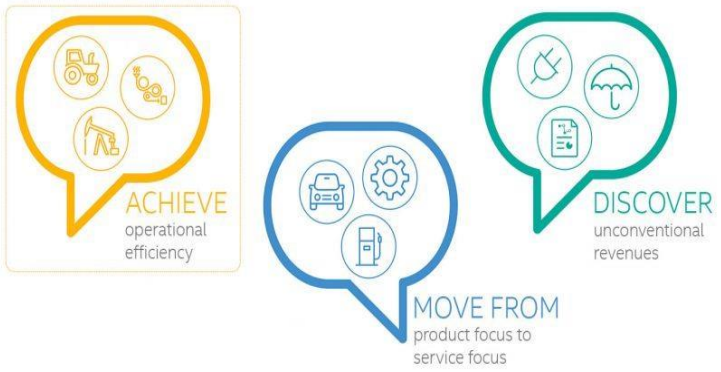
INTEGRATING ASSET MANAGEMENT AND CLIMATE CHANGE – A PATH FORWARD



ClimAction Services Inc.

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INTRODUCTION

Over the past 50 to 100 years the climate has been changing and we are now experiencing:

- Wetter, warmer winters / hotter, drier summers – more heat wave / stress;
- Increase in frequency and severity of extreme weather events;
- Change in nature of precipitation – more floods, more drought; and
- Coastal and inland flooding / sea level rise / storm surges / coastal erosion.

Climate change has resulted in significant impacts to infrastructure such as roads, bridges, and culverts. These trends will become increasingly significant and more wide-spread causing damage, underperformance of infrastructure and future failures, resulting in threats to public and private assets, and the subsequent economic loses.

In 2013, the International Institute for Sustainable Development prepared paper entitled" Climate Change Adaptation and Canadian Infrastructure: A review of the literature". Their findings indicate:

- Climate change has the potential to substantially affect the effectiveness and lifespan of infrastructure in Canada, particularly transportation, buildings, marine and water management infrastructure.
- Adaptive measures can be taken to limit costs and strengthen the resiliency of infrastructure.

CLIMATE CHANGE IMPACTS ON INFRASTRUCTURE

This section focuses on four categories of critical infrastructure: land transportation, buildings and wastewater management and water resources. These categories are described in term of observed impacts as a result of climate change.

Land Transportation (roads, railways and bridges) - The impacts of climate change on land transportation corridors are the direct and indirect result of temperature changes:

- Warmer winters, increasing freeze-thaw cycles which can accelerate the deterioration of transportation infrastructure (including roads, ramps and bridges).
- Increased summer temperatures contribute to pavement softening, rutting and bleeding of liquid asphalt.
- Increased frequency of storm surges, higher tides and flooding shortens the life span of coastal roads and bridges. In addition, roads are damaged, bridges are washed out, causeways rendered impassable and, especially when undersized (under-designed), culverts are overwhelmed.

Building infrastructure (public and private buildings) - Climate hazards can have wide-ranging consequences for exterior and interior surfaces buildings. The impacts commonly reported on buildings is as follows:

- Increased snowfall has led to numerous incidences of the structural collapse, or potential detrimental structural impacts of public and private building structures.
- Severe wind damage to roofs and building cladding on all three of Canada's coasts is on the rise.
- Increased precipitation has resulted in significantly more incidences of flooding and resulted in property damage and basement flooding, which have reduced the functionality and service life of buildings.
- Warmer temperatures will stress already under-designed HVAC capacity, resulting in structural compromise and potential health issues.

Stormwater Management and Wastewater Treatment Facilities – The main concern is on the impacts of heavy rainfall and an increase increasing the risk of flooding. Floods will damage both water supply and waste systems by overwhelming the system:

- Several municipalities have reported that storm water management facilities have become completely inundated during severe rainfall.
- High water events exceeding 3 meters, through a combination of sea level rise and storm surge, has created significant potential for flooding pump or lift stations located within 100 meters of the ocean.
- Coastal erosion from increased sea level rise and storm surge have threatened sewage treatment plants and undermined the integrity of treatment plant outfalls and pump stations overflow pipes.
- Increasing number of high wind (sustained from 90 km/h and gusts up to 130 km/h) and freezing rain events (more than 10 per year) affects power lines resulting in power outages and compromising the ability to pump and treat wastewater. Power utilities are already designing infrastructure for ice events.

Water Treatment Facilities - While many of the impacts resulting from flooding on water treatment facilities are similar to those described in the wastewater treatment section; there are additional impacts that we have documented across Nova Scotia. They include:

- Increasingly high temperatures (greater than 30C), low soil moisture and dry days (10 consecutive days without rain) makes forest fires in watersheds more likely and could impact available water quantity and quality.
- High temperatures (greater than 30C) can create a situation where there is less water available to replenish supply.
- Treatment costs and the level of treatment are increased during droughts as the concentration of water quality parameters are increased making it more difficult to meet Drinking Water Standards and Guidelines.
- Pumps, distribution system and service lines are stressed to meet increased demand for water when temperatures are high and water levels are low.
- Water distribution system at risk from seasonal shift in freeze/thaw cycle.

KEY CLIMATE CHANGE / ASSET MANAGEMENT QUESTIONS

It is becoming increasingly clear that climate change has and will continue affect the effectiveness, life span and operation of infrastructure in Canada resulting in failure or under performance. This could result in socio economic, public health and safety impacts which will become increasingly more widespread and significant over time.

There are a variety of tools, approaches and methodologies designed to predict future threat to infrastructure as a result of climate change and strategies that can reduce impacts and help municipal government adapt to an ever-changing climate. The key questions that these tool and approaches can answer include:

- How is climate change going to impact the municipal asset infrastructure over the next 80 years?
- What assets are at particular risk and if so why?
- What are the key climate thresholds that will dictate the sustainability of municipal assets over time (e.g., temperature, extreme weather, precipitations) and how often will they be exceeded in the future?
- How could construction practices, best practices and infrastructure design standards be modified to reduce future impacts and design resilient infrastructure?

Answering these questions will help position municipal governments to design and operate resilient infrastructure and sustainable community objectives.

ASSET MANAGEMENT DEFINITION

Asset Management is a process to enable maintenance of infrastructure assets, to defined Levels of Service within acceptable risk tolerances, at minimum cost, over the lifecycle of the asset.

INFRASTRUCTURE LIFECYCLE – CLIMATE CHANGE CONSIDERATIONS

All infrastructure is developed for a specific purpose and all infrastructure requires initial capital as well as ongoing operations and maintenance cost. While the construction of a new asset brings excitement, the ongoing operations and maintenance can be overlooked. Only looking at infrastructure from a holistic – or lifecycle – perspective can the true cost of infrastructure be understood.

The 5-step process below identifies general principles of how physical infrastructure, such as a building, road, or water system, passes through the lifecycle. It also identifies for each lifecycle step climate change considerations and their importance in supporting asset management approaches
.

Step 1: Needs Identification: An idea of a new service and required infrastructure is conceived or existing infrastructure has been identified as requiring an upgrade.

Climate Change Considerations: Climate change considerations can be the motivator for a new asset. (e.g., a washout requires a new segment of road, drought requires a new water source, an older building has reached the end of its lifecycle.) Remediation after the fact is costly and unnecessary is infrastructure is designed to withstand extreme weather events and climate change impacts.

Step 2: Infrastructure Planning & Design: The asset is envisioned and designed to address identified needs.

Climate Change Considerations: Understanding potential climate change impacts over the lifecycle of the asset is essential. Having effective standards designed to mitigate impacts associated with climate hazards enables resilient design.

Step 3: Construction: The asset is built and opened for use.

Climate Change Considerations: Minimal impacts here as it is already under construction and following the design standards set during the planning process.

Step 4: Operate & Maintain: The asset is operated and maintained throughout its service life.

Climate Change Considerations: Impacts for built infrastructure are best assessed through monitoring and inspections to determine how a changing climate is affecting performance.

Step 5: Refit or Dispose: Major capital refit, or disposal of the asset. If major refit is selected, return to Step1.

Climate Change Considerations: Having a clear understanding of the potential climate change impacts is required when developing the business case to decide on whether to dispose or re-capitalize the asset. Given climate change impacts, it can be more effective to retrofit or dispose of asset.

There are a number of important guiding principles that need to be considered early in the development of asset management frameworks. It is recognized that the principles can be adapted and tailored by asset managers to meet their individual priorities. As a reference guide these principles are outlined in an easy to follow flowchart as Appendix I.

INTEGRATING CLIMATE CHANGE & ASSET MANAGEMENT: A path forward using a life cycle approach

It is becoming increasingly clear that there is a need to integrate climate change considerations into the development of asset management approaches.

There are numerous examples in this paper that have shown how climate change considerations can be factored into infrastructure lifecycles and during the course of developing an asset management framework.

A Flowchart (Appendix 1) has also been drafted to show how climate change considerations can be addressed as part of developing a broader asset management framework for a municipality. This Flowchart outlines the steps that can guide the integration of climate change into a broader asset management framework. It shows the flow from securing strategic commitment at the decision-making stages down to incorporating key elements of the risk management assessment and adaptive management approaches to achieve sustainable infrastructure in the face of a changing climate.

The nature and type of risk-based decision tools available to help integrate climate change into the development of asset management plans are also presented on the flow chart. In addition, a schematic entitled “Designing Resilient Infrastructure Using Risk-Based Climate Tools” has been included immediately following the flow chart (Appendix II). The main elements include:

- Identifying climate hazards specific to the type of infrastructure under consideration and establishing thresholds for each hazard beyond which performance and / or failure becomes more likely.

- Undertaking a forensic analysis of key climate hazards, determining how often thresholds have been (using a forensic analysis model) and will be exceeded (through the projection of climate hazards to prepare climate scenarios).

- Develop an adaptive management plan to mitigate climate hazard impacts specific to the type of infrastructure under consideration.

In summary, the schematic features how the tools and the type of tool that can be employed to design resilient infrastructure consistent with the lifecycle approach commonly used by municipalities in managing their assets.

APPLYING A LIFE CYCLE APPROACH TO ASSET MANAGEMENT	
Project Element	***Strategic Considerations***
Project Design	Infrastructure needs to be designed to withstand future extreme weather events and climate change impacts. This will involve: Undertaking a **forensic analysis** of past failures for similar infrastructure located in similar locations. This will provide information needed to isolate the climate hazard that contributed to underperformance or failure of infrastructure. Developing **climate change scenarios** to project future trends for each climate hazard using indices and thresholds on parameters most relevant to the infrastructure under consideration (see appendix 1 for list of climate hazards by infrastructure type). These scenarios provide important information that can be used to: • Identify risk, vulnerabilities and threats from climate change to help inform the development of adaptation strategies and the design of the infrastructure itself; this analysis is done by undertaking a comprehensive risk and vulnerability assessment as part of an overall **Risk Management Plan**. • Develop standard operating procedures, best practices guidebooks and codes and land management practices to respond to extreme hazards and prevent similar impacts in the future. There are risk-based decision tools available to help better understand and identify the significance of climate trends and hazards and take measures to ensure that future infrastructure design can accommodate increased threats. (e.g., Climate Change Hazards Information Portal [CCHIP]). The **forensic analysis** and **the projection of climate hazards** can be used to review building standards to determine if they need to be revised and made more stringent to ensure that infrastructure is resilient and will not fail in the face of a changing climate.
Operation and Maintenance (existing / built)	Addressing climate change for built infrastructure should be placed on the operation and maintenance of the asset, how a changing climate is affecting performance, and determining the climate hazard/event that results in underperformance and/or failure. • **Effective performance monitoring** – Monitor to determine if the primary intent of the asset is performing as designed (e.g., water treatment plant – drought conditions can affect the availability of water and interrupt the level of service to the community). • **Frequent inspections** - The inspection must be effective and targeted on climate hazards have affected the physical integrity of the asset (e.g., building – heavy precipitation which can affect structural integrity, premature weathering of external structures). Based on the monitoring, inspections and a forensic analysis of climate hazard impacts a more informed decision can be made on the condition of the asset and if it requires retrofitting and/or replacement to accommodate changing climate conditions. This means going back to the Project Design component element and following the process outlined there.

RISK ASSESSMENT

Whether existing or a new build it will be necessary to evaluate the impacts of climate change on the asset to determine its vulnerability in the face of a changing climate. This would be accomplished by using the climate change scenarios as a basis to undertake a detailed risk and vulnerability assessment.

- A risk assessment will identify the vulnerability of municipal assets to climate change so that adaptive management approaches can be developed and ensure the infrastructure remains viable and resilient in the face of a changing climate. The focus here will be placed on:

  - The PIEVC Protocol (Engineers Canada) to assess the nature, severity and probability of future climate change impacts on infrastructure by identifying components of infrastructure at higher risk of failure or underperformance.

  - The Vulnerability Assessment Process (VAP) is a hybrid of assessment approaches combining climate change scenarios with detailed knowledge of the specific infrastructure (e.g., water/wastewater) to come up with a general assessment of the degree of vulnerability to threats from climate change.

Both of these approaches allow the assessor/designer/builder the opportunity to determine the level of risk resulting from a suite of climate change scenarios on specific assets including built environment assets, transportation assets as well as operations and ongoing maintenance procedures. The power of these approaches is that, by following the specific protocol and steps, specific "risk scores" are developed. These quantities can then be compared to an array of scores (from low to high risk) to aid in discriminating between assets that are currently at risk of failure or will be subject to failure later and how high a risk exists.

The following are examples of the steps used to assign a final risk assessment score:

1. Determine what infrastructure is of interest and at risk. For example, is the road at risk of flooding due to heavy rainfall?
2. Determine what climate parameters are of most concern and/or impact to that infrastructure. For example, is the building susceptible to overheating due to high daytime temperatures?
3. Determine what threshold is critical for that infrastructure, i.e. how much heavy rain can the facility handle before it floods?
4. Determine the likelihood of the event occurring.
5. Determine the consequence of the event on the infrastructure, i.e. if it floods, how much damage would occur?
   Combine the likelihood and consequence to create a risk score that reflects these two aspects of vulnerability.

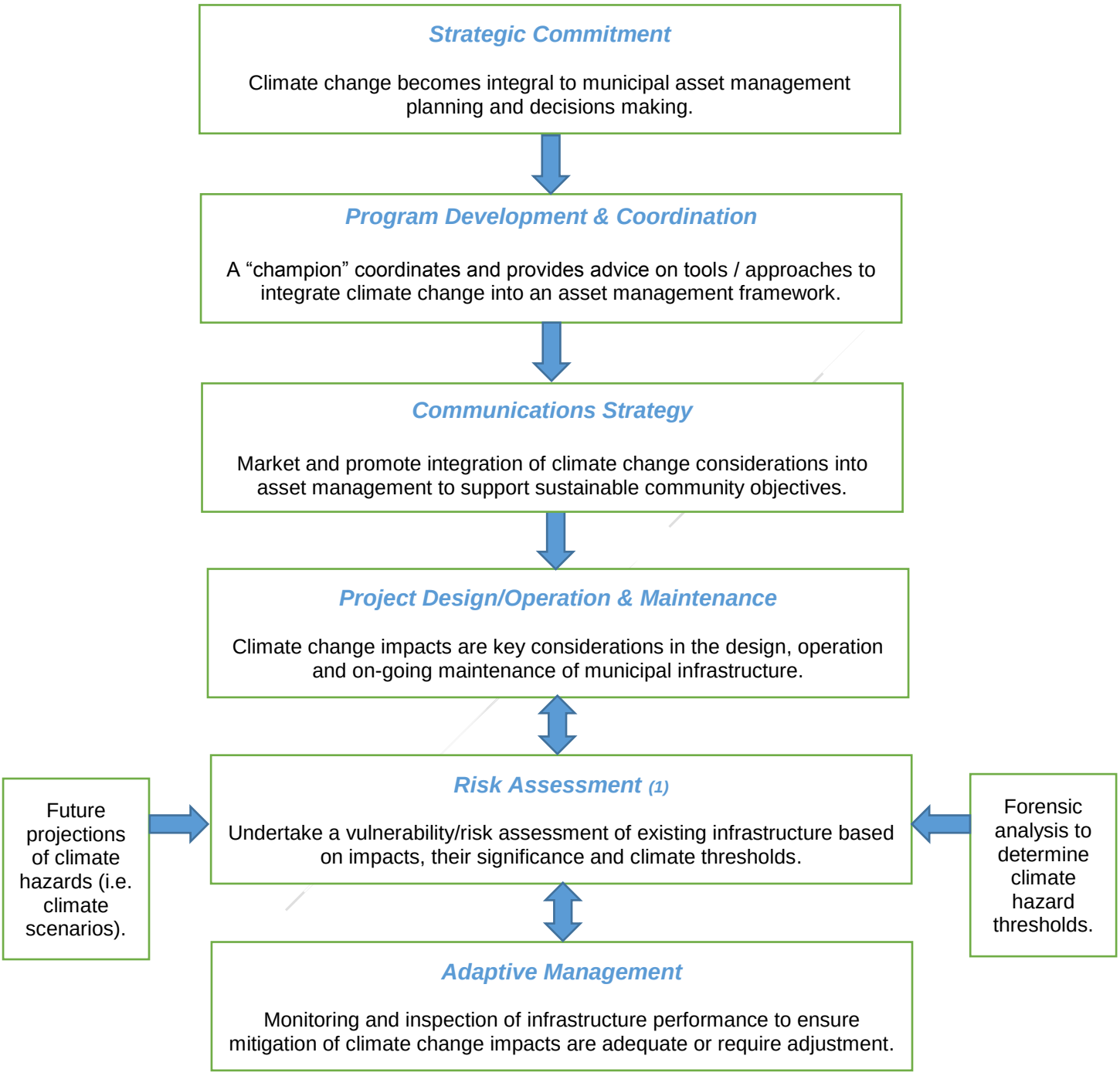
ADAPTATIVE MANAGEMENT

Once the nature, extent and significance of impacts have been assessed it will be necessary to incorporate adaptive management into the overall operation of the asset. Adaptive management includes:

- Develop adaptation plans - Tailored plans are developed to address specific threats to protect the infrastructure components at highest risk.
- Implement the adaptation plans – Plans are put into action.
- Monitor the changes in means and extremes of weather/climate trends.
- Evaluate the performance of the adaptation measures during significant weather/climate events. Document and analyze impacts and changes.
- Adjust the adaptation approach - If measures are not adequate to protect infrastructure, they should be re-designed accordingly.

APPENDIX I

INTEGRATION OF ASSET MANAGEMENT AND CLIMATE CHANGE - FLOWCHART



1. See details in Appendix II.

APPENDIX II

DESIGNING RESILIENT INFRASTRUCTURE USING RISK BASED CLIMATE TOOLS

Anticipate and prevent infrastructure failures

Undertake a **risk / vulnerability assessment** of impacts and their significance (PIEVC Protocol, VAP, etc.)

- Identify climate threats and establish thresholds. (CCHIP)
- Produce climate projections for each threshold. (CCHIP)
- Determine how often thresholds have been (forensic analysis) and will be exceeded (climate scenarios). (CCHIP)
- Assess flood hazards and implications on infrastructure. (IF Flood Mapping)

Design and modify engineering structures that are resilient to future climate threats.

> ***Note:*** These steps are used during the design phase of infrastructure projects and when assets fail and or underperform.

Reduce climate hazards impacts on infrastructure to maintain peak performance

- Develop an adaptive management plan to mitigate climate hazard impacts specific to the type of infrastructure under consideration.
- Undertake a forensic analysis of key climate hazards, determine how often they have been and will be exceeded and take appropriate action to reduce impacts.
- Monitor and inspect infrastructure performance to ensure that mitigation of climate change impacts is adequate or require adjustment.
- Revise plan as appropriate and continue to monitor performance

Benefits

- Helps answer key engineering questions related to design, resilience and construction standards.
- Facilitates the design of resilient infrastructure which satisfies public expectation for uninterrupted services and supports economic growth, health and well - being.
- Allows for the design of adaptive management strategies to address impacts in the face of a changing climate.

APPENDIX III

DEVELOPING AN ASSET MANAGEMENT FRAMEWORK – KEY CONSIDERATIONS

It has been already stated that asset management is fundamentally a process designed to design, build, operate and maintain assets effectively. Each asset owner will adapt and tailor their asset management framework in ways which contribute to the most effective way of managing their assets.

While asset management is not one size fits all, there are standard guiding principles that should be used in the development of any asset management framework. They include:

Develop a Strategic Plan: The asset management framework must consider all aspects of the managing assets at each and every stage of their lifecycle development. In this regard, the framework must address policy priorities, strategic needs, planning requirements, processes, sub-processes, data requirements, key process and performance indicators, as well as framework sustainability and evolution.

- Climate Change Considerations: Climate change should be woven throughout the asset management framework and described in sufficient detail to demonstrate how climate change priorities will factored into the decision-making process as infrastructure passes through its various lifecycle phases.

Implementation Considerations: With council and senior staff approval, the asset management framework will be implemented as part of ongoing municipal operations directed towards infrastructure development and maintenance. It will be necessary to ensure that implementing the framework will be done in a consistent manner. This is best accomplished through education and outreach to build capacity and understanding of staff with an involvement in infrastructure priorities, procedures and requirements.

- Climate Change Considerations: A clear understanding of when and how staff shall consider climate change is necessary during program implementation and again this is best accomplished through education, training, webinar series and other capacity building tools as appropriate.

Monitoring / Measuring performance: Tracking an asset management framework is done through measuring and monitoring of the processes and the performance of the asset itself. Process audits and reviews will identify the efficacy of the asset management framework and any areas where the framework is lacking effectiveness. This information, based on audit results, can be used to refine and adjust the framework to ensure that it remains an effective tool in the management of infrastructure resources.

- Climate Change Considerations: Audits and measures will review how well climate change recommendations described in the framework are working in minimizing impacts on municipal assets, their performance defined in terms of failure or underperformance and isolating measures to adapt infrastructure to a changing climate.

Evaluating / Modifying / Adjusting the Framework: Where monitoring of the process has identified areas where the framework is found to be limited in terms of overall effectiveness, a root case or forensic analysis should be undertaken to isolate performance problems, recommend improvements and amend the framework and its processes as required.

- Climate Change Considerations: Ongoing monitoring of physical infrastructure performance in response to a changing climate is important to identify implications on the performance of municipal assets. Monitoring is also useful in helping to determine where and how the framework should be modified to help asset managers adapt and tailor their asset management framework to respond to an ever-changing climate.

Communications Strategy: Each of the guiding principles outlined under an asset management framework should be marketed and promoted across the municipality to employees, residents and others as appropriate as a priority that will:

Position the municipality to be “climate ready” and adapt to an ever-changing climate in ways which support sustainable community objectives by:

- Protecting municipal assets
- Designing resilient infrastructures
- Protecting public safety and health
- Supporting viable economic sectors
- Incorporating risks assessment into municipal decision-making

Provide ongoing municipal services with fewer interruptions by designing infrastructure that can withstand extreme weather events.

An asset management framework defines the processes that the municipality employs to manage infrastructure. The framework needs to receive leadership from senior leadership and elective officials.

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