience: recommendations to the government of Canada” written by Canada’s Expert Panel on Climate Change Adaptation and Resilience.
- There are various methods to estimate the costs and benefits of adaptation. Conduct a search of resources relevant to your sector. The Federation of Canadian Municipalities, Canadian Center for Climate Choices, and Intact Centre and IBC have several publications on costs of climate change impacts and adaptation.

Step: Re-assess and Iterate.

Description:

- Determine when you will re-evaluate climate risks and vulnerabilities and update your adaptation actions. Best practice is to update adaptation plans approximately every 5-7 years.

Questions to consider:

- When will the plan become out of date or require updating?
- How will the KPIs be used to improve the plan?
- Are there other initiatives (e.g. budgets) that should be aligned with an update to the plan?

Resources:

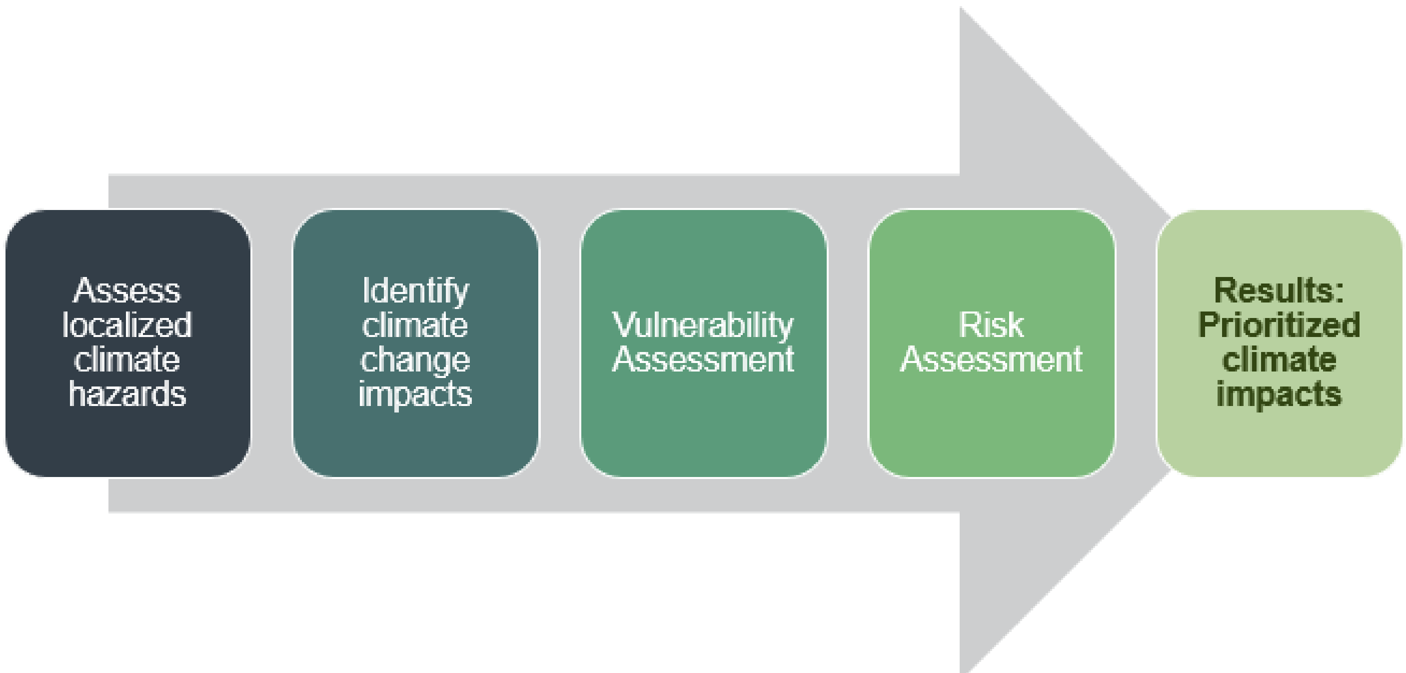
- Consult best practices in adaptation indicators such as “Measuring progress on adaptation and climate resilience: recommendations to the government of Canada” written by Canada’s Expert Panel on Climate Change Adaptation and Resilience.

- There are various methods to estimate the costs and benefits of adaptation. Conduct a search of resources relevant to your sector. The Federation of Canadian Municipalities, Canadian Center for Climate Choices, and Intact Centre and IBC have several publications on costs of climate change impacts and adaptation.

Methodology

Methodology

This section describes the methodology applied to complete the Vulnerability and Risk Assessment. This method builds on the approaches for community vulnerability and risk assessments outlined in ICLEI Canada's Building Adaptive and Resilient Communities Framework and the ISO Standard for Risk Management.



Identification of Climate Hazards and Indicators

A climate hazard is a hazard that is related to physical climate events or trends. The assessment began by considering a broad range of potential climate hazards that could impact Kingston. This early in the process, the hazards were intentionally broad to avoid eliminating consideration of potential risks. Hazards considered included heat waves, mean increases in temperature, freezing rain, flooding, storm activity, forest fires, drought, and freeze-thaw cycles. Certain climate hazards were excluded from the assessment because of the City's geographic location. This included hazards associated with landslides, permafrost melt, and coastal flooding. To determine potential changes in each hazard, a series of climate variables were selected to be analyzed for future climate.

Temperature indicators

- Annual temperature
- Winter temperature, Spring temperature, Summer temperature, Fall temperature
- Maximum summer temperature
- Average warmest maximum temperature
- Annual number of very hot days over 30°C
- Annual number of days above 32°C
- Longest consecutive spell of days above 30°C
- Annual number of cooling degree days
- Annual number of heat waves
- Average length of heat waves
- Annual number of tropical nights above 20°C
- Annual frost-free season
- Annual number of winter days above -15°C

Precipitation indicators

- Annual precipitation
- Winter precipitation, Spring precipitation, Summer precipitation, Fall precipitation
- Annual number of wet days
- Annual number of dry days
- Annual number of days with over 20 mm of precipitation
- Maximum 1-day precipitation
- Maximum 5-day precipitation
- IDF (Intensity Duration Frequency) 1 hr 50-year return
- IDF 24 hr 59-year return

- IDF 1 hr 100-year return
- IDF 24 hr 100-year return
- Annual frequency of freezing rain events lasting six or more hours

Winter conditions indicators

- Annual number of frost days
- Annual freeze-thaw cycles
- Annual thaw days
- Annual snow cover
- Snow precipitation in winter (January to March)

Wind indicators

- Mean summer wind speed
- Mean winter wind speed
- Summer wind gust speed
- Winter wind gust speed
- Annual number of wind gusts over 90 km/hr

Other climate hazard indicators

- Annual number of lightning impacts
- Fire weather index (Canada)
- Climate moisture index

Hazard Assessment

A number of variables were selected as indicators for each climate hazard. For example, variables observed for heat waves included:

- Mean annual temperature
- Mean summer temperature
- Number of tropical nights
- Number of very hot days
- Number of extremely hot days
- Number of cooling degree days
- Number of annual heat waves
- Average length of heat waves
- Longest spell of +30C
- Maximum summer temperature

Baseline data and future projections for the variables were compared to determine the likelihood of occurrence and probability of change in the future.

The hazard assessment used projection data founded on the RCP8.5 emissions scenario. Three time horizons were examined during this assessment: historic baseline (1976-2005), mid-century (2021-2050), and end-of century (2051-2080). These were selected due to the availability of data. Where data was not available for these exact time horizons, the closest available dates were used. Table 1 shows the time horizons available from various data sources.

Table 1 Climate data source time horizons

Data Source	Variables	Baseline	Mid-Century	End-of-Century
Climate Atlas	Multi	1976-2005	2021-2050	2051-2080
IDF_CC Tool	IDFs	1914-2007	2021-2050	2051-2080
Kingston Climate Action Plan	Freezing Rain	1981-2010	2050	NA
Possible Impacts of Climate Change on Freezing Rain Using Downscaled Future Climate Scenarios: Updated for Eastern Canada	Freezing Rain, annual maximum	1958-2007	2046-2065	2081-2100
Changes in Climate Extremes and their Impacts on the Natural Physical Environment	Mean wind speeds, annual number of wind gusts over 90 km/hr	1981-2000	NA	2081-2100
Fire Weather Index (Canada)	Fire likelihood	NA	NA	2080s
Bergeron, Y., D. Cyr, M. P. Girardin, and C. Carcaillet (2010), Will Climate Change Drive 21st Century Burn Rates in Canadian Boreal Forest Outside of its Natural Variability: Collating Global Climate Model Experiments with Sedimentary Charcoal Data	Forest burn rate	1961-1999	2046–2065	2081-2100
Climate Moisture Index	Soil moisture	1981-2010	2041-2070	2071-2100
Canada's Changing Climate Report: Chapter 5 Changes in Snow, Ice, and Permafrost Across Canada	Snow cover, snow precipitation in winter	2000-2020	2020-2050	NA

Primary sources for climate projection data include:

- The Climate Atlas of Canada Kingston Municipal Cell (Prairie Climate Center, 2021)
- IDF_CC Tool 4.5 (Western University, 2021)

- Climate Data Canada (CRIM, 2021)

Additional sources consulted include:

- Climate Moisture Index (NRCan, 2018)
- Canada's Changing Climate Report: Chapter 4 Changes in Temperature and Precipitation Across Canada (Zhang et al., 2019)
- Canada's Changing Climate Report: Chapter 5 Changes in Snow, Ice, and Permafrost Across Canada (Derksen et al., 2019)
- Will Climate Change Drive 21st Century Burn Rates in Canadian Boreal Forest Outside of its Natural Variability: Collating Global Climate Model Experiments with Sedimentary Charcoal Data (Bergeron et al., 2010)
- Possible Impacts of Climate Change on Freezing Rain Using Downscaled Future Climate Scenarios: Updated for Eastern Canada (Cheng et al., 2011)
- Change in Climate Extremes and their Impacts on the Natural Physical Environment (Sonia et al,. 2012)
- Projected Increases in Lightning Strikes in the United States Due to Global Warming (Romps et al., 2014)
- Kingston Climate Action Plan (City of Kingston, 2014)
- of Kingston Official Plan Schedule 11A: Constraint Mapping 2017 (consolidated 2019)
- City of Kingston Official Plan Appendix A: Wildland Fire Hazard Areas (2017, consolidated 2019)
- International Joint Commission Impacts of Extreme 2019 Great Lakes High Water Levels Felt Throughout Lake Ontario and the St. Lawrence River (2019)

Following the analysis of individual variables as they related to each hazard, the variables were then assessed together to determine a hazard trend rating for each hazard.

Hazard trends were analyzed for each climate hazard by comparing future climate projections with historical baselines. Hazard trend ratings show the degree that the climate variable or hazard is expected to evolve (increase or decrease) in the future. If there was no significant change from historic to future, the hazard is less likely to change and the hazard trend rating would be low. The hazards were rated using a five point scale from “Very Low” to “Very High” based on the degree to which future conditions where projected to change. Where design or hazard thresholds were known (i.e. a level where a hazard has been known to occur), they were incorporated into the assessment. Professional judgement was used when projection data was highly uncertain. The list below shows the scale and criteria used for this assessment:

- Very Low: Projected ranges in future climate are similar to historic ranges and no trend can be identified.
- Low: Projected ranges in future climate completely or significantly overlap historic baseline means and uncertainty ranges and/or do not exceed historic or design thresholds.
- Moderate: Projected ranges in future climate overlap historic baseline means and lower or upper uncertainty ranges (dependant on if the trends are increasing or decreasing) and/or meet or marginally exceed historic or design thresholds.
- High: Projected ranges in future climate overlap historic lower or upper uncertainty ranges (dependant on if the trends are increasing or decreasing) and/or exceed historic or design thresholds.
- Very High: Projected ranges in future climate are entirely out of the range of historic baseline means and uncertainty ranges and/or significantly exceed historic or design thresholds.

To represent the accuracy of the data, confidence penalties were applied to scores. Confidence penalties are representations of the data based on the granularity, number of models used, types of variables, precision, scientific consensus, and source of data. Three possible confidence penalties were applied. The list below shows the scale and criteria used for this assessment:

- 0: There is a strong consensus in the scientific community on the climate trends and the data is specific to the Kingston area.
- 0.5: There is uncertainty in the consensus in the scientific community on the climate trends and/or the data is not specific to the Kingston area.
- 1: The is high uncertainty in the consensus in the scientific community on the climate trends and/or the data is presented at a large scale.

Assumptions and Limitations

- Climate variables were selected to represent trends in hazards based on professional judgement of WSP's climate science team and understanding of the current availability of climate data
- Where no detailed climate projections were available, historical instances of hazards were used as a proxy.

- The Baseline Vulnerability and Risk Assessment assumes that all of Kingston is equally exposed to all climate hazards. Detailed geospatial analysis with data from different weather stations in Kingston could help provide a better understanding of areas of the city that are more and less exposed to certain hazards.
- The scale and the granularity of the data. Where possible, regional downscaled data specific to the City of Kingston was used. However, certain data may have only been available at the regional, provincial, national, or continental scale.
- The IDF-CC tool is the only data portal that provides IDF curves that consider climate change across the whole Canadian territory. However, there are methodological limitations associated with a tool providing climate change data at such an important spatial scale. For example, the algorithm considers a stationary relationship between subdaily and daily precipitation events. Therefore, while the outputs of the IDF-CC tool indicate the trend and magnitude of change in extreme short-duration precipitation events, the output should not be relied upon for design purposes without a proper sensitivity analysis specific to the area of the project.
- Projection information developed prior to 2013 do not use the RCP8.5 scenario (as the RCP scenarios were released in 2013). These projections use the most conservative scenarios of the SRES emissions scenarios.

Impact Identification

Climate change impacts are the influences and consequences of climate change on built, environmental, and human systems. A preliminary list of climate change impacts was developed based on:

- Research of previous climate or weather events. Online news media accounts, technical reports, and any scientific research available for Kingston and the surrounding area was considered when compiling a preliminary list of climate change impacts. Impacts that had already occurred in the City helped to establish points of vulnerability for changing climate conditions.
- Online public engagement Survey. A public survey was distributed online in an effort to understand the perspective of residents on which climate impacts are currently affecting them or have affected the community in the past, as well as which climate impacts concern them most in the future. Respondents were asked to identify if and how a variety of climate hazards had impacted the social, economic, built systems, and natural environment around them, and how those impacts affected their lives. They were also asked to rate what climate hazards they felt were most relevant to them. These climate hazards included high temperatures and heat waves, heavy precipitation and flooding, freeze-thaw impacts, storms, droughts, and forest fires. This information helped to supplement and guide the selection of preliminary climate impacts. Further details from the survey can be found in the What We Heard Report created for the Climate Leadership Plan project.
- Adaptation Technical Team workshop. A workshop was hosted in July of 2020 with the Adaptation Technical Team, which included representatives from various City departments, advisory committees, the Cataraqui Conservation Authority, power utilities, Sustainable Kingston, and members of the WSP project team. The aim of the workshop was to determine potential climate change impacts to the City of Kingston. Participants were asked to name the critical infrastructure and services within the City of Kingston. They were then asked to discuss past and potential future impacts from increases in temperature, heat waves, freeze-thaw, precipitation, flooding, drought, storms, forest, and forest fires. The information from the workshop was used to supplement and guide the refinement of preliminary climate impacts.
- Comparison to other municipalities. Municipalities of similar size and/or geographic location that has also completed climate change assessments were used as baseline for supplementing the selection of preliminary climate impacts where their work was applicable to the City.

At this stage in the assessment the probability of impacts occurring and the magnitude of consequences was not yet considered. The list of impacts was carried forward to the Vulnerability Assessment.

Assumptions and limitations

- Information received during the engagement surveys or workshops was limited to viewpoints of the attendees.
- Climate impacts were kept to a relatively high level and may not represent nuances of geospatial or sociodemographic diversity present within the City of Kingston.

Vulnerability Assessment

Vulnerability is the degree to which people and systems are susceptible to, or unable to cope with, the adverse impacts of climate change. Vulnerability is driven by two factors: sensitivity and adaptive capacity. A rating from “Very Low” to “Very High” was determined for sensitivity and adaptive capacity for each climate impact considered during the impact assessment. These impacts were multiplied in a matrix to give a final vulnerability score.

The sensitivity and adaptive capacity rating for each climate change impact was determined during a Vulnerability Assessment workshop held in October of 2020 with the Adaptation Technical Team. The workshop was attended by representatives from various City departments, KFL&A Public Health, Cataraqui Conservation Authority, power utilities, Sustainable Kingston, and members of the WSP project team. Participants were asked to rate the adaptive capacity and sensitivity of a sub-set set of climate change impacts and discuss the results.

Results from the workshops were used in conjunction with professional judgement, comments from the public survey, and City information to assign sensitivity and adaptive capacity ratings to the remaining impacts.

Sensitivity refers to the degree to which a system is affected or responsive to a hazard. Sensitivity was rated on a five point scale from “Very Low” to “Very High” relative to the potential effects various climate hazards could have on a system.

Sensitivity Scale and Criteria

Very Low (1):

- The system/group will not be affected by the impact (functionality would stay the same).
- The system/group does not possess attributes that would cause sensitivity.

Low (2):

- The system/group will be minimally affected by the climate impact (functionality would likely stay the same).
- A small proportion of the system group possesses attributes which increases sensitivity.

Medium (3):

- The system/group will be somewhat affected by the climate impact (functionality may be disrupted).

- The system/group possess some of the attributes/indicators which increase sensitivity.

High (4):

- The system/group will be affected by the climate impact (functionality will be disrupted).
- A considerable proportion of the system/group possess attributes which increase sensitivity.

Very High (5):

- The system/group will be significantly affected by the climate impact (functionality will be severely disrupted/fail/become unmanageable).
- A high proportion of the system/group possess attributes which increase sensitivity

To ensure a holistic representation of sensitivity, three sub-scales were used to help supplement the final rating. These scales offered narrative descriptors of sensitivity levels for social, built environment, and natural environment systems.

Social

Social sensitivity refers to the degree to which the health of a person or population group is affected by climate-related stimuli. It captures the proportion of the population that is more vulnerable due to particular physiological characteristics. Physiology, access to health resources and services, gender, and age can make some populations more sensitive to the health impacts of climate change. Indicators of social sensitivity include:

- Existing stressors such as pre-existing/chronic illness, Cognitive impairment, Low-income households, Socially isolated people, Homeless, Low education level, Not English speaking, Recent immigrants, Racialized groups
- Elderly residents, Infants and young children,
- Living conditions such as geographic location, isolated/limited access areas, rental households, mobile homes, underserved neighbourhoods,
- Socioeconomic factors such as livelihood, income, dependence on economic or social support

Social Sensitivity Scale and Criteria

Very Low (1):

- The community will not be affected by the climate impact.

- The community does not possess attributes which increase sensitivity

Low (2):

- The community will be minimally affected by the climate impact.
- The community has a low number of attributes which increase sensitivity; or a low percentage of the community possess attributes which increase sensitivity.

Medium (3):

- The community will be somewhat affected by the climate impact.
- The community possesses some of the attributes that increase sensitivity; or a proportion of the community possesses attributes which increase sensitivity.

High (4):

- The community will be affected by the climate impact.
- The community possesses many of the attributes that increase sensitivity; or a considerable percentage of the population has attributes that increase sensitivity.

Very High (5):

- The community will be significantly affected by the climate impact.
- The community possesses most of the attributes that make them sensitive; or a high percentage of the population has attributes that increase sensitivity.

Built Environment

Built environment sensitivity refers to the degree to which the condition and/or functionality of the built environment/infrastructure is affected by climate-related stimuli. It captures the proportion of the built environment that is more vulnerable due to certain characteristics/attributes. For example, infrastructure age, condition, infrastructure type, geographic location, and stress/damage due to previous impacts of weather/climate events can make certain infrastructure/built environments more vulnerable than others. Indicators of built environment sensitivity include:

- Infrastructure features, i.e. design standards that do not meet current/future climate and weather conditions, or if the type of infrastructure is by nature more directly affected by climate and weather (i.e. storm sewers), geographic location (i.e. in a flood plain), limited access potential (i.e. singular access point),

- Infrastructure condition i.e. aging infrastructure, poor asset condition, existing stress or damage due to past events

Built Sensitivity Scale and Criteria

Very Low (1):

- The infrastructure will not be affected by the climate impact (functionality would stay the same).
- The infrastructure does not have any attributes which increase sensitivity.

Low (2):

- The infrastructure will be minimally affected by the climate impact (functionality would likely stay the same).
- The infrastructure has a low number of attributes which increase sensitivity; or a low percentage of the infrastructure possesses attributes which increase sensitivity.

Medium (3):

- The infrastructure will be somewhat affected by the climate impact (functionality may be disrupted).
- The infrastructure has some of the attributes that increase sensitivity; or a proportion of the infrastructure possesses attributes which increase sensitivity.

High (4):

- The infrastructure will be affected by the climate impact (functionality would be disrupted).
- The infrastructure has many of the attributes increase sensitivity; or a considerable percentage of the infrastructure has attributes that increase sensitivity.

Very High (5):

- The infrastructure will be significantly affected by the climate impact (functionality would be severely disrupted, to the point of failure/unmanageable conditions).
- The infrastructure has most of the attributes that make it sensitive; or a high percentage of the infrastructure has attributes that increase sensitivity.

Natural Environment

Natural environment sensitivity refers to the degree to which the condition, health, and/or functionality of the natural environment is affected by climate-related stimuli. It captures the proportion of the natural environment that is more vulnerable due to particular characteristics/attributes. Type of species or natural feature (i.e. those that cannot withstand changing climate / weather conditions), geographic location, type of land use (i.e. developed, permeable vs. impermeable, agriculture, etc.), the presence or lack of natural buffers, and previous stressors and damage from weather/climate events can make certain infrastructure/built areas more vulnerable than others. Indicators of natural environment sensitivity include:

- Natural features: Geographic location (i.e. shoreline), natural features, types of species , type of land use (over-developed, agriculture, impermeable surfaces, open space, etc.), etc.
- Existing Stress: existing stress or damage to the area caused by previous events/impacts

Natural Sensitivity Scale and Criteria

Very Low (1):

- The natural environment will not be affected by the climate impact (condition/functionality/health would stay the same).
- The natural environment does not have any attributes which increase sensitivity.

Low (2):

- The natural environment will be minimally affected by the climate impact (condition/functionality/health would likely stay the same).
- The natural environment has a low number of attributes which increase sensitivity; or a low percentage of natural areas has attributes which increase sensitivity.

Medium (3):

- The natural environment will be somewhat affected by the climate impact (condition/functionality/health may be disrupted).
- The natural environment has some of the attributes that increase sensitivity; or a proportion of natural areas has attributes which increase sensitivity.

High (4):

- The natural environment will be affected by the climate impact (condition/functionality/health would be disrupted).

- The natural environment has many of the attributes increase sensitivity; or a considerable percentage (>30%) of the natural environment has attributes that increase sensitivity.

Very High (5):

- The natural environment will be significantly affected by the climate impact (condition/functionality/health would be severely disrupted, to the point of failure/loss).
- The natural environment has most of the attributes that make it sensitive; or a high percentage (>50%) of the natural area has attributes that increase sensitivity.

Adaptive Capacity

Adaptive capacity is the capacity of systems, institutions, and humans to adjust to potential damage, respond to consequences, or take advantage of potential opportunities. Adaptive capacity was rated on a five point scale from “Low” to “High.”

Adaptive Capacity Scale and Criteria

Low (1):

- There are no resources (information/skills, institutions, infrastructure, networks, finances, human resources, technology, etc.) available to support adaptation.
- The system or responsible authority (i.e. the City as a municipal corporation) does not have the capacity to adjust, cope or respond to the climate impact.
- There are significant barriers that prevent the implementation of adaptation measures.

Low-medium (2):

- There are minimal resources (information/skills, institutions, infrastructure, networks, finances, human resources, technology, etc.) available to support adaptation.
- The system or responsible authority (i.e. the City as a municipal corporation) has a limited ability to use the resources to adjust, cope or respond to the climate impact.
- There are considerable barriers that prevent the implementation of the resources/adaptation measures.

Medium (3):

- There are some resources (information/skills, institutions, infrastructure, networks, finances, human resources, technology, etc.) available to support adaptation.

- The system or responsible authority (i.e. the City as a municipal corporation) has some capacity to use the resources to adjust, cope or respond to the climate impact.
- There may be some barriers that prevent the implementation of the resources/adaptation measures.

Medium-high (4):

- There are ample resources (information/skills, institutions, infrastructure, networks, finances, human resources, technology, etc.) available to support adaptation
- The system or responsible authority (i.e. the City as a municipal corporation) is able to adequately use the resources available to adjust, cope or respond to the climate impact.
- There are minimal barriers that prevent the implementation of the resources/adaptation measures.

High (5):

- All the necessary resources (information/skills, institutions, infrastructure, networks, finances, human resources, technology, etc.) are in place to support adaptation
- The system/responsible authority (i.e. the City) has a strong ability to effectively use the resources to adjust, cope or respond to the climate impact.
- There are no barriers that prevent the implementation of the resources/adaptation measures.

Vulnerability score

The sensitivity and adaptive capacity scores were multiplied using a matrix to determine a final vulnerability score for each climate change impact. Table 2 shows the vulnerability rating matrix used for this assessment.

Table 2 Vulnerability rating matrix

-	Very Low Sensitivity	Low Sensitivity	Moderate Sensitivity	High Sensitivity	Very high Sensitivity
Very Low Adaptive Capacity	Very Low Vulnerability	Low Vulnerability	Moderate Vulnerability	High Vulnerability	Very High
Low Adaptive Capacity	Very Low Vulnerability	Low Vulnerability	Moderate Vulnerability	High Vulnerability	High Vulnerability
Moderate Adaptive Capacity	Very Low Vulnerability	Low Vulnerability	Low Vulnerability	Moderate Vulnerability	High Vulnerability
High Adaptive Capacity	Very Low Vulnerability	Very Low Vulnerability	Low Vulnerability	Moderate Vulnerability	Moderate Vulnerability
Very High Adaptive Capacity	Very Low Vulnerability	Very Low Vulnerability	Low Vulnerability	Low Vulnerability	Moderate Vulnerability

Assumptions and Limitations

- When considering high-level vulnerability of a City to climate change there is some subjectivity in determining the sensitivity and adaptive capacity of various systems. This subjectivity can impact the assessment process and results based on the level of knowledge and experience of workshop participants using the rating scales.
- Vulnerability and sensitivity are geographically variable. Further analysis may be required to determine vulnerability for specific assets or populations within the City of Kingston.
- A condensed list of climate change impacts were discussed during the October 2020 workshop. The results and discussions of these impacts were extrapolated and used by the WSP team to determine appropriate ratings for the remaining impacts.

Likelihood of Impact

The exposure and vulnerability scores were multiplied in a matrix to determine the likelihood of impact. The likelihood of impact represents the likelihood that a climate hazard will occur based on the climate projections, combined with the sensitivity and adaptive capacity of individual systems. This is different than the hazard trend rating, which is focused on the climate variables and the likelihood that the hazard will evolve. The likelihood of impact rating is used to focus the analysis to impacts that are both a) expected to increase and b) to which the community is vulnerable. Climate change impacts with "Low" or "Very Low" likelihood of impact ratings were not further considered in this stage of the assessment. Table 3 shows the likelihood of impact rating matrix used for this assessment.

Table 3 Likelihood of impact matrix

-	Very low Vulnerability	Low Vulnerability	Moderate Vulnerability	High Vulnerability	Very high Vulnerability
Very High Exposure	Low Likelihood	Moderate Likelihood	High Likelihood	Very High Likelihood	Very High Likelihood
High Exposure	Low Likelihood	Moderate Likelihood	High Likelihood	High Likelihood	Very High Likelihood
Moderate Exposure	Low Likelihood	Low Likelihood	Moderate Likelihood	High Likelihood	High Likelihood
Low Exposure	Very Low Likelihood	Low Likelihood	Low Likelihood	Moderate Likelihood	Moderate Likelihood
Very Low Exposure	Very Low Likelihood	Very Low Likelihood	Low Likelihood	Low Likelihood	Moderate Likelihood

Magnitude of Consequences

Magnitude of consequences is the anticipated level of consequence from an impact occurring, considered across three systems: economic and service delivery, health and social, and environmental systems. Each of the climate change impacts was assigned three magnitude of consequence score (one per system) from “Very Low” to “Very High”.

The magnitude of consequence scoring for each climate change impact was determined through a workshop held in March of 2021 with the Adaptation Technical Team. The workshop was attended by representatives from various City departments, KFL&A Public Health, Cataraqui Conservation Authority, power utilities, Sustainable Kingston, and members of the WSP project team. Attendees were asked to score the magnitude of consequence of a sub-set of climate change impacts and discuss the results.

The workshop results and ratings were used in conjunction with professional judgement, comments from the public survey, and City information to assign magnitude of consequence scores to the remaining impacts. During the workshop and subsequent analysis, the magnitude of consequence was scored for economy and service delivery, health and social, and environmental systems.

The highest of the three scores was selected to represent the overall magnitude of consequence score for each climate change impact. The lists below show the scales and criteria for economic and service delivery, health and social, and environmental categories. The consequences scales were tailored with input from City staff.

Consequence Scale and Criteria for Economic and Service Delivery Impacts

Very Low (1):

- No damage costs or financial losses.

Low (2): Minor damage costs or financial losses, for example:

- City: Costs are easily absorbed in current operation and maintenance (O&M) budgets.
- Minor, short-term impacts to City services (approx. one day).
- Community: Costs can be easily absorbed by the owner.
- Business continuity is temporarily disrupted for a small number of businesses

Moderate (3): Considerable damage costs or financial losses, for example:

- City: Cost are manageable within current O&M budgets but may require budget revisions for other activities. Higher frequency of the impact would deplete the budget prematurely.
- Moderate disruption to City services (lasting a few days).
- Community: Costs are manageable but frequent occurrences would cause strain.
- Business continuity is temporarily disrupted, multiple businesses affected.

High (4): Major damage costs or financial losses, for example:

- City: Repair/replacement costs would require alternate reserves that may need further Council approval.
- Significant disruption to City service delivery (e.g. disrupted for over a week).
- Community: Costs exceed the owner's financial capacity and alternate sources are needed (e.g. loan), affecting long term savings.
- Business continuity is significantly disrupted for several days, multiple businesses affected.

Very High (5): Extreme damage costs or financial losses, for example:

- City: Costs far exceed the municipality's financial ability to mitigate damage, federal/provincial or other external financial assistance would be required.
- Inability to continue City service delivery.
- Community: Costs are far beyond the owner's capacity and would require significant external funding (e.g. loan). Costs may not be recoverable (e.g. uninsured) and/or the owner may face long term financial strain.
- Business continuity fails or is severely impaired for weeks or months, affecting many businesses in Kingston.

Consequence scale and criteria for health and social impacts

Very Low (1):

- Appearance of a threat but no physiological harm or injury.
- Functionality (of the affected group the community) is not affected.
- No impact on public administration.

Low (2):

- Small number of minor injuries or illnesses
- Day-to-day lives (of the affected group the community) are temporarily disrupted over a short period (not longer than 24 hrs).
- Minor and manageable stress on public administration, e.g. contained to one department.

Moderate (3):

- Multiple public injuries or illnesses have occurred.
- Day-to-day lives (of the affected group the community) are temporarily disrupted (a few days to a week).
- Moderate stress on public administration, e.g. affecting multiple departments and management.

High (4):

- Multiple serious injuries or illnesses, or a particular population has been harmed (e.g. outdoor workers, a community living in mobile homes).
- Day-to-day lives (of the affected group the community) are disrupted over an extended period (>1 week)
- High stress on public administration, significant concerns for management and City reputation.

Very High (5):

- Many serious injuries or illnesses, even fatalities.
- Day-to-day lives (of the affected group the community) are disrupted over a prolonged period (>1 month).
- Extreme or debilitating stress on public administration, management and/or City reputation.

Consequence Scale and Criteria for Environmental Impacts

Very Low (1):

- Appearance of a threat but no adverse effects on natural environment or ecosystems.

Low (2):

- Minimal, short-term (a few days) effect on the natural environment or ecosystems.

- Impact is localized to a small area e.g. one park or neighbourhood.
- No intervention or monitoring needed

Moderate (3):

- Moderate, medium-term (a few months) effect on the natural environment or ecosystems.
- The impacted site is large, but localized (e.g. one section of the waterfront, part of a riverbank).
- Intervention, monitoring or remedial measures are needed.

High (4):

- Significant, long-term (<1 year) effect on the natural environment or ecosystems.
- The impacted site is widespread (e.g. multiple parks or neighbourhoods, large area of the shoreline).
- Intensive interventions, monitoring or remedial measures are needed.
- The impact results in damage or loss of ecosystem services.

Very High (5):

- Irreversible or severe damage caused to the natural environment or ecosystems.
- The impacted site(s) is widespread across the City or even beyond the City boundaries (e.g. Lake Ontario).
- The impact results in permanent or long-term loss of ecosystem services.
- High-cost, urgent, and intensive interventions, monitoring, and remedial measures are needed.

Preliminary Risk Rating

The likelihood of impact and magnitude of consequence scores for each climate impact were multiplied to produce a preliminary risk rating for each climate impact. Table 4 shows matrix used to calculate risk ratings for this assessment.

Table 4 Preliminary risk rating matrix

-	Very low Consequence Severity	Low Consequence Severity	Moderate Consequence Severity	High Consequence Severity	Very high Consequence Severity
Very High Likelihood of Impacts	Low Risk	Moderate Risk	High Risk	Very High Risk	Very High Risk
High Likelihood of Impacts	Low Risk	Moderate Risk	High Risk	High Risk	Very High Risk
Moderate Likelihood of Impacts	Low Risk	Low Risk	Moderate Risk	High Risk	High Risk
Low Likelihood of Impacts	Very Low Risk	Low Risk	Low Likelihood	Moderate Risk	Moderate Risk
Very Low Likelihood of Impacts	Very Low Risk	Very Low Risk	Low Risk	Low Likelihood	Moderate Risk

A numerical value was assigned to each rating of magnitude of consequence and likelihood of impact. Table 5 shows the numerical values used for the risk scale for this assessment.

Table 5 Risk rating numerical values

Scale	Numerical value
Very Low	0.2
Low	0.4
Moderate	0.6
High	0.8
Very High	1.0

When the risk ratings are multiplied, they produce a numerical value for each risk. For example, if a climate impact had a magnitude of consequence score of “High” (0.8) and a likelihood of impact score of “Moderate” (0.6) the final numerical value would be:

$$0.6 \times 0.8 = 0.48$$

This number would be used in the in the final stages of analysis.

Urgency of Decision

Urgency of decision refers to the timing of adaptive action in response to a climate impact. Two high impacts with the same likelihood of occurrence in the same timescale may require different urgencies in decision making due to:

- Difference in adaptation costs over time
- Short-term benefits of adaptation – for example, improved resilience to the current climate
- Long-term consequences- risk of lock-in, or irreversible losses to the natural environment
- Lead-time Between policy adaptation and implementation in practices

Each impact was given an urgency rating on a scale of three from “Low” to “High.” Urgency ratings were assigned using data from the public survey, research and literature review, and the results of the three Adaptation Technical Team workshops. Each urgency rating was assigned a numerical value that was then applied to the climate impact. Climate impacts with lower urgency ratings were reduced to reflect a less immediate risk, while impacts with higher urgency ratings stayed the same to represent more immediate adaptation needs. The list below displays the urgency of decision rating scale and criteria used for this assessment.

Urgency of Decision Scale and Criteria

Low

- Criteria: Adaptation costs are low or are unlikely to increase over time. There are no short term benefits to implementation, little to not risk of lock in, and a short lead-time between policy adaptation and implementation in practices.
- Action: -0.16

Moderate

- Criteria: Adaptation costs are moderate and may increase over time. There are some short term benefits to implementation, moderate risk of lock in, and a moderate lead-time between policy adaptation and implementation in practices.
- Action: -0.08

High

- Criteria: Adaptation costs are high or are likely to increase over time. There are short term benefits to implementation, large risk of lock in, and a long lead time between policy adaptation and implementation between practices.
- Action: -0.0

Final Risk Score

The final risk score was determined by subtracting the urgency of decision value from the risk rating value. The risk score scales were given numerical values to capture the nuances of each risk within a five point scale. For example, an impact with a “Very High” likelihood of impact and a “Very High magnitude of consequence would have a higher numerical result than an impact with a “Very High” magnitude of consequence and a “High” likelihood of impact, despite both presenting as “Very High” risks. The scores corresponding to final risks were established based on the distribution of the results and the preliminary risk results (above). Table 6 shows the final risk score values as they correspond to the ratings used in this assessment.

Table 6 Final risk rating scale

Scale	**Final Risk Score**
0.04-0.11	Very Low
0.12-0.31	Low
0.32-0.40	Moderate
0.48-0.79	High
0.8-0.1.0	Very High

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Climate Data

The climate data and future projections used for this project are available in a separate file.