



Town of Oxford

Main Street Climate Hazard and Feasibility Analysis



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1 Executive Summary

The Town Oxford, situated within Cumberland County in Nova Scotia, faces growing risks due to climate change. A multi-hazard climate assessment was completed as part of the FCM Municipal Asset Management Program in 2021, which identified several key issues, such as riverine flooding from River Philip and Black River, risks to health and wellness from extreme heat events, water supply risks from extended drought periods, fire risk from insufficient flow and pressure for some areas of Town and flood risk along Main Street from undersized stormwater infrastructure connected to flood prone watercourses.

Based on the timeline of these risks, current funding availability and municipal ability to support projects, the Town has elected to address the immediate risk of flooding on Main Street. Current precipitation events cause flooding near the Town Hall and the Black River bridge, which impacts resident's ability to access pedestrian routes as well as access for emergency vehicles that need to cross the bridge. Extreme events will cause these issues, as well as risk flooding properties along the street and increasing inflow to the sanitary sewer system. Without adequate overland flow paths for surface runoff to escape, there is a greater risk of catastrophic erosive failure as runoff flows from the street to Black River over its banks. Increase in precipitation from climate change will increase the frequency and magnitude of flooding events.

This climate hazard analysis assesses Oxford's current and projected exposure to climate-related hazards for the Main Street resurfacing and stormwater upgrade. Using local climate datasets, this analysis evaluates vulnerabilities and presents adaptation options relevant to Oxford's unique setting.

This report aims to:

- *Quantify climate hazards for Oxford's high-risk infrastructure.*
- *Identify design targets that will impact design of adaptation projects.*
- *Provide project options and coordinate option assessments.*

Through climate projections, infrastructure vulnerability assessments, and adaptation strategies, this report will provide options for Oxford to enhance community resilience. An options analysis compares traditional and nature-based solutions to determine the most effective mitigation measures. Key findings and recommendations are presented in the tables below.

Finding	Details
The 150 mm storm sewer is undersized for modern design standards.	Installed in 1992, the storm sewer was likely designed for no greater than a 5-year return period storm event based on historical data at that time. It predates climate change considerations in stormwater management.
Inadequate overland flow paths.	When runoff exceeds storm sewer capacity, the street acts as an overland channel to convey flow. There are no planned relief points for this overland flow, causing ponding in front of Town Hall at the Black River Bridge.
Erosion potential	Overland flow that overtops the street corridor are conveyed to the rivers over unprotected land, increasing risk of rapidly compounding erosion and potential catastrophic failure of banks in extreme storm events.

Recommendation	Details	Time Horizon
Conduct a detailed topographic survey.	Verify preferential overland flow paths.	Immediate
Replace the storm sewer.	Replace the storm sewer with a minimum 300-millimeter pipe for the section of Main Street from Hanlon to Water Street to convey at least the 10-year, climate adjusted return period based on IPCC SSP5-8.5 climate projections.	Immediate
Develop overland flow paths.	Include overland flow paths, either by confirming stability under expected flow for storms that may exceed the 100-year return period, or by including adequate surface inlets and conveyance pipes for the section of storm sewer from Water Street to the Black River outlet.	Immediate
Reduce paved area and include low-impact development features in the streetscape.	From at least the post office to Water Street, reduce the large paved area, which is in excess of Transportation Association of Canada (TAC) recommended lane widths, to standard 3.6m lanes. Add rain gardens at catch basin locations and change parking areas to permeable pavers.	Immediate

This report was developed through the Climate Ready Infrastructure Services (CRIS) program funded by Housing, Infrastructure and Communities Canada (HICC) to support the Town of Oxford in preparing for long-term climate resilience.



2 Introduction

This report examines how the Town of Oxford, can reduce or adapt to the impacts of climate change on Main Street in the downtown centre. Drawing from local data, previous reports, and national climate projections, the assessment identifies present and future hazards and outlines adaptation options.

As part of the Climate Ready Infrastructure Services (CRIS) program, Housing, infrastructure and Communities Canada (HICC) is providing communities with access to a Climate Roster of Experts. This is part of Canada's Climate Toolkit for Housing and Infrastructure, offering infrastructure owners and practitioners access to a curated list of technical experts who can provide targeted advice on integrating climate resilience and net-zero considerations into projects. This report supports early planning and decision-making to help ensure infrastructure is designed for long-term sustainability and climate adaptation.

Climate change poses significant challenges to Nova Scotian communities, particularly in terms of coastal erosion, flooding, extreme heat, and infrastructure vulnerabilities. This report provides a detailed, community-specific climate risk assessment and adaptation strategy for Oxford.

This report consolidates information from past relevant reports and enhances our understanding of climate change by incorporating uncertainties and scenarios from the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), climatedata.ca, PCIC (Pacific Climate Impacts Consortium), and historical weather trend data to assess present and future vulnerabilities.

Each section of this report provides in-depth analysis on climate risks, projected impacts, and adaptation strategies, ensuring that local municipalities have the necessary data to inform policy decisions, infrastructure investments, and climate resilience planning.

The goals of this report include:

- Identifying and quantifying current climate hazards and projected future risks under different warming scenarios affecting coastal roads and critical infrastructure.
- Exploring flexible options to reduce or mitigate these risks while avoiding maladaptation.
- Empowering the Town with the information needed to make informed decisions and implement adaptations that align with community needs.

2.1 Background

Oxford, Nova Scotia, is a small town connected within Cumberland County. The Main Street in Oxford is part of Highway 321, a crucial regional link that has experienced flooding in the downtown area during relatively low precipitation events in relation to the long-term potential for rainfall. The increasing frequency and intensity of storms due to the early impacts of climate change have made flooding more pronounced in the years since 2000. Increasing precipitation amounts pose an ongoing and increasing threat to Oxford's accessibility and infrastructure. The Town has been actively discussing measures to protect this essential connection, with concerns about both its performance and place in the Town's urban plan.

Oxford faces a difficult balancing act, protecting its only mainland connection from the growing threats of climate change while ensuring that it focuses on projects that are possible to deliver within the current funding regime and community support for project delivery. Based on strong community support for Main Street renewal and the immediate potential for project development under current funding programs and anticipated project cost, Oxford has elected to proceed with a stormwater renewal and streetscape redesign as a priority while it pursues funding for water system upgrades also needed for climate resilience, but with much larger cost investment required.

2.2 Objectives

This Climate Hazard Analysis aims to:

- Identify key climate risks and vulnerabilities.
- Identify current and projected climate hazards affecting Oxford's Main Street
- Analyze how these hazards will evolve under different climate scenarios
- Compare adaptation intervention measures under different climate scenarios
- Conduct an options analysis of mitigation strategies.

2.3 Key Terms

This section defines essential terms used throughout the report to ensure clarity and consistency. These terms are critical to understanding the concepts, methodologies, and discussions presented. Where applicable, definitions are based on industry standards, regulatory guidelines, or established best practices.

Term	Definition
1-in-100-year Event	A statistical term describing an event (e.g., flood) with a 1% chance of occurring in any given year—not once every 100 years.
Asset Exposure	The presence of an infrastructure asset where a climate hazard may occur.
Asset Response Capacity	The capacity for an infrastructure asset to accommodate a hazard event.
Climate Hazard	A combination of climate variables and climate events which pose a potential source of harm to people, infrastructure or ecosystems.
Climate Variable	Individual aspects of climate for which trends may vary over time (e.g. temperature, precipitation).
Confidence Tier	A level of scientific certainty associated with a climate projection. Higher tiers have more supporting data and stronger consensus.
Consequence	The impact or outcome of a climate hazard vulnerability scenario as defined by the AIM Consequence of Failure matrix (see Appendix A)
Design Horizon	The expected lifetime of infrastructure for which climate conditions must be considered in planning and design. Often 25–100 years.
Freeze-Thaw Cycle	A weather pattern where water freezes and thaws repeatedly, which can cause cracking and shifting in roads and infrastructure.
Maladaptation	An adaptation action that unintentionally increases vulnerability to climate impacts elsewhere or in the future. Example: hardening one shoreline might worsen erosion downstream.
Nature-Based Solution (NBS)	An approach to infrastructure that uses natural systems or processes like dunes, vegetation, or wetlands to reduce risk and build resilience.
Probability	The likelihood of a vulnerability scenario occurring because of a climate hazard in each time horizon.
Risk	The combination of the probability and consequence of a vulnerability scenario.
Vulnerability Scenario	A scenario used in the climate hazard analysis process that illustrates a degree of harm that may occur as the result of an asset’s response to a climate hazard.



3 Cross-Function Government Response

3.1 The Need for a Coordinated Government Response

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC6) highlights the urgent need for a coordinated response to climate risks across all levels of government. Since climate change affects systems beyond jurisdictional boundaries, local, regional, and national governments must work together, not in silos, to plan and act. Fragmented governance and lack of collaboration among different levels of government can delay climate adaptation and reduce the effectiveness of disaster response.

To address these challenges, governments must develop integrated frameworks that enable cohesive decision-making across various sectors, including infrastructure, health, environmental protection, and economic development.

Because financial and human resources to address these risks are limited, all levels of government need to find smart and flexible ways to deal with these problems as they become more certain in the future. A well-coordinated approach ensures the efficient allocation of resources, reduces duplication of efforts, and enhances the overall resilience of communities facing climate threats.

3.2 The Urgency of Rapid Response

IPCC6 emphasizes the growing urgency for governments to act swiftly to mitigate and adapt to climate change impacts. As climate risks become more pronounced and frequent—such as extreme weather events, rising sea levels, and ecosystem degradation—delays in response can lead to irreversible damage and escalating costs. The report highlights that early, proactive intervention is significantly more cost-effective than reactive measures taken post-disaster.

Rapid response mechanisms must include clear risk assessment methodologies, emergency planning, and scalable mitigation strategies to ensure timely and effective actions at all levels of governance. Governments must embrace adaptive management strategies that allow for flexibility and swift modifications as new climate risks emerge. Additionally, leveraging technology and data-driven approaches can significantly enhance the speed and effectiveness of decision-making in emergency situations.

3.3 Organizational Capacity and Capacity Gaps

IPCC6 also acknowledges significant gaps in organizational capacity that impede the implementation of climate adaptation and resilience strategies. Many governments, particularly at the local level, face limitations in financial resources, technical expertise, and institutional structures necessary for effective climate action. These capacity gaps result in delays in policy implementation and reduced effectiveness of climate programs.

To address these issues, IPCC6 suggests investing in workforce development, fostering cross-sectoral partnerships, and leveraging technology to enhance data-driven decision-making. Capacity-building initiatives should focus on training government officials, improving interagency communication, and ensuring that climate adaptation policies are informed by the latest scientific research. Additionally, financial support mechanisms, such as international climate funds and public-private partnerships, can help bridge resource gaps and enhance overall governance effectiveness in responding to climate change challenges.

3.4 Conclusion

Given the interconnected nature of climate risks, governments at all levels must adopt a cross-functional approach, prioritize rapid response measures, and address capacity limitations through targeted investments in institutional strengthening. By following the guidance outlined in IPCC6, policymakers can enhance resilience, reduce vulnerabilities, and build a more sustainable future in the face of evolving climate challenges.



4 Climate Hazard Analysis Methodology

This Climate Hazard Analysis is a high-level screening process for a selected asset or group of assets that have been identified as being exposed to one or more climate hazards. The process for this analysis is shown below, with further details provided in **Appendix A**.

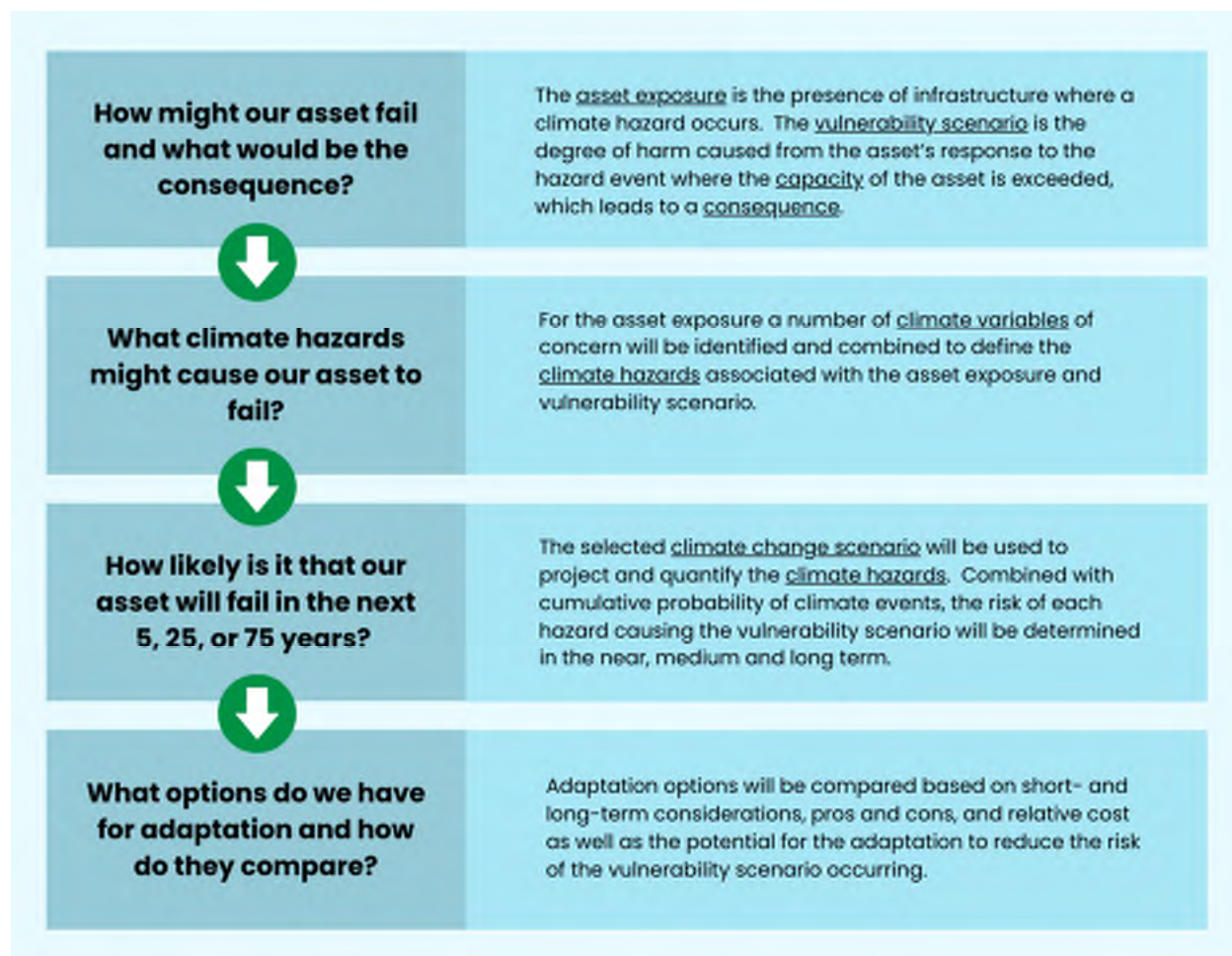


Figure 4-1 Climate Hazard Analysis Process Overview

For this analysis, a combination of the **SSP5-8.5 and SSP2-4.5 Shared Socio-Economic Pathways Scenario** under difference time horizons has been selected as the basis for climate projections used in this analysis. As the selected project option progresses to conceptual design the Town will need to consider the risks of maladaptation and complete more rigorous analysis to select an appropriate climate scenario for projections. More information on climate projections can be found in **Appendix B**.

This analysis considers the probability of the asset vulnerability scenario occurring on three different time horizons: near-term (within the next five years), medium term (within the next 25 years) and long term (within the next 75 years). The climate hazard projections generated using the selected climate scenario are used to predict the probability of the asset vulnerability scenario occurring at each of these time horizons. This probability includes the cumulative probability of a climate event occurring within the specified time horizon, if a specific event is associated with the hazard (e.g. storm surge).

For each climate hazard, the risk of the vulnerability scenario is evaluated at each of the three time horizons by combining the consequence with the probability. Adaptation options are then considered and compared based on the projected cost, pros and cons, and the potential to reduce risk.

In addition, several other climate variables will pose an operational strain on the assets, increasing maintenance demands and increase the degradation rate of the asset. Recommendations to monitor and intervene will be made.



5 Project Site

5.1 Project Description

The section of Main Street (Highway 321) considered in this study is a 370-metre section from Hanlon Street to the Black River outfall north of water street. This section is where flooding has been experienced and includes the downtown area of Oxford, including the Town Hall.

Historical staff accounts and recent observations confirm that the stormwater system on this section of Main Street is not functioning as intended. Flood events from 2000 to present have ranged from minor pedestrian impacts to flooding that could impact the passage of emergency vehicles.

These are signs of a system that was built to older standards that is inadequate to provide acceptable levels of service under the impact of climate change. With increased precipitation being one of the more accelerated effects of climate change, this project is a top priority for the Town.

5.2 Background Document Review

Background information was reviewed as part of this analysis:

- AIM Network Asset Management Climate Multi-Hazard Analysis
- Nova Scotia flood hazard mapping for Black River and River Philip
- Staff reports of flood events since 2000

5.3 Asset Vulnerability and Consequence of Failure

In accordance with CSA standards and IPCC recommendations, this report examines two scenarios for climate impacts, an average and worst-case scenario, represented by IPCC Assessment Report 6 SSP2-4.5 median and SSP5-8.5 worst case scenarios. Details are presented in Figure 5-1. These vulnerability scenarios have been assessed using Consequence of Failure Matrix presented in Appendix A.

 Climate Hazard and Vulnerability Definition for Selected Asset(s)			
This process is in consultation with the municipal staff and Council to determine the selected asset's response to a climate hazard based on infrastructure design parameters. Vulnerability and Consequence of failure to be determined in discussions with municipal staff and Council.			
Selected Asset (Exposure)	Asset Vulnerability Scenario	Vulnerability Consequence Ranking	Consequence of Failure notes
Main Street	Extreme flood inundation (1:100 year storm) overtops road corridor, causing building flooding and eroding the bank at Black River, potentially preventing emergency vehicles from accessing areas of Town	5	The consequence of this failure scenario is catastrophic in terms of safety, economic, equity impact.
	Minor flood inundation (<1:100 year storm) causes flooding that slows but does not prevent emergency vehicle access, localized flooding prevents pedestrian and vehicle access on Highway 321	3	The consequence of this failure scenario is significant in terms of safety, economic, equity impact.

Figure 5-1: Climate Hazard Consequence of Failure



6 Climate Change Variables of Concern

For Oxford, the following climate variables of concern have been identified. Two climate scenarios are presented for all variables. The **Average**, which represents the SSP2-4.5 (50th percentile), and the **Extreme**, which represents the SSP5-8.5 (83rd percentile). Further details on climate projections basis are presented in Appendix B.

6.1 Temperature

Temperature variables show a clear increase in temperature trends that are expected to increase as climate change effects become more pronounced in the coming decades. Increased frequency of hot days and increase in mean temperature can decrease the life of roadway surfaces as asphalt becomes more pliable in heat and is subject to heavy traffic loading. However, this is expected to be a minimal impact over the approximate 25-year life of any new roadway surface. Climate predictions indicate that the number of annual freeze-thaw cycles is expected to decrease with climate change. Freeze-thaw cycles cause heaving in the road embankment and decrease the life of the roadway. The decrease in number of freeze-thaw cycles is expected to have a minor, but positive effect on roadway expected life.

Warmer temperatures need to be considered in any nature-based design to ensure viability as average temperatures increase.

Temperature can also impact the viability of intertidal and terrestrial vegetation. Because modern hybrid engineering approaches seek to use nature-based solutions like sea grass, dune grass and deep rooting embankment vegetation as an integral part of resiliency design, the proposed design will need to consider species that are resistant to projected changes in average annual and maximum temperatures over the next century.

Scenario	1850-1900	1994-2015	2030	2050	2100
Average	0	0.85	1.50	2.00	2.70
Extreme			1.77	2.72	5.10

Table 6-1: Temperature Projections

6.2 Precipitation

Precipitation, both in annual total precipitation and intensity of short duration storms is increasing. This increases the rate of runoff from paved surfaces during short duration storms and can increase the period of road saturation during prolonged rainfall events. Saturated road bases contribute to premature degradation of asphalt surfaces and road life.¹ Subdrains should be included in the roadway, particularly around any low impact development features that may cause water to infiltrate into the roadway structure.

Changes in rainfall patterns may impact road life and maintenance needs for the causeway road.

As with the discussion under temperature, any nature-based installations will need to consider changes in precipitation, both from increased annual rainfall and longer and more frequent dry periods. Vegetation will need to be resilient to periodic prolonged saturation as well as summer drought periods.

Scenario	1971-2000	2000-2030	2020-2050	2070-2100
Average	51mm	54mm (+6%)	56mm (+10%)	59mm (+16%)
Extreme		59mm (+16%)	63mm (+24%)	70mm (+37%)

Table 6-2: Precipitation Projections

6.3 Other Variables

Other climate variables were considered but were not deemed to be relevant to adaptation projections for this project, such as wind energy, lightning strikes, drought, extreme heat and ice accretion.

However, related impacts from increased precipitation were assessed for project impact.

➤ **Inland Flooding:**

The project is outside the 2100 projected flooding extents of all local watercourses as shown in the Province of Nova Scotia coastal flood hazards, which includes inland flooding estimates for Black River and the River Philip through Oxford.

➤ **Increased lightning strikes:**

Increased lightning strikes are not expected to have any impact on project performance.

➤ **Extreme Heat & Drought:**

Increased temperatures and extended dry periods will increase the frequency and spread of forest fires in the area, but this is not expected to be a factor in roadway design, outside of installing rain garden vegetation and streetscape trees that will not increase fire risk through maladaptation.

➤ **Ice Accretion:**

Warmer winters will increase the likelihood of temperatures being near zero degrees which is expected to increase the frequency and amount of ice accretion from freezing rain. This may lead to increased operational requirements for de-icing the roadway, and suggests that salt resistant, native species should be selected for low impact development features like rain gardens.

¹ Guthrie, W. S., & Worel, B. (2007). Moisture Sensitivity of Asphalt Pavements: A National Seminar (FHWA Report No. FHWA-HIF-07-046). Federal Highway Administration



7 Climate Hazard Analysis Results

To systematically evaluate and manage the climate hazards facing Oxford, a structured rubric was applied to prioritize exposures based on their level of risk. This rubric considers both the likelihood that a hazard will occur and the consequence of its impacts if it does. Each hazard is scored against standardized criteria, ensuring a transparent, consistent, and defensible prioritization process.

7.1 Extreme Event Flood Inundation

7.1.1 Probability of Failure

Table 7-1, presents the year when risk advances to the next classification. The full methodology, including the scoring rubric and classification thresholds, is detailed in Appendix A.

Probability of Failure		Time Horizon
Score	Likelihood	
1	Rare	2025
2	Unlikely	2061
3	Possible	2066
4	Likely	2071
5	Almost Certain	2075

Table 7-1: Probability of Failure Projections

7.1.2 Risk

Risk ultimately drives decision making. Risk is evaluated by combining the Probability of Failure (PoF), defined in section 7.1.1, and Consequence of Failure (CoF), defined in section 5.3, using a standardized matrix to produce a numerical risk score. This score helps determine when adaptation action maybe required. Table 7-2 presents the year when risk advances to the next classification. The full methodology, including the scoring rubric and classification thresholds, is detailed in Appendix A.

Score	Time Horizon
Lowest	-
Low	2025
Medium	2066
High	2071
Extreme	2075

Table 7-2: Risk Projections

Elevation data sourced prior to Hurricane Fiona. Risk is expected to be greater than detailed in this report.

7.2 Precipitation Based Flooding

The existing storm sewer is inadequately sized for current rainfall and flooding is expected to increase as rainfall increases in magnitude and frequency. Without intervention Oxford will continue to experience accelerating impacts of flooding on Main Street with increasing consequences.

7.3 Results

The key climate hazard driving the need for adaptation on Main Street is extreme precipitation. Risk has been quantified based on potential events, from more frequent and less consequential flooding to less frequent and more catastrophic flooding from extreme rainfall. Summary details of the infrastructure at risk are discussed below:

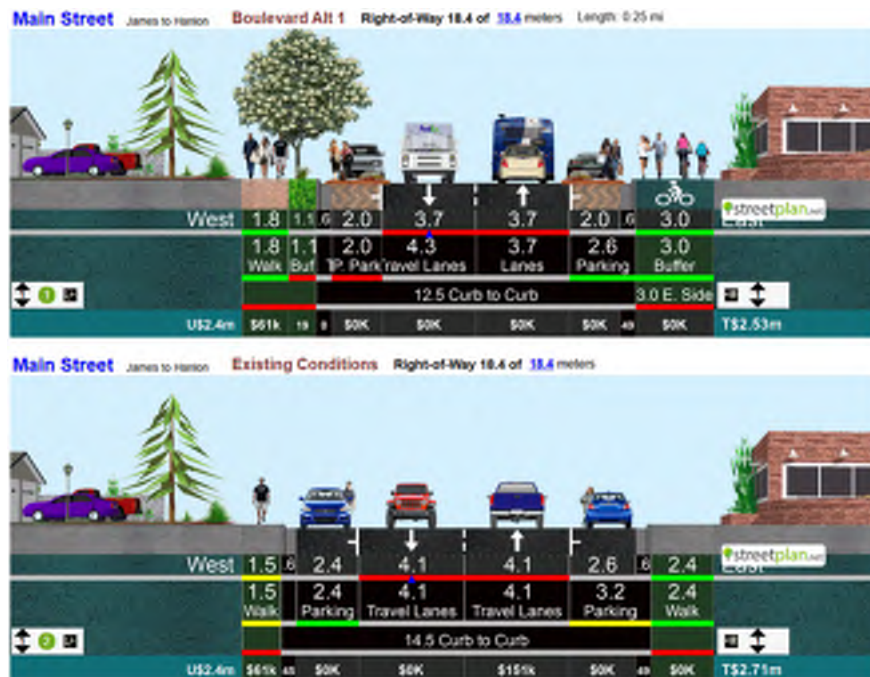
- *The roadway is at high risk of minor flooding under current conditions.*
- *The roadway is at high risk of catastrophic flooding by 2050.*



8 Options Analysis

The climate resilience assessment highlights the urgency of implementing adaptation strategies tailored to the unique challenges faced by each community. Proactive measures, coupled with ongoing monitoring and community involvement, are essential for ensuring the long-term sustainability and resilience of the Town, in the face of a changing climate.

The recommended interventions that Oxford can pursue to protect Main Street are a combination of replacing the existing 150-millimetre storm sewer in the area of concern and rebuilding the street section with low impact development features like narrowed asphalt lanes for driving, permeable pavers for parking areas and rain gardens at catchbasin locations. The proposed street section, compared to the existing street section is shown in the figure below.



The proposed intervention impact is shown below.

 Adaptation Intervention									
Asset	Lockeport Causeway, Dunes & Roadway								
Asset Vulnerability	Baseline Consequence	Baseline Asset	Key Driving Climate Hazard	Baseline Stacked Likelihood of			Baseline Calculated Risk		
				2030	2050	2100	2030	2050	2100
Minor flooding during major storms (1:100 year event)	5	Main Street Flooding	Frequent precipitation	3	4	5	High	Extreme	Extreme
Project Option	Short-term Considerations			Long-term Considerations			Impact on Asset Adaptive Capacity		
Low impact development upgrade	Feasible under current funding regimes, low technical risk			Low risk from climate projection uncertainty, low cost impact to design to worst case scenario			Reduces the likelihood of flooding to negligible		
Relative Cost	Impact on Asset Response Capacity			Adjusted Probability of Asset Vulnerability Scenario			Adjusted Calculated Risk		
				2030	2050	2100	2030	2050	2100
Approximately \$1,000,000	Increases response capacity so that event is likely to happen but consequence trigger becomes negligible in all climate scenarios.			1	1	1	Low	Low	Low

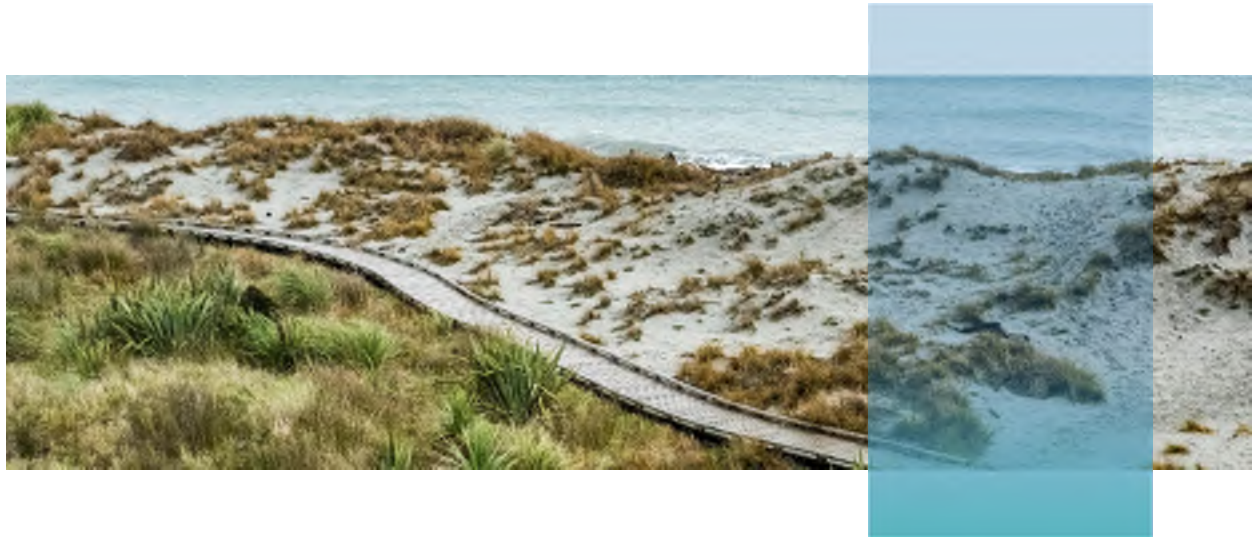
8.1 Avoiding Maladaptation

There is a low risk of maladaptation with this project, although detail design should give preference to increasing low point capacity for major flow paths over increasing resilience of overland flow paths through hard armouring, which will impact vegetation and riverbank biodiversity.

8.2 Cost Estimates

Cost estimates have been developed for the project and are shown on the following page.

		Class D Cost Estimate		CLIENT: Town Of Oxford	
		PROJECT NO.: AIM-136-A		Main Street Watermain Renewal	
ITEM NUMBER	DESCRIPTION	TENDER QUANTITY	UNIT	UNIT PRICE	TOTAL ESTIMATE
STORM SEWER SYSTEM					
31	Pipe				
	300mm HDPE	250		\$670.00	\$167,500
32	Manholes				
✓ .1	1050mm Manholes, precast	8	Ea	\$4,520.00	\$36,160
33	Catch Basin				
✓ .1	1050mm Single Frame & Grate Catch Basin, precast	6	Ea	\$5,160.00	\$30,960
34	Catch Basin Leads				
✓ .1	150mm PVC	64	m	\$580.00	\$37,120
37	Culverts				
✓ .1	450mm HDPE	0	m	\$260.00	\$0
39	Subdrains				
✓ .1	150mm Subdrain c/w drain rock, beneath rain gardens	500	m	\$80.00	\$40,000
STREET / LOT CONSTRUCTION					
51	Gravels				
✓ .1	Type 1 Gravel, 300 mm	300	m3	\$40.00	\$12,000
✓ .2	Type 2 Gravel, 450 mm	225	m3	\$35.00	\$7,875
53	Asphalt Concrete				
✓ .1	Type B - 75 mm	88	t	\$240.00	\$21,150
✓ .2	Type C - 50 mm	59	t	\$240.00	\$14,100
54	Concrete Curb and Gutter				
✓ .1	Curb and Gutter	80	m	\$210.00	\$16,800
✓ .2	Sidewalk	450	m2	\$150.00	\$67,500
55	Parking Areas				
✓ .1	Permeable Pavers for Parking Areas, includes rain garden costs	500	m2	\$322.75	\$161,375
ACTIVE TRANSPORTATION CORRIDOR					
56	Gravels				
✓ .1	Type 1 Gravel, 150 mm	135	m3	\$40.00	\$5,400
✓ .2	Crusher Dust	0	m3	\$20.00	\$0
57	Asphalt Concrete				
✓ .1	Type C - 50 mm	106	t	\$250.00	\$26,438
SUMMARY					Total Opinion Probable Cost
EARTHWORK					\$ -
WATER MAIN SYSTEM					\$ -
SANITARY SYSTEM					\$ -
STORM SYSTEM					\$ 311,740
STREET / LOT CONSTRUCTION					\$ 332,639
LANDSCAPING					\$ -
LIGHTING AND POWER					\$ -
ENVIRONMENTAL PROTECTION					\$ -
SUBTOTAL					\$ 644,379
CONTINGENCY FOR LANDSCAPING AND UNKNOWN					\$ 128,876
CONTINGENCY FOR COST VOLATILITY					\$ 64,438
DESIGN & INSPECTION FEES					\$ 161,095
TOTAL					\$ 998,787



9 Conclusions and Recommendations

This Climate Hazard Assessment identifies extreme precipitation as the primary climate hazard affecting the Oxford Main Street. The road is currently exposed to flooding during major storm events, driven by post-tropical systems and compounding storm systems in summer rainfall.

This vulnerability has been demonstrated during multiple flood events since 2000 that impacted the downtown core and surrounding properties, including the extreme rainfall in July of 2023. Without intervention, the Town will continue to see increased flood vulnerability and increasing consequences. This report recommends pursuing funding to replace the existing storm sewer, include nature positive and hybrid engineered-natural solutions and reducing the paved area of the street.

10 CLOSURE

This report (including any enclosures and attachments) has been prepared for the exclusive use and benefit of the Municipality of the Town of Oxford and solely for the purpose for which it is provided. The report is not intended nor are to be used as a guarantee or warranty, expressed or implied, regarding the future adequacy, performance or condition of any inspected structure, item, or system. The inspector is not an insurer of any inspected conditions. Unless we provide express prior written consent, no part of this report should be reproduced, distributed, or communicated to any third party. We do not accept any liability if this report is used for an alternative purpose from which it is intended, nor to any third party in respect of this report.

AIM Network is a not-for-profit organization with a mandate to support long-term planning for municipal service delivery and infrastructure management in Atlantic Canada. Municipalities in Atlantic Canada are witnessing the impacts of a changing climate and understand the benefits of regional collaboration in addressing climate risk. They also recognize the need to integrate adaptative measures into their asset management planning and to engage their residents and other community stakeholders.

Town of Oxford

Climate Hazard Analysis: Appendix A

Assessment Methodology



A CLIMATE HAZARD METHODOLOGY

A.1 Project Definition

Our weather is becoming more unpredictable and extreme because of climate change. Most of our infrastructure was designed for loads from wind, precipitation, flood levels and other weather events based on historic data that did not consider climate change. Climate change increases the annual likelihood of having a weather event outside the design load of critical assets like building roofs, storm sewers, river crossings; even urban tree cover, failing. Most of these assets are taken care of by local governments which means they need useful tools to understand and deal with the risks from climate change.

It's important to know that climate change affects not only our local area but the whole country. To prepare for these changes, cities need money to make their infrastructure (like roads and buildings) more resistant to extreme weather. The problem is many projects are competing for this infrastructure investment. Therefore, it is crucial for the government to spend the right amount of money, not too little and not too much, to make sure everything is safe and works well in the future.

“Effective climate action requires political commitment, well-aligned multi-level governance and institutional frameworks, laws, policies and strategies. It needs clear goals, adequate finance and financing tools, coordination across multiple policy domains, and inclusive governance processes.”²

Because there are limited financial and human resources to address these risks, governments need to find smart and flexible ways to deal with these problems as they become more certain in the future across multiple sectors and jurisdictions.

“Systemic barriers constrain the implementation of adaptation options in vulnerable sectors, regions and social groups. Key barriers include limited resources, lack of private-sector and civic engagement, insufficient mobilization of finance, lack of political commitment, limited research and/or slow and low uptake of adaptation science and a low sense of urgency.”³

² Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (H.-O. Pörtner, D. C. Roberts, M. Tignor, et al., Eds.). Cambridge University Press.

³ Ibid

This Climate Hazard Analysis is modeled after the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol and High-Level Screening Guide (HLSG). Unlike a full risk assessment, this analysis does not evaluate the consequences of failure but instead focuses on establishing the likelihood of various climate hazards over multiple time horizons. The approach follows a simplified methodology adapted from the HLSG, using readily available data and professional judgment to assess climate exposure. This ensures a practical and efficient evaluation, serving as a foundation for informed decision-making and future adaptation planning. *The goal of this report is to allow Oxford to fully consider future climate impacts when selecting a project to proceed.*

A.2 Scope

A.2.1 Objectives

This **Climate Hazard Analysis** identifies and quantifies present and future climate hazards that the specified project site is exposed to. The assessment focuses on evaluating the probability and severity of these hazards over time, providing a structured understanding of climate exposure without defining specific consequences to the organization's services, residents, and infrastructure outside the project site.

The objectives of this analysis are to:

- Identifying and quantifying present and future climate hazards the project is exposed to.
- Exploring flexible options to reduce or mitigate the exposure, while avoiding maladaptation.
- Empower the Town with the information to make informed decisions on the project and pursue adaptations that meet the needs of their community.

Ultimately, the assessment endeavors to empower the Town to make informed decisions and undertake meaningful climate adaptation initiatives, thereby contributing to long-term resilience and sustainability in Atlantic Canada.

A.2.2 Context

This **Climate Hazard Analysis** focuses on risks that can be managed within the organization. It includes high level assessments of infrastructure performance based on potential changes in load case from climate change. It does not consider impacts of the failure and does not include scope that would need to be addressed by agencies outside the municipality (such as provincial or federal regulatory policies).

Impact assessment will be limited to those that lie within the geographic and jurisdictional boundaries of the Town. The initial assessment will be limited to consultation with municipal staff, but the report may recommend further consultation with outside stakeholders such as other levels of government, First Nations, and members of the community.

A.3 Why Timescale Matters

Understanding how climate risks change over time is essential for protecting the project site—both today and decades into the future. Climate hazards aren't fixed; they evolve. And to plan effectively, we need to think in terms of *when*, *how*, and *how much* things could change.

Three key factors influence how climate hazards are assessed:

1. **Time** – The longer into the future we look, the more likely we are to see an increase in the severity or frequency of hazards. That means the design choices we make today may not hold up tomorrow, depending on how long the infrastructure is expected to last.
2. **Emissions Scenarios** – Future climate conditions depend heavily on global greenhouse gas emissions. High-emissions scenarios generally lead to more severe local impacts. The choices made globally will shape the risks faced locally.
3. **Uncertainty** – Climate projections are based on the best available science, but they come with uncertainty—especially as we look further ahead. Acknowledging this isn’t a weakness; it’s a way to plan smarter, by staying flexible and ready to adjust.

A more detailed technical discussion of climate projection data is included in **Appendix B**.

To make climate adaptation practical, we assess risks across four timeframes. Each horizon supports a different kind of decision-making:

- **Present Day (2025)** – What immediate risks exist? These are the conditions we face now and must consider in current planning and design.
- **Near-Term (2026–2030)** – What needs attention in the next five years? This phase helps flag priority areas for deeper investigation and early action.
- **Medium-Term (After 2030, up to ~2045)** – What long-term projects should we start setting money aside for? This is where strategic planning and financial readiness come into play.
- **Long-Term (Up to 2100)** – What are the bigger shifts we might need to prepare for over the coming decades? Long-term risks require monitoring, flexibility, and adaptation strategies that can evolve as conditions change.

By taking this phased approach, we can match today’s decisions to tomorrow’s challenges—without overbuilding too early or getting caught off guard too late. The goal is a site that stays resilient, no matter how the future unfolds.

A.4 Data

This Climate Hazard Analysis relies on historical climate data and future projections to assess the likelihood of climate hazards impacting the project site. Only climate hazards that pose a potential risk to the project site are considered and detailed in the main body of this report. Climate variables which combine to create a hazard are detailed in Section 6, along with sources and confidence in the project over various time horizons.

Appendix A details how climate projections are developed and the inherent layers of uncertainty. Decisions need to consider three levels of uncertainty:

1. **Time:** how long will the infrastructure be operational? Climate impacts are lower mid-century compared to beyond 2100
2. **Emissions:** how much will global emissions be reduced? **Table 1** shows potential scenarios, where the final number in the IPCC scenario column (4.5, 7.0 and 8.5) are increasing GHG emissions.
3. **Modeling errors:** All long-term models have high and low estimates. This assessment uses the mean values of the modelling scenarios.

Table 1: Degrees of Warming under SSP Scenarios

Warming Threshold	SSP1-2.6 (Low)	SSP2-4.5 (Intermediate)	SSP3-7.0 (High)	SSP5-8.5 (Very High)
+1.5°C	~2040	~2037	~2034	~2032
+2.0°C	~2060	~2052	~2048	~2043
+2.5°C	>2100	~2080	~2065	~2055
+3.0°C	-	>2100	~2085	~2070
+3.5°C	-	-	>2100	~2085–2090
+4.0°C	-	-	-	~2100

Table 2: Warming Scenarios

Warming Scenario	Likelihood	Expected Temperature Increase	IPCC Scenario
Near Term	Certain before 2050	1.5°C increase from pre-industrial	Current State
Intermediate	Unlikely by 2050 Almost certain by 2100	2.5°C increase from pre-industrial	SSP2-4.5
High	Unlikely by 2050 Possible by 2100	3.5°C increase from pre-industrial	SSP3-7.0
Very High	Unlikely by 2050 Low likelihood by 2100	>3.5°C increase from pre-industrial	SSP5-8.5

In order to appropriately communicate the uncertainty in climate projections, this Climate Hazard Analysis as adopted a multi-tiered approach to defining the certainty of design variables as detailed in the Environment and Climate Change Canada, ECCC Climate-Resilient Buildings and Core Public Infrastructure, 2020⁴. Table 3 presents confidence tiers.

A.5 Assess

This Climate Hazard Analysis utilizes a combination of quantitative and qualitative approaches to identify exposures to climate related hazards at a specified project site. Climate data projections, various open data sources, and past studies, are used in combination with engineering judgement to identify the potential exposures at the project site or different time horizons and emissions scenarios.

A.6 Options and Next Steps

Implementation actions to mitigate potential climate hazards at the project site are outlined at a conceptual level, considering both near- and long-term adaptation needs. Emphasis is placed on avoiding maladaptation and ensuring flexibility over multiple time horizons.

For organizations managing multiple climate risks beyond this project site, guidance on a scoring matrix is provided to help prioritize competing needs effectively. The goal of this section is to outline a clear path toward implementation, identifying key considerations that should be assessed as the project plan evolves.

⁴Environment and Climate Change Canada. (2020). *Climate-resilient buildings and core public infrastructure: An assessment of the impact of climate change on climate design data and adaptation strategies*. Government of Canada.

Table 3: Confidence Levels

Confidence Tier	Confidence Level	Description
Tier 1	High or Very High	This level of confidence is afforded by in-depth understanding of the processes involved, as well as an abundant and a strong body of evidence (including evidence for other parts of the world) that deals with the causes of observed changes. This implies relatively high confidence in projected change factors for these variables, which suggests that specific values of these change factors could be considered when designing new infrastructure if justified from an engineering perspective and if suitable approaches exist to consider remaining uncertainties, including uncertainty in the amount of warming that might occur by the end of the service life of the structure that is being designed.
Tier 2	Medium	In most instances, an assessment of medium confidence means there is some understanding of the processes that lead to future change. This might be supplemented by a body of evidence linking the causes of observed changes at large scales, but generally, such evidence would be much less extensive, with available studies showing a lower degree of consistency, than for Tier 1 variables. In contrast to situations when climate scientists have high or very high confidence, climate scientists are generally not able to estimate the likelihood of a projected change when they determine that they have medium confidence in future projections. Change factors for these variables are therefore more suitable for cost/benefit analyses or for a risk analysis, as well as for the exploration of uncertainty associated with design.
Tier 3	Low or Very Low	Low or very low confidence is given to projections for variables that have not been widely studied in the published literature or for which the processes involved are poorly understood. In some instances, very low confidence is given to projections for variables that are diagnosed indirectly, for example, using empirical relationships because process understanding is limited. While change factors are projected, they are likely best suited to exploring the potential impacts of climate change on structural reliability in different warming and load combination scenarios.

A.1 Assess

This Climate Hazard Analysis utilizes a combination of quantitative and qualitative approaches to analyze exposures to climate-related hazards at a specified project site. Climate data projections, various open data sources, and past studies, are used in combination with engineering judgement to assess the potential exposures at the project site for different time horizons and emissions scenarios, given a defined vulnerability scenario.

The hazard analysis process is initiated with the identification of the project site and the asset(s) exposed to potential climate hazards. Climate variables and projections are examined to narrow the scope to relevant climate hazards, which may be the combination of one or more climate variables and events. In collaboration with the municipality, a vulnerability scenario and a consequence of failure are established to fix the consequence using the AIM Consequence of Failure Matrix shown in Figure A-2.

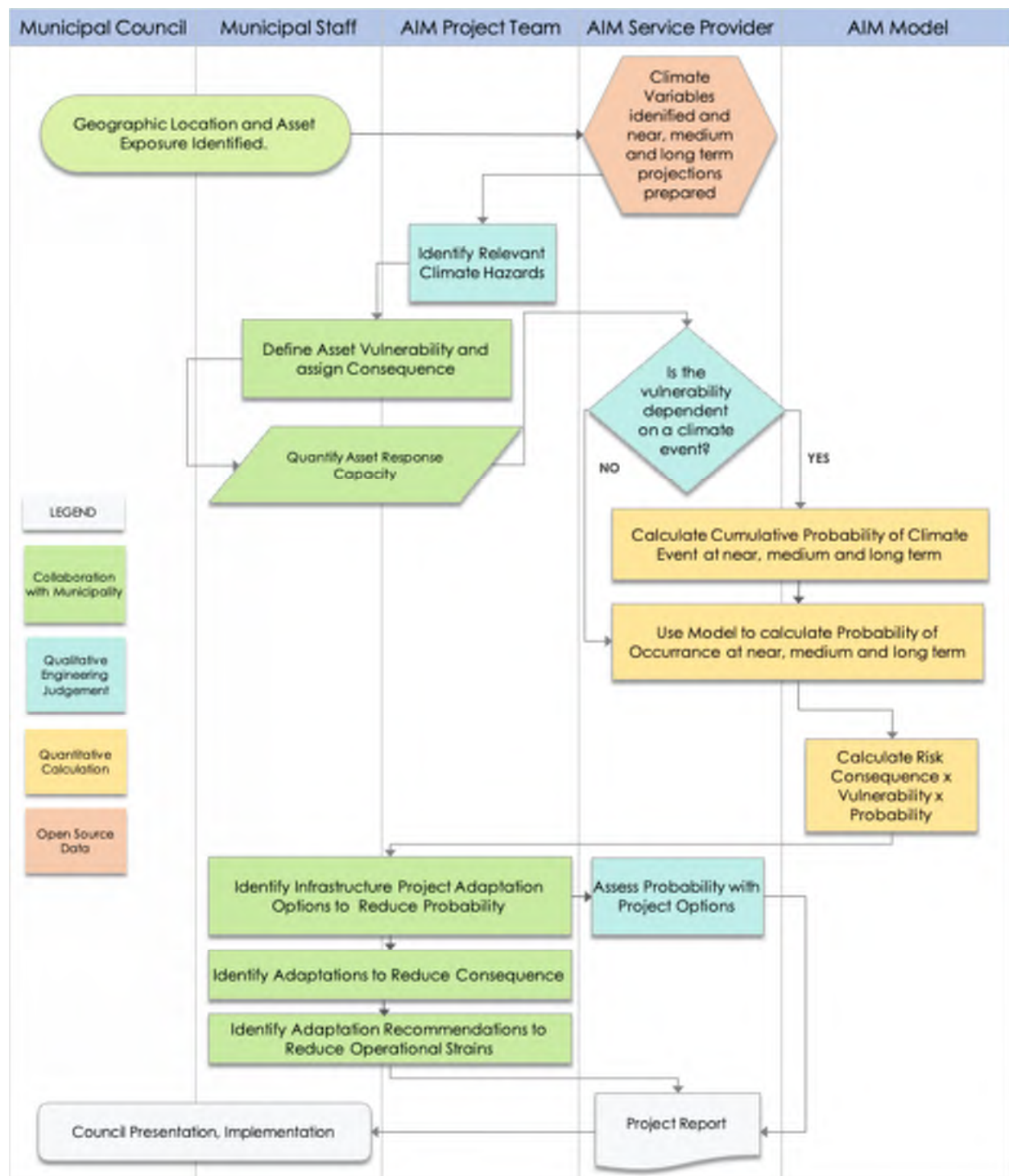


Figure A-1 Detailed Climate Hazard Analysis Process

AIM Consequence of Failure Assessment Matrix								
CONSEQUENCE	RANK	CULTURAL / POLITICAL	ECONOMIC	LEGAL	SAFETY	ENVIRONMENTAL	EQUITY	OPPORTUNITY COST / REWARD

Figure A-2 Consequence of Failure Matrix

The capacity of the asset to respond to the climate event(s) is quantified (e.g. the elevation of the asset) and probability is evaluated using the combination of the cumulative probability of a climate event, if applicable, and the probability of the vulnerability scenario occurring at the near-, medium- and long-term based on the selected climate scenario.

Probability and consequence are combined to determine a relative risk (consequence is fixed by the vulnerability scenario) using the risk matrix and tolerance detail below.

	Consequence				
Probability	1	2	3	4	5
1	1	3	6	10	15
2	2	5	9	14	19
3	4	8	13	18	22
4	7	12	17	21	24
5	11	16	20	23	25

Table A-4: Risk Matrix

Risk	Tolerance	General Actions
Lowest	1-6	-
Low	7-15	-
Medium	16-19	Observe in 10-year outlook
High	20-22	Include in 5-year plan
Extreme	23-25	Act immediately

Table 5: Risk Tolerance

With the consequence of failure fixed by the vulnerability scenario the adaptation options can be evaluated and compared with the baseline risk using engineering judgement, and considerations of effectiveness.

A.2 Options and Next Steps

Implementation actions to mitigate potential climate hazards at the project site are outlined at a conceptual level, considering both near- and long-term adaptation needs. Emphasis is placed on avoiding maladaptation and ensuring flexibility over multiple time horizons.

For organizations managing multiple climate risks beyond this project site, guidance on a scoring matrix is provided to help prioritize competing needs effectively. The goal of this section is to outline a clear path toward implementation, identifying key considerations that should be assessed as the project plan evolves.



Town of Oxford

Climate Hazard Analysis: Appendix B

Climate Projections



B CLIMATE PROJECTIONS

Modern climate models are developed by the World Climate Research Programme (WCRP). The WCRP compiles projections from dozens of climate modelling institutions from around the world in a coordinated effort to develop the Coupled Model Intercomparison Project (CMIP). These individual models attempt to replicate global climate processes with focuses on specific processes or regions. Every five to seven years, the models are combined and undergo a coordinated suite of model simulations to assess their performance and are reported to the Intergovernmental Panel on Climate Change (IPCC). The latest, and most used phases of climate models are the fifth and sixth phases of CMIP (CMIP5 & CMIP6).⁵

B.1 Climate Change Scenarios

It is impossible to predict precisely what the impacts of a changing climate will be. All these existing models contain uncertainty. This uncertainty does not mean we are unsure if increased carbon dioxide, methane and other greenhouse gas emissions will result in a changing climate. It means that the **extent** of impact, and the **speed** that those impacts occur are controlled by many variables, making it difficult to predict exactly when impacts will occur and how drastic those impacts will be. These underlying uncertainties come from two causes:

- 1) The quantity of greenhouse gas (GHG) emissions globally is tied to a great extent to activities of large emitters like China, the United States, India and Russia. The expected increase in sea level, precipitation and wind energy in Canada is impacted by political changes and policies in these other countries.
- 2) Even with certainty about the rate of greenhouse gas emissions, there is uncertainty in any computer model with the number of variables needed to predict climate impacts. Again, this does not mean the models might incorrectly predict effects; it means that the best they can do is predict a *range* of likely impacts over time, with low, high and average values.

⁵ USDA Northwest Climate Hub. (n.d.). What are climate model phases and scenarios? U.S. Department of Agriculture. Retrieved March 26, 2025

B.1.1 Global Emissions Projections

To address the first uncertainty, CMIP5 uses representative concentration pathways (RCP), which describes different rates of change in GHG concentrations. Detailed technical information on these scenarios are available in the IPCC synthesis reports. The primary RCP scenarios are presented in **Table B-1**.

Table B-1: Representative Concentration Pathways Scenario Description

Scenario	Description
RCP2.6	Aggressive emissions reduction – declining CO2 emissions within 20 years.
RCP4.5	Rapid reduction in emissions with stabilization and reduction mid-century.
RCP6.0	Slow reduction in emissions with stabilization and reduction late century.
RCP8.5	Continue with current growth in global emissions, low GHG mitigation.

CMIP6 introduced shared socioeconomic pathways (SSP) to better relate the RCP scenarios to human activities that impact the climate, such as population, economic growth, education, urbanization, rate of technological development, etc. There are 5 primary SSP scenarios, presented in **Table B-2**.

Table B-2: Shared Socioeconomic Pathways Scenario Description⁶

Scenario	Description
SSP1	Sustainability - Taking the green road (few social and political challenges to mitigation and adaptation)
SSP2	Middle of the road - (moderate social and political challenges to mitigation and adaptation)
SSP3	Geo-political rivalry - A rocky road (high social and political challenges to mitigation and adaptation)
SSP4	Inequality-A Road divided (successful efforts for GHG reduction, low success for adaptation)
SSP5	Fossil-fueled development - (little success in GHG reduction, aggressive adaptation efforts)

How these SSP scenarios are related to the corresponding RCP scenario is presented in **Figure 1**. The difference between each scenario when impacts to climate change are significant. **Figure 2** presents the project mean temperature for 3 different SSP scenarios. The SSP numbers, one through five, reflect our ability to manage cause and effect of GHG emissions, while the second decimal number, 1.9 to 8.5 reflects the severity of climate impacts by the RCP numbers.

B.1.2 Model Uncertainty

Climate models are inherently uncertain. First, all models rely on calculations of complex systems. Such modelling has potential for error, represented by how confident we are that the future condition will exceed a given result. Projected changes in our climate are typically shown as a mean projection with increasing potential for error above or below that mean as we project further into the future. **Figure 3** demonstrates this for one climate case.

⁶ Canadian Centre for Climate Services. (n.d.). *CMIP6 and Shared Socio-economic Pathways overview*. Government of Canada. Retrieved March 26, 2021

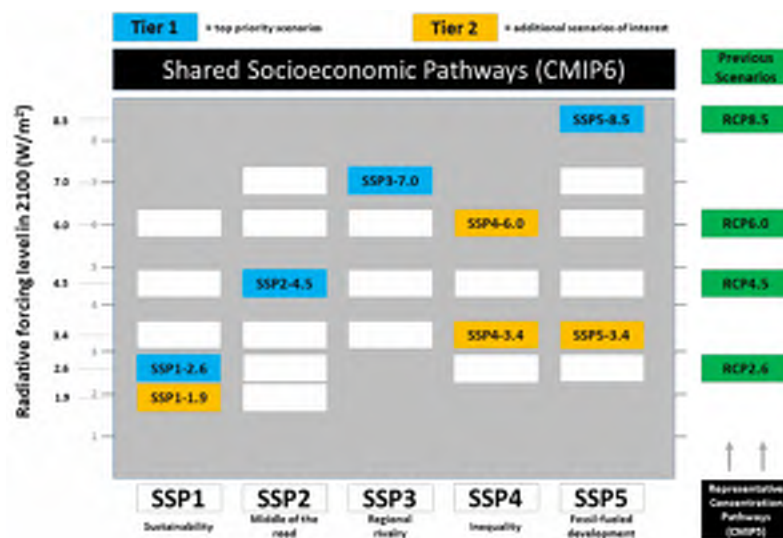


Figure 1: SSP and year 2100 RCP combinations used in Scenario

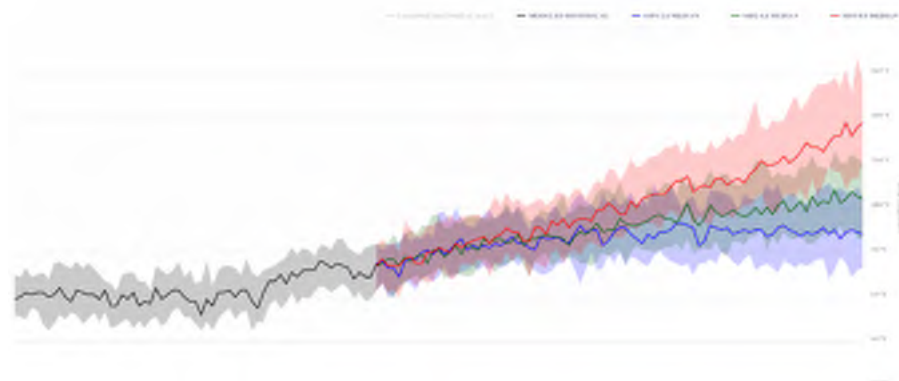


Figure 2: Sample Mean Temperature Projections, all scenarios

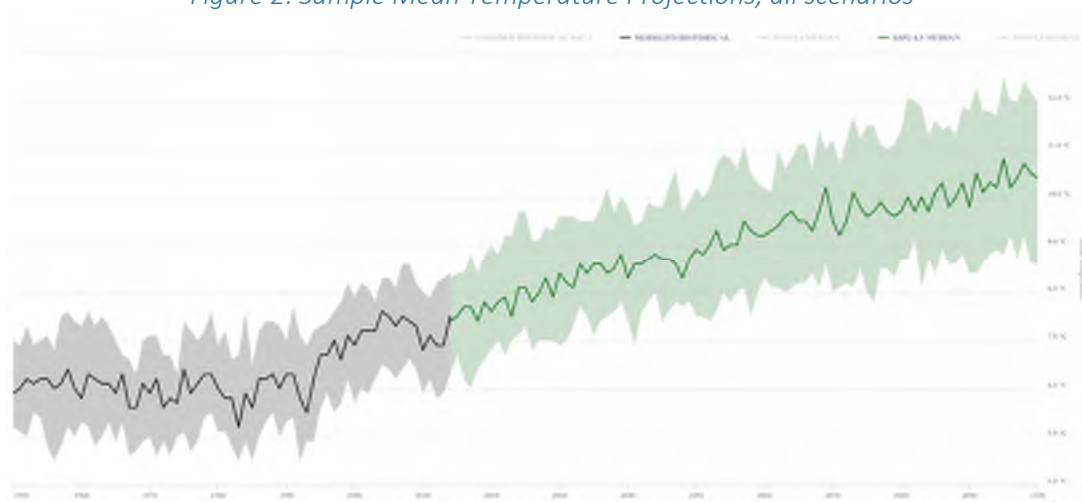


Figure 3: Sample Mean Temperature Projection, SSP2-4.5⁷

⁷ <https://climatedata.ca/>

This shows that for a given year, all probable predictions will be higher than the lowest band of the error (bottom of the shaded part). This refers to the “10th percentile”, meaning that 90% of the results exceed the given value, that is, we have a high level of confidence that this increase will be exceeded in the given period. In contrast, all probable predictions will be lower than the highest band of the error, referring to the “90th percentile”, which is only exceeded by 10% of the values, therefore, while it is possible that the increase will be this much, we have a lower level of confidence that it will occur.

More plainly, it is almost certain that climate impacts are higher than the 10th percentile, and unlikely that it will be higher than the 90th percentile. The mean is the line with half predictions higher and half predictions lower than that value. The mean is typically utilized for design, providing a balance of risk and adaptation cost.

In summary, it is important to consider that there is no “right” prediction for climate change impacts, only more or less likely possibilities. Adaptation measures that consider smaller, more likely scenarios are less costly and more accessible. Adaptation measures that consider worse case scenarios are more robust, but also more costly and prohibitive. This basis allows a risk managed approach to developing climate change adaptation measures.