Case Study Series

# Using Better Data to Identify Climate Change-Related Infrastructure Vulnerabilities in Canadian Communities




PSD RESEARCH CONSULTING SOFTWARE

Canadian Water Network

FCM FEDERATION OF CANADIAN MUNICIPALITIES

CWWA ACEPU Canadian Water and Wastewater Association canadienne des eaux potables et usées

# Contents

# Introduction:
# Climate Change and Policy Context in Canada

In 2017, Public Sector Digest (PSD), Canadian Water Network (CWN), and the Canadian Water and Wastewater Association (CWWA) completed a national study of municipal asset management, focusing on how data is being used to inform decision-making on water, wastewater, and stormwater infrastructure. Surveyed municipalities and utilities identified a specific gap that exists in their infrastructure datasets. Respondents indicated that data pertaining to the impacts of climate change is either absent or not well integrated into local infrastructure decision-making. In response to the increasing severity and frequency of climatic events in Canada, along with recent studies confirming the predicted future impacts of climate change on our communities, local leaders are searching for a way to engage in climate change adaptation.

In response, PSD, in partnership with CWN, CWWA, and the Federation of Canadian Municipalities (FCM), has compiled five case studies of Canadian municipalities and utilities who are incorporating climate change considerations into their asset data collection, analysis, and decision-making. Each case study highlights the types of data that are necessary to assess vulnerabilities to critical risks posed by climate change, and how these datasets are collected and analyzed by municipalities to inform decision-making on risk reduction and adaptation for municipal water systems.

## Climate Change in Canada

Climate change poses a significant impact to humans and natural systems around the world. The United Nation's Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment report indicates that associated risks to human health and safety, infrastructure, natural environments, and the economy are increasing. The report identified a global average temperature increase of 0.85ºC above pre-industrial levels (1948)[1] and scientists are predicting a global temperature increase of 1.5ºC between 2030 and 2052.[2]

In 2019, Canada's Changing Climate Report (CCCR 2019) was released by Environment and Climate Change Canada (ECCC) as part of its national assessment. This report contained information from scientists at ECCC, Natural Resources Canada, Fisheries and Oceans Canada, and Canadian universities. The report indicated that between 1948 and 2016, the average temperature increase across Canada was 1.7ºC, double that of the global average.[3] Observed precipitation changes in Canada have increased by approximately 20% between 1948 and 2012. By the late 21st century, the projected increase could reach an additional 24%.[4] During the summer months, some regions in Canada are expecting more frequent periods of drought. Other recorded events include flooding, cold extremes, warm extremes, wildfires, and record minimum arctic sea ice extent.[5] Extreme weather events and storms are also more common across the country.

A changing climate poses a significant risk to Canada's economy, society, environment, and infrastructure. Climate-related extremes such as droughts, floods, higher-frequency freeze-thaw cycles, extended periods of high temperatures, high winds, and wildfires can damage physical infrastructure. The economic impacts are most evident in the costs associated with damage caused by extreme weather events such as hurricanes, heavy rain, droughts, lightning storms, extreme winds, and storm surges.[6] Certain economic sectors, such as agriculture, tourism, and energy will be affected, depending on the geographic region and the influence on demand.[7] Individuals who are economically or socially marginalized and Indigenous people are especially vulnerable to the effects of climate change. Canadian municipalities have a responsibility to protect their local economy, citizens, environment, and physical infrastructure from these impacts.

## Policy Context for Local Governments

Municipal assets and public services are vulnerable to the impacts of climate change, placing local leaders at the front-lines of protecting public resources.[8] The IPCC Fifth Assessment report indicated that the most significant progress towards climate change adaptation in North America is seen at the municipal level. Acting proactively rather than reactively is a key principle of asset management, which aligns well with climate change adaptation approaches. In Canada, local governments can leverage this opportunity to implement climate change adaptation approaches while advancing their asset management practices.

Municipalities are engaging in proactive adaptation planning and assessments through the adoption of plans and policies that integrate climate change considerations for public infrastructure.[9] National, provincial, and municipal policies, regulations, and funding programs currently reflect a political landscape that supports these efforts. The provinces have yet to impose any regulatory requirements for local governments to develop climate change adaptation plans, but many have released guidelines, funding programs, and related regulations that enable and encourage municipalities to take action. For example, the Government of Alberta released a climate change adaptation framework manual in 2010, and the Government of British Columbia released a climate change and asset management primer in 2018.

The Government of Ontario was the first to enact a regulation requiring local governments to adopt asset management practices. In 2017, Ontario released O. Reg. 588/17: Asset Management Planning for Municipal Infrastructure. This regulation has deadlines to ensure that local governments are maintaining progress on their asset management programs. The first approaching deadline was July 1, 2019; by this date, municipalities must have adopted a strategic asset management policy that includes climate change considerations.

The Federal Gas Tax agreements have been amended by some provinces to require municipalities to prioritize climate change adaptation. For example, municipalities in Nova Scotia were required to complete a Municipal Climate Change Action Plan by 2014 in order to receive their Gas Tax Funding. According to the 2014-2024 Saskatchewan Gas Tax Fund Agreement, municipalities are required to make progress on developing and implementing an Asset Management Plan prior to March 2018.

Municipal associations and international organizations also play a significant role in driving progress in the areas of climate change and asset management. For example, ICLEI is an international network of local governments. Through this network, Canadian local governments are successfully adopting adaptation and risk management practices through standardized approaches informed by experts and local leaders.

Engineers Canada recently released a protocol in partnership with Natural Resources Canada that provides a framework to review climate change information and establish the adaptive capacity of an organization's infrastructure and operations. FCM has also delivered numerous guides, webinars, and networks to support municipalities in their efforts to formalize comprehensive asset management programs and climate change adaptation strategies. Major grant programs include the Municipal Asset Management Program, Municipalities for Climate Innovation Program, and Climate and Asset Management Network.

Municipalities in Canada are vulnerable to the impacts of climate change, and simultaneously constrained by provincial regulations, restricted budgets, and public expectations. The five case studies included in this report are designed to support local governments with learnings that may be relevant to their own organizations.

A description of each organization's maturity in asset management and climate change adaptation sets the stage for each case study. Interviews with municipal and utility staff provide an overview of their approach to adapt water, wastewater, stormwater, and other municipal infrastructure to the impacts of climate change. Each case provides a roadmap that led to successful climate change adaptation planning that can guide others to take action on climate change.

# Endnotes

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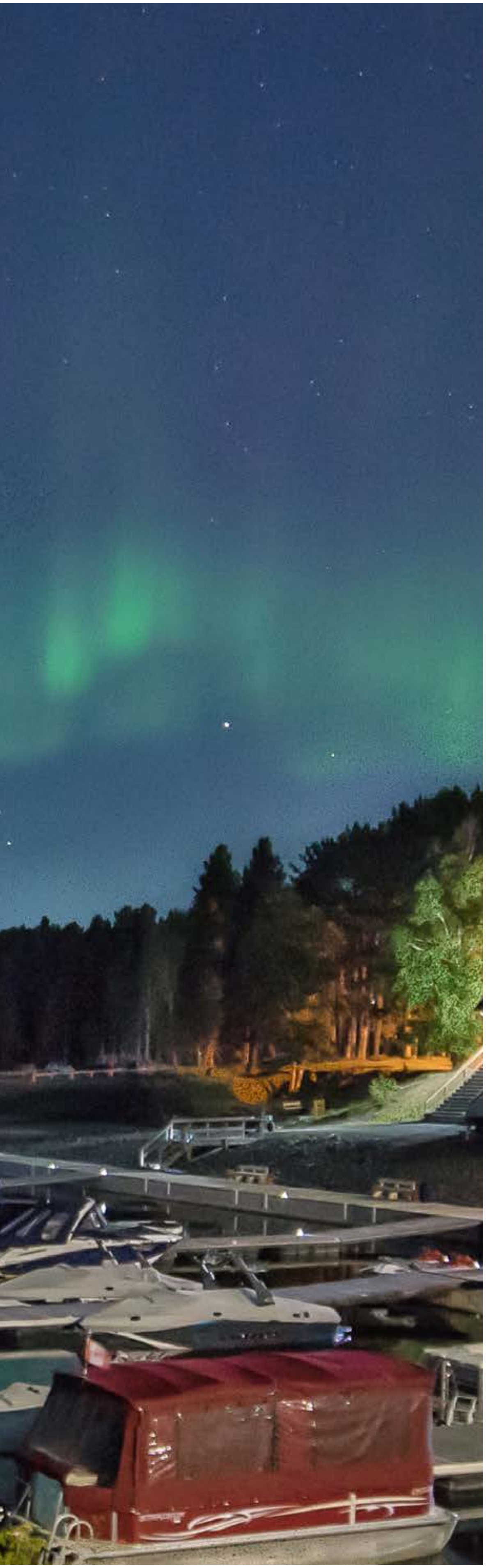
Case Study

# City of Kenora

Canadians are becoming more aware of the significant impacts that climate change can have on our local infrastructure. Federal and provincial governments are reacting to this concern by introducing new guidelines, regulations, and funding opportunities to encourage local governments to act now to adapt to climate change impacts. The City of Kenora took advantage of the Federation of Canadian Municipalities' Climate and Asset Management Network grant program to undertake a climate change risk assessment.



## Background: Kenora and its Asset Management Efforts

The City of Kenora is a small northern city located within the borders of Ontario, less than 100 km away from Manitoba. The economy relies on four major industries: boating, healthcare, manufacturing, and mining. The City's population is 15,096 with a service area of approximately 25,000. Like many municipalities in northern Ontario, Kenora is experiencing a population decline.[1]

The municipality is simultaneously confronting a declining tax base and an increasing infrastructure deficit. Adam Smith, Special Projects and Research Officer at the City of Kenora, says the "infrastructure deficit is top of mind" for city staff. Kenora's unique asset portfolio includes 19 vehicular bridges and 64 lift stations, a reflection of their unique geography. Within its borders there are several small lakes, in addition to larger bodies of water such as the Winnipeg River, Black Sturgeon Lake, and Lake of the Woods. Lake of the Woods has over 14,000 islands, many of which make up the land of Kenora.

In 2015, Kenora adopted a new Strategic Plan to guide its projects and planning for the next five years. Over 1,800 residents, city staff, elected officials, stakeholders, and Indigenous community members were consulted, using online surveys and a series of local workshops. The Strategic Plan clearly defines goals and corporate actions as it relates to the City's infrastructure and local environment. It states that the City should manage and maintain municipal infrastructure through a robust asset management plan and process; consider climate change impacts in managing current and future infrastructure; and make efforts to mitigate the impacts of climate change on City operations. These goals are intended to guide decision-making to ensure that community values are further integrated into municipal planning.

Kenora's asset management journey began in 2009, around the time that the Public Sector Accounting Board adopted PS 3150, requiring municipalities to include capital assets in their financial reporting. Between 2009 and 2012, Kenora acquired a number of asset management software tools, including: an asset register that hosts attribute data and creates projections to support project prioritization; a capital planning and analysis tool to support capital budget planning; and a GIS system to integrate with asset inventory data. In 2013, the City completed its first Asset Management Plan (AMP). Between the years of 2016 and 2017,

**Highlights from the Kenora Case Study**

- Kenora is a small, rural community in northern Ontario with cold winters and mild summers.
- The City struggles with a declining population and a significant infrastructure deficit.
- Kenora has been advancing its asset management program since 2009, and has also been working toward improving its climate change adaptation efforts.
- The City successfully applied for $80,500 from the Federation of Canadian Municipality's (FCM) Climate and Asset Management Network grant program.
- In 2018, city staff worked with asset management consultants at PSD to produce a climate change adaptation and resilience study and Climate Change Risk Assessment Framework.
- The City needed to gather meaningful asset attribute data to identify problem areas and integrate the information into its GIS system.
- The Climate Change Risk Assessment Framework can be modified by city staff in the future to include new or updated data as it becomes available.

with the support of an external consultant (PSD), the City completed a comprehensive asset management roadmap, which includes:

- Developing a state of maturity report which compares the current state of the City's asset management maturity to industry best practices.
- Ensuring that the City's AMP aligns the asset management strategy and objectives to the Strategic Plan, and updating it to be O.Reg.588/17 compliant.
- Completing a data and asset condition analysis to review the City's existing asset condition data to identify gaps and deliver a condition assessment framework that defines the condition of all asset categories.
- Conducting a risk and criticality assessment to identify the assets and asset groups most at risk within the City's portfolio, based on measures of economic and social consequences of asset failure.
- Creating a lifecycle activities framework through the development of lifecycle protocols, lifecycle models by asset type, and asset deterioration curves.
- Developing a levels of service framework with key performance indicators for city staff, which are informed by citizen expectations, strategic and corporate goals, and legislative standards.
- Ensuring financial strategies that define the relationships between maintenance and capital requirements, debt strategy, reserve strategy, and annual revenue opportunities and strategies. Recommendations have been made for short- and long-term budget requirements.

These stages culminated in a comprehensive final AMP in 2017. The municipality received a grant of $52,335 through FCM's Municipal Asset Management Program to fund its asset management roadmap and CCTV scans of sewers, gather asset data from under roads, and shift from age-defined to condition-defined data for water and wastewater assets.

Kenora is committed to being "Stewards of the Lake." The City's Environmental Advisory Committee was enacted in 2009, as a part of an environmental policy outlined in the Official Plan which is "intended to create a culture of environmental awareness." The Committee is made up of representatives from the general public, regional school boards, Lake of Woods Property Owners Association, business community, and City Council. The role of the Committee is to provide direction to City Council and maximize opportunities to adapt to the impacts of climate change and reduce negative impacts on the environment. Kenora's most recent steps towards climate change adaptation include a comprehensive Climate Change Adaptation and Resilience Study and a Climate Change Risk Assessment Framework.

According to the Ontario Ministry of Natural Resources and Forestry (MNRF), northern Ontario will experience greater temperature increases due to climate change, as compared to southern Ontario.[2] Increases in temperature, as well as increased severity of rainfall events, have resulted in a higher frequency of storms, severe winds, and flooding, which have impacted the stormwater system. The 2017 AMP identified stormwater as the asset category most at risk. With 48% of all stormwater assets in poor to very poor condition, the municipality received an F in this asset category on its Infrastructure Report Card.

A major flood in the spring of 2014 resulted in water levels reaching the highest peak in 85 years of record keeping. Frequent flooding during the summer of 2016 cost over $290,000 in repairs to damaged culverts and roads.[3] Funding programs exist for local governments in Ontario under the Municipal Disaster Recovery Assistance program, but Kenora has not been eligible to apply, since their flooding events were not deemed significant under the eligibility requirements.[4] Flooding and other extreme weather events result in both short-term costs for immediate repairs, as well as long-term costs as a result of accelerated asset deterioration. The water assets that are most at risk due to these weather events are extremely valuable to the city. According to the 2017 AMP, these assets have a combined value of $229 million based on replacement costs, which can be broken down to $111 million for potable water infrastructure, $96 million for wastewater collection and treatment infrastructure, and $22 million for stormwater infrastructure.

Social and ecological impacts of climate change have also been noticed by local residents and municipal staff. Higher temperatures during the winter and summer months, as well as flooding, affect the day to day lives of citizens. Algae bloom proliferation as a result of increased light, warmer temperatures, and damage to beaver dams from heavy rainfall and storms can have a significant effect on the local environment.[5]

## Climate Change Impact Profile

Kenora experiences very cold winters and mild summers, with high levels of precipitation.[6] The chart below shows the average high and low temperatures in the months of January and July, as well as annual precipitation in 1960, 1980, 2000, and 2018.

### Temperature Range and Annual Precipitation in Kenora

| | Average High January | Average Low January | Average High July | Average Low July | Yearly Precipitation |
|---|---|---|---|---|---|
| 1960 | -11.6ºC | -19.3ºC | 24.4ºC | 14.2ºC | 683.1 mm |
| 1980 | -12.5ºC | -21.6ºC | 22.2ºC | 12.9ºC | 574.8 mm |
| 2000 | -11.5ºC | -21.5ºC | 24.3ºC | 14.4ºC | 982.3 mm |
| 2018 | -10.4ºC | -19.5ºC | 25.8ºC | 25.8ºC | 612.4 mm |

Source: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html

# Climate Change Adaptation and Risk Assessment

The Environmental Advisory Committee supported city staff in implementing climate adaptation measures such as LED lighting conversion, window replacement at City Hall, stakeholder engagement for a Community Energy Plan, and energy audits on all City facilities.[7] However, prior to 2018, the City did not have a comprehensive plan to address the impacts of climate change on municipal infrastructure, which is a goal outlined in its Strategic Plan.

Special Projects and Research Officer, Adam Smith, determined that the City could utilize its existing AMP and software to integrate climate change considerations. In 2017, FCM introduced the Climate and Asset Management Network, which included peer learning and training, access to a network of professionals and asset management resources, as well as a total of $1.6 million in grant funding. These grants were available to support projects with an objective of better integrating climate change and sustainability goals into decision-making about infrastructure assets and services. The City of Kenora was a successful recipient ($80,500) and hired the consulting firm PSD to update their AMP and risk framework to include climate change adaptation. PSD undertook a climate change adaptation resilience study, followed by a Climate Change Risk Assessment Framework for core infrastructure.

The following catalysts were used to gain buy-in from City Council, staff, and other stakeholders:

- Physical, economic, social, and ecological impacts of climate change were already becoming apparent to city staff and members of the community, therefore prompting action.
- Under O.Reg 588/17, municipalities in Ontario are required to adopt an AMP which includes commitment to levels of service, lifecycle management, and mitigation approaches to climate change.
- The proposed project would satisfy the environmental principles defined in the City's Strategic Plan.
- The FCM grant of $80,500 would cover a significant portion of the project costs.
- The findings from the study and framework would generate staff awareness of climate change impacts.
- The findings could also contribute to future business case reports; supplement applications for grant programs, garner support from City Council, and make a business case to the province for funding.
- PSD was already familiar with the City's asset management program/software and could ensure that the research was properly integrated with the AMP.

The project was led by Smith, who works within the CAO's office. As the Special Projects and Research Officer, Smith guides the City's asset management program and works with the finance, public works, and engineering departments, as well as the GIS technologist. During this project, the various departments worked together to increase staff awareness of climate change impacts on city infrastructure and operations.

Municipal staff from all departments contributed to the research by identifying climate change-related risks to infrastructure, the local environment, key economic industries, and citizens' health and safety. Information was gathered by PSD through interviews, the City's environmental assessments and other reports, and through correspondence with city staff. The Climate Change Risk Assessment Framework required further data gathering; public works and engineering worked together to identify linear assets and gather necessary asset attributes to fill the data gaps. A GIS technician integrated the asset data with the GIS system and also identified problem areas on the map based on the likelihood of flooding and population density.

## Climate Change Adaptation and Resilience Study

Kenora's climate change adaptation and resilience study was developed by PSD. The study began with an overview of how climate change is affecting Canadian municipalities and the associated costs of mitigation. The implications of climate change on the City's key physical (roads, water, bridges, and facilities), social (public health and safety), economic, and ecological factors (biodiversity and eco-assets) were defined. PSD worked with municipal staff to gather the information needed and determine the best methods to calculate vulnerability and analyze risk. Sources from the municipality included: interviews with staff, environmental assessments, and the asset inventory and AMP. To supplement this data, information was also collected from Environment and Climate Change Canada (ECCC), ICLEI Canada, Standards Council of Canada, and the Public Infrastructure Engineering Vulnerability Committee (PIEVC).

According to the MNRF, temperature increases and higher levels of precipitation will be the most significant climate change threats within the Nelson River watershed. Projections suggest a mean annual temperature increase of 8.8°C by the year 2080, largely due to increased temperatures in the winter. Winter precipitation levels are projected to increase slightly from 19 to 22 mm between 2011 and 2040, to 31 mm by 2070. In the summer, precipitation is projected to be volatile, with a possible decrease by 19 to 21 mm between 2011 and 2040; 7 to 27 mm between 2041 and 2070; and 3 to 44 mm between 2071 and 2100. Based on findings from the 2014 Intergovernmental Panel on Climate Change's fifth assessment report, MNRF data, the City's current asset condition and levels of service, the following climate change impacts were identified to be a threat to the City's water infrastructure:

- Higher temperatures accompanied by reduced precipitation in the summer can reduce soil porosity. Reduced soil porosity limits the volume of water than can be absorbed, resulting in higher volumes of water flowing through routes and minor systems.
- Increased flooding caused by an increased intensity in precipitation can overwhelm the capacity of storm infrastructure. Flooding can cause damage to public and private property, potential sanitary sewer overflow, and malfunction of electric systems.
- Variability in temperatures within seasons can exacerbate freeze/thaw cycles and winter flooding. These impacts can cause pipe bursts and shifting infill, which leads to increased stress on subsurface infrastructure.
- Higher temperatures and drier conditions can create a higher risk of forest fires, which poses a risk to green and grey infrastructure.

The study concluded that the City's current level of service and procedures surrounding asset management would not suffice to prevent these adverse effects of climate change. An analysis of Kenora's eco-assets and wildlife identified four possible ecological impacts of climate change: 1) a decline in the local moose population due to warming winter temperatures, which can result in

### PSD's Climate Change Risk Assessment Framework

A risk assessment framework is a useful tool for municipalities when limited internal resources are available to immediately address capital and operating needs. Risk acts as a key measure related to the level of service provided in the community and can guide planning for numerous departments. The framework focuses on assets identified by the overall value, relative to the community's entire asset portfolio, the level of detailed asset data available, and their criticality level. Once the asset categories are identified, consultants work with staff to create tailored risk matrices that translate the risk potential into a quantifiable format. Risk is defined by the probability of failure multiplied by the consequence of failure. The consequence of failure parameters are aligned with a triple bottom line approach, which includes economic, social, and environmental considerations. Once the consultants identify the data gaps and the data inventory is updated, the matrices support a risk analysis, which can apply risk ratings to all assets. The consultants can then provide guidelines that allow the community to apply the risk assessment framework on an ongoing basis when new or updated data sources are introduced.

parasite infestation and disease proliferation; 2) the growth of algae blooms as a result of increased light, warmer temperatures, and lower precipitation in the summer and fall; 3) threatened fish survival as a result of increased greenhouse gas (GHG) emissions; and, 4) altered wind patterns which may cause the lake to no longer stratify. If the lake does not stratify, the entire lake (instead of just the top layer), will experience warming during the summer months, impacting underwater habitat.

The study also describes how climate impacts on infrastructure and the environment will have negative impacts on the economy and the health of citizens. It provides a number of recommendations to alter or further develop the City's governance strategy, data gathering and analysis, and levels of service. The following list includes a sample of some of the study's recommendations:

- Modify disaster management planning to respond to new risks identified in the risk assessment.
- Switch insurance and adapt financial risk management.
- Work toward developing a Water Infrastructure Master Plan to assess the capability of existing infrastructure to meet future operational requirements and provide a framework to guide long-term asset management planning.
- Promote the planting of local natural vegetation along bodies of water to reduce the risk of erosion and need for maintenance, while enhancing local biodiversity.
- Research and invest in new structural materials that are more resistant to flooding and extreme weather events.

- Improve the data collected at weather and climate monitoring stations, to satisfy the needs of both climate change experts and engineers.
- Determine the most suitable approach to gathering climate data for the municipality, and ensure that data is collected efficiently and is made available in a centralized location.
- Develop public engagement initiatives to increase awareness of the value of climate change response strategies.
- Determine the municipality's capacity to identify and evaluate the cost of the natural assets, particularly those that provide tangible benefits to the municipality.
- Identify and create a plan to address the potential risks to key economic industries, such as boating, healthcare, manufacturing, and mining.

## Climate Change Risk Assessment Framework

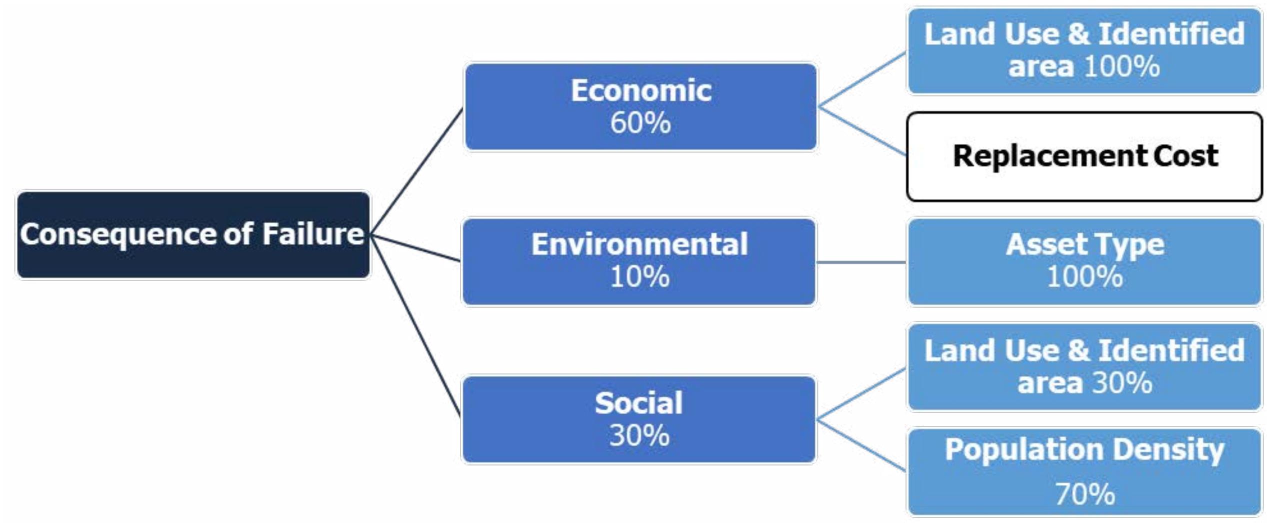
The risk assessment framework is an effective avenue to integrate climate change considerations into a community's asset management program because it supports short- and long-term infrastructure planning. The types of data needed are: an asset inventory that is comprised of all core and non-core asset groups; asset attributes such as measurements, materials, and other details specific to the asset type; location; historical costs; in-service years; estimated useful life; replacement cost; and assessed condition. The City needed further attribute data on linear assets and population density data and to identify problem areas based on the likelihood of flooding. Staff in public works and engineering, along with the GIS technician, worked together to ensure the risk assessment framework had meaningful data. The risk model was defined by the following equation:

**Risk = Probability of Failure (POF) × Consequence of Failure (COF)**

POF describes the likelihood that an asset will fail at a given time and the parameters are often defined by the current physical condition and service life remaining. Kenora's POF included current physical condition and identified problem areas. COF describes the overall effect that an asset's failure will have on the community and its asset management goals. Kenora's COF parameters were aligned with a triple bottom line approach, and include economic, social, and environmental consequences. Economic measures were defined by the monetary consequences of asset failure to the community and its citizens; social measures were defined by the consequences of asset failure on the citizen health and safety and the interruption of day-to-day life; and environmental measures were defined by the consequences of asset failure on an asset's surrounding environment.

The weighting process for the POF and COF were determined through consultations with city staff to identify priority concerns. The first risk parameter used to determine POF was current asset condition, and the second was the identification of problem areas throughout the City. Staff identified geographic areas that have experienced extreme weather events in a higher frequency and severity in recent years, and more specifically, significant flooding due to heavy rainfall.

COF is a much more complex matrix and was defined by the following graphic:




A major roadblock to the climate change risk assessment was a lack of data to define the economic COF. The City's dataset is incomplete as it relates to asset replacement costs. To move the project ahead, economic consequences were defined by "land use" and did not take into consideration replacement costs. The Official Plan Designation of land use by the City can inform the economic consequences of asset failure in a zone based on whether the use of the land significantly impacts the City's economy. Once the replacement cost data is gathered, the matrix can be amended to include the new data in the weighting system. With the current dataset, PSD performed a full risk analysis on the asset group identified in the table below. These assets were identified to have the highest risk rating based on the new risk matrices that include climate considerations, and nine of the ten assets identified were water assets.

### Kenora's Top 12 Highest Risk Assets

| Asset ID | Asset Type | Name | In-Service Date | POF | COF | Risk Rating |
|---|---|---|---|---|---|---|
| 17712 | Storm Mains | Sewer 458 | 1/1/1920 | 5 | 3.9 | 19.5 |
| 16590 | Water Mains | Water Line 562 | 1/1/1930 | 5 | 3.8 | 19 |
| 19688 | Sewer Mains | Sanitary Line 847 | 1/1/1930 | 5 | 3.8 | 19 |
| 17544 | Storm Mains | Sewer 292 | 1/1/1920 | 5 | 3.6 | 18 |
| 18654 | Storm Mains | Sewer 1399 | 1/1/1920 | 5 | 3.6 | 18 |
| 20877 | Paved Roads | Ninth Avenue S | 1/1/1985 | 5 | 3.6 | 18 |
| 16529 | Water Mains | Water Line 501 | 1/1/1905 | 4.2 | 4.16 | 17.47 |
| 16530 | Water Mains | Water Line 502 | 1/1/1905 | 4.2 | 4.16 | 17.47 |
| 16538 | Water Mains | Water Line 510 | 1/1/1900 | 4.2 | 4.16 | 17.47 |
| 16539 | Water Mains | Water Line 511 | 1/1/1905 | 4.2 | 4.16 | 17.47 |

At the end of the project, the City was provided with a risk assessment framework, recommendations for future data gathering, and guidelines on how to implement the framework on new or updated data sets. The matrices can be modified over time to fit the City's changing needs and priorities. By using the framework to identify the risk ratings of municipal assets, the City can improve project prioritization, short- and long-term financial planning, and day-to-day maintenance planning.

## Roadmap for Municipal Adoption

The City of Kenora will have an opportunity to use the risk assessment results to inform its short- and long-term financial strategies. In the future, city staff will gather replacement cost data and introduce more climate change impact measures within the matrices. Adam Smith notes that the climate risk project allowed them to refocus the City's AMP, and that involving staff from engineering, public works, and finance led to a much better overall understanding of the requirements and policies surrounding asset management planning. Kenora's infrastructure deficit, limited staff capacity, and restricted budget are typical of many small Canadian municipalities. Nevertheless, they were able to use their existing asset management program to integrate climate change considerations and begin more advanced climate change research.

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Case Study

# City of Edmonton

The City of Edmonton and EPCOR have been working to establish a baseline of climate risks facing the community, including risks and vulnerabilities to assets. Edmonton has taken on a city-wide approach to climate change adaptation through its Climate Change Resiliency and Adaptation initiative. The City's Environmental Strategies group identified vulnerabilities and conducted a risk assessment for the city. EPCOR has been working to develop a more specific assessment of risks and vulnerabilities at the storm-water sub-basin level.

## Background: Edmonton and EPCOR's Leadership on Climate Change

The Edmonton Declaration was established following a Global Mayors' Climate Summit on March 3-4, 2018 in Edmonton. This Declaration calls on all levels of government "to undertake climate risk and vulnerability assessments to guide planning and investment decisions, increase climate resilience, and minimize the exposure of people and assets to the impacts of climate change."[1] Edmonton Mayor Don Iveson led this initiative, as well as the development of Edmonton's Climate Resilient Adaptation Strategy and Action Plan, which considers risk assessment and vulnerabilities for Edmonton. By identifying potential climate impacts now, Edmonton can prioritize mitigation and adaptation efforts to build greater resiliency.

EPCOR, a commercial utility that provides power, water, drainage, and natural gas services to more than 2 million customers in Canada and the United States, has been working with the City to develop a more specific assessment of risks and vulnerabilities at the stormwater sub-basin level. EPCOR is governed by an independent Board of Directors, but Edmonton is their sole shareholder.

Edmonton's water, wastewater and drainage system assets are owned by EPCOR and water rates are set by City Council. Because of their unique relationship, the City and EPCOR work closely together on municipal goals and priorities. EPCOR's team have contributed to Edmonton's overall resiliency goals by providing a detailed risk assessment of stormwater assets. They are looking at risks and vulnerabilities at the stormwater sub-basin level and recently completed a climate risk overview using GIS and flood plain mapping for more than 1,400 stormwater basins. As part of this effort, EPCOR is developing a stormwater integrated resource plan (SIRP), building out risk through several different dimensions to prioritize adaptation actions.

## Climate Change Impact Profile

Historically, Edmonton experiences a continental climate, characterized by cold winters, short summers and low precipitation. Maximum precipitation typically occurs in June, with the majority of precipitation occurring through the summer months. Severe weather is frequent as a result of localized conventional heating and cooling at higher altitudes. Winter is typically long and cold, frequently with the occurrence of continuous snow cover. Edmonton generally experiences a lot of sunshine in both the summer and winter. Their average daily lows throughout the winter range from -11ºC to -19ºC, and 3ºC and 9ºC in the summer.[2]

### Highlights from the Edmonton Case Study

- This region experiences a prairie-steppe climate; dry, with the majority of precipitation happening in the summer months. The winters are very cold, with a very long snow season.
- EPCOR provides water, wastewater and drainage services to over 800,000 residents in Edmonton.
- In 2018, the City of Edmonton created a 4-year Climate Resilient Adaptation Strategy and Action Plan. In conjunction, EPCOR introduced an Integrated Resource Planning (IRP) approach to stormwater management that considers environmental and social externalities; operational, planning and infrastructure responses; risk assessment and management; and a participatory process to incorporate continuous improvement.
- EPCOR undertook comprehensive public engagement on the prioritization of sub-basins for flood mitigation measures. The public identified health and safety and social impact risks as a higher priority than environmental and financial risks.
- The consequences of a range of flooding scenarios was assessed. Data from a range of sectors and departments were incorporated.
- Results from both the public consultation and risk assessment yielded useful information to inform decision making on flood mitigation measures, including capital, operational, green infrastructure and flood-proofing by property owners.

The City consulted models from the Intergovernmental Panel on Climate Change and other scientific studies to determine local climate variables and their potential impact. Four overarching categories are identified in Edmonton's Climate Resilient Adaptation Strategy and Action Plan: changing temperatures, changing precipitation, changing weather extremes, and changing ecosystems.

- **Changing temperatures:**[3] Edmonton will see an increase in average temperatures across all seasons. The current average temperature in Edmonton is 2.5ºC, but this is expected to increase by approximately 3.5ºC to 5.6ºC by 2050 and 6ºC to 8ºC by 2080 (see figure below). The average winter temperature of -13ºC is predicted to increase by 4.5ºC by 2050 and 7ºC by 2080. These temperature changes will impact precipitation and drought conditions.

Projected Annual Temperature Change in Edmonton, Alberta

- **Changing precipitation:** Edmonton currently experiences an annual average precipitation of 458mm. Between 2014 to 2080, Edmonton may see an increase of 40mm; and an increase of 54mm is expected between 2071 and 2099. The biggest seasonal increase in precipitation is expected to occur in the spring, while precipitation is expected to decrease during the summer months. It is likely that Edmonton will experience drier summers, wetter winters, and more heavy precipitation events.[4]
- **Changing weather extremes:** The frequency and severity of extreme weather such as wildfire, extreme rainfall or snow, freezing rain, high winds, and lightning are expected to increase.[5]
- **Changing ecosystems:** Long-term ecological changes (e.g., frost, length of growing season) could contribute to a shift from a boreal/aspen parkland ecosystem to a grassland ecosystem, similar to what we see currently in Southern Alberta.[6]

## Edmonton's Adaptation Strategy and Action Plan

Edmonton's Climate Resilient Adaptation Strategy and Action Plan includes three phases:

**Phase 1: Investigation**

The City considered other cities' adaptation strategies and participated in the International Council for Local Environmental Initiatives' (ICLEI) Building Adaptive and Resilient Communities (BARC) program. Edmonton's unique climate change risks and vulnerabilities were identified using a taxonomy of hazards created by the Global Covenant of Mayors for Climate and Energy. The Covenant's standardized reporting framework — Climate Risk and Adaptation Framework and Taxonomy — enables cities to perform robust and consistent reporting of local climate hazards and impacts, risk and vulnerability assessment, and adaptation planning and implementation.[7] The City then formed stakeholder groups to identify potential impacts of climate hazards and create an overarching baseline.

**Phase 2: Direction Setting**

The City consulted local stakeholders about vulnerability and risk. This was a quantitative process that looked at each climate hazard through an assessment of the likelihood and consequence of climate variables such as freeze-thaw cycles, heavy precipitation, urban flooding, heavy snow, freezing rain, impacts on the growing season, and drought. Likelihood was based on event probability, such as a 1-in-25 year storm. Consequences in four categories (health and safety, economy, social well-being, and natural environment) were determined by quantifying potential physical damages and service losses to assets and service levels using published damage curves, quantitative vulnerability indices scales, and subject matter expertise.

**Phase 3: Taking Action**

Based on the findings described above, Edmonton established five paths to climate resilience: science and evidence-based decisions; preparing for changing temperatures; preparing for changing precipitation; preparing for changing weather extremes; and, preparing for changing ecosystems. Within each path, there are a series of goals and actions identified. The development of Edmonton's comprehensive adaptation strategy and action plan took a considerable amount of staff time and resources. Edmonton had one full-time employee on the initiative over the past two years, with additional help from other team members who were not dedicated solely to this work. Edmonton did retain consulting services to help with the strategy development. City Council has allocated some funding to this work over the next four years, and a staff implementation team has been assigned to oversee this work.

# EPCOR's Stormwater Integrated Resource Plan

One of Edmonton's identified goals in its adaptation strategy is to become a flood resilient city. To achieve this, the City has partnered with EPCOR to develop and implement an urban flooding resilience program. This includes the implementation and update of EPCOR's Stormwater Integrated Resource Plan (SIRP). EPCOR's integrated resource planning (IRP) approach "takes a holistic approach that integrates environmental and social externalities; operational, planning and infrastructure responses; risk assessment and management; financial analysis; and an open participatory process that incorporates continuous improvement."[8]

## Establishing Mitigation Priorities through Public Engagement

EPCOR consulted Edmonton's citizens to determine which flood impacts should be priorities in the SIRP risk framework.[9] They surveyed local residents on the following four types of impacts during moderate, major and extreme flooding: public health and safety, social issues, environmental issues, and financial losses. Protecting public health and safety and minimizing social impacts from flooding emerged as clear priorities. Based on this public opinion research, EPCOR established specific risk exposure targets for the public's highest flood protection priorities — hospitals, essential services, protection of life, and social services. The next most important priority identified in the survey was household flooding. Financial and environmental impacts were ranked lower that other types of impacts. Using this information, areas that could experience various types of impacts were prioritized accordingly in the risk framework.

## Building the Risk Framework: Determining Potential Flood Impacts, Risk Dimensions, and Priority Sub-basins

Stormwater sub-basin capacity risks were determined by assessing the potential for basement and overland flooding. Risk frameworks were developed using various forms of data, including historical engineering analysis reports, historical flood records, and overland flood models from the Province of Alberta and insurance industry. Stormwater asset condition information, sanitary surcharge modelling, underpass modelling, river valley neighbourhood modelling, hydraulic models of stormwater pipes, GIS data, and the location of key features, such as hospitals, fire halls, schools, wastewater and water treatment plants, reservoirs, and pump stations were also used.[10] Potential flood impacts were based upon flood risk exposure and whether the sub-basins could reach damaging flood depth levels. Five storm events were assessed: 1:20, 1:50, 1:75, 1:100 and 1:200 year storm events.

EPCOR also collaborated with the insurance industry to ensure that they were aligned in their approach to assessing risk to a property over its lifetime. They purchased insurance flood forecast maps for Edmonton at a relatively low cost from a modelling company that estimates overland and river flooding depths for seven different storm scenarios (1:20, 1:50, 1:75, 1:100, 1:200, 1:500, and 1:1500). EPCOR incorporated this information up to the 1:200 storm level in their risk framework analysis. The utility plans reference 1:500 and 1:1500 storm levels when developing mitigation plans for the sub-basins to determine how these events could be managed by the proposed improvements.[11] While the insurance overland flood maps can provide a baseline for flooding risk assessment, it is important to highlight that the flood maps used by the insurance industry currently do not consider the capacity of municipal stormwater pipe networks to reduce flood risk.

The risk framework was developed based on the four types of flooding impacts used in the public engagement survey (public health and safety; social issues; environmental issues; financial losses). For each of the four categories, data sets were analyzed to determine the consequence and likelihood of flooding occurring within a particular sub-basin. When looking at these four different risk dimensions, risk was driven by different flooding conditions. For example, risk to health and safety was largely driven by three flooding conditions:

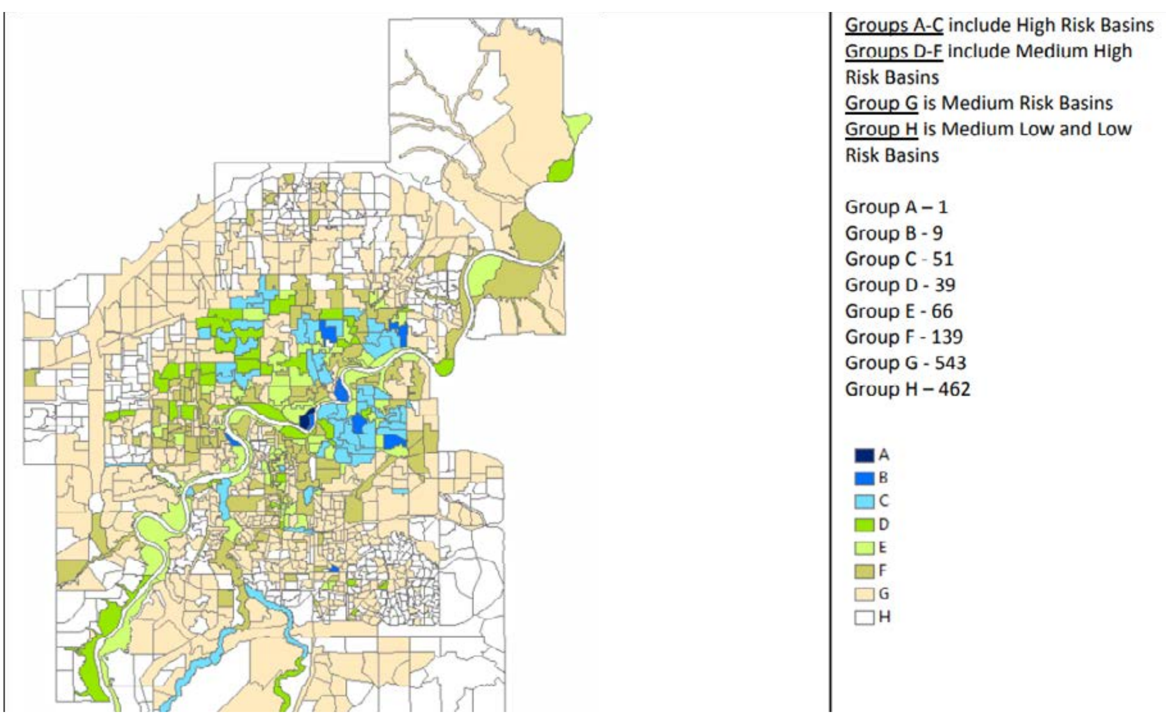
- Increased risk of basement flooding due to sanitary sewer pipes surcharging to a depth greater than typical basement floor elevation. If the home does not have a backwater valve, this can result in the health risk of exposure to sanitary sewage (1:50 storm and greater).
- Increased risk of creek erosion due to higher flows may impact the stability of banks and trails and increase the risk to personal safety (1:20 storm and greater).
- Increased depth of overland flooding in low-lying areas like underpasses and sag areas (1:20 storm and greater).[12]

EPCOR worked with the City of Edmonton's Utility Committee, which is made up of representatives from Edmonton City Council, to identify scenarios exploring different weighting schemes for the four risk dimensions:

- Scenario 1: Equal weighting of all four risk dimensions – 25% each
- Scenario 2: 30% Health and Safety, 30% Social, 25% Financial, 15% Environment
- Scenario 3: 40% Financial, 20% for all Health and Safety, Social and Environment

The map below shows the results of Scenario 2, which places a higher emphasis on risk to health and safety and social impacts, highlighting the basins which are at higher risk based on the various flooding conditions considered. This scenario was selected by the Utility Committee to prioritize flood mitigation efforts and the development of a 20-year capital and operational plan.

## Assessed Risk for Sub-basins in Edmonton Using Scenario 2 Weighting of Risk Dimensions



## Using the Risk Framework to Inform Adaptation Measures

EPCOR's approach created a holistic view of the impacts of flooding on various city features, enabling the SIRP to reflect public priorities in flood management. Some of the flood mitigation measures that EPCOR will implement are trunk and sewer separation, outfalls and control gates, dry ponds, maintenance, weather forecasting, and emergency response. After evaluating historical basement flooding records and local convective storm patterns, EPCOR broadened the mix of capital and operational investments to also include green infrastructure and flood proofing of at risk properties. These measures are intended to reduce ponding on roads after storm events in areas which have depressions or sagging.

EPCOR is moving away from developing capital projects that are "named" projects (i.e. fixing an issue on a specific street or neighbourhood) to performance-driven projects (i.e. choosing projects based on the developed risk models, which identify issue areas). Their risk framework provides more flexibility in their response to flood resilience, as there is more concrete information on flooding conditions and risk dimensions to prioritize projects and inform decision-making. The development of EPCOR's SIRP is directly aligned with Edmonton's overarching adaptation goals.

EPCOR's reports to Edmonton's Utility Committee as the SIRP was being developed can be accessed at epcor.com/products-services/drainage/flood-mitigation/Pages/default.aspx. In May 2019, they presented a proposed capital plan to the Utility Committee and are developing a 20-year capital plan.[13] Future flood mitigation work will include a combination of homeowner programs, drainage system improvements, green infrastructure, and planning. EPCOR is also implementing a smarter stormwater network that will allow the utility to anticipate and react to storms in real time using monitoring and control technology. EPCOR's overall goal is to slow, move, secure, predict, and respond to flooding events to prevent or reduce impacts.

# Roadmap for Municipal Adoption

There are several elements of the approach Edmonton and EPCOR undertook that could be applied by other municipalities looking to implement a holistic, risk-based stormwater management program in the context of a broader climate change adaptation plan.

- Edmonton used the framework for adaptation from the Global Covenant of Mayors to establish potential local impacts from climate change, as well as current risks and vulnerabilities. Establishing a baseline of climate hazards and assessing the current state of vulnerabilities is something that the majority of municipalities can accomplish with the assistance of staff and/or third-party expertise.
- Municipal leadership on citywide climate change adaptation contributed to the successful advancement of EPCOR's innovative stormwater management program. The initial stages of Edmonton's broader adaptation goals are achievable for small to mid-sized municipalities and will go a long way in supporting climate change adaptation for municipal water systems, including driving efforts to identify infrastructure vulnerabilities.
- This case study highlights the importance of bringing multiple stakeholders together to advance climate adaptation. EPCOR conducted public and stakeholder engagement to help prioritize actions. The results contributed to the creation of a combined risk scenario that placed greater emphasis on reducing health and safety and social impact risks, with less emphasis on financial and environmental risks.

- EPCOR, with direction and input from the City's Utility Committee, developed a risk framework to prioritize the ranking of stormwater sub-basins for five storm scenarios (1:20, 1:50, 1:75, 1:100 and 1:200 year storm events) and four dimensions of risk (health and safety, environment, social impact, and financial).
- The risk analysis incorporated a wide variety of data sources, including overland flood maps from the insurance industry, historical basement flooding data, GIS mapping and hydraulic models. A holistic picture of risk was established on a sub-basin level across the city. EPCOR coordinated with the insurance sector to access overland flood risk evaluations for Edmonton. This was an economical approach to incorporate key information into the risk framework.
- Based on the SIRP, EPCOR will focus on various types of flood mitigation measures, including capital and operational investments, as well as green infrastructure and home/business flood proofing. A review of historical information and an understanding of local and changing weather patterns pushed EPCOR to consider a broader range of mitigation measures that would compliment traditional solutions. Identifying system vulnerabilities and gathering public input equips municipalities to make long-term investment decisions that optimize the timing and type of investment, thus helping to address challenges at the sub-basin level.
- EPCOR and the City of Edmonton have a unique relationship that enabled them access to unique expertise, while still being maintained under the overarching governance structure of the City. The governance structure between the two entities was very similar to a municipality's connection to their council. Having the dedicated expertise of EPCOR greatly assisted the City in putting together their climate change adaptation material and continuing to work towards better management of their water, wastewater and stormwater assets.

# Endnotes

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Case Study

# The City of Moncton

The City of Moncton initiated a climate change adaptation initiative in 2010 by applying for funding through Natural Resources Canada's Regional Adaptation Collaborative. The City will be impacted by storm surges, with greater precipitation and coastal erosion, as well as adaptation difficulty due to the presence of low-lying marshland. The City has linked its 2013 Climate Change Adaptation Plan to its current Strategic Plan and routinely looks to incorporate the recommendations into all future City initiatives.

## Background: Moncton and its Climate Change Adaptation Process

The City of Moncton is the largest city in New Brunswick. The population is 71,889; the population of the Greater Moncton Area (GMA) is 144,810. The City of Moncton provides water services that include drinking water, wastewater, and stormwater services to all area residents and businesses. The Greater Moncton Region includes the City of Dieppe and the Town of Riverview; however, the water services of those local governments are managed independent of the City of Moncton. The potable water for the Greater Moncton Region is sourced primarily from the Turtle Creek Reservoir, which is owned and operated by the City of Moncton. The City of Dieppe and the Town of Riverview purchase water from the City of Moncton and manage its delivery to residents and businesses within the respective jurisdictions.

In Eastern Canada, the primary hazard associated with climate change is increasing frequency and intensity of storm events. Coastal erosion, fluvial flooding from the Petitcodiac River, and an exceptionally high tidal range are also factors in the area's hydrodynamic location. In 2010, the GMA, including Moncton, Dieppe, and Riverview, was approached by the Atlantic Climate Adaptation Solutions Association to apply for funding through Natural Resources Canada's Regional Adaptation Collaborative (RAC), a federal cost-sharing program.

After being selected for the RAC partnership, a technical study was prepared by an environmental consulting firm to identify the potential impacts of climate change to the community and vulnerable infrastructure. In 2012, the results were presented to Moncton City Council and Council asked staff to develop an action plan and flood management strategy. In 2013, the City released a corporate Climate Change Adaptation and Flood Management Strategy, which identified key vulnerabilities and more than 60 action items to help address identified gaps.

The City has since amalgamated some of these action items into the 2016-2020 Strategic Plan, including: passing a new by-law with habitable space elevation requirements for building construction, conducting a Neighbourhood Flood Mitigation Study, and identifying the costs associated with potential solutions. The City has also made progress in applying climate change information to asset management planning, and a finalized asset management plan is projected to be completed in 2019.

**Highlights from the Moncton Case Study**

- The Greater Moncton Area (GMA) is highly urbanized, with three municipalities that experience flooding from the Bay of Fundy and inland watercourses.
- The GMA has been experiencing storm surges and significantly greater precipitation, as well as extreme maritime weather events, such as hurricanes, and increased flooding caused by increases in tidal range and coastal erosion.
- Using the results of a 2011 regional study, the City of Moncton released its Climate Change Adaptation and Flood Management System in 2013, which includes sixty action items.
- Many of these climate change action items have been amalgamated into Moncton's 2016-2020 Strategic Plan, and timelines for implementation have been established.
- In the near future, Moncton intends to review its stormwater and sewer system master plan to align with its Climate Change Action Plan.

# Climate Change Impact Profile

Moncton is located at the head of the Bay of Fundy and is bisected by the Petitcodiac River. It is a highly urbanized location that experiences flooding from both the coast and inland watercourses. Environment and Climate Change Canada (ECCC) describes the climate as, "typical of most cities located in the maritime provinces of Canada, but heavily influenced by strong seasonal weather from continental sources."[1] Despite Moncton's location by the Bay of Fundy and close proximity to the Northumberland Straight, average weather patterns are similar to inland Quebec. Summers are comfortable, with significantly less humidity than neighbouring maritime provinces, and in the winter, Moncton experiences greater snowfall amounts and storm intensity than Nova Scotia or Prince Edward Island.

Moncton has a history of extreme weather events; from 1950 to 2012, over 280 extreme weather events have been recorded. There are two specific extreme weather events that are used as reference points for climate change impacts: the Saxby Gale (1869) and Groundhog Day Storm (1976). The Saxby Gale was one of the largest storm surges in Atlantic Canada's recorded history and resulted in 37 fatalities and extensive property damage. The gale was made more intense from the unusually high tides at the time of the storm, and has been used in environmental analysis as a baseline for the degree of impact that a storm larger than a 1:100 year storm can cause. This particular storm shows how compounding factors can add a layer of unpredictability to any climate model, exemplifying the difficulty in predicting the intensity of climate change-induced extreme events.

The Groundhog Day Storm has also been used as a reference example in environmental analysis. Unlike the Saxby Gale, which was associated with a hurricane, the Groundhog Day Storm was caused by a weather system originating in the Canadian Prairies. Near its peak, the storm generated sustained wind speeds of 164 km/hour in coastal and neighbouring areas. Southern New Brunswick experienced coastal flooding of up to 1.6 metres, causing extensive damage to residential and municipal infrastructure. Although Moncton wasn't impacted as severely as other communities in New Brunswick, the storm provides an important reference point in the region's climate.

ECCC has identified storm surges with significantly greater precipitation, extreme maritime weather events (such as hurricanes), and increased flooding caused by an increased tidal range and coastal erosion, as key areas of concern for the area.[2] Environmental analysis has projected increases in precipitation amounts from non-extreme storm events of approximately 20% by 2100.[3] The following chart shows average high and low temperatures and yearly precipitation for Moncton in the years 1961, 1980, 2000 and 2018. The City has shown a steady increase in both average July and January temperatures and total precipitation.[4]

**Temperature Range and Annual Precipitation in Moncton**

| | Average High January | Average Low January | Average High July | Average Low July | Yearly Precipitation |
|---|---|---|---|---|---|
| 1961 | -6.2ºC | -18.8ºC | 25.3ºC | 11.7ºC | 1028.0 mm |
| 1980 | -2.7ºC | -12.0ºC | 23.4ºC | 13.5ºC | 1054.4 mm |
| 2000 | -1.2ºC | -11.7ºC | 24.4ºC | 13.1ºC | 1163.6 mm |
| 2018 | -2.0ºC | -12.6ºC | 27.8ºC | 14.8ºC | 1319.9 mm |
| Source: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html | | | | | |

The potential impact of climate change is significant within the City of Moncton. Various arterial roadways and essential services infrastructure have been identified as being at risk due to increased probability of flooding or soil erosion. Many underground and water infrastructure assets are located in areas that were identified as higher risk in the climate change adaptation assessment. A significant risk for the community was also identified in the natural and historical assets categories. Numerous areas of low-lying marshland and wetlands exist within the GMA. These marshlands along the Petitcodiac River were historically used as fertile farmland and protected from daily flooding by dykes and aboideaux. Over time, many of the dykes have not been maintained, so it has become possible for extremely high tides to flood these areas.

Commercial developments such as the Champlain Place Mall have been built on former marshland, as well as the infrastructure needed to support these developments, such as roads, water, wastewater, and stormwater assets. The ground elevation in many of these areas is around 8.2 metres and are in danger of being significantly impacted if a 1:100 year storm event occurs. Urban densification in these areas has compounded the risk of physical, social, and economic impacts. Limited space to construct new dykes poses a significant barrier to adaptation.

## Identifying Gaps in Neighbourhood and Stormwater Development Standards

To identify gaps in neighbourhood and stormwater development standards, the City of Moncton needed to establish its specific climate profile. Environmental consultants were tasked with building a model that would project likely scenarios and determine priorities for adaptation planning. The consultants used modified intensity-duration-frequency (IDF) curves to identify the probability of a climate event occurring in the GMA. IDF curves traditionally use long-term rainfall and storm records to identify historic trends, but the consultants modified the traditional IDF curves to adjust for potential variability by including simulated climate outcomes. These modified curves reflect changes in the characteristics of precipitation that might be caused by changes in climate.

The study specified three timeframes for the projections: 2025, 2055, and 2085. The data that the study utilized included adjusted historical weather observations from 1946 to 2007, as well as global climate projections. The statistical model produced 48 future projected change outcomes in temperature and precipitation, which were adjusted to reduce statistical bias from the model. The final results provided a range of outcomes and a robust projection of the potential climate impact that the GMA is likely to face. Based on the climate projections and IDF curves established in the study, the consultant was then able to establish a risk assessment for key infrastructure assets located within the GMA, and within the risk assessment, identify and prioritize infrastructure assets based on their usage for transportation, essential services, storm sewers, and sanitary sewers.

The prioritization was evaluated using four criteria:

**Constructability/Functionality**: Geotechnical issues and construction risks such as the potential for encountering poor soils and/or elevated groundwater conditions; infrastructure requirements or work required to maintain and sustain current infrastructure; operational impacts of infrastructure maintenance required; property acquisition accessibility; and, system reliability indicated by the proximity of the infrastructure to storm sewer outlets or watercourses.

**Economy**: What additional benefits could be established through improving infrastructure? Was there potential to address additional problematic areas in a single project? Is the infrastructure asset efficiently utilizing existing capacity? Are opportunities available in reducing energy consumption or construction costs through large scale or multi-level infrastructure projects?

**Natural Environment**: Impact on significant natural environment assets including the potential loss of natural areas due to the installation of works; impact on aquatic systems such as the potential impact to the local fish habitat; impact on groundwater and surface waters including the impact caused by construction activities or operations; and, climate change impacts caused by the infrastructure project.

**Caring and Healthy Community**: Potential displacement of residents, recreation centres, and institutions and the direct effects caused by this displacement; potential disruptions to the existing community and the extent of works affecting existing residences and businesses; and the consistency with planned land use and infrastructure and its compatibility with city land use, design guidelines and infrastructure planning.

The evaluation criteria (Appendix I) were applied to all infrastructure classes that were projected to be impacted. Individual assets were not included; the risk assessment focused on the overarching asset categories and their risk. The results established a prioritization matrix that allowed the City to identify which assets were more likely to be affected by climate change and the corresponding consequences of failure should that asset be affected. Eight recommendations were made to reduce the risk posed to the community:

1. Develop a policy framework for adapting and mitigating the effects of climate change.
2. Review and update the flood protection standards currently in place within the GMA.
3. Review the by-laws governing flood protection standards.
4. Develop a strategy and policy framework for addressing current and potential future developments in flood prone areas.
5. Commission a more detailed and in-depth infrastructure review and planning study.
6. Develop a warning and emergency response plan for a potential high flooding event.
7. Communicate a plain language summary of the report to the public.
8. Produce a technical bulletin of the study, to be used by civil engineers to ensure future developments meet adequate standards.

## Actions Undertaken

Once the technical study was finalized and presented to City Council, staff were tasked with completing a Climate Change Adaptation and Flood Management Strategy using the findings of the study to better prepare for extreme climate events. To correspond with the eight recommendations laid out in the technical report, Moncton proposed eight strategic priorities to help reduce the identified gaps. Each priority included several action items for better adaptation planning for the City. These strategic priorities are:

1. Development of a major storm/hurricane/flood emergency response plan
2. Enhanced community engagement (education, consultation and partnerships)
3. Research, planning, and priority setting
4. Adaptation policies and regulations
5. Physical adaptation
6. Monitoring
7. Funding
8. Oversight and ongoing updates

Under the 'adaptation policies and regulations' priority, the City set out to modify existing by-laws for neighbourhood and stormwater development plans. Under zoning by-law Z-213, new minimum floor elevation requirements (increasing from 10.2 metres to 10.5 metres) for habitable space and structured parking were established. Setbacks from watercourses were moved to 30 metres, preventing new developments from building in higher risk zones. In total, 19 action items were identified as proposed solutions to reduce the potential impacts of surface flooding within the City. The City proposed and has since adopted a net-zero stormwater policy to help reduce stormwater run-off volumes, and has also established additional landscaping and urban planning provisions to assist with reducing stormwater run-off through parking lot design, planting trees on city streets and more.

The 'physical adaptation' priority included two primary courses of action. The first was the development and implementation of the Backwater Valve Incentive Plan for existing homeowners, which was seen to be a significant mitigating solution to stormwater overflows and basement flooding. The program required all new construction to install a backwater valve and provided existing homeowners with a $500 rebate towards the installation of an approved backwater valve. The second action was to undertake an in-depth Neighbourhood Flood Mitigation Study. In 2018, the City contracted an engineering firm to assess neighbourhood vulnerabilities and all costs associated with updating existing vulnerable neighbourhoods to meet the new required standards. This report has yet to be presented to City Council, but the City's Director of Environmental Planning and Management, Elaine Aucoin, notes that that the "initial report is very in-depth and looks at all possible solutions available to the City to reduce these risks."

Many of the action items identified within the Climate Change Adaptation Plan have been amalgamated into the City's 2016-2020 Strategic Plan, with proposed timelines associated with the key areas of focus. Chief Administrative Officer Marc Landry explains, "Our Strategic Plan is reviewed on an annual basis. One of the five pillars is the environmental pillar, where we have a number of priorities related to climate change adaptation and data analysis, as well as water infrastructure assets. Climate change will continue to be an important component of Moncton's Strategic Plan moving forward." In the near future, the entire Stormwater and Sewer System Master Plan will be under review, and additional action items can be added or modified to meet the needs outlined in the Adaptation Plan. The Water Treatment Facility Management Plan will also be reviewed in 2019.

## Roadmap for Municipal Adoption

An ongoing challenge Moncton, and many communities face, in advancing climate change adaptation activities is effectively engaging the public to develop their buy-in. Despite a general desire among the public for adaptation solutions, gaining acceptance of the proposed alternatives can be difficult. Some of the efforts Moncton has made to improve public engagement on climate change initiatives includes regular public council meetings as well as providing opportunities for residents to voice concerns. Incremental progress has been a focus for City staff. For example, while the solutions that offer the greatest amount of adaptation benefit for the City may be difficult to accept by stakeholders due to the required trade-offs involved, incremental progress is being made by introducing measures which yield some positive adaptation outcomes, such as the backwater valve incentive, which moves the needle in the right direction.

Aucoin notes that, "capitalizing on federal programs like RAC or Federation of Canadian Municipalities' Green Municipal Fund has been instrumental in allowing Moncton the opportunity to address climate change for our community." While the City routinely looks for funding programs and other opportunities to further address this issue, collaborative programs such as the RAC partnership have had the greatest impact to the community. Strategic partnerships and collaborative funding can be instrumental in ensuring municipalities have the resources to effectively ascertain the feasibility of climate change activities and programs, as well as implementing the proposed activities. For example, partnering with ACASA and NRCan allowed Moncton to organize efforts towards an effective adaptation plan. Capitalizing on the knowledge of subject experts to develop climate adaptation programs can also simplify and optimize the process.

## Endnotes

1 Environment Canada. "Climate of New Brunswick Report." 2007.

2 Ibid.

3 AMEC Earth & Environmental. "Climate Change Adaptation Measures for Greater Moncton Area, New Brunswick." December 2011.

4 Environment and Natural Resource Canada. "Past Weather and Climate Daily Data Report – Moncton."

## Appendix I.

### Evaluation Criteria Used to Prioritize Infrastructure Assets in the GMA's Risk Assessment

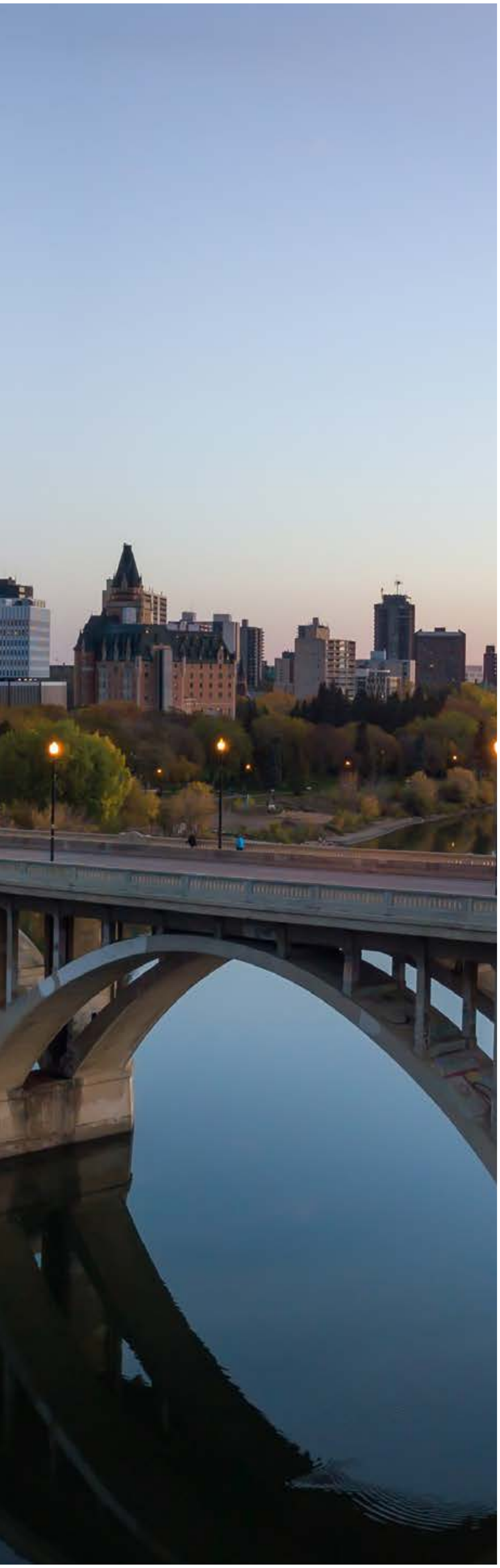
| Evaluation Criteria | | |
|---|---|---|
| Category | Criteria | Indicator |
| Constructability / Functionality | | |
| C1 | Geotechnical issues and construction risks | Potential for encountering poor soils and/or elevated groundwater conditions. |
| C2 | Infrastructure requirements | Extend of works required. |
| C3 | Operational impacts | Amount of maintenance intensive infrastructure required. |
| C4 | Property acquisition | Ease and extent of property acquisition (i.e. vacant, private, or leased lands). |
| C5 | System reliability | Proximity of infrastructure to storm sewer outlet or watercourse. |
| Economy | | |
| E1 | Additional benefits | Potential to address addition problematic areas in a single project. |
| E2 | Efficient use of existing capacity | Uses available capacity. |
| E3 | Energy consumption | Electricity requirements. |
| E4 | Construction cost | Capital cost of construction. |
| Natural Environment | | |
| N1 | Impact on significant natural features | Loss of natural areas due to installation of works. |
| N2 | Impact on aquatic systems | Potential to impact fish habitat. |
| N3 | Impact on groundwater and surface waters | Potential to impact groundwater and surface water due to construction activities or operations. |
| N4 | Global warming | Impact on global warming. |
| Caring and Healthy Community | | |
| H1 | Displacement of residents | Effects on residential areas, institutions or businesses. |
| H2 | Disruption to existing community | Extent of works affecting existing residences and businesses. |
| H3 | Consistency with planned land use and infrastructure | Compatibility with city land use, design guidelines and infrastructure planning. |

Source: AMEC Earth & Environmental. "Climate Change Adaptation Measures for Greater Moncton Area, New Brunswick." December 2011.

Case Study

# City of Saskatoon

Larger municipalities with multiple divisions may find it difficult to build a climate adaptation program from the top-down. Some departments may be ready to engage, while others are not as advanced. In the case of the City of Saskatoon, prior to adopting a climate action plan, a number of projects were already underway. The City is now working on creating a corporate adaptation strategy that will guide all existing and future adaptation initiatives.



## Background: Saskatoon and its Climate Change Adaptation Efforts

Saskatoon is located on the shores of the Saskatchewan River in central Saskatchewan and is the largest city in the province. According to the 2016 census, the City grew by 11% between 2011 and 2016, and today the population has reached over 278,000.[1] Saskatoon has historically served as a major distribution centre for agriculture,[2] but its economy has now diversified to include thriving education and business sectors. As the City's population and economy have grown, demand for public services has also increased.

In 2018, the City produced a new organizational chart for municipal departments and divisions to facilitate communication between staff and citizens. Departments are divided into two categories: customer-facing and strategic partners. Strategic partners include departments that support internal organizational tasks, such as Financial Services, Strategy and Transformation, and Human Resources. Customer-facing departments include Transportation and Construction, Utilities and Environment, Community Services, and Saskatoon Fire. Although the impacts of climate change affect multiple municipal departments, projects related to climate change adaptation and asset management tend to fall under customer-facing departments.

The 2018-2021 Strategic Plan identifies 'environmental leadership' as one of its seven strategic goals.[3] This goal includes mitigation and adaptation priorities such as increasing energy-efficiency, reducing greenhouse gas (GHG) emissions related to city operations, adapting municipal infrastructure to accommodate severe weather events, and reducing the quantity of stormwater run-off going into the river. Initially, the City employed an ad hoc approach to climate change adaptation and mitigation based on need. Recently, corporate-wide plans have been underway to integrate these initiatives in a holistic adaptation strategy. City staff have been collaborating with external experts and groups such as the Saskatchewan Research Council, University of Saskatchewan, Indigenous communities, and the Meewasin Valley Authority as part of this holistic approach.

In 2015, the City of Saskatoon became a signatory of the Global Covenant of Mayors for Climate and Energy, which is a commitment to reduce GHG emissions and plan for changing climate conditions. Since then, the City has made significant progress in building a corporate GHG emissions inventory and setting targets to reduce

**Highlights from the Saskatoon Case Study**

- The City of Saskatoon is the largest community in Saskatchewan, with over 278,000 citizens.
- Saskatoon experiences cold winters and warm summers. Possible changes to climate include extended periods of drought and heat, as well as localized flooding caused by heavy rainfall events.
- The City's population and economy are experiencing significant growth.
- The City has been a successful recipient of Federation of Canadian Municipality's (FCM) Climate and Asset Management Network grant, the National Disaster Mitigation Program, and the Municipalities for Climate Innovation program.
- Multiple adaptation programs and plans have been developed in separate municipal divisions.
- The City is currently supporting a Corporate Asset Management Plan, a Flood Control Strategy, and a Green (Infrastructure) Strategy.
- The City is developing 'Local Actions: The City of Saskatoon's Adaptation Strategy' to formalize a collaborative approach to build resiliency against projected climate changes.

corporate and community wide GHG emissions. The City has also been advancing its asset management practices. Within the 2018-2021 Strategic Plan, the 'asset and financial sustainability' goal makes a commitment to corporate asset management, which involves proactive strategic management of municipal assets and operations. Individual asset management plans (AMPs) have been developed for roadways and sidewalks, bridges and structures, parks, fleet, transit, water and wastewater, and the electrical utility. A Facilities AMP is expected to be released in 2019.

Saskatoon's Climate and Asset Management Committee is heading the project for the corporate AMP. Funded by FCM's Climate and Asset Management Network grant, staff have completed the preliminary vulnerability and risk assessment and integrated climate change language into the AMPs. The pilot will test a risk matrix to prioritize projects within the adaptation action plan. Since the existing AMPs lack adaptation strategies, the corporate AMP will include adaptation strategies (reliable forecasting, risk mitigation, and service level adjustments) as part of the implementation plan.

## Climate Change Impact Profile

The City of Saskatoon is located at the centre of the Canadian prairies, and experiences cold winters and warm summers, with low levels of precipitation throughout all seasons. According to Saskatoon's annual rainfall report, the annual average rainfall is 265 mm, but has ranged from 131 mm in 2001 to 569 mm in 2010. The chart on the following page shows the average high and average low temperatures in the months of January and July, followed by yearly precipitation for the years 1960, 1980, 2000, and 2018.

### Temperature Range and Annual Precipitation in Saskatoon

| | Average High January | Average Low January | Average High July | Average Low July | Yearly Precipitation |
|---|---|---|---|---|---|
| 1960 | -14.0ºC | -23.1ºC | 28.4ºC | 13.0ºC | 251.9 mm |
| 1980 | -13.1ºC | -22.9ºC | 26.0ºC | 11.6ºC | 305.9 mm |
| 2000 | -11.5ºC | -23.1ºC | 25.3ºC | 12.0ºC | 315.4 mm |
| 2018 | -7.8ºC | -17.9ºC | 26.3ºC | 11.0ºC | 216.3 mm |

Source: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html and Wittrock, V. (2019). Climate reference station Saskatoon annual summary 2018. Saskatchewan Research Council, Publication No. 10440-1E19

Possible changes in climate that pose a risk to the community include localized heavy rainfall, variability in the weather during transitional months, higher frequency of freeze-thaw cycles, higher risk of grass and bush fires, periods of drought, and extended periods of heat. Severe rain events, like those experienced in 2017, are generating repair costs for the City, as well as local businesses and homeowners. The Saskatchewan blizzard of 2007 spurred the creation and funding of an Emergency Measures Organization within the Saskatoon Fire Department.

The municipality's infrastructure is primarily impacted by extended periods of heat, freeze-thaw cycles, and flooding. The City has identified 30 areas in the community that are at a higher risk of flooding. Residents have expressed concern about flooding and lower air quality as a result of forest fires. There are also significant concerns about the protection of Saskatoon's natural environment and heritage. Areas such as the Northeast Swale and the riverbank are at risk of being harmed by the changing climate due to changing temperatures and periods of drought, as well as commercial and residential development.

## Flood Control Strategy

The Saskatoon Water division falls under the customer-facing department of Utilities and Environment. Angela Schmidt, Storm Water Utility Manager, oversees the Flood Control Strategy, a priority project. She notes that citizen advocacy is one of the key driving factors for this project. Prior to 2014, a number of flooding events prompted the initial flood mapping and risk assessment initiatives. Two major flooding events in 2017 – occurring in consecutive months in the summer – renewed demands for municipal action to prevent residential and business properties from flooding. As a result, City Councillors requested the development of a Flood Control Strategy, which was approved in 2018.

The Flood Control Strategy identifies 30 priority areas that are prone to frequent flooding. The areas were identified by modeling different types of storms, from 1:2 year storms to 1:100 year storms, to determine how they impact roadways, properties, and buildings. The flood-prone areas were ranked based on risk and impact of flooding. The City also partnered with Intact Centre for Climate Adaptation to offer a Home Flood Protection program. A 50-point home inspection with customized recommendations to reduce flood impacts were offered free of charge to almost 1,900 residents in flood-prone areas.

In 2018, Saskatoon Water undertook an evaluation of flood mitigation options, which looked at maintaining the status quo, directing stormwater to retention ponds in parks, and redeveloping areas at risk of flooding. The evaluation recommended options for future infrastructure projects, as well as potential funding strategies. Schmidt's team applied to Infrastructure Canada's Disaster Mitigation and Adaptation Fund (DMAF). The application included a $54 million Flood Control Strategy over the next nine years that would focus on 10 of the 30 priority areas. In 2019, funding for the Flood Control Strategy was approved; DMAF will contribute $21.6 million, which will cover up to 40% of the funds needed for the project.

The City is also updating its intensity-duration-frequency curves (IDF curves), which are based on historical rainfall up to 1986. Saskatoon Water recently received a grant from the National Disaster Mitigation Program to update these IDF curves, as well as funds to quantify cost impacts from flooding, and complete a cost/ benefit assessment for alternative storm water infrastructure design standards. The City has partnered with Concordia University and the University of Saskatchewan for this initiative.

### Green Infrastructure

> Green infrastructure is an inventory of a community's natural resources and ecosystems, (e.g. wetlands, forests, parks, soil, and lakes), as well as enhanced or engineered elements that support municipal services (e.g. urban trees, stormwater ponds, bioswales, and urban parks, or permeable pavement, green roofs, and rain barrels). These assets can moderate temperatures, filter the air, and manage water. Green infrastructure can mitigate the impact of climate change on grey infrastructure assets made from concrete, steel, and other non-natural materials. For example, stormwater run-off ponds can prevent flooding.[4]

## Green Infrastructure Strategy

The environmental protection team in the City's Sustainability division is developing a Green Infrastructure Strategy (Green Strategy). This project has been underway since 2017 and was motivated in part by the City's experience with establishing resource management guidelines for development in the vicinity of the Northeast Swale. The Strategy focuses on protecting the City's natural environment and optimizing green infrastructure to improve public services. It encompasses all open spaces within the City and will include guiding principles for the incorporation of natural areas into the urban environment, as well as considering service levels for maintenance, over the long term.

Genevieve Russell, Project Manager for the Green Strategy, is responsible for the project and oversees three staff with backgrounds in environmental coordination and planning. The team has consulted other divisions and community experts about community development, heritage sites, and the conservation of naturalized areas. Phase one of the Green Strategy has been completed, and the team is now working on phase two, which will be presented to City Council in 2020.

The first phase of the Green Strategy established a baseline inventory of open spaces within city limits. The inventory was based on an abundance of data, including civic policies, best practice research of other municipalities, and plans for future urban growth. The baseline report, published in May 2018, considered grasslands, wetlands, heritage sites, First Nation urban holdings and reserves, trees, wet ponds, dry ponds, invasive species, and more. The report includes ten guiding principles and 32 key findings that define the vulnerabilities to the green infrastructure network, as well as opportunities to improve the network. Some of the key findings addressed governance, land allocation, stormwater servicing, and heritage and culture.

The Green Strategy also identified opportunities to enhance grey infrastructure with green infrastructure, thereby optimizing the City's natural resources, and limiting new development that could harm biodiversity. During phase two, the municipal team is engaging internal and external stakeholders. They will also develop ideas for policy and projects that align with the guiding principles and draft an implementation framework.

## Local Actions: Saskatoon's Adaptation Strategy

When Saskatoon signed the Global Covenant of Mayors for Climate and Energy, it committed to developing a plan for climate change adaptation. Previously, a number of City divisions worked on different sustainability initiatives, including the Corporate Asset Management Plan, Flood Control Strategy, and Green Strategy. In 2017, the City began looking for an approach to develop a more holistic plan, which resulted in Local Actions: The City of Saskatoon's Adaptation Strategy (Local Actions). This overarching climate action plan was developed by the Sustainability division and includes a Low Emissions Community Plan.

Local Actions was supported by funding from FCM's Municipal Climate Innovation Program. Local Actions considers the impacts of climate change on municipal programs, services, and infrastructure. The project used ICLEI Canada's adaptation methodology — Building Adaptive and Resilient Communities (BARC) — which prescribes a five-milestone framework (initiate, research, plan, implement, and monitor/review.)

The first milestone, which included identifying stakeholders, assessing climate change impacts, describing current actions, and passing a Council resolution, was achieved with the support of the signature on the Global Covenant. The second milestone was completed over seven months. Kristin Bruce, Project Manager, led the research on the climate projections, working closely with community experts from the Saskatchewan Research Council and the University of Saskatchewan. Some of the other resources used included publicly available sources such as the Climate Atlas of Canada and the Canadian Centre for Climate Services.

A risk ranking system was developed during the second milestone using ICLEI Canada's phased approach. The potential effects of climate change were mapped against municipal assets and services with input from civic staff through the organization. Existing data was referenced for the Climate risk inventory priorities areas. Risk ratings were based on a triple bottom line approach (i.e. a risk framework that accounts for social, environmental, and economic consequences of failure). The risk analysis was completed to support the prioritization of projects in the final Local Actions and inform the implementation process. Work on the third milestone is currently underway. The final Local Actions will establish the vision and goals for corporate climate change adaptation; provide recommendations for priority projects; and, establish implementation timelines. Kristin and her team will be presenting the finalized Local Actions Strategy to City Council in October 2019.

# Roadmap for Municipal Adoption

The City of Saskatoon is growing at a remarkable rate and is the fourth fastest growing CMA in Canada.[5] As the need for climate change adaptation becomes more urgent, municipal staff have been working to advance the City's resiliency. Numerous projects have been undertaken:

- The Flood Control Strategy focuses on projects to mitigate the impacts of flooding in flood-prone areas and includes flood mapping, risk assessment, and cost/benefit analysis to identify how the City can most effectively adapt to the potential risks of flooding.
- The Green Strategy considers ways to protect the City's natural environment and optimize existing green infrastructure. The team behind the Green Strategy has made significant efforts to integrate various departments in their efforts to identify key problem areas and develop solutions to these problems.
- The Climate and Asset Management Committee is working on amalgamating existing AMPs and developing further adaptation considerations for municipal asset categories to formalize a corporate AMP.
- All of these projects require capital funding (and the development of business cases) because they are outside the scope of regular operations. In some cases, applications were made for provincial or federal funding, which helped to propel the projects forward. Collaborating with academic experts and stakeholder organizations has also improved the outcomes.

These projects are critical to the adaptation of their respective divisions and will be significantly supported with the implementation of an overarching Corporate Adaptation Strategy. The City of Saskatoon has made a clear commitment to proactively prepare for the effects of climate change on civic services and assets.

# Endnotes

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2 City of Saskatoon. "Saskatoon History & Archives."https://www.saskatoon.ca/community-culture-heritage/saskatoon-history-archives/history.
3 City of Saskatoon. "Strategic Plan 2018-2021. https://www.saskatoon.ca/sites/default/files/documents/asset-financial-management/cofs-strategic-plan-2018-final_web.pdf.
4 Mnai. "Defining and Scoping Municipal Natural Assets." September 2017 https://mnai.ca/media/2018/02/finaldesignedsept18mnai.pdf.
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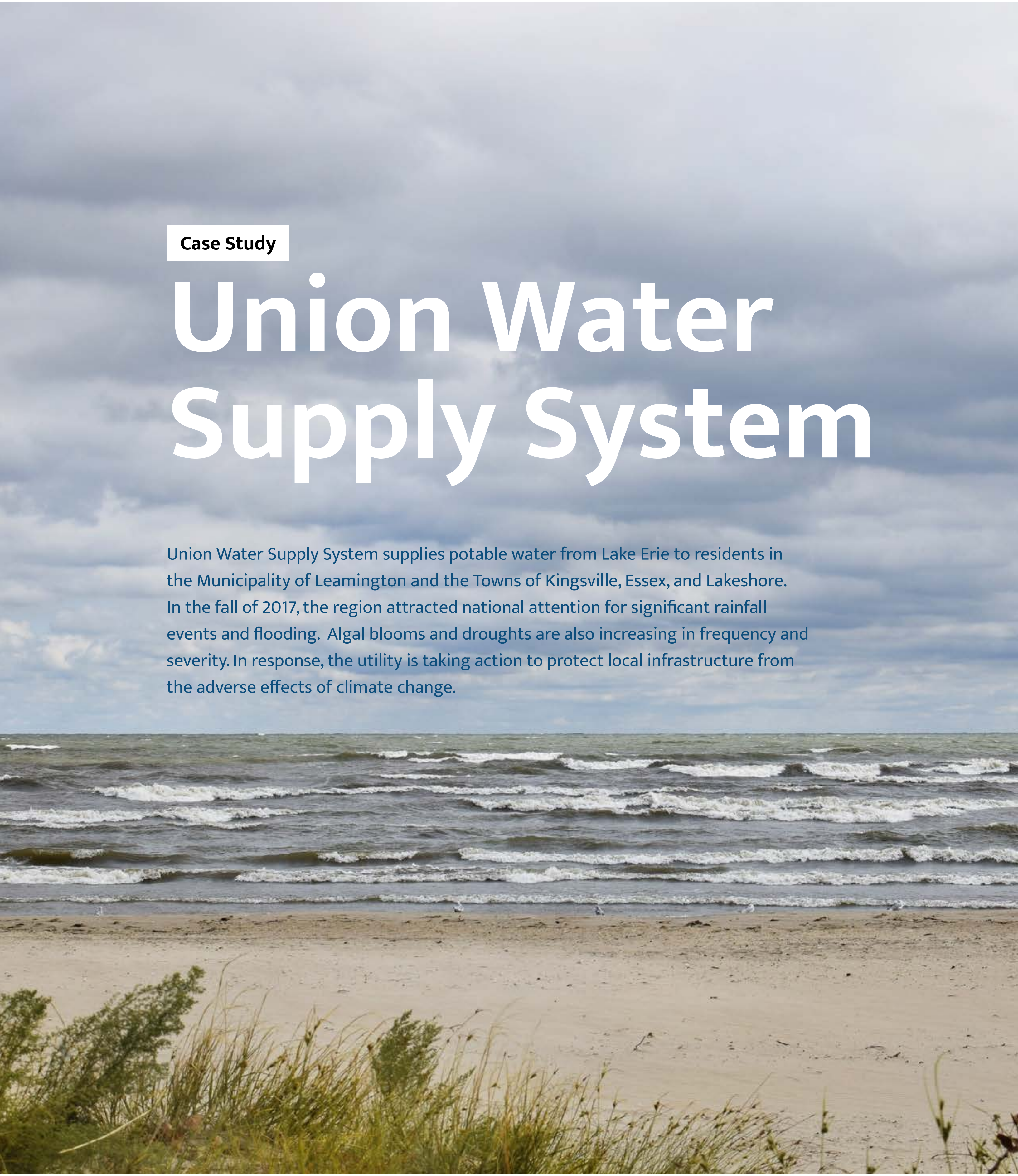


Case Study

# Union Water Supply System

Union Water Supply System supplies potable water from Lake Erie to residents in the Municipality of Leamington and the Towns of Kingsville, Essex, and Lakeshore. In the fall of 2017, the region attracted national attention for significant rainfall events and flooding.  Algal blooms and droughts are also increasing in frequency and severity. In response, the utility is taking action to protect local infrastructure from the adverse effects of climate change.

## Background: Union Water Supply System and its asset management efforts

Union Water Supply System (UWSS) was created in 1958 by the Province of Ontario, with a mandate to develop an area-wide water scheme for a cluster of municipalities in Essex County — Leamington, Kingsville, Essex, and Lakeshore. The water systems of several smaller municipalities were combined to reduce inefficiencies. Following the introduction of the Municipal Water and Sewage Transfer Act in 1997, ownership of the system and all assets were transferred to the four municipalities.

The UWSS utility is managed by a Joint Board of Management. There are thirteen members on the Board, with representatives from the four municipal councils. Membership on the Board is based on ownership of UWSS, which is determined by the amount of water used by each municipality. The utility supplies water to 65,000 residents, as well as commercial, industrial and agricultural customers, including several large food processors and numerous hydroponic greenhouses. The General Manager is the administrative authority for the Board and develops the capital and operating budget. The utility has contracted Ontario Clean Water Agency (OCWA) for operation and maintenance. UWSS practices asset management and prioritizes better data management. Under O. Reg. 588/17: Asset Management Planning for Municipal Infrastructure, Ontario municipalities are required to gather data on core municipal infrastructure assets, including age, materials, replacement costs, condition assessment, and lifecycle. By July 1, 2021, all municipalities must complete an asset management plan.

Leamington, Kingsville, Essex, and Lakeshore have all been engaging in asset management since before 2010. The four communities, which hold ownership of the UWSS assets, were able to advance their asset management in part by utilizing specialized software to manage their data inventory and facilitate condition assessments, lifecycle management, risk assessment, and to define levels of service. The communities are far along in their asset management practices but have not yet fully integrated climate change considerations into their asset management program.

**Highlights from the UWWS Case Study**

- UWSS treats water from Lake Erie and delivers it to approximately 65,000 residents in four communities in southwestern Ontario.
- This region experiences thunderstorms, heavy rainfalls, extended periods of high summer temperatures, and drought.
- In 2011, UWSS partnered with Engineers Canada to conduct an Infrastructure Climate Risk Assessment using the PIEVC protocol. Engineers Canada agreed to fund the assessment.
- To overcome challenges related to gaps in historical data, UWSS used archived data, Environment Canada data, and anecdotal information from residents and staff.
- The Climate Risk Assessment identified potential impacts of current and future climate events such as flooding, algal blooms in source water, and loss of power.
- UWSS has been working to implement the Climate Risk Assessment recommendations over time, with measured improvements in resiliency.

# Climate Change Impact Profile

Essex County is located in Southern Ontario, with a temperate climate that includes cold winters, warm summers, and high levels of precipitation.[1] The chart below shows the average high and low temperatures in the months of January and July, as well as annual precipitation for 1969, 1980, 2000, and 2018.

### Temperature Range and Annual Precipitation in Essex County

| | Average High January | Average Low January | Average High July | Average Low July | Yearly Precipitation |
|---|---|---|---|---|---|
| 1969 | -1.3ºC | -8.9ºC | 25.1ºC | 17.7ºC | 1012.5 mm |
| 1980 | -0.6ºC | -7.4ºC | 27.1ºC | 18.1ºC | 981.3 mm |
| 2000 | -0.4ºC | -7.5ºC | 25.7ºC | 17.4ºC | 813.8 mm |
| 2018 | -1.0ºC | -7.3ºC | 27.3ºC | 19.5ºC | 726.5 mm |
| **Source: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html** | | | | | |

Historically, weather in southwestern Ontario has included extreme events. Leamington, Kingsville, Essex, and Lakeshore have all experienced tornadoes, severe thunderstorms, heavy rainfall and drought. According to data from Environment and Climate Change Canada's (ECCC) Canadian Climate Normals, Climate Data Online and Canadian Daily Climate Data, the Ontario node of the Canadian Atmospheric Hazards Network, and testimony from local residents, extreme events in Essex County have been increasing in severity and frequency.[2] This has resulted in various impacts to UWSS, including:

- **Physical Impacts:** High speed wind from tornadoes and thunderstorms have damaged green and grey infrastructure, threatening public safety and resulting in power outages. Service lines and other underground infrastructure have frozen as a result of extremely low temperatures and breakage has occurred during the freeze-thaw cycle. Flooding has damaged pipes and caused debris blockage.
- **Economic Impacts:** Climate events have increased costs for unplanned repairs and updates to protect infrastructure from extreme weather.
- **Social Impacts:** Water distribution has been impacted as a result of damaged infrastructure. Thunderstorms that cause power outages have resulted in failed communication services and disabled water treatment and monitoring. Studies by ECCC have indicated that algal growth in Lake Erie can affect the taste and quality of the drinking water.[3] The General Manager of UWSS reports that customer complaints about the taste of treated water have increased in recent years.
- **Ecological Impacts:** Prolonged periods of high temperatures and stagnant water promote the growth of algae. Local drinking water quality and aquatic ecosystems have been impacted by increases in algal blooms.

## Implementing the PIEVC Protocol at UWSS

Over the last decade, General Manager Rodney Bouchard has encouraged UWSS to participate in climate research. The utility has participated in numerous studies, including the Algal Blooms, Treatment, Risk Assessment, Prediction and Prevention through Genomics project, as well as research initiatives supported by Canadian Water Network and the Canadian Water and Wastewater Association.

In 2011, David Lapp at Engineers Canada reached out to Bouchard about the possibility of conducting a climate risk assessment on UWSS' physical assets using the Public Infrastructure Engineering Vulnerability Committee's (PIEVC) protocol. Engineers Canada was interested in using the protocol to assess a water utility and offered to supply the framework and cover related consulting costs. The UWSS Board saw this request as an opportunity to develop knowledge on potential climate impacts and to integrate the resulting information into future asset management risk assessments. In addition, the project did not require additional financial resources, aside from staff time.

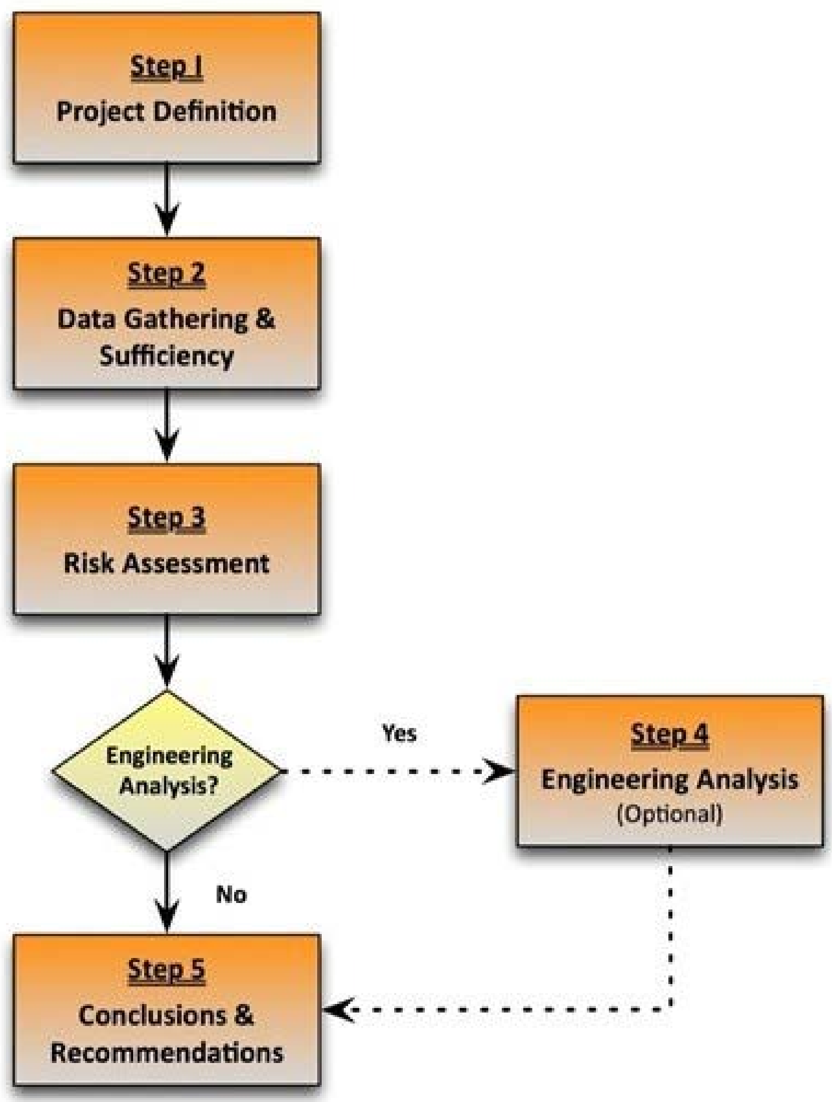
## Using the PIEVC Protocol to Assess the Risk and Vulnerability of Utility Infrastructure

The PIEVC protocol is a five-step process to analyze the engineering vulnerability of physical assets to current and future climate parameters. The protocol relies on gathering accurate and reliable input data, a process which may require compilation from a range of sources. Once the data has been gathered, the third and fourth steps (risk assessment and engineering analysis) identify interactions between environmental conditions and infrastructure, as well as the likelihood and severity of risks. Recommendations are generated in the final step, and typically identify vulnerable infrastructure, potential management actions, monitoring recommendations, and remedial engineering opportunities. The information obtained can be used to make informed engineering decisions on which asset components require adaptation, as well as what adaptation measures need to be implemented.

An engineering consulting firm was hired to assist with the research and analysis, although it should be noted that PIEVC protocol can be completed internally by utilities if staff resources are available. All four municipalities participated in the effort to gather data, although much of the necessary data and research was already available through open source databases, such as ECCC's Canadian Climate Normals.

In addition, for steps one through four, the utility, Engineers Canada, and the Ontario Ministry of the Environment agreed to collaborate to support the assessment of the vulnerability of the water system infrastructure to local climate change impacts. The water system infrastructure assessed included the drinking water treatment plant (intake, low life pumping station, reservoir, and booster pumping station) and distribution network (elevated towers, distribution mains).

**PIEVC Protocol**



**“UWSS is planning a climate risk assessment of linear asset conditions and is working toward integrating climate data into the asset management plans of Leamington, Kingsville, Essex and Lakeshore. The most significant impact of the initial climate risk assessment has been a shift in decision-making. Staff are now regularly considering potential climate change effects in both operations and planning.”**

In step one, climate parameters were determined based on climate conditions and trends relevant to the region and its known seasonal variability. Historical climate condition data were retrieved from ECCC's Canadian Climate Normals, Climate Data Online, Canadian Daily Climate Data, and the Ontario node of the Canadian Atmospheric Hazards Network. Gaps in the climate data were filled by accessing past news reports and municipal archives data. The timeline for future climate change projections was extended to the year 2050. To create future climate projections, the consultants referred to ECCC's Canadian Climate Change Scenario Network plots, the Intergovernmental Panel on Climate Change's fourth assessment report, and other scientific journals. Some of the climate conditions considered for the risk assessment were high temperatures, heavy rainfall, drought or dry period, lightning, hurricane, tornado, sub-zero temperatures, freezing rain, heavy snow, heavy fog, freeze-thaw, and Lake Erie water levels.

During step two, gathering sufficient data on the physical elements and condition of the water system infrastructure, including operation and maintenance practices, posed particular challenges. Records from several decades earlier were difficult to find, with numerous gaps in the condition assessments of water system assets. Moreover, the data that was digitized 15 to 20 years prior was hosted in files that were run by outdated software. This data was difficult or even impossible to open on the current software. A workshop was organized to bring together past and present officials from the four municipalities, other stakeholders, and interested citizens to discuss the project and to share anecdotal information. This information helped fill in gaps in the availability of older data.

The third step of the PIEVC protocol is risk assessment. Risk was calculated based on the probability of the event multiplied by the severity of the event. Each element of the water system infrastructure was evaluated based on probability and the severity of the impact, resulting in a ranking of low, medium or high risk. The severity dimension of the risk matrix considered watershed, surface water, and ground water emergency responses; related policy; social indicators, such as the quality of drinking water; environmental effects; and other performance responses. The probability dimension considered climate events identified through research and analysis in previous steps as having the highest probability of occurring and/or increase in frequency. These included high temperatures, heat waves, heavy rains, droughts or dry periods, freezing rain, lightning, and hurricanes. The risk assessment indicated that certain climate events were found to pose higher risk to certain elements of UWSS infrastructure. The assets determined to be at highest risk were the communication system, transformers and transmission lines (mainly due to lightning strikes); chemical storage (due to blowing snow and blizzards); and emergency intake (due to lower lake water levels).

Kingsville, Ontario

## Using PIEVC Protocol Outputs to Inform Infrastructure Adaptation Measures

In the final step of the PIEVC protocol process, a list of short- to medium-term recommendations was developed, based on climate impacts to the infrastructure. Some of the key recommendations were:

- Extreme weather procedures for operations personnel should be reviewed and updated.
- Operating procedures should be reviewed to account for potential power disruptions.
- Storage systems for SCADA and other data should be modified to account for potential power disruptions.
- In response to drought and sustained heat, which can cause lower lake levels, there is a need to renew and potentially modify the emergency intake.
- Older elevated storage tanks should be modified sooner than originally planned to ensure adequate circulation and minimize water quality issues caused by warm weather.

The final report was comprehensive and detailed and included many more recommendations than those mentioned above, which empowered the utility to include climate risk assessment in their infrastructure and operation planning processes, including their asset management plan. The Board endorsed all of the recommendations, and today UWSS is well on its way to implementing the full list. Some recommendations must be addressed over several years and have been prioritized based on the General Manager and Boards' consideration of costs and risk. Their adaptation efforts to date include:

- A change to the communication system from land lines to radios.
- Creating communications system redundancies in case of power failure.
- Purchasing four large portable generators in case of power failure.
- Staff training sessions on climate-related risks.
- Installing real-time instrumentation to measure algae on raw water intakes to predict water quality and alter water treatment as necessary.

UWSS is planning a climate risk assessment of linear asset conditions and is working toward integrating climate data into the asset management plans of Leamington, Kingsville, Essex and Lakeshore. The most significant impact of their initial climate risk assessment has been a shift in decision making. Staff are now regularly considering potential climate change effects in both operations and planning.

## Roadmap for Municipal Adoption

There were several main factors that enabled UWSS' climate risk assessment:

1. The PIEVC protocol framework and consulting expertise were provided to UWSS free of cost. Note, the PIEVC protocol and case studies are freely available to municipalities across Canada.
2. With a focus on drinking water, UWSS holds an asset inventory that is smaller and less diverse than most municipalities, and the existence of asset management plans for the member municipalities made the task of assessing vulnerabilities less onerous.
3. Much of the required climate data is freely available in open source databases.
4. The municipal councillors that serve on the UWSS Board provided the necessary political support.

According to Bouchard, the greatest challenge the utility encountered was gathering all the data necessary for analysis, as local records from decades earlier were difficult to access (due to software incompatibilities) and had gaps. UWSS tackled this challenge by organizing a workshop with relevant community stakeholders to gather anecdotal evidence to fill in the gaps. He found the PIEVC protocol framework was easy to use and relatively inexpensive to apply. The report made it clear to the members of the Board that the decision to begin integrating climate change considerations was a necessary action. The assessment allowed for stronger planning and future budgeting and also helped identify new technologies and processes to support ongoing delivery of water services in light of potential climate change impacts.

The UWSS experience highlights the reality of the level of effort, resources, creativity and political will required to conduct a systematic review of local climate risks and infrastructure vulnerabilities, which exist regardless of the size of the municipality or extent of the analysis. However, it also highlights that there are tools and resources available - such as freely available frameworks, data and proxy data – which any municipality can access to overcome common obstacles in completing this work.

UWSS recommends that other municipalities in Canada make an effort to conduct a climate risk assessment on their infrastructure and suggests that municipalities/utilities combine efforts with neighbouring municipalities to reduce costs. Bouchard notes, "climate change impacts are happening yesterday, so local leaders need to start learning how to adapt today."

## Endnotes


1 Climate Data. "Climate Leamington." https://en.climate-data.org/north-america/canada/ontario/leamington-26627/.

2 Public Infrastructure Engineering Vulnerability Committee (PIEVC). "Assessment of the Union Water Supply System." Engineers Canada https://pievc.ca/assessment-union-water-supply-system.

3 Environment Canada. "Canada-U.S. Great Lakes Water Quality Agreement." Government of Canada. https://www.ec.gc.ca/grand-slacs-greatlakes/default.asp?lang=En&n=6624C737-1&wbdisable=true.

# Summary of Insights

Local governments across the country are making significant efforts to build their capacity to adapt to climate change impacts. The cases of Kenora, Edmonton and EPCOR, Moncton, Union Water Supply System, and Saskatoon depict five ways local leaders are pursuing infrastructure climate change adaptation. These communities are situated in diverse geographic regions, and exemplify different governance structures, asset portfolios, climate change impacts, opportunities and challenges. The five case studies highlight the common need to gather and analyze data and coordinate efforts among a range of community stakeholders in order to effectively identify vulnerabilities and prioritize local actions to adapt infrastructure to current and projected effects of climate change.

## Drawing on Diverse Datasets

Municipalities need to collect substantial amounts of data to build infrastructure risk assessments in light of local climate change projections. To most effectively inform decision-making on infrastructure investments, data should be of good quality and processes need to be put in place to support continuous improvement on data collection and analysis. There exists a clear opportunity for municipalities to build processes that account for climate change adaptation into existing municipal asset management programs.

Infrastructure risk assessment evaluations require a better understanding of the local projected climate conditions over the lifespan of the infrastructure. Climate history and projections can be defined using historical data and climate models from publicly available resources such as Environment and Climate Change Canada's Canadian Climate Normals, Climate Data Online, and Canadian Daily Climate Data. Union Water Supply System demonstrated that observed historical climate data can also be derived from public consultation through workshops with municipal staff and the public. A range of different climate change scenarios (e.g. storm return periods, freeze-thaw conditions, increase in severe storms, etc.) can be used to determine the impacts on systems and the probability of occurrence. Moncton and Saskatoon collaborated with an environmental consultant and University of Saskatchewan to make use of modified intensity-duration-frequency (IDF) curves that better reflect changes in the characteristics of precipitation projected due to changes in climate.

Infrastructure risk assessments require data and information to properly define the state of municipal infrastructure and to build the evaluation criteria required to determine the potential impacts of failure for the community. Drawing from asset management plans, water system asset datasets often include an asset inventory comprising all core and non-core asset groups; asset attributes such as measurements, materials, and other details specific to the asset type; location; historical costs; in-service years; estimated useful life; replacement cost; and assessed condition. The incorporation of additional datasets beyond traditional asset data can also be layered into the analysis to build a more complete picture. For example, EPCOR included insurance overland flood maps, historical flood data, operational data, sanitary surcharge modelling and location of key community features such as hospitals in their flood risk framework.

A range of information can be used to determine the economic, environmental and social consequences of infrastructure failure due to vulnerabilities to climate change impacts. Consequences of failure can be defined through staff, public and stakeholder consultation by asking questions such as:

- What additional economic benefits will result from improving infrastructure?
- What will be the impacts on our community's natural areas as a result of construction and installation of infrastructure?
- What are the risks to residents' safety if some infrastructure is not updated?
- Gathering information related to community values is a critical step in prioritizing efforts and investments to increase climate change resiliency.

## Making the Most of Available Resources

Planning for municipal climate change adaptation is an expansive endeavour. Municipalities making progress in adaptation have benefited from taking a holistic corporate-wide or community-wide approach and coordinating across municipal departments responsible for implementing the solutions. This includes strategically accessing resources – expertise and funding – from outside the community to accelerate progress.

**Leadership Required at Multiple Levels**

The advantage of support from municipal Councils, staff and the public cannot be overstated. Adaptation projects require the engagement of multiple municipal departments, with incremental and sustained efforts over time to build towards more comprehensive approaches. Dedicated, passionate municipal staff proved to be critical drivers of these adaptation projects. Council support and approval of policies and plans, such as when Edmonton and Saskatoon became signatories of the Global Covenant of Mayors for Climate and Energy, ensured that the adaptation efforts had financial backing and political support. Furthermore, in many cases the public bringing forth their concerns related to climate change encouraged both staff and Council to successfully embark on these journeys. A key factor to success is in the creation of well-defined goals and strategies that are set out clearly in policies and plans supported by Council, citizens and key stakeholders.

**Use of Proven Frameworks to Guide the Process**

Progress can be made by using existing frameworks to guide the adaptation process while still allowing the flexibility to customize the approach based on local settings. For example, Edmonton and Saskatoon both followed ICLEI Canada's Building Adaptive & Resilient Community program to establish an overarching strategic adaptation plan. ICLEI Canada's methodology uses a five-milestone framework: initiate, research, plan, implement and monitor/review. Union Water Supply System used Engineers Canada's PIEVC protocol, a five-step process that guides the analysis of the engineering vulnerability of physical assets in the context of current and future climate parameters. In addition to these frameworks, organizations such as Federation of Canadian Municipalities have provided the opportunity for peer-to-peer knowledge sharing and exchange on Canadian and international approaches to climate change adaptation through the Climate and Asset Management Network.

**Accessing Relevant Funding Sources**

Planning and implementing adaptation programs can be a costly endeavour for any community. Given budget constraints, communities may rely on a combination of funding sources to support the initial development of proactive mandates to increase infrastructure resilience. The communities included in this series, as well as many others across Canada, have benefited greatly from a range of grant programs. The cities of Edmonton, Moncton, and Saskatoon were all recipients of FCM's Municipalities for Climate Innovation Program climate change grants. The cities of Kenora and Saskatoon were participants in FCM's Climate and Asset Management Network and recipients of the associated grant. Kenora was also able to build their asset management program through FCM's Municipal Asset Management Program. Moncton successfully applied for Natural Resource Canada's Regional Adaptation Collaborative program grant. Saskatoon and Edmonton accessed the Disaster Mitigation and Adaptation Fund and the National Disaster Mitigation Program through the Government of Canada. These funds have enabled the development of knowledge, capacity, and even infrastructure capital support, to make incremental progress towards greater infrastructure resilience.

## Moving Forward on Climate Change

The title of the report indicates that there is a need for communities to use better data — i.e. more creative, diverse, and robust data — to effectively identify opportunities to build community resilience. The case studies outlined here highlight the shared success factors of the municipal climate change adaptation process, which can increase the resilience of municipal water systems: multi-level leadership, connecting with community values, embracing incremental progress, and building on available resources, such as diverse infrastructure and climate datasets, asset management programs, and proven guidance frameworks, and governmental grant programs.

This report was prepared in partnership by PSD, CWN, CWWA and FCM.

PSD is a global leader in the provision of enterprise asset management and budgeting research, consulting and software. Its research team publishes the Public Sector Digest – North America's resource for asset management, budgeting and climate change adaptation research for the public sector. PSD regularly conducts applied research projects, currently working with the University of Oxford to implement the Climate Change and Asset Management Resiliency Roadmap (CARR) pilot program. CARR will provide participating Canadian municipalities and utilities with support to align their asset management and climate change adaptation practices.

Canadian Water Network is a trusted broker of insights for the water sector. Informed decisions result from addressing the right questions. When decision makers ask, 'What does the science say about this?' Canadian Water Network frames what is known and unknown in a way that usefully informs the choices being made. Their unique approach begins with an in-depth understanding of the problem and identifying where progress can be made. They talk to the experts and consult the knowledge base to frame the knowns and unknowns. From there, they communicate relevant insights to practice and policy leaders, moving the conversation forward.

FCM has been the national voice of municipal government since 1901. Our members include more than 2,000 municipalities of all sizes, from Canada's cities and rural communities, to northern communities and 20 provincial and territorial municipal associations. Together, they represent more than 90 percent of all Canadians from coast to coast to coast. Municipal leaders from across Canada assemble each year to set FCM policy on key issues. Today, we advocate for municipalities to be sure their citizens' needs are reflected in federal policies and programs.

CWWA is a non-profit national body representing the common interests of Canada's public sector municipal water and wastewater services and their private sector suppliers and partners. CWWA is recognized by the federal government and national bodies as the national voice of this public service sector.

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