Town of Aurora

Climate Change Adaptation Plan

April 2022

Quality Management

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Land Acknowledgement

We begin this report by acknowledging that the Town of Aurora is on Indigenous land that has been inhabited by Indigenous peoples from the beginning.

As settlers, we thank all the generations of people who have taken care of this land - for thousands of years.

Long before today, there have been Indigenous peoples who have been the stewards of this place.

In particular, we acknowledge this the town of Aurora is on the traditional territory of the Wendat, the Haudenosaunee, and the Anishinaabe peoples. We also acknowledge that Aurora resides within Treaty 13 (1805) and Williams Treaty (1923).

We recognize and deeply appreciate their historic connection to this place. We also recognize the contributions of Métis, Inuit, and other Indigenous peoples have made, both in shaping and strengthening this community in particular, and country as a whole.

As settlers, this recognition of the contributions and historic importance of Indigenous peoples must also be clearly and overtly connected to our collective commitment to make the promise and the challenge of Truth and Reconciliation real in our communities, and in particular to bring justice for Murdered and Missing Indigenous Women across our country.

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Glossary of Terms

Annual cooling degree-days (CDD): Measure of how hot the temperature is or will be during a given year. This is used as a measure of energy use required to cool and maintain comfortable indoor temperatures. Annual cooling degree days are equal to the number of degrees Celsius a given day's mean temperature is above 18°C, compounded throughout the year. For example, if the daily mean temperature is 21°C, the CDD value for that day is equal to 3. If the daily mean temperature is below 18 °C, the CDD value for that day is set to zero. The sum of each day's CDD is added together to create an annual total. There are no units associated with CDDs.

Climate: The weather conditions prevailing in an area in general over a long period, typically a minimum of 30 years. Climate differs from weather in that weather reflects short term (minute, hourly, daily, weekly, seasonal) conditions of the atmosphere and does not denote the long-term trends.

Climate change: Any significant long-term change in the expected patterns of average weather of a region over a significant period of time, usually averaged to a minimum of 30 years.

Exposure: Presence of people, livelihoods, assets, services, resources or infrastructure in place in a specific region that could be adversely affected by climate change.

Freeze-thaw cycle: Number of days where the maximum temperature is above 0°C and the minimum temperature is below 0°C. Under these conditions, it is likely that some water at the surface was both liquid and solid at some point during the day.

Heatwave: Extended period of extreme heat. A heat wave is defined here as a period of three or more consecutive days with maximum temperatures above 30°C.

High summer temperature (2.5% July temperature): The highest temperature at or above which only a certain small percentage of the hourly outside air temperatures in July occur. There are two measurements commonly used: wet bulb temperature and dry bulb temperature. Wet bulb temperature is the lowest temperature to which air can be cooled by evaporation of water into the air at a constant pressure. It is measured by wrapping a wet wick around the bulb of a thermostat and is impacted by the relative humidity of the air. Dry bulb temperature is the temperature of air measured by a thermometer that is freely exposed to the air but shielded from radiation and moisture. The dry bulb temperature is indicative of the air temperature without the effect of moisture.

Intensity-duration-frequency (IDF) curve: IDF curve is a representation of the probability that a given rainfall intensity or quantity occurs over a sub-daily time period.

Low winter temperature (2.5% January temperature): The January design temperature is defined as the lowest temperature at or below which only a certain small percentage of the hourly outside air temperatures in January occur.

Mitigation: Reducing the amount of greenhouse gases in the atmosphere by reducing the sources of greenhouse gases or increasing the sinks which accumulate and store the gases.

Resilience: The ability of a system to absorb disturbances while maintaining the same basic structure and ways of functioning.

Risk: The possibility of injury, loss or negative environmental impact created by a hazard. The significance of risk is a function of the probability of an unwanted incident and the severity of its consequence.

Risk rating: The assessment of the level of risk through a pre-defined scale.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of changing climate, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Executive Summary

A changing climate has resulted in increases in temperature and extreme weather events in southern Ontario. Physical impacts from heat waves, strong winds, and flooding have been experienced in the Town of Aurora and are projected to occur more frequently and with greater intensity. As climate change continues to shift weather patterns and norms, it is important to understand how these changes may manifest in the Town of Aurora, and what the impact to the community may be.

Infrastructure is fundamental to community wellbeing and supports the services a municipality provides to residents. Much of the Town's infrastructure is exposed to the environment and therefore could be impacted by the changing weather patterns associated with climate change. With significant investments in infrastructure and services that the community depends on, it is important that the Town protects public infrastructure from avoidable damages related to climate change. Understanding potential climate risks to Town infrastructure and how to adapt is important for the sustainability of public assets and long-term financial management.

The Town commissioned WSP to prepare a climate change adaptation plan to guide asset management planning and better prepare for the impacts of climate change. The adaptation plan is based on a climate risk assessment of Town-owned infrastructure as defined in the Town of Aurora 2018 Asset Management Plan. The assets, and therefore the assessment, was divided into four infrastructure categories: linear engineering, water infrastructure, parks and natural heritage, and facilities.

To determine the potential impacts of climate change on the infrastructure in the Town, localized climate projections were analyzed. WSP identified climate trends that are expected to materialize in the near term, between 2021 and 2050. The most likely trend to occur is an increase in temperatures, and this is expected to impact several climate and weather parameters:

- Mean summer maximum temperatures are projected to increase by 9%,
- The number of heat waves are projected to increase from 1.2 to 3.6 per year,
- Cooling Degree Days (used for cooling system design and planning) are projected to almost double (increase of 86%),
- Winter temperatures are expected to increase, leading to a reduction in extreme cold risks, snow depth, and annual freeze-thaw cycles (although freeze-thaw cycles concentrated in winter months may still be damaging to infrastructure).

Otherwise, precipitation, wind, and low air quality events associated with wildfires are also projected to increase in the future. Interactions between each asset category and these climate trends were evaluated to determine where vulnerabilities may exist.

In this assessment, risk is defined as the possibility of injury, loss, or negative environmental impact created by a hazard. Risk is a product of the probability that a climate hazard may impact infrastructure and the severity (or benefit) of this impact. The risk assessment is completed by answering the three following questions:

1. Which climate / infrastructure interaction events could occur in the lifespan of the infrastructure?
2. How likely is it that these events will occur?
3. If the event happens, what are the consequences (or benefits)?

The risk assessment identified 185 relevant climate-infrastructure interactions using available data, scientific literature, Town staff input, and the professional judgment of WSP's project team. Whereas the majority of the risks were evaluated to have a low or medium risk rating, it is notable that no high risks were found. All risk results were reviewed by WSP and Town staff, and based on the relative risk scoring, recommendations for adaptation actions were developed. These actions are intended to guide further climate change adaptation planning for Town infrastructure with specific actions identified for the short, medium, and long term.

Short term priorities for adaptation actions are summarized as follows:

- For **Linear Engineering Assets**, actions are focused on improving the flood resilience of the stormwater system through proactive maintenance, evaluating future projected precipitation impacts to the system, and applying lot-level runoff controls. Other specific short-term actions include preparing road signage and traffic signals for increased power outages and maintaining stormwater management ponds in dry summer conditions.
- For **Water Infrastructure**, actions relating to flood management are important in reducing risks to the sanitary system. Otherwise, continued emergency response and increased surveillance planning are recommended to help reduce the worst impacts of flood risks to water infrastructure if issues can be detected and repaired quickly.
- For **Parks and Natural Heritage**, actions focus on preventing and repairing debris hazards through proactive landscape maintenance.
- At **Facilities**, actions relate to ensuring sufficient cooling capacity in critical buildings as temperatures and heatwaves increase, ensuring backup power is in place at facilities as needed, inspecting domed (bubble) roofs proactively and after high wind events, and considering flood preparedness and drainage systems of facilities.

Medium and long-term priorities for adaptation actions focus on three key themes:

- Incorporating climate change projections into asset management planning to ensure that infrastructure designs, operations and maintenance procedures are prepared for future conditions,
- Managing risks through updated operation and maintenance procedures based on identified risks, and

- Planning for and implementing resilience interventions upon asset renewal, during major retrofits, or as needed when new risks are identified.

This risk assessment also highlighted the importance of continuing ongoing activities such as emergency response planning, flood risk studies, and maintenance activities to manage some of the highest identified risks. Another important recommendation is to integrate climate risks and adaptation into the Town of Aurora asset management planning to inform decision-making and reduce climate change risks. It is also important to assess the Town's desired levels of service along with future climate projections. In some cases, this will mean designing infrastructure or building retrofits to exceed current codes and standards which are based on historical climate conditions. Proactively considering the future climate conditions and levels of service an asset will need to support, will result in right-sizing infrastructure and investments to build resilience into operations.

With proactive adaptation to climate change, the Town of Aurora can continue to provide high quality services to the community into the future. Every dollar invested today in resilience saves six in future costs (IBC, 2019), so the benefits of acting on climate adaptation now are clear. As the Town continues on its climate mitigation and adaptation journey, this risk assessment should be reviewed and updated alongside future asset management planning at regular intervals.

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1 Introduction

1.1 Background

Extreme climate events have increased in frequency and severity in southern Ontario in the recent past. Heatwaves have caused pavement to buckle resulting in the closure of major highways, and severe storms have overwhelmed stormwater systems, downed trees and power lines impacting people, businesses, and property. In the Town of Aurora (Town), heat waves have affected people and buildings, strong winds have damaged bubble roofs, and flooding has affected stream integrity, parking lots and roads. As climate change continues to shift weather patterns and norms, it is important to understand how these changes may manifest in the Town of Aurora, and what the impact to the community may be.

Infrastructure is fundamental to community wellbeing and supports the services a municipality provides to its residents. The Town owns and operates many types of infrastructure from roads to parks and recreation facilities. Much of the Town's infrastructure is exposed to the environment and therefore could be impacted by the changing weather patterns associated with climate change. Understanding how infrastructure will be affected by a changing climate is an important step for the Town to improve its service delivery and manage risks to its assets.

The Town has taken steps on climate action to reduce energy emissions through the 2021 Community Energy Plan. In terms of planning for resilience, the Town has conducted flood studies to better understand and manage flood risk in the Tannery Creek watershed (Aquafor Beech Ltd., 2019). The Town's asset management planning helps to ensure infrastructure is operated, maintained, and designed for longevity; however, it does not consider the impacts that climate change may have on infrastructure. The Town is planning to invest $123 million in its infrastructure between 2018 and 2028 (Asset Management Plan, 2018) and has a responsibility to protect this public investment from avoidable damages related to climate change. Climate change adaptation and mitigation interventions have the potential to be low cost while providing significant future benefits. According to the Insurance Bureau of Canada, every dollar invested today in resilience saves six in future costs (IBC, 2019). It is often much more challenging and expensive to implement reactive measures when damage from extreme events has already occurred and retroactive repairs or refurbishments are required.

To that end, the Town engaged WSP to develop a Climate Change Adaptation Plan for the infrastructure assets within the Town's municipal asset inventory. The adaptation plan presented in this report is intended to guide future actions to reduce risks associated with climate change and public infrastructure. In addition to managing climate impacts to Town infrastructure, the plan is intended to help the Town better integrate climate resilience into design, operations, planning, and decision-making with respect to asset management.

The adaptation plan builds upon work done locally by York Region and the Lake Simcoe Region Conservation Authority (LSRCA) and will help Aurora align with provincial and regional direction on climate change including the Ontario Regulation 588/17, and the Town's Asset Management Policy and climate change initiatives.

1.2 Scope of Project

The Adaptation Plan is informed by a climate change risk and vulnerability assessment completed using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol. The PIEVC protocol is a nationally recognized tool for assessing infrastructure risk due to climate change. The PIEVC protocol and therefore this Adaptation Plan maintain a specific focus on infrastructure and operation of Town assets. It does not consider the full extent of social and environmental impacts that may occur in Aurora as a result of climate change. This assessment consisted of a desktop study with virtual engagement with Town staff and did not include a site visit. Assumptions and infrastructure condition descriptions are based on the Town of Aurora Asset Management Plan and Town staff input, and the results are intended to inform future asset management planning.

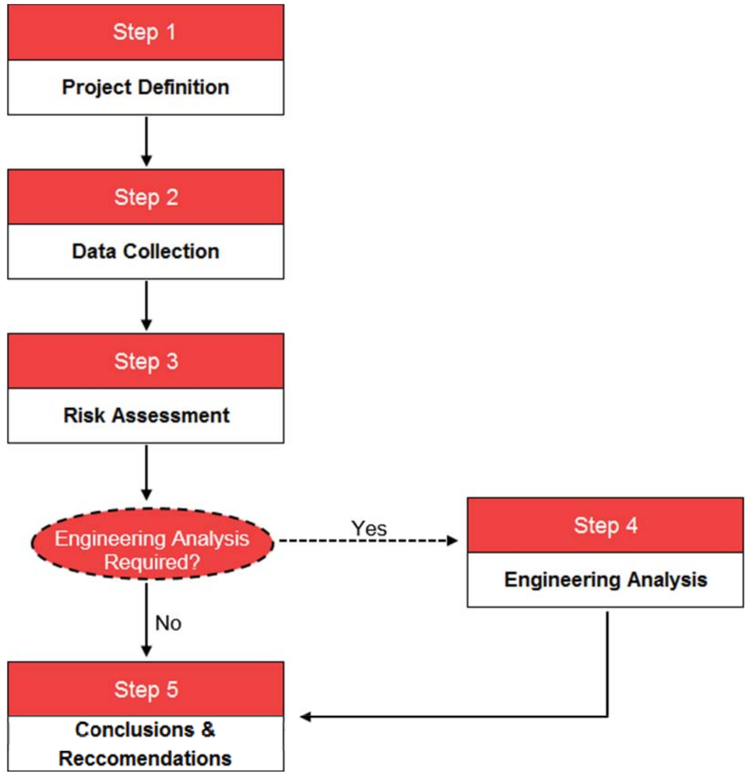
2 Approach

2.1 Overview of the PIEVC process

The PIEVC protocol is a tool that supports the systematic assessment of the risks posed by extreme weather and future climate to public infrastructure. It is a five-step process (Figure 5) including project definition, data collection, risk assessment, engineering analysis (if needed), and conclusions and recommendations. This risk assessment process is similar to other methodologies for completing climate change risk assessments and was chosen for this project as it was developed specifically to assess infrastructure vulnerability.

The key actions of the risk assessment approach are to:

- Collect and review background information on infrastructure and asset management practices,
- Analyze historical climate information and future climate hazard projection data,
- Estimate the likelihood and severity of climate impacts to the infrastructure to evaluate and prioritize potential risks,
- Develop recommendations on adaptation pathways for specific assets (e.g., design adjustments, changes to operations, or maintenance).



WSP's team of resilience specialists and engineering discipline Subject Matter Experts (SMEs) completed Steps 1, 2, 3, and 5 with input from Town staff along the way. Step 4, Engineering Analysis, is only implemented where there is insufficient information to evaluate risks and complete the study. This was not the case for this project, so Step 4 was not performed. Three technical worksheets (found in Appendix B) are completed throughout the process to gather and organize information, confirm assumptions, and guide the process of the assessment. The results of the risk assessment form the basis of the adaptation plan presented in this report. The following sections summarize the risk assessment process, results, and recommended adaptation actions. For more details on the PIEVC inputs and process, refer to the worksheets in Appendix B.

3 Project Definition

The first step in completing a PIEVC assessment is to clearly define the project scope and boundaries, describe the infrastructure being assessed, and identify relevant documents and information sources. Detailed information on this step can be found in Worksheet 1 in Appendix B.

3.1 Policy and Context

This climate change adaptation plan aligns with policy directions on climate change mitigation and adaptation established by the Town of Aurora, Regional Municipality of York, and the Government of Ontario. A summary of key policy documents relevant to this study is given in Table 1.

Table 1: Policy documents guiding climate change action in Aurora

POLICY DOCUMENT	KEY STATEMENT(S)
A Place to Grow: Growth Plan for the Greater Golden Horseshoe (Government of Ontario, 2020a)	"Municipalities will assess infrastructure risks and vulnerabilities, including those caused by the impacts of a changing climate, and identify actions and investments to address these challenges, which could be identified as part of municipal asset management planning."
Provincial Policy Statement (Government of Ontario, 2020b)	"[I]nfrastructure and public service facilities shall be provided in an efficient manner that prepares for the impacts of a changing climate while accommodating projected needs."
Asset Management Planning for Municipal Infrastructure (O. Reg. 588/17)	"5. The municipality's commitment to consider, as part of its asset management planning, i. the actions that may be required to address the vulnerabilities that may be caused by climate change to the municipality's infrastructure assets, in respect of such matters as, A. operations, such as increased maintenance schedules, B. levels of service, and C. lifecycle management"
Draft York Region Official Plan (Regional Municipality of York, 2021)	"Climate change and adaptation goals cannot be achieved by the Region alone and will require partnership and efforts from all levels of government, conservation authorities, community stakeholders, businesses, the development industry, and the public"
Strategic Asset Management Policy (Town of Aurora, no date)	In alignment with the Town's strategic direction, "prepar[ing] a Climate Change Adaptation Plan" is a key priority.

3.2 Infrastructure Description

The public infrastructure within the municipal boundary of Aurora is owned and operated by the Town, York Region, and the Province of Ontario. The risk assessment and the associated adaptation plan consider the assets owned and operated by the Town as defined in the 2018 Asset Management Plan (AMP). This infrastructure is divided into four categories including Linear Engineering Assets, Water Infrastructure Assets, Parks and Natural Heritage Systems, and Facilities. Provincial, regional, and privately owned assets within the Town are excluded from this assessment.

The risk assessment is completed at the asset sub-class level, aggregated according to the Asset Management Plan classification (Town of Aurora, 2018). Data from the AMP was used to determine the average condition and age of each infrastructure type, which was then considered in the risk assessment. The time period selected for this assessment is for the near future, between 2021-2050, since most of the infrastructure assessed will reach end of life within this time (AMP 2018).

The sections below provide a list of the asset sub-categories considered in this assessment and an overview of where these assets are located in the Town. Detailed maps with scales and legends are located in Appendix A.

Linear Engineering Assets

The Town’s linear engineering assets include stormwater management and road systems. The asset sub-categories include the following:

Road Network

- Pavement and curbs
- Pedestrian paths
- Road luminaires
- Signage
- Traffic signals

Stormwater Network

- Sewers
- Maintenance chambers
- Catch basins
- Laterals
- Oil grit separators
- Cleanouts
- Headwalls
- Stormwater management ponds
- Equalization tanks
- Bridges and culverts

Since linear infrastructure is necessary for mobility and flood management, these are located throughout all developed areas of the Town. Although not all assets had spatial data points available, the map below in Figure 1 provides an overview of the distribution of linear engineering assets across the Town.

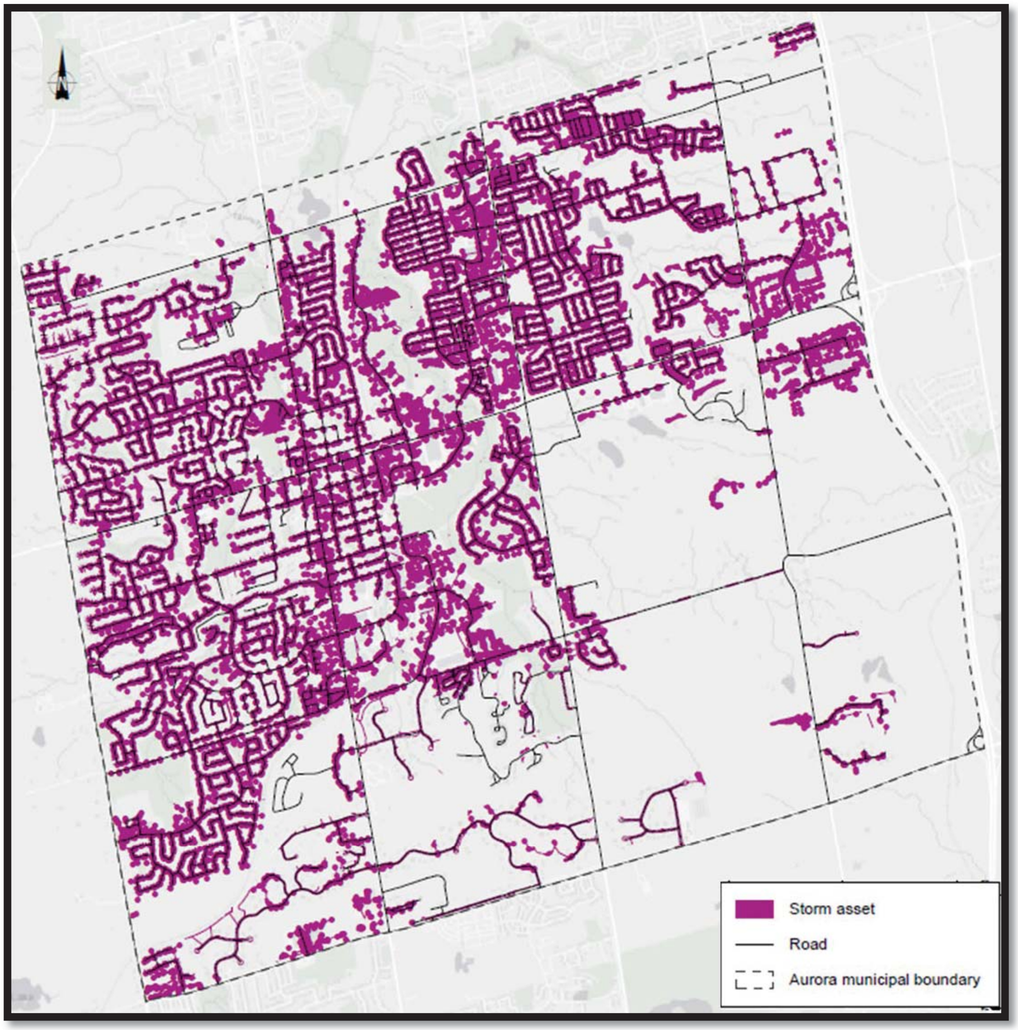


Figure 2: Map of Roads and the Stormwater Network

Water Infrastructure

The Town's water infrastructure includes all components of the water and sanitary networks. The asset sub-categories include the following:

Water Network

- Water mains
- Water valves
- Underground enclosures
- Fire hydrants
- Service connections
- Bulk water filling stations
- Booster stations

Sanitary Network

- Sewers
- Maintenance chambers
- Laterals
- Equalization tanks
- Pumping stations

Water and sanitary networks service all developed areas of the Town. Figure 2 provides an overview of sanitary assets distributed throughout Aurora.

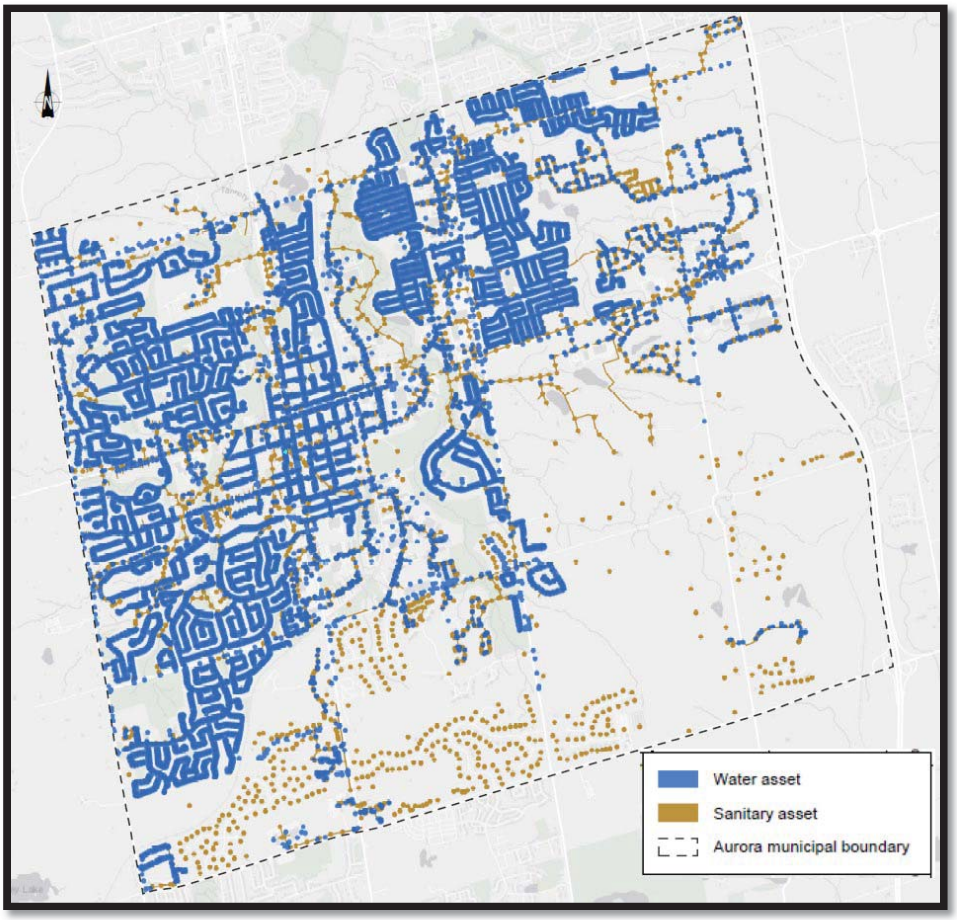


Figure 3: Map of Water and Sanitary Networks

Parks and Natural Heritage System

Parks and natural heritage assets throughout the town include athletic fields, trail networks, areas of open and undeveloped space, as well as supporting infrastructure including lighting, fencing, and signage (AMP 2018). The following asset sub-categories are used for the risk assessment:

- Open space and parkland
- Land associated with municipal facilities
- Land maintained for environmental purposes
- Off-road trails
- Park structures

Parks and natural heritage features are geographically distributed throughout the community. Figure 3 provides an overview of the location of parks features included in the Town of Aurora. Not shown on the map are lands associated with municipal facilities and natural forested areas throughout the town.

Figure 4: Map of Parks and Natural Heritage System

Facilities

The Town owns and operates 19 facilities that serve the community including government buildings such as the Town Hall, protection services including two fire halls, recreation and culture facilities including the Stronach Aurora Recreation Complex, and transportation services buildings (AMP 2018). These facilities may be considered single assets, but they consist of several inter-connected infrastructure systems. Therefore, common building components across all facilities have been considered in the risk assessment rather than assessing each facility independently. A list of building component infrastructure considered for all facilities is as follows:

- Heating, Ventilation, and Air-Conditioning (HVAC) systems
- Building envelope systems
- Building structural systems
- Electrical systems
- Plumbing systems
- Hardscaping

Facilities owned and operated by the Town are predominantly located in the central core of the community with some outlying facilities. Figure 4 provides an overview of the facilities included in the risk assessment for which spatial data was available.

Figure 5: Map of Town Facilities

4 Data Gathering

The purpose of Step 2 of the PIEVC process is for gathering further information on the infrastructure being assessed and the future climate conditions that may impact it. To accomplish this, WSP conducted a document review, stakeholder engagement, and an analysis of publicly available climate change projection data, as described in the sections below.

4.1 Document Review

Background documents relevant to infrastructure and asset management were provided to WSP by the Town. Key resources informing this assessment include the 2018 Asset Management Plan, an Asset Database Listing (2018), and a draft Levels of Service Framework for asset management. The 2018 Asset Management Plan provides information on infrastructure age, useful life, and maintenance schedules for each asset type. The 10-Year Capital Investment Plan includes plans for continued growth and development, however, due to the scale of this assessment, only existing infrastructure was assessed. Other reports and databases were reviewed as needed, and information gaps were filled in through stakeholder engagement. WSP had sufficient data to conduct the risk assessment of the Town's infrastructure.

4.2 Stakeholder Engagement

At the beginning of this project, WSP supported the Town in forming a Resilient Infrastructure Working Group including Town stakeholders from areas such as Climate Change Planning, Asset Management, Linear and Water Infrastructure Engineering, Parks and Natural Heritage, Facilities, Emergency Response, Legal, and Finance. Stakeholders in the Resilient Infrastructure Working Group were engaged at key milestones throughout the project to provide commentary on interim results. The engagement process was designed to consolidate practical knowledge from stakeholders and to build institutional resilience through an improved understanding of climate risks and climate-informed decision-making.

Town Staff Interviews

Town staff with knowledge of and experience related to the Town's infrastructure portfolio and asset management were interviewed to better understand the infrastructure systems. The purpose of these interviews was to validate information identified in the background document review and provide further insight into potential concerns around climate change and infrastructure in Aurora. Topics of discussion included critical infrastructure, previous failures, the historical impact of climate events, risk and response protocols, and more.

4.3 Future Climate Analysis

Four major climate hazards and trends were evaluated as part of this study: increasing and extreme temperatures, precipitation and flooding, changing winter conditions, and extreme weather and storms. Within these hazards and trends, WSP identified 13 important climate indicators (i.e., specific data points such as “number of days above 30 degrees Celsius”) and performed an analysis of future climate change projection data. This analysis provides an understanding of how climate change is likely to impact infrastructure in Aurora. A summary of notable climate trends in the short term (2021-2050) is provided below. A more detailed description of climate indicators and future climate projection data along with references for all data presented in this section are provided in Worksheet 2 in Appendix B.

Higher average temperatures and extreme heat

Temperatures are projected to be higher on average year-round with more hot days in the summer. Specifically:

- Mean summer maximum temperatures are projected to increase by 9%,
- The annual number of heatwaves is projected to increase from 1.2 to 3.6,
- Cooling Degree Days (used for cooling system design and planning) are projected to almost double (increase of 86%),
- Winter temperatures are expected to increase, leading to a reduction in extreme cold risks.

High summer temperatures may exceed the capacity of facilities to maintain safe and comfortable indoor temperatures, which may compromise the ability to deliver cooling shelters during extreme heat events. Heatwaves may render playing fields unusable due to periods of extended dryness and high temperatures and can accelerate the degradation of other exterior assets that are sensitive to temperature (e.g., pavement expansion and buckling at high temperatures).

Increase in average precipitation, heavy precipitation, and flooding

More precipitation is expected to fall on an annual basis, particularly in spring, fall and winter. Rainfall is projected to become more frequent and intense. More rain may fall on a typical rainy day and during extreme short-duration high-intensity storm events. Climate projections for Aurora show that:

- Annual precipitation is projected to increase by 6.3%,
- Extreme precipitation for the 1 in 100-year storm event is projected to increase by 17.5%.

Stormwater infrastructure has been designed to accommodate historical rainfall amounts and may be overwhelmed by future increases in extreme precipitation events. Exceeding stormwater system capacity may cause localized flooding, bank erosion, or compromise the foundations and structural integrity of bridges. Similarly, extreme precipitation may cause sanitary backups or wastewater leakage into the environment.

Freeze-thaw cycles and snowpack

As temperatures warm, climate projections show the following changing winter conditions:

- With warmer temperatures, freeze-thaw cycles are likely to decrease annually but become more concentrated during the winter months,
- Winter freeze-thaw cycles are projected to increase by 17% from an average of 31 cycles to 36.5,
- The maximum annual snow depth is estimated to decrease by 5% to 7.5% per decade.

Freeze-thaw patterns are projected to shift in frequency and timing, which can impact winter operations and maintenance activities and affect how exposed assets age due to expansion and contraction, and icing. Warmer winters are also expected to be associated with decreases in snow depth, reducing the structural load on buildings.

Severe weather

Strong wind gusts and lightning impacts may increase as global temperatures continue to rise. Climate projections for Aurora show that:

- The number of days with wind gusts greater than 100 km/h is expected to increase by 30% from 5 to 6.5 days,
- The annual number of lightning strikes is expected to increase by 12% for every 1°C in mean temperature increase.

Severe weather events can cause physical damage to infrastructure requiring expansive repairs and disruptions to municipal service delivery. In the past, wind has damaged two bubble-style roofing systems in Aurora. Lightning is a high consequence impact that may interrupt and damage the power supply and electrical systems in facilities.

5 Risk Assessment

The PIEVC Protocol defines risk as the possibility of injury, loss or negative environmental impact created by a hazard. Risk is a product of the probability of occurrence of an impact and, given that it has happened, its consequences. The risk assessment is then completed by answering the following questions:

1. Which climate / infrastructure interaction events could occur in the lifespan of the infrastructure?
2. How likely are specified climate / infrastructure interactions to occur within the lifespan of the infrastructure?
3. If the events do occur, what might the consequences be?

For this assessment, the probability that selected climate events occur in the future is calculated by determining the likelihood that historic climate conditions may be exceeded within a specified time period. This likelihood is rated from 0 to 7, 0 being the least likely and 7 being the most likely. Further details on likelihood calculations complete with climate projection data outputs are described in Worksheet 2 in Appendix B.

The potential consequences of a climate-infrastructure interaction were evaluated qualitatively by incorporating input from Town staff and engineering SMEs on the WSP project team. The severity of potential consequences is rated on a scale from 0 to 7, where 0 means no negative consequences and 7 means a significant failure. The product of the probability and the severity scores results in a risk score between 0 and 49.

The following risk evaluation grid was applied in this assessment (Table 2):

Table 2: PIEVC Risk Categories and Responses

RISK RANGE	THRESHOLD	RESPONSE
< 12	Low risk	No action necessary.
12 – 36	Low medium risk (12-25)	Action and/or an engineering analysis may be required.
	High medium risk (26-36)	
> 36	High risk	Action required.
= 7	Special Case	Requires special attention in risk assessment to determine if action is necessary.

– **Low-risk** interactions represent no immediate vulnerability associated with the infrastructure component. No further action is recommended for low risks.

- **Medium-risk** interactions represent a potential vulnerability. Medium risks may require mitigative action. Medium risks are further broken down into low-medium and high-medium risks to aid in the prioritization of mitigation measures.
- **High-risk** interactions represent an identified vulnerability. Mitigative actions are required to ensure the viability of the infrastructure.

Special cases will also be highlighted and carefully considered in the assessment. Special cases (with a risk score of 7) may warrant specific mitigative measures due to either a severe outcome and low probability of occurrence, or a high probability and low severity event.

5.1 Risk Workshop

For this project, the risk assessment was first completed by the WSP project team, then results were validated with Town staff during a risk workshop. The workshop was held on October 29, 2022, to inform the stakeholders of the risk assessment process, discuss and confirm risk tolerance of the organization, and validate the preliminary results of the risk assessment. Stakeholders were asked to comment on the highest risks associated with each climate hazard and infrastructure category to ensure the information captured in the risk assessment is consistent with the Town’s understanding of its infrastructure. Feedback from the workshop was then incorporated into the final risk scores and used to inform adaptation actions.

5.2 Risk Assessment Results

The risk assessment identified 186 relevant climate-infrastructure interactions using available data, scientific literature, and the professional judgment of WSP’s project team. Of the 185 interactions assessed, 97 correspond to a low risk, 59 to a low medium risk, and 29 correspond to an opportunity. No high medium risks, high risks, or special cases were identified.

The following subsections present the risk profile for linear engineered assets, water infrastructure assets, parks and natural heritages system assets, and Town facilities. For simplicity, and since no high medium, high or special case risks were identified, only the low medium risks are presented. Opportunities are discussed in Section 5.3. See Worksheet 3 in Appendix B for the complete risk assessment results.

Linear Engineered Assets

The low medium risks for linear engineered assets are presented below, in Table 3 for roads and Table 4 for stormwater infrastructure.

Road Networks

The risk assessment identified five low medium risks related to road network infrastructure and no high medium or high risks (Table 3). These top risks relate to temporary flooding of roads and sidewalks, damage to pedestrian paths from freeze-thaw cycles, traffic hazards resulting from power outages and freezing rain reducing the visibility of road signs during severe weather events.

Table 3: Low medium risks of the road network infrastructure

COMPONENT	CLIMATE HAZARD	P	S	R	JUSTIFICATION
Traffic signals	Lightning	4	6	**24**	Power outages caused by lightning strikes impacting traffic lights, potentially leading to safety hazards.
Pedestrian paths	Extreme short-duration precipitation	5	4	**20**	Temporary loss of access to pedestrian paths due to flooding. Erosion and washouts of paths may require in increased maintenance.
Pavement and curbs	Extreme short-duration precipitation	5	3	**15**	Temporary loss of access to paved surfaces due to flooding. Erosion and washouts around paving may require increased maintenance.
Pedestrian paths	Freeze-thaw cycles	3	4	**12**	Trip hazards and loss of accessibility to sidewalks caused by heaving and ground shift from freeze-thaw cycles. Damage to concrete caused by expansion and contraction.
Traffic signals	Freezing rain	2	6	**12**	Icing over of signs causing safety hazards and increased maintenance requirements. Power outages caused by ice-related downed power lines can last for multiple days.

P: Probability S: Severity R: Risk

Stormwater Network

The risk assessment identified 12 low medium risks related to the stormwater network infrastructure and no medium high or high risks (Table 4). Ten of these risks relate to extreme short-duration precipitation events overwhelming components of the stormwater management system. The highest risk is specific to bridges and culverts which may have a higher severity of consequence leading to flooding or washouts if capacity is exceeded. Risks related to high temperatures and drought reducing the functionality of stormwater management ponds were also identified.

Table 4: Low medium risks of the stormwater network infrastructure

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
Bridges and culverts	Extreme short-duration precipitation	5	5	**25**	Exceeded culvert capacity and debris blockages leading to flooding of surrounding areas and increased erosion. Bridges could be washed out due to extreme floods.
Sewers	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
Maintenance chambers	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
Catch basins	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
Laterals	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity leading to flooding in the system.
Oil grit separators	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
Cleanouts	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
Headwalls	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system. Bank stability issues and washout around headwalls caused by higher flows.
Stormwater management ponds	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity leading to washouts, collapsed berms, and the flooding of surrounding areas. Reduced capacity to manage sediment.
Equalization tanks	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
Stormwater management ponds	Heatwaves	5	4	**20**	Increased evaporation due to prolonged high temperatures can result in a decreased functionality of wet ponds.

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
Stormwater management ponds	High summer temperature	4	4	**16**	Increased evaporation due to high temperatures can result in a decreased functionality of wet ponds.

P: Probability S: Severity R: Risk

Water Infrastructure Assets

The low medium risks for water infrastructure assets are presented for the water network and sanitary network below.

Water Network

The risk assessment identified three low medium risks related to water network infrastructure and no medium high or high risks (Table 5). The highest risk is related to maintaining adequate water pressure in the system for firefighting due to increased water use during extended periods of hot weather. Lesser risks exist for the Town's bulk water filling station and booster station which could experience damages from flooding in extreme short-duration precipitation events.

Table 5: Low medium risks of the water network infrastructure

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
Fire hydrants	Heatwaves	5	4	**20**	Increased water usage during the heatwave may affect water pressure for the hydrants.
Bulk water filling stations	Extreme short-duration precipitation	5	3	**15**	Potential for electrical failures caused by flooding.
Booster stations	Extreme short-duration precipitation	5	3	**15**	Potential for electrical failures caused by flooding.

P: Probability S: Severity R: Risk

Sanitary Network

The risk assessment identified 13 low medium risks related to the sanitary network infrastructure and no medium high or high risks (Table 6). The highest risk is related to excess stormwater entering the sanitary network during extreme short-duration precipitation events, limiting capacity, and potentially leading to sewer backups. All other risks relate to increasing temperatures leading to more frequent occurrences of odour events within the sanitary network.

Table 6: Low medium risks of the sanitary network infrastructure

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
Sewers	Extreme short-duration precipitation	5	5	**25**	Increased inflow and infiltration (I&I) in precipitation events may lead to sanitary backups in the system impacting users and leading to wastewater in the environment.
Maintenance chambers	Extreme short-duration precipitation	5	5	**25**	Increased I&I in precipitation events may lead to sanitary backups in the system impacting users and leading to wastewater in the environment.
Laterals	Extreme short-duration precipitation	5	5	**25**	Increased I&I in precipitation events may lead to sanitary backups in the system impacting users and leading to wastewater in the environment.
Equalization tanks	Extreme short-duration precipitation	5	5	**25**	Excess flows may enter the system, affecting capacity.
Pumping stations	Extreme short-duration precipitation	5	5	**25**	Increased I&I in precipitation events may lead to sanitary backups in the system impacting users and leading to wastewater in the environment. The building itself may become flooded as a result of overland flows and system breakdown.
Sewers	Heatwaves	5	3	**15**	Increased corrosion leading to odour events.
Laterals	Heatwaves	5	3	**15**	Increased corrosion leading to odour events.
Equalization tanks	Heatwaves	5	3	**15**	Increased corrosion leading to odour events.
Pumping stations	Heatwaves	5	3	**15**	Increased corrosion leading to odour events. Increased potential for cooling requirements to maintain equipment.
Sewers	High summer temperature	4	3	**12**	Increased corrosion leading to odour events.
Laterals	High summer temperature	4	3	**12**	Increased corrosion leading to odour events.
Equalization tanks	High summer temperature	4	3	**12**	Increased corrosion leading to odour events.

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
Pumping stations	High summer temperature	4	3	**12**	Increased corrosion leading to odour events. Increased potential for cooling requirements to maintain equipment.

P: Probability S: Severity R: Risk

Parks and Natural Heritage System

The low medium risks for the parks and natural heritage system are presented in Table 7. The risk assessment identified 10 low medium risks related to parks and natural heritage and no medium high or high risks. The top risks relate to issues with playing fields that are difficult to maintain and become unusable during both extended periods of hot dry weather and extreme precipitation events. High temperatures, extreme precipitation, and severe thunderstorms also present a risk for damage to landscaping requiring increased maintenance and cleanup costs.

Table 7: Low medium risks of the park and natural heritage system infrastructure

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
Land associated with municipal facilities	Heatwaves	5	5	**25**	Playing fields may become unusable after dry and high-temperature periods.
Land associated with municipal facilities	Extreme short-duration precipitation	5	5	**25**	Playing fields may become unusable after periods of very heavy rain and flooding.
Land associated with municipal facilities	High summer temperature	4	5	**20**	Playing fields may become unusable after dry and high-temperature periods.
Land maintained for environmental purposes	Heatwaves	5	3	**15**	Vegetation dieback and increased watering or replacement of vegetation required.
Land maintained for environmental purposes	Extreme short-duration precipitation	5	3	**15**	Washout of vegetation, erosion of soil, exposure of roots, and damage to trees and vegetation.
Park structures	Snow	5	3	**15**	Decreased snow available for ice making for the outdoor ice rinks.

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
Land maintained for environmental purposes	High summer temperature	4	3	**12**	Vegetation dieback and increased watering or replacement of vegetation required.
Open space and parkland	Lightning	4	3	**12**	Replacement and maintenance of vegetation may be required after lightning damage to trees and plants. Debris can also cause physical hazards.
Land associated with municipal facilities	Lightning	4	3	**12**	Replacement and maintenance of vegetation may be required after lightning damage to trees and plants. Debris can also cause physical hazards.
Land maintained for environmental purposes	Lightning	4	3	**12**	Replacement and maintenance of vegetation may be required after lightning damage to trees and plants. Debris can also cause physical hazards.

P: Probability S: Severity R: Risk

Facilities

The low medium risks for facilities are presented in Table 8. The risk assessment identified 16 low medium risks related to facilities and no medium high or high risks. The highest risk relates to heatwaves which are projected to increase in frequency and duration. Heatwaves may exceed the cooling capacity of Town facilities, leading to uncomfortable indoor temperatures for staff and patrons and limiting the ability to use Town facilities as cooling centres during heatwaves. Increasing summer temperatures and heatwaves may also accelerate the degradation of facility hardscaping like parking lots and walkways. Other risks exist for facility components that may be damaged by extreme precipitation and severe storm events. These components include electrical systems, exterior HVAC components, building envelope components, and plumbing systems.

Table 8: Low medium risks of the facilities infrastructure

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
HVAC Systems	Heatwaves	5	5	**25**	Potential to exceed the capacity of cooling systems in facilities, which impacts the ability of facilities to act as cooling shelters.
Electrical systems	Heatwaves	5	4	**20**	Increased demand on cooling systems and therefore electrical systems, potentially exceeding facility capacity.
Hardscaping	Heatwaves	5	3	**15**	Increased deterioration of pavements and concrete slabs through rutting and/or buckling, requiring increased maintenance, and leading to a decreased service life.
HVAC Systems	High summer temperature	4	4	**16**	Potential to exceed the capacity of cooling systems in facilities, which may require replacements to meet demand.
Hardscaping	High summer temperature	4	4	**16**	Increased deterioration of pavement and concrete slabs through rutting and/or buckling, requiring increased maintenance and leading to a decreased service life.
Electrical systems	High summer temperature	4	4	**16**	Increased demand on cooling systems and therefore electrical systems, potentially exceeding facility capacity.
HVAC Systems	High summer temperature (CDD)	5	3	**15**	Increased annual demand on cooling systems, potentially leading to increased maintenance and energy costs.
Electrical systems	High summer temperature (CDD)	5	3	**15**	Increased annual demand on cooling systems and associated increase in demand for electricity potentially leading to increased maintenance costs.

COMPONENT	CLIMATE PARAMETER	P	S	R	JUSTIFICATION
Electrical systems	Lightning	4	5	**20**	Lightning can lead to increased power outages depending on the reliability of the local utility supply. Facilities without emergency generators may temporarily lose the ability to operate, which is significant for emergency and shelter facilities.
HVAC Systems	Lightning	4	4	**16**	Damage to rooftop components if struck by lightning.
HVAC Systems	Wildfires	4	4	**16**	Smoke from wildfires may impact indoor air quality in buildings and increase filter replacements.
Plumbing systems	Extreme short-duration precipitation	5	3	**15**	Precipitation may exceed rooftop drainage capacity leading to ponding on roofs. Infiltration to foundation drainage systems may exceed sump pump capacities leading to flooding in basements or on ground floors.
Building envelope systems	Wind	3	6	**18**	Potential for damage to building envelope components if design wind loading is exceeded. Potential for the bubble roof to blow off of the JOC and sports dome considering past issues with wind.
Building structural systems	Wind	3	5	**15**	Potential for wind loads to exceed structural design capacities.
Electrical systems	Wind	3	5	**15**	Windstorms can lead to increased power failures depending on the reliability of the local utility supply. Facilities without emergency generators may temporarily lose the ability to operate, which is significant for emergency and shelter facilities.
Electrical systems	Freezing rain	2	6	**12**	Freezing rain can lead to increased power failures depending on the reliability of the local utility supply. Facilities without emergency generators may temporarily lose the ability to operate, which is significant for emergency and shelter facilities.

P: Probability S: Severity R: Risk

5.3 Discussion of Risks

The risk assessment identified 59 low medium risk interactions. Neither high medium, high risks nor special cases were identified. The distribution of the low medium risks across the Town's asset classes is as follows: 17 for linear engineered assets, 16 for water infrastructure assets, 10 for parks and natural heritage systems assets, and 16 for facilities.

While the distribution of low medium risks across asset types is comparable, the highest risks are associated with three climate parameters. With extreme short-duration precipitation, there is a potential risk of flooding and backups in the stormwater and sanitary systems. Further, playing field and landscape maintenance may increase due to flooding events, which may become more frequent in the future. High summer temperatures and heatwave events may exceed the cooling capacity of HVAC systems in the future. Again, playing field and landscape maintenance needs may increase following periods of dryness and high temperatures.

Opportunities identified in the risk assessment are associated with snow and low winter temperatures. For both climate parameters, milder winter conditions may lead to reduced or decreased demands, requirements, or impacts to infrastructure. A summary of the opportunities for each asset class is given below.

- Facilities: reduced demand on heating systems and reduced snow clearing requirements.
- Linear engineered assets: decreased salting and winter maintenance requirements for road components, bridges, and culverts; decreased impacts of salt corrosion and damage from snowplows for road luminaires and traffic signals; decreased snowmelt events which may reduce demand on stormwater system components.
- Water infrastructure assets: decreased impacts of salt corrosion for fire hydrants; decreased breakages to water mains, water valves, and service connections; decreased snowmelt events which may reduce the likelihood of sanitary backups.
- Parks and natural heritage system assets: decreased snow load on park structures.

The identified opportunities primarily relating to reduced maintenance requirements for the most part come with increases in maintenance due to opposing climate trends. Therefore, budget requirements may not reduce, but priorities for maintenance can be shifted.

6 Recommendations

Step 5 of the PIEVC process is to provide recommendations and conclusions based on the risk assessment. For this project, these formed the basis of the adaptation plan described in this section.

Potential adaptation actions are proposed for all risks rated medium or above identified through the risk assessment process. These actions are informed by feedback from the risk workshop and input from the WSP project team with expertise related to each risk. A list of proposed actions and associated implementation details including priority, approximate duration, cost, and the Town staff lead were provided to the Resilient Infrastructure Working Group for feedback, which was then incorporated into the final adaptation plan below. Recommendations for adaptation actions and details on their implementation are presented in table format for the four asset categories covered in this assessment. The implementation tables are organized as follows:

- **Actions and Justification:** Descriptions of the recommended adaptation actions and how and why these contribute to resilience in the specific infrastructure category.
- **Risk rating:** The rating of the highest risk that the action is aimed to address. Please refer to Section 5 for a description of risk ratings used in this project.
- **Priority:** The urgency with which the action should be pursued.
  - **Short term** actions should be implemented within the next 1-5 years,
  - **Medium term** actions should be planned and budgeted for soon but implemented in the next 5-10 years,
  - **Long term** actions should be evaluated and planned for over time and implemented on an ongoing basis or in the long term (>10 years).
- **Duration:** An estimate of the required timeline based on the action type to help inform planning and budgeting.
- **Cost Range:** Order of magnitude cost estimates for the adaptation actions. These have been developed with input from SMEs and are based on similar projects, current market conditions, and costs. Cost ranges are broken down as follows:
  - **$:** <$10,000
  - **$$:** $10,000-$100,000
  - **$$$:** $100,000-$1M
  - **$$$$:** 1M+

6.1 Linear Engineered Assets

Most risks related to Linear Assets are caused by an increase in extreme precipitation that may overwhelm stormwater systems leading to localized flooding and erosion of stormwater channels and roadsides. Actions for this asset category focus on improving the resilience of the stormwater system to both extreme precipitation and drought events. Actions are also directed at improving road maintenance and operations to manage increasing degradation from shifting temperatures and extreme events (Table 9).

Table 9: Adaptation actions for Linear Engineered Assets (Roads and Stormwater)

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration (years)	Cost Range	Lead
L-1	Apply Low Impact Development (LID) and other "at-source" or "lot-level control" strategies aimed at reducing and delaying conveyance system loading.	LID and other source controls can reduce the volume of water entering the linear storm system, improving water quality by capturing and treating rainfall where it lands. This will also reduce the risk of overwhelming the storm systems' capacity during heavy rainfalls, avoiding flooding and erosion.	25	Short	10+ (considering city-wide improvements)	$$	Development Planning, Policy Planning, Engineering

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration (years)	Cost Range	Lead
L-2	Review maintenance procedures to reduce storm and sanitary system blockages and improve levels of service.	Increased extreme precipitation events may exceed the capacities of the stormwater and sanitary networks. Increasing the frequency of stormwater inspections following storm events is a relatively low-cost option to identify potential problem areas and undertake preventative maintenance measures where needed. Similarly, preventative inspections and maintenance prior to large storm events to clear out blockages can reduce flooding impacts.	25	Short	< 1	$	Operational Services

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration (years)	Cost Range	Lead
L-3	Increase the resilience of assets identified as vulnerable in the Tannery Creek Flood Study and maintain the asset management system to prioritize and track resilience actions. Consider expanding floodplain studies to include all Town infrastructure and future climate projections.	Increased extreme precipitation events may exceed the capacities of the stormwater and sanitary networks. A floodplain analysis was conducted to identify areas of concern within the original developed area of the town. This study can guide preliminary actions to improve flood resilience. Further studies may be required to account for projected increases in precipitation. These should aim to identify the value of assets at risk, and how risk may change in the future at each location. This information should be maintained in an asset management system that is updated as resilience actions are completed.	20	Short	< 1	$$	Engineering

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration (years)	Cost Range	Lead
L-4	Increase the resilience of erosion-prone areas of the stormwater network in association with the Stream Management Master Plan and LSRCA inspections.	Enhancements such as increased rip rap and other protections against erosion at high flow locations such as headwalls may reduce impacts associated with extreme precipitation and flooding. Improvements should be in line with the Asset Management Plan, the Stream Management Master Plan, and existing work completed in partnership with the LSRCA. Costs may be higher if many improvements are required.	20	Medium	5 years	$$	Operational Services
L-5	Enhance stormwater management wet pond protections for drought and heatwaves.	Plant trees and other drought-resistant vegetation around stormwater management wet ponds to provide shading and reduce evaporation in high temperatures, heatwaves, and/or periods of drought. This may also contribute to increased urban biodiversity.	16	Medium	5 years	$$	Operational Services
L-6	Increase stormwater management wet pond maintenance during drought and heatwaves.	Increase wet pond inspections and add water as required to maintain adequate levels during drought and heatwave events where drawdown is a problem. Remove organics if odour becomes a problem during these events, and/or where there are concerns about water quality of future runoff.	16	Short	As required	$	Operational Services

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration (years)	Cost Range	Lead
L-7	Increase the resilience of erosion-prone areas of the pedestrian paths and road network.	Enhancements such as increased rip rap and other protections against erosion at vulnerable locations may prevent damages to roads and pathways associated with extreme precipitation and flooding. Improvements should be in line with the Asset Management Plan, targeting potentially vulnerable areas first due to age, condition, or potential for erosion. Costs may be higher if many improvements are required.	20	Medium	5 years	$$	Operational Services
L-8	Conduct a frost heave mitigation program.	Freeze-thaw cycles are projected to increase in concentration in the winter and decrease annually, which may require adjustments to maintenance schedules to respond to frost heave damages. Accept that sidewalk heave will occur and institute an inspection program to grind the lips smooth at heave locations to remove the trip hazards and associated liability. Should frost heave damage become a significant issue, investment into preventative measures such as replacement of base course, regrading, ditching, and crack sealing may reduce damages, however, requires significant upfront capital.	12	Long	10 years	$$	Operational Services

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration (years)	Cost Range	Lead
L-9	Conduct a high visibility signage replacement program.	Replacement and/or conversion of all safety signage to High-Intensity Prismatic (HIP) or Diamond Grade sheeting would maximize retro-reflectivity which may be important for visibility during freezing rain or poor visibility events. Diamond grade sheeting also has the longest service life of available sheeting alternatives. The Town can monitor for visibility issues (accidents) and implement upgrades as needed.	12	Long	5 years	$$$	Operational Services
L-10	Prepare temporary signage for traffic signals during power failures.	Ensure traffic signals have temporary battery backups so these may continue to operate in power outages. Consider installing temporary folding stop signs at critical intersections as a low-cost, quickly deployable solution for extended periods of power outages, or having some prepared for deployment when needed.	24	Short	2 years	$$	Operational Services

$:<$10,000
$$: $10,000-$100,000
$$$: $100,000-$1M
$$$$: $1M+

Some roads and stormwater assets are located within floodplain areas (Figure 6) and may be impacted by flooding during extreme precipitation events. The Regional and 100-year Tannery Creek floodplain profiles were mapped as part of the 2019 Town of Aurora Stream Management Master Plan and Tannery Creek Flood Relief Study (Aquafor Beech Ltd., 2019). The map below shows the intersection between this floodplain and the Town's linear infrastructure. This does not represent all linear assets that may be affected by extreme precipitation and pluvial (overland) flooding but shows areas at risk of riverine flooding as assessed in 2019. More detailed information in the Tannery Creek Flood Study should be consulted in prioritizing flood adaptation actions. Precipitation associated with future climate conditions has not been modeled, so at-risk assets are likely to include more than what is shown on the map below and in the recent flood study.

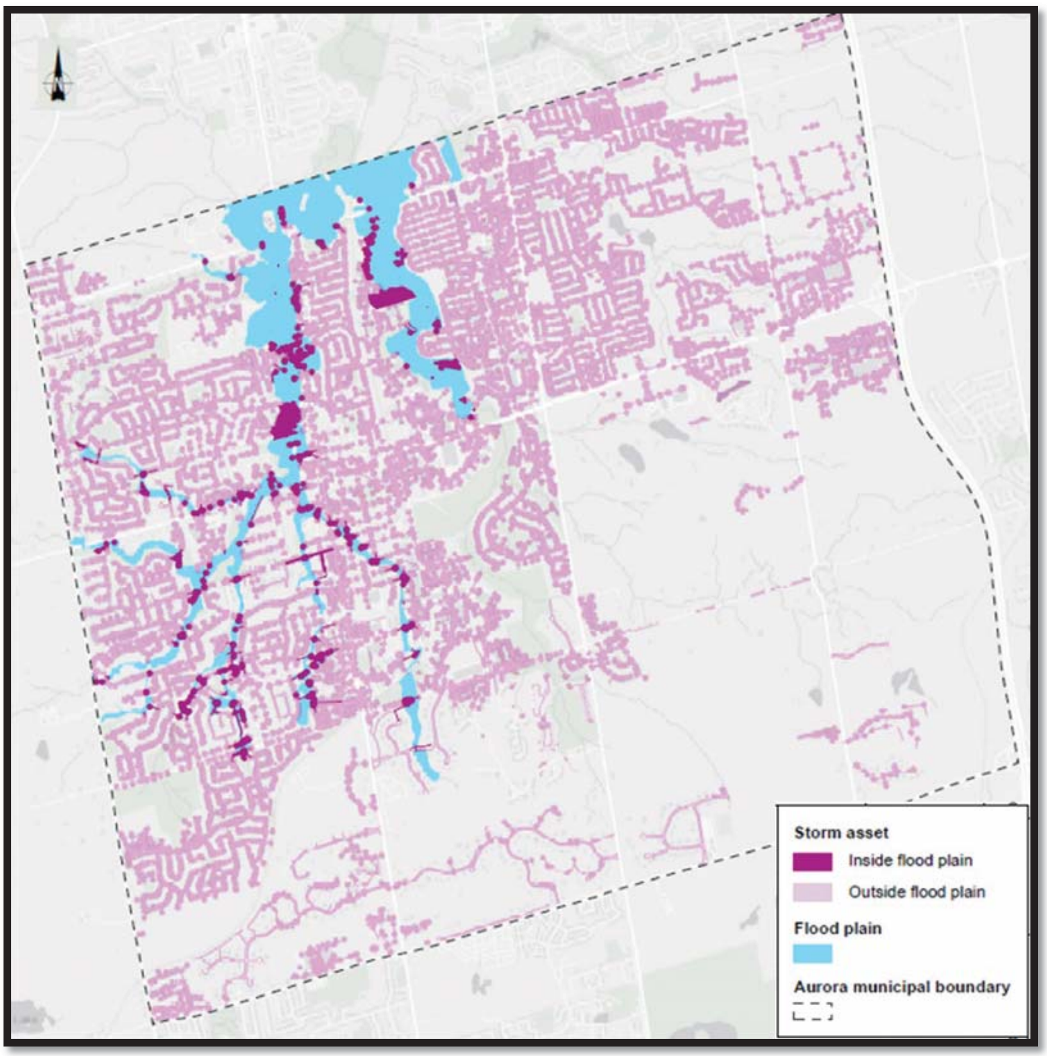


Figure 5: Map of Stormwater infrastructure located in floodplain areas

6.2 Water Infrastructure Assets

The highest rated moderate risks to the water and sanitary networks relate to increasing precipitation and flooding during extreme events. Actions for this asset category focus on understanding the capacity and vulnerability of water and sanitary networks to manage risk related to heavy precipitation and severe weather events that may damage components, overload systems capacity, or cause indirect issues like power outages (Table 10).

Table 10: Adaptation Actions for Water Infrastructure Assets (Water and Sanitary Networks)

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Town Staff Lead
W-1	Support landowners to protect their property from sanitary backups through education and incentive programs.	Many issues related to sanitary backups can be addressed at the property level by ensuring new construction is properly graded and that owners of new and existing properties have backflow protection installed within their property or building plumbing system. Public outreach can ensure property owners understand the risk of sewer backups and how they can protect their property. Incentives that offset the cost of backup valve installation can increase public uptake, saving property owners and the municipality money in the long term. Community outreach is required to raise awareness and trigger inquiries from landowners. Building Services (inspectors) and the Operational Services team may also be required to provide input or assessments for certain sites. Associated costs include staff time and subsidies.	25	Medium	5-10 years	As low as $ per year, $$ over 5 years, $$$ over 10 years	Development Planning, Policy Planning, Engineering, Building Services, Operational Services

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Town Staff Lead
W-2	Conduct a system-wide study to understand the age, conditions, and capacity of all storm and sanitary components.	This is a large-scale project that would help to prioritize long-term planning for infrastructure construction and maintenance. The study should address both sanitary and storm systems and include hydrologic modeling to understand system loading issues and future climate risk. This information should be maintained up to date in an asset management system that is updated as resilience actions are completed.	25	Medium to long	5-10 years	$$$	Engineering, GIS / IT
W-3	Continue to develop and practice emergency response plans as part of the Drinking Water Quality Management System to protect and restore critical water system infrastructure in the event of damage from severe storms or natural disasters.	Storms and extreme precipitation events are projected to increase in the future, and these may impact the water and wastewater systems in the Town. Aside from the actions recommended to prevent or reduce these impacts, response planning is also important to recover quickly from disruptions. Moderate costs are associated with updating and practicing emergency response plans, but this can save costs in the long-term by reducing the consequence of and disruption to services associated with asset failures.	15	Short	2-5 years	$$	Operational Services

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Town Staff Lead
W-4	Implement flood monitoring systems at water booster stations and sanitary lift stations to identify issues early before damage to infrastructure or loss of power occurs.	An increase in extreme precipitation events may lead to flooding, which could impact infrastructure at booster stations and interrupt service. Manual or automated monitoring systems can improve response times and mitigate the worst impacts of flooding with early detection. Engineering staff would be needed to manage the implementation of the system and determine warning triggers (whether measured manually or automatically), and Operations and Maintenance staff would be needed to implement response.	15	Short	1-3 years	$$	Operational Services

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Town Staff Lead
W-5	Review HVAC sufficiency at all pumping facilities to ensure the system is designed for increased temperatures. Review HVAC equipment connections to standby power in the event of power failures and maintenance practices in high-temperature conditions as needed.	Extreme heat may lead to high temperatures in pumping stations which could impact functionality. A review of cooling capacities at pumping stations is low-cost and could be coupled with other asset initiatives (e.g., condition assessments). New infrastructure should be designed to consider a larger range and potentially higher ambient temperatures. This adaptation measure would reduce the likelihood of equipment failures in extreme heat events.	15	Medium	2-5 years	$$	Engineering, Operational Services
W-6	Continue to inspect and maintain backup generators for the water booster station and consider installing backup power at the sanitary lift station.	As flooding due to extreme precipitation and lightning events may lead to more frequent power outages, having backup power systems at booster stations helps avoid or reduce interruptions to the water network. Installing a fixed or mobile backup power system at the sanitary lift station and ensuring that the generator at the water booster station is in good working order may become more important in the future.	15	Medium	2-5 years	$$	Engineering, Operational Services

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Town Staff Lead
W-7	Monitor for problematic sites for odour control issues in the sanitary system. Additive systems and/or air scrubbers may be used to respond to issues.	There is a potential for future high temperatures to lead to increased corrosion in the sanitary system, which could lead to more odour events. Preventative maintenance and asset management practices can respond to corrosion, and there are odour management practices that the Town may consider applying to respond to odour events as needed. Wastewater additives and air scrubbers may be used at concentrated point sources.	15	Medium	2-5 year	$$	Operational Services

$:<$10,000
$$: $10,000-$100,000
$$$: $100,000-$1M
$$$$: $1M+

Like linear engineered assets, some water and sanitary infrastructure is located within the Regional and 100-year floodplain areas and may be at risk of flood-related damage. See Figure 7 and Appendix A for an overview of exposed areas in the sanitary network. More detailed information on creek flooding is available in the Town of Aurora's Tannery Creek Flood Study (Aquafor Beech Ltd., 2019). Precipitation associated with future climate conditions has not been modeled, so at-risk assets are likely to include more than what is shown on the map below and in the recent flood study.

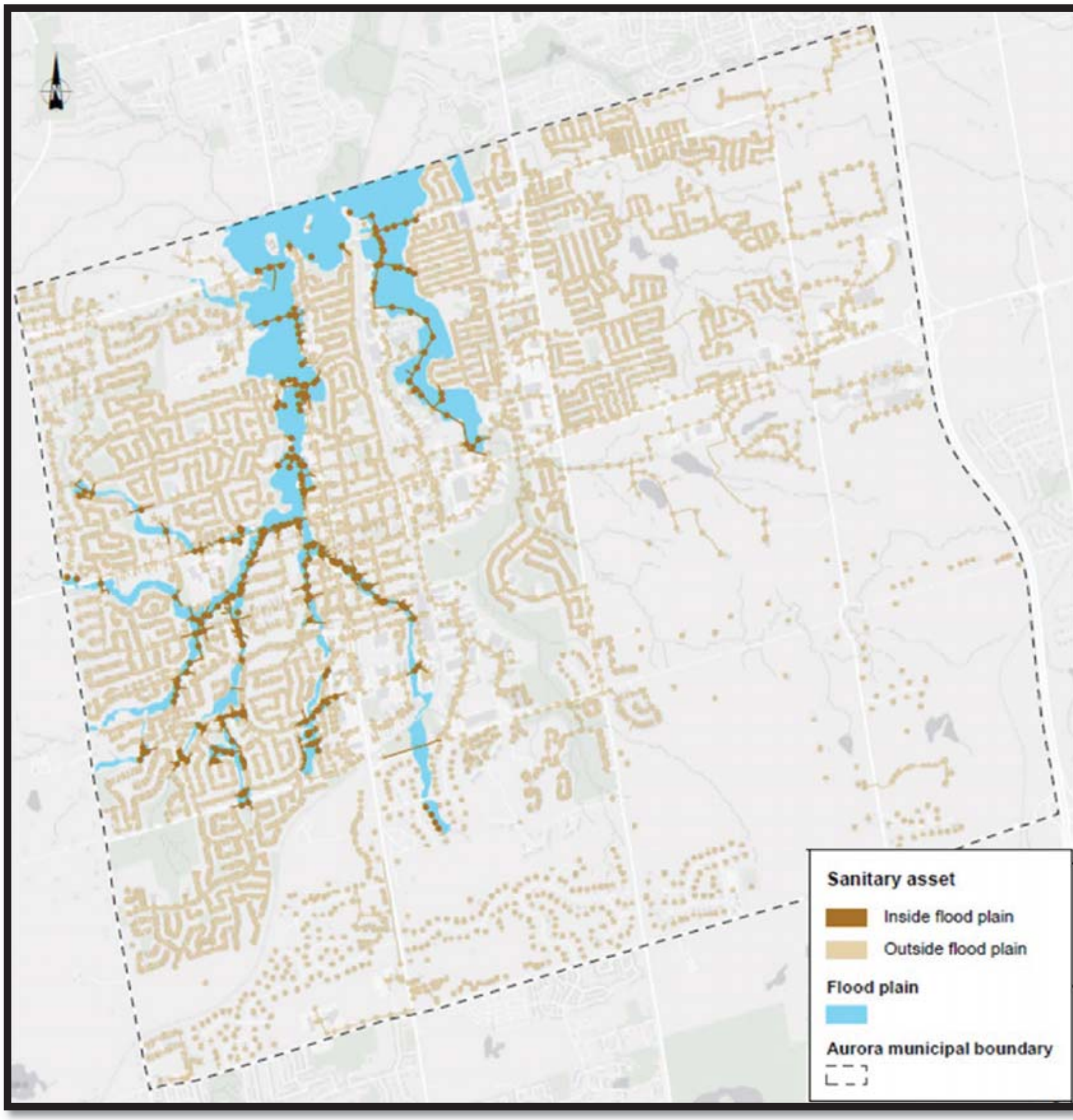


Figure 6: Map of Sanitary infrastructure located in floodplain areas

6.3 Parks and Natural Heritage System

Most risks associated with Parks and Natural Heritage are related to damaged landscaping from increasing temperatures and severe weather events. Increasing temperatures may also impact the operation of recreation facilities like ice rinks, requiring more maintenance and increasing operating costs. Actions to adapt parks and natural heritage assets to climate change focus on operations and maintenance changes and exploring solutions to improve water use and storage for landscaping needs (Table 11).

Table 11: Adaptation Actions for Parks and Natural Heritage System

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
P-1	Conduct a study to investigate rainwater capture and storage needs and solutions for irrigation and drainage improvements for sports fields, parks, and municipal facilities.	Sports fields become unusable during extended periods of hot, dry weather, and after periods of heavy rain. Capturing and storing rainwater during rainy periods can make more water available for irrigation during drought conditions. Improvements to water storage and irrigation infrastructure should be considered in a study alongside field drainage improvements to minimize interruptions to field usage.	25	Long	1-3 years	$$	Recreation Services, Facilities Management

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
P-2	Plan for low maintenance landscaping with hardy species adapted to future climate conditions.	As temperatures warm, choosing native plants for landscaping can improve local ecosystem health and make landscaping more resilient to climate change. Planted species may need to change over time as climate conditions shift. Consider future climate projections when planning new landscaping works and consider opportunities for increasing urban biodiversity.	15	Long	>10 years (ongoing)	$	Environment, Operational Services
P-3	Plan for changes to ice rink management in warmer winters.	Warmer winters and increased variability in snowpack may strain the Town's ability to provide consistent outdoor ice-skating rinks to the public. If or when skating rinks become difficult to maintain with natural conditions of snow and cold temperatures, consider alternative methods of ice generation, or reduce the level of service related to public outdoor skating facilities.	15	Medium to Long	1-3 years	$$	Community Services - Recreation Services, Operational Services
P-4	Adopt maintenance procedures to proactively identify hazardous trees and undertake preventative maintenance before damage occurs during extreme events.	Conduct regular inspections of high-use parks and natural heritage assets to identify sick or damaged trees that could become a hazard during extreme weather events (wind, lightning, storms). Undertaking preventative maintenance on these trees will reduce risk and reduce reactive cleanup costs.	12	Short	1-3 years	$	Operational Services

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
P-5	Adopt maintenance procedures to inspect parks following extreme weather events to identify damaged landscaping and amenities to prioritize repairs and minimize service disruptions.	Conduct damage inspections following extreme events to address hazards caused by debris or damage to trees that may require repair (i.e., trees and plants contributing to soil stability).	12	Short	1-3 years (Policy change)	$	Operational Services

$:<$10,000
$$: $10,000-$100,000
$$$: $100,000-$1M
$$$$: $1M+

6.4 Facilities

The highest rated moderate risks for facilities are related to increases in extreme summer temperatures, which may exceed building cooling capacities. Risks are also present for damage related to heavy precipitation and severe weather events. Adaptation actions for facilities focus on incorporating future climate projections into future cooling system upgrades and improving operation and maintenance procedures to identify and correct weather-related damage to facilities before major repairs are required (Table 12).

Table 12: Adaptation Actions for Facilities

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
F-1	Monitor cooling demand at facilities to identify where exceeding maximum cooling capacities is possible with high summer temperatures. Upgrade HVAC systems to meet future cooling demands, prioritize key facilities that could be used as cooling centers.	Both extreme and average summer temperatures are expected to increase in the future putting strain on cooling systems and potentially exceeding system capacity during extreme events making it difficult to maintain comfortable indoor air temperatures. Identifying which systems are most likely to have capacity challenges with future temperature will help to prioritize upgrades at the time of asset renewal or sooner if necessary. Facilities that are used as cooling centers, or that vulnerable populations rely on (e.g., Aurora Family Leisure Complex, Aurora Public Library) should be prioritized to maintain comfortable temperatures in extreme heat.	25	Short	5 years	$$$	Community Services - Facilities Management

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
F-2	Consider both current and future cooling demands with increased temperatures during the planning and design of HVAC and electrical systems. Where cooling systems are being replaced, assess and upgrade the electrical system accordingly.	Electrical systems are designed based on maximum cooling loads. If increased temperatures exceed the capacity for cooling at certain facilities, upgrades to both the cooling system and electrical system may be required. An engineering assessment would be required to determine capacity needs and plan for future climate conditions.	20	Short	5 years	$$$	Facilities Management
F-3	Provide access to backup power at all facilities critical to Town operations to maintain essential operations during power outages. Prioritize low-carbon sources of backup power where possible.	Although difficult to predict, lightning strikes and storms may become more frequent in the future. Along with wind and heat events, critical buildings should be prepared for power outages in the future. This is particularly important for facilities that are designated for use as emergency shelters.	20	Short	1-3 years	$$$	Community Services – Facilities Management

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
F-4	Install lightning protection systems on tall or isolated buildings (such as Town Hall, the Aurora Community Centre), and those which are deemed critical for Town operations.	Although difficult to predict, lightning strikes may become more frequent in the future. This could damage electrical systems in buildings, and potentially cause power outages. Critical buildings should be prepared for extended power outages in the future. This is particularly important for facilities that are designated for use as emergency shelters.	16	Medium	1-3 years	$$	Community Services – Facilities Management
F-5	Continue to inspect and maintain roof systems, paying particular attention to domed roofs at the Sports Dome and the JOC regularly and after extreme wind events. Proactively repair signs of material distress to avoid roof failure.	The Aurora Sports Dome and JOC bubble roofs were previously damaged in high wind events. Although these have since been repaired, domed fabric roofs remain more vulnerable to extreme wind than fixed building roof enclosures. As extreme wind events may increase in the future, continue to inspect and maintain roof systems, paying particular attention to domed roofs at the Sports Dome and JOC regularly and after extreme wind events to proactively repair signs of material distress.	18	Short	Ongoing	$	Community Services – Facilities Management

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
F-6	Monitor air quality for key municipal facilities (e.g., those with many staff or public users) and consider upgrading HVAC systems to accommodate higher-rated filters such as MERV 13 equivalent filters as well as including space for the addition of MERV 8 pre-filters in case of a poor air quality event.	Wildfires in Canada are projected to increase in the future, and smoke from either nearby or distant fires can impact air quality in Aurora. This may reduce the indoor air quality in buildings and increase the frequency of filter replacement. Filter sizing increases must remain within manufacturer recommendations to not impact equipment efficiency.	16	Medium	1 year	$$	Community Services – Facilities Management
F-7	Continue to inspect parking lots and hardscaping regularly to identify heat-related damage and implement small repairs where feasible to avoid further degradation in hot weather. Review the granular base structure and asphalt mix design during the next replacement cycle.	Extreme heat can lead to increased deterioration and wear on hardscaping.	16	Medium	Ongoing	$ - $$	Operational Services, Engineering

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
F-8	Monitor internal drainage systems in facilities and prepare for a projected increase in precipitation events. Where facilities rely on sump pumps to manage inflow and roof drainage, review precipitation load calculations based on future climate projections, and incorporate the increased load when sump units are to be upgraded or replaced.	A projected increase in extreme precipitation may lead to an increase in below-ground flooding events at residences and at Town facilities. It is best practice to store electrical and mechanical equipment above grade where possible and ensure that where sump pumps are used, these are designed to manage current and future projected extreme precipitation and flooding events.	15	Short	1-3 years	$$	Community Services – Facilities Management

Action ID	Action	Description / Justification	Risk Rating	Priority	Duration	Cost Range	Lead
F-9	Continue inspections of facilities structures regularly and after extreme wind events. Proactively repair damages as needed. An engineering study would be required to assess whether projected wind loads may surpass designed structural capacities at facilities, which could be initiated if regular inspections identify potential wind-related issues.	There is a potential for wind loads to increase in the future, which may exceed the designed capacities of the facility structures. Building structures are inspected regularly (every 5 years) to monitor for deterioration and damages. In addition to this existing practice, inspections of facilities after extreme wind events could identify any areas requiring further inspection.	15	Short	Ongoing	$-$$	Community Services – Facilities Management, Engineering

$:<$10,000
$$: $10,000-$100,000
$$$: $100,000-$1M
$$$$: $1M+

7 Conclusions and Future Considerations

This report identified 59 climate risks that have the potential to impact the Town of Aurora's municipal assets in the next 30 years and beyond. These risks arise from changes in temperature, precipitation, and severe weather that are beyond the historical range of climate conditions for which infrastructure has been designed. The risk assessment identified increases in temperature and extreme precipitation to be prevalent climate hazards across all asset categories with risk related to severe storms also expected to impact road networks, parks, and facilities. To manage these risks and adapt to the changing climate, the Town will need to take strategic actions to continue providing quality services to residents in a warmer and more unpredictable climate.

This risk assessment presented an overview of the conditions climate change is expected to bring, and how that might impact infrastructure under the jurisdiction of the Town of Aurora. Not only does this help identify potential vulnerabilities, but it also highlights the importance of certain activities that the Town is already doing. For example, studying potential flood-prone areas in the Town and collaborating with the local conservation authority is currently a priority, and this study demonstrates that this will continue to be important in the future. Certain Town operations and procedures related to mitigating risks were discussed in this study (such as emergency response planning for flooding and heat), which provides justification to continue executing and budgeting for such activities in the future.

Consideration should be given to integrating climate risks and adaptation into the Town of Aurora's asset management policy to inform decision-making about the operations and maintenance of Town assets and prioritize future investments to reduce climate change risks. When considering adaptation action to increase the resilience of Town assets, it is important to assess the Town's desired levels of service along with future climate projections. In some cases, this will mean designing infrastructure or building retrofits to exceed current codes and standards which are based on historical climate conditions. Proactively considering the future climate conditions and levels of service an asset will need to support will allow the town to right-size its infrastructure and investments to build resilience into its operations. As the Town continues on its climate mitigation and adaptation journey, this risk assessment should be reviewed and updated alongside future asset management planning.

Managing risk and adapting the Town's infrastructure to a changing climate is just one component to increasing community resilience. Beyond infrastructure damage and disruptions to service, a variety of economic, social, and environmental impacts related to climate change that may require broader community adaptation strategies should be addressed. Additionally, the first step in adapting to climate change is to reduce local greenhouse gas emissions to help limit global warming and mitigate climate change risks in the long term. The Town is already taking action on climate change mitigation through initiatives like the Community Energy Plan, Green Fleet Action Plan, Municipal

Building Challenge, and installing Solar PV systems on Town Facilities. To take climate action further, Aurora can start to coordinate its efforts for both adaptation and mitigation to develop policies and actions that simultaneously reduce community emissions and risks while supporting social, economic, and environmental co-benefits. Approaching climate action in this way will support the Town's journey toward Low Carbon Resilience.

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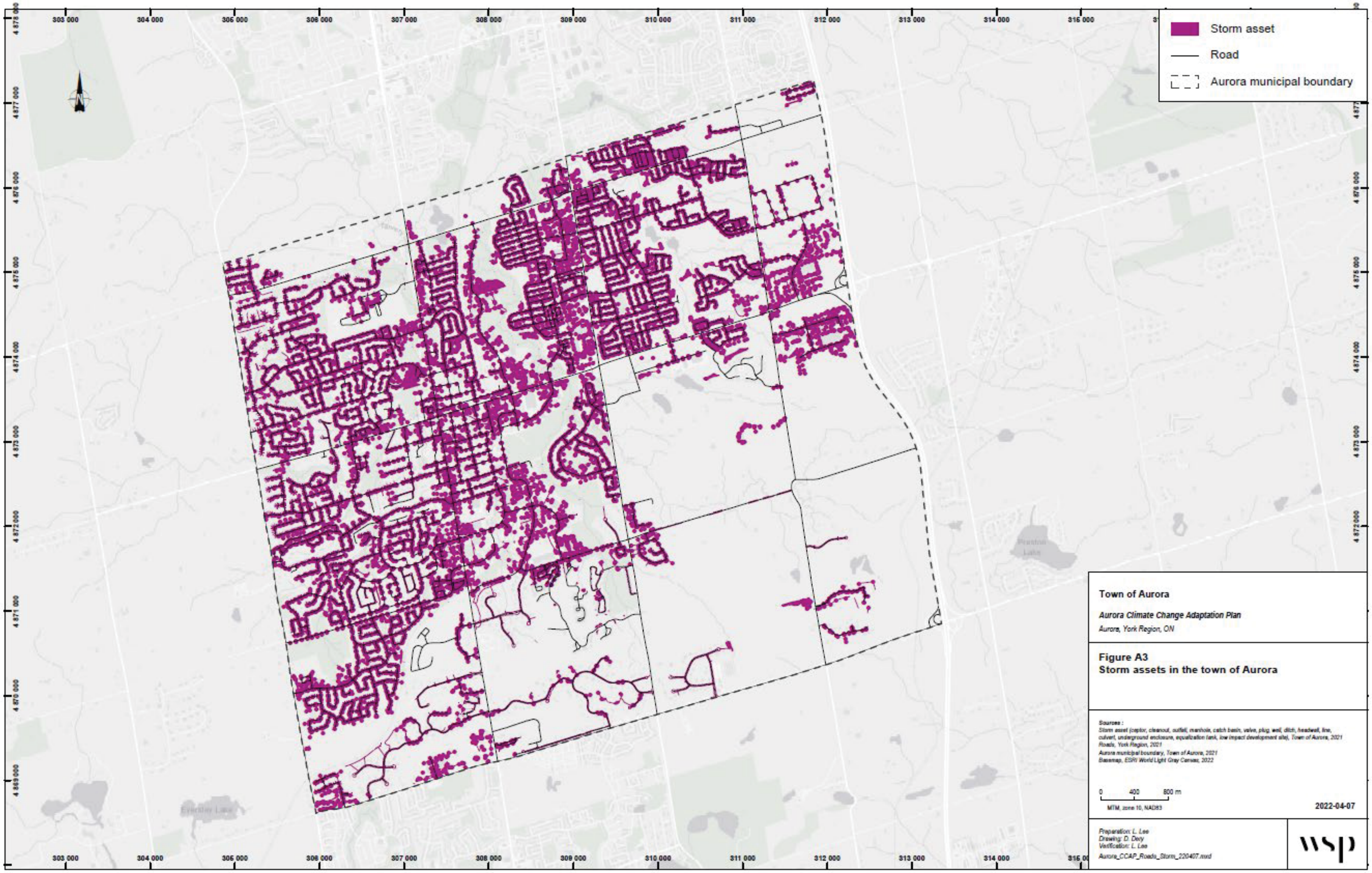
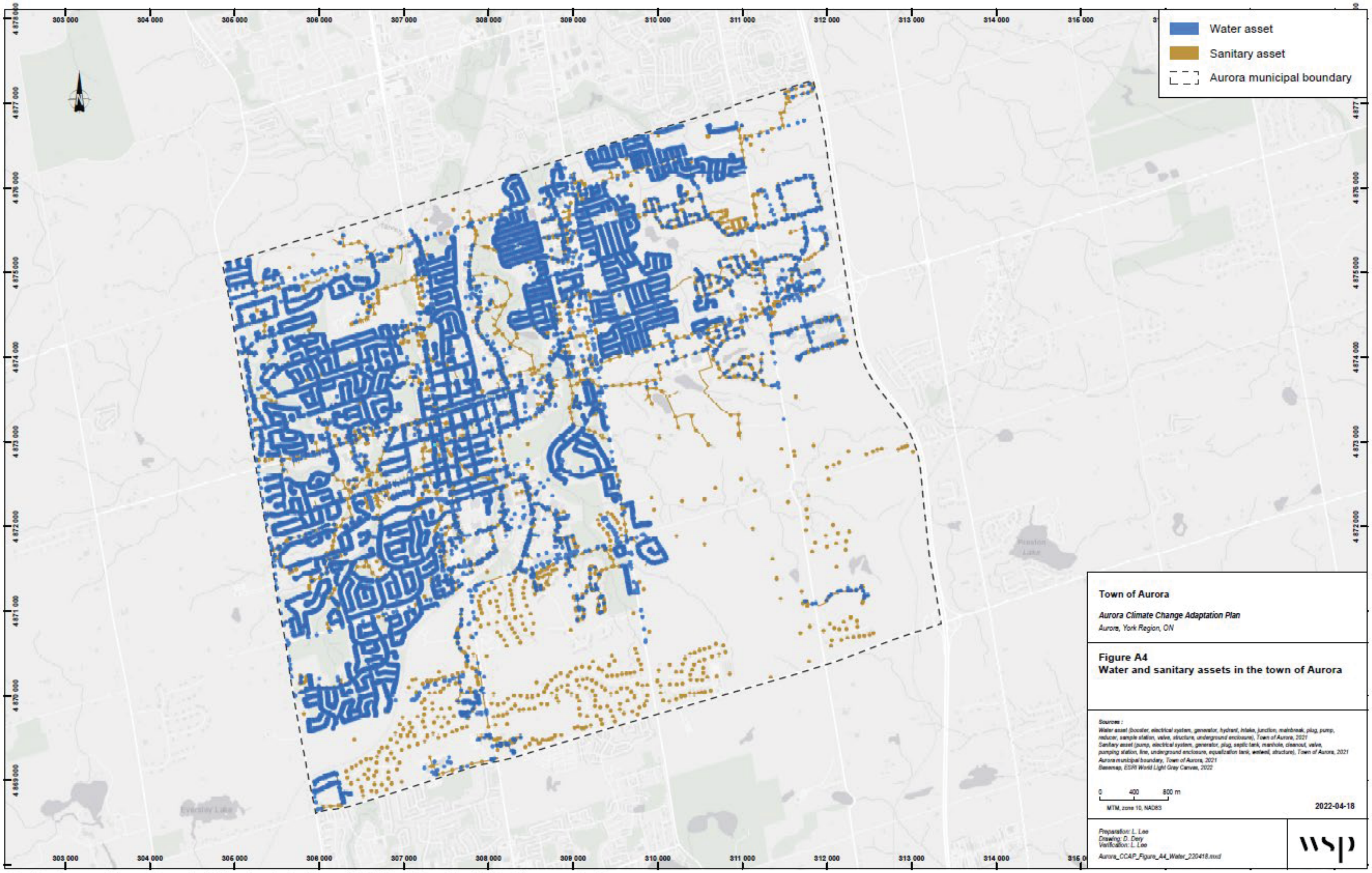
Appendix

A. Mapping



Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.



Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

Town of Aurora

Aurora Climate Change Adaptation Plan

Aurora, York Region, ON

Figure A5
Park, open space and recreation areas in the town of Aurora

Sources :
Park, open space and recreation area, Town of Aurora, 2021
Roads, York Region, 2021
Aurora municipal boundary, Town of Aurora, 2021
Basemap, ESRI World Light Gray Canvas, 2022

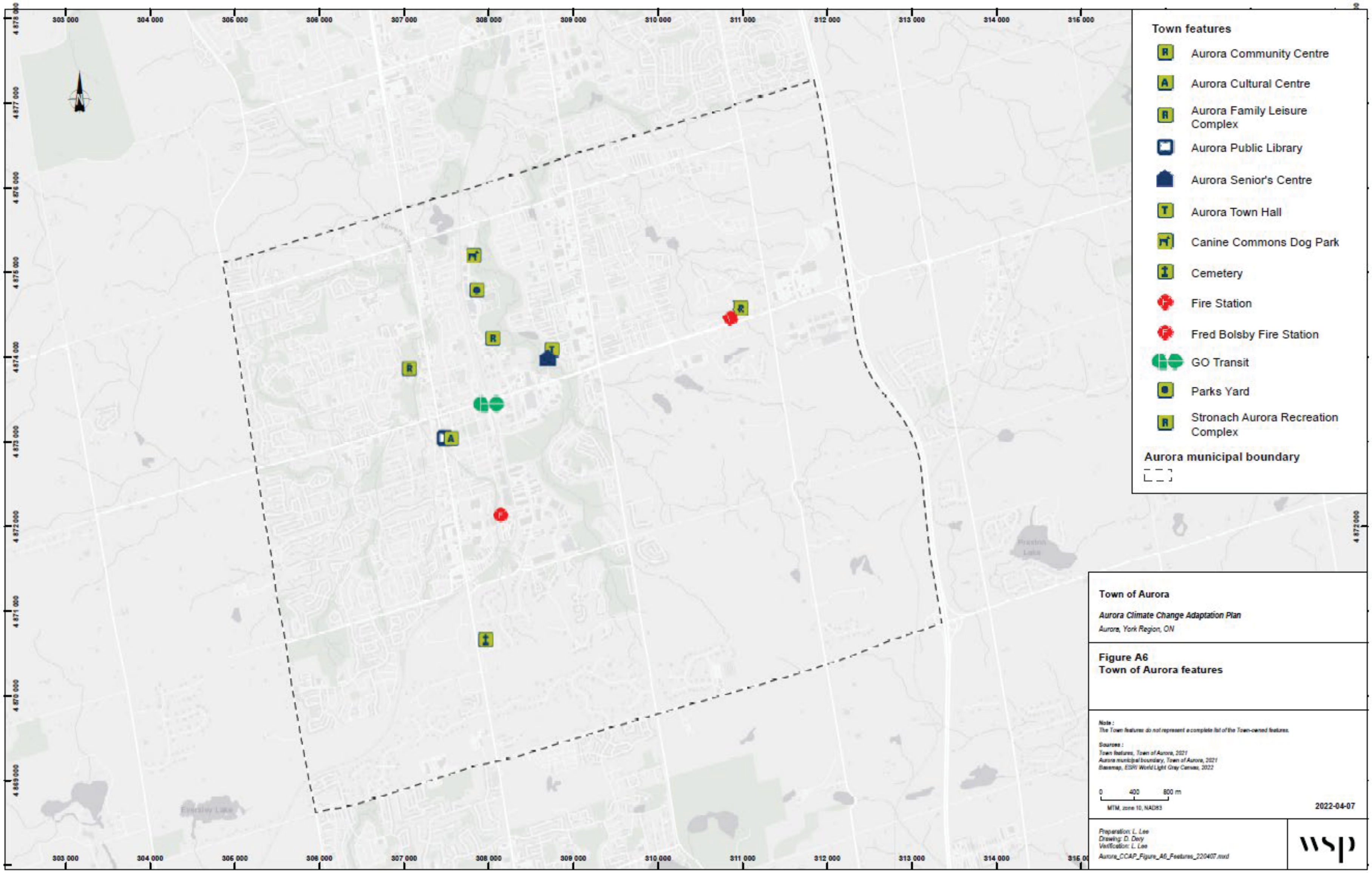
0 400 800 m
MTM, zone 10, NAD83

2022-04-07

Preparation: L. Lee
Drawing: D. Dery
Verification: L. Lee
Aurora_CCAP_Figure_A5_Parks_220407.mxd

wsp

Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.



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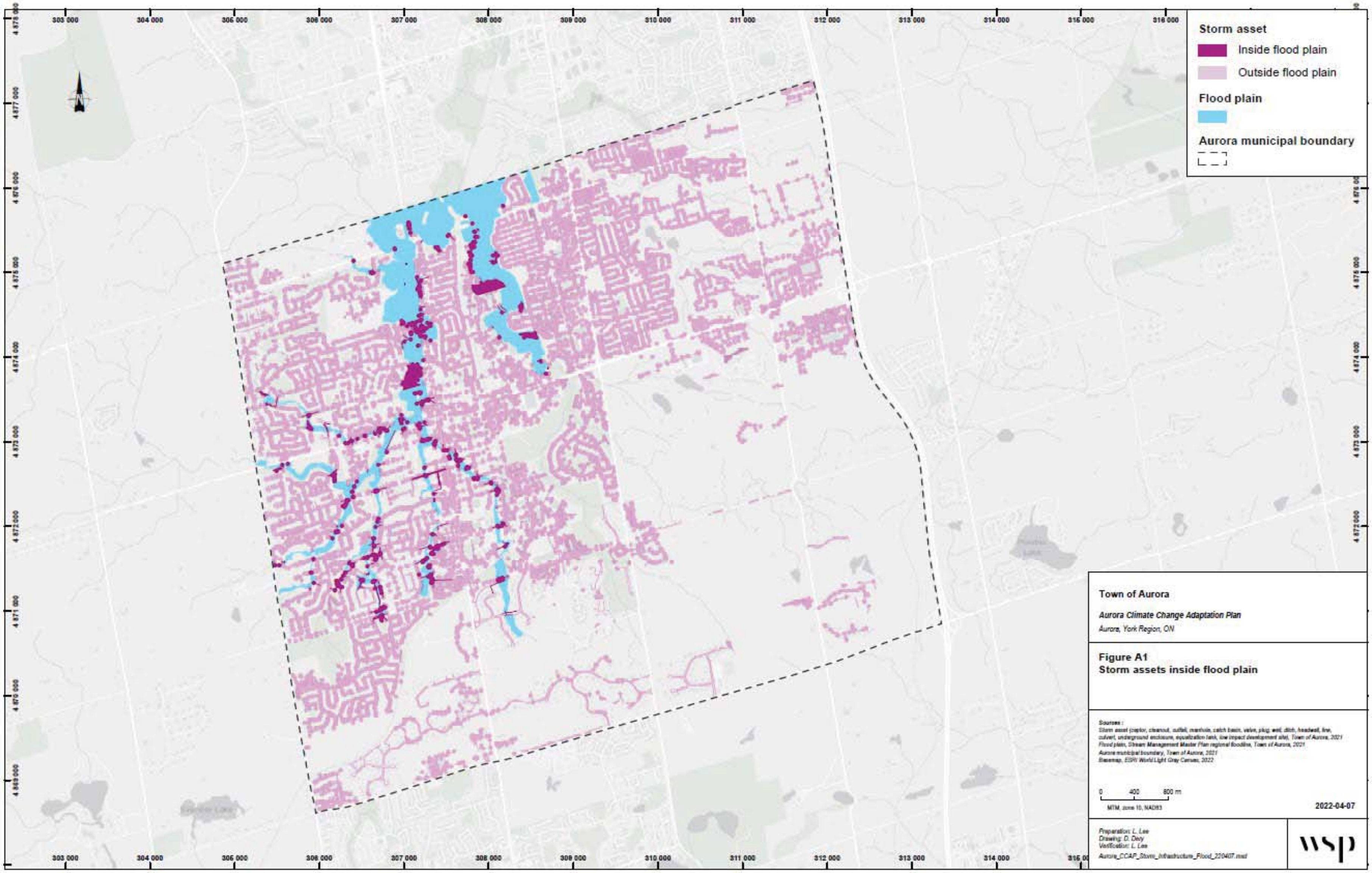
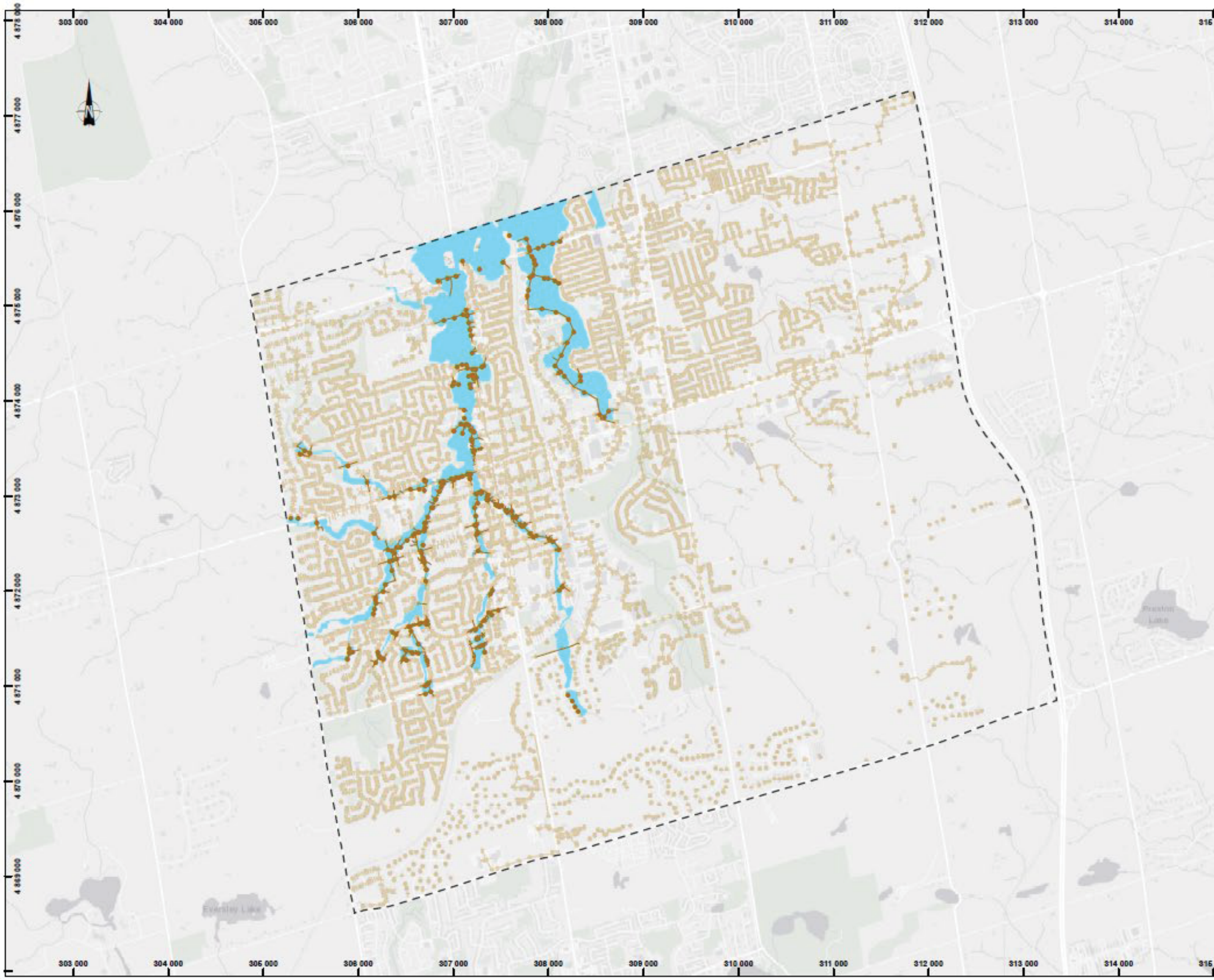


Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.



Town of Aurora

Aurora Climate Change Adaptation Plan

Aurora, York Region, ON

Figure A2
Sanitary assets inside flood plain

Sources :
Sanitary asset (pump, electrical system, generator, plug, septic tank, manhole, cleanout, valve, pumping station, line, underground enclosure, equalization tank, wetwell, structure), *Town of Aurora, 2021*
Flood plain, Stream Management Master Plan regional floodline, *Town of Aurora, 2021*
Aurora municipal boundary, *Town of Aurora, 2021*
Basemap, *ESRI World Light Gray Canvas, 2022*

2022-04-07

Preparation: L. Lee
Drawing: D. Dery
Verification: L. Lee
Aurora_CCAP_Sanitary_Infrastructure_Flood_220407.mxd

Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

Appendix

B. PIEVC Worksheets

Appendix

B-1. Worksheet 1

TECHNICAL MEMORANDUM #1

CLIENT:	Town of Aurora		
PROJECT:	Town of Aurora Climate Change Adaptation Plan	**WSP Ref.:**	211-03040-00
SUBJECT:	PIEVC Worksheet #1	**DATE:**	13 August 2021
RECIPIENT:	Natalie Kehle, Town of Aurora		
FROM:	Lisa MacTavish, P.Eng.		

1 INTRODUCTION

The Town of Aurora has engaged WSP to conduct a climate change adaptation plan for the infrastructure assets within the Town of Aurora. The adaptation plan will be informed by a climate change risk and vulnerability assessment to be completed using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol as it is a nationally recognized tool for assessing infrastructure risk due to climate change. This technical memo presents the results of the project definition step (Step 1) of the PIEVC protocol.

2 WORKSHEET 1

2.1 PREPARE STEP 1 WORKSHEET

	Enter *Yes* or *No*
a. Use this *Worksheet*; or	YES
b. Prepare practitioner specific documentation. i. Practitioner specific documentation *MUST* detail each task outlined in this step of the Protocol.	NO
<u>Comments and Observations</u> The worksheet provided by PIEVC is exhaustive. By using it, WSP makes sure that it completes every requirement from the protocol. It also allows Town of Aurora to review the progress made by WSP in the assessment as each step is completed.	

2.2 IDENTIFY THE INFRASTRUCTURE

Choose the infrastructure to be evaluated for changing climate vulnerability.	Infrastructure assets in the Town of Aurora, Ontario.
Provide a general description of the infrastructure.	The scope of this study includes bridges & culverts, buildings, parks, the road network, sanitary network, storm water services, and the water network within the Town of Aurora, Ontario. The Town owns and operates some infrastructure services which are integrated with infrastructure systems owned by other parties including York Region and the Province of Ontario. Third party assets are excluded from this assessment. The Town of Aurora owns and operates the following infrastructure systems within the municipal boundaries: — Municipal roads, bridges, culverts, and walkways; — Municipal government, protection, recreation, and cultural services facilities; — Municipal transportation services and related infrastructure; — Parks; — Drinking water and sanitary water distribution and pumping systems; and — Stormwater infrastructure.
Reference additional background and detailed information sources.	Asset Database Listing, 2018. Draft 2018 Asset Management Plan. Aurora Classification Structure Review V4, (no date).
Comments and Observations Privately owned property within the Town is excluded from this assessment. The risk assessment will be completed at the asset sub-class level, aggregated according to the asset management plan classification (AMP 2018).	

2.3 IDENTIFY CLIMATE PARAMETERS

Based on professional judgement, identify which climate trends and weather events may contribute to infrastructure vulnerability.

- Rise in summer temperatures;
- Rise in winter temperatures, with more winter rain and thawing events;
- Increase in frequency of extremely warm temperatures (heat waves);
- Increase in intensity and frequency of short-duration precipitation events;
- Increase in annual or seasonal precipitation;
- Drought;
- Wind regime change (gusts and hourly wind speeds);
- Increase in storm activity (thunderstorms, tornadoes, hail, dust);
- Increase in ice storm episodes; and
- Changes in freeze/thaw cycles.

Based on professional judgement, identify which climatic trends and/or weather events may *combine* to create infrastructure vulnerability.

- Rain or freezing rain on snow events can combine and increase the weight of the snowpack;
- Significant snow accumulation accompanied by strong winds;
- Strong winds or freezing rain episode (causing power outages) directly followed by a cold wave requiring an increase in heating capacity; and
- Storms or thunderstorms (causing power outages) directly followed by a heatwave requiring an increase in cooling capacity.

Comments and Observations

Assessment of the evolution of the above-mentioned climatic trends and meteorological phenomena will be conducted using a relevant selection of the following climate-related parameters:

Temperature

- Average maximum summer temperature;
- Average minimum winter temperature;
- Annual cooling degree days;
- Annual heating degree days;
- Extreme maximum temperature;
- Extreme minimum temperature;

- Length and frequency of heat waves; and
- Freeze-thaw cycles.

Precipitation

- Annual precipitation;
- Annual snowfall;
- Extreme rain events;
- Extreme snowfall;
- Number of snowstorms; and
- Freezing ice.

Wind

- Maximum hourly windspeed; and
- Maximum wind gust speed.

Natural hazards

- River or creek flooding;
- Wildfire;
- Tornado; and
- Lightning and storm activity.

Climate projections will likely be unavailable for some climate variables (e.g. wind, tornadoes. lightning). We will refer to historical events and trends as well as to the scientific literature to estimate probable change in these parameters.

2.4 IDENTIFY TIME HORIZONS

Define the period over which the infrastructure must operate and for which climate trends will be projected for the engineering vulnerability assessment.	As per the Asset Database Listing, the Estimated Useful Life of Town infrastructure varies from six months to 100 years. We will therefore assess climate trends based on the baseline (historical data), and the near future (2021-2050) time horizon. The near future is appropriate for components with a shorter design life (e.g. HVAC systems with lives from 10-30 years), and other infrastructure that is part-way through its life or nearing end of life, and has therefore been chosen for this assessment. This also allows comparability of the results for these components with components designed for the far future (e.g. the mains system for water, wastewater and sanitary network with design lives of 100 years).

Comments and Observations

Potential risks are given a threshold at which impacts may occur to the infrastructure. These are based on design codes, historical events, or professional judgement. The protocol is designed such that every threshold is given one probability rating to define the likelihood that future climate may exceed the infrastructure threshold. WSP will analyze climate trends and provide a probability rating for the 2021-2050 time horizon for this assessment.

2.5 IDENTIFY THE GEOGRAPHY

Summarize site-specific, local, and/or geographical features relevant to the evaluation.
Geographical Considerations — The Town of Aurora is 50 km north of Toronto in Ontario and is partially situated on the Oak Ridges Moraine, an ecologically important geological landform.
Water Features — Aurora is located within the Great Lakes region approximately 50 km north of Lake Ontario. — Aurora is approximately 25 km from Lake Simcoe and is situated in the Lake Simcoe watershed. — Tannery Creek and East Holland River flow through the Town. — Aurora is built on the Yonge Street Aquifer.
Topography — The Town of Aurora is partially situated on the Oak Ridges Moraine meaning there is some variation in elevation (~100 metres above sea level), decreasing from south/south-east to north/north-west.
Ground conditions — The Oak Ridges Moraine consists of sand, silt and gravel deposits which infiltrates water easily. — Surficial geology in Aurora is mostly silt. — As Aurora is a partially urbanized environment surrounded by crops, forest and other municipalities, minimal ground permeability in the industrial and commercial areas and moderate permeability in residential areas can be expected due to paving and surfacing. Park lands, crops and golf courses predominantly located in the higher South East area of Town can be expected to provide high infiltration.
Provide references.
Lake Simcoe Region Conservation Authority, Regulation Maps https://www.lsrca.on.ca/maps Oak Ridges Moraine Land Trust, Water and the Moraine https://www.oakridgesmoraine.org/water/ The Regional Municipality of York, Appendix D: Yonge Street Aquifer Well Capacity Restoration Project - Alternative Well Area Selection Report https://www.york.ca/wps/wcm/connect/yorkpublic/f5ab38b7-ac7a-4941-b90d-8af0be675ad3/App+D_Part1.pdf?MOD=AJPERES&CVID=mu99hNU Google Earth, 2021

Comments and Observations
Topography and local flooding history and extents will be investigated to inform pluvial and riverine flooding, respectively, through available flood maps and supplemented by Town staff interviews. Proximity to water courses with fluctuating levels may indirectly impact the groundwater table and infiltration.

2.6 IDENTIFY JURISDICTIONAL CONSIDERATIONS

List the jurisdictions, laws, regulations, guidelines and administrative processes that are applicable to the infrastructure.
Land use and planning: The Town of Aurora Zoning By-law 6000-17 regulates development and the use of all lands within the Town of Aurora. The Town of Aurora Strategic Plan identifies and assesses growth and development opportunities that ensure the future economic, social and environmental sustainability and health of Aurora. Land use planning in the Town of Aurora is subject to the rules and directions through the Planning Act, the Provincial Policy Statement and geographically specific policies in provincial plans in the Lake Simcoe Protection Plan and the Oak Ridges Moraine Conservation Plan which include land use designations and regulations on new developments. Lake Simcoe Region Conservation Authority regulates approximately 40% of the Lake Simcoe watershed, including some areas in the Town of Aurora. The Asset Management Plan for the Town of Aurora was most recently updated in 2018. Details regarding level of service requirements were in progress at the time of this study but this assessment will be based on the information available from the Asset Management Plan 2018. The Growth Plan for the Greater Golden Horseshoe from the Ontario government states that municipalities should assess infrastructure risks and vulnerabilities caused by climate change, and identify actions and investments to address these challenges. Similarly, the Provincial Policy Statement for Ontario includes a statement on preparing for the impacts of climate change to public infrastructure.
Laws & By-laws: The Emergency Management and Civil Protection Act established the provincial framework for managing emergencies and key municipalities requirements. The Town of Aurora has the following bylaws in place which apply to the infrastructure in the Town: — Backflow Prevention Bylaw – 20191022 – 621319; — Respecting Property Standards – 19990623 – 404499P; — Sewer Use By-Law – 20130611 – 551813 (2); and — Amend 330591 Municipal Waterworks Distribution Bylaw – 20210330- 632221. The Regional Municipality of York has the following bylaws which apply to the Town of Aurora Infrastructure: — Discharge of Sewage, Storm Water and Land Drainage Bylaw (Amended 2014) 2014-23.

Applicable environmental laws: – Environmental Protection Act; and – Ontario Water Resources Act.
Regulations: The Asset Management Planning for Municipal Infrastructure Regulation (O. Reg 588/17) requires municipalities to develop a strategic asset management policy, and an asset management plan and has details around level of service requirements. It also requires municipalities to consider the impact of climate change to their assets, costs that may arise from those vulnerabilities and adaptation opportunities. The Drinking Water Systems regulation (O. Reg 170/03) applies to the water network in the Town of Aurora and the sewer system is regulated by the Environmental Compliance Approval in Respect of Sewage Works (O. Reg. 208/19). The road network in the Town of Aurora is regulated by the Minimum Maintenance Standards for Municipal Highways Regulation (O. Reg. 239/02)
Design Codes and Standards: New construct or refurbishment of infrastructure in the Town of Aurora is required to follow the Ontario Building Code, governed by the Ontario Building Code Act. The Ontario Drinking Water Quality Standards (O. Reg. 61/14) applies to water network in the Town of Aurora.
Guidelines: The following guidelines are applicable to the different infrastructure types in the Town of Aurora: – Infrastructure Ontario's Buildings Systems Design Guidelines; – Canadian Water Quality Guideline; – Design Guidelines for Sewage Works; and – Design Guidelines for Drinking-Water Systems.
Provide references.
Land Use Planning: – Town of Aurora Zoning By-law https://www.aurora.ca/en/business-and-development/planning-and-development-zoning.aspx?_mid_=17542#Comprehensive-Zoning-Bylaw – 2011 – 2031 Aurora Strategic Plan https://www.aurora.ca/en/town-services/resources/Documents/Publications/Strategic-Plan.pdf – Planning Act https://www.ontario.ca/laws/statute/90p13 – Provincial Policy Statement (PPS) https://www.ontario.ca/pps

– Lake Simcoe Protection Plan https://www.ontario.ca/page/lake-simcoe-protection-plan – Oak Ridges Moraine Conservation Plan (ORMCP) https://www.ontario.ca/page/oak-ridges-moraine-conservation-plan-2017 – Town of Aurora Draft 2018 Asset Management Plan – A Place to Grow: Growth Plan for the Greater Golden Horseshoe (2019) – Provincial Policy Statement (2020)
Laws & By-laws: – Backflow Prevention Bylaw https://records.aurora.ca/WebLink/DocView.aspx?id=17731&dbid=0&repo=Public&cr=1 – Respecting Property Standards https://records.aurora.ca/WebLink/DocView.aspx?id=15145&dbid=0&repo=Public – Sewer Use By Law https://records.aurora.ca/WebLink/DocView.aspx?id=16705&searchid=7b086c3a-337f-4827-8465-9a72a5c06366&dbid=0&repo=Public – Amend 330591 Municipal Waterworks Distribution Bylaw https://records.aurora.ca/WebLink/DocView.aspx?id=18012&dbid=0&repo=Public – Discharge of Sewage, Storm Water and Land Drainage Bylaw (Amended 2014) 2014-23 https://www.york.ca/wps/portal/yorkhome/yorkregion/yr/bylaws/dischargeofsewage%2Cstormwaterandlanddrainagebylaw(amended2014)/!ut/p/z0/pU8xjsIwEHwLRSSQOK0vQpDWogCCEG1wgxa8cXwkNth7F_L784X-GoqRdmZ3RzOgoALl8McaZOsdtomf1PK8k5vddrsX5XFRrIUUR1nmq0IU-xWUoP4_SA55OKwPBtQdufmwrvZQXYYW-wiVtvHaYDDk60g9GppH9qHrkSmg022CDmhd2owvU-zIadK5-FzM_rzt1-OhJKird0xPhmoI53F2nInBh1sikS1_j0LjO3rJgUxqmIlXkEy8F-R-U6ciyskvpMbnlg!!/#.YRauCYhKhPY – Ontario Environmental Protection Act https://www.ontario.ca/laws/statute/90e19 – Ontario Water Resources Act https://www.ontario.ca/laws/statute/90o40
Regulations: – Asset Management Planning for Municipal Infrastructure https://www.ontario.ca/laws/regulation/r17588 – Drinking Water Systems https://www.ontario.ca/laws/regulation/030170 – Environmental Compliance Approval in Respect of Sewage Works https://www.ontario.ca/laws/regulation/r19208 – Minimum Maintenance Standards for Municipal Highways Regulation https://www.ontario.ca/laws/regulation/020239
Design Codes and Standards:

— Ontario Building Code https://www.ontario.ca/laws/regulation/120332 — Ontario Drinking Water Quality Standards https://www.ontario.ca/laws/regulation/030169
Regulations: — Infrastructure Ontario's Buildings Systems Design Guidelines https://www.infrastructureontario.ca/Building-Systems-Design-Guidelines/ — Canadian Water Quality Guideline https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/water-quality/guidelines-canadian-drinking-water-quality-summary-table.html — Design Guidelines for Sewage Works https://www.ontario.ca/document/design-guidelines-sewage-works-0 — Design Guidelines for Drinking-Water Systems https://www.ontario.ca/document/design-guidelines-drinking-water-systems-0
Comments and Observations

2.7 CONDUCT A SITE VISIT

Conduct a site visit.
If Site Visit Not Conducted – Explain Why and Provide Supporting Information No site visit will be conducted as this is a desktop assessment. Site-specific information was gathered as part of the Town Staff interview process.
Based on information gathered to date, conduct interviews with facility owners and operating personnel in order to field-test and validate initial project definition findings.
To be completed in WS #2.
Examine infrastructure and local geographical features as they may apply to the vulnerability assessment.
To be completed in WS #2.
Additional Comments and Observations None.

2.8 ASSESS DATA SUFFICIENCY

Where assumptions are proposed for the assessment, identify these as such and provide a rationale for their use.	
Assumption	**Rationale**
The infrastructure is assumed to have been designed to the relevant design standards at the time of construction.	Design drawings will not be reviewed for all Town infrastructure, but it is required for infrastructure to follow such standards.

Document where there is insufficient information currently available to proceed with an element of the assessment.		
Insufficient Information	**Where there is insufficient information currently available, identify a process to develop or infill that data.**	**Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations.**
None identified at this time.		

Date:	August 13, 2021
Prepared by:	Alice Berry

3 CONCLUSION

WSP is confident to have enough data to carry on to step 2 of the PIEVC protocol. During step 2, a main focus will be to define climate thresholds that could trigger an interaction with the different components of the infrastructure.

PREPARED BY

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Appendix

B-2. Worksheet 2

TECHNICAL MEMO #2

CLIENT:	Town of Aurora		
PROJECT:	Town of Aurora Climate Change Adaptation Plan	**WSP Ref.:**	211-03040-00
SUBJECT:	PIEVC Worksheet #2	**DATE:**	20 August 2021
RECIPIENT:	Natalie Kehle, Town of Aurora		
FROM:	Lisa MacTavish, P.Eng.		

1 INTRODUCTION

The Town of Aurora has engaged WSP to conduct a climate change adaptation plan for the infrastructure assets within the Town. The adaptation plan will be informed by a climate change risk and vulnerability assessment to be completed using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol. This technical memo presents the results of the data gathering and sufficiency (Step 2) of the PIEVC Protocol.

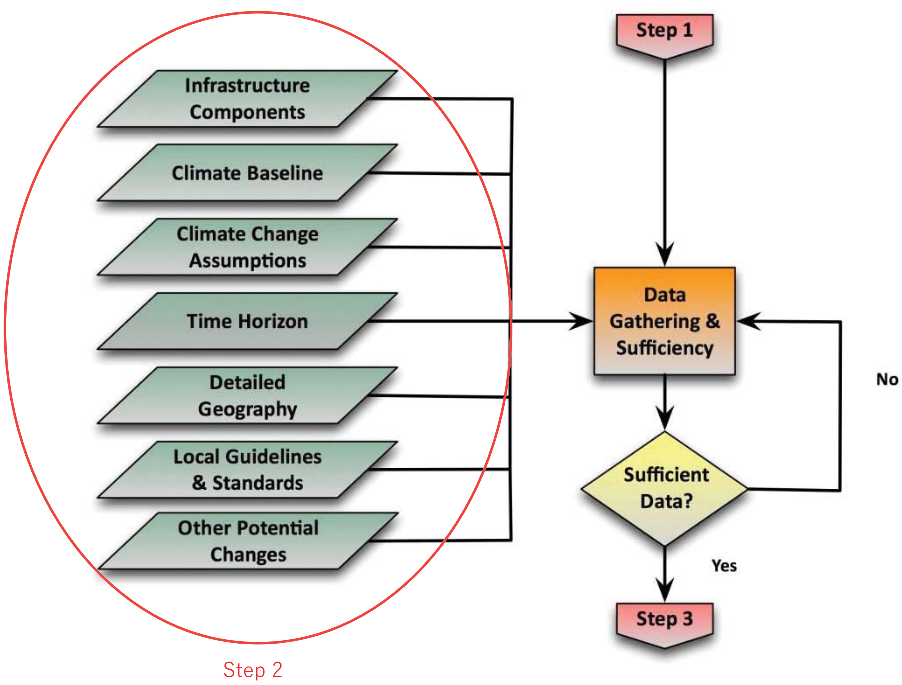

Figure 1 **Step 2 flowchart**

In this step, WSP defines the infrastructure components assessed, specific climate trends, geographic and jurisdictional considerations for the climate risk assessment. The data provided to WSP was reviewed and supplemented by interviews with Town of Aurora staff. In this step, the information required to conduct the preliminary risk assessment is assembled, and this information, along with professional judgement and Town input, will form the basis of the likelihood and consequence analysis of the climate risk assessment. Assumptions are stated, data gaps are identified, data sources, including where professional judgement was used, are provided. The following section contains the tables required to complete Worksheet #2.

2 WORKSHEET #2

2.1 PREPARE STEP 2 WORKSHEET

	Enter ***Yes*** or ***No***	
a. Use this ***Worksheet***; or	Yes	
b. Prepare practitioner specific documentation. i. Practitioner specific documentation ***MUST*** detail each task outlined in this step of the Protocol.		No
Comments and Observations The PIEVC worksheet allows the practitioner to detail each task required, thus was chosen by WSP to proceed with step 2.		

2.2 STATE INFRASTRUCTURE COMPONENTS

a. List the major components of the infrastructure that are influenced by climate.

i. Only select those infrastructure components that, in the practitioner's professional judgment, are relevant to this assessment.

ii. Where available, review operations incident reports, daily logs and reports to assist in the identification of infrastructure components with a history that could result in vulnerability and are relevant to this process.

iii. Interview infrastructure owner's operators and maintenance staff to identify historical events that may not be documented or retrievable from databases and evaluate if these events are relevant to this assessment.

The infrastructure assessed in this study is broken into four major categories as determined by the Town of Aurora, including facilities (buildings), water infrastructure assets (drinking water and sanitary), linear engineering assets including roads and storm water management assets, and parks and natural heritage system assets. The infrastructure components within each of these categories are further broken down as per the 2018 Asset Management Plan (AMP) and are described below. This study assesses climate risks for each infrastructure type across the Town, rather than for each individual asset.

The facilities assessed in this study include municipal government, protection services, recreation & cultural services, and transportation services facilities. The facilities infrastructure components include:

- Heating, Ventilation and Air-Conditioning (HVAC) systems;
- Building envelope systems;
- Building structural systems;

- Electrical systems;
- Plumbing systems;
- Hardscaping.

The water infrastructure assets include the sanitary and water networks.
The water network infrastructure includes:

- Water mains;
- Water valves;
- Underground enclosures;
- Fire hydrants;
- Service connections;
- Bulk water filling stations;
- Booster stations.

The sanitary network infrastructure consists of:

- Sewers;
- Maintenance chambers;
- Laterals;
- Equalization tanks;
- Pumping stations.

The linear engineering assets include the road network and the storm water management assets.
The storm water network infrastructure includes:

- Sewers;
- Maintenance chambers;
- Catch basins;
- Laterals;
- Oil grit separators;
- Cleanouts;
- Headwalls;
- Stormwater management ponds;
- Equalization tanks;
- Bridges and culverts.

The road network infrastructure includes:

- Pavement and curbs;
- Pedestrian paths;
- Road luminaires;
- Signage;
- Traffic signals.

The park and natural heritage system asset infrastructure includes:

- Open space and parkland;
- Land associated with municipal facilities;
- Land maintained for environmental purposes;
- Off-road trails;
- Park structures.

b. Provide references.

Draft Asset Management Plan, Town of Aurora, 2018 Asset Database Listing, Town of Aurora, 2018 Aurora Classification Structure Review V4, Town of Aurora, (no date).
Comments and Observations The AMP classifies the facilities assets by individual building. For this assessment, professional judgement was applied to break up the major facility infrastructure systems such that these can be assessed for climate risk, since these systems will be impacted in a similar way across the Town. Note that the risks to landscaping and municipal infrastructure assets on the facilities property are addressed by the park and natural heritage & and water asset categories respectively. The AMP and other reviewed data do not contain details on the material and type of infrastructure of the facility systems, therefore professional judgement will be applied to identify climate risks which could be expected to impact facilities. These risks will be discussed with Town staff in the workshop to confirm these assumptions and identify any special cases.

2.3 STATE THE TIME HORIZONS FOR THE ASSESSMENT

a. State the period over which the infrastructure must operate.

b. State the design life of the infrastructure components.

The 2018 Asset Management Plan provides information on infrastructure age, useful life and maintenance schedules for each asset type. The table below presents this information as well as the asset inventory, value and condition as of December 31, 2017.

Functional Area	Asset Type	Inventory /Quantity /Extent	Financial Accounting Valuation	Replacement Cost Valuation	Average Asset Age (Years)	Estimated Average Useful Life (Years)	Estimated Remaining Useful Life (Years)	Overall Asset Condition
Watermain	Water Mains	216.6 km	$56,042,584.77	$203,027,001	23.8	67	43.2	Good
	Water Valves	4152 valves	$3,120,616.69	$7,204,581	22.5	30	7.5	Poor
	Underground Enclosures	665 enclosures	$2,394,239.77	$6,218,077	22.7	50	27.3	Good
	Fire Hydrants	1479 hydrants	$3,994,084.37	$6,980,753	22.5	30	7.5	Fair
	Service Connections	15063 services	$5,366,053.02	$19,111,335	26.4	67	40.6	Fair
	Bulk Water Filling Station	1 station	$56,841.52	$	20	19	-1	Very Good
	Booster Stations	1 station	$94,556	$167,384	19.8	30	10.2	Fair
Wastewater	Sewers	188.9 km	$42,324,148.76	$240,378,285	30.5	67	36.5	Good
	Maintenance Chambers	2778 chambers	$14,369,062	$39,556,321	30.1	50	19.9	Fair
	Laterals	14445 laterals	$6,213,658.46	$21,906,822	27.7	67	39.3	Good
	Equalization Tanks	2 tanks	$290,354.10	$751,217	23	50	27	Good
	Pumping Stations	6 stations	$781,600	$1,347,625	15.3	30	14.7	Fair

c. Document the maintenance and/or refurbishment schedule for the infrastructure as it may apply to the useful service life of the infrastructure.		Sewers	217.8 km	$52,462,065.26	$187,206,528	24.9	67	42.1	Good
		Maintenance Chambers	2747 chambers	$10,824,153	$27,584,618	25.8	50	24.2	Good
		Catchbasins	4951 catch-basins	$8,444,225.46	$21,949,932	24.2	50	25.8	Fair
		Laterals	11010 laterals	$5,399,082	$19,266,201	24.8	67	42.2	Good
		Oil Grit Separators	30 filters	$1,115,573	$1,924,969	10.6	30	19.4	Very Good
		Cleanouts	12 clean-outs	$5,541.05	$14,121	25	50	25	Very Good
		Headwalls	225 head-walls	$1,138,420	$2,901,187	24.8	50	25.2	Good
		SWM Ponds	64 ponds	$13,539,340	$17,692,402.31	22	25	3	Fair
		Equalization Tanks	32 tanks	$2,370,458	$5,647,558	29.6	55	25.4	Fair
d. State the useful service life remaining in the infrastructure components.	Stormwater	Bridges & Culverts	161 cross-ings	$6,889,954	$12,293,809	24.3	Inspect-ed every 2 years		Fair
		Pavement & Curbs	193.9 center-line km	$68,634,324	$121,892,876	22.8	Pave-ment inspect-ed every 3-5 years		Fair
		Pedestrian Paths	205.2 km	$10,013,610	$17,726,236	20.8	30	9.2	Poor
		Road Luminaires	4813 lumin-aires	$11,043,075	$16,687,957	17.6	20	2.4	Very Good
		Signage	6918 signs	$387,044	$687,376	22.6	Reflect-ivity Test Conduct-ed Annual-ly		Good
	Roads	Traffic Signals	16 signal intersect-ions	$1,220,172	$1,487,383	20.9	Inspect-ion conduct-ed bi-annually (fall and spring)		Very Good

	Facilities		21 facilities and buildings	$97,526,209.03	$240,888,230.54	28.7	28.3	-0.4	Fair
	Parking Lots		26 parking lots	$6,692,987	$16,531,574.23	28.7	27.5	-1.2	Fair
	Land, Parkland & Land Improvements		● 700 acres of combined open space and parkland ● land associated with each Municipal Facility ● land maintained for environmental purposes ● 57 kilometers of off-road trails.	$22,773,729	$41,702,132	10.5	28.09	17.59	Good

Comments and Observations

The average age of the infrastructure shown in the table above is as of 2017, which as of the time of this assessment is four years out of date. This has been considered when selecting the appropriate time scale for this assessment.

The time scale selected for this assessment is the short term, 2021-2050, since most of the infrastructure assessed will reach end of life within this time period. Therefore, this assessment will evaluate the climate risk during this time period, and future climate risk can be assessed at time of equipment upgrade depending on the design criteria and climate conditions at that time.

2.4 STATE THE GEOGRAPHY

a. List the major features of the local geography that may influence the microclimate of the infrastructure or impose peripheral risk.

   i. Specifically identify hills, valleys, river systems, lakes, ocean frontage that may moderate the climate parameters considered in the evaluation.

   ii. Only select those geographical features that, in the practitioner's professional judgment, are relevant to this assessment.

Please refer to Worksheet #1 for a detailed description of geographical features of the Town of Aurora. Below is an explanation of how these geographical features may expose the Town to climate risk.

- Approximately 40% of the Lake Simcoe watershed is regulated by Lake Simcoe Region Conservation Authority (LSRCA), including the rivers and watercourses within the Town of Aurora. The yellow areas shown in Figure 2 below are LSRCA regulated, which means they contain environmental significance or feature natural hazards for the watershed, such as flooding. These areas are particularly concentrated in the north of the Town of Aurora by St John's side road where there is a convergence of watercourses, Vandorf Side road, north of Wellington Street and west of Yonge Street. The latter two areas were also identified during interviews with asset management as areas with flooding in the past.

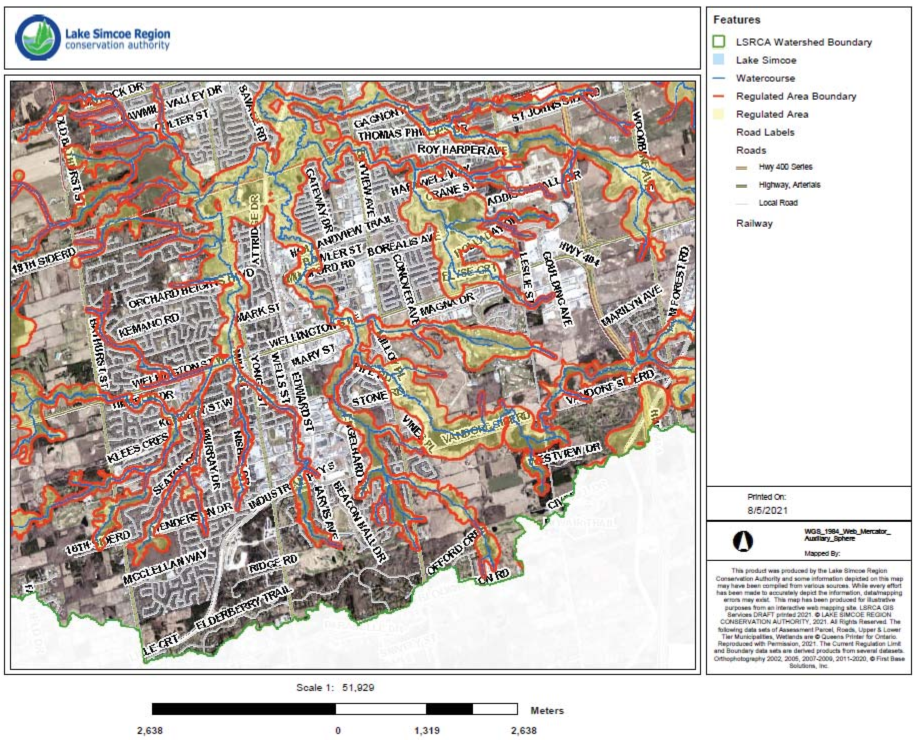

Figure 2 Lake Simcoe Region Conservation Authority Regulated Areas Map – Town of Aurora

- Forest fires have not historically occurred in the areas surrounding the Town of Aurora according to the Canadian National Fire Database. The Town of Aurora is an urban environment; however, it is surrounded by forested land. Although wildfires are unlikely to occur near the Town, it should be noted that wildfire smoke from nearby or distant fires in other parts of the province can impact the air quality and may result in health issues.

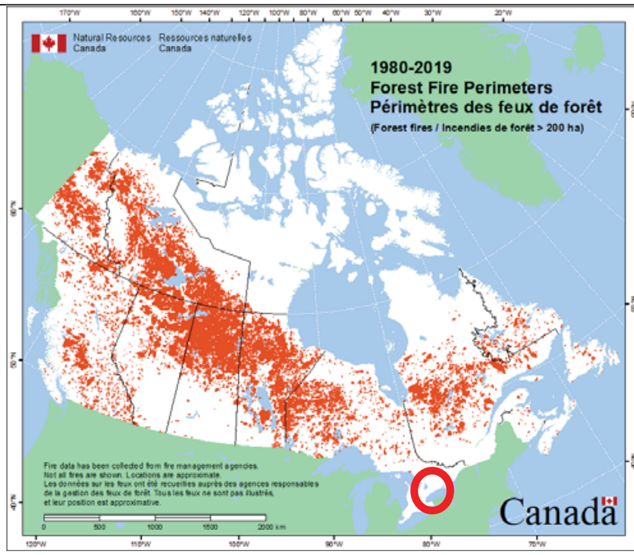

Figure 3 Forest fires (>200 ha) recorded in Canada for the 1980-2018 period (adapted from Natural Resources Canada)

- The Town of Aurora is in the zone prone to F2-F5 tornadoes, as shown in the figure below. In 2009, an F2 tornado caused damaged to more than 650 homes in Vaughan, approximately 20km from the Town of Aurora (https://toronto.ctvnews.ca/residents-recall-devastation-10-years-after-tornado-rips-through-vaughan-1.4556496).

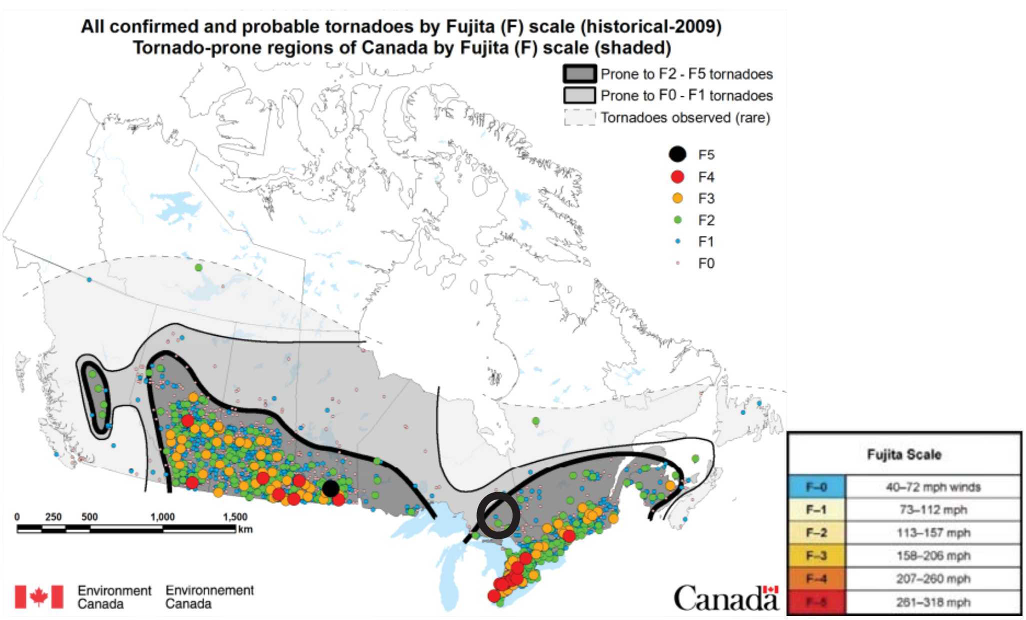

Figure 4 Map showing the F0-F1 and F2-F5 tornado prone areas as well as a 'rare occurrence' area, with all known Canadian tornadoes from 1792 to 2009 superimposed for comparison (adapted from Sills et al, 2012)

- Lightning activity is noted to be in the 1-2 range (flashes per square kilometer, per year) from 1999 to 2018, as shown in the figure below:

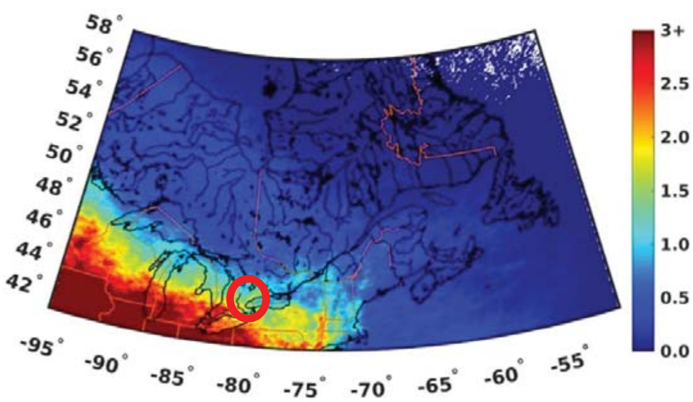

Figure 5 The average lighting flash density (flashes per square kilometre, per year) in Eastern Canada (1999 to 2018) (adapted from Government of Canada, Environmental and Natural Resources 2016)

b. Provide references.
– Lake Simcoe Region Conservation Authority, 2019. *Regulation maps.* Retrieved August 10th from https://maps.lsrca.on.ca/EH5Viewer/index.html?viewer=LSRCARegulations
– Natural Resources Canada, NA. *Canadian National Fire Database.* Retrieved August 10th from Canadian National Fire Database https://cwfis.cfs.nrcan.gc.ca/ha/nfdb?type=poly&year=9999
– Sills et al. (2012). Using tornado, lightning and population data to identify tornado prone areas in Canada. 26th Conference on Severe Local Storms. Retrieved August 10th from: http://www.yorku.ca/pat/research/dsills/papers/SLS26/SLS26_manuscript_TornadoProne_FINAL.pdf
– Government of Canada, Environment and Natural Resources (2016, June 21) *Map of Canada's lightning hotspots.* Retrieved August 10th from https://www.canada.ca/en/environment-climate-change/services/lightning/statistics/maps-hotspots.html

Comments and Observations

The impact that these specific geographical conditions have on the climate risk to the infrastructure will be discussed further in Worksheet 3.

2.5 STATE SPECIFIC JURISDICTIONAL CONSIDERATIONS

a. As applicable, itemize:		b. Provide references.
Jurisdictions that have direct control/influence on the infrastructure;	The Town of Aurora owns and operates the following infrastructure systems within the municipal boundaries: — Municipal roads, bridges, culverts and walkways; — Municipal government, protection, recreation and cultural services facilities; — Municipal transportation services and related infrastructure; — Parks; — Drinking water and sanitary water distribution and pumping systems; — Stormwater infrastructure.	— Town of Aurora (2018). *Draft Asset Management Plan.*
Sections of laws and bylaws that are relevant to the infrastructure;	The Town of Aurora has the following bylaws in place which apply to the infrastructure in the Town: — Backflow Prevention Bylaw – 20191022 – 621319; — Respecting Property Standards – 19990623 – 404499P; — Sewer Use By Law – 20130611 – 551813 (2); — Amend 330591 Municipal Waterworks Distribution Bylaw – 20210330- 632221. The Regional Municipality of York has the following bylaws which apply to the Town of Aurora Infrastructure: — Discharge of Sewage, Storm Water and Land Drainage Bylaw (Amended 2014) 2014-23.	— Town of Aurora (2020). *Frequently requested by-laws.* Retrieved August 10th, 2021 from https://www.aurora.ca/en/your-government/frequently-requested-bylaws.aspx — York Region. (2020). *By-laws.* Retrieved August 10th, 2021 from https://www.york.ca/wps/portal/yorkhome/yorkregion/yr/bylaws/!ut/p/z1/jZBBb4MwDIV_yw4ci92sLdFuEdMWYBWVqmkslylMEJAoQSFt1P36RW0vk1Za32x9z-_ZIKAA0ctDq6RtdS8733-K1VfCXhPOM0zzBY2RYc5SElGkWQQfJwCvFEMQ9-gnADG9Pr1l4C8gZh2vFYhB2mbW9rWGojx20o3eXZz0hCxWfB5jijynmLxEm-Uz5XOMlzeAjFyA6Yiq0-X5m6wvH6nPYqq6MpUJ98aPG2uH8SnAAJ1zodJadVX4rXcB_idp9Gih-EvCsHsvft7qbTIT5dGxh1-2DCko/dz/d5/L2dBISEvZ0FBIS9nQSEh/#.YRLh94hKhPY

a. As applicable, itemize:		b. Provide references.
	The Town of Aurora is in the province of Ontario and the following laws therefore apply: – Ontario Water Resources Act, R.S.O. 1990, c.O.40; – Building Code Act, 1992, S.O. 1992, c.23; – Municipal Act 2001, S.O. 2001, c.25; – Lake Simcoe Protection Act, 1992, S.O 1993, c.23; – Oak Ridges Moraine Conservation Act, 2001, S.O. 2001, c. 31.	– Ontario (2020). *E-Laws.* https://www.ontario.ca/laws?search=water&filteroption=current&filterstate%5B%5D=current&filteryear=&source_type%5B%5D=public&source_type%5B%5D=regulation&pit_date=&filtertype=Statute&sort=relevance&sort_letter=
Sections of regulations that are relevant to the infrastructure;	Drinking water systems. O. Reg. 170/03 Environmental compliance approval in respect of sewage works. O. Reg. 208/19. Asset Management Planning for Municipal Infrastructure. O. Reg. 588/17	– Ontario (2020). *E-Laws.* https://www.ontario.ca/laws?search=water&filteroption=current&filterstate%5B%5D=current&filteryear=&source_type%5B%5D=public&source_type%5B%5D=regulation&pit_date=&filtertype=Statute&sort=relevance&sort_letter=
Standards that are relevant to the design, operation and maintenance of the infrastructure;	Ontario Building Code. O. Reg. 332/12 Ontario Drinking Water Quality Standards. O. Reg. 61/14 Performance Standards. O. Reg. 260/08	– Ontario (2020). *E-Laws.* https://www.ontario.ca/laws?search=water&filteroption=current&filterstate%5B%5D=current&filteryear=&source_type%5B%5D=public&source_type%5B%5D=regulation&pit_date=&filtertype=Statute&sort=relevance&sort_letter=
Guidelines that are relevant to the design, operation and maintenance of the infrastructure; and	– Infrastructure Ontario's Buildings Systems Design Guidelines – Canadian Water Quality Guideline – Design Guidelines for Sewage Works – Design Guidelines for Drinking-Water Systems	– Infrastructure Ontario (2020). *Standards and Guidelines.* https://www.infrastructureontario.ca/Standards-and-Guidelines/ – Ontario (2020). *Water management: policies, guidelines, provincial water quality objectives.* https://www.ontario.ca/page/water-

a. As applicable, itemize:		b. Provide references.
		management-policies-guidelines-provincial-water-quality-objectives – Ontario (2020). *Design Guidelines for Sewage Works.* https://www.ontario.ca/document/design-guidelines-sewage-works-0 – Ontario (2020). *Design Guidelines for Drinking-water Systems.* https://www.ontario.ca/document/design-guidelines-drinking-water-systems-0
Infrastructure owner/operator administrative processes and policies as they apply to the infrastructure.	Infrastructure is maintained and replaced as per asset-specific schedule, as detailed in the Town of Aurora Asset Management Plan.	– Town of Aurora (2018). *Draft Asset Management Plan.*

Comments and Observations

In Ontario, municipalities are responsible for maintaining local infrastructure. This assessment considers only the infrastructure owned and maintained by the Town of Aurora, therefore does not evaluate regional and provincial infrastructure and its design, operation and maintenance details.

2.6 STATE OTHER POTENTIAL CHANGES THAT MAY AFFECT THE INFRASTRUCTURE

a. Identify and document other factors that can affect the design, operation, and maintenance of the infrastructure:	
i. Document changes in use pattern that increase/decrease the capacity of the infrastructure.	All expansion activities are scheduled in the 10-Year Capital Investment Plan.

ii. Document operation and maintenance practices that increase/decrease the capacity or useful life of the infrastructure.	The Asset Management Plan for the Town of Aurora sets out the monitoring regime for each infrastructure component. The outcomes of the monitoring then inform the required rehabilitation/renewal in the 10-year capital plan.
iii. Document changes in management policy that affect the load pattern on the infrastructure.	WSP is not aware of upcoming changes to management policy which would affect the results of this assessment, however continued expansion and development will increase the demand on Town infrastructure.
iv. Document changes in laws, regulations and standards that affect the load pattern on the infrastructure.	The design of infrastructure is assumed to comply with the most recent applicable code. Subsequent infrastructure rehabilitations or upgrades are assumed to meet design criteria in place at the time.
Comments and Observations The Town will continue to grow and develop as per the 10-Year Capital Investment Plan, however due to the scale of this assessment, only current infrastructure was assessed. It can be expected that future infrastructure will follow similar operation, maintenance and design standards as the existing infrastructure, and therefore it should also have similar climate risks to those identified in this assessment, unless designed with future climate conditions in mind.	

2.7 IDENTIFY RELEVANT CLIMATE PARAMETERS

List the relevant climate parameters associated with the design, development, and management of the infrastructure.	State the climate information source(s).
Temperature: – Average annual temperature; – Average maximum summer temperature; – Average minimum winter temperature; – Highest annual maximum temperature; – Lowest annual minimum temperature; – Annual heating degree-days; – Annual cooling degree-days; – Annual freeze-thaw cycles; – Winter freeze-thaw cycles; – Number of heat waves;	– Daily and monthly data, Environment and Climate Change Canada, Toronto Buttonville A weather station (ID 615HMAK); – Climate Normals 1981-2010, Environment and Climate Change Canada, Toronto Buttonville A weather station (ID 615HMAK); – Climate Atlas of Canada, Newmarket small grid square; – IDF_CC Tool, Western University, Toronto Buttonville A weather station (ID 615HMAK); – Canada's Changing Climate Report (2019), Environment and Climate Change Canada;

— Average length of heat waves.	— Intergovernmental Panel on Climate Change reports on global climate change projections; — Scientific literature.
Precipitation: — Average total annual precipitation; — Average annual precipitation as rain; — Average annual precipitation as snow; — Number of days with freezing rain; — Extreme precipitation: IDF curves over 15 minutes and 24 hours, return periods of 10, 50 and 100 years; — Maximum snowfall over 24 hours; — Snow cover and snow depth.	
Storm activity: — Maximum hourly wind speed; — Maximum wind gust speed; — Cloud-to-ground lightning flashes.	
Other: — River or creek flooding; — Wildfires; — Tornadoes;	
Comments and Observations The list of climate parameters will be adjusted following the selection of infrastructure threshold values, as it might be impossible to identify thresholds for some of these parameters, and some of these parameters may not directly influence designs or operations of identified infrastructure. Toronto Buttonville A has been chosen as the weather station for this assessment as it is the closest station to the Town with a long enough timeseries to assess IDF curves. Using this station means the climate assessment can consistently use the same weather station throughout the assessment.	

2.8 IDENTIFY INFRASTRUCTURE THRESHOLD VALUES

For each climate parameter selected, identify a threshold value above which, or below which, the infrastructure performance will be affected.

Threshold values may be based on:

- Codes;
- Standards;
- Engineering Guidelines;
- Operating or Maintenance Procedures;
- Professional Judgement; and/or

- Other, as appropriate.

As appropriate, a number of different thresholds may be identified for a specific climate parameter based on varying degrees of infrastructure response arising from parameter values changing over a broader range.

- In such cases, each parameter-threshold pair would be treated as a separate event within the context of the assessment.

Threshold Value	a. Clearly document the source of the threshold value.	b. Provide justification for the threshold value selected.

<u>Comments and Observations</u>

The infrastructure threshold identification will be performed as part of the next step of this assessment.

2.9 IDENTIFY POTENTIAL CUMULATIVE OR SYNERGISTIC EFFECTS

Review the selected climate parameters and threshold values and evaluate the potential cumulative impact of combining or sequencing weather events and/or climate trends to assess the possibility of these combined events yielding a higher impact compound event.

Include relevant cumulative or synergistic events on the list of climate parameters carried forward for risk assessment.

i. The practitioner must exercise professional judgment in establishing conceivable combined or synergistic events to avoid assessing multiple, improbable, combinations.

Cumulative and/or Synergistic Event	Threshold Value	Justification

<u>Comments and Observations</u>

The cumulative and synergistic effects identification will be performed as part of the next step of this assessment.

2.10 STATE CLIMATE BASELINE

Historical Climate	Value	Reference
Average annual temperature (1976-2005)	6.8 °C	– Environment and Climate Change Canada (2020b). *Canadian Climate Normals 1981-2010 Station Data*, Toronto Buttonville A weather station (ID 615HMAK)
Average maximum summer temperature	24.9 °C	

Historical Climate	Value	Reference
(1976-2005)		– Environment and Climate Change Canada (2020a) *Historical Data*, Toronto Buttonville A weather station (ID 615HMAK) – Prairie Climate Centre (2019) *Climate Atlas of Canada, version 2.0*, Newmarket small grid square. Retrieved from: https://climateatlas.ca/ – Western University (2021) *The IDF_CC tool, Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change – Version 5.0*, Toronto Buttonville A weather station (ID 615HMAK). Retrieved from: https://www.idf-cc-uwo.ca – Government of Canada (2019) *Lightning activity in Canadian cities.* The baseline value is for Vaughan which is approximately 20km from the Town of Aurora. Retrieved from: https://www.canada.ca/en/environment-climate-change/services/lightning/statistics/activity-canadian-cities.html – Cheng *et al*. (2012). *Possible impacts of climate change on extreme weather events at local scale in south-central Canada*, Climate Change, 112, 963-979. DOI 10.1007/s10584-011-0252-0
Average minimum winter temperature (1976-2005)	-10.3 °C	
Highest annual maximum temperature (1976-2005)	32.8 °C	
Lowest annual minimum temperature (1976-2005)	-26.9 °C	
Annual number of heating degree-days (1976-2005)	4296	
Annual number of cooling degree-days (1976-2005)	217.2	
Annual number of freeze-thaw cycles (1976-2005)	83.7	
Number of winter freeze-thaw cycles (1976-2005)	35.5	
Average number of heat waves (>30°C) (1976-2005)	1.2	
Average length of heat waves (>30°C) (1976-2005)	2.7	
Average total annual precipitation (1976-2005)	821 mm	
Average annual precipitation as rain (1981-2010)	717.4 mm	
Average annual precipitation as snow (1981-2010)	142.6 cm	
Number of days with freezing rain (1958-2001)	2 - 5	

Historical Climate	Value	Reference
IDF 15 minutes 1:10 (1986-2016)	23.32 mm	
IDF 24 hours 1:10 (1986-2016)	72.60 mm	
IDF 24 hours 1:50 (1986-2016)	95.28 mm	
IDF 24 hours 1:100 (1986-2016)	104.87 mm	
Average maximum daily precipitation (1976-2005)	39 mm	
Annual number of cloud-to-ground lightning flashes (1999-2018)	3,021	
Total number of days with wind gust speed > 110 km/h since 1986 (1986-2015)	5	
Annual number of days with precipitation as snow > 15 cm + maximum gust speed > 50 km/h (1986-2015)	0.4	
Annual number of days with precipitation as rain > 5 mm + maximum gust speed > 50 km/h (1986-2015)	7.8	
Annual number of days with precipitation as rain > 5 mm + occurrence of freeze-thaw cycle (1986-2015)	8.6	
Historic Extreme Weather Event	**Value**	**Reference**
Extreme maximum temperature recorded (1981-2010)	37.8 °C	– Environment and Climate Change Canada (2020b). *Canadian Climate Normals 1981-2010 Station Data*, Toronto Buttonville A weather station (ID 615HMAK) – Environment and Climate Change Canada (2020a). *Historical Data*, Toronto
Extreme minimum temperature recorded (1981-2010)	-35.2 °C	

Historical Climate	Value	Reference
Extreme daily precipitation as rain (1981-2010)	80.3 mm	Buttonville A weather station (ID 615HMAK) – Natural Resources Canada (n.d.). *Canadian Wildland Fire Information System, Fire Weather Normals*. Retrieved from: https://cwfis.cfs.nrcan.gc.ca/ha/fwnormals
Extreme daily precipitation as snow (1981-2010)	37.4 cm	
Extreme snow depth (1981-2010)	70 cm	
Maximum hourly wind speed recorded (1981-2010)	80 km/h	
Maximum wind gust speed recorded (1981-2010)	135 km/h	
1981-2010 mean fire weather index (numeric rating of fire intensity and danger, ranging from 0-30+). The highest monthly value is used.	5 – 10	

Comments and Observations

This climate baseline will be used to inform some infrastructure climate thresholds and climate probability scores as relevant.

2.11 STATE THE CHANGING CLIMATE ASSUMPTIONS

a. Assess the relevancy and applicability of observed global, regional or site-specific changing climate trends with respect to the infrastructure.

i. Document how these trends influence the infrastructure.

Trend	**Influence**
Mean annual average temperature: significant increase	Could lead to an increase in likelihood of record hot weather, discomfort of occupants, staff and road users, deformation of material, increase in energy and water consumption, and water consumption
Mean summer maximum temperature: significant increase	Could lead to an increase in likelihood of record hot weather, discomfort of occupants, staff and road users, deformation of material, increase in energy and water consumption, and water consumption

Mean winter minimum temperature: significant increase	Could lead to less energy consumption, decrease in depth of frozen ground
Extreme maximum temperature: insignificant increase	Could lead to an increase in likelihood of record hot weather, discomfort of occupants, staff and road users, deformation of material, increase in energy and water consumption, and water consumption
Extreme minimum temperature: significant increase	Could lead to less energy consumption, decrease in depth of frozen ground
Total annual rain: no trend	Could lead to more load on structures, more moisture, more pressure on the stormwater network, more disruption to the road network
Total snowfall: no trend	Could lead to less load on structures, less melt during spring, less disruption to the road network
Heating degree-day: significant decrease	Could lead to less energy consumption
Cooling degree-day: significant increase	Could lead to more energy consumption, and discomfort

Comments and Observations The impacts of these trends on the infrastructure will be described in Worksheet 3.
b. Where appropriate, identify incremental changes to the **Climate Baseline** conditions based on the trends identified in (a) above.

Incremental Change	**Influence**
Mean annual average temperature: significant increase	+ 0.02 °C/year from 1950-2013 + 0.04 °C/year from 1980-2013
Mean summer maximum temperature: significant increase	+ 0.01 °C/year from 1950-2013 + 0.04 °C/year from 1980-2013
Mean winter minimum temperature: significant increase	+ 0.04 °C/year from 1950-2013 + 0.05 °C/year from 1980-2013
Extreme maximum temperature: insignificant increase	+ 0.01 °C/year from 1950-2013 + 0.07 °C/year from 1980-2013
Extreme minimum temperature: significant increase	+ 0.03 °C/year from 1950-2013 + 0.14 °C/year from 1980-2013
Total annual rain: no trend	No trend from 1950-2013 No trend from 1980-2013
Total snowfall: no trend	No trend from 1950-2013 No trend from 1980-2013
Heating degree-day: significant decrease	-6.4 HDD/year from 1950-2013 -12.8 HDD/year from 1980-2013
Cooling degree-day: insignificant increase	+1.2 CDD/year from 1950-2013 +2.0 CDD/year from 1980-2013

Comments and Observations Data from ECCC Toronto Buttonville A weather station (ID 615HMAK), Climate Atlas of Canada (Newmarket small grid square). Two trends have been presented above to illustrate that climate change has been accelerating during the last decades.
c. Where appropriate, identify incremental changes to the **Climate Baseline** conditions based on sensitivity analysis. i. Increase or decrease Climate Baseline conditions by percentages selected based on the practitioner's professional judgement. ii. Provide written justification/substantiation for the assumptions and incremental values used in the sensitivity analysis.

Incremental Change	**Justification**

Comments and Observations Sensitivity analysis were not deemed necessary, as this would be especially useful for changes where a precise level could have negative impacts, such as sea level rise, where a sensitivity analysis with projections at 0.5, 1, 1.5 and 2 m are useful in terms of risk assessment.
d. Where appropriate, use surrogate information from other geographic areas to respond to identified data gaps and uncertainties. i. Document the source of the infill data. ii. Provide written justification/substantiation for using the infill data.

Incremental Change	**Justification**
Freezing rain: decrease in the number of events in November, March and April (- 10-15% by 2050, - 10-15% by 2080)	Cheng *et al*. (2012). *Possible impacts of climate change on extreme weather events at local scale in south-central Canada*, Climate Change, 112, 963-979. DOI 10.1007/s10584-011-0252-0
Freezing rain: increase in the number of events in December, January and February (+35-45% by 2050, +35-55% by 2080)	Cheng *et al*. (2012). *Possible impacts of climate change on extreme weather events at local scale in south-central Canada*, Climate Change, 112, 963-979. DOI 10.1007/s10584-011-0252-0

Number of lightning strikes: increase by 12% per °C of global warming	Romps *et al.* (2014). *Projected increase in lightning strikes in the United States due to global warming*, Science, 346(6211), 851-854. DOI 10.1126/science.1259100
Snow cover: 5%-7.5% decrease per decade by 2050	Derksen *et al.* (2019). *Changes in snow, ice, and permafrost across Canada;* Chapter 5 in *Canada's Changing Climate Report*, (ed.) E. Bush and D.S. Lemmen, Government of Canada, Ottawa, Ontario, p.194-260
Number of days with hourly wind speed > 90 km/h per year: +250% by 2050, +200% by 2080.	Cheng *et al.* (2014). *Possible impacts of climate change on wind gusts under downscaled future climate conditions: update for Canada*, Journal of Climate, 7, 1255-1270. DOI 10.1175/JCLI-D-13-00020.1
Number of days with wind gust speed > 90 km/h per year: +30% by 2050, +15% by 2080	Cheng *et al.* (2014). *Possible impacts of climate change on wind gusts under downscaled future climate conditions: update for Canada*, Journal of Climate, 7, 1255-1270. DOI 10.1175/JCLI-D-13-00020.1
Change in hourly wind pressure for Ontario: +8.5% [-0.8%; 18.6%]	Government of Canada (2020). *Climate-Resilient Buildings and Core Public Infrastructure: an assessment of the impact of climate change on climatic design data in Canada*. Consulted online [November 3rd, 2020]: https://climate-scenarios.canada.ca/index.php?page=buildings-report
Expected decrease in solar radiation for North America: 1% per decade	Wild, M., Folini, D., Henschel, F., Fischer, N., & Müller, B. (2015). *Projections of long-term changes in solar radiation based on CMIP5 climate models and their influence on energy yields of photovoltaic systems.* Solar Energy, 116, 12-24.
Comments and Observations Despite the lack of available projection data for these indicators, the scientific literature provides trends that can be useful in the following steps of the Protocol.	
e. Where appropriate, arbitrarily define changing climate assumptions or predictions. i. Provide written justification/substantiation for using the assumptions.	
Incremental Change	**Justification**
Increase in rain on snow events	As winter climate warms, the temperature is projected to oscillate around 0 °C more often, which may cause an increased variation in the precipitation type. Days with snow followed by rain in the next 24 hours may therefore be more frequent.

Number of days with > 15 cm of snow: increase by 2050, decrease by 2080.	The annual number of days with > 15 cm of snow in the town of Aurora is approximately 1.2 per year between 1986 and 2015. As precipitation intensity is expected to increase and winter temperature increases, projections show an increase in annual snowstorms in the first half of the 21st century. By 2080, it is expected that temperature may have risen sufficiently, and the ratio of liquid/solid winter precipitation may be high enough for the number of major snowstorms to decrease.
Comments and Observations No comment.	
f. Where appropriate, employ regional climate change models to project changing climate effects in the region of the infrastructure. ii. Review the basis and basic assumptions of the model(s). iii. Provide written justification/substantiation for using the model in the evaluation.	
Incremental Change[1]	**Justification**
Mean January daily minimum temperature – Baseline: -12.1 °C [-16.5; -7.6] – 2021-2050: -9.1 °C [-13.9; -4.3] – 2051-2080: -6.1 °C [-10.8; -1.6]	Good climate modelling outputs are now readily available. They provide the best source of information regarding what the future should look like. The baseline is defined by modelled data from 1976 to 2005.
Mean July daily maximum temperature – Baseline: 26.1 °C [24.1; 28.2] – 2021-2050: 28.4 °C [26.1; 30.7] – 2051-2080: 30.8 °C [28.0; 33.5]	
Mean maximum daily summer temperature – Baseline: 24.9 °C [23.5; 26.3] – 2021-2050: 29.4 °C [25.4; 28.9] – 2051-2080: 29.4 °C [27.2; 31.6]	
Mean minimum daily winter temperature	

[1] Numbers in bracket are the 10th and 90th percentiles of model outputs

— Baseline: -10.3 °C [-13.2; -7.4] — 2021-2050: -7.6 °C [-10.8; -4.4] — 2051-2080: -4.8 °C [-8.1; -1.7]	
Extreme annual maximum temperature — Baseline: 32.8 °C [30.8; 34.8] — 2021-2050: 35.2 °C [32.6; 37.8] — 2051-2080: 37.7 °C [34.8; 41.1]	
Extreme annual minimum temperature — Baseline: -26.9 °C [-31.7; -22.2] — 2021-2050: -23.1 °C [-28.2; -18.0] — 2051-2080: -18.8 °C [-23.9; -13.4]	
Number of heating degree-days — Baseline: 4296 [3944; 4662] — 2021-2050: 3699 [3264; 4142] — 2051-2080: 3148 [2640; 3571]	
Number of cooling degree-days — Baseline: 217.2 [134.2; 306.9] — 2021-2050: 404.5 [267.9; 550.2] — 2051-2080: 647.0 [445.3; 876.2]	
Number of heat waves (> 30 °C) — Baseline: 1.2 [0.0; NaN] — 2021-2050: 3.6 [1.1; 6.4] — 2051-2080: 6.0 [3.3; 9.0]	
Average length of heat waves (> 30 °C) — Baseline: 2.7 days [0.0; 5.7] — 2021-2050: 4.9 days [2.4; 7.6] — 2051-2080: 7.4 days [4.3; 11.7]	
Annual freeze-thaw cycles — Baseline: 83.7 [69.2; 98.0] — 2021-2050: 77.7 [62.9; 92.9] — 2051-2080: 68.5 [52.9; 83.0]	

Winter freeze-thaw cycles – Baseline: 31.0 [21.8; 40.4] – 2021-2050: 36.5 [27.4; 46.3] – 2051-2080: 38.5 [29.4; 47.7]	
Annual precipitation – Baseline: 821 mm [679; 967] – 2021-2050: 873 mm [709; 1048] – 2051-2080: 897 mm [730; 1081]	Climate modelling of annual precipitation allows to illustrate that annual trends are not conclusive, but an increase in the interannual variability of the precipitation is expected.
Winter precipitation – Baseline: 179 mm [125; 235] – 2021-2050: 197 mm [137; 267] – 2051-2080:211 mm [147; 283]	
15-min 1:10 precipitation – Baseline: 23.32 mm – 2021-2050: 24.82 mm [23.89; 27.12] – 2051-2080: 25.95 mm [22.37; 27.97]	Climate modelling of daily to sub-daily extreme events comes with high uncertainty in the representation of extreme precipitation patterns, as projections are based on the daily outputs of global climate models, spatially downscaled to a cell of approximately 10 km x 10 km. However, every model projects an increase in the magnitude of short-duration extreme precipitation. Even if there is a low confidence in the number, there is a high likelihood to observe an increase. As there is considerable uncertainty surrounding the projections of extreme precipitation as a result of climate change, it is beneficial to consider other sources of projection data. The CSA PLUS 4013:19 standard on the development, interpretation and use of rainfall IDF information states that a 7% increase can be expected for every degree of warming. This has been applied to the increase in mean annual temperature to provide an alternative set of projections for mean and extreme precipitation, although the projections are the same for each precipitation duration as its based on the same temperature change. It is recommended to use the most conservative projections data when carrying out flooding modelling or planning exercises to ensure a worst-case scenario is considered. The percentages from calculations using CSA's proxy, shown on the left, should therefore be used.
24-hr 1:10 precipitation – Baseline: 72.60 mm – 2021-2050: 75.06 mm [72.01; 82.64] – 2051-2080: 78.23 mm [67.43; 85.37]	
24-hr 1:50 precipitation – Baseline: 95.28 mm – 2021-2050: 108.23 mm [97.11; 120.02] – 2051-2080: 117.63 mm [100.45; 134.46]	
24-hr 1:100 precipitation – Baseline: 104.87 mm – 2021-2050: 123.24 mm [109.36; 141.57] – 2051-2080: 133.52 mm [110.96; 159.16]	
Mean and extreme precipitation statistics (CSA, 2019) – 2021-2050: +16% [+14%; +18%] – 2051-2080: +34% [+30%; +39%]	

Comments and Observations Projections under the passive emission scenario (RCP8.5), as this is the most conservative, and currently a likely scenario. Sources: – CRIM – Computer Research Institute of Montreal (2019). *Climate Data Canada.* Retrieved from: https://climatedata.ca/ – PCC – Prairie Climate Centre (2019). *Climate Atlas of Canada, version 2.0*, Newmarket small grid square. Retrieved from: https://climateatlas.ca/ – Western University (2021). *The IDF_CC tool, Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change – Version 5.0*, Toronto Buttonville A weather station (ID 615HMAK). Retrieved from: https://www.idf-cc-uwo.ca – CSA Plus 4013-2019 *Technical Guide: Development, Interpretation and Use of Rainfall Intensity-Duration-Frequency (IDF) Information: Guideline for Canadian Water Resources Practitioners.* Retrieved from: https://webstore.ansi.org/standards/csa/csaplus40132019

2.12 ESTABLISH CHANGING CLIMATE PROBABILITY SCORES

a. From Figure 1, choose Method A or Method B to define probability scores. i. Record in project documentation the Method that was used. ii. Use the same method for all probabilities used in the evaluation.	**Method** **Enter Either A or B** Method A will be conducted in the next phase of this assessment.
b. Choose the changing climate probability scoring approach. Either: i. Assign scores for the probability of climate parameters changing over the time horizon of the assessment such that the infrastructure threshold is triggered. ▪ If this approach is selected, go to **Task 2.12.c**	**Method** **Enter Either Yes or No** Yes, probability scores will be provided in the next phase of this assessment.
OR: i. Assign scores for the probability of climate parameters triggering infrastructure thresholds in the baseline climate and assign scores for the probability that climate parameters will trigger the infrastructure thresholds in the future climate. Changing climate impacts are assessed from the difference between the two scores. ▪ If this approach is selected, go to **Task 2.12.d**	**Method** **Enter Either Yes or No** No.

2.13 IDENTIFY THE DATA GAPS

Review the data set developed in **Sections 2.1 through 2.12**. a. For data selected for the evaluation, assess and comment on:	
▪ Data gaps;	Climate – Confidence is low on climate change projections regarding wind, snow and lightning given the complexity of these indicators. We therefore rely on studies conducted on larger geographic zones given the lack of site-specific data. – There is a lack of consensus regarding the impact of climate change on the frequency and magnitude of tornado regime.
▪ Data quality;	– Data from Environment Canada is of high quality. – Data from the Climate Atlas of Canada is of high quality for trends and low quality for extreme discrete events. – Climate change IDF curves have a high degree of uncertainty, especially with respect to short duration, high intensity events.
▪ Data accuracy;	– There are high uncertainties with climate change projections (natural variability and inter-model spread). However, climate change projections provided by climate model ensembles such as the one used in this assessment are the best tool to evaluate how climate conditions will evolve in the coming decades.
▪ The applicability of trends;	– Trends are applicable.
▪ Reliability of selected climate model(s);	– The use of ensemble modeling increases the reliability of climate models and is in agreement with the best practice regarding dealing with climate change uncertainty. – Every source uses reliable models that are recognized as valid by the scientific community.
▪ Reliability of changing climate assumptions or scenarios; and	– RCP8.5 is the emission scenario that represents business as usual, or the ongoing trend in anthropogenic emissions.
▪ Other factors.	
Comments and Observations Despite the data gaps identified above, we can move forward with the risk assessment, using professional judgement where needed.	

2.14 CONDUCT A SITE VISIT

Conduct a site visit.
<u>If Site Visit Not Conducted – Explain Why and Provide Supporting Information</u> No site visit will be conducted as this is a desktop assessment. Site-specific information was gathered as part of the Town Staff interview process.
Based on information gathered to date, conduct interviews with facility owners and operating personnel in order to field-test and validate initial project definition findings.
The town staff interviews resulted in some key findings relevant for this study, as summarized below: – Higher temperatures in the winter means that Emerald Ash Borer insect continues to be an issue for plant life throughout the year as they are able to survive the winter conditions. – Dry conditions mean that watering of plants and landscaping must be undertaken, particularly during the earlier stages of growth. – Temperature control in arenas to keep the ice the right temperature requires more effort during warmer winters. – Heat waves put pressure on the HVAC systems and result in condensation causing mould and other issues in facilities. – Roof leaking in facilities has occurred when temperatures increase from low to high, ice is present on the roof and roof drains are blocked. – Stream flooding and erosion has been an important issue historically and will likely continue to be an issue. – Basement flooding has also been a key issue historically, most noticeably in June 2018 and December 2020, and could continue to be an issue in the future. – Freeze-thaw cycles have caused potholes in the roads and sidewalk heaving and has noticeably become more common in recent years. – Streetlights have been damaged in high windstorms twice in the last four to five years which results in significant financial implications as well as a safety risk.
Examine infrastructure and local geographical features as they may apply to the vulnerability assessment.
As discussed in Section 2.4.
<u>Additional Comments and Observations</u> Findings from interviews will inform the risk assessment in the next step.

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TOWN OF AURORA CLIMATE ADAPTATION PLAN – WORKSHEET 2 – APPENDIX A

Climate Hazard	Threshold Value	Historical values	Short-Term Projections (2021-2050)[1]	Will the Interaction Change Over the Time Horizon of the Assessment? (Y/N)	More-Same-Less (+/0/-)	Projected Change in Magnitude (H/M/L)	Projected Change in Frequency (H/M/L)	Robustness of Forecast (H/M/L)	Probability Score (1-7)
Low winter temperature	Mean January daily minimum temperature < -12.1 °C	-12.1 °C [-16.5; -7.6]	-9.1 °C [-13.9; -4.3]	Y	-	M	L	H	3
High summer temperature	Mean July daily maximum temperature > 26.1 °C	26.1 °C [24.1; 28.2]	28.4 °C [26.1; 30.7]	Y	+	M	M	H	4

[1] Numbers correspond to mean projections and, in brackets, to the 10th and 90th percentiles of the modelled distribution.

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Climate Hazard	Threshold Value	Historical values	Short-Term Projections (2021-2050)[1]	Will the Interaction Change Over the Time Horizon of the Assessment? (Y/N)	More-Same-Less (+/0/-)	Projected Change in Magnitude (H/M/L)	Projected Change in Frequency (H/M/L)	Robustness of Forecast (H/M/L)	Probability Score (1-7)
Heat waves	Number of heat waves (3 consecutive days above 30 ºC) > 1.2	1.2 [0.0; NaN]	3.6 [1.1; 6.4]	Y	+	H	H	H	5
HDDs	Heating Degree Days (HDDs) > 4296	4296 [3944; 4662]	3699 [3264; 4142]	Y	-	H	H	H	5
CDDs	Cooling Degree Days (CDDs) > 217.2	217.2 [134.2; 306.9]	404.5 [267.9; 550.2]	Y	+	H	H	H	5
Freeze-thaw cycles	Number of winter freeze thaw cycles > 31.0	31.0 [21.8; 40.4]	36.5 [27.4; 46.3]	Y	+	M	L	H	3

Climate Hazard	Threshold Value	Historical values	Short-Term Projections (2021-2050)[1]	Will the Interaction Change Over the Time Horizon of the Assessment? (Y/N)	More-Same-Less (+/0/-)	Projected Change in Magnitude (H/M/L)	Projected Change in Frequency (H/M/L)	Robustness of Forecast (H/M/L)	Probability Score (1-7)
Short-duration precipitation	24-hr 1:100 precipitation > 104.87 mm	104.87 mm	123.24 [109.36; 141.57]	Y	+	M	M	M	5
Annual precipitation	Annual precipitation > 821 mm	821 mm [679; 967]	873 mm [709; 1048]	Y	+	L	L	M	2
Snow	Maximum snow depth > 70 cm	70 cm	5%-7.5% decrease per decade by 2050[2], i.e. [51; 57] cm	Y	-	H	M	L	5

[2] Derksen et al. (2019). Changes in snow, ice, and permafrost across Canada; Chapter 5 in Canada's Changing Climate Report, (ed.) E. Bush and D.S. Lemmen, Government of Canada, Ottawa, Ontario, p.194-260

Climate Hazard	Threshold Value	Historical values	Short-Term Projections (2021-2050)[1]	Will the Interaction Change Over the Time Horizon of the Assessment? (Y/N)	More-Same-Less (+/0/-)	Projected Change in Magnitude (H/M/L)	Projected Change in Frequency (H/M/L)	Robustness of Forecast (H/M/L)	Probability Score (1-7)
Freezing rain	Number of days with freezing rain events per year > 5	3 – 7	+10-18% by 2050[3], i.e. 6 [3 – 8]	Y	+	L	L	L	2
Wind	Number of days with wind gusts > 100 km/h > 5	5	+30%[4], i.e. 6.5	Y	+	L	M	L	3
Lightning	Annual number of lightning strikes > 3,021	3,021	+12% per degree of increase in mean temperature[5], i.e. 3,876 [3,307; 4,491]	Y	+	H	M	L	4

[3] Cheng et al. (2012). Possible impacts of climate change on extreme weather events at local scale in south-central Canada, Climate Change, 112, 963-979. DOI 10.1007/s10584-011-0252-0. The historical baseline has been determined by summing the values in the paper for the Dec-Feb period (2-5) and November, March and April period (1-2), giving us a baseline of 3-7 and a threshold of 5 (the average of 3-7). The projections have been determined using the average of the projections in the paper and a weighting based on the number of months.
[4] Cheng et al. (2014). Possible impacts of climate change on wind gusts under downscaled future climate conditions: update for Canada, Journal of Climate, 7, 1255-1270. DOI 10.1175/JCLI-D-13-00020.1, increase in 90km/h wind gusts can be applicable to 100km/h wind gusts with moderate confidence.
[5] Romps et al. (2014). Projected increase in lightning strikes in the United States due to global warming, Science, 346(6211), 851-854. DOI 10.1126/science.1259100

Climate Hazard	Threshold Value	Historical values	Short-Term Projections (2021-2050)[1]	Will the Interaction Change Over the Time Horizon of the Assessment? (Y/N)	More-Same-Less (+/0/-)	Projected Change in Magnitude (H/M/L)	Projected Change in Frequency (H/M/L)	Robustness of Forecast (H/M/L)	Probability Score (1-7)
Wildfire	Mean annual area burnt in the Eastern temperate zone[6] > 0.04%	0.04%	+50%[7], i.e. 0.06%	Y	+	H	M	L	4

The probability scores have five distinct levels (very low, low, moderate, high and very high), and correspond to the terminology detailed in the table below. The scores are balanced by the data confidence scoring (i.e. robustness of forecast). If we have a medium confidence in datasets, a penalty of -0.5 is applied to get the final score. If the confidence is low, a penalty of -1 is applied. Each probability score is then rounded to the superior integer.

SCORE	PROBABILITY	CONFIDENCE
1	**Negligible** Projected ranges in future climate are similar to historic ranges and no trend can be identified. The threshold would therefore be passed as frequently as it has been historically.	**Low (-1)** - Data source has certain shortcomings and the projections have relatively large uncertainties. - Results come from the scientific literature and the uncertainty ranges are not specified.
2	**Very Low** Projected ranges in future climate completely or significantly overlap historic baseline means and uncertainty ranges and/or do not exceed historic or design thresholds. Therefore, the probability that the threshold would be passed more frequently is very low.	

[6] Wang, X. et al. (2014). The potential and realized spread of wildfires across Canada, Global Change Biology (2014) 20, 2518–2530, doi: 10.1111/gcb.12590
[7] FLANNIGAN, M. (2020): Mike Flannigan – Fire Management Systems Laboratory. Fire and Climate Change. Consulted on September 30, 2021. Website: https://sites.ualberta.ca/~flanniga/climatechange.html, based on 2081-2100 projections of +100%.

SCORE	PROBABILITY	CONFIDENCE
3	**Low** Projected ranges in future climate significantly overlap historic baseline means and uncertainty ranges and/or do not exceed historic or design thresholds. Therefore, the probability that the threshold would be passed more frequently is low.	**Medium (-0.5)** - Data source is reliable, but the projections have relatively large uncertainties. - Data source has certain shortcomings, but projections have relatively small uncertainties. - Results come directly from the scientific literature.
4	**Moderate** Projected ranges in future climate overlap historic baseline means and lower or upper uncertainty ranges (dependant on if the trends are increasing or decreasing) and/or meet or marginally exceed historic or design thresholds. Therefore, the probability that the threshold would be passed more frequently is moderate.	
5	**High** Projected ranges in future climate overlap historic lower or upper uncertainty ranges (dependant on if the trends are increasing or decreasing) and/or exceed historic or design thresholds. Therefore, the probability that the threshold would be passed more frequently is high.	**High (-0)** - Data source is reliable. - Enough climate models have been used. - Projections have relatively low uncertainties.
6	**Very high** Projected ranges in future climate are entirely out of the range of historic baseline means and uncertainty ranges and/or significantly exceed historic or design thresholds. Therefore, the probability that the threshold would be passed more frequently is very high.	
7	**Extreme** Projected ranges in future climate are considerably out of the range of historic baseline means and uncertainty ranges and significantly exceed historic or design thresholds. Therefore, the probability that the threshold would be passed more frequently is extremely high.	

Appendix

B-3. Worksheet 3

TECHNICAL MEMO #3

CLIENT:	Town of Aurora		
PROJECT:	Town of Aurora Climate Change Adaptation Plan	**WSP Ref.:**	211-03040-00
SUBJECT:	PIEVC Worksheet #3	**DATE:**	25 April 2022
RECIPIENT:	Natalie Kehle, Town of Aurora		
FROM:	Lisa MacTavish, P.Eng.		

1 INTRODUCTION

The Town of Aurora engaged WSP to conduct a climate change adaptation plan for the infrastructure assets within the municipal boundary. The adaptation plan is informed by a climate change risk and vulnerability assessment completed using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol as it is a nationally recognized tool for assessing infrastructure risk due to climate change. This technical note presents the results of the risk assessment step (Step 3) of the PIEVC protocol prepared by WSP's team which includes a group of climate resilience specialists and Subject Matter Experts in water, parks, and asset management.

Building on the results obtained during Steps 1 and 2 of the Protocol, WSP's project team established a list of possible interactions between each of the asset sub-categories and climate trends/extreme weather events previously identified. WSP then assessed the future probability of the climate-infrastructure interactions occurring, as well as the severity of these interactions, if the defined thresholds were exceeded. The probability and severity scores were used to calculate a risk score for relevant infrastructure-climate interactions and enabled the development of a climate change risk profile of the Town of Aurora's assets.

This risk profile was subsequently validated by the Town during a virtual workshop that took place on October 29, 2021. The results from this step of the Protocol are used by WSP to formulate and prioritize the recommendations as part of the final phase of the analysis (i.e. Step 5 of the Protocol).

1.1 PREPARE STEP 3 WORKSHEET

	Enter *Yes* or *No*
a. Use this ***Worksheet***; or	Yes
b. Prepare practitioner specific documentation. i. Practitioner specific documentation ***MUST*** detail each task outlined in this step of the Protocol.	No
<u>Comments and Observations</u> The worksheet provided by the PIEVC addresses adequately every step of the Protocol and was therefore selected. The following sections present the outcomes of Worksheet 3, without mentioning each of the steps on a strict basis. However, note that each step of the Protocol (Figure 1) has been followed. A detailed methodology for Step 3 is available upon request from its owner at pievc@iclr.org.	

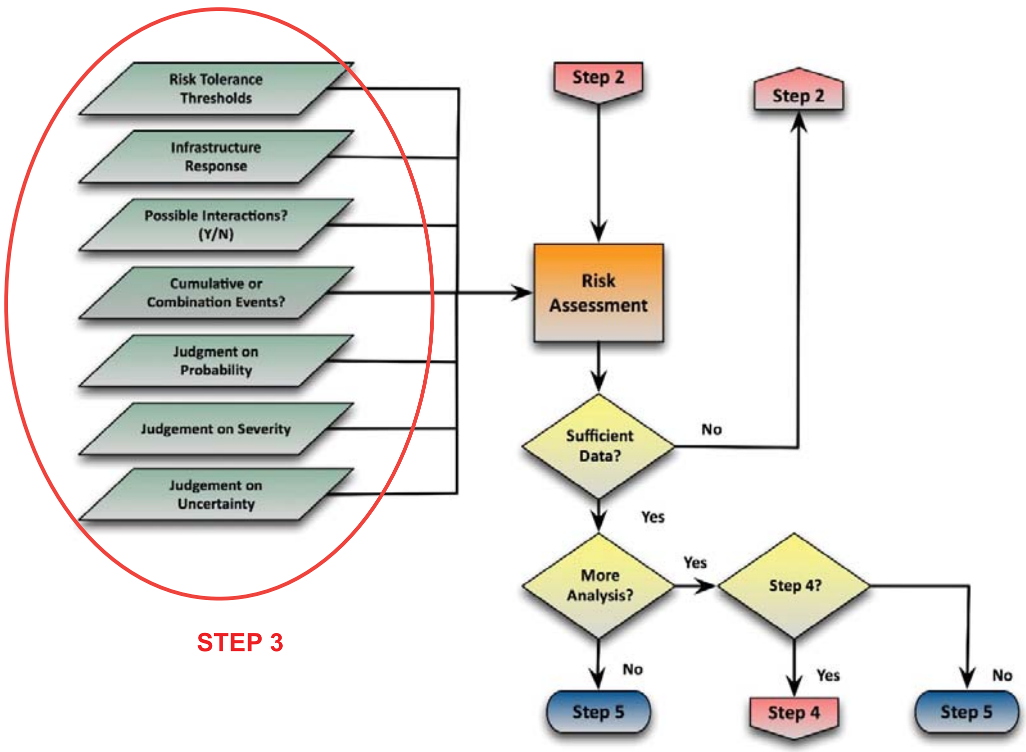

Figure 1 Step 3 Flowchart

Figure 1 details the steps undertaken as part of Step 3 of the protocol, this worksheet elaborates on the findings from Step 3 for the Town infrastructure.

2 RISK ASSESSMENT

The PIEVC Protocol defines risk as the possibility of injury, loss or negative environmental impact created by a hazard. Risk is a product of the probability of occurrence of a negative consequence and of the level of severity of this consequence. The risk assessment is then completed by answering the three following questions:

1. Which events could occur in the lifespan of the infrastructure?
2. How likely is it that these events will occur?
3. If the event happens, what are the consequences?

Thus, after determining plausible interactions between the climate and the infrastructure components and calculating probabilities that climate conditions exceed historical baselines, a vulnerability assessment is conducted to determine the severity of potential consequences. The product of the probability and the severity scores (both on a scale of 0 to 7) results in a risk score (0 to 49).

The following risk evaluation grid was used in this assessment (Table 1):

Table 1 Risk evaluation grid

Risk range	Threshold	Response
< 12	Low risk	No action necessary.
12 – 36	Low medium risk (12-25)	Action and/or an engineering analysis may be required.
	High medium risk (26-36)	
> 36	High risk	Action required.
= 7	Special Case	Requires special attention in risk assessment to determine if action is necessary.

- **Low-risk** represent no immediate vulnerability; there is minimal changing-climate vulnerability associated with the asset. No further action is required for low risks.
- **Medium-risk** interactions represent a potential vulnerability. Further engineering analysis may be necessary if there is not adequate information to provide a clear, unambiguous determination of the vulnerability. Medium risks may require mitigative action. Medium risks have been further broken down into low-medium and high-medium risks to aid in prioritization of mitigation measures.
- **High-risk** interactions represent an identified vulnerability. Mitigative actions are required to ensure the viability of the infrastructure.

Special cases will also be highlighted and carefully considered in the assessment. When a risk score of 7 is estimated, interactions with climate and the infrastructure present either:

- A very high severity and a very low probability; or
- A very low severity and a very high probability.

Special cases may warrant specific mitigative measures due to either a very severe outcome, or very high likelihood of occurrence. However, there were no special cases identified in this assessment.

For this project, the vulnerability analysis was first completed by WSP's project team, then validated with the client during a workshop. The risk profile presented in Section 4.2 is based on this preliminary assessment and was confirmed during the workshop.

3 RISK TOLERANCE AND VERIFICATION OF STEP 2 RESULTS

Risk tolerance and risk thresholds vary between organizations and individuals. It is important that organizations understand the risks associated with meeting their objectives and levels of service and make informed decisions regarding risk. Risk tolerance was discussed with the Town of Aurora to confirm alignment with their organization and operational requirements, however defining levels of service for the infrastructure assessed in this study is still underway for the Town.

Prior to the risk assessment, the Town reviewed the outcomes of Steps 1 and 2 of the Protocol. During the October 29th workshop, the Town once again confirmed that the assumptions and methodology presented were applicable to this study in this location.

4 VULNERABILITY ASSESSMENT

Vulnerability is based on the severity of the consequences from interactions between climate and various assets. Potential responses of the infrastructure can be summarized as follows:

- Structural design – i.e. safety; load carrying capacity;
- Loss of functionality – i.e. level of service; level of effective capacity; component selection;
- Serviceability – i.e. ability to conduct routine maintenance activities;
- Watershed and environmental effects – i.e. discharge quality in sensitive environments;
- Material performance – i.e. rate of degradation, capacity to achieve expected level of performance;
- Operations and maintenance – i.e. occupational safety; equipment performance; functional and effective capacity; changes from design expectation; pavement performance;
- Emergency response – i.e. procedures and systems to address severe storm events, flooding, water damage, road closures;
- Insurance considerations – i.e. rates; ability to insure; policy limitation or exclusions;
- Policy and Legal considerations – i.e. codes; guidelines; internal policies and procedures; land use planning;
- Social effects – i.e. public safety, transportation of goods to a community; accessibility to critical facilities such as hospitals, fire and police services; community business viability; public perception, reputation and interaction, archaeological resources, historically important resources and First Nations territorial impacts.

Severity is assessed following the 0 to 7 scale from Method E proposed by the PIEVC Protocol (Table 2).

Table 2 Definition of severity scores

Score	Severity of consequences and effects
0	Negligible Not Applicable
1	Very Low Some Measurable Changes
2	Low Slight Loss of Serviceability
3	Moderate Loss of Serviceability
4	Major Loss of Serviceability Some Loss of Capacity
5	Loss of Capacity Some Loss of Function
6	Major Loss of Function
7	Extreme Loss of Asset

4.1 YES/NO ANALYSIS

The first step of the risk assessment is to determine which infrastructure components could be impacted by climate hazards. This is completed through a Yes/No analysis. Infrastructure components identified in Step 2 are compared with infrastructure thresholds defined in Worksheet #2 to develop a list of possible climate-infrastructure interactions (Table 3). The interactions deemed irrelevant (i.e. not vulnerable to the climate threshold identified) in the professional judgment of WSP's project team are identified by a "N" in Table 3. Irrelevant interactions are not scored in the risk analysis. Interactions which are determined to be relevant are identified by as "Y" in Table 3. Relevant interactions are further considered and assigned risk scores.

Table 3 Results of the yes/no analysis

Climate parameters	Low winter temperature	High summer temperature	Heat waves	Low winter temperature (HDD)	High summer temperature (CDD)	Freeze-thaw cycles	Extreme short-duration precipitation	Annual Precipitation	Snow	Freezing rain	Wind	Lightning	Wildfires
Facilities													
HVAC systems	Y	Y	Y	Y	Y	N	Y	N	N	N	N	Y	Y
Building envelope systems	N	Y	Y	N	N	Y	Y	Y	N	N	Y	N	N
Building structural systems	N	N	N	N	N	Y	N	N	N	N	Y	N	N
Electrical systems	N	Y	Y	N	Y	N	N	N	N	Y	Y	Y	N
Plumbing systems	N	N	N	N	N	N	Y	Y	N	Y	N	N	N
Hardscaping	N	Y	Y	N	N	Y	Y	N	Y	Y	N	N	N
Water Network													
Water mains	Y	N	N	N	N	Y	N	N	N	N	N	N	N
Water valves	Y	N	N	N	N	Y	N	N	N	N	N	N	N
Underground enclosures	N	N	N	N	N	Y	N	N	N	N	N	N	N
Fire hydrants	N	N	Y	N	N	Y	Y	N	Y	Y	N	N	N
Service connections	Y	N	N	N	N	Y	N	N	N	N	N	N	N
Bulk water filling stations	N	N	N	N	N	Y	Y	N	N	N	N	N	N
Booster stations	N	N	N	N	N	Y	Y	N	N	Y	Y	Y	N
Sanitary Network													
Sewers	N	Y	Y	N	N	Y	Y	Y	Y	N	N	N	N
Maintenance chambers	N	N	N	N	N	Y	Y	N	N	N	N	N	N
Laterals	N	Y	Y	N	N	Y	Y	Y	Y	N	N	N	N
Equalization tanks	N	Y	Y	N	N	Y	Y	Y	Y	N	N	N	N
Pumping stations	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N

Climate parameters	Low winter temperature	High summer temperature	Heat waves	Low winter temperature (HDD)	High summer temperature (CDD)	Freeze-thaw cycles	Extreme short-duration precipitation	Annual Precipitation	Snow	Freezing rain	Wind	Lightning	Wildfires
Stormwater Network													
Sewers (stormwater)	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
Maintenance chambers (stormwater)	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
Catch basins	N	N	N	N	N	Y	Y	Y	Y	N	Y	N	N
Laterals (stormwater)	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
Oil grit separators	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
Cleanouts	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
Headwalls	N	N	N	N	N	Y	Y	N	Y	N	Y	N	N
Stormwater management ponds	N	Y	Y	N	N	N	Y	Y	Y	N	N	N	N
Equalization tanks (stormwater)	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N
Bridges and culverts	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	N
Road Network													
Pavement and curbs	Y	Y	Y	N	N	Y	Y	N	Y	Y	N	N	N
Pedestrian paths	Y	Y	Y	N	N	Y	Y	N	Y	Y	N	N	N
Road luminaires	N	N	N	N	N	Y	N	N	Y	Y	Y	Y	N
Signage	N	N	N	N	N	N	N	N	N	Y	Y	Y	N
Traffic signals	N	N	N	N	N	Y	N	N	Y	Y	Y	Y	N
Park and Natural Heritage System													
Open space and parkland	Y	Y	Y	N	N	N	Y	N	N	Y	Y	Y	N
Land associated with municipal facilities	Y	Y	Y	N	N	N	Y	N	N	Y	Y	Y	N
Land maintained for environmental purposes	Y	Y	Y	N	N	N	Y	Y	N	Y	Y	Y	N
Off-road trails	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N
Park structures	N	Y	N	N	N	Y	Y	N	N	N	Y	N	N

4.2 RISK PROFILE

The 185 relevant climate-infrastructure interactions identified in the previous section have been assessed using available data, scientific literature and the professional judgment of WSP's project team. Table 4 summarizes the results of this assessment. Of the 185 interactions assessed, 98 correspond to a low risk, 58 to a low medium risk, and 29 correspond to an opportunity. No high medium risks, high risks or special cases have been identified. These are split into the infrastructure components as shown in Table 4. Extreme short-duration precipitation and heat waves have caused the highest rated risks as a result of the high probability scoring (5) and higher consequence ratings. These risks are summarized as follows:

Heat waves

- Facilities - HVAC systems: Potential to exceed the capacity of facilities' cooling systems, which impacts the ability for facilities to act as cooling shelters.
- Park and Natural Heritage System - Land associated with municipal facilities: Playing fields may become unusable after dry and high temperature periods.

Extreme short-duration precipitation

- Sanitary Network - Sewers, Maintenance Chambers, and Laterals: Increased inflow and infiltration (I&I) may cause sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate into the system affecting capacity.
- Sanitary Network - Equalization tanks: Excess flows may enter the system, affecting capacity.
- Sanitary Network - Pumping stations: Increased I&I may cause sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate affecting capacity. The building itself may become flooded as a result of overland flows and system breakdown.
- Stormwater Network - Bridges and culverts: Exceeded capacity and debris blockages leading to flooding of surrounding areas and increased erosion. Bridges could be washed out due to extreme floods.
- Park and Natural Heritage System - Land associated with municipal facilities: Playing fields may become unusable after periods of very heavy rain.

Lightning has a slightly lower probability score but as a result of the high consequence, it also resulted in some higher rated risks. These include:

- Road Network - Traffic signals: Power outages caused by lightning strikes.
- Facilities - Electrical systems: Lightning can lead to increased power failures depending on the reliability of the local utility supply. Facilities without emergency generators may temporarily lose ability to operate, which is significant for emergency and shelter facilities.

The breakdown for each infrastructure category can be found in Table 5, Table 6, Table 7, Table 8, Table 9, and Table 10.

Table 4 Risk profile summary of the infrastructure in the Town of Aurora

Infrastructure category	Relevant interactions	Opportunities	Low risks	Low medium risks
Facilities	31	3	12	16
Water Network	19	4	12	3
Sanitary Network	29	4	12	13
Stormwater Network	47	11	24	12
Road Network	27	6	16	5
Park and Natural Heritage system	32	1	22	9
Total	**185**	**29**	**98**	**58**

4.2.1 FACILITIES

Table 5 Risk profile of the facilities infrastructure in the Town of Aurora

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT			JUSTIFICATION
		P	S	R	
FACILITIES					
HVAC Systems	Low winter temperature	3			Opportunity: Reduced demand on heating system.
	High summer temperature	4	4	**16**	Potential to exceed the capacity of facilities' cooling systems, may require replacements to meet demand.
	Heat waves	5	5	**25**	Potential to exceed the capacity of facilities' cooling systems, which impacts the ability for facilities to act as cooling shelters.
	Low winter temperature (HDD)	5			Opportunity: Reduced demand on heating system.
	High summer temperature (CDD)	5	3	**15**	Increased annual demand on cooling system, potentially leading to increased maintenance costs and energy demands.
	Extreme short-duration precipitation	5	2	**10**	Potential for water damage to equipment on poorly drained rooftops.
	Lightning	4	4	**16**	Damage to rooftop components if struck by lightning.
	Wildfires	4	4	**16**	Smoke from wildfires may impact indoor air quality in buildings and increase filter replacements.
Building envelope systems	High summer temperature	4	1	**4**	Increased deterioration of sealants around windows and metal paneling at facilities.
	Heat waves	5	1	**5**	Increased deterioration of sealants around windows and metal paneling at facilities.
	Freeze-thaw cycles	3	2	**6**	Increased deterioration to brick and sealants around windows and doors.
	Extreme short-duration precipitation	5	2	**10**	Increased ponding on rooftops may lead to accelerated deterioration or leaks to building interiors.
	Annual precipitation	2	1	**2**	Increased moisture can increase deterioration rate of brick and building envelope systems over time.
	Wind	3	6	**18**	Potential for damage to building envelope components if design wind loading is exceeded. Potential for the roof to blow off the JOC and sports dome.
Building structural systems	Freeze-thaw cycles	3	1	**3**	Increased deterioration to structures exposed to the outdoors at facilities.
	Wind	3	5	**15**	Potential for wind loads to exceed structural design capacities.

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT			JUSTIFICATION
		P	S	R	
Electrical systems	High summer temperature	4	4	**16**	Increased demand on cooling system and therefore electrical systems, potentially exceeding facility capacity.
	Heat waves	5	4	**20**	Increased demand on cooling system and therefore electrical systems, potentially exceeding facility capacity.
	High summer temperature (CDD)	5	3	**15**	Increased annual demand on cooling system and associated increase in demand on electrical system potentially leading to increased maintenance costs.
	Freezing rain	2	6	**12**	Freezing rain can lead to increased power failures depending on the reliability of the local utility supply. Facilities without emergency generators may temporarily lose ability to operate which is significant for emergency and shelter facilities.
	Wind	3	5	**15**	Windstorms can lead to increased power failures depending on the reliability of the local utility supply. Facilities without emergency generators may temporarily lose ability to operate, which is significant for emergency and shelter facilities.
	Lightning	4	5	**20**	Lightning can lead to increased power failures depending on the reliability of the local utility supply. Facilities without emergency generators may temporarily lose ability to operate, which is significant for emergency and shelter facilities.
Plumbing systems	Extreme short-duration precipitation	5	3	**15**	Precipitation may exceed rooftop drainage capacity leading to ponding on roofs, infiltration to foundation drainage systems may exceed sump pump capacities leading to flooding in basements or on ground floors.
	Annual precipitation	2	1	**2**	Increased demand on drainage systems leading to moderately increased maintenance.
	Freezing rain	2	1	**2**	Freezing rain can temporarily block roof drainage systems leading to ponding on roofs.
Hardscaping	High summer temperature	4	4	**16**	Increased deterioration of pavement and concrete slabs through rutting and/or buckling, requiring increased maintenance and decreased service life.
	Heat waves	5	3	**15**	Increased deterioration of pavements and concrete slabs through rutting and/or buckling, requiring increased maintenance and decreased service life.
	Freeze-thaw cycles	3	2	**6**	Increased deterioration of pavements, pedestrian pathways and retaining walls leading to increased maintenance requirements.
	Extreme short-duration precipitation	5	2	**10**	Rainwater may pool on pavements reducing access to facilities or lead to erosion around parking areas and pathways.
	Snow	5			Opportunity: Reduced snow clearing requirements.
	Freezing rain	2	2	**4**	Increased ice maintenance to prevent slips trips and falls.

4.2.2 WATER NETWORK

Table 6 Risk profile of the water network infrastructure in the Town of Aurora

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT P	RISK ASSESSMENT S	RISK ASSESSMENT R	JUSTIFICATION
WATER NETWORK					
Water mains	Low winter temperature	3			Opportunity: Decreased breakages caused by the freezing of water in pipes due to the milder winters resulting in decreased maintenance and replacement requirements.
	Freeze-thaw cycles	3	2	**6**	Breaking or tension in older pipes as a result of frost heave leading to increased maintenance and potential water quality impacts.
Water valves	Low winter temperature	3			Opportunity: Decreased breakages caused by the freezing of water in valves due to the milder winters resulting in decreased maintenance and replacement requirements.
	Freeze-thaw cycles	3	3	**9**	Breaking of valves as a result of frost heave leading to increased maintenance and replacement requirements. Increased deterioration (corrosion) as a result of exposure to salt from melt.
Underground enclosures	Freeze-thaw cycles	3	1	**3**	Increased deterioration (corrosion) as a result of exposure to salt from melt.
Fire hydrants	Heat waves	5	4	**20**	Increased water usage during the heat wave may affect water pressure for fire hydrants.
	Freeze-thaw cycles	3	1	**3**	Connection lines strained and potential for decreased pressure as a result of frost heave.
	Extreme short-duration precipitation	5	1	**5**	Lack of access to fire hydrants if surrounding area is flooded.
	Snow	5			Opportunity: Decreased usage of salts will mean hydrants are less affected.
	Freezing rain	2	1	**2**	Road salt applied around fire hydrants to manage freezing rain increase the rate of corrosion and overall life of hydrant.
Service connections	Low winter temperature	3			Opportunity: Decreased breakages caused by the freezing of water in pipes due to the milder winters resulting in decreased maintenance and replacement requirements.
	Freeze-thaw cycles	3	3	**9**	Breaking or tension in the pipes as a result of frost heave leading to increased maintenance and replacement requirements.
Bulk water filling stations	Freeze-thaw cycles	3	1	**3**	Increased deterioration of associated infrastructure as a result of exposure to salt from melt.
	Extreme short-duration precipitation	5	3	**15**	Potential for electrical failures as a result of flooding.
Booster stations	Freeze-thaw cycles	3	1	**3**	Increased deterioration of infrastructure as a result of expansion and contraction and exposure to salt from melt.
	Extreme short-duration precipitation	5	3	**15**	Potential for electrical failures as a result of flooding.
	Freezing rain	2	1	**2**	Temporary access limitations during a freezing rain event.
	Wind	3	2	**6**	Potential damage to structure. Risk of power outage impacting communication system.
	Lightning	4	2	**8**	Potential damage to structure. Risk of power outage impacting communication system.

4.2.3 SANITARY NETWORK

Table 7 Risk profile of the sanitary network infrastructure in the Town of Aurora

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT P	RISK ASSESSMENT S	RISK ASSESSMENT R	JUSTIFICATION
SANITARY NETWORK					
Sewers	High summer temperature	4	3	**12**	Increased corrosion leading to odour events.
	Heat waves	5	3	**15**	Increased corrosion leading to odour events.
	Freeze-thaw cycles	3	2	**6**	Breaking or tension in the pipes as a result of frost heave leading to increased maintenance and replacement requirements.
	Extreme short-duration precipitation	5	5	**25**	Increased inflow and infiltration (I&I) causing sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate into the system affecting capacity.
	Annual precipitation	2	3	**6**	Increased I&I causing sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate into the system affecting capacity.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity and resulting in sanitary backups in the system.
Maintenance chambers	Freeze-thaw cycles	3	1	**3**	Increased deterioration as a result of exposure to salt from melt.
	Extreme short-duration precipitation	5	5	**25**	Increased I&I causing sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate affecting capacity.
Laterals	High summer temperature	4	3	**12**	Increased corrosion leading to odour events.
	Heat waves	5	3	**15**	Increased corrosion leading to odour events.
	Freeze-thaw cycles	3	3	**9**	Breaking or tension in the pipes as a result of frost heave leading to increased maintenance and replacement requirements.
	Extreme short-duration precipitation	5	5	**25**	Increased I&I causing sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate affecting capacity.
	Annual precipitation	2	3	**6**	Increased annual I&I causing sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate affecting capacity. Consequences of chronic increase are lower than for acute events.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity and resulting in sanitary backups in the system.

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT			JUSTIFICATION
		P	S	R	
Equalization tanks	High summer temperature	4	3	**12**	Increased corrosion leading to odour events.
	Heat waves	5	3	**15**	Increased corrosion leading to odour events.
	Freeze-thaw cycles	3	1	**3**	Increased deterioration as a result of exposure to salt from melt.
	Extreme short-duration precipitation	5	5	**25**	Excess flows may enter the system, affecting capacity.
	Annual precipitation	2	3	**6**	Excess flows may enter the system, affecting capacity.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity and resulting in sanitary backups in the system.
Pumping stations	High summer temperature	4	3	**12**	Increased corrosion leading to odour events. Increased potential for cooling requirements to maintain equipment.
	Heat waves	5	3	**15**	Increased corrosion leading to odour events. Increased potential for cooling requirements to maintain equipment.
	Freeze-thaw cycles	3	1	**3**	Increased deterioration of infrastructure as a result of expansion and contraction and exposure to salt from melt.
	Extreme short-duration precipitation	5	5	**25**	Sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate affecting capacity. The building itself may become flooded as a result of overland flows and system breakdown.
	Annual precipitation	2	4	**8**	Sanitary backups in the system impacting users and leading to wastewater in the environment. Groundwater may infiltrate affecting capacity. The building itself may become flooded as a result of overland flows and system breakdown.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity and resulting in sanitary backups in the system.
	Freezing rain	2	1	**2**	Temporary access limitations during a freezing rain event.
	Wind	3	2	**6**	Potential damage to structure. Risk of power outage impacting communication system.
	Lightning	4	2	**8**	Potential damage to structure. Risk of power outage impacting communication system.

4.2.4 STORMWATER NETWORK

Table 8 Risk profile of the stormwater network infrastructure in the Town of Aurora

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT			JUSTIFICATION
		P	S	R	
STORMWATER NETWORK					
Sewers	Freeze-thaw cycles	3	2	**6**	Breaking or tension in the pipes as a result of frost heave leading to increased maintenance and replacement requirements.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
	Annual precipitation	2	3	**6**	Exceeded capacity leading to flooding in the system. Operating at higher capacities can lead to faster deterioration of infrastructure.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
Maintenance chambers	Freeze-thaw cycles	3	1	**3**	Increased deterioration as a result of exposure to salt from melt.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
	Annual precipitation	2	3	**6**	Exceeded capacity leading to flooding in the system. Operating at higher capacities can lead to faster deterioration of infrastructure.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
Catch basins	Freeze-thaw cycles	3	2	**6**	Increased requirement of maintenance and cleaning as a result of debris and ice buildup causing blockages.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
	Annual precipitation	2	3	**6**	Exceeded capacity leading to flooding in the system. Operating at higher capacities can lead to faster deterioration of infrastructure.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
	Wind	3	3	**9**	Localised flooding caused by debris and blockages.
Laterals	Freeze-thaw cycles	3	2	**6**	Breaking or tension in the pipes as a result of frost heave leading to increased maintenance and replacement requirements.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity leading to flooding in the system.
	Annual precipitation	2	3	**6**	Exceeded capacity leading to flooding in the system. Operating at higher capacities can lead to faster deterioration of infrastructure.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
Oil grit separators	Freeze-thaw cycles	3	2	**6**	Increased deterioration as a result of exposure to salt from melt.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
	Annual precipitation	2	3	**6**	Exceeded capacity leading to flooding in the system. Operating at higher capacities can lead to faster deterioration of infrastructure.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT			JUSTIFICATION
		P	S	R	
Cleanouts	Freeze-thaw cycles	3	1	**3**	Increased deterioration as a result of exposure to salt from melt.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
	Annual precipitation	2	3	**6**	Exceeded capacity leading to flooding in the system. Operating at higher capacities can lead to faster deterioration of infrastructure.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
Headwalls	Freeze-thaw cycles	3	2	**6**	Increased deterioration as a result of exposure to salt from melt. Increased requirement of maintenance and cleaning as a result of debris buildup.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system. Bank stability issues and washout around headwalls causes by higher flows.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
	Wind	3	3	**9**	Localised flooding caused by debris and blockages.
Stormwater management ponds	High summer temperature	4	4	**16**	Increased evaporation due to high temperatures can result in a decreased functionality of wet ponds.
	Heat waves	5	4	**20**	Increased evaporation due to prolonged high temperatures can result in a decreased functionality of wet ponds.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity leading to washouts, collapsed berms and the flooding of surrounding areas. Reduced capacity to manage sediment.
	Annual precipitation	2	4	**8**	Exceeded capacity leading to less active storage and fuller ponds with higher risk of overtopping and flooding.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
Equalization tanks	Freeze-thaw cycles	3	1	**3**	Exposure to salt from melt can increase deterioration.
	Extreme short-duration precipitation	5	4	**20**	Exceeded capacity and debris blockages leading to flooding in the system.
	Annual precipitation	2	3	**6**	Exceeded capacity leading to flooding in the system. Operating at higher capacities can lead to faster deterioration of infrastructure.
	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
Bridges and culverts	Low winter temperature	3			Opportunity: Decreased salting and maintenance requirements as a result of milder winters.
	High summer temperature	4	2	**8**	Rutting and buckling of the pavement on the bridges and culvert crossings resulting in increased maintenance requirements.
	Heat waves	5	2	**10**	Rutting and buckling of the pavement on the bridges and culverts resulting in increased maintenance requirements.
	Freeze-thaw cycles	3	3	**9**	Increased deterioration as a result of exposure to salt from melt and expansion and contraction from freeze-thaw. Ice blockages in culverts can cause backups in the system and physical damage.
	Extreme short-duration precipitation	5	5	**25**	Exceeded capacity and debris blockages leading to flooding of surrounding areas and increased erosion. Bridges could be washed out due to extreme floods.
	Annual precipitation	2	3	**6**	Increased erosion around bridges and culverts due to higher water levels.

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT P	S	R	JUSTIFICATION
Bridges and culverts	Snow	5			Opportunity: Decreased snowmelt events affecting capacity of the system.
	Freezing rain	2	4	**8**	Bridge decks usually reach the freezing temperature before the adjacent roads, leading to hazardous surface conditions in freezing rain/ice storms.
	Wind	3	3	**9**	Localised flooding caused by debris and blockages. Potential damage to structures from the wind load.

4.2.5 ROAD NETWORK

Table 9 Risk profile of the road network infrastructure in the Town of Aurora

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT P	S	R	JUSTIFICATION
ROAD NETWORK					
Pavement and curbs	Low winter temperature	3			Opportunity: Decreased salting and maintenance requirements as a result of milder winters.
	High summer temperature	4	2	**8**	Rutting and buckling of the pavement resulting in increased maintenance requirements.
	Heat waves	5	2	**10**	Rutting and buckling of the pavement resulting in increased maintenance requirements.
	Freeze-thaw cycles	3	3	**9**	Damage to pavement and concrete caused by expansion and contraction, resulting in increase pothole formation.
	Extreme short-duration precipitation	5	3	**15**	Temporary loss of access due to flooding. Erosion and washouts resulting in increased clearing and maintenance required.
	Snow	5			Opportunity: Decreased requirement for snow clearing and maintenance.
	Freezing rain	2	4	**8**	Increased salting and maintenance requirements. Higher risks of accidents which can cause delays and blockages.
Pedestrian paths	Low winter temperature	3			Opportunity: Decreased salting and maintenance requirements as a result of milder winters.
	High summer temperature	4	2	**8**	Rutting and buckling of the path resulting in increased maintenance requirements.
	Heat waves	5	2	**10**	Rutting and buckling of the path resulting in increased maintenance requirements.
	Freeze-thaw cycles	3	4	**12**	Trip hazards and loss of accessibility to sidewalks caused by heaving and ground shift as a result of freeze thaw cycles. Damage to concrete caused by expansion and contraction.
	Extreme short-duration precipitation	5	4	**20**	Temporary loss of access. Erosion and washouts resulting in increased clearing and maintenance required.
	Snow	5			Opportunity: Decreased requirement for snow clearing and maintenance.
	Freezing rain	2	4	**8**	Increased salting and maintenance requirements. Temporary loss of access during events.

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT			JUSTIFICATION
		P	S	R	
Road luminaires	Freeze-thaw cycles	3	2	**6**	Damage to posts or concrete base caused by expansion and contraction of metal over time.
	Snow	5			Opportunity: Decreased corrosion from salt and damage from snowploughs.
	Freezing rain	2	2	**4**	Deterioration from salt and damage from snow ploughs.
	Wind	3	1	**3**	Damage to the luminaires and power lines servicing the luminaires caused by the wind. Potential for increased wind induced vibration leading to cracking over time.
	Lightning	4	1	**4**	Power outages caused by lightning strikes.
Signage	Freezing rain	2	2	**4**	Icing over of signs causing safety hazards and increased maintenance requirements.
	Wind	3	1	**3**	Damage caused by wind.
	Lightning	4	1	**4**	Damage and power outages caused by lightning strikes.
Traffic signals	Freeze-thaw cycles	3	2	**6**	Damage to posts or concrete base caused by expansion and contraction of metal over time.
	Snow	5			Opportunity: Decreased corrosion from salt and damage from snowploughs.
	Freezing rain	2	6	**12**	Icing over of signs causing safety hazards and increased maintenance requirements. Power outages caused by ice-related downed power lines can last for multiple days.
	Wind	3	2	**6**	Damage to the luminaires and power lines servicing the luminaires caused by the wind.
	Lightning	4	6	**24**	Power outages caused by lightning strikes.

4.2.6 PARK AND NATURAL HERITAGE SYSTEM

Table 10 Risk profile of the park and natural heritage system infrastructure in the Town of Aurora

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT			JUSTIFICATION
		P	S	R	
PARK AND NATURAL HERITAGE SYSTEM					
Open space and parkland	Low winter temperature	3	3	**9**	Invasive species such as the gypsy moth could impact vegetation if temperatures are warm enough throughout the winter for them to survive.
	High summer temperature	4	2	**8**	Vegetation dieback and increased watering or replacement of vegetation required.
	Heat waves	5	2	**10**	Vegetation dieback and increased watering or replacement of vegetation required.
	Extreme short-duration precipitation	5	2	**10**	Washout of vegetation, erosion of soil, exposure of roots and damage to trees and vegetation.
	Snow	5	3	**15**	Decreased snow available for ice making for the outdoor ice rinks.
	Freezing rain	2	1	**2**	Replacement of vegetation required as a result of damage to the trees and plants caused by the ice.
	Wind	3	3	**9**	Replacement and maintenance of vegetation required as a result of damage to trees and plants. Debris can also cause physical hazards.
	Lightning	4	3	**12**	Replacement and maintenance of vegetation required as a result of damage to trees and plants. Debris can also cause physical hazards.
Land associated with municipal facilities	Low winter temperature	3	3	**9**	Invasive species such as the gypsy moth could impact vegetation if temperatures are warm enough throughout the winter for them to survive.
	High summer temperature	4	5	**20**	Playing fields may become unusable after dry and high temperature periods.
	Heat waves	5	5	**25**	Playing fields may become unusable after dry and high temperature periods.
	Extreme short-duration precipitation	5	5	**25**	Playing fields may become unusable after periods of very heavy rain.
	Freezing rain	2	1	**2**	Replacement of vegetation required as a result of damage to the trees and plants caused by the ice.
	Wind	3	3	**9**	Replacement and maintenance of vegetation required as a result of damage to trees and plants. Debris can also cause physical hazards.
	Lightning	4	3	**12**	Replacement and maintenance of vegetation required as a result of damage to trees and plants. Debris can also cause physical hazards.
Land maintained for environmental purposes	Low winter temperature	3	3	**9**	Invasive species such as the gypsy moth could impact vegetation if temperatures are warm enough throughout the winter for them to survive.
	High summer temperature	4	3	**12**	Vegetation dieback and increased watering or replacement of vegetation required.
	Heat waves	5	3	**15**	Vegetation dieback and increased watering or replacement of vegetation required.
	Extreme short-duration precipitation	5	3	**15**	Washout of vegetation, erosion of soil, exposure of roots and damage to trees and vegetation.
	Annual precipitation	2	4	**8**	Impact to the viability of the ecosystem.

COMPONENT	CLIMATE PARAMETER	RISK ASSESSMENT			JUSTIFICATION
		P	S	R	
Land maintained for environmental purposes	Freezing rain	2	1	**2**	Replacement of vegetation required as a result of damage to the trees and plants caused by the ice.
	Wind	3	3	**9**	Replacement and maintenance of vegetation required as a result of damage to trees and plants. Debris can also cause physical hazards.
	Lightning	4	3	**12**	Replacement and maintenance of vegetation required as a result of damage to trees and plants from lightning or resultant forest fires. Debris can also cause physical hazards.
Off-road trails	Freeze-thaw cycles	3	1	**3**	Potential for increased pothole formation in paved surfaces (short sections) resulting in increased maintenance for both trails and in particular for trail bridges that are typically boardwalks. Decreased quality in cross country skiing surface in winter.
	Extreme short-duration precipitation	5	2	**10**	Washout of gravel surfaces, local vegetation, erosion of soil, exposure of roots and damage to trees and vegetation.
	Annual precipitation	2	1	**2**	Increased maintenance required due to the washout of material.
	Wind	3	2	**6**	Increased maintenance and clearing of paths required. Potential for debris accumulation at bridge/boardwalks over watercourses.
	Lightning	4	2	**8**	Increased maintenance and clearing of paths required.
Park structures	High summer temperature	4	1	**4**	Degradation of plastics as a result of UV radiation.
	Freeze-thaw cycles	3	1	**3**	Increased deterioration of infrastructure caused by expansion and contraction.
	Extreme short-duration precipitation	5	1	**5**	Temporary loss of recreational use due to access limitations.
	Wind	3	1	**3**	Damage to structures from falling branches.

5 DATA SUFFICIENCY

5.1 CLIMATE INFORMATION

Most of the climate information available was of very good quality and there is high confidence in the data presented in this report. Historical data from Environment and Climate Change Canada is precise and accurate. The climate change information portals consulted present the most up-to-date information on anticipated climate trends.

Projected changes in Intensity-Duration-Frequency (IDF) curve data with the help of the IDF_CC tool[1] and scientific literature is currently the best way to assess the likelihood of heavy rain events in eastern Canada, although sub-daily climate modeling is evolving. When more sub-daily simulation from regional models are available, climate projections for short duration extreme precipitation events will be more accurate.

No data is available for climate projection of wind characteristics at the regional scale. However, a peer-reviewed article on the projected trends in the frequency and magnitude of strong wind episodes coupled with historical data from a local weather station provided sufficient information about wind characteristic to assess the likelihood of triggering the thresholds. Local-scale projections for lightning, snow, freezing rain, and tornadoes are also unavailable. Data from scientific literature has been used to robustly complete the assessment.

5.2 INFRASTRUCTURE INFORMATION

WSP's project team had access to all required reports and plans, including the Town of Aurora's Asset Management Plan. Discussions with the stakeholders from the Town also gave valuable insight into past events, key concerns and current adaptation measures.

Given the scale of the assessment, it was not possible to use thresholds based on design codes and therefore the historical climate baseline was used. No other data gaps were identified. Therefore, the project team deemed it had sufficient data to conclude the assessment and issue recommendations (Step 5).

6 ENGINEERING ANALYSIS

Where there is potentially high risk and high uncertainty, an Engineering Analysis (Step 4 of the PIEVC Protocol) allows the practitioner to assess the impact of projected climate change loads on the infrastructure capacity. This may be required when existing information does not provide a sufficient basis to evaluate vulnerability, and where further analysis would reduce the uncertainty of the evaluation. Step 4 of the Protocol takes a different perspective on climate-infrastructure interaction and may include a load versus capacity assessment and detailed calculations for direct comparison. Through review of the risk register, it was determined that an engineering analysis to determine the quantitative impact of the projected climate change loads was not warranted in this assessment.

7 NEXT STEPS

Discussions, recommendations, adaptation measures and conclusions are all provided in the Climate Change Adaptation Plan report which summarizes the project process and results.

[1] Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change developed by Western University (https://www.idf-cc-uwo.ca/home).

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