Integrating Climate Change Risk Assessment and Adaptation in Asset Management

A Case Study for Municipal Staff and Decision-Makers

Introduction

Climate change has been impacting and will continue to impact all of us. Over the next couple of decades, our collective global actions on greenhouse gas (GHG) emissions reductions will determine how much climate change we experience. But even if we stop emitting GHGs today, we are still locked into a certain degree of climate change as carbon dioxide can linger in the atmosphere for decades or even centuries before being reabsorbed by carbon sinks. We must learn to adapt in order to avoid catastrophic damage.

The Insurance Bureau of Canada (IBC) tracks insured losses related to climate events and has recorded an increasing trend in annual catastrophic losses in recent decades. **Table 1** on the following page presents Canada's top 10 highest insured loss years on record, with the last 5 years (2018 to 2022) consistently being within the ranks. According to the IBC, 2022 is currently ranked as the third worst year for insured losses in Canadian history with disasters experienced throughout most regions of the country.

This information, along with individual experiences of critical infrastructure loss and damage, have prompted many municipalities and government organizations to begin addressing climate change from both mitigation (reduce GHG emissions) and adaptation (build resilience to climate change) perspectives.

Climate action is recognized as a pressing need, but many municipalities struggle with how to integrate a climate change lens into asset management and decision-making at the executive level. The complexity of climate change adaptation planning can leave staff and decision makers unsure of where to start. This case study examines the high-level steps taken by the Region of Waterloo in Ontario to develop a decision-making framework that supports the integration of climate change considerations into asset management. By providing an easy-to-understand process that is collaborative, the case study offers an example of how organizations can quickly move toward a high-level climate adaptation plan.

Table 1: Canada's Top 10 Highest Insured Loss Years on Record (adjusted in 2022 dollars)

Rank	Year	Total Loss ($ billion)	Notable severe weather events
1	2016	5.96	Fort McMurray, Alberta fire
2	2013	3.87	Alberta floods; Greater Toronto Area (GTA) floods and ice storm
3	2022	3.12	Multiple events
4	1998	2.83	Quebec ice storm
5	2021	2.48	Calgary hailstorm, British Columbia floods
6	2020	2.46	Fort McMurray, Alberta flood, Calgary hailstorm
7	2018	2.40	Multiple events: Ontario and Quebec rainstorms and windstorms
8	2011	1.97	Slave Lake, Alberta fire and windstorm
9	2012	1.65	Calgary rainstorm
10	2019	1.56	Multiple events

Sources 1983–2007: IBC, PCS Canada, Swiss Re, Deloitte. 2008–2021: Catastrophe Indices and Quantification Inc. (CatIQ). Note: Adapted from Insurance Bureau of Canada Severe Weather in 2022, http://www.ibc.ca/ab/resources/media-centre/media-releases/severe-weather-in-2022-caused-3-1-billion-in-insured-damage-%E2%80%93-making-it-the-3rd-worst-year-for-insured-damage-in-canadian-history

The Region of Waterloo (Municipality) has recognized that critical systems and infrastructure are at risk from climate change impacts; this is especially true for potable water services, systems, and infrastructure. Although these municipal assets in the Municipality have not been directly impacted yet, the potential for climate impact is high – and the consequences could be extreme. Recognizing this, the water services department at the Municipality has begun to assess and address risks with a collaborative and integrated approach.

The Municipality followed a three-step process, as outlined in this case study: Alignment, Assessment, and Synthesis. This climate change risk assessment and adaptation planning process centred on the use of a modified bowtie process model, described herein. Each step in the process was highly collaborative, drawing on the knowledge and experience of key stakeholders from across the department, each with unique and specialized expertise pertaining to the operations, management, and planning for the entire water services system.

Step 1: Alignment

The integration of climate change considerations into any decision-making process for local government is most effective when it brings together various stakeholders from across multiple sectors. It is crucial to align those around the table (e.g., managers, directors, operators, asset managers, etc.) with a shared and objective understanding of climate change knowledge. Hence, the first step is to engage multiple groups of people and discuss the science behind climate change, including climate change scenarios, projected trends in climate, and potential impacts, including downscaled, localized climate projections, if such data is available. It is important to make the information presented easy to understand, relatable, and relevant to the audience. In this case study, this alignment occurred during the first interactive engagement session, which was designed to build this shared baseline understanding.

At this initial stage of the process, it can also be helpful to work with collaborating partners outside the municipal administration. For this initiative, the Municipality was fortunate to receive support from the University of Waterloo Climate Institute, which was able to provide data on downscaled climate projections for the local area. Other potential collaborators and sources of valuable data could include Conservation Authorities, local researchers, as well as Provincial or Federal government data.

Engagement 1 – Baseline Understanding

In this first engagement session, municipal staff were invited to a workshop that included presentations and discussions covering the following topics:

- Understanding the importance of and difference between climate change mitigation and adaptation.
- Acknowledging the increased unpredictability in the climate and how the past may no longer be a reliable predictor of the future. As the climate continues to become unpredictable, more extreme events become more important to consider.
- Understanding past and existing actions taken to support adaptation efforts at the Municipality.
- Recognition that some degree of climate change adaptation is already embedded in the design, construction, and operation of infrastructure.
- Acknowledgement that staff may be the best suited to identifying risks and finding ways to reduce them at a high level.
- Beginning general discussions around anticipated climate change hazards and scenarios for the Municipality (e.g., a growing number of extreme heat days, the increase in heavy precipitation events, etc.).

- Presenting risk analyses for each scenario – typically presented as a grid of likelihood and consequence (e.g., a tornado event, in this Municipality's anticipated climate scenarios is high consequence, but low likelihood).
- Collaboratively brainstorming some potential general impacts of the different climate change scenarios.

Step 2: Assessment

At this stage, once a shared understanding of climate change and the anticipated localized climate impacts have been discussed, the process moves on to the identification, assessment, prioritization, and management of climate-related risks as relevant to the infrastructure assets and processes related to water services in the Municipality. This step is centred on a facilitated process in which participants share their knowledge and experience to collaboratively develop a series of process models for climate-related impacts and potential adaptation actions using a modified bowtie model.

Engagement 2 – Climate Change Impacts and Actions

In Step 2, the following topics were covered in a second facilitated process with all invited stakeholders (although presented here as a second engagement session, if necessary, this step, or components of it, can be combined with Engagement 1):

- Identify infrastructure/services that are critical to the community's level of service (LOS).
- Identify infrastructure/services classes or categories.
- Collective brainstorm of impacts of climate scenarios on infrastructure/service classes/categories and potential adaptation actions using the bowtie methodology (described below).

At the Region of Waterloo Water Services, there are approximately 500 unique classified assets. Due to the significant number of unique assets, the assessment's approach needed to be modified before moving on to the bowtie exercise (as completing 500 separate bowtie assessments was unrealistic). Drawing on feedback from workshop participants, unique assets were categorized into asset classes, which in this scenario included:

1. Water treatment plants: surface water
2. Water treatment plants: groundwater
3. Reservoirs
4. Watermains and chambers
5. Pump stations
6. Elevated tanks
7. System wells

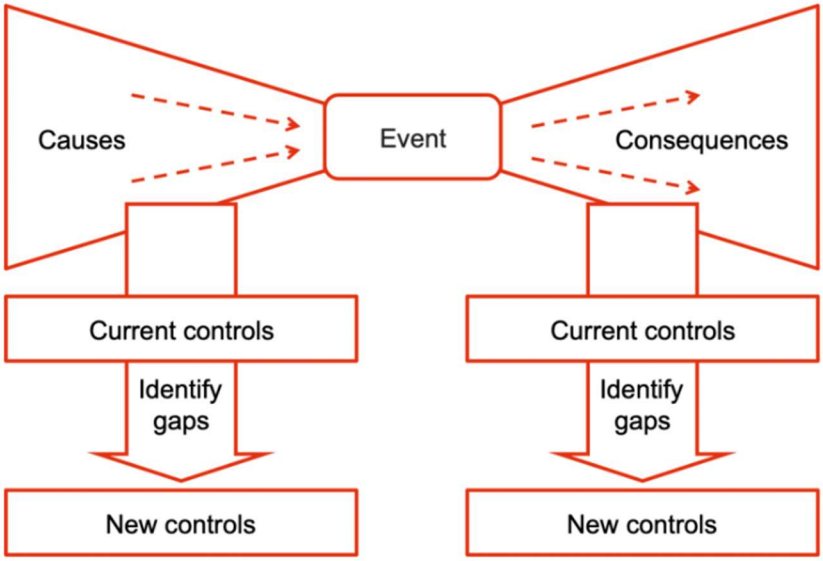
Assessments were made at the asset class level. Likely repetition in impacts and solutions among the assets to climate hazards allowed this method of grouping and simplification.

Bowtie Methodology

With asset categories identified, the group moved on to the bowtie exercise. The bowtie methodology is a visual risk management tool that is scenario-based and enables non-technical staff and multi-stakeholder teams to conceptualize and discuss potential risks and identify potential opportunities that could manage those risks. This screening level risk assessment methodology uses storytelling, to some extent, to bring people along in the process. The bowtie method can be depicted in various ways but the conventional depiction (shown in the figure below) presents fault trees that assess the cause of an event on the left section of the diagram, and the fault trees that assess the consequences on the right section of the diagram. In reference to the figure below, 'Causes' are elements that will cause the 'Event' to occur, while 'Consequences' are the results of the 'Event' occurring.

The diagram sets a clear progression of events from left to right, starting with the probable causes of an event and ending with the potential consequences if no risk mitigation measures or controls are introduced. This is typically followed by discussions of 'Controls' which are risk mitigation measures that can be implemented to either address 'Causes' to stop the event from occurring or address 'Consequences' to manage the severity of impacts. These actions can be viewed as either preventative or reactive, respectively.

Figure 1: Bowtie Diagram

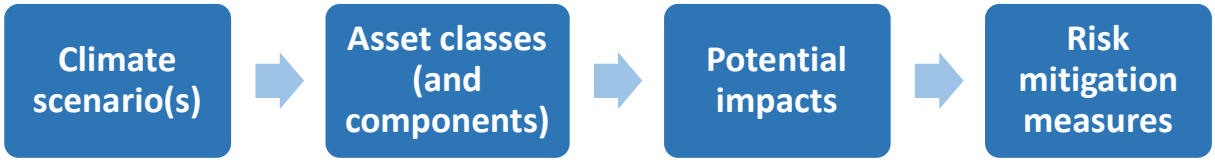


A simple bowtie analysis can be conducted using the following steps:

1. Identify the risk or event to be examined and/or managed in the bowtie analysis.
2. List the causes of the risk on the left and the consequences of the risk on the right.
3. List the existing controls on the causes (preventative measures) below the causes on the left, and the existing controls on the consequences (reactive measures) below the consequences on the right. If a control acts on both causes and consequences, it should be noted on both sides.
4. Assess the effectiveness of the controls and identify options for improvement or new solutions.
5. Evaluate the advantages and disadvantages of each option, and develop implementation plans for the options to be pursued.

The bowtie analysis methodology is an important tool in risk management that can be adapted and modified to meet the needs of the planning process and participants. In the case of the Region of Waterloo Water Services department, climate risk assessment and action planning were sequenced as described in the flow chart below.

Figure 2: Sequence of Discussion for the Municipality's Bowtie Process

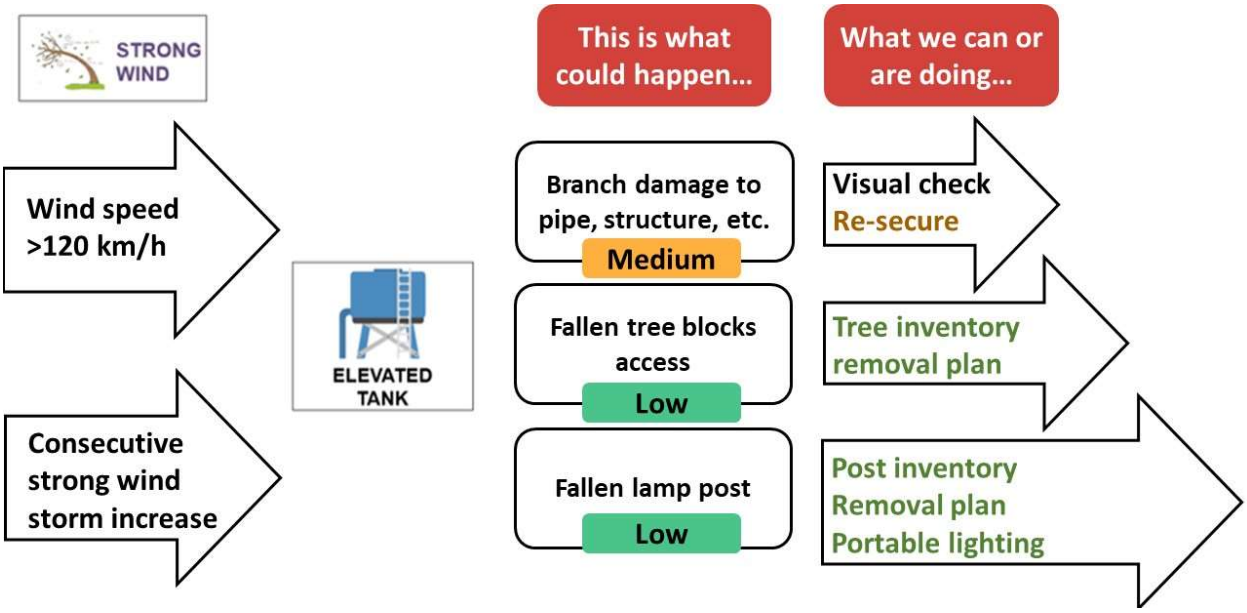


It is important to ensure that multiple groups are represented in this discussion. During the bowtie exercise with the Municipality, operators, hydrogeologists, engineers, asset managers, corporate climate change coordinators, financial analysts, and senior management were engaged. The process began with the reiteration of the anticipated impacts of climate change, with staff prompted to begin thinking about, "How are we going to cope with these changes in the future?" Through a facilitated dialogue, participants are asked specific questions for each identified asset such as, "What could happen to the facility?", "What actions are we doing already and can we take?", and "What other actions can we consider?".

Suggested solutions were verified and filtered by other participants so as to arrive at a list of reasonable and feasible recommendations. The operators, especially, as the individuals closest to the assets on a day-to-day basis, provided substantial input, and important insights were gained through their direct conversations with other stakeholders present. These dialogues narrowed to a series of reasonable actions for each asset category related to each climate hazard. Reasonable actions were defined as actions that can be undertaken without compromising the Municipality's ability to deliver services within the existing regulatory framework and area of responsibility.

The figure below shows an excerpt from the bowtie assessment done with the Municipality on the impacts of strong winds on elevated storage tanks and what adaptive actions can be taken to manage risks. Suggested solutions that were gathered are colour-coded in the right-most column. In this case study, green signifies actions that are already being taken, black signifies actions that are new, and orange signifies actions that need to be taken at a greater capacity. These colour codes are used to quickly indicate which existing actions should be elevated and which entirely new ones should be implemented.

Figure 3: Bowtie Excerpt (Impacts of Strong Wind on Elevated Tanks)



Occasionally, it can be daunting for those new to climate change conversations to provide their feedback in a complex climate risk assessment and action planning process. The bowtie methodology provides participants with a framework to work within. This step-wise approach guides stakeholders to where their expertise can provide value to the discussion, improving collaboration, trust, and comfort in the process. Furthermore, this guided process can support participants' further understanding of the climate change hazards, helping them to conceptualize the potential impacts of climate change in their work.

Step 3: Synthesis

The sorts of collaborative and multi-stakeholder workshops that characterize the process described here are especially helpful in surfacing and focusing the knowledge of staff members most familiar with the actual operations and management of a community's vital infrastructure. They also allow for decision-makers and asset managers to hear directly from operators themselves to get a better understanding of what the impacts of climate hazards could be, and what needs to be done to mitigate climate-related risks. In order to interpret and then efficiently communicate all of the gathered information, the process must conclude with a synthesizing exercise. Summarizing the results of the workshops into a coherent and concise format (such as tables) can then allow for prioritization of actions based on feasibility and urgency.

Potential actions identified through the engagement process can be summarized based on several metrics, including by which group is required to implement actions, and types

of actions (e.g., monitoring or capital renewal). Other metrics such as cost of action, timeline to implement, level of effort/resourcing capacity can also provide additional lenses for organizing and prioritizing potential risk mitigation actions. Throughout, it is advisable to keep the information digestible and relatively easy to follow.

Following the completion of the bowtie assessment phase, lists of impacts and opportunities for each asset class/category can be consolidated for further processing. In this case study, this was done using summary charts, such as the one illustrated in the **Table 2** below.

Table 2: Summary of Recommendations to Address Impacts of Extreme Heat

	Operations	Engineering & Planning/ Design & Construction	Hydrogeology and Source Water/ Water Engineering
Event Monitoring	• Ensure all managers receive heat warning notices • Active monitoring of water temperature and residuals	• Active monitoring of demands	• Active groundwater level monitoring
Training / Studies	• Reservoir management simulation / training • HV reservoir mixing efficacy and technology review	• HVAC and emergency review for new projects • Optimization studies • Fire analysis • Tank mixing design • Review max week demand • Continued IUS network modelling • Renewable energy opportunities in EA, CA's and AMPs	• Low Impact Development (LID) opportunities • Increased role of Aquifer Storage and Recovery (ASR) in Water Supply Master Plan (WSMP) • Rainwater harvesting opportunity WSMP • Tier 3 SP modelling
Long-term Measures	• Program or Standard Operating Procedure to anticipate chemical and generator set fuel top-up		• Program to exercise less used wells

In this case study, tables of solutions for different climate hazards were also produced, as seen in **Table 3** below. Numbers can be assigned to prioritize initiatives, responsible parties can be assigned, and timing of initiatives can be noted. These initiatives could also be monitored through a Power BI dashboard, and revisited annually to understand how progress is being made.

Table 3: Extreme Heat Adaptation Initiatives

Initiative Type	Proposed Initiative	Action	Assigned to/Lead	Timing
Event Monitoring	**OP-H1 – Managers and staff receive heat warnings:** Identify WS managers and staff who should receive emergency warnings from EMS.			
Event Monitoring	**OP-H2 – Active monitoring of water storage parameters**: Upon heat warning, on-call operators to actively monitor for changes to key parameters at storage facilities such as water temp, residuals, DO, pH.			
Event Monitoring	**OP-H3 – HVAC monitoring from SCADA:** Upon heat warning, on-call operators to actively monitor for changes in HVAC performance.			
Event Monitoring	**OP-H4 – Monitor VFD temperature:** Upon heat warning, on-call operators to actively monitor for changes in VFD performance.			
Training/ Studies	**OP-H5 – Reservoir management simulation training:** Retain an operations professional to provide Region-specific training for reservoir operations during heat wave. Topics may include demand.			

Next Steps: Sharing and Realignment

Following the alignment, assessment, and synthesis process, next steps should involve reconnecting with stakeholders and decision makers and sharing the synthesized results of the workshops. Results should also be used to realign asset management plans and costing of initiatives in consideration of the new knowledge produced through the assessment process.

Key Takeaways

Climate Data is Important

- Collecting, analyzing, and interpreting climate data is a critical step in the process. The process of climate modeling and understanding potential future impacts of climate change can be supported by university researchers or specialized consultants. Climate specialist involvement or the use of data from outside resources allows for the accurate and defensible interpretation of climate projections that can be used as the basis for all adaptation planning processes.

The Bowtie as a Simplified, Yet Powerful Tool

- When assessing and planning for climate change risks in asset management, both support from the top and participation and input across all levels and departments are key drivers of success. Identifying and engaging the appropriate stakeholders can be pivotal for accessing the wide range of knowledge required for the assessment as well as gaining senior management buy-in. The bowtie methodology illustrates the climate-related challenges asset managers can anticipate in a sequential manner that can speak to non-technical professionals in a cross-disciplinary dialogue with little friction in a process that can align with broader municipal plans and processes.
- The bowtie methodology provides stakeholders with a framework to work within, making clear where they can provide their input. This clear direction creates a comfortable dialogue space, better enabling access to specialized knowledge and cross-disciplinary collaboration.
- The bowtie methodology utilized in this case study required fewer resources, time, and technical expertise in comparison to other standard methodologies, such as the PIEVC Protocol, ISO31000, and the Climate Lens. However, each municipality should research a number of alternative strategies and methods in order to determine which might be best suited to their local needs and resources.
- In this case study, the bowtie analysis was shown to other departments and received positive reception due to its clear and easy-to-understand representation of potential risks and how they can be managed.

- Due to its simplicity, flexibility, and general accessibility, the bowtie methodology can be adopted and adapted by other initiatives across other departments in a municipality.

Collaboration is Key

- Critical to the success of this case study was a commitment to the careful planning and process design necessary to hold a collaborative and multi-stakeholder dialogue. Bringing together staff members who offered different types of knowledge and expertise enabled richer and more productive dialogue, led to the creation of new knowledge, resulting in a more robust climate risk assessment and the development of more realistic and implementable actions.
- This collaboration and participation, involving those who will be responsible for implementation doing the analysis and generating the actions themselves, engendered the kind of buy-in that will be necessary to make climate risk mitigation a reality.

Resources

Additional information on the bowtie methodology are linked below.

Bowtie Analysis (Broadleaf Capital International; 2019), https://broadleaf.com.au/resource-material/bow-tie-analysis/

The Bowtie Method (Wolters Kluwer), https://www.wolterskluwer.com/en/solutions/enablon/bowtie/expert-insights/barrier-based-risk-management-knowledge-base/the-bowtie-method

---

This case study was prepared by Dillon Consulting Limited.

Thank you to the Region of Waterloo for sharing their approach for this case study.

This knowledge product was developed through the Municipal Asset Management Program, which is delivered by the Federation of Canadian Municipalities and funded by the Government of Canada. fcm.ca/assetmanagementprogram