Climate Change Vulnerability and Risk Assessment

City of Ottawa
Planning, Real Estate and Economic Development Department

May 30 2022

ottawa.ca/climatechange
ottawa.ca 3-1-1
TTY/ATS 613-580-2401

Table of Contents

EXECUTIVE SUMMARY ..... **i**
Methodology and Approach ii
Focus Areas and Climate Hazard Themes iii
CVRA Findings iv
Next Steps vi
ACKNOWLEDGEMENTS ..... **i**
1.0 Introduction **2**
1.1 Context For Climate Action 2
1.2 Responding to the Impacts of Climate Change 4
1.3 Project Objective and Scope 6
2.0 CVRA Engagement **8**
2.1 Internal Engagement 8
2.2 Targeted External Engagement 9
2.3 Public Engagement 9
2.4 Engagement Timeline 10
3.0 Methodology **11**
3.1 Methodology Overview 11
3.1.1 Scope 12
3.1.2 Climate Hazard and Impact Identification 12
3.1.3 Vulnerability Assessment 14
3.1.4 Risk Assessment 15
3.1.5 Evaluating Priority Risks 17
3.2 Limitations of the CVRA 18
4.0 CVRA – Overall Findings **20**
4.1 Summary of Findings 20
4.1.1 Priority Risks 23
4.1.2 Disproportionately Impacted Populations 25
4.2 Extreme Heat, Drought and Humidity 28
4.2.1 Projected Changes in Climate Variables 28
4.2.2 Potential Impacts 29
4.2.3 Adaptive Measures in Place 34
4.2.4 Interpretation of Results 35
4.2.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings 36
4.3 Seasonable Variability and Change 39
4.3.1 Projected Changes in Climate Variables 39
4.3.2 Potential Impacts 39
4.3.3 Adaptive Measures in Place 43
4.3.4 Interpretation of Results 44
4.3.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings 44
4.4 Increased Volume and Intensity of Precipitation 48
4.4.1 Projected Changes in Climate Variables 48
4.4.2 Potential Impacts 49
4.4.3 Adaptive Measures in Place 56
4.4.4 Interpretation of Results 57

4.4.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings 58
4.5 Extreme Weather Events 62
4.5.1 Projected Changes in Climate Variables 62
4.5.2 Potential Impacts 64
4.5.3 Adaptive Measures in Place 68
4.5.4 Interpretation of Results 69
4.5.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings 69
4.6 Global Climate Change 73
4.6.1 Overview 73
4.6.2 Potential Impacts 74
4.6.3 Adaptive Measures in Place 76
4.6.4 Interpretation of Results 77
4.6.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings 78
5.0 Key Gaps 79
6.0 Conclusion and Next Steps 82
7.0 Glossary 83

List of Tables

Table E-1. Summary of Priority Risks v
Table 2. Engagement Timeline 10
Table 3. Probability Rating Based on Climate Event Occurrence 15
Table 4. Consequence Rating Scale 16
Table 5. Summary of Priority Risks 24
Table 6. Most Vulnerable Population Groups 27
Table 7. Summary of Extreme Heat, Drought and Humidity Impacts, Vulnerabilities and Consequences 31
Table 8. Current or Planned City of Ottawa Adaptive Measures – Extreme Heat, Drought and Humidity 34
Table 9. Extreme Heat, Humidity and Drought Impacts That Require Immediate Action 36
Table 10. Extreme Heat, Humidity and Drought Impacts That Require a Plan to Address Risk 37
Table 11. Extreme Heat, Humidity and Drought Impacts That Require a Review of Controls / Monitoring 37
Table 12. Summary of Seasonal Variability Impacts, Vulnerabilities and Possible Consequences 41
Table 13. Current and Planned Adaptive Measures in Place or Planned – Seasonal Variability 43
Table 14. Seasonal Variability Impacts That Require Immediate Action 45
Table 15. Seasonal Variability Impacts That Require a Plan to Address Risk 45
Table 16. Seasonal Variability Impacts That Require a Review of Controls / Monitoring 46
Table 17. Types of Flooding and Common Vulnerabilities 50
Table 18. Summary of Increased Volume and Intensity of Precipitation Impacts, Vulnerabilities and Possible Consequences 53
Table 19. Current or Planned City of Ottawa Adaptive Measures - Precipitation 56
Table 20. Increased Volume and Intensity of Precipitation Impacts That Require Immediate Action 58
Table 21. Increased Volume and Intensity of Precipitation Impacts That Require a Plan to Address Risk 60
Table 22. Increased Volume and Intensity of Precipitation Impacts That Require a Review of Controls / Monitoring 61
Table 23. Summary of Extreme Weather Impacts, Vulnerabilities and Possible Consequences 66
Table 24. Current or Planned City of Ottawa Adaptive Measures – Extreme Weather 68
Table 25. Extreme Weather Impacts That Require Immediate Action 70
Table 26. Extreme Weather Impacts That Require a Plan to Address Risk 71
Table 27. Extreme Weather Impacts That Require a Review of Controls / Monitoring 71
Table 28. Summary of Global Climate Change Impacts, Vulnerabilities and Possible Consequences 75
Table 29. Current or Planned City of Ottawa Adaptive Measures – Global Climate Change 76

Table 30. Global Climate Change Impacts That Require Immediate Action 78
Table 31. Summary of Key Gaps and Proposed Responses 79

List of Figures

Figure E-1. Climate Projections for the National Capital Region i
Figure E-2. Climate Vulnerability and Risk Assessment Process ii
Figure E-3. Focus Area Grouping iii
Figure 4. Climate Projections for the National Capital Region 4
Figure 5. Adaptation Aims to Reduce Vulnerability by Increasing Coping Ranges 5
Figure 6. Adaptation Planning Process 7
Figure 7. Climate Vulnerability and Risk Assessment Framework 11
Figure 8. Focus Area Grouping 12
Figure 9. Summary of Climate Indices Used in the CVRA by Climate Hazard Theme 14
Figure 10. Basis of Vulnerability 14
Figure 11. Basis of Risk 15
Figure 12. Basis of Assessing Priority Risks 17
Figure 13. Summary of Risk Ratings 21
Figure 14. Breakdown of High and Very-High Risks by Climate Hazard to the City of Ottawa (Corporate Risks) 22
Figure 15. Breakdown of High and Very-High Risks by Climate Hazard to the Community 22
Figure 16. Summary Results of Public Survey on Climate Impacts of Concern 22
Figure 17. Distribution of climate impacts by vulnerability and risk ratings 23
Figure 18. Average Annual Temperature 28
Figure 19. Number of Days above 30°C 29
Figure 20. Count of Average Risks Related to Extreme Heat, Drought and Humidity Climate Hazards Between the Baseline and the 2080s 35
Figure 21. Summary of Seasonal Changes Relative to the 1980-2010 Baseline 39
Figure 22. Count of Average Risks Related to Seasonal Variability Climate Hazards Between the Baseline and the 2080s 44
Figure 23. Annual Max. 1-Day Precipitation 48
Figure 24. Annual Total Snowfall 49
Figure 25. Count of Average Risks Related to Increased Volume and Intensity of Precipitation Climate Hazards Between the Baseline and the 2080s 58
Figure 26. Catastrophic Losses from Natural Disasters ($Billions, 1983–2019) 62
Figure 27. Count of Average Risks Related to Extremer Weather Climate Hazards Between the Baseline and the 2080s 69
Figure 28. The impacts of a climate change under RCP8.5 scenario 73
Figure 29. Count of Average Risks Related to Global Climate Change Between the Baseline and the 2080's 77

List of Appendices

Appendix A: Methodology A.1
A.1 Methodology Overview A.1
A.1.1 Variances From the BARC Protocol A.1
A.1.2 Climate Hazard and Impact Identification A.2
A.1.3 Assessing Vulnerability A.5
A.1.4 Assessing Risk A-9
A.1.5 Evaluating Priority Risks A.13
Appendix B: Probability Table Used in the CVRA B.1
Appendix C: Priority Risks (all hazards) C.1
C.1 Risks Requiring Immediate Action C.1

EXECUTIVE SUMMARY

The impacts of climate change are being felt globally and locally, and these impacts are expected to continue to intensify and impact Ottawa and the surrounding region for decades to come. On a global scale, climate change has already resulted in a warmer atmosphere, warmer oceans, reduced amounts of sea ice and higher sea levels. At the local scale, Ottawa has seen higher temperatures and more precipitation, as well as extreme weather events such as flooding, heat waves and tornados. The Climate Projections for the National Capital Region study forecasted that Ottawa will continue to become warmer, wetter and have more unpredictable extreme weather events over the coming decades compared to a 1980-2010 baseline (Figure E-1).[1] Average seasonal temperatures are projected to increase and periods of extreme heat will become more common. Precipitation is projected to increase in all seasons, except summer, and the volume and intensity of rainfall events will also increase. Annually, less snowfall and a shorter snow season are projected resulting in longer shoulder seasons. The changes in weather parameters are also expected to create more favorable conditions for extreme events like freezing rain, tornadoes and wildfires. All of these changes are expected to have significant consequences to local health and safety, infrastructure, the economy and the environment.

	What to expect*	2030s	2050s	2080s
Temperature	Average temperature	↑ 1.8°C	↑ 3.2°C	↑ 5.3°C
	Very hot days (above 30°C)	2.5 times more	4 times more	6.5 times more
	Very cold days (below -10°C)	20% less	35% less	63% less
Seasons	Winters shorter by	4 weeks	5 weeks	8 weeks
	Springs earlier by	2 weeks	2 weeks	4 weeks
	Winter freeze-thaw	↑ 13%	↑ 33%	↑ 54%
Precipitation	Fall-winter-spring precipitation	↑ 5%	↑ 8%	↑ 12%
	Intense precipitation	↑ 5%	↑ 14%	↑ 19%
	Snowfall	↓ 10%	↓ 20%	↓ 44%
Extreme events	Possible increases in freezing rain			
	Warming favours conditions conducive to storms, tornadoes, wildfires			

More certainty

Less certainty

* For a high carbon emission scenario (RCP

Figure E-1. Climate Projections for the National Capital Region

[1] National Capital Commission and City of Ottawa (2020). Climate Projections for the National Capital Region. *Volume 1: Results and Interpretation for Key Climate Indices*

Much like other cities and organizations across Canada, the City of Ottawa (the City) is facing a strong climate change adaptation imperative as it becomes increasingly vulnerable to a range of climate hazards that include rising temperatures, floods, droughts, wildfires, winter freeze thaw events, and more frequent and intense extreme weather events, like tornados. These hazards magnify existing challenges (such as aging infrastructure) and are expected to create new ones. To reduce Ottawa's vulnerability to climate change and increase resiliency to the associated impacts, the City has completed a Climate Vulnerability and Risk Assessment (CVRA) at both the City and community scale.

Methodology and Approach

A CVRA consists of two distinct parts: a vulnerability assessment and a risk assessment (Figure E-2).

- The vulnerability assessment aims to measure the extent to which a segment or group of the population, asset, system, or sector is susceptible to, or unable to cope with, climate hazards. It also examines existing adaptive measures to determine if additional action is needed. While a vulnerability assessment helps to identify the potential impacts, the number and scope of potential impacts may be beyond what can be practically addressed using available resources.
- The risk assessment helps prioritize these potential impacts or vulnerabilities by assessing the probability of the climate hazard occurring and estimating what the social, economic, and environmental consequences would be in the 2030s, 2050s, and 2080s.
- Priority climate risks arise because of the confluence of vulnerability, probability, and consequence. The overall risk rating serves to prioritize impacts for adaptation planning and risk reduction measures.

The final vulnerability and risk ratings are used to prioritize the level of action required including:

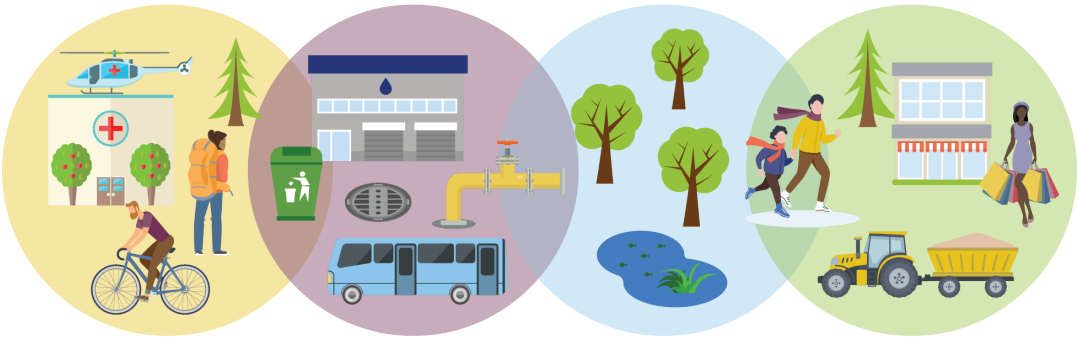
- Immediate action required (take action within the next 1-3 years)
- Develop a plan to address risk (take action within the next 4-7 years)
- Identify possible controls and continue to review for change
- Continue to manage through existing controls and procedures

Figure E-2. Climate Vulnerability and Risk Assessment Process

The CVRA methodological approach broadly followed the steps from ICLEI Canada's Building Adaptive and Resilient Communities Program (BARC) protocol and was designed to integrate findings from complementary City climate risk assessments being conducted for water services, public health and emergency management. It also took into consideration other risk assessment methodologies used by the City, such as corporate risk management and asset management. The methodology drew on knowledge from City staff, subject matter experts and key community stakeholders, as well as public input. Several surveys were distributed, and a series of online workshops were held to help identify and confirm potential hazards, identify who or what may be impacted, gather input on factors that contribute to vulnerability and hazard related consequences, as well as identify information gaps and resiliency actions already in place.

Focus Areas and Climate Hazard Themes

The CVRA assessed climate vulnerabilities and risks across all sectors that affect the livability and prosperity of Ottawa. To organize the assessment in a meaningful manner, the CVRA was structured around 12 Focus Areas pertaining to public health and community well-being, infrastructure, natural environment and the economy (Figure E-3).



Community
- Emergency Management
- Health and Community Well-Being
- Recreation and Parks

Infrastructure
- Drinking Water
- Wastewater
- Stormwater
- Buildings and Facilities
- Transportation
- Solid Waste

Natural Environment
- Forests, Wetlands, Watercourses, Lakes and Groundwater

Economy
- Agriculture and Food Systems
- Economic Development

Figure E-3. Focus Area Grouping

Within each of the Focus Areas, the CVRA examined the vulnerabilities and risks at two distinct scales:

- **City** – this involved looking at how climate change would impact City operations and programming, infrastructure, levels of service, and staff.
- **Community** – this involved looking at how Ottawa residents (daily activities and lifestyles), businesses and service providers would be impacted by changing climate conditions.

The CVRA examined vulnerabilities and risks based on five climate hazard themes:

Climate Hazard	Climate Indices
Extreme heat, drought and humidity	Increase in extreme heat days Increase in heat warnings Increased occurrence of drought like conditions
Seasonal variability and change	Change in seasonal characteristics Increase in average temperatures Increase in winter average temperature Increased occurrence of seasonal winter freeze thaw Less cold extremes
Increased precipitation volume and intensity	Increase in the occurrence of intense precipitation Increase In total precipitation Increase in three-day snow melt and precipitation events Increase in riverine flooding
Extreme weather events	Increase in wildfires Increase in extreme wind / tornadoes Increase in extreme snow and blizzards Increase in freezing rain events Increase in multi-day ice storms Increase in winter freeze thaw and ice storms
Global climate change	Increase in global climate change

CVRA Findings

To identify priority risks, the CVRA methodology took the average of the future risks (2030s, 2050s and 2080s) for each impact statement and compared the average risk rating to the rated vulnerability. Of the 150 climate impacts assessed, a total of 40 impacts were identified as priority risks through the CVRA process. These are impacts that have a medium or higher vulnerability and a medium-high or higher risk rating and require immediate action to mitigate risks.

Based on the priority risk assessment, if no further adaptive actions are taken, the climate related hazards associated with extreme heat, seasonal variability, precipitation, extreme weather events and global climate change are expected to present as significant risks to the physical and mental health of residents, visitors and staff, the construction, operation and maintenance of City infrastructure, the delivery of community, emergency and recreational programs and services, the operation of the economy and the natural function of ecosystems.

A summary of the priority risks is presented in Table E-1. The full list of priority risks are described in the report and summarized in Appendix C and D.

Table E-1. Summary of Priority Risks

Climate Hazard	Priority Risks
Extreme heat, drought and humidity	• Increased heat-related illnesses • Less outdoor recreation and active transportation • Increased building cooling demands, inadequate air conditioning (especially in schools, low-income housing, community buildings, and long-term care facilities) • Increased demand for shaded areas and indoor and outdoor recreation facilities to offset heat • Increased tree stress, reduced stream baseflow, degraded aquatic habitat, algae blooms • Reduced agricultural yields and increased irrigation

Seasonal variability and change	• More invasive species, pests and diseases harming:
	  ○ trees, parks and ecosystems
	  ○ agricultural production and food supply
	• New or intensified disease vectors and illnesses (e.g. Lyme disease or West Nile virus)
	• Increased winter freeze-thaw damage and reduced asset life of:
	  ○ roads
	  ○ buildings (e.g. foundation cracking and heaving, pipe bursts)
	  ○ surface and shallow stormwater and wastewater infrastructure (e.g. catch basins, driveway culverts, maintenance holes, pump stations)
	• Increased winter roads, sidewalks and pathway maintenance and risks to users due to freeze-thaw cycles and freezing rain
	• More park and beach degradation from increased use
	• Decline of winter tourism and recreation

Increased volume and intensity of precipitation	• Reduced access to roads, transit and pathways, as well as property and infrastructure due to riverine or inland flooding • Riverine flood damage and reduced access to Water Purification Plants • Damaged / overwhelmed stormwater, wastewater and flood protection infrastructure in floodplains (e.g. pump stations, culverts, sewers, berms) • Increased runoff from overwhelmed stormwater infrastructure causing reduced water quality, erosion, bank destabilization and localized and basement flooding • Building damage (inland or riverine flooding) and basement flooding/ sewer backup (overwhelmed wastewater systems) • Mental, physical & financial health - injuries, stress, mold, contaminated private wells and septic systems • Delayed planting/ harvesting and reduced pasture

Climate Hazard	Priority Risks
Extreme weather events	• Increased winter slips / falls and isolation • Increased winter maintenance of roads, sidewalks and pathways and risks to users due to freeze-thaw cycles and freezing rain • Reduced ability of City and community services to effectively respond to simultaneous or repeated extreme events • Reduced access to essential services during extreme weather (e.g. electricity, health, education, food banks, transit) • Increased pressures on people experiencing poverty or in precarious economic situations (physical, financial and mental health) • Ditch and culvert blockages from windborne debris causing localized flooding • Business disruptions
Global climate change	• Supply chain instability and impacts to the availability and cost of food, energy and other goods and services • Additional pressures on disproportionately impacted populations • Additional pressures on social service providers

These findings also align with what the City heard back from the public on its climate change survey. Overall, 93% of the 502 respondents identified that they are very concerned about the effects of climate change. When asked about main impacts of concern, the top concerns were related to extreme heat, precipitation, seasonal change and extreme weather events.

While nearly all individuals within Ottawa will be impacted in one way or another, there are specific segments of the population more vulnerable to the identified climate hazards. These include older adults, persons with disabilities, persons living in poverty, racialized people, Indigenous people, rural residents, immigrants women and youth. Individuals or groups may experience more than one vulnerability to climate change at one time, putting them further at risk. Consideration for social identities and inequalities relating to gender, race, socioeconomic class, cultural and ethnic background, age, and disability and how they intersect is critical when addressing climate vulnerabilities and risk. Vulnerable groups were identified in each of the climate hazard themes and Focus Areas. Further assessment to determine why, where and how some individuals and groups are at an increased risk to the impacts of climate change, as well as consideration for holistic actions to address these risks, will be further studied in the development of the Climate Resiliency Strategy.

Next Steps

The completion of the CVRA is an important step in Ottawa's adaptation planning process as it assessed and prioritized the highest climate-related vulnerabilities and risks to the City and the community. By identifying the highest risks to Ottawa, the City can take the next step to identify adaptation pathways and implement strategies to

reduce the consequences of climate driven events, as well as better respond to and recover from climatic events when they occur.

The top risks identified in the CVRA will be the focus of the next phase of the project – the development of the Climate Resiliency Strategy (CRS). The CRS will identify a series of progressive and pragmatic actions focused on minimizing Ottawa's vulnerability to the effects of climate change by increasing resilience. It will identify opportunities to embed climate resiliency considerations into key City plans, budget and risk assessment processes, and identify gaps and resource needs. For example, while the CVRA process identified impacts to each of the Focus Areas, further assessment is needed to clearly identify which communities and specific groups will be most impacted by the identified climate related hazards. Steps will be taken to address remaining information gaps through the development of the CRS as well as through planned City programs, such as the development of Master Plans and Asset Management Plans. The development of the CRS will commence in 2022 and is expected to be completed in 2023, pending sufficient resources.

ACKNOWLEDGEMENTS

Land Acknowledgement

Ottawa is built on un-ceded Algonquin Anishinabe territory. The peoples of the Algonquin Anishinabe Nation have lived on this territory for millennia. Their culture and presence have nurtured and continue to nurture this land. The City of Ottawa honours the peoples and land of the Algonquin Anishinabe Nation and honours all First Nations, Inuit and Métis peoples and their valuable past and present contributions to this land.

Project Acknowledgement

This project was led by the City's Climate Change and Resiliency unit. The Project Team gratefully acknowledges everyone who participated in the development of this Climate Vulnerability and Risk Assessment (CVRA). The CVRA is a culmination of efforts and contributions by City staff and external subject matter experts and reflects a diverse range of knowledge and expertise from stakeholders.

Internal Task Teams

More than 120 City staff from multiple departments participated in the 12 Focus Area Task Teams and provided input into the impact statements, vulnerability and risk assessments, and the prioritization of the risks across the City and the community. Specific thanks to the staff who served as primary contacts for the Focus Area Task Teams and provided additional feedback on the comparison of all risks. Thanks also to the staff that led more detailed climate vulnerability and risk assessments on drinking water, wastewater and stormwater services, and on extreme heat and health.

External Subject Matter Experts

The Project Team also acknowledges external matter subject experts and partners that lent their time and expertise to the project. These stakeholders provided input into the community impact statements, vulnerability and risk ratings.

Consulting Team

The Project Team acknowledges the consulting team that supported the development of the project:

Stantec Consulting Ltd.: **Daniel Hegg**, Senior ESG, Carbon and Climate Change Advisor (Project Technical Lead); **Norman Shippee**, National Climate Change Technical Lead (Canada) (Climate Scientist); **Nicole Flanagan**, Senior ESG, Carbon and Climate Change Advisor (Quality Reviewer)

A. Kennedy Consulting Ltd.: **Amanda Kennedy**, Principle (Engagement Lead)

1.0 INTRODUCTION

1.1 Context For Climate Action

Since the industrial revolution, human activities such as burning fossil fuels, deforestation, agricultural practices, and other land use changes have resulted in the release of unnaturally large volumes of greenhouse gas (GHG) emissions into the Earth's atmosphere causing global climate systems to change. In its sixth assessment report, the Intergovernmental Panel on Climate Change (IPCC) concluded that "the scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years."[2] To substantially reduce the risks and effects of climate change, and limit global warming to 1.5°C, scientists and policy makers agree that global society must dramatically reduce greenhouse gas (GHG) emissions 50–60% by 2030, 80% by 2040, more than 90% by 2050 with the remaining emissions being offset or neutralized (e.g. direct air capture, reforestation, etc.) and be net negative in the second half of the century. Recognizing the importance and benefits to addressing climate change, many governments – including the Government of Canada and the City of Ottawa – as well as publicly traded organizations representing more than $23 trillion in market capitalization have now committed to these GHG reduction targets.[3]

While these commitments are inspiring, if global GHG emissions targets are not met and the upward trajectory continues, scientists estimate that global temperatures could rise by an average of 4 to 6°C this century, yield up to six feet of sea level rise and result in severe social, environmental, and economic costs to society. As described in IPCC's special report, even missing the 1.5ºC target by 0.5ºC is expected to have drastic and severe implications including[4]:

- Almost three times as many people exposed to severe heat at least once every five years
- Higher risk to human health, including heat-related morbidity and mortality in urban areas
- An additional 457 million people exposed to climate risks and related poverty
- Habitat loss for twice as many plants and vertebrates and three times as many insects
- Double the rate of ecosystem instability and habitat loss or change from one ecosystem to another
- Double the decline in global fisheries
- Ice-free summers in the Arctic Ocean every 10 years instead of every 100 years
- Greater rise in sea levels and up to 79 million people exposed to flooding
- Greater economic losses resulting from extreme weather events

While these implications are being presented as one of many possible futures, many of the climate related impacts are already occurring and no country, city, community or resident is immune. In fact, depending on physical geography many locations will be impacted more than others. Environment and Climate Change Canada (ECCC) concluded that Canada is warming at twice the rate of the rest of the world.[5] ECCCs climate models project that this

[2] IPCC (2022). Sixth Assessment Report (AR6).
[3] Science Based Targets initiative and United Nations Global Compact (2021). More than 1,000 companies commit to science-based emissions reductions in line with 1.5 ºC climate ambition.
[4] IPCC (2018). Summary for Policymakers: Global Warming of 1.5 ºC.
[5] Government of Canada (2019). Canada's Changing Climate Report.

warming trend will materialize as an increase of precipitation in the winter, spring and fall seasons and a decrease in summer, warmer and more acidic oceans, and more extreme heat events that last longer. These changes increase the chances that Canadians will experience multiple climate related disasters in a single year. 2021 was noted as a record climate disaster year with: the country's most expensive hailstorm in Calgary (and the fourth most expensive storm in Canadian history); multiple windstorm events and flooding in BC causing billions of dollars in damage (and likely the most costly event in Canadian history); the occurrence of 4 heat domes across the country that contributed to expansion of wildfires, property damage, and a significant loss of life; tornados in Quebec resulting in damage to property and loss of life; hurricanes along the east coast; and extreme cold temperatures in the Prairies.[6]

Locally, Ottawa is already experiencing the outcome of these changes with the weather becoming warmer, more variable, unpredictable and extreme. For example, as a result of changing precipitation patterns, there is now more precipitation falling as rain or snow in the spring and fall. In the spring of 2017 and 2019, this change resulted in significant flooding along the Ottawa River, causing extensive property damage and public health concerns. Warming seasons and seasonal variability have resulted in freezing rain and extreme ice storms like the event in January 1998 where five ice storms occurred in succession. This event caused massive damage to trees and electrical infrastructure causing widespread electricity outages and a shutdown of activities across Ottawa and the region for several weeks. Summer temperatures have increased and resulted in extreme heat events like the heat wave that lasted six days in July 2018. Finally, the National Capital Region has seen an increase in extreme events like the tornadoes in 2018 and 2019 that caused extensive damage to property and trees, as well as electricity outages.

These trends are anticipated to continue. A summary of these projected changes (as compared to the 1980 to 2010 baseline) for the National Capital Region are presented in Figure 4. The full report contains data and interpretation for 178 climate indices.

[6] Government of Canada (2021). Canada's top 10 weather stories of 2021.

	What to expect*	2030s	2050s	2080s
Temperature	Average temperature	↑ 1.8°C	↑ 3.2°C	↑ 5.3°C
	Very hot days (above 30°C)	2.5 times more	4 times more	6.5 times more
	Very cold days (below -10°C)	20% less	35% less	63% less
Seasons	Winters shorter by	4 weeks	5 weeks	8 weeks
	Springs earlier by	2 weeks	2 weeks	4 weeks
	Winter freeze-thaw	↑ 13%	↑ 33%	↑ 54%
Precipitation	Fall-winter-spring precipitation	↑ 5%	↑ 8%	↑ 12%
	Intense precipitation	↑ 5%	↑ 14%	↑ 19%
	Snowfall	↓ 10%	↓ 20%	↓ 44%
Extreme events	Possible increases in freezing rain			
	Warming favours conditions conducive to storms, tornadoes, wildfires			

More certainty

Less certainty

*** For a high carbon emission scenario (RCP 8.5)**

More certainty

Less certainty

Figure 4. Climate Projections for the National Capital Region[7]

If no additional measures are put in place to reduce the magnitude of the impacts, climate change is expected to magnify existing stressors or challenges, like aging infrastructure, and create new ones as the climate related hazards intensify over time. While the City has many practices in place to adapt to variable climate conditions, the inevitability that these climatic changes will increase in both frequency and intensity has prompted the City to examine the potential impacts and identify ways to build resilience more systematically.

1.2 Responding to the Impacts of Climate Change

The IPCC Sixth Assessment Report notes that the climate-related costs to cities, communities and supportive infrastructure systems will rise rapidly in the mid- and long-term if the current upward GHG emissions trajectory does not stop and reverse course.[8] Since 2009, catastrophic losses from weather-related events in Canada have come close to, or exceeded, $1 billion in most years and in aggregate, have exceeded $20 billion.[9] Natural Resources

[7] National Capital Commission and City of Ottawa (2020).Climate Projections for the National Capital Region. *Volume 1: Results and Interpretation for Key Climate Indices*.
[8] 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.
[9] Government of Canada (2021): Costs and Benefits of Climate Change Impacts and Adaptation.

Canada estimates that the annual costs of climate change could reach $30-$62 billion per year by the 2050s and $74 to $319 billion by the 2080s in Canada.[10]

Addressing climate change and reducing these potential costs requires efforts to mitigate GHG emissions sources by reducing / eliminating sources of GHG emissions, known as climate mitigation, as well as efforts to prepare for changes that are irreversible and already underway, known as climate adaptation. Climate change adaptation involves accepting that climate change is happening and adjusting to actual or expected effects of future climate. Adaptation reduces an organization's vulnerability to the harmful effects of climate change - like sea-level encroachment, more intense extreme weather events or food insecurity - by enabling a sector or process to have a greater range of tolerance as a result of new or changing environments (Figure 5).

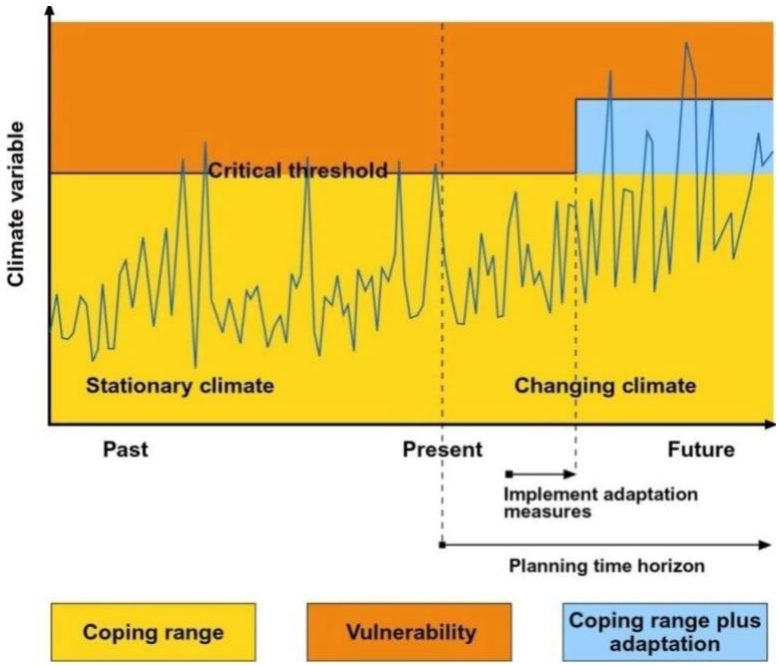


Figure 5. Adaptation Aims to Reduce Vulnerability by Increasing Coping Ranges[11]

Climate adaptation is now considered an essential aspect of managing assets and infrastructure and when proactively implemented is expected to result in significant avoidance of costs. The proactive management of assets in a changing climate is also quickly becoming a regulatory requirement for asset managers and owners. For example, the Province of Ontario established *O. Reg. 588/17: Asset Management Planning For Municipal Infrastructure* which requires that all local governments have approved asset management plans for all municipal infrastructure assets by 2025.[12] Under this regulation, there is a requirement to consider climate change as part of the asset management planning process. In a similar theme, the United States Securities and Exchange Commission recently released a draft Climate Rule that will require publicly traded companies to disclose their climate change risk

[10] Government of Canada (2021). Costs and Benefits of Climate Change Impacts and Adaptation
[11] ERM (2021) A Changing Climate for the Extractives Sector
[12] Government of Ontario (2021). Ontario Regulation 588/17: Asset Management Planning for Municipal Infrastructure

management and strategy as it relates to operations and assets as well as estimate the possible material financial losses that they could face.[13]

In terms of benefits and costs, the National Round Table on the Environment and the Economy concluded that the benefit-to-cost ratio of proactive adaptation is 38:1 under a high GHG emissions scenario (i.e. RCP 8.5)[14] - meaning that for every $1 spent on adaptation measures, $38 is avoided in terms of climate related costs. Under a lower GHG emissions scenario (i.e. RCP 2.6), the same benefit-to-cost ratio is still 9:1.[15] An FCM/IBC study estimated that every $1 proactively invested in resilient infrastructure could avoid $6 of losses resulting from climate change, however this window of opportunity is closing as the concentration of GHG emissions released to the atmosphere increase.[16]

It is important to note that adaptation and mitigation are not mutually exclusive. Both can have positive mutual benefits but require careful planning and a climate lens perspective to ensure strategies do not undermine each other.

1.3 Project Objective and Scope

Since the release of the IPCC's reports, hundreds of municipal and regional governments around the world have declared a climate emergency, recognizing the importance of accelerating GHG reduction programs and initiatives to curb global warming as well as to adapt to the unavoidable effects of climate change. In April 2019, Ottawa City Council declared a climate emergency which resulted in the development of the City's Climate Change Master Plan (CCMP)[17] and direction to staff to complete a vulnerability assessment and develop a Climate Resiliency Strategy (CRS) to reduce the impacts of a changing climate.

The completion of the CVRA is an important step in the adaptation planning process (Figure 6). The purpose of the Climate Vulnerability and Risk Assessment (CVRA) is to assess and prioritize the highest climate-related vulnerabilities and risks to the City and the community. This involved using local climate projections to identify potential climate interactions, hazards and impacts, followed by an assessment of how vulnerable the City and the community may be to the projected impacts, and an assessment of the social, economic and environmental consequences should the climate hazards materialize. The assessment also examines existing adaptive measures to determine if additional action is needed. By identifying the highest risks to Ottawa, the City can take the next step to identify adaptation pathways and implement strategies to reduce the consequence of climate driven events, as well as better respond to and recover from climatic events when they occur. This will be captured in the upcoming CRS.

---

[13] U.S. Securities and Exchange Commission (2022). SEC Proposes Rules to Enhance and Standardize Climate-Related Disclosures for Investors.

[14] The IPCC has established four Representative Concentration Pathways (RPCs) based on projected GHG emissions scenarios. RCP 8.5 is the internationally recognized most pessimistic - "business as usual" GHG emissions scenario – where the ambient concentrations of GHGs are the highest. Other GHG emissions scenarios, RCP 6, 4.5 and 2.6, represent more substantial and sustained reductions in GHG emissions. RCP 2.6 is representative of a scenario that aims to keep global warming below 1.5°C. RCP 4.5 is considered the 'medium stabilization' scenario where global mitigation efforts result in intermediate levels of GHG emissions.

[15] Canada. National Round Table on the Environment and the Economy (2011). Paying the Price: The Economic Impacts of Climate Change for Canada

[16] IBC & FCM (2020). Investing in Canada's Future: The Cost of Climate Adaptation at the Local Level.

[17] The CCMP commits the City to reduce corporate and community GHG emissions 100% by 2040 and 2050, respectively.

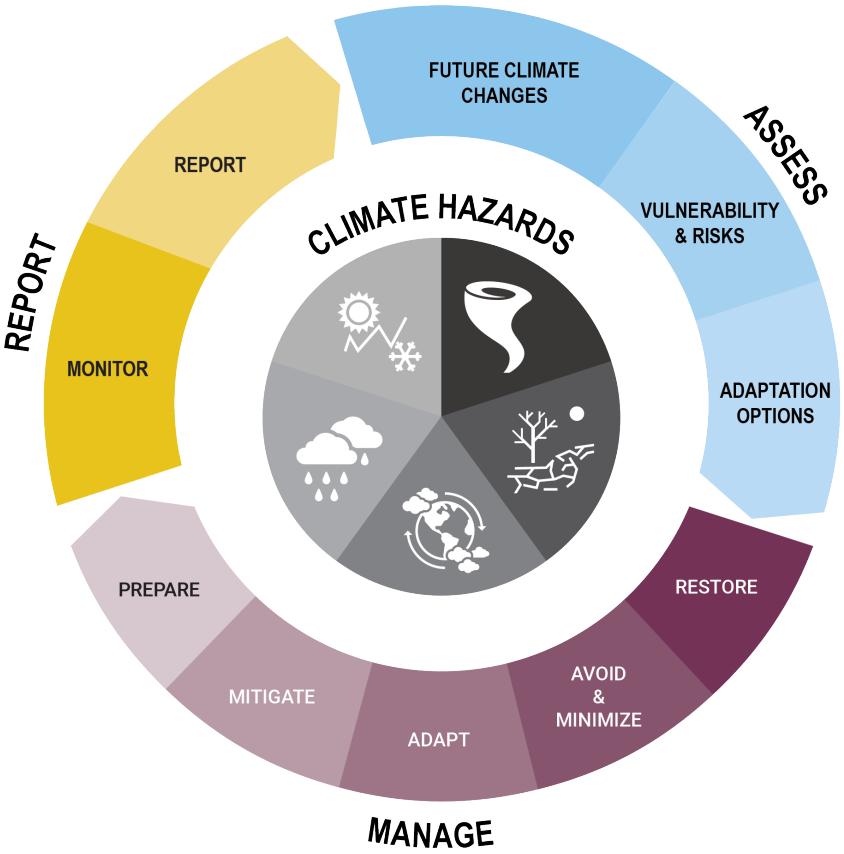


Figure 6. Adaptation Planning Process

2.0 CVRA ENGAGEMENT

This CVRA was developed with the involvement of City staff and external stakeholders and with input from residents and local businesses and organizations. The purpose of engagement was to:

- Generate broad interest and awareness of the development of the City's Climate Resiliency Strategy.
- Educate the public and stakeholders on the climate projections, impacts, and solutions.
- Seek input from the public and stakeholders on key issues, vulnerabilities, risks, and solutions to inform the CVRA and the upcoming CRS.
- Collaborate with key stakeholders to identify shared risks and opportunities to develop shared solutions.

A summary of stakeholders and their role in the CVRA follows.

2.1 Internal Engagement

More than 120 staff from various City departments participated in 12 inter-departmental Task Teams established to examine climate risks in all City service areas. Staff were engaged in both online surveys and virtual workshops throughout the project to provide vulnerability and risk ratings, to identify adaptive measures underway and gaps, and to provide input on the priority risks. Risk assessments for drinking water, wastewater and stormwater services, as well as for the water purification and wastewater treatment plants were led by staff in Infrastructure Services as separate assignments. Ottawa Public Health also conducted an in-depth assessment of health risks associated with extreme heat. Representatives from each of the 12 Task Teams also reviewed and commented on the priority risks from all Focus Areas. Internal stakeholders were provided an opportunity to review and provide feedback on the draft CVRA.

The following City departments participated in the CVRA:

Community and Social Services
- Business Support Services
- Children's Services
- Community Safety, Well-Being, Policy and Analytics
- Employment and Social Services
- Gender and Race Equity, Indigenous Relations, Diversity and Inclusion – Anti-Racism, Women and Gender Equity; Integrated Neighborhood Services; Social Development and Funding
- Housing
- Long Term Care

Emergency and Protective Services
- Ottawa Fire Services
- Ottawa Paramedic Service
- Public Safety - Office of Emergency Management

Infrastructure and Water Services
- Asset Management – Buildings and Parks; Infrastructure Planning; Infrastructure Renewal; Strategic Asset Management; Transportation, Water Resources

Ottawa Public Library – Branch Operations

Planning, Real Estate and Economic Development
- Corporate Real Estate Office
- Economic Development and Long Term Planning – Climate Change and Resiliency; Community Planning/ Official Plan; Economic Development; Natural Systems and Rural Affairs
- Planning – Development Review
- Transportation Planning - Policy and Networks; Environmental Assessments
- Right-of-Way, Heritage and Urban Design
-

Public Works
- Parks and Forestry Services
- Roads and Parking Services
- Solid Waste Services – Long Term Planning, Collections, Compliance, Operations
- Traffic Services – Traffic Operations; Traffic Safety

Recreation, Cultural and Facilities Services
- Business and Technical Support Services

- Infrastructure Services - Design and Construction, Quality Management-
- Water Services

Innovative Client Services
- Fleet Services – Fleet Supply Chain

Ottawa Police Services

Ottawa Public Health
- Communicable Diseases Service - Emergency Management
- Communications and Community Engagement Service – Community operations
- Environmental Health and Knowledge Exchange - Healthy Communities Branch
- Community Recreation, Culture and Sport
- Facility Operations - Building Engineering and Energy Management
- Parks and Facilities Planning

Transit
- Transit Customer Systems and Planning Service – Service Planning

Rail Construction Program – O Train Planning and Traffic Management

2.2 Targeted External Engagement

Ottawa-based subject matter experts and partners were invited to participate through online surveys and workshops to provide input on key areas where there were notable knowledge gaps. Surveys and workshops were organized around five themes: Agriculture and Food Systems; Health and Social Systems; Infrastructure and Built Environment, Local Economic Development; and Natural Environment, Parks and Land Use.

Approximately 50 representatives were invited from a range of government, non-government and private sectors for the following service areas:

- Agricultural producers and processers
- Business and economic development
- Community and social service organizations
- Community associations
- Conservation authorities
- Emergency preparedness and response
- Environmental organizations
- Equity-seeking groups
- Federal and other local governments
- Property management and development
- Public health and hospitals
- School Boards, Colleges and Universities
- Utilities

Representatives from Indigenous communities were provided information and invited to participate through the Business and Technical Support Services team of Planning, Real Estate and Economic Development Department, as part of engagement on departmental issues.

2.3 Public Engagement

Public engagement focused on individuals, organizations and businesses and involved education on climate projections on the City's website, communication through social media channels and the deployment of two online surveys (one for residents and one for businesses, organizations and institutions) to collect information on the following topics:

- How climate change is affecting residents and their communities
- The future impacts of climate change residents are most concerned about
- How we can best prepare Ottawa to be resilient to the impacts
- What residents are doing to adapt to current and future climate change

The project received 502 responses to the surveys.

2.4 Engagement Timeline

The engagement timeline is summarized in Table 2 below.

Table 2. Engagement Timeline

Timeline		Stakeholder Engaged	Method	Purpose
2020	**DEC**	Internal Stakeholders: Focus Area Task Teams	Project Launch	Present the project and form inter-departmental Task Teams.
2021	**FEB – MAR**	Internal Stakeholders: Focus Area Task Teams	9 Focus Area Introductory Workshops	Brief Task Teams and confirm subject matter expertise.
	MAR – DEC	Residents, Local Businesses, Organizations and Institutions	Online Survey	Gather information on climate hazards experienced, what hazards are of greatest concern, and overall level of preparedness for the possible hazards.
	MAY	Internal Stakeholders: Focus Area Task Teams	9 Focus Area Vulnerability Surveys	Validate and provide input on each Focus Area impact statements (presented in a backgrounder) and rate the level of exposure and sensitivity at the City and community scale.
	JUN	Internal Stakeholders: Focus Area Task Teams	9 Focus Area Vulnerability Workshops	Present survey findings for additional feedback and comments, rate the City and community's sensitivity, exposure, and adaptive capacity to derive vulnerability ratings.
	AUG	External Stakeholders	5 Sectoral Vulnerability Surveys	Collect information on community vulnerability, fill information gaps, and identify adaptive opportunities. Surveys were collapsed into 5 Sectors: Food and Agriculture, Built Environment Health and Social Systems, Local Economic Development, Environment, Parks, and Land Use
	SEP – OCT	Internal Stakeholders: Focus Area Task Teams	9 Consequence Surveys	Assess the social, economic, and environmental consequences of the impact statements (ratings and rationale).
	OCT	External Stakeholders	5 Sectoral Workshops	Review and discuss the possible consequence of the impacts, identify which populations, assets and/or areas are most vulnerable to the impacts, and gather information on what existing adaptation measures are in place in the community.
	OCT – NOV	Internal Stakeholders: Focus Area Task Teams	9 Consequence Workshops	Review the outcomes of the preliminary risk assessment and provide feedback and comments.
2022	**FEB**	Internal Stakeholders: Internal Working Group	Priority Risk Review Workshop	Review all priority risks, discuss whether the overall ratings are appropriate and if any have been missed.
	MAR – APR	Internal Stakeholders: Focus Area Task Teams and Internal Working Group	Draft Report	Draft CVRA report shared for review and comment.

Risk assessments for drinking water, wastewater and stormwater services, as well as for the water purification and wastewater treatment plants, and for health risks associated with extreme heat, were also conducted in 2021-2022.

3.0 METHODOLOGY

A Climate Vulnerability and Risk Assessment (CVRA) consists of two distinct parts: a vulnerability assessment and a risk assessment. The vulnerability assessment aims to measure the extent to which a segment or group of the population, asset, system, or sector is susceptible to, or unable to cope with, climate hazards. While a vulnerability assessment can help to identify the potential problems, the number and scope of potential problems may be beyond what can be practically addressed using available resources. Conducting a risk assessment is used to help prioritize these potential problems or vulnerabilities by assessing the probability of the climate hazard occurring and estimating what the social, economic, and environmental consequences would be. In determining the probability of a hazard's occurrence, the future frequency is compared to the historical climate trends using a threshold relevant to the population, asset, system or focus area being considered. Priority climate risks arise because of the confluence of vulnerability, probability, and consequence. The overall risk rating serves to prioritize impacts for adaptation planning and risk reduction measures.

3.1 Methodology Overview

The CVRA process deployed is based on (International Council for Local Environmental Initiatives' (ICLEI) Building Adaptive and Resilient Communities (BARC) Protocol[18], International Organization for Standardization (ISO) 14090-92 standards and the City's Enterprise Risk Management (ERM) framework which is based on the ISO 31000 risk management standard. This hybrid approach enabled the City to integrate findings from Ottawa's Hazard Identification and Risk Assessment (HIRA) (led by Emergency and Protective Services), a Health and Climate Vulnerability Assessment (led by Ottawa Public Health), and climate risk assessments conducted on wastewater, stormwater and drinking water assets (led by Infrastructure Services using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) methodology). The overall approach is depicted in Figure 7.

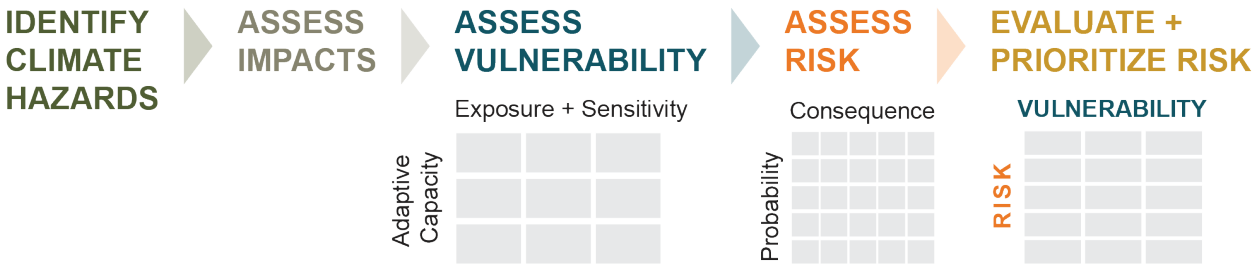


Figure 7. Climate Vulnerability and Risk Assessment Framework

A summary of the methodology follows. A more detailed overview of the CVRA methodology is presented in Appendix A:.

[18] International Council for Local Environmental Initiatives: Local Governments for Sustainability Canada (2018). Building Adaptive and Resilient Communities (BARC).

3.1.1 Scope

The CVRA assessed climate vulnerabilities and risks across all sectors that affect the livability and prosperity of Ottawa. To organize the assessment in a meaningful manner, 12 Focus Areas were selected to represent the built, natural, and human sectors that provide important services to the community (Figure 8).

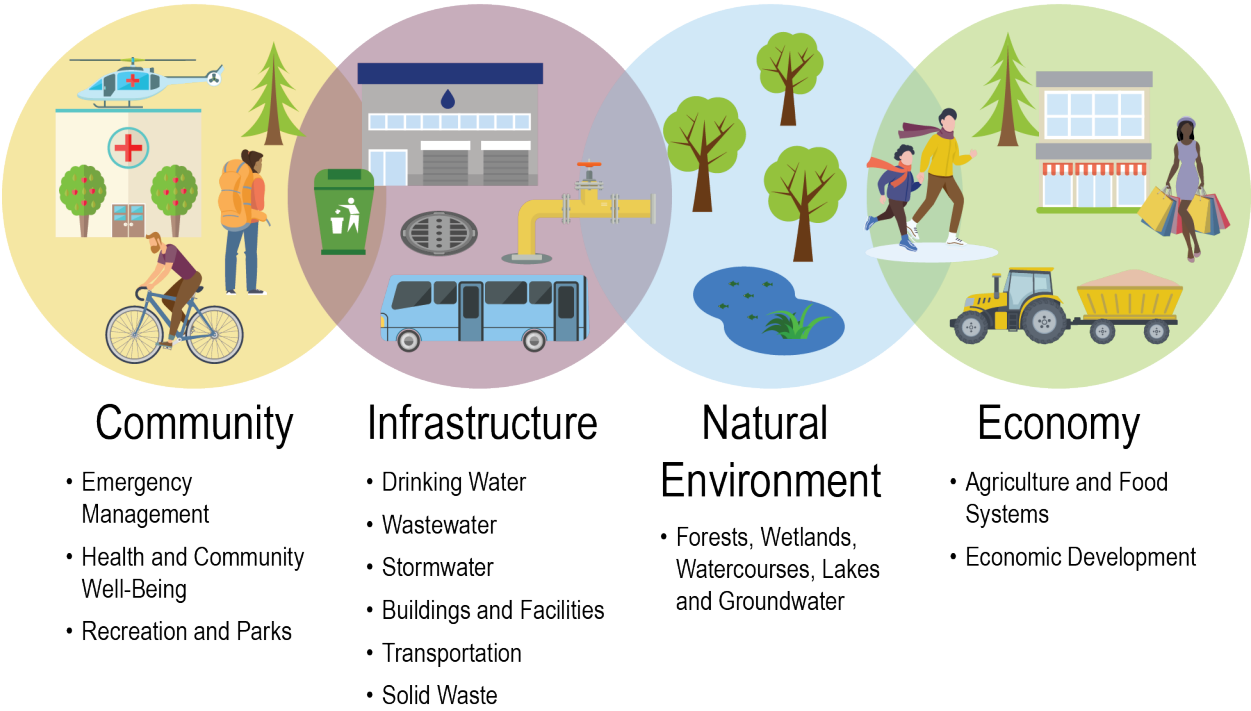


Figure 8. Focus Area Grouping

Within each of the Focus Areas, the CVRA examined the vulnerabilities and risks at two distinct scales:

- **City** – this involved looking at how climate change would impact City operations and programming, infrastructure, levels of service, and staff.
- **Community** – this involved looking at how Ottawa residents (daily activities and lifestyles) and businesses would be impacted by changing climate conditions.

Upon completion of the CVRA, the results from each Focus Area were rolled up to reflect the top climate risks to Ottawa.

3.1.2 Climate Hazard and Impact Identification

The first step in the CVRA process begins with using climate projections to assess which climate indices might materialize as impacts today and in the future. To understand anticipated future climate conditions in the National Capital Region, the City, in partnership with the National Capital Commission and Environment and Climate Change Canada, developed and released a comprehensive climate change projection study called "Climate Projections for the National Capital Region"[19]. It used advanced climate science modelling to predict changes in 178 climate indices by the 2030s (2021-2050), 2050s (2041-2070) and 2080s (2071-2100) compared to a 1980-2010 baseline. The

[19] National Capital Commission and City of Ottawa (2020) Climate Projections for the National Capital Region report.

indices were calculated from climate parameters like wind, snow, temperature, and precipitation, to provide detailed and meaningful projections that can be used by decision-makers.

By assessing how climate indices may change (i.e. no noticeable change, warmer and drier summer, more frequent and intense storm events, less frost days, change in growing degree days, etc.), a preliminary analysis of the climate hazards and impacts for each focus area was completed. The possible range of impacts were described in concise impact statements that outlined projected threats or opportunities and briefly described how those changes are expected to affect a particular area, asset, or sector (in both positive and negative ways). Impact statements are intended to capture:

- A climatic hazard (i.e. increase in freezing rain events, warmer summer temperatures)
- The outcome of the climatic hazard (i.e. damage to trees or electrical infrastructure, heat waves)
- The impact associated with this outcome (i.e. electricity outages, specific health impacts)

As a result of this work, 20 primary climate indices were used to generate a total of 149 impact statements across the 12 Focus Areas (Figure 9). To simplify reporting, these climate indices were organized into the following climate hazard themes. Details on the probabilities associated with these climate indices are presented in Appendix B:

Climate Hazard	Climate Indices
Extreme heat, drought and humidity	Increase in extreme heat days Increase in heat warnings Increased occurrence of drought like conditions
Seasonal variability and change	Change In seasonal characteristics Increase In average temperatures Increase in winter average temperature Increased occurrence of seasonal winter freeze thaw Less cold extremes
Increased precipitation volume and intensity	Increase in the occurrence of intense precipitation Increase In total precipitation Increase in three-day snow melt and precipitation events Increase in riverine flooding
Extreme weather events	Increase in wildfires Increase in extreme wind / tornadoes Increase in extreme snow and blizzards Increase in freezing rain events Increase in multi-day ice storms Increase in winter freeze thaw and ice storms
Global climate change	Increase in global climate change

Figure 9. Summary of Climate Indices Used in the CVRA by Climate Hazard Theme

3.1.3 Vulnerability Assessment

Vulnerability is the measure of the extent to which a segment or group of the population, asset, system or sector is susceptible to, or unable to cope with, the impacts as a result of a changing climate. Vulnerability is based on assessing exposure, sensitivity, and adaptive capacity (Figure 10).

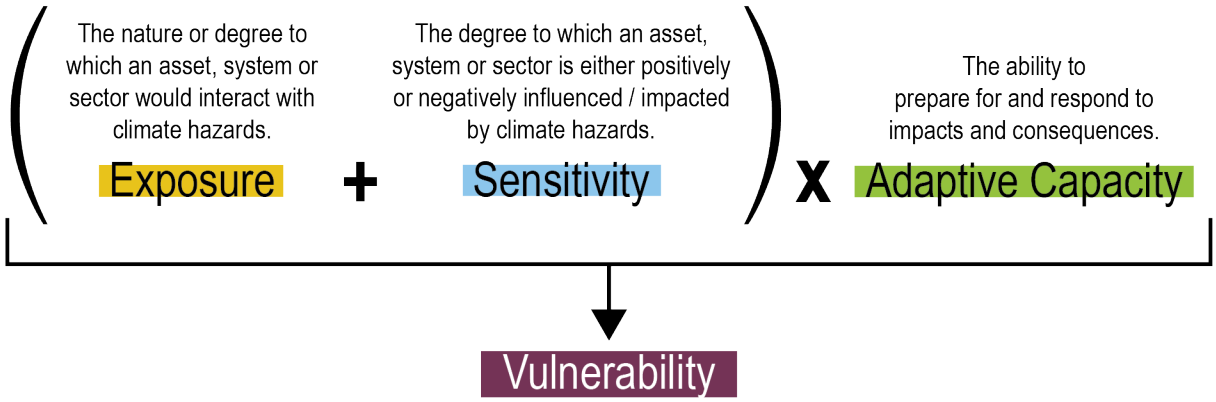


Figure 10. Basis of Vulnerability

While vulnerability is a function of a Focus Area's exposure, sensitivity and adaptive capacity, broader socio-economic factors also come into play. The following factors were also considered as part of the analysis:

- **Physical** – Physical vulnerability is a measure of how damage to structures (e.g. buildings, infrastructure) and systems (e.g. electricity, communications) impact the ability of the community to withstand and recover from a climate related impact. Physical vulnerability depends on a wide range of factors including geographic proximity to the climate hazard and impact, how systems that provide the flow of services to meet social and economic needs are impacted, and the cascading impacts that may occur. Typically, to assess physical vulnerability, engineering-based CVRAs of specific assets are required.
- **Social** – Social vulnerability is a measure of how climate hazards will impact different groups within a study area as well as the institutional structures and systems designed to help them cope. Social vulnerability varies, but typically increases where there are seniors, children, disabled individuals, socially or geographically isolated individuals, homeless or precariously housed persons, equity-seeking groups and people of lower social-economic status.
- **Economic** – Economic vulnerability is a measure of how exposed economic assets and processes (i.e. business interruption, secondary effects such as increased poverty and job loss) are to shocks and their ability to withstand or recover from the effects of such shocks. Economic vulnerability will vary based on the economic sector as well as the cascading impacts that may occur (e.g. business closures lead to job losses which can result in a loss of homes and place greater pressure on social systems).
- **Environmental** – Environmental vulnerability is a measure of how climate hazards and impacts could impact flora, fauna, ecosystems, and biodiversity and result in changes to provisioning (e.g. food, clean water) regulating (e.g. flood control), supporting (e.g. nutrient cycling), and cultural (e.g. recreational, educational) services that ecosystems provide.

The vulnerability assessment relied on information collected through City staff interviews, literature reviews, information collected from surveys and workshops with City staff and subject matter experts, findings collected in the public and business surveys, and the PIEVC climate risk assessments of water, wastewater, and stormwater infrastructure systems.

3.1.4 Risk Assessment

Following the completion of the vulnerability assessment list, the next step was to determine the relative risk posed by each hazard. To calculate the risk scores, it was necessary to assess both the likelihood of each climate hazard's occurrence and its potential consequences. The assessment was grounded in engagement with City staff, and subject matter experts, and was supplemented with research into historical and notable hazard events. Risk is commonly calculated by multiplying the probability score by the total consequence score (Figure 11).

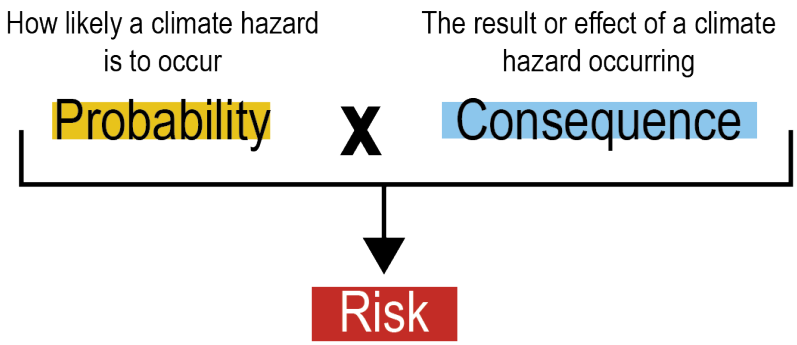


Figure 11. Basis of Risk

The probability ratings were based on the National Capital Region climate projections data which used climate science/climate models to determine the likelihood a certain climate hazard will exceed the threshold assigned (i.e. 15 mm of freezing rain in four hours) as compared to the baseline. Thresholds are based on best practices and indices (e.g. health indices, engineering standards, etc.). The probability ratings also relied on a 5-point scale where 1 is 'rare' and 5 is 'almost certain' the event will occur (Table 3).

Table 3. Probability Rating Based on Climate Event Occurrence

Occurrence	Qualitative Descriptor	Recurrent Event	Single Event	Rating
>1:50 year	Rare	Not likely to occur in the assessment period.	Negligible: probability very small, less than zero	1
1:30-50 year	Unlikely	Likely to occur at least once between 30-50 years	Unlikely but not negligible: probability noticeably greater than zero	2
1:10-30 year	Possible	Likely to occur at least once every 10 to 30 years	Less likely than not but still appreciable – probability less than 50% but still quite high	3
1: 1-10 year	Likely	Likely to occur at least once per decade	As likely as not – 50/50 chance	4
>1/year	Almost Certain	Likely to occur once or more annually	More likely than not – probability greater than 50%	5

The consequences of the described impacts were assessed using a five-point rating system ranging from "very low" to "very high" for each impact statement. For this risk assessment, the maximum value of the economic, social, and environmental consequence ratings was used as the final consequence rating.

Table 4. Consequence Rating Scale

	Consequence Dimension		
Rating	**Social**	**Economic**	**Environment**
Very High (5)	• Large number of fatalities or serious injuries, permanent illness (physical or mental) or displacement of a large number of people. • Large disturbances leading to permanent changes in people's normal routines and way of life (> 1 month but causing daily changes) • Permanent decline in services, causing the city to be seen as unattractive, and not providing essential services to the community	• Regional decline leading to widespread business failure, loss of employment and hardship • Catastrophic damage and costs incurred by the City / property owner ($$$$$)	• Major loss of environmental amenity (includes air, water, soil, vegetation, natural heritage and ecological functions) and irrecoverable damage
High (4)	• A low number of fatalities, serious injuries, or long-term illness (physical or mental) or displacement of people. • Severe decline in services and quality of life within the community • Large disturbances leading to prolonged changes in people's normal routines and way of life (> 1 month but not daily)	• Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth. • Major damage and costs incurred by the City / property owner ($$$$)	• Severe and widespread loss of environmental amenity and danger of continuing environmental damage
Medium (3)	• Small number of injuries, or cases of illness. • Some isolated instances of temporary displaced people. • Isolated but noticeable examples of decline in services. • Moderate disturbances leading to short-term changes in people's normal routines and way of life (1 week to 1 month)	• General reduction in economic performance relative to current forecasts. • Moderate damage and costs incurred by the City / property owner ($$$)	• Isolated but significant instances of environmental damage that could be reversed with intensive efforts
Low (2)	• Near misses or minor injuries. • Isolated instances of temporary displaced people in localized areas. • There would be minor areas in which the community is unable to maintain its current services • Minor and short-term changes to people's normal routines and way of life (<1 week)	• Isolated areas of reduction in economic performance relative to current forecasts. • Minor damage and costs incurred by the City / property owner ($$)	• Minor instances of environmental damage that could be reversed
Very Low (1)	• Appearance of a threat but no actual harm or displacement. • No changes to people's normal routine and way of life. • No real pressure on current services.	• No real impact to the local economy and growth. • No damage and costs incurred by the City / property owner ($)	• No real environmental damage

Positive consequences were assessed in the same manner as negative consequences, but the consequence descriptor is reversed and viewed in a positive light. For example, a positive impact to agriculture may be an increased growing period which could have an "isolated improvement in economic performance relative to current forecasts" thereby warranting a consequence rating of a 2.

The risk assessment relied on information presented in the City's most recent Hazard Identification and Risk Assessment (HIRA) survey, information collected from surveys and workshops with City staff and subject matter experts, findings collected in the public and business climate related impact surveys, and detailed PIEVC climate risk assessments of water, wastewater, and stormwater infrastructure systems.

3.1.5 Evaluating Priority Risks

To determine the final risk level and the priority nature of the climate related impact, the final vulnerability and risk ratings were assessed and used to prioritize the timing to which risks will need to be addressed (Figure 12) including:

- Immediate action required (within the next 1-3 years)
- Develop a plan to address risk (within the next 4-7 years)
- Identify possible controls and continue to review for change
- Continue to manage through existing controls and procedures

The CVRA methodology evaluated risks for all future periods (2030s, 2050s and 2080s) based on a 1980-2010 baseline and took an average of these risks to inform the prioritization process. Where there were duplicate or similar impact statements due to different Focus Areas evaluating the impacts, the highest risk rating was applied. The highest-ranking priority impacts require immediate attention and will form the basis of the adaptive actions in the CRS.

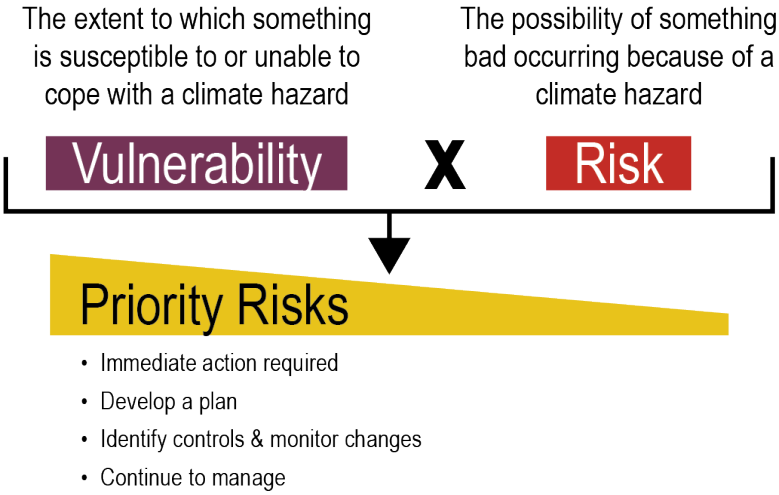


Figure 12. Basis of Assessing Priority Risks

3.2 Limitations of the CVRA

Like any vulnerability and risk assessment, the CVRA assessment is subject to some uncertainty and limitations – these include:

- **Time Horizon**
  Future climate change is dependent upon the amount of global GHG emissions that have and will be emitted. In the near term, it is easier to predict GHG emission levels because they will be like today's rate of emissions production. However, it is increasingly difficult to project emission levels out 50 to 100 years into the future because it is not known how our global society will evolve over time (e.g. population growth, economic growth, energy use, development of significant technological advancements, political action mitigating emissions). Thus, uncertainty associated with the probability of climate hazards will increase for longer time horizons. Climate models will be updated and improved as new data becomes available. Reviewing new future climate data on a regular basis will provide decision makers with the best available science, research and evidence on which to make climate-based policies, procedures and operating/management decisions.

- **Climate Parameter Data**
  There remains uncertainty surrounding climate projections and indices, particularly for non-temperature climate variables such as precipitation and extreme events. These uncertainties arise from natural variability, scenario uncertainty, and scientific uncertainty. While all climate projections and probabilities are subject to this uncertainty, it should not stop the City, organizations and agencies from using this information when developing projects, policies and programs.

- **Scale**
  This assessment was contained to the City of Ottawa municipal boundaries. While there was an assessment to City operations and the broad community, it does not present an assessment for individual communities within Ottawa. This is important as not all communities within Ottawa will be equally at risk to each of the climate related hazards and impacts. The impacts and consequences will be related to the magnitude of the event, the social, economic, physical and environmental vulnerabilities already present, and the ability of the City and community to cohesively come together to respond (i.e. adaptive capacity). Considering this, the results of the CVRA assessment serve as a starting point to complete more detailed climate vulnerability and risk analyses for specific communities and infrastructure.

- **Perspective**
  It is important to note that the CVRA process is not an exact science. It is a subjective exercise that utilizes participants' understanding and perceptions of sensitivity, exposure, vulnerability and social, economic and environmental consequences to the City and the community that may result from climate hazards occurring. While steps were taken to engage City departments, the public, community members and local subject matter experts, the CVRA does not capture every stakeholder perspective.

- **Vulnerability and Consequence Ratings**
  City staff were engaged in vulnerability and risk surveys to provide their ratings of sensitivity, adaptive capacity, and consequence ratings at the City and community scale. These ratings or perceptions are often influenced by contextual factors like the timing of the event occurring again (if it already happened) or if it is unlikely to occur. For example, when there are looming threats/hazard on the horizon, then perceptions tend to be more pessimistic. The same applies to threats/hazards that are thought to be uncontrollable. To minimize this risk, workshops were hosted with staff where the vulnerability and risk ratings were presented to staff for review, discussion and where necessary modification of the ratings. Where there was divergence in vulnerability assessments, consequence or risk ratings, City staff were asked to discuss the rationale behind their ratings.

- **Information Gaps**
  Where there were deemed to be gaps in City knowledge, such as in determining risks to the community or economy, external subject matter experts were engaged. While there are still gaps in information that would help refine vulnerability and risk assessments, these gaps can and will be addressed through the development and implementation of the CRS.

While there are limitations with any risk assessment process, the identification of priority risks is the most important result of this project. Continuing to use the CVRA process with City staff will not only provide useful information about changing vulnerabilities and risks, but it will also build the City and the community's understanding of the impacts of climate change to Ottawa and how to take a systematic approach to climate change risk management at the City and community scales. The input to the CVRA process and supporting documentation will need to be updated and adjusted as new information becomes available and should be updated at least every five years as best practice.

4.0 CVRA – OVERALL FINDINGS

The following sections present the findings of the CVRA. Section 4.1 presents a summary of the CVRA assessment, the priority risks, and the populations within Ottawa that are most likely to be impacted by climate change. Sections 4.2 to 4.6 present a breakdown of the findings by climate hazard theme. These sections summarize the climatic changes expected for Ottawa between now and 2100, what impacts are likely to occur, who or what is most vulnerable, existing adaptive measures, and the associated average risk rating for each impact (2030-2100). These sections are organized by climate hazard theme:

- Extreme heat, drought and humidity
- Seasonal variability and change
- Increased volume and intensity of precipitation
- Extreme weather events
- Global climate change

A summary of the Priority Risks for all climate hazards is available in Appendix C. Appendix D presents the full list of impact statements by the 12 Focus Areas and includes the vulnerability and risk ratings and supporting information.

4.1 Summary of Findings

The CVRA process examined how changes to 178 climate indices could result in climate hazards and impact each of the 12 Focus Areas. This resulted in the use of 20 primary climate indices (refer to Figure 9) and the generation of 149 impact statements that described a range of possible climate-related impacts to the City and the community. During the vulnerability and risk assessment stages, each impact statement was assessed on the City's and community's ability to respond to the impact should it occur, how the impact would affect the functionality (i.e. the ability to provide services, complete daily activities, etc). and what the social, economic and environmental consequences could be. The Vulnerability Assessment stage resulted in 110 City-based impact statements and 82 community based impact statements moving through the risk assessment stage where probabilities and consequences were assessed (Figure 13). Once this stage was complete, the overall risk and vulnerability ratings were reviewed to identify the 40 priority risks to Ottawa (Table 5).

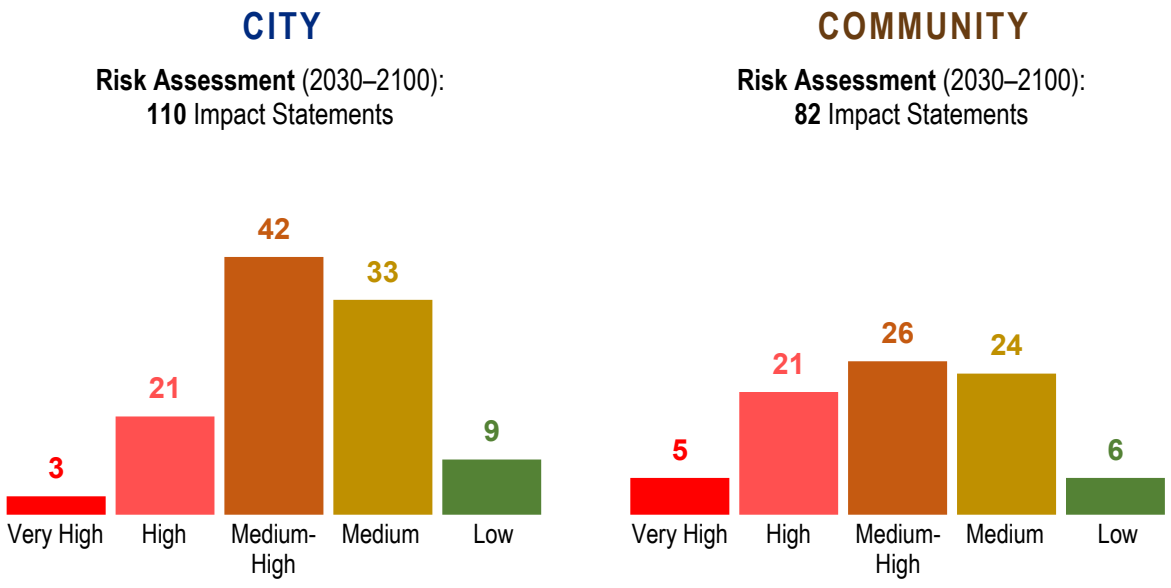


Figure 13. Summary of Risk Ratings

Figure 13 presents the outcome of the risk assessment before the impact statements were evaluated on their risk and vulnerability to identify priority risks. As noted in the above figure, of the 110 potential impacts to the City over the 2030-2080 period, 19 were deemed to be high or very-high risk. 60% of these risks are related to extreme heat and changes to precipitation. Seasonal variability also presents a greater risk to the City in terms of the possible impacts to operational demands, ecosystems (salt use, invasive species, ecosystem shifts), maintenance of assets that are most vulnerable to winter-freeze thaw events and road salt application (e.g. roads, bridges, ecosystems, etc.). While extreme weather (e.g. tornados) accounts for a smaller proportion of overall risks (8% - due to the low probability of occurrence), the consequences can be severe and long-lasting. Global climate change, accounting for 13% of the risks, was also noted in several Focus Areas due to the cascading effects on the availability of material goods and especially fuel, and the resulting impact on capital costs and operational budgets.

At the community scale, of the 82 impact statements assessed, 26 were deemed to be high or very high risk. Like the City, more than 60% of the risks are related to extreme heat and changes to precipitation (Figure 15). Compared to the City, extreme weather (e.g. tornados) and global climate change accounts for a slightly higher portion (15%) of the high and very high risks in the community. This is not surprising considering the socioeconomic vulnerabilities to supply chain disruptions and the extent of damage and cascading impacts that can result during and long after an extreme weather event. Seasonal variability had a smaller proportion of overall risks (7%), as compared to the City (17%), largely due to the fact the direct impacts will be most felt by the City in terms of infrastructure repair and renewal. Seasonal change can result in health and safety impacts to the community in terms of flooding, slips and falls due to icy conditions, and potential isolation.

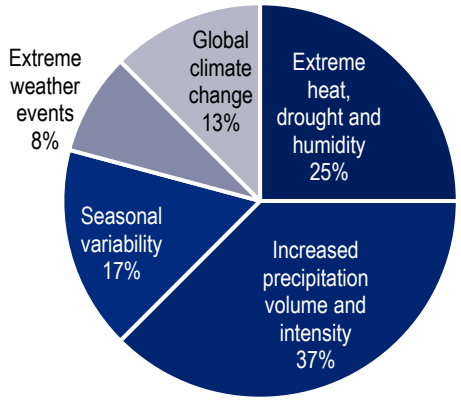


Figure 14. Breakdown of High and Very-High Risks by Climate Hazard to the City of Ottawa (Corporate Risks)

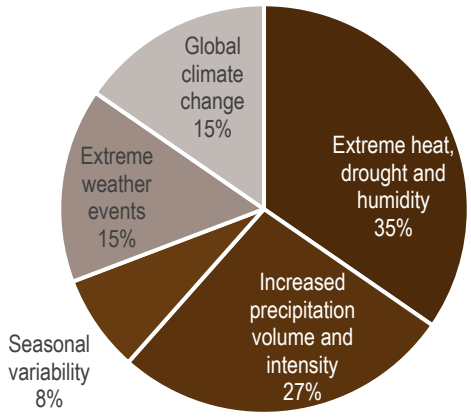


Figure 15. Breakdown of High and Very-High Risks by Climate Hazard to the Community

The assessment findings also align with what the City heard back from the public through the online climate change surveys. Overall, 93% of the 502 respondents identified that they are very concerned about the effects of climate change. The top climate issues of concern relate to extreme heat, seasonal change, flooding and extreme weather (Figure 16).

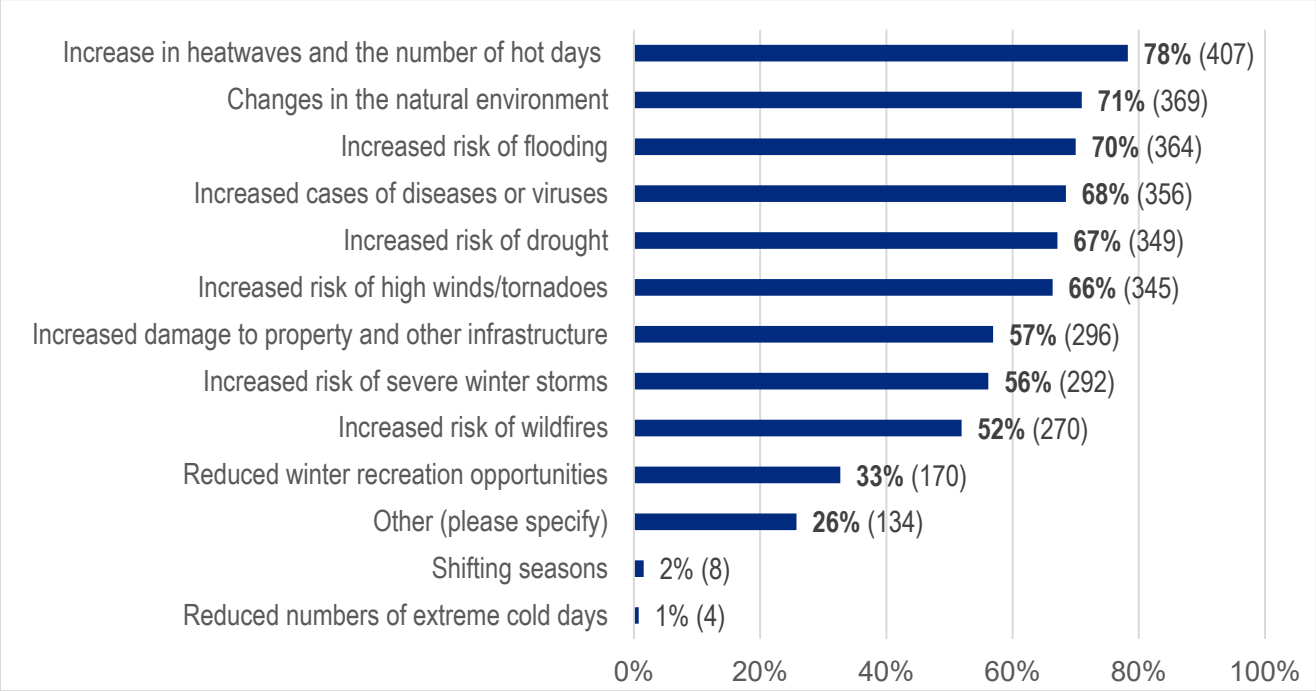


Figure 16. Summary Results of Public Survey on Climate Impacts of Concern

Respondents who selected 'other' most commonly expressed concern about food security, greater risks to equity seeking groups (due to environmental racism or inequality) and impacts to physical and mental health. Examples of "other" comments received include:

- "Food insecurity due to crop failure"
- "Impact on ability to grow food locally"
- "The cumulative impact of all those changes - especially on our most vulnerable people"
- "Inequitable effects of climate change (people who are poorer, racialized people, people with health issues etc. will be hurt more)"
- "Underprivileged and other vulnerable people bearing the brunt of effects"
- "Increased risk to local health"
- "The impact of the above on my mental and physical health"

The most common climate related impacts that have been experienced by respondents included heatwaves (77%), changes in the natural environment (51%) and high winds/tornadoes (49%). When asked to describe how they have been affected by climate related hazards, respondents told stories of their property, health or lifestyles being impacted by extreme weather events (heatwaves, drought, flooding, tornadoes, ice storms), Lyme disease and warmer winter temperatures.

4.1.1 Priority Risks

To identify priority risks, the CVRA methodology took the average of the future risks (2030s, 2050s and 2080s) for each impact statement and compared the average risk rating to the rated vulnerability. The priority risks are those impacts that have a medium or higher vulnerability and a medium-high or higher risk and thus require immediate action – i.e. within 1-3 years (see Figure 12 in Section 3.1.5). Where there was a higher priority rating between the City and the community impact statement assessment, and where there were duplicate impact statements between Focus Areas, the higher assessment rating took precedence. Figure 17 shows the distribution of climate impacts by vulnerability and risk ratings.

	Vulnerability		
Risk	**High**	**Medium**	**Low Vulnerability**
Very High	2	5	0
High	18	4	0
Medium-High	11	17	2
Medium Risk	7	20	0
Low Risk	1	1	2
Immediate action required.			
Develop a plan to address risk.			
Identify possible controls and continue to review for change.			
Continue to manage through existing controls and procedures.			

Figure 17. Distribution of climate impacts by vulnerability and risk ratings

A total of 40 priority risks were identified. A summary of the priority risks are presented in Table 5 by Climate Hazard. Note that several priority risks cross multiple focus areas but may only be captured under one or two areas. The complete list of Priority Risks is described in subsequent sections of this report and can be found in Appendix C. Appendix D describes the full list of risks by Focus Area.

Table 5. Summary of Priority Risks

Climate Hazard	Priority Risks
Extreme heat, drought and humidity	• Increased heat-related illnesses • Less outdoor recreation and active transportation • Increased building cooling demands, inadequate air conditioning (especially in schools, low-income housing, community buildings, and long-term care facilities) • Increased demand for shaded areas and indoor and outdoor recreation facilities to offset heat • Increased tree stress, reduced stream baseflow, degraded aquatic habitat, algae blooms • Reduced agricultural yields and increased irrigation

Seasonal variability and change	• More invasive species, pests and diseases harming:
	  ○ trees, parks and ecosystems
	  ○ agricultural production and food supply
	• New or intensified disease vectors and illnesses (e.g. Lyme disease or West Nile virus)
	• Increased winter freeze-thaw damage and reduced asset life of:
	  ○ roads
	  ○ buildings (e.g. foundation cracking and heaving, pipe bursts)
	  ○ surface and shallow stormwater and wastewater infrastructure (e.g. catch basins, driveway culverts, maintenance holes, pump stations)
	• Increased winter roads, sidewalks and pathway maintenance and risks to users due to freeze-thaw cycles and freezing rain
	• More park and beach degradation from increased use
	• Decline of winter tourism and recreation

Increased volume and intensity of precipitation	• Reduced access to roads, transit and pathways, as well as property and infrastructure due to riverine or inland flooding • Riverine flood damage and reduced access to Water Purification Plants • Damaged / overwhelmed stormwater, wastewater and flood protection infrastructure in floodplains (e.g. pump stations, culverts, sewers, berms) • Increased runoff from overwhelmed stormwater infrastructure causing reduced water quality, erosion, bank destabilization and localized and basement flooding • Building damage (inland or riverine flooding) and basement flooding/ sewer backup (overwhelmed wastewater systems) • Mental, physical & financial health - injuries, stress, mold, contaminated private wells and septic systems • Delayed planting/ harvesting and reduced pasture

Climate Hazard	Priority Risks
Extreme weather events	• Increased winter slips / falls and isolation • Increased winter maintenance of roads, sidewalks and pathways and risks to users due to freeze-thaw cycles and freezing rain • Reduced ability of City and community services to effectively respond to simultaneous or repeated extreme events • Reduced access to essential services during extreme weather (e.g. electricity, health, education, food banks, transit) • Increased pressures on people experiencing poverty or in precarious economic situations (physical, financial and mental health) • Ditch and culvert blockages from windborne debris causing localized flooding • Business disruptions
Global climate change	• Supply chain instability and impacts to the availability and cost of food, energy and other goods and services • Additional pressures on disproportionately impacted populations • Additional pressures on social service providers

4.1.2 Disproportionately Impacted Populations

During the impact identification and vulnerability assessment stages, the CVRA considered which aspects of the City and community are most vulnerable to the anticipated effects of climate change including people, buildings and infrastructure, ecosystems and natural resources, services, and economic drivers. During the surveys and workshops, participants were asked to provide information on which segments of the population would be impacted and how. While nearly all individuals within Ottawa will be impacted in one way or another, there are specific segments of the population more vulnerable to specific climate hazards and who have less adaptive capacity to respond. These include older adults, persons with disabilities, persons living in poverty, racialized people, Indigenous people, rural residents, immigrants, women, and youth.

Some key demographics of Ottawa and examples of climate implications include:

- Ottawa is the fourth largest municipality in Canada and home to over one million residents. By the mid 2030s, the population is anticipated to increase by more than 200,000 residents and it is estimated that residents over the age of 65 will account for over 22% of the population by 2035.[20] This is a concern as older adults are more susceptible to heat-related illnesses, air pollution (smoke) and pathogens because of existing health conditions and other factors that can limit their access to air-conditioned spaces. They may also be more prone to slips and falls or isolation in icy conditions.

- In 2016, more than one quarter (29%) of Ottawa residents self-identified as a visible minority with the largest groups identifying as Black, Arab, South Asian, Chinese, and Southeast Asian. 2.5% of the population identified as Indigenous, that is, First Nations (North American Indian), Métis or Inuk (Inuit). All of these populations may

[20] Ottawa Public Health (2018). Socio-demographic Data and Population Projections.

be more exposed and vulnerable to the effects of climate change as they could be hesitant or unable to seek help due to language barriers, citizenship or immigration concerns, and racially based discrimination / profiling.

- Households with limited financial resources are highly vulnerable to the effects of climate change and are often under-served by climate investment programs and policies due to inequitable distribution of resources and access to opportunities and lack the financial resources to prepare and/or recover. While Ottawa boasts a high median household income of $87,000, approximately 12.6% of the population is below the low-income measure.[21] Furthermore, 42% of renters and 14.1% of homeowners reported to pay more than 30% of their before-tax household income on housing, meaning that there are fewer financial resources to prepare for and respond from the effects of climate change.

- Rural Ottawa makes up 80% of the city's land area and accounts for roughly 10% of the city's population. These areas include significant agricultural lands, aggregate resources, rural hamlets and villages. Changing climate conditions can negatively affect individual and community well-being in rural communities due to impacts to agricultural practices and livelihoods, water security for those on private wells, isolation during extreme events, and protection from vector-borne diseases.

- Women, girls and gender diverse persons face barriers to access adequate, affordable, and suitable services and resources. Women and gender diverse persons coming from intersectional backgrounds face complex and multi-layered forms of discrimination and barriers and are at a higher risk of poverty and gender-based violence. The majority of health care workers are women, resulting in women providing more care in their work life during extreme climate events while also juggling increase domestic responsibilities in their home life. This is on top of women typically experiencing increased domestic responsibility and a decrease in economic stability during a disaster event.

- 24.1% of residents identified as persons with disabilities over the age of 15 in the National Capital Region.[22] Persons living with disabilities have an increased risk to the effects of climate change as they may have limited access to knowledge, resources or services to effectively respond to the events around them, may have difficulties during required evacuations due to restricted mobility leading to isolation, or may have compromised health conditions that make them more vulnerable to infectious diseases.

Individuals or groups may experience more than one vulnerability to climate change at one time, putting already vulnerable populations further at risk. Consideration for social identities and inequalities relating to gender, race, socioeconomic class, cultural and ethnic background, age, and disability and how they intersect is critical when addressing climate vulnerabilities and risk. A preliminary summary of vulnerable population groups is presented in Table 6, while Sections 4.2 to 4.5 break down and identify vulnerable populations by climate hazard theme. Further assessment to determine why, where and how some individuals and groups are at an increased risk to the impacts of climate change, as well as consideration for holistic action to address these risks, will be further studied in the development of the Climate Resiliency Strategy. Resources such as the Ottawa Neighbourhood Study and the Neighbourhood Equity Index will factor into this research.

[21] City of Ottawa (2021). Ottawa's Community Safety and Well-Being Plan 2021-2031.
[22] Statistics Canada (2019). Table 12-10-0750-01. Persons with and without Disabilities aged 15 years and over, census metropolitan areas.

Table 6. Most Vulnerable Population Groups

Population Typology	Population Groups	Climate Hazards Most Vulnerable To
Households with limited financial resources	• Persons living in poverty • Cost-burdened households • Low-income households • Unemployed persons • Female-headed households • People without air conditioning	• All hazards
Individuals that spend a significant amount of time outdoors	• Children and youth • Recreation enthusiasts • Athletes • Active transportation and transit users	• Extreme heat t and humidity • Seasonal variability
Outdoor workers	• Agricultural workers (especially migrant workers) • Construction, landscaping and other sectors	• Extreme heat, drought and humidity • Seasonal variability • Extreme events
Individuals with health conditions or limited mobility	• Persons with disabilities and/or chronic illnesses including mental health conditions. • Persons with limited access to social support systems • Older adults • Older adults living alone	• All hazards
Disadvantaged or marginalized populations	• Persons living in poverty • Cost-burdened households • Low-income households • Unemployed persons • Female-headed households • Indigenous Peoples • Racialized people • Women • Older adults • Children and youth	• All hazards
Individuals experiencing homelessness / Precariously housed populations	• Persons experiencing homelessness • Persons living in rooming houses, social housing, etc.	• All hazards

The following sections present a breakdown of the CVRA findings by climate hazard theme.

4.2 Extreme Heat, Drought and Humidity

4.2.1 Projected Changes in Climate Variables

In 2018, the Canadian Centre for Climate Services (CCCS) reported that between 1948 and 2016 the average annual temperature in Canada rose by 1.7ºC.[23] Ottawa has warmed by 1.3ºC over a similar time period (based on data collected at the local weather stations) and is projected to continue warming in all seasons over the next century. The climate models project that the annual mean temperatures in the National Capital Region will be 2–3°C warmer by the mid-century and potentially 3–5°C warmer by as early as 2071 (Figure 18). This means warmer seasons, more extreme heat events and fewer cold extreme events.

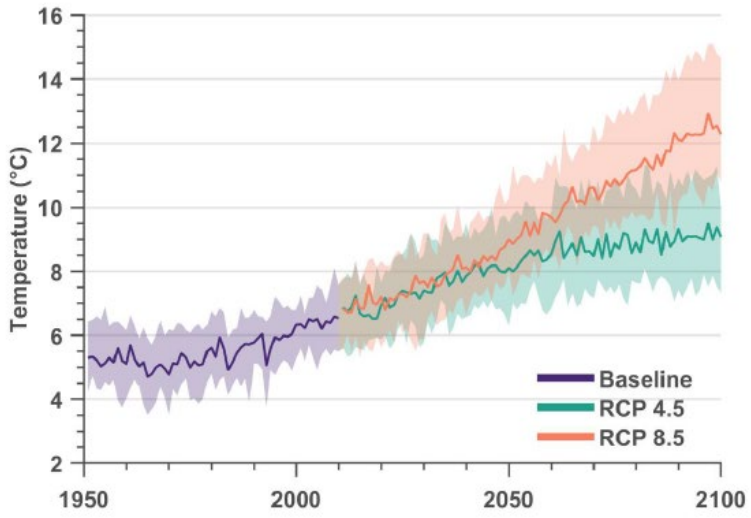


Figure 18. Average Annual Temperature[24]

While a general warming of all seasons may be viewed as a positive change in that there are likely to be longer seasons for construction, crop growing, and active transportation, these changes can have negative consequences in that the warming leads to significant changes in temperature extremes and can materialize into hazards and impacts on the human, natural and built environment. In short, most positive impacts are outweighed by negative ones.

Specifically, the average annual number of days with a maximum temperature of 30°C or greater was approximately 11 days per year in the 1981–2010 period. Depending on what emission scenario the world ends up following, this is expected to increase to approximately 25–28 days in the 2030s, 32–43 days in the 2050s and 36–72 days by the 2080s (Figure 19).

[23] Government of Canada (2019). Canada's Changing Climate Report: Changes in Temperature and Precipitation Across Canada; Chapter 4.
[24] National Capital Commission and City of Ottawa (2020).Climate Projections for the National Capital Region. *Volume 1: Results and Interpretation for Key Climate Indices*.

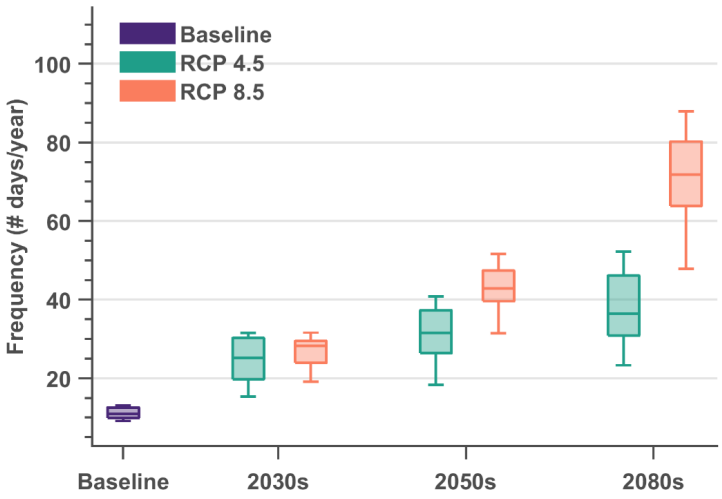


Figure 19. Number of Days above 30°C[25]

Humidex - an index calculation based on both temperature and humidity - is also projected to increase over the next century in the National Capital Region. As it can exacerbate the effects of elevated temperatures, humidex is a variable of concern for emergency response and management systems. The number of instances with a humidex of 40 or more for 2 days or more is expected to increase from approximately 1 day in the baseline to approximately 4 days in the 2030s, 5–6 days in the 2050s, and 6–9 days in the 2080s.[26]

A drought is typically defined as a period of time where there is abnormally dry weather and there is little to no precipitation. The climate projections analyses indicate that droughts will increase in frequency and occurrence as with the overall increases in temperatures and changes to precipitation. The number of water scarcity days (an index based on precipitation and temperature) is expected to increase from 26 days in the baseline to 39-42 days in the 2030s, 45-54 days in the 2050s and 48-69 in the 2080s.

4.2.2 Potential Impacts

Hotter and more humid summers will increase the incidence of extreme heat events, where the daytime temperature is above 31°C and the nighttime temperature does not go below 20°C for several days. These events have already had serious implications for human health and safety (including hundreds of deaths across Canada during the 2021 heat dome), especially for people who work and exercise outdoors, those with no access to air conditioning, and people with pre-existing health conditions (e.g. physical and mental health conditions, respiratory, circulatory and cardiovascular conditions). Factors that contribute to heat vulnerability in Ottawa include areas with minimal tree canopy and hard surfaces which can amplify the urban heat island effect[27], older housing stock (heritage buildings, social housing, etc) that may be poorly adapted to hot weather due to lack of adequate natural ventilation or air conditioning and building mechanical systems that are not rated to operate in higher temperatures. Vulnerability to

[25] National Capital Commission and City of Ottawa (2020).Climate Projections for the National Capital Region. *Volume 1: Results and Interpretation for Key Climate Indices*.
[26] Ibid
[27] City of Ottawa (2019). Map 1: City of Ottawa Urban Heat Island Map

extreme heat events is also increased by demographic and socioeconomic factors (e.g. the very young and older adults, low income, race and gender, and living alone, etc.).

The occurrence of hotter and more humid summers is likely to result in changes to community services, such as a decrease in outdoor recreation and sports, the cancellation or postponement of events to the public, and the temporary closure of buildings that do not have adequate air conditioning (e.g. daycares, churches, schools etc.). These changes can also have cascading impacts to mental health and wellness especially for low-income individuals and families who could find themselves even more isolated if low cost/free outdoor community activities are cancelled due to increases in high temperature days. In Ottawa, the most disproportionately impacted populations include women, seniors, children and infants, socially and economically disadvantaged, those with chronic illnesses, and residents in rural areas.

In terms of impacts to the built and natural environment, hotter summers can accelerate the degradation of infrastructure like asphalt roads (softening and rutting), cause heat-related damage to steel structures (e.g. bridges and rail systems), place greater stress on water and wastewater treatment operations, increase cooling demands in buildings, and because of the high demand for air conditioning, an increase in the likelihood of brownouts. Electricity outages, or brownouts, can exacerbate the risks to the community resulting in the overwhelming of emergency response and community support systems. Extreme heat days and droughts place additional stress on already stressed terrestrial and aquatic ecosystems and can result in cascading impacts including the expansion of invasive species, pests and vector-borne diseases and algae blooms all of which increase the risks to human health. Hotter and drier environments are at a greater risk to wildfires which can have a direct impact to the community (destruction of property, displacement of population and long-term mental health impacts) and indirect impacts like smoke and increased ground-level ozone levels which also result in health and safety hazards (especially for disproportionately impacted populations).

A summary of the possible range of heat, drought and humidity related impacts, vulnerabilities and consequences are presented in Table 7.

Table 7. Summary of Extreme Heat, Drought and Humidity Impacts, Vulnerabilities and Consequences

Focus Areas	Potential Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Agriculture and Food Systems	• Reduced food and agricultural production • Increased irrigation demands and costs • Increased spread of invasive species and insect pressure • Increased health and safety risks to workers • Increased health and safety risks to livestock • Increased occurrence of shallow dry wells • Reduced water quality (algal blooms) • Increased risk of wildfires	• Smaller farms with less access to risk reduction actions (e.g. crop insurance, technologies such as. tunnels and shade cloth) due to cost • Monoculture style farms (limited crop rotation and invasives) • Farms with poor soil quality • Food industry sectors that rely on low-cost food sources • Workers who may not have access to adequate shade structures and may be incented to work in all conditions	• Increased operational costs (e.g. to invest in adaptive measures and technologies) • Higher risk of insolvency • Higher food costs and reduced local food security • Stress on crop insurance systems • Less people entering the farming sector • Farmlands are sold and become non-productive (e.g. hobby farms) • Loss of soils
Buildings and Facilities	• Increased cooling demands • Reduced indoor air quality in buildings with no or poor cooling • Increased urban island effect	• Community facilities without adequate air conditioning (e.g. churches/ synagogues, private daycares or long-term care centers etc.) • 60% of schools do not have A/C and are not easily retrofitted because of the building envelope, infrastructure and lack of funding • 20% of Ottawa residents lack A/C access in their homes • Social housing typically only has A/C in common areas • Poorly insulated buildings (e.g. constructed before 1980s) • The Building Code has not yet adapted requirements to mitigate increases in extreme heat.	• Costs to retrofit buildings with cooling and ventilation • Increased operating costs due to the need for higher/longer use of A/C • Increased waste and GHG emissions • More heat- and smoke-related illnesses and fatalities, especially for disproportionately impacted populations • Loss of worker productivity in inadequately cooled buildings • Canceled City or community programming or services in facilities with no or poor A/C
Drinking Water	• Reduced pressure from increased outdoor water demand • Reduced aquifer recharge / increased occurrence of dry shallow wells • Increased risk of wildfires can increase treatment demands and cause taste/ odor issues from nutrients, particulate or contaminants	• Private landowners with shallow wells (9% of Ottawa is on private wells) • Past droughts (e.g. 2012) required trucked water and deeper wells • Communal wells are less equipped than water purification plants to treat nutrients, particulate or contaminants from wildfires (fire chemicals/foam can persist for years) • Electrical and communication systems can malfunction in extreme heat	• Reduced level of service (reduced pressure in water distribution) or no service (no electricity) • Increased costs if water delivery is required to privately serviced areas • Demand for more reliable water supply for areas on private wells • Increased costs for increased water treatment (from fires)
Economy	• Increased health and safety risks to workers • Reduced or shifting economic development opportunities • Reduced water quality (algal blooms)	• Businesses that rely on summer outdoor recreation and tourism (reduced people outside / using services due to heat) • Outdoor events and venues could be cancelled or at the extreme, become unviable (e.g. Ottawa Race Weekend, Cycling Tour, festivals and fairs) during extreme heat events • Businesses and City services that operate outdoors (landscape, construction, waste collection etc.) could see reduced productivity and/or working hours, increased breaks or changes to work conditions • Businesses, organizations or institutions operating in buildings without air conditioning can lead to reduced productivity and/or working hours • Businesses that depend on waterways (e.g. river or canal tours) may be adversely affected by algal blooms and increased weed growth • Businesses requiring fire suppression water storage permits (e.g. Lee Valley Ltd. warehouse, etc.)	• Increased costs to upgrade buildings for greater climatic resiliency (e.g. insulation, greater energy costs to cool buildings, greater insurance costs, etc.). • Adjusted work schedules for outdoor workers/ lost productivity to meet health and safety regulations • Canceled or rescheduled City or community programming or services • Changes to or increased tourism pressures due to a more compressed season • Reduced walkability and water recreation in portions of the summer with extreme heat • Costs to retrofit buildings • Increased climate control expenses (A/C)
Emergency Management and Health and Community Well-Being	• Increased severity of heat-related health and safety issues • Increased health and safety risks for athletes, active recreation participants and active transportation users • Increased risk of food-borne illnesses • Insufficient community cooling amenities such as splash pads, pools and beaches • Additional strain/ reduced capacity of emergency response and social support systems (e.g. paramedics) • Increased risk of wildfires and poor air quality	• Everyone is at risk – some more than others which is based on sensitivity, exposure and other factors (i.e. age (older adults and young children), sex, gender, ethnicity, race, and being a member of indigenous populations, mental health and chronic diseases, pregnancy, medication use and substance misuse, occupational exposure, and exposure to urban heat islands). . • Individuals with pre-existing physical and mental health conditions or who have mobility barriers, the very young and older adults, pregnant women.	• More heat- and smoke-related illnesses and fatalities, especially for disproportionately impacted populations • Decrease in outdoor recreation and sports, leading to poorer physical and mental health • Overwhelming of hospitals and social services • Increased climate control expenses (A/C) • Cancellation or postponement of outdoor public events (e.g. sports, festivals) • Lost workdays due to extreme heat (e.g. outdoor workers)

Focus Areas	Potential Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Natural Environment	• Reduced aquifer recharge, baseflow and degraded aquatic habitat • Increased tree and ecosystem instability, habitat shifts, habitat loss, loss of forest cover, decline in some native species • Reduced water quality (algal blooms) • Increased risk of wildfires	• Individuals that spend a significant amount of time outdoors, such as children, youth, athletes, and outdoor workers (especially Workers) • Households with limited financial resources (homes have less insulation or lack A/C, cannot afford to run A/C systems, cannot access many services with A/C due to costs) • 19% of residents lack A/C access (81% of Ottawa residents had some form of AC in 2019).[28] • Individuals experiencing homelessness or who are precariously housed • People living in smaller spaces • People who lack of access to green space • Immigrant communities, linguistically isolated persons • Rural communities adjacent to areas at risk of wildfire, with limited water for firefighting • Smaller creeks that run dry in warm summers; Rideau River relies on reservoir lakes in Perth • Urban trees and forests susceptible to heat (e.g. sugar maple) • Drought increases the vulnerability of trees and plants to invasive impacts (including Emerald Ash Borer); pesticides can be less effective in drought • Climate change scenarios increase risk of introduction and establishment of new invasive species (insects and disease). • Anticipate changing phenology of existing forest insects and disease under climate change that will impact tree and forest cover and pests shift range and behaviour. • Algal blooms have impacted some waterways e.g. Rideau River and Canal, Constance Lake, and stormwater ponds	• Increased demand for libraries and community centers as cooling centers, especially in at-risk neighborhoods • Reduced beach / recreational access due to health hazards (algal blooms) • Increased wildfire management requirements and costs • Increased demands on emergency response and social services • Lost tree canopy and terrestrial ecosystems • Reduction in baseflow impacts aquatic habitat • Increased forest management to reduce fire risk • Hazardous algal blooms can kill pets and wildlife e.g. anything that drinks it.
Parks and Recreation	• Increased demand for cooling facilities like splash pads, outdoor pools and beaches • Increased demand for shaded parks and recreational facilities • Increased demands for cooled indoor recreational spaces • Increased health and safety risks during extreme heat events at outdoor facilities (splash pads or play equipment) or artificial sports fields • Increased degradation of sports fields • Reduced water quality at beaches or other swimming areas	• Limited availability and size of parks create challenges for space for trees alongside recreation amenities (especially in downtown and inner urban areas) • Shading sails are an option to mitigate heat, but require increased maintenance and cost • Extending opening of supervised beach and outdoor pools is limited by seasonal staffing availability	• Increased costs to improve and operate indoor and outdoor amenities (and extend opening hours) • Cancelled City programming or services in community buildings where there is no A/C (e.g. churches, City community buildings, fieldhouses, etc.) • Cancelled or delayed sporting events or outdoor recreation • Reduced attendance at sporting events. • Increased waterfront management (e.g. water circulation pumps, waterfowl management) • More frequent beach closures as a result of increased E. coli contamination in the rivers. • Residents may need to travel outside their community to access facilities with air conditioning (programs may be more expensive or oversubscribed)
Solid Waste	• Increased health and safety risks to workers • Increased odors • Increased fire risk	• Fires are more likely to be caused by increased moisture in material stockpiles or increased oxygen in an anaerobic environment • People improperly dispose of pool chemicals which can lead to truck fires • Ministry of Labour has halted work during extreme heat events	• Operating adjustments (turning schedules) • Cost to repair infrastructure • Delays to waste collection services if working hours or truck fleet are affected
Stormwater	• Disruption to natural stormwater systems • Increased risk of wildfires	• Natural stormwater systems such as wetlands, forests, watercourses and stormwater ponds and bioswales • Wildfires can increase sediment and debris in rural and urban watercourses	• Additional maintenance of stormwater facilities (e.g. bioswales, vegetated stormwater ponds) • Degraded water quality, higher temperature flows and impacts on aquatic habitat

[28] Statistics Canada (2021). Table 38-10-0019-01 Air Conditioners.

Focus Areas	Potential Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Transportation	• Decreased use of active transportation systems • Decreased use of public transit systems • Damaged / compromised rail transportation systems • Damaged / compromised road transportation systems	• Asphalt based transportation systems (Transitway) • Steel grating on bridges • Rail systems • Individuals who rely on transit or active transportation for mobility may face health risks or may struggle to make trips	• Decreased asset life and greater repair/renewal rate • Decreased use of public transportation and active transportation would have a negative impact on equity, accessibility and public health. • Decreased use of sustainable transportation could lead to increase in private vehicle use, thus increasing GHG emissions, congestion, noise; air quality; and reversing gains made in sustainable modal shares
Wastewater	• Damaged / compromised wastewater collection and treatment systems • Odor issues from increased fermentation • Damage to wastewater collection infrastructure from increased risk of wildfires	• Increased wastewater temperatures may require increased biological treatment • Extreme temperatures could increase wastewater fermentation in the collection system resulting in increased odors • Electrical systems are vulnerable to prolonged extreme heat (pumping stations, SCADA systems, blowers and cogeneration equipment) • Pump stations and odor control facilities could be exposed to wildfires	• Reduced level of service / reduced wastewater treatment capacity • Increased water treatment / disinfection requirements (capital investment) • Increased capital and repair costs • Reduced wastewater treatment capacity can significantly affect disposal of leachate from Trail Road Facility

4.2.3 Adaptive Measures in Place

Throughout the CVRA, City staff and subject matter experts provided input on existing adaptive measures to reduce vulnerability and increase resilience to climate hazards, and what gaps remain. These adaptive measures were taken into consideration during the vulnerability rating step of the CVRA and are summarized in Table 8.

Table 8. Current or Planned City of Ottawa Adaptive Measures – Extreme Heat, Drought and Humidity

Current or Planned City of Ottawa Adaptive Measures
• The City of Ottawa has an Extreme Heat, Cold and Smog Plan to respond to extreme heat events. The plan ensures integration of prevention, mitigation, and preparedness as well as risk monitoring and early warning. • Ottawa Public Health (OPH) conducts syndromic surveillance of heat related illnesses and deaths to ensure preventive actions are in place to protect human health • Ottawa Public Health staff assist service providers of priority populations to develop resiliency plans for extreme heat, cold and smog events. • OPH is in the process of updating who is at risk during hot weather in a Climate Change and Health Vulnerability Assessment to inform further actions to reduce the effects of climate change on extreme heat, vector borne disease, water and foodborne illnesses, air quality and stratospheric ozone. • The Community Paramedicine Program supports seniors and disproportionately impacted populations who are living at home, reducing the need for emergency paramedic services. • Most City facilities have cooling, including all public libraries. 2 of 4 City LTC homes have air conditioning, and the Peter D. Clark Long Term Centre is currently being renovated to improve cooling and ventilation. • The City's Social Housing Improvement Program (SHIP) and Housing and Homelessness Investment Plan (HHIP) support upgrades to heating and building envelope components in social housing. Ottawa Community Housing is undertaking deep energy retrofits on 2,400 units by 2028. These retrofits will add cooling through heat pumps. • Recreation, Cultural and Facility Services (RCFS) have many water-based cooling facilities that provide free or low cost ways to cool down including splash pads, wading pools, indoor and outdoor swimming pools and beaches. During a heat warning, pools change their programing to permit public swimming and splash pads can be opened earlier. • City buildings are increasingly providing water bottle refill water fountains. • The Extreme Temperature Places of Refuge Program allows for library facilities to be used as heating or cooling centers during extreme temperature events. • The new Official Plan (OP) includes policies to reduce the urban heat island effect through cool or green roofs, light colored reflective materials, retention of mature trees, tree planting, and other urban greening. • The City's High-Performance Development Standard and Municipal Green Building Policy update will include requirements to mitigate the urban heat island effect using cool or green roofing, reflective materials and greening. • The new Official Plan and draft Transportation Master Plan include policies to provide shaded walking, cycling and transit facilities, to enable sustainable transportation to remain safe and comfortable even on hot days. • The City is completing a building condition assessment and energy audit at long-term care facilities. • OPH works with Hydro Ottawa and Hydro One to request that they avoid planned brownouts / construction during a heat warning.

Current or Planned City of Ottawa Adaptive Measures
• The City has developed urban heat island mapping and will use it to inform tree planting plans and help inform locations for parks and recreation facilities.[29] • The City plans to undertake a wildland fire risk assessment for all forested areas • The City has updated bus shelter and transit station design to account for the effects of climate change. • The City provides agricultural grants through the Rural Clean Water Program to help farms adapt to the effects of climate change including more variable water conditions.

4.2.4 Interpretation of Results

The CVRA examined a cross section of impact statements related to extreme heat, drought and humidity at the City and community scale. Of these identified impacts, more than 30% are already at risk of occurring (rated as medium-high or higher) in the baseline. The CVRA showed that more than half of the medium to medium-high risks in the baseline are expected to shift to high and very-high risks over the next 80 years if no action is taken by the City to increase climate resilience (Figure 20).

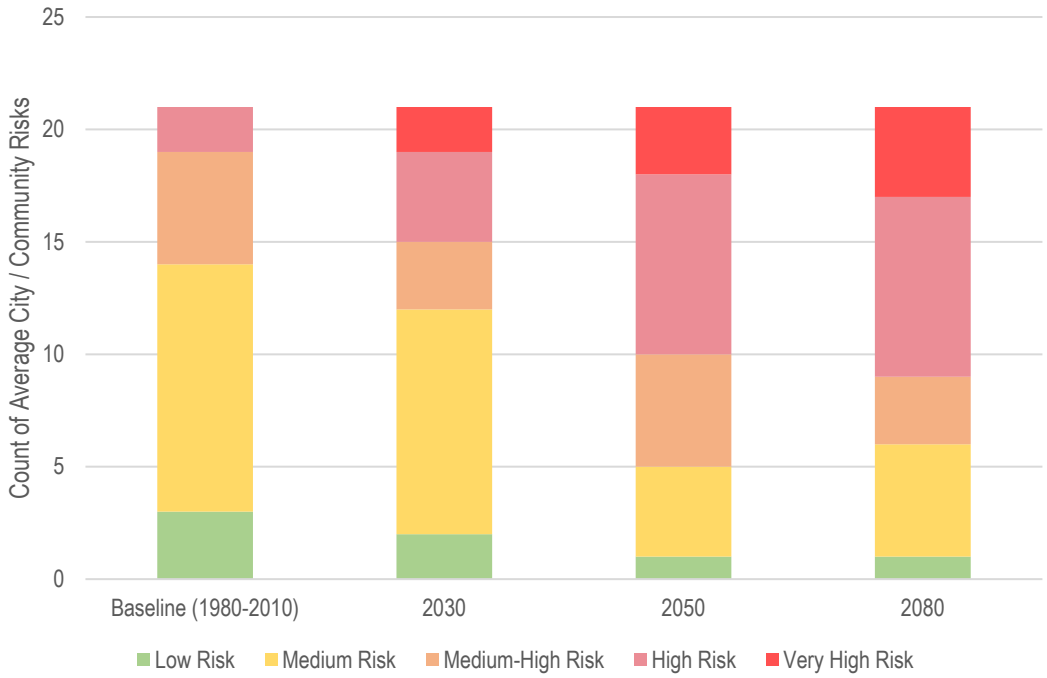


Figure 20. Count of Average Risks Related to Extreme Heat, Drought and Humidity Climate Hazards Between the Baseline and the 2080s

In the baseline, the highest rated risks (medium-high) are related to damaged / compromised buildings (e.g. mechanical systems not being able to keep buildings cool, or buildings without A/C), increased cooling demands / pressures on buildings and reduced indoor air quality especially in older buildings, and the negative implications to

[29] City of Ottawa (2019). Map 1: City of Ottawa Urban Heat Island Map

the physical, mental, cultural, and recreational wellbeing of residents and the community. By the 2080s, these baseline risks escalate in magnitude (by aggravating the existing socioeconomic inequalities that led to vulnerability in the first place) as do other risks to ecosystems, community, and emergency services (overloaded and delayed) and City infrastructure (damage to roads and rail infrastructure). While the vulnerability of physical infrastructure to climate hazards is affected by several factors, the three main factors that influence exposure and sensitivity are age, composition, and design. Much of the City's current infrastructure will still be in place in the 2080s, yet it has been designed for historical climate conditions. For example, many building mechanical systems are not rated for the projected change in heat; road materials are not rated for the extent and duration of the heat events projected; etc.

4.2.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings

The tables that follow present a consolidated summary of the impact statements rated in the CVRA and are organized by priority rating starting with those risks that require immediate action. Risks that require action will be used to inform the future Climate Resiliency Strategy (CRS) and early actions through the City's Extreme Heat, Cold and Smog Planning Committee. Appendix C: includes the priority impacts for all hazards. Appendix D presents the original impact statements, by Focus Area, where the changing risk in the 2030s, 2050s, and 2080s is noted.

The following impacts require actions to be implemented within the next 1-3 years to mitigate these risks.

Table 9. Extreme Heat, Humidity and Drought Impacts That Require Immediate Action

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Reduced agricultural yields.	–	High	–	Very High
Increased number and severity of heat-related health and safety issues to emergency responders, disproportionately impacted populations, active transportation users, and athletes or active recreation users.	Medium	Medium	Very High	Very High
Less outdoor recreation and sports impacting overall physical and mental health of the community.	Medium	Medium	High	Very High
Increased cooling demands, increased occurrence of inadequate indoor environmental conditions where no A/C, and increased demand / cost to upgrade buildings / facilities.	Medium	Medium	High	Very High
Increased demand for shaded areas in parks and additional indoor and outdoor recreational facilities.	High	Medium	High	High
Increased irrigation pressures at food production and agricultural operations.	–	Medium	–	High
Increased tree mortality and ecosystem instability and habitat loss requirements.	High	High	High	High
Decreased use of active transportation and transit systems due to more extreme heat.	Medium	High	Medium-High	Medium-High
Reduced aquifer recharge, lower baseflow to streams and degraded aquatic habitat.	Medium	Medium	Medium-High	Medium-High

The following impacts require actions to be implemented within the next 4-7 years to manage the risk.

Table 10. Extreme Heat, Humidity and Drought Impacts That Require a Plan to Address Risk

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Deterioration and buckling of rail systems.	Medium	Medium	Medium-High	Medium-High
Additional maintenance of vegetation in stormwater facilities.	Medium	–	Medium-High	–
Damage and failure of electrical equipment at ROPEC (blowers and cogeneration equipment) resulting in reduced wastewater treatment capacity.	Medium	–	Medium-High	–
Potential failure of electrical systems resulting in reduced performance of wastewater and stormwater pumping stations or SCADA systems.	Medium	–	Medium-High	–
Deterioration of asphalt-based surfaces.	Medium	–	Medium-High	–
Reduced water quality at beaches and natural outdoor swimming areas impacting tourism / recreation.	–	Medium	–	Medium-High

The following impacts require a possible review of current controls and monitor for change.

Table 11. Extreme Heat, Humidity and Drought Impacts That Require a Review of Controls / Monitoring

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Increased occurrence of dry wells on private lands.	–	Medium	–	Medium
Health and safety risks for outdoor workers.	–	Medium	–	Medium
Inconsistent tourism in summer and shoulder seasons.	–	Medium	–	Medium
Increased biological treatment required at ROPEC wastewater treatment plant.	Medium	–	Medium	–
Damage to wastewater treatment plant electrical systems resulting in reduced performance of pumping stations or SCADA systems.	Medium	–	Medium	–

The following impacts were not evaluated at the risk stage due to being deemed a low vulnerability or not applicable:

- Increased opportunities for legionella bacteria to grow in outdoor environments (e.g. cooling towers, water features) resulting in more people getting Legionnaires' disease and Pontiac fever.
- Change in wildlife migration patterns resulting in an increase in encounters between domestic animals and wildlife.
- Reduced pressure in water distribution systems due to increased outdoor water demand.
- Increased agriculture and food production opportunities.
- Agricultural materials stored in bulk (e.g. stored fertilizer, grain in silos, manure piles) catch fire.
- Burns from asphalt at splash pads and metal slides.
- Restriction of outside work negatively impacting business operations and economic development.
- Incidence of fires at the landfill which could spread to the landfill gas (LFG) collection systems resulting in shutdowns to the LFG to energy systems.
- Shortened road and infrastructure construction / repair operational windows.

4.3 Seasonable Variability and Change

4.3.1 Projected Changes in Climate Variables

As average temperatures across all seasons increase, the typical characteristics of the seasons will also change. By the 2080s, the last day of spring frost is projected to shift from early May to mid- to late April and the first day of fall is projected to shift from late September / early October to the last week of October. While this potentially means a longer agricultural, landscaping, and growing season, more variability within the seasons is expected (e.g. unexpected frost events) which can undermine these benefits. A summary of seasonal changes is presented in Figure 21.

	What to expect	2030s	2050s	2080s
SEASONS	Winters **shorter** by	4 weeks	5 weeks	8 weeks
	Springs **earlier** by	2 weeks	2 weeks	4 weeks
	Winter freeze-thaw **increase** by	13%	33%	54%

Figure 21. Summary of Seasonal Changes Relative to the 1980-2010 Baseline

Seasonal changes will also impact the timing and frequency of freeze thaw cycles which occur when daily temperatures fluctuate above and below freezing (0˚C). The annual number of spring and fall freeze-thaw cycles is projected to decrease under climate change, from 24 cycles per season to approximately 19–18 cycles per season in the 2030s, 17–14 cycles per season in the 2050s and 16–8 cycles per season in the 2080s. While the number of spring and fall freeze-thaw cycles is projected to decrease, the number of winter freeze thaw cycles are projected to increase from 24 days in the baseline (1980–2020) to approximately 27–28 days in the 2030s, 30–32 days in the 2050s and 32–37 days in the 2080s.

As a result of warming and shifting seasons, a warmer and shorter winter season is also projected. It is projected that cold temperature extremes will be, on average, less severe and less frequent in occurrence. In particular, the number of days where the daily minimum temperature is less than -10°C is projected to decrease from approximately 71 cycles in the baseline to approximately 59–57 cycles in the 2030s, 53–46 cycles in the 2050s and 48–28 cycles in the 2080s.

4.3.2 Potential Impacts

Warming across all seasons will have implications for agriculture, ecosystems, watersheds, outdoor workers and recreational enthusiasts and will require changes to ecosystem and park management. For instance, increases in year-round temperatures over time could also increase the potential for vector-borne disease transmission, the

intensification of existing invasive species and the migration of new invasive species. This can cause cascading impacts in terms of increased human health and safety risks (e.g. West Nile virus, Lyme Disease, etc.), the permanent alteration of natural habitats, loss of at-risk species due to the loss of habitat and shifts in wildlife patterns. Invasive species and ecosystem management is already a challenge in terms of resources demands and is expected to increase substantially over time as new invasive species emerge, existing species become more invasive in nature, and it takes more effort to protect and grow the tree canopy (extreme heat is going to impact tree growth and maturity). Loss of ecosystems can also have significant social, spiritual and health impacts to the community – e.g. loss of tree species for cultural practices (e.g. birchbark) and could require more built infrastructure to provide the goods and services ecosystems provide (e.g. preventing and mitigating floods, erosion, and landslides, mitigating effects of extreme heat, purifying groundwater, etc.). From an economic perspective, the warming and shorter winter trend is expected to shorten winter season activities – for example under the high GHG emissions scenario (RCP8.5), it is projected that by the 2080s, the skating season in the National Capital Region will only last between 20 and 40 days.[30]

Winter freeze thaw events are particularly damaging to vegetation (especially urban trees), roads and sidewalks (thermal cracking, frost heave, potholes, and rutting), buildings (foundational damage, premature deterioration of concrete, roof damage due to ice dams, and moisture damage), and surface or shallow buried infrastructure. Freeze thaw cycles will create more ice on sidewalks and roads with increased health and safety risks to users and ice dams in stormwater infrastructure will cause localized flooding and property damage.

A summary of the possible range of seasonal variability impacts, vulnerabilities and consequences are presented in Table 12.

[30] National Capital Commission – Standards Council of Canada (2021). Risk Assessment of the Effects of Climate Change on the Rideau Canal Skateway: Analysis and Recommendations Options.

Table 12. Summary of Seasonal Variability Impacts, Vulnerabilities and Possible Consequences

Focus Areas	Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Agriculture and Food Systems	• Reduced food and agricultural production • Increased spread of invasive species and insect pests • Increased health and safety risks to workers • Increased health and safety risks to livestock • Reduced pollinators • Increased tree and ecosystem instability, habitat shifts and/or habitat loss	• Longer but inconsistent growing season (no net benefit to farmers) • Smaller farms who do not have access to risk reduction actions (e.g. crop insurance, technology (e.g. tunnels, shade cloth) due to cost) • Farms dependent on municipal drains (e.g. issues with Phragmites which are tall grasses and reeds) • Pollinators have an important role to play in the natural fertilization of crops, fruit trees, etc. Seasonal changes will likely disrupt pollinator lifecycles until a new natural equilibrium is reached.	• Increased land management and operational costs (e.g. invest in adaptive measures and technologies) • Higher risk of insolvency • Reduced local food security and higher food costs • Stress on crop insurance systems • Artificial methods of pollination and/or managed pollinators • Loss of professional farmers
Buildings and Facilities	• Damaged / compromised buildings (foundational damage, premature deterioration of concrete, roof damage due to ice dams, and moisture damage) • Damaged underground irrigation systems	• Buildings constructed before 1980 (includes much social housing) largely due to construction methods, materials used and historically poor maintenance regimes. • Heritage buildings • Park field houses and community buildings	• Increased cost to manage and maintain buildings
Drinking Water	• Damaged / compromised water distribution and treatment systems • Reduced water quality in shallow wells	• Increased settlement, heave, and misalignment of surface or shallow potable water conveyance infrastructure • Increased frazil ice (collection of ice crystals in flowing water) can affect water purification plants • Shallow private wells are vulnerable to contamination from road salt • Cumberland and Fitzroy residents who get their water from a "sand pipe" directly from the Ottawa River (changes to water quality will have a direct impact). • Potential illness related to shallow well water contamination and need for well water disinfection systems to prevent waterborne illnesses.	• Water main breaks, reduced level of service and increased repairs and renewals. • Damage to water purification plants intake systems, reduced functionality and increased repair / renewal. • Costs to develop deeper source of drinking water (private wells)
Economy	• Reduced business operations and economic development opportunities due to declining winter	• Winter tourism (e.g. Winterlude) • Seasonal agritourism	• Reduced revenue from decline of winter tourism or seasonal agritourism. • Reduced tax revenues from a decline in businesses in the area
Health and Community Well-Being	• Increased risk of disease vectors and illnesses spreading (e.g. Lyme disease, West Nile virus) • Increased slips and falls from increased winter freeze-thaw	• Park users and recreationalists • Outdoor workers • Older adults and people with mobility challenges	• Increased pressure to maintain parks and address public health and safety risks • Increased claims to City for slip and falls, resulting in higher payouts and higher insurance premiums.
Natural Environment	• Increased spread of invasive species and insect and disease pressure • Increased risk of disease vectors and illnesses spreading • Reduced water quality from increased salt application • Increased tree and ecosystem instability, habitat shifts and/or habitat loss from increased salt and winter freeze-thaw	• Increased spread of Wild Parsnip and Giant Hogweed already occurring • Invasive forest insects like Emerald Ash Borer (EAB) and Dutch Elm can be expected to be more severe with stressed trees from drought and extreme weather • Maple species comprise a large percentage of forest cover and could be severely impacted by a pest like Asian Long Horn Beetle • No comprehensive province wide pest risk analysis has been completed for invasive species or native species that will shift in behaviour and phenology under climate change • Limited capacity to track and manage emerging species of concern. Focus is on species that impact health and safety • Freeze-thaw stresses trees and root systems • Road salt limits urban tree's ability to reach maturity • The City has a salt management program, but it does not apply to private property (e.g. private parking lots)	• Significant loss of tree canopy (e.g. ~25% EAB loss) has high social, health and economic consequences • Increased impact on species at risk and associated City response • Increased stress on wildlife and change / hampering of migration patterns • Overuse of existing parks resulting in damage to trees and amenities. • Social, spiritual, health impacts of changing landscapes - e.g. loss of tree species for cultural practices (e.g. birchbark)

Focus Areas	Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Parks and Recreation	• Restrictions / closures of park and recreation areas or amenities (e.g. outdoor rinks) • Increased spread of invasive species and insect pressure • Increased risk of disease vectors and illnesses spreading • Increased tree and ecosystem instability, habitat shifts and/or habitat loss • Overuse of existing parks	• Outdoor rinks will be more difficult to maintain. The new Parks and Facilities Master Plan calls for 36 new outdoor rinks by 2031 and possibly three new, additional outdoor refrigerated rinks. • Springtime variability affects opening of sports fields (e.g. from increased rains and freezing rain). • Invasive species control programs pose great challenges due to costs and scale. Strategy is to focus on species that pose health risks and try to manage new invasive species before they become established. • The tick *Borrelia burgdorferi* that can carry Lyme disease is now prevalent in Ottawa and has been found on 60% of NCC greenbelt trails.	• Increased demand for alternative recreational amenities (i.e. refrigerated rinks) • Increased cooling costs (e.g. refrigerated rinks) and GHG emissions • Increased costs due to required facility retrofits (cooled facilities) or maintenance regimes (e.g. invasive species) • More frequent program/rental cancellations and loss of City revenue • Environmental damage to trees and amenities. If new parkland is not available, existing facilities will suffer environmental damage.
Solid Waste	• Damaged / compromised solid waste management systems from increased winter freeze-thaw	• Leachate or landfill gas management infrastructure (especially older infrastructure).	• Increased costs to repair and replace infrastructure
Stormwater	• Disruption to natural stormwater and drainage systems from increased spread of invasive species • Damaged / compromised stormwater systems from winter freeze-thaw	• Increased spread of invasive species (e.g. Phragmites) impacting stormwater ponds, bioswales and constructed wetlands. • Increased maintenance of Municipal Drains or roadside ditches • Increased settlement, heave and misalignment of surface or shallow stormwater infrastructure such as catch basins or driveway culverts. • Increased winter maintenance and structural damage to berms, levees and dykes	• Reduced level of service (e.g. reduced water quality, localized flooding) • Additional maintenance of stormwater facilities (e.g. bioswales, ponds) • Increased maintenance of Municipal Drains or roadside ditches. • Increased capital and repair costs
Transportation	• Damaged / compromised active transportation systems from increased winter freeze-thaw • Damaged / compromised rail and bus transit transportation systems • Damaged / multi-modal transportation systems (thermal cracking, frost heave, potholes, and rutting) • Extended road load restrictions • Health and safety risks to users (slips and falls)	• Hazardous winter sidewalks conditions are a top public concern in the review of maintenance quality standards, with particular impacts on older adults or people with mobility issues • Plowing snow combined with rain and ice causes a big strain on services • De-icing salts are very detrimental to steel structures • Premature deterioration of concrete in bridges and reduced load capacity • Possible unexpected failure of drainage structures due to corrosion • Street furniture (e.g. waste containers, benches) can fail after 2-3 seasons • Limited alternatives to salt since sand provides traction but does not reduce risk to slips and falls.	• Increased maintenance demands and costs • Reduced life of asset, requiring earlier renewal/replacement and increased costs • Accelerated degradation of roads, transit, active transportation and bridge infrastructure from patching activities and freeze thaw/heave of road cuts • Temporary closures of transportation systems (including from watermain breaks) • Increased claims from residents for property and car damage (e.g. from City equipment during winter, or potholes) • Seasonal Load Restrictions could lead to shortened construction seasons and/or higher costs for trucking, and more GHG emissions (more trips as a result of lighter loads). • Increased slips and falls.
Wastewater	• Damaged / compromised wastewater collection systems	• Increased settlement, heave, and misalignment of surface wastewater infrastructure such as maintenance holes and pump stations • Lower wastewater temperatures can affect nitrification processes and treatment processes	• Increased inflow and infiltration • Reduced level of service (wastewater treatment capacity) • Increased capital and repair costs

4.3.3 Adaptive Measures in Place

Throughout the CVRA, City staff and subject matter experts provided input on existing adaptive measures to reduce vulnerability and increase resilience to climate hazards, and what gaps remain. These adaptive measures were taken into consideration during the vulnerability rating step of the CVRA and are summarized in Table 13.

Table 13. Current and Planned Adaptive Measures in Place or Planned – Seasonal Variability

Current and Planned City of Ottawa Adaptive Measures
• OPH conducts syndromic surveillance of climate-related health conditions including vector-borne diseases such as Lyme disease and West Nile virus • City policies require lands within the minimum setback from rivers, lakes, streams and other surface water features to remain in a naturally vegetated condition to protect ecological function and to restore any natural vegetation that is disturbed due to development. • New OP policies require future climate change conditions to be considered in sub-watershed assessments. • The City's Urban Forest Management Plan requires tree inventory and forest canopy cover analysis and sets tree planting and protection guidelines. A Tree Planting Strategy is being developed to prioritize planting in areas with poor canopy cover, high urban heat island effects and higher socioeconomic inequities. • The City supports community-based stewardship programs to monitor and manage invasive species in natural areas. • The City participates in a Regional Forest Health Network for advanced awareness, training, and preparation for upcoming insects, pests, and diseases that could impact Ottawa's trees and forests. • The City provides invasive species and pest education and awareness programs (). • The City supports awareness and education campaigns related to outdoor air quality and how to reduce allergens in the community. • The City implements a Smart About Salt program to reduce the harmful effects of salt and continues to test new technologies such as using pre-treated salt on sidewalks, replacing salt with grit, and using rubber plow blades. • The City is reviewing and updating its road and sidewalk winter maintenance quality standards, taking into consideration future climate conditions. • The water intake pipe at the Lemieux Water Purification Plant is being relocated to mitigate the risks of frazil ice build-up.

4.3.4 Interpretation of Results

The CVRA examined a cross section of impact statements related to seasonal variability. Of these possible impacts, more than 80% are rated as medium and medium-high risk in the baseline and are related to shifting ecosystems and pests. In the baseline there is a very high rating which is related to invasive species. By the 2080s, 60% of these impacts are projected to shift to a high or very high risk rating. The shift is related to the effects that an increased frequency of winter freeze thaw events will have on buildings, park and recreational assets, road and rail transportation systems and agricultural systems. Many of these impacts will have cascading impacts to the community in terms of increased slips and fall and claims made against the City, possible road load restrictions, and damage to buildings, roads, and the natural environment from increased salt use. A summary of the risk trends related to seasonal variability is presented in Figure 22.

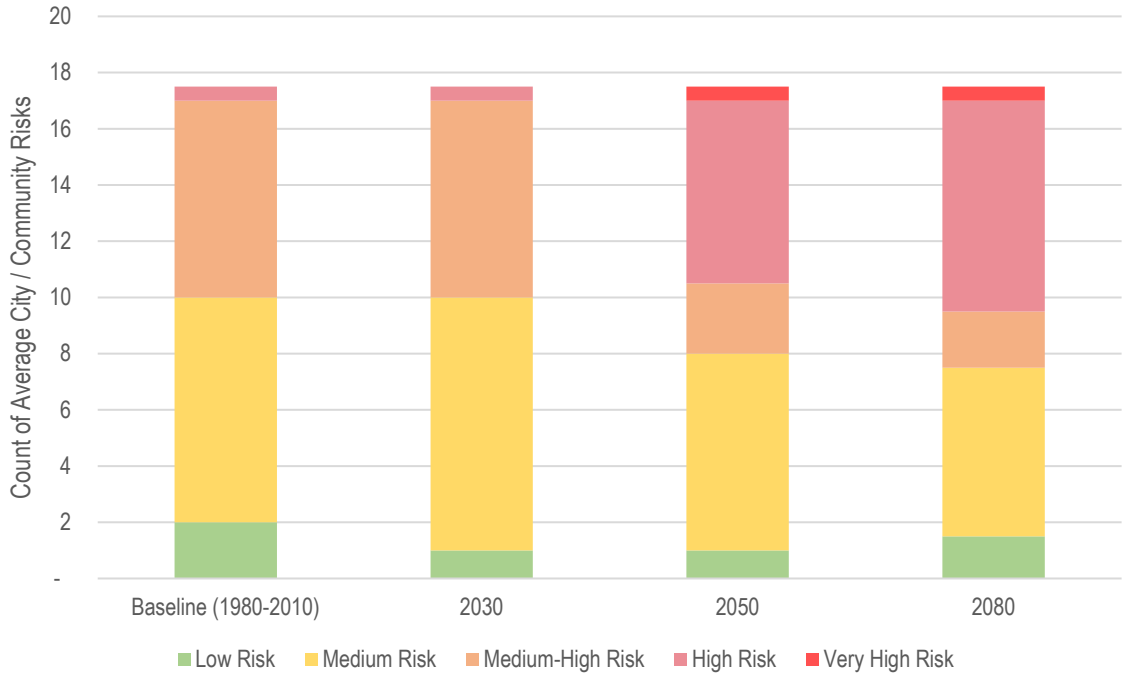


Figure 22. Count of Average Risks Related to Seasonal Variability Climate Hazards Between the Baseline and the 2080s

As noted previously, the biggest risks in the baseline period (historically and today) and the future are related to the impact that winter freeze thaw events can have on the built environment, such as transportation and stormwater infrastructure systems (accelerated degradation of roads, buildings, etc.). Freeze thaw events can also be harmful to trees as frost heaving damages the root structure and causes bark cracking and reduces resilience against invasive species and pests. While the risks to tree and ecosystem instability, habitat shifts and/or habitat loss and invasive species show up as medium and low in the baseline, they shift to medium-high and medium by the 2080s.

4.3.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings

The tables that follow present a consolidated summary of the impact statements rated in the CVRA and are organized by priority rating starting with those risks that require immediate action. Risks that require action will be used to inform the future Climate Resiliency Strategy (CRS). Appendix C: includes the priority impacts for all

hazards. Appendix D presents the original impact statements, by Focus Area, where the changing risk in the 2030s, 2050s, and 2080s is noted.

The following impacts require actions to be identified and implemented within the next 1-3 years to begin to mitigate these risks.

Table 14. Seasonal Variability Impacts That Require Immediate Action

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Increased spread of invasive species, agricultural pests, extinctions of local flora and fauna and reduced food production.	Medium	High	Very High	High
Intensification of existing, and the migration of, new disease vectors and illnesses into the community.	High	High	High	Medium-High
Increased settlement, heave and misalignment of surface or shallow stormwater infrastructure resulting in reduced run off capture, localized flooding, interruptions to transportation systems, and more frequent repairs and renewals.	High	–	High	–
Increased settlement, heave, and misalignment of surface wastewater infrastructure such as maintenance holes and pump stations resulting in increased inflow and infiltration.	Medium	–	High	–
Increased winter freeze-thaw resulting in damage to berms, levees and dykes.	High	-	Medium-High	-
More frequent repairs and renewals to buildings (freeze-thaw).	High	Medium	Medium-High	Medium-High
Increased use of parks and associated damage / degradation from overuse.	High	Medium	Medium-High	Medium
Decline of winter tourism and recreation, some seasonal agritourism, and economic welfare.	Medium	High	Medium	Medium-High

The following impacts require actions to be implemented within the next 4-7 years to manage the risk.

Table 15. Seasonal Variability Impacts That Require a Plan to Address Risk

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Reduced winter / outdoor park programming and required changes to facilities to adapt to changes in climate.	Medium	Medium	Medium-High	Medium-High

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Extended road load restrictions and the restriction of goods and services movement.	Medium	Medium	Medium-High	Medium-High
Accelerated susceptibility / mortality of salt-weakened plants and trees to insects, pathogens and extreme weather.	Medium	High	Medium-High	Medium
Increased road salt use, accelerated corrosion and damage to steel transportation structures, street furniture and vehicles.	Medium	High	Medium	Medium

The following impacts require a possible review of controls and to monitor for change.

Table 16. Seasonal Variability Impacts That Require a Review of Controls / Monitoring

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Increased invasive species spreading resulting in damage / disruptions to natural stormwater management systems.	Low	-	Medium-High	–
Increased settlement, heave, and misalignment of potable water conveyance infrastructure resulting in water main breaks and more frequent repairs and renewals.	Low	-	Medium-High	–
Increased migration of wildfowl resulting in water quality issues.	Medium	Medium	Medium	Medium
Increased likelihood of poor air quality (e.g. ozone, allergens) leading to additional respiratory illnesses and allergic reactions.	-	Medium	-	Medium
Damage to concrete-based solid waste infrastructure resulting in more frequent repairs and renewals.	Medium	-	Medium	–
Development of frazil ice and damage to the water purification plants intake systems.	Medium	-	Medium	–
Reduced shallow well water quality due to increased road salt application.	Low	Medium	Low	Medium
Change in the timing for protecting breeding birds and breeding amphibians/ reptiles.	Medium	-	Low	–

The following impacts were not evaluated at the risk stage due to being deemed a low vulnerability or opportunity, or not applicable:

- Less energy needed to heat agricultural buildings that house livestock and poultry.
- More lands suitable for farming operations.
- Reduction of building heating requirements.
- Increased migration and tourism to the City strains land affordability including housing.
- Increased ecosystem productivity where adequate water is available.
- Increased spread of invasive noxious weeds and pests resulting in increased health and safety risks to solid waste collection workers.
- Increased incidence of landfill odour generation resulting in complaints from neighboring communities.
- Reduced snow maintenance and removal requirements.
- Extended road construction / repair operational windows in the spring and fall.
- Increased demand for active transportation in the spring and fall.

4.4 Increased Volume and Intensity of Precipitation

4.4.1 Projected Changes in Climate Variables

Across Canada, the average annual precipitation (including rain, snow, freezing rain, hail, and drizzle) has increased and is expected to continue to increase between 9.1% and 37.8% by 2100.[31] These changes will be regionally dependent, with northern regions of Canada expected to see the greatest increase in precipitation, with the southern areas of Canada to see smaller increases. Warmer winters will also mean that precipitation will be realized as freezing rain or sleet, and there may be more rain on snow events which can result in localized flooding.

In the National Capital Region, total annual precipitation is expected to increase between 3-5% in the 2030s, 6-8% in the 2050s and 7-12% in the 2080s. Future climate projections indicate that these increases will occur in the winter and shoulder seasons, with no meaningful change in summer. The annual maximum 1-day precipitation (known as the wettest day of the year) is expected to increase by 11–19% by the 2080s (Figure 23).

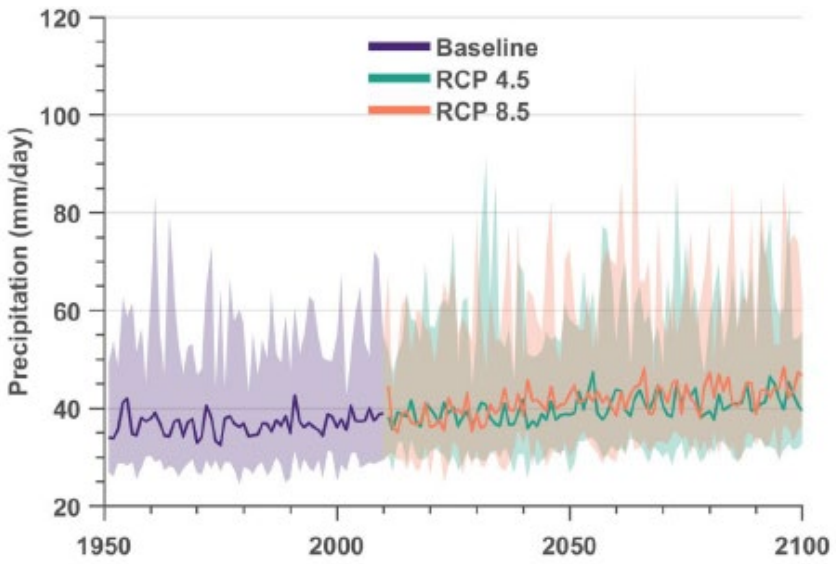


Figure 23. Annual Max. 1-Day Precipitation[32]

More importantly, the short duration-high intensity (SDHI) rainfall events – i.e. a rainfall of 50 mm in one hour – are expected to increase in annual probability. Heavy rains can result in inland flooding as stormwater infrastructure is overwhelmed by the sheer volume of water being deposited and can result in riverine flooding when combined with other factors, such as rapid snowmelt, saturated soils, prolonged spring rains, etc.

Projected warming across all seasons means that the total monthly snowfall is expected to decline in winter months, with the greatest absolute decreases projected to occur in the months that currently have the most snow (December, January, February, and March) (Figure 24). The number of days with snow cover is also projected to decrease from

[31] Government of Canada (2015). Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation.
[32] National Capital Commission and City of Ottawa (2020).Climate Projections for the National Capital Region. *Volume 1: Results and Interpretation for Key Climate Indices*.

approximately 115 days in the baseline to approximately 95–94[33] days in the 2030s, 90–72 days in the 2050s and 78–43 days in the 2080s.

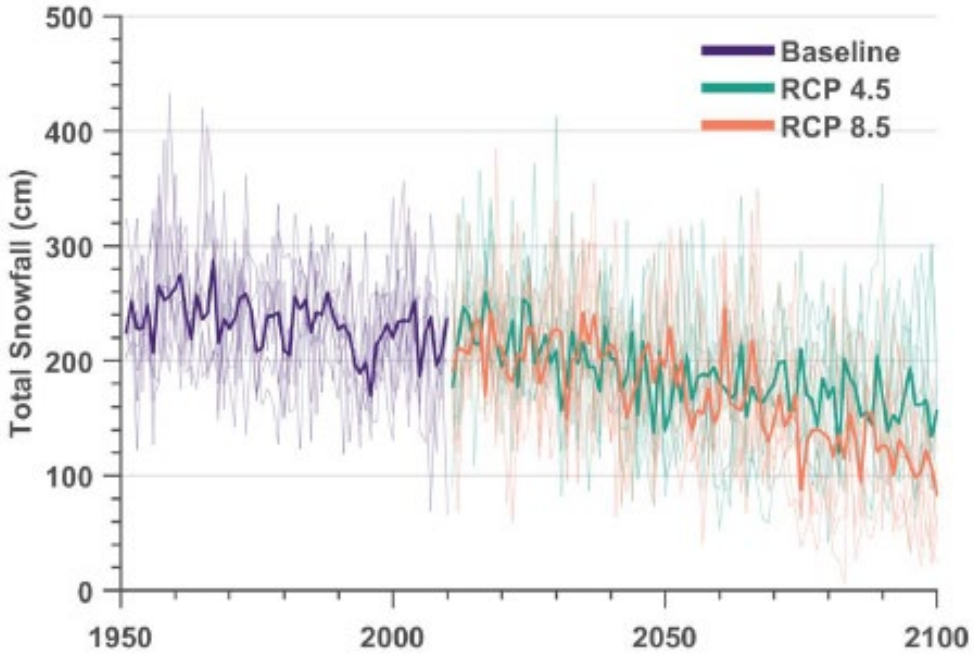


Figure 24. Annual Total Snowfall[34]

4.4.2 Potential Impacts

Flooding is the one of the most common, long-lasting and most expensive weather-related disasters in Canada.[35] According to the Insurance Bureau of Canada (IBC) flood related events have resulted in annual insurance payouts that have exceeded $1-billion and required $900-million in federal disaster-relief annually since 2008. It is estimated that the actual cost of flooding is 3 to 4 times the insurable losses with business and homeowners taking the brunt of the impact.[36] While flood response and repairs are typically made within a short period of time, the impacts of flooding are long lasting as they can result in higher insurance premiums, increased occurrence of mortgage defaults, increased litigation and they can have long lasting physical and mental health impacts including post-traumatic stress disorder, depression, sleep disturbances, etc.[37] A projected increase in more intense or prolonged precipitation events is likely to have substantial impacts to both the City and community as inland, sewer, and riverine flooding can damage natural and built infrastructure (roads, buildings) cause temporary park or road closures, and create health and safety hazards.

[33] The first number represents the average amount for the mid emission scenario and the second is under the high emission scenario.
[34] National Capital Commission and City of Ottawa (2020).Climate Projections for the National Capital Region. *Volume 1: Results and Interpretation for Key Climate Indices*
[35] Intact Centre on Climate Adaptation (2019). Weathering the Storm: Developing a Canadian Standard for Flood-Resilient Existing Communities.
[36] Intact Center on Climate Adaptation (2020). Under one Umbrella: Practical Approaches for Reducing Flood Risks in Canada.
[37] Foudi et al. (2017). The effect of flooding on mental health; Lessons learned for building resilience.

Flooding results when rainfall (also referred to as stormwater) cannot be adequately managed. Stormwater management in Ottawa is similar to many cities in that it is based on a minor and a major system. The stormwater system is comprised of roof gutters, downspouts, service connections, swales, street gutters, catch basins, conveyance controls (catch basins, rain gardens, bioswales, etc.) and storm sewer pipes. The minor stormwater system is typically designed to convey run-off from more frequent storms (e.g. those that typically occur every 2 or 5 years). The major stormwater system encompasses the watershed scale and includes roads, natural valleys, stormwater ponds / wetlands and riverine / stream systems. It is designed to handle more infrequent yet larger rainfall events (up to a 100-year storm event) without causing considerable damage to private and public property. The challenge with climate change is that the 100-year storm event is becoming more frequent, and more severe rain or riverine flooding (referred to as a 200- and 350-year precipitation events) have a greater probability of occurrence. Larger rain events can result in several types of flooding depending on the geography, size of the system, and existing vulnerabilities (Table 17).

Table 17. Types of Flooding and Common Vulnerabilities[38]

Type of Flooding	Typical Factors that Increase Vulnerability to Flooding
Riverine flooding (also known as fluvial flooding) Riverine flooding occurs when water levels rise within watercourses and exceed the height of the streambank. Riverine flooding can be caused by debris build up, ice jams, increased precipitation and snow melt. This type of flooding can result in shoreline scouring and erosion and weakened bridge structures. Riverine flooding can result in damage to private and public property (e.g. infrastructure), result in resident displacement, and result in health and safety impacts to people and animals.	• Outdated floodplain data and mapping • Development within or close to the floodplain • Ice, sediment and debris jams • Undersized / improperly maintained / deteriorated stormwater systems • Use of outdated design standards for flood protection infrastructure (e.g. dikes and floodwalls) • Lack of resources / technology to retrofit existing stormwater systems • Long-term reliance on temporary riverine flood-protection measures

[38] Adapted from: Intact Centre on Climate Adaptation (2019). Weathering the Storm: Developing a Canadian Standard for Flood-Resilient Existing Communities.

Type of Flooding	Typical Factors that Increase Vulnerability to Flooding
Overland flooding (also known as pluvial flooding) Overland flooding occurs when the minor and/or major stormwater system cannot process the volume of water moving through the system. This results in overland and localized flooding where water enters buildings through low lying entry sources (e.g. basement windows and doors, depressed driveways) and results in damage to buildings and building contents, and potential health and safety concerns (e.g. from mold, electrocution). Overland flooding can also disrupt and damage other public infrastructure systems (e.g. transportation, wastewater systems) resulting in reduced level of services.	• Reverse slope driveways • Poor lot grading practices • Buildings and infrastructure in low lying areas • Increased upstream development and imperviousness (increases flow) which downstream stormwater systems did not account for the additional flows • Undersized / improperly maintained / deteriorated / obstructed stormwater systems • Use of outdated design standards for culvert grates, inlets and catch basins
Stormwater and wastewater back-up flooding This kind of flooding occurs when the stormwater and/or wastewater collection and conveyance systems are overwhelmed usually due to an increased volume of precipitation. The surcharge causes back-up into basements resulting in health and safety risks, resident displacement, and damage to private and public property.	• Older stormwater systems designed for low intensity events, without consideration of dual drainage • Infiltration and inundation of wastewater collection infrastructure where groundwater seeps into the collection system through aging or defective pipes, pipe joints, leaky manholes and through cross-connections • Low-lying areas are typically more at risk due to standing water that accumulates above maintenance holes • Partially blocked wastewater collection systems due to build-up of sediment, silt, sand, debris, fat, oil, grease, sanitary products and other detritus • Deteriorated structural condition of collection systems (e.g. sags, partial pipe collapses, etc.) • High water levels in receiving waterbodies (e.g. rivers, creeks and lakes) • Failure of wastewater treatment pumping stations (e.g. overland and riverine flooding can disrupt a pump station)

Type of Flooding	Typical Factors that Increase Vulnerability to Flooding
Foundation system flooding This type of flooding occurs when perimeter drainage systems fail and water enters basements though foundation drains or seeps through the foundation walls. Similar to the other types of flooding, the impacts can be severe – e.g. health and safety risks, resident displacement, and damage to private and public property.	• Where a direct gravity connection exists between the storm sewer and basement foundation drain • Reverse slope driveways • Poor lot grading and backfilling practices • Older homes (e.g. 50-80 years) do not have appropriate foundation drainage systems like weeping tiles, sump pump systems, or these systems have deteriorated beyond their reasonable life • No sump-pumps installed • Lack of, or inadequate back-up electricity for, sump pump systems • Buildings located within areas with high groundwater levels • Unintended increase in groundwater elevations due to infrastructure renewal (e.g. as old clay and concrete sewer pipes with leaking joints are replaced with new sealed pipes resulting in increased groundwater levels and seepage)

Flood events are not only damaging at the time of their occurrence, but they can also have lasting effects on the built environment. For instance, flood waters can impact the structural integrity of buildings (weakening of building supports, buckling of floors) and cause contamination from sewage and other pollutants, resulting in the condemnation of the structures and temporary / permanent displacement of the residents. Because of the damage and debris involved with a flood, emergency services, public health response and waste collection services can be directly impacted with other City services being diverted to support emergency measures. Well-water and drinking water systems can also be contaminated following a flood, especially in areas with private septic systems, and create health and safety risks. Finally, repeated floods can cause long lasting mental health impacts for those directly flooded or those supporting them (e.g. first responders, paramedics, nurses, volunteers, etc.).

A summary presenting the possible range of precipitation related impacts, vulnerabilities and consequences are presented in Table 18.

Table 18. Summary of Increased Volume and Intensity of Precipitation Impacts, Vulnerabilities and Possible Consequences

Focus Areas	Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Agriculture and Food Systems	• Delayed planting / harvesting, crop loss or reduced pasture / forage due to saturated agricultural lands • Increased agricultural run-off and sediment loading • Increased soil loss	• Agricultural lands prone to overland or riverine flooding • Downstream landowners • Farms that have difficulty keeping water on the land (uncovered soil, etc.)	• Increased land management and operational costs (e.g. cost to invest in adaptive measures and technologies, increased fertilization due to soil loss, etc.) • Reduced food and agricultural production • Pollution of potable water sources and nearby creeks and rivers • Higher risk of insolvency from farms • Higher food costs and reduced local food security • Increased demand for Municipal Drain clean-outs
Buildings and Facilities	• Damage to buildings from overland / riverine flooding (roof and foundation damage, water ingress) and sewer-related damage (backups) • Reduced access to buildings and facilities • Private wells and septic system damage from flooding	• Properties within the floodplain (e.g. Britannia and Lemieux Water Purification Plants, Ottawa Rowing Club) • Approximately 300 – 400 homes were impacted by Ottawa River flooding in 2017 and 2019 • Residential lots adjacent to ravines at risk of erosion (e.g. Bilberry Creek, Mosquito Creek) • Heritage and older buildings (more susceptible to water ingress) • Properties in low-lying areas • Private wells and septic systems in flood-prone areas	• Increased repair and replacement costs • Interruption/impacts to service. • Financial hardship and displacement of populations • Higher insurance premiums • Decrease in property value for homes in flood plains • Increased cost of housing • Increased costs to respond to flood events and support residents dealing with flooding – staff redeployment from other departments to support response
Drinking Water	• Damaged / compromised water systems from riverine or inland flooding (including private wells) they were contaminated with flood waters and possibly flooded septic systems. • Reduced access to critical infrastructure (water purification plants)	• Riverine flooding has reduced access to the Britannia Water Purification Plant. Both water purification plants have detailed response plans based on river levels for up to a 1:500 year river level but long-term solutions are needed • Localized flooding from heavy rains can impact operations at both plants • Erosion can damage trunk watermains at watercourse crossings • Pump stations located in the floodplain • Private wells contaminated with flood waters/ septic waste putting shallow aquifers and some drinking water wells at risk.	• Reduced level of service • Increased capital and repair costs • Possible water-borne illnesses in the community from private well water contamination. • Contamination of rural wells due to poor soil drainage issues.
Economy	• Reduced business operations and economic development opportunities	• Businesses along the Ottawa and Rideau Rivers • Businesses affected by inter-provincial bridge closures (Chaudière bridge closed in 2019)	• Investment / business loss (as well as lost opportunity) • Reduced tourism • Reduced availability / increased cost of insurance for businesses in vulnerable locations • Loss of inventories due to water damage.

Focus Areas	Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Emergency Management and Health and Community Well-Being	• Physical, mental, and financial impacts from overland / riverine flooding and sewer-related damage • Isolation of residents / reduced access to communities • Increased demands on emergency response and social support systems	• Communities in West Carleton including Fitzroy Harbour, Britannia, and Cumberland (~300 – 400 homes along Ottawa River affected in 2017 and 2019) • Communities along the Rideau River located within the RVCA identified flood plain(e.g. near Brewer, Brantwood and Windsor parks, Vanier) • Lower income households are most impacted as they may not have insurance and may not be able to find alternative accommodations • People injuring themselves trying to keep their homes safe • Basement apartments in low-lying areas subject to flooding and sewer back up in heavy rains • Emergency services can be stretched as they respond to the flood impacts, while maintaining continuity of operations with other calls for service and regular operations	• Financial hardship and displacement of populations • Physical and mental impacts to community members • Increased demand for / use of community services, like food banks • Increased stress on disproportionately impacted populations • Increased pressure on emergency responders • Increase in pressure on the City's building inspection unit • Losing access to childcare, work, etc. if people are required to leave their community to seek relief from flooding • Decreased property value for homes in flood plains • Damage to underground infrastructure (telecom, gas etc.) and danger to residents if water reaches electrical panels in basements of homes (ESA – 2019 flood event – had to shut off electricity to various dwellings) • Exposure to septic waste and damage to buildings and mold exposure resulting in impacts to health and safety. • Communications outages
Natural Environment	• Shoreline erosion / bank destabilization / habitat loss • Reduced water quality from increased stormwater runoff • Increased agricultural run-off and sediment loading in aquatic systems • Increase in tree and ecosystem instability, habitat shifts and/or habitat loss and tree damage	• Urban creeks in areas with minimal stormwater management • Rural creeks subject to increased agricultural runoff • Watercourses and ravines susceptible to erosion and retrogressive landslides, including areas of sensitive marine clay	• Accelerated shoreline erosion • Retrogressive landslides • Reduced water quality/ habitat loss/ erosion from greater stormwater run-off • Increase in tree damage and maintenance and emergency response to issues • Increased demands for creek and ravine management •
Parks and Recreation	• Restrictions / closures of park and recreation areas	• Parks and recreational areas prone to saturation • Parks and recreational facilities in flood-prone areas next to watercourses (e.g. Brewer Park, Windsor Park, Brantwood Park, Britannia, Petrie Island) • Increased pressure to integrate stormwater management in parks, which reduces their functionality	• Park closures • Delayed opening • Reduced revenues (e.g. sports fields/ball diamond rentals) • Increased costs to repair damages • Loss of use of recreational shoreline space/City beaches due to high e.coli counts
Solid Waste	• Leachate management / treatment systems can be overwhelmed during high precipitation events • Increased health and safety risks to collection workers (increased weight of wet bags)	• The leachate treatment facility at Trail Road needs replacing • Reduced wastewater treatment capacity at ROPEC could significantly affect disposal of leachate from Trail Road Facility • Precipitation can increase weights for all waste streams on collection days	• Unmanageable leachate could result in a spill to the natural environment with regulatory consequences and environmental impacts • Alternate solutions to treat hauled leachate from Trail Road would result in significant costs
Stormwater	• Can damage or overwhelm stormwater systems (e.g. ditches, pumping stations, sewers and culverts) • Can result in the overtopping of berms and flood protection infrastructure along the Rideau and Ottawa Rivers • More intense precipitation may lead to increased water flows, erosion and sediment inflow into stormwater systems (e.g. stormwater ponds and watercourses) • Increase in back ups into private dwellings and businesses	• Flooding in the Ottawa River can occur from a range of factors including snowpack, speed of spring melt, and intensity and duration of spring rains • Rideau River and other tributaries is more vulnerable to flooding due to heavy rains (in spring and summer) • Stormwater infrastructure in the floodplain • Berms, pump stations and other flood protection infrastructure along the Rideau and Ottawa Rivers (built to lower standards) • Older areas of Ottawa are more vulnerable to flooding under heavy rains • Undersized / older culverts	• Reduced level of service (overwhelmed minor and major stormwater systems) • Increased capital and repair costs • Health and safety, mental and physical health impacts • Property damage from overland / riverine flooding and basement flooding • Culvert failures and sinkholes • Degraded water quality from sewer overflows • Financial hardship and displacement of population • Increased demands on pro-active storm drain maintenance and creek and ravine management • Reduced system capacity during major events – particularly multi-day precipitation events

Focus Areas	Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Transportation	• Damaged / compromised active transportation systems • Damaged / compromised road transportation or transit systems (road washout, bridge failures, landslides affecting roads, bridges, etc.) • Increased health and safety risks to users	• Low lying areas • People who use pathways and roads impacted by floodwaters. • Underground parking garages with inadequate drainage systems • Areas with ditch drainage systems (extreme rain overburdens these systems) • Inter-provincial bridges (Chaudière Crossing closed in 2019)	• Flooded pathways and roads (adjacent to watercourses) • Weakened or washed-out soil resulting in sinkholes • Higher infrastructure maintenance/renewal costs (enlarge sewers and drainage systems, raise road profile grades, address erosion issues) • Washout of roads, culvert collapses and bridges could result in major detours • Reduced access to schools, businesses, essential services, etc.
Wastewater	• Damaged / compromised wastewater systems/ critical infrastructure assets • Damaged / compromised buildings	• Precipitation events increase inflow and infiltration into the wastewater collection system (e.g. private septic systems) • Extreme riverine events can damage wastewater collection sewers and pumping stations in the floodplain • Extreme riverine flooding can result in surcharge at chlorine contact tank weirs and inadequate capacity at outfalls at ROPEC	• Basement flooding • Health and safety, mental and physical health impacts • Sewage overflows, flooded pump stations and ponding septic systems • Reduced level of service • Increased capital and repair costs • Damage to buildings from overland / riverine flooding and sewer-related damage

4.4.3 Adaptive Measures in Place

Throughout the CVRA, City staff and subject matter experts provided input on existing adaptive measures to reduce vulnerability and increase resilience to climate hazards, and what gaps remain. These adaptive measures were taken into consideration during the vulnerability rating step of the CVRA and are summarized in Table 19.

Table 19. Current or Planned City of Ottawa Adaptive Measures - Precipitation

Current and Planned City of Ottawa Adaptive Measures
• The City already designs storm water management systems to accommodate more extreme rainfall events and is reviewing and updating the Sewer Design Guidelines to ensure they reflect projected future climate conditions. • New OP policies require consideration of future rainfall in site planning and infrastructure design and use of on-site management of stormwater. • The renewed Infrastructure Master Plan will further assess risks to water, wastewater and stormwater infrastructure from future climate conditions and identify measures to build resiliency (expected in 2023). An intensification task force is specifically examining solutions for stormwater management to support growth management targets. • As part of the Wet Weather Infrastructure Management Plan, the City has completed community flood risk profiles to identify areas at risk under heavy rainfall and prioritize neighborhoods for proactive measures to reduce flood risks. The Residential Protective Plumbing Program supports homeowners to install backflow prevention valves and sump pumps to protect their homes from flooding. • The Backflow Prevention Program helps prevent the backflow of contaminated water from buildings connected to the City's drinking water system. • Free well water testing at Public Health Ontario laboratories to ensure safe drinking water for homes serviced by private wells. • The Combined Sewage Storage Tunnel, a key project of the Ottawa River Action Plan, reduces the frequency of sewage overflows into the Ottawa River and reduces the risk of basement flooding in downtown neighborhoods. • Low impact development solutions such as bioswales and permeable paving are being used to mitigate overland flooding and reduce harmful runoff, especially in areas with Stormwater Management Retrofit Plans. • Rain Ready Ottawa provides education and incentives to private property owners for rain gardens, permeable driveways and other measures that encourage onsite infiltration. • The Rural Clean Water Program provides education and incentives to farmers to deploy best management practices to protect water quality (manure storage and treatment, wash water treatment, nutrient management plan, precision farming, clean water diversion, tile drain control structures, etc.) • Flood mitigation structures like berms, underground storage tanks and pumping stations protect local communities from flooding along the Ottawa and Rideau Rivers. The Britannia berm was reinforced following the 2017 and 2019 Ottawa River flooding. • Road reconstruction to raise elevation of roadways that are susceptible to flooding to provide safe access during flood events (e.g. planned projects in West Carleton). • Riverbank stabilization along the Ottawa River to protect Highway 174 (planned project awaiting funding confirmation).

Current and Planned City of Ottawa Adaptive Measures
• The Kanata Recreation Complex was retrofitted in 2019 to improve drainage and reduce risks of flooding damage (as part of the West End Flooding Mitigation Program). • The City works in partnership with local Conservation Authorities to update flood hazard mapping. New mapping for a more severe riverine flood was made available on the City's website in 2022. New OP policies require flood risk mitigation to a 1:350 riverine flood for new development. • The spring freshet team monitors flood levels on the Ottawa and Rideau Rivers and coordinates response plans across service agencies as needed. • The City closes flooded roads and pathways and establishes detours to reduce health and safety risks. • The City and OPH have web and print education, awareness, and response plans to help residents and businesses prepare for flooding and to reduce injuries, illness and death from flooding • The City has developed detailed flood response plans for the Britannia and Lemieux Water Purification Plants based on the 2017 and 2019 Ottawa River floods to ensure a continued supply of drinking water. A long-term solution is being identified as part of the Plant Comprehensive Development Plans. • The City has applied for external funding to accelerate projects to address flooding impacts and reduce known risks.

4.4.4 Interpretation of Results

The CVRA examined a cross section of impact statements impacts to the City and community resulting from changes in precipitation. While many of the average risks do not change significantly between the baseline and the 2030s, there is a significant shift of risks (65%) from medium and above to high and very-high risk once the 2050 and 2080 periods occur. This is largely due to fact that the change in probabilities for precipitation occur post 2030. The other factor is due to the moderate consequence ratings that reflect the fact that pockets of areas will be impacted, not the entire City. The highest risks are related to flood-level disruption and damage of infrastructure and the cascading impacts that this can have on the community and emergency systems. Through the CVRA, it has been noted that additional flood analysis is required to further understand what areas and who is most at risk to the four types of flooding. This will require an evaluation of the age of developments and the design standard applied, history of flooding, topography and proximity to the floodplain, upstream development and projected changes (to understand stormwater sewer system capacity), presence of critical infrastructure, essential services and social economic vulnerabilities.

A summary of the risk trends related to increased volume and intensity of precipitation climate related hazards is presented in Figure 25.

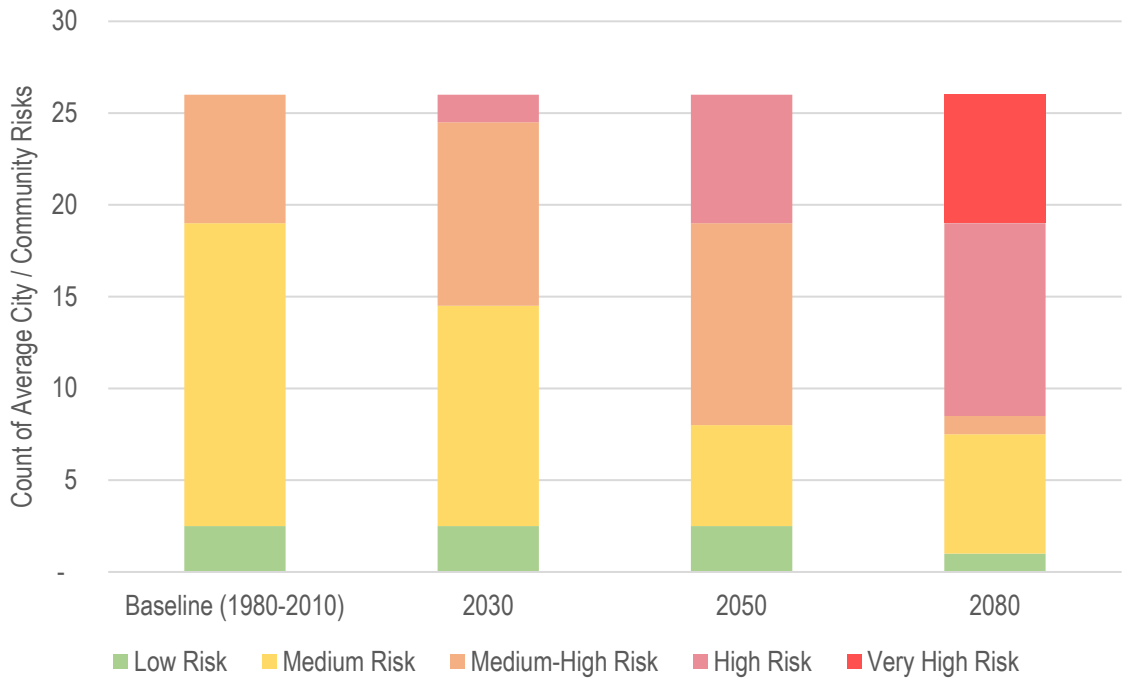


Figure 25. Count of Average Risks Related to Increased Volume and Intensity of Precipitation Climate Hazards Between the Baseline and the 2080s

4.4.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings

The tables that follow present a consolidated summary of the impact statements rated in the CVRA and are organized by priority rating starting with those risks that require immediate action. Risks that require action will be used to inform the future Climate Resiliency Strategy (CRS). Appendix C: includes the priority impacts for all hazards. Appendix D presents the original impact statements, by Focus Area, where the changing risk in the 2030s, 2050s, and 2080s is noted.

The following impacts require actions to be identified and implemented within the next 1-3 years to begin to mitigate these risks. It should be noted that many of the precipitation related impacts are to City infrastructure which is why in some cases there are no community ratings.

Table 20. Increased Volume and Intensity of Precipitation Impacts That Require Immediate Action

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average.)
Riverine flood related damage to / overwhelming of sewers, ditches, pumping stations and culverts located in the floodplains.	High	-	High	-
Increased stormwater runoff or sewer overflows resulting in poor surface water quality, riverbank	High	High	High	High

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average.)
and ravine bank destabilization, erosion and loss of habitat.				
Increased water flows, erosion and sediment inflow into stormwater systems, resulting in a reduced level of service, localized flooding, basement flooding and more frequent repairs and renewals.	High	-	High	-
Riverine flooding damages or overburdens berms and flood protection infrastructure along the Rideau and Ottawa Rivers resulting in localized flooding and more frequent repairs and renewals.	High	-	High	–
Increased basement flooding and sewer overflows due to increased inflow and infiltration in wastewater collection systems and reduced capacity in pump stations or sewers.	High	-	High	–
Riverine flood related damage to water treatment plant and reduced access.	High	-	High	-
Overwhelmed stormwater systems resulting in inland flooding resulting in damage to buildings.	High	Medium	High	High
Riverine flood-related access issues to key roadways, property and infrastructure throughout the community, leading to isolation of residents and/or challenges for emergency services.	Medium	High	High	High
Riverine flood related damage to buildings.	High	High	Medium-High	High
Saturation or flooding of agricultural lands leading to delayed planting/harvesting and reduced pasture availability.	Medium	Medium	Medium	High
Increased run-off from agricultural lands resulting in nutrient loading of nearby aquatic ecosystems.	-	Medium	–	High
Heavy rains compromise roof and foundation drainage.	Medium	High	Medium-High	Medium-High
Exposure of vulnerable segments of the population to physical injuries, respiratory,	Medium	High	Medium-High	Medium-High

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average.)
water-borne and food-borne illnesses, and mental health impacts from flooding.				

The following impacts require actions to be identified and implemented within the next 4-7 years to manage the risk.

Table 21. Increased Volume and Intensity of Precipitation Impacts That Require a Plan to Address Risk

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average.)
Inland flood-related damage to road infrastructure.	Medium	Medium	Medium-High[39]	Medium-High
Inland flood-related access issues to key roadways, property and infrastructure throughout the community, leading to isolation of residents and/or challenges for emergency services.	Medium	Medium	Medium-High	Medium-High
Increased erosion of riverbanks adjacent to roads which could result in washouts and road closures.	Medium	Medium	Medium	Medium-High
Damage and contamination of private wells.	Medium	Medium	Medium	Medium-High
Flooding of parks, sports fields, and outside event spaces, resulting in park closures and loss of recreational opportunities.	Medium	Medium	Medium-High	Low
Riverine flooding related damage to trunk watermains at watercourse crossings or pump stations in the floodplain.	Medium		Medium-High	
Unmanageable volumes of stormwater on landfill sites.	High	Medium	Medium	Medium

[39] Impact statements with a medium vulnerability and medium-high risk may be listed as requiring immediate action or a plan depending on the final combined scores (refer to Methodology).

The following impacts require a possible review of controls and to monitor for change.

Table 22. Increased Volume and Intensity of Precipitation Impacts That Require a Review of Controls / Monitoring

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average.)
Increased demand for establishing emergency shelters and temporary housing during floods.	Medium	-	Medium	-
Unmanageable volumes of landfill leachate.	High	Medium	Low	Low
Riverine flood related damage to wastewater treatment systems.	Medium	-	Medium	–
Increased inflow and infiltration resulting in reduced wastewater treatment capacity.	Medium	-	Medium	–
Localized flooding at the water purification plants from heavy rains resulting in reduced level of service.	Low		Low	–
Damage to private septic drain fields.	-	Low	–	Low

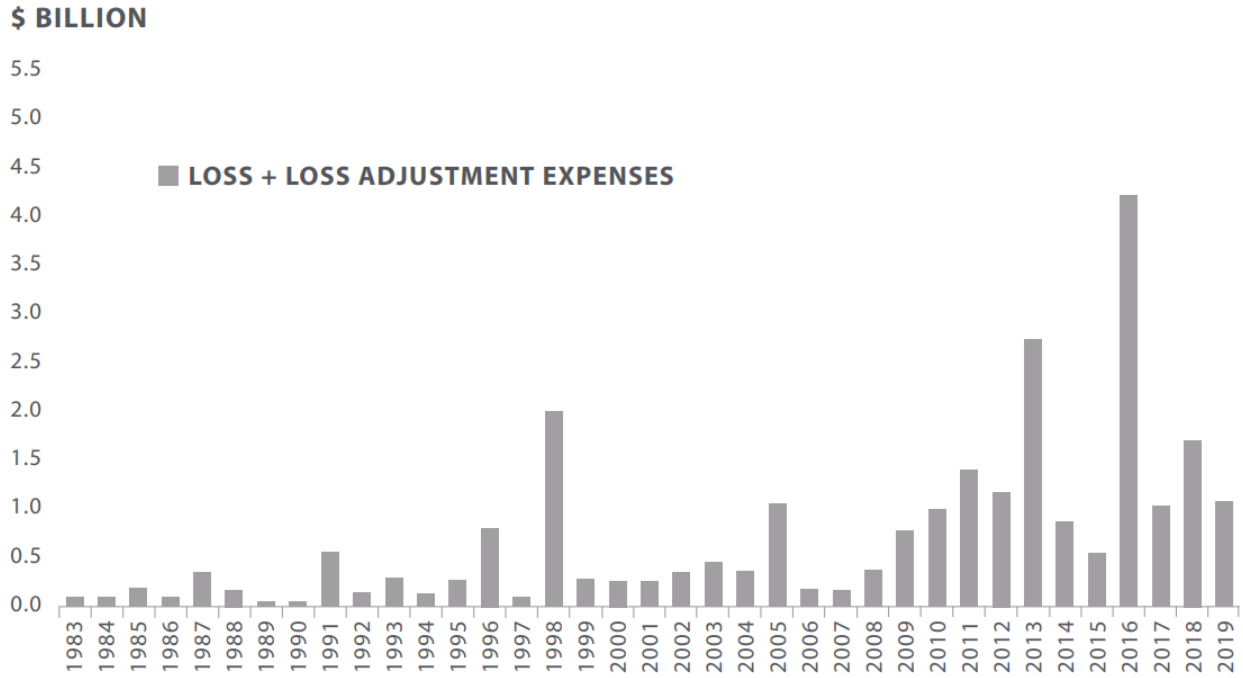
The following impacts were not evaluated at the risk stage due to being deemed a low vulnerability or opportunity, or not applicable:

- Natural wetland creation in areas where conditions were previously unsuitable.
- Increased weight of yard waste from greater precipitation resulting in health and safety risks to solid waste collection workers.

4.5 Extreme Weather Events

4.5.1 Projected Changes in Climate Variables

Ontario is prone to extreme weather events like freezing rain and ice storms, extreme winds and gusts, and tornados which can produce disproportionate damage to the natural and built environment and pose significant health and safety risks to populations in the areas that these events occur, or economic impacts to affected businesses. While the costs of extreme weather events depend on multiple factors, climate change is already increasing the intensity of severe weather events in Canada. Since the 1980s, catastrophic losses from weather-related events have been growing (Figure 26). Since 2009, these costs have come close to, or exceeded, $1 billion in most years and in aggregate, have exceeded $20 billion. Using data between 2010 and 2019, this results in an average cost of $112 million per climate event (including public and private costs).[40] This only includes insured losses – it is estimated that the uninsured costs are more than double.[41]



*Insured losses for a given disaster are deemed catastrophic when they total $25 million or more.
Catastrophic losses for a year are the sum total of insured losses from these natural disasters.
Source: Insurance Bureau of Canada

Figure 26. Catastrophic Losses from Natural Disasters ($Billions, 1983–2019)[42]

[40] Canadian Institute for Climate Choices (2020). Tip of the Iceberg: Navigating the Known and Unknown Costs of Climate Change for Canada.
[41] Ibid
[42] Federation of Canadian Municipalities (FCM) and Insurance Bureau of Canada (IBC) (2020). Investing in Canada's Future: The Cost of Climate Adaptation at the Local Level.

More concerning is that the catastrophic losses from natural disasters in Canada are expected to grow from about $5 billion in 2020 to between $30 billion and $62 billion per year by 2050.[43] Without aggressive action to meet global emission targets, there is a 5% chance that costs could exceed $113 billion per year.

At the local level, recent extreme weather events have had significant costs to the City and the community. The 2017 Ottawa River spring flood affected approximately 500 households and the City's emergency response was mobilized for a total of 54 days. The financial impact of the flood cost $2.6 million in City resources (staff, supplies and equipment)[44] and more than $223 million in insured damages in the National Capital Region[45]. The following year, the September 2018 tornados cost Hydro One and Hydro Ottawa combined nearly $16 million to repair extensive damage to their assets, including fixing a major transmission station, and more than 50 per cent of Hydro Ottawa's customers had no electricity at the peak of the outages[46]. Additionally, the tornados destroyed approximately 60 buildings and caused close to $1 billion in insured losses in the National Capital Region.[47] And the combined events of the 2019 spring flood and tornado cost the City over $5.6 million in resources (largely staffing costs), while the flood alone is estimated to have cost the National Capital Commission between $6 to $10 million in repairs to their bridges, pathways, and shorelines[48].

4.5.1.1 Freezing Rain and Ice Storms

Freezing rain falls as a liquid but freezes on contact with roads and sidewalks, electricity lines and trees and is one of the most damaging and costly weather events that occur in Canada.[49] Ice storms are a combination of a winter storm and freezing rain. These events damage vegetation, overhead wires (causing electricity and communication disruptions) and crops due to ice accumulation, create dangerous driving and walking conditions, increase road salt use (further harming ecosystems), and damage private property. For example, the 1998 ice storm was one of the worst natural disasters in Canadian history causing 5 million people in Ontario, Quebec and northeastern United States to lose power ,with some areas not having power restored for over 30 days. Over $1 billion in insurance claims were made ($200 million of which damage occurred in Ontario) and dairy farmers in Quebec and Ontario had a combined $14 million financial loss as operations were halted due to power outages. In Ottawa alone, 67.6 millimetres of freezing rain was recorded with no melting, most of which fell within the first 24 hours.[50] The projected increase in near-freezing temperatures in the National Capital Region suggests that there will be an increase in freezing rain occurrence. This assessment aligns with a freezing rain study completed by Environment and Climate Change Canada who concluded that freezing rain is likely to increase about 40% in the months of December, January, and February in Southern Canada over the next 30 years.[51]

---

[43] Government of Canada (2021): Costs and Benefits of Climate Change Impacts and Adaptation
[44] City of Ottawa Community and Protective Services Committee (2018). Security and Emergency Management Branch 2017 Annual Report.
[45] Ottawa Business Journal (2017). Ottawa-area flooding caused $223M in insurable damages: industry.
[46] Britneff, B.(2019). Global News: Ottawa tornadoes cost Hydro One, Hydro Ottawa $15.7M, utilities estimate.
[47] International Institute for Sustainable Development (IISD) (2021). Advancing the Climate Resilience of Canadian Infrastructure.
[48] Porter, K (2019). CBC News: Flood repairs to cost NCC up to $10M.
[49] Cheng et al. (2011). Possible Impacts of Climate Change on Freezing Rain using Downscaled Future Climate Scenarios: Updated for Eastern Canada.
[50] Spears,T (2018). Ottawa Citizen: The Great Ice Storm of 1998, by the numbers.
[51] Cheng et al. (2011). Possible Impacts of Climate Change on Freezing Rain using Downscaled Future Climate Scenarios: Updated for Eastern Canada.

4.5.1.2 Extreme Wind and Gusts

High winds can also result in considerable damage to infrastructure, properties, electricity lines, and trees resulting in significant social, economic, and environmental costs. Damaging straight-line wind events, in the form of microbursts, can result in more damage than tornadoes as the winds can be stronger and affect a much larger area than a tornado. The frequency of straight-line wind events with wind gusts that are greater than 60 km/hour are projected to increase from 14–15 times per year to 16 times per year by the 2050s. High straight-line wind gust events where the winds exceed 80 km/hour are projected to remain steady with ~1–2 times per year. It should be noted that the prediction of wind gusts and extreme wind events are typically based on historical trends and other climate indices; therefore, there is a low confidence in the predictions related to future wind events.

4.5.1.3 Tornados

A tornado is a narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground.[52] Eastern Ontario and Western Quebec have historically been subject to periodic significant tornado events – most recently the 2018 and 2019 events. It is conservatively estimated that an annual probability of an EF1+ tornado (winds of 138-177 km/hour) occurring within the Region could increase from 14.6% to 18.2% by the 2050s. Although the probability of a tornado event occurring remains low over the next century, a tornado can result in considerable damage to infrastructure and can result in significant injury and loss of life.

4.5.1.4 Wildfires

Wildfires are part of natural ecological processes that, while destructive, allow for the renewal and regeneration of the impacted ecosystems. Wildfires clear grasslands and the forest floor from debris and low-lying vegetation, renew the soil with nutrients and open up the canopy to enable existing trees to grow stronger and healthier. While there are numerous ecological benefits, wildfires also pose a risk when the fire is near rural and urban populations as it can destroy property, infrastructure, and result in a loss of life. Wildfires also result in reduced air quality both locally and regionally and can significantly impact disproportionately impacted populations (children, athletes, individuals with existing health conditions, homeless, etc.).

Wildfires are the result of a variety of elements which include, but are not limited to, temperature change, drought like conditions, precipitation patterns, and human (e.g. increasing population, expansion of urban areas into wildlands) and non-human interactions (e.g. lightening), flammability of material and timing of the season. According to the National Guide for Wildland-Urban Interface Fires, Canada is going to experience incidences of larger, more intense wildland fire events in areas that have not historically experienced significant wildland fire hazards.[53] Climate projection models include a high degree of variability for future wildfires in the National Capital Region. So while the probability of wildfire is not shown to increase (see Appendix C), the uncertainty and variability should be considered given the potential high consequences from more severe wildfires.

4.5.2 Potential Impacts

Ottawa has already experienced several destructive and costly climate-driven events including the 2017 and 2019 floods and the 2018 and 2019 tornados, as well as increasing numbers of extreme heat events. The impact of these events not only ranged in economic magnitude , they also resulted in significant disruption to daily community life, damage and loss of physical and natural assets, the divergence of resources to emergency response and repairs,

[52] National Capital Commission and City of Ottawa (2020).Climate Projections for the National Capital Region. *Volume 1: Results and Interpretation for Key Climate Indices*
[53] National Research Council Canada (2021). National Guide for Wildland-Urban Interface Fires.

increased stress on emergency responders, community services and impacted residents, amongst many others. Strong winds or gusts can damage and bring trees down and damage private property, disrupt electricity and communication systems, and in more extreme cases, cause injury and loss of life. Loss of electricity and communication systems can have cascading impacts to emergency services and critical infrastructure and the broader community especially during extreme heat or cold events. A summary presenting the possible range of extreme weather-related impacts and consequences are presented in in Table 23.

Table 23. Summary of Extreme Weather Impacts, Vulnerabilities and Possible Consequences

Focus Areas	Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Agriculture and Food Systems	• Reduced food and agricultural production (direct damage) • Electricity or communication interruptions / blackouts • Increased health and safety risks to workers • Increased health and safety risks to livestock • Disruptions to food supply chain	• Farmers operating with losses or low margins • Food industry sectors that rely on low-cost food sources / imports (e.g. secondary and restaurants, etc.) • Livestock farms (electricity outages impact ventilation) • Crop insurance and re-insurance sectors	• Increased insurance premiums • Higher risk of insolvency • Reduced mental health of farmers • Increased repairs to farm infrastructure (tunnel, barns, equipment)
Buildings and Facilities	• Damaged / compromised buildings • Electricity or communication interruptions / blackouts	• Buildings under construction • High rise buildings and their tenants • Exposed roof-top mechanical systems • Most City facilities and buildings have back-up electricity for limited lighting and some critical systems • Private and public buildings with sump pumps and back-up electricity	• Compromised building functionality and/or loss of use • More frequent unplanned repairs and renewals and associated costs • Loss of housing/facilities and associated mental health impacts • Increased insurance premiums • Increased waste (from damaged buildings)
Drinking water	• Damaged / compromised drinking water distribution or treatment systems • Electricity or communication interruptions / blackouts	• Electricity outages affect pump stations, communal wells, elevated storage tanks	• Reduced level of service or loss of service • Increased capital and repair costs
Economy	• Direct damage to businesses and associated financial losses • Disrupted business continuity	• Brick and mortar based businesses are more exposed to extended closures and a loss of revenue (vs. online businesses)	• Investment / business loss (as well as lost opportunity) • Physical and mental health? • Loss of utility service (including telecommunications, electricity, gas service) to businesses due to damage • Tourism losses due to damaged infrastructure
Emergency Management and Health and Community Well-Being	• Physical and mental health impacts, and financial impacts • Increased demands on emergency response and social support systems • Electricity or communication interruptions / blackouts • Damaged / compromised critical infrastructure assets (water / wastewater, health) • Isolation of priority populations	• Disproportionately impacted populations such as Indigenous Peoples, older adults, low income, homeless, and racialized people • More remote rural populations who may be cut off from roads / utilities • Persons with disabilities / mobility issues (homebound as they wait for snow and ice clearing) • Increased anxiety in communities that have experienced past emergencies (i.e. West Carleton experiencing floods and tornado) • First responders • Social service agencies • Response during concurrent events (e.g. winter storm and electricity outage; flooding and electricity outage) • Persons without insurance, or inadequate insurance (ex: no flood coverage)	• Increased health and safety risks (physical and mental) • Financial hardship and displacement • Increased risk of isolation • Increased demands on emergency response and social services (increased call volume) • Increased disruption to all City operations and business continuity (re-deployment of staff). • Overwhelming of hospitals and social services • Increased demand on emergency responders - staff health; staff shortages; Workplace Safety and Insurance Board (WSIB) • Increased claims to City for slip and falls, resulting in higher payouts and higher insurance premiums • Communications outages, such as during the 2019 Tornado event
Natural Environment	• Increased tree mortality/ damage • Shoreline erosion/ bank destabilization / habitat loss • Increased agricultural run-off and sediment loading	• Trees and ecosystems already stressed by the impacts of climate change (e.g. drought) • Urban trees more vulnerable than natural areas / forests • Loss of tree canopy	• Electricity or communication interruptions / blackouts due to trees falling on electricity lines. • Increase in tree damage and removal, storm response, claims and property damage. Increased pressure on tree replacement programs • Increased operations from downed trees / hazard trees • Health and safety risks from hazard trees • Blocked culverts and drainage

Focus Areas	Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Parks and Recreation	• Increased tree and ecosystem instability, habitat shifts and/or habitat loss • Damaged / compromised park and recreational assets	• Natural areas are pretty resilient, but urban areas can require substantial restoration. • Ice damage to shoreline properties	• Restrictions / closures of park and recreation areas • Reduced revenues and increased costs to repair damages • Loss of recreational services if Parks and Recreation facilities are used as emergency shelters • Planning and programming required to re-establish and rehabilitate natural forest areas.
Solid Waste	• Damaged / compromised solid waste collection systems • Increased health and safety risks to workers • Increased pressure on waste collection services (e.g. hazardous waste pickup following an extreme event)	• All types of extreme weather (e.g. heat, winter storms) can impede collections • Extreme cold weather events can result in frozen organic waste loads that are hard to unload without thawing • Wind events can disrupt landfills, blow litter into the community and increase risks to staff and equipment	• Reduced worker productivity • Reduced collection capacity • Delayed services • Reallocation of services to affected areas (e.g. flood or tornado site) impacts service to the rest of City
Stormwater	• Damaged / compromised stormwater systems	• Freezing rain and ice accretion may lead to the clogging of stormwater conveyance systems such as culverts, ditches, catch basins and outfalls. • Increased windborne debris, blockages and clogging of ditches and culverts	• Reduced level of service • Increased capital and repair costs • Reduced water quality • Sewer/Stormwater back up
Transportation	• Damaged / compromised active transportation system • Damaged / compromised road transportation or transit systems • Increased health and safety risks to users • Electricity or communication interruptions / blackouts • Impacts to traffic signal operations, transit operations, traveler information systems, EV charging, emergency response, etc.	• Public transit can become unreliable in extreme conditions (but is an essential service) • More remote, rural properties who may be cut off from roads / utilities • Buried hydro lines help mitigate electricity outages from freezing rain and high winds • Extreme precipitation events bring additional challenges for City fleet and emergency services to operate/reach all areas of the city	• Increased accidents due to road issues • Reduced public safety, road safety, quality of life, equity, and accessibility. • Disruptions to businesses and goods movement • Costly repairs and uncertain timelines • Loss of utility service, including telecommunications service
Wastewater	• Damaged / compromised wastewater collection and treatment systems (critical infrastructure) • Reduced land availability / road accessibility for biosolids haulage/land application • Multi-day electricity or communication interruptions / blackouts	• Multi-day electricity outages can affect pump stations and treatment plants • ROPEC Co-gen project increases resilience of wastewater treatment plant to electricity outages, but diesel stacks remain vulnerable • Reduced land availability/road accessibility for biosolids haulage / land application which would require that biosolids be stored on site (limited capacity)	• Basement flooding • Health and safety, mental and physical health impacts • Sewage overflows, flooded pump stations and ponding septic systems • Reduced level of service • Increased capital and repair costs • Damage to buildings from overland / riverine flooding and sewer-related damage

4.5.3 Adaptive Measures in Place

Throughout the CVRA, City staff and subject matter experts provided input on existing adaptive measures to reduce vulnerability and increase resilience to climate hazards, and what gaps remain. These adaptive measures were taken into consideration during the vulnerability rating step of the CVRA and are summarized in Table 24.

Table 24. Current or Planned City of Ottawa Adaptive Measures – Extreme Weather

Current and Planned City of Ottawa Adaptive Measures
• The City's Municipal Emergency Plan (MEP) takes an all-hazard function-based approach and is always in effect, as elements can be employed on a flexible and scalable basis to provide effect mitigation and response efforts in the Ottawa area, while still ensuring the delivery of city services to the other areas of the City. • The MEP is supported by the Emergency Social Services (ESS) Plan, Health Emergency Plan for Priority Populations and plans that coordinate protective measures, such as evacuation, secure facility, lockdown or sheltering-in-place, of people impacted by an emergency. • The City continually reviews and updates existing emergency response and business continuity plans with input from service partners. • The City's Emergency Communications Tactical Roll Out Plan is used to inform and engage the community with timely, relevant and accurate information about City emergency response activities. • The Paramedic Pandemic Response Plan provides the City with the capability to respond to mass casualty incidents. • The City promotes emergency preparedness information to residents so that they can prepare for disruption of services of up to 72 hours. • The City's Community Paramedicine Program improves the resiliency of disproportionately impacted populations such as older adults who are living at home, reducing the need for emergency paramedic services. • Under the Extreme Weather Heat, Cold and Smog Plan, OPH staff assist service providers to develop resiliency plans for extreme weather events. The plan ensures integration of prevention, mitigation and preparedness via risk monitoring and early warning to inform local service providers and partners in health and emergency management to guide their actions as an early intervention. • OPH conducts syndromic surveillance of climate-related health visits to emergency departments associated with extreme heat, cold and poor air quality events and poor air quality episodes) ,) to ensure preventive actions are in place to protect human health and emergency responders are aware when interventions and responses need to be implemented. . • The City's Office of Emergency Management completes an annual Hazard Identification and Risk Assessment (HIRA) which requires considerations of the effects of climate change • The City is exploring ways to supplement resources with an "all-hazard" Urban Search and Rescue type response team that can be deployed locally to assist in extreme weather events. • The City has established environmental health education, awareness, and response plans to reduce climate related illnesses and deaths associated with extreme heat and humidity, cold weather, poor air quality (including wildfire smoke) and flooding. • The City is upgrading its wastewater treatment plant to provide independence from the electricity grid by upgrading cogens and electrical components (expected completion 2024). • The City has backup generators for drinking water purification plants and pumps to ensure continued availability of quality drinking water. • Ottawa Public Health has an Adverse Drinking Water Response Plan to alert when a boil water advisory is in effect. The City maintains a $100,000,000 line of credit and annual budget for times of crisis. • The City will develop a Poverty Reduction Strategy, as part of the Community Safety and Well-Being Plan.

4.5.4 Interpretation of Results

With respect to extreme weather events, the CVRA shows that with the increasing probability of occurrence and intensity of extreme weather related events, the risks will shift upwards. The risk scores tend to be lower as many extreme events are localized, and the City has existing adaptive capacity to respond. In terms of those most vulnerable, workshop respondents noted that approximately 10-15% of the total population impacted by an extreme event need some form of emergency and social support, and these individuals tend to be individuals living alone, with limited mobility, or those with existing health conditions. When extreme events occur, these individuals may not be able to maintain their homes or properties, have difficulty evacuating, may refuse to evacuate to protect uninsured belongings, and may be vulnerable to service disruptions which tend to follow extreme events. Those in poverty, or near poverty, may lack the financial means to recover from the damages and from mental or physical impacts caused by the event. Immigrant communities and linguistically isolated persons may also be highly vulnerable due to hesitancy, or they may not know how to seek help due to language barriers, citizenship status, and prior discrimination experiences. A summary of the risk trends related to extreme weather hazards is presented in Figure 27.

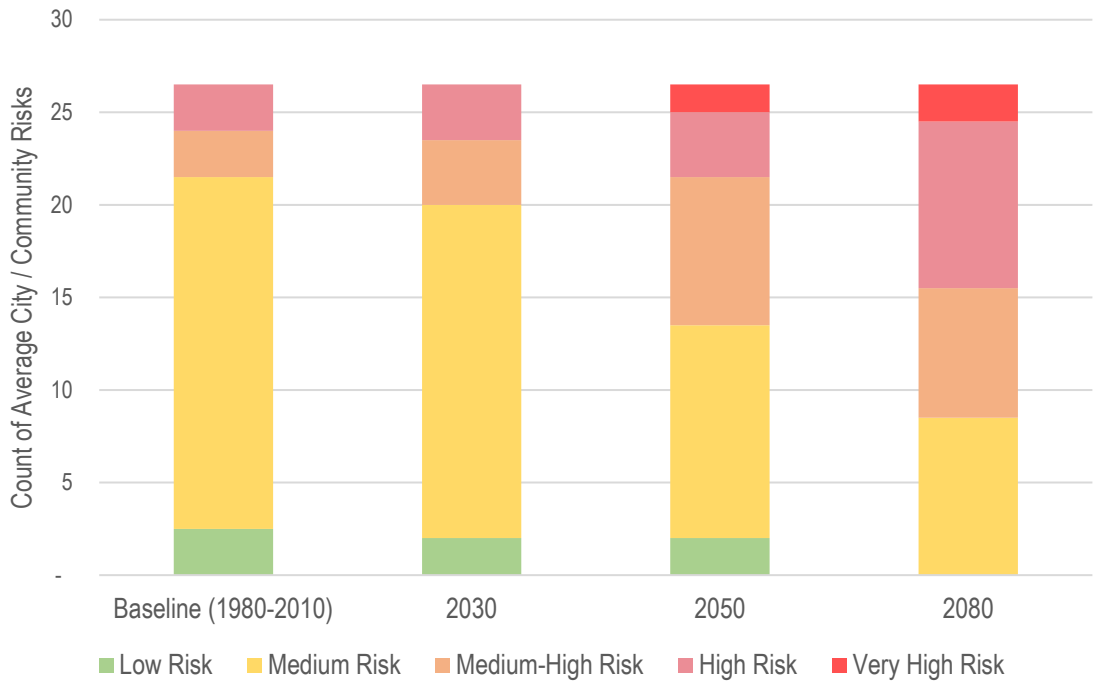


Figure 27. Count of Average Risks Related to Extremer Weather Climate Hazards Between the Baseline and the 2080s

4.5.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings

The tables that follow present a consolidated summary of the impact statements rated in the CVRA and are organized by priority rating starting with those risks that require immediate action. Risks that require action will be used to inform the future Climate Resiliency Strategy (CRS). Appendix C: includes the priority impacts for all hazards. Appendix D presents the original impact statements, by Focus Area, where the changing risk in the 2030s, 2050s, and 2080s is noted.

The following impacts require actions to be identified and implemented within the next 1-3 years to begin to mitigate these risks.

Table 25. Extreme Weather Impacts That Require Immediate Action

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Changing winter conditions may increase the number and severity of extreme cold-related health and safety issues (slips and falls, isolation, etc.).	Medium	High	Very High	Very High
Extreme winter events and winter freeze-thaw may increase winter maintenance needs and reduce asset life of roads, sidewalks, bridges, etc. thereby decreasing the availability of transportation systems and increasing the risks to users.	High	Medium	Medium-High	Very High
Disruption to business continuity, extended closures and wide range of financial impacts in the community.	Medium	High	Medium-High	High
Reduced ability of the City, community service providers and social support systems to provide services and effectively respond to simultaneous and future events.	Medium	High	Medium-High	High
Reduced / delayed delivery of essential services (e.g. electricity supply, food banks, mental health supports, etc.).	Medium	High	Medium-High	Medium-High
Damage and disruption to electrical and communication systems, impacting communication, transportation, building and emergency systems.	High	High	Medium-High	Medium-High
Blockages and clogging of ditches and culverts from windborne debris resulting in damaged infrastructure and localized flooding.	High	-	Medium-High	–

The following impacts require actions to be implemented within the next 4-7 years to manage the risk.

Table 26. Extreme Weather Impacts That Require a Plan to Address Risk

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Increased personal stress (e.g. anxiety, depression, violence) for disproportionately impacted populations.	Medium	Medium	Medium-High	Medium-High
Ice storms and other extreme events resulting in damaged public and private property and temporary closures of outdoor public spaces including parks and recreational facilities.	Medium	Medium	Medium-High	Medium-High
An increase in ice storms and other extreme weather may increase multi-day electricity outages resulting in compromised wastewater pump stations and ROPEC, reduced performance, and increased maintenance	Medium	_	Medium-High	-
Ice blockages and clogging of stormwater conveyance systems resulting in reduced run off capture and localized flooding.	High	-	Medium	–
Additional strain on forest management / wildfire suppression programs and resources.	High	High	Medium	Medium
Increased pressure on solid waste collection and management resulting in a delay of services.	High	High	Medium	Medium
Wildfire damage to forests and wetlands resulting in increased sediment and debris in rural and urban watercourses.	High	-	Medium	–

The following impacts require a possible review of controls and to monitor for change.

Table 27. Extreme Weather Impacts That Require a Review of Controls / Monitoring

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Wildfire damage to forests and wetlands resulting in the release of nutrients and particulate into source waters and causing increased treatment demands and taste/ odour issues.	Medium	-	Medium	-
Wildfire damage to above ground wastewater infrastructure from wildfires resulting in non-	Medium	-	Medium	-

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
functioning pumps and in-ability to access systems.				
Freezing rain resulting in increased landfill site management to reduce the risk of subsidence and slope instability.	Medium	-	Medium	-
Damage to water-based recreational and shoreline assets from extreme winds.	Medium	Medium	Medium	Medium
Extreme wind events resulting in damage to properties and infrastructure, weather related injuries and loss of life.	Medium	Medium	Medium	Medium
Ice storms and other extreme weather resulting in multi-day electricity outages resulting in compromised stormwater pump stations reduced performance, shortened lifespan and increased maintenance.	Medium		Medium	
Increased health and safety risks to solid waste collection and management workers.	Medium	Medium	Medium	Low

The following impacts were not evaluated at the risk stage due to them being deemed to be a low vulnerability or opportunity or not applicable:

- Demand for weather protection or remediation services, or technical innovation, creating economic development opportunities.
- Damage to livestock and the need for the City to support the emergency disposal of deadstock.

4.6 Global Climate Change

4.6.1 Overview

Despite global awareness and commitments to reducing GHG emissions, the impacts of climate change are already being experienced, and the inertia in the atmosphere dictates that the planet is 'locked into' some level of temperature rise due to historic GHG emissions. In fact, some changes are "effectively irreversible", e.g. major melting of the ice sheets[54], which could be exacerbated if GHG levels do not decrease resulting in abrupt and severe impacts to global climate systems, value chains, personal well-being, and economic stability (Figure 28).

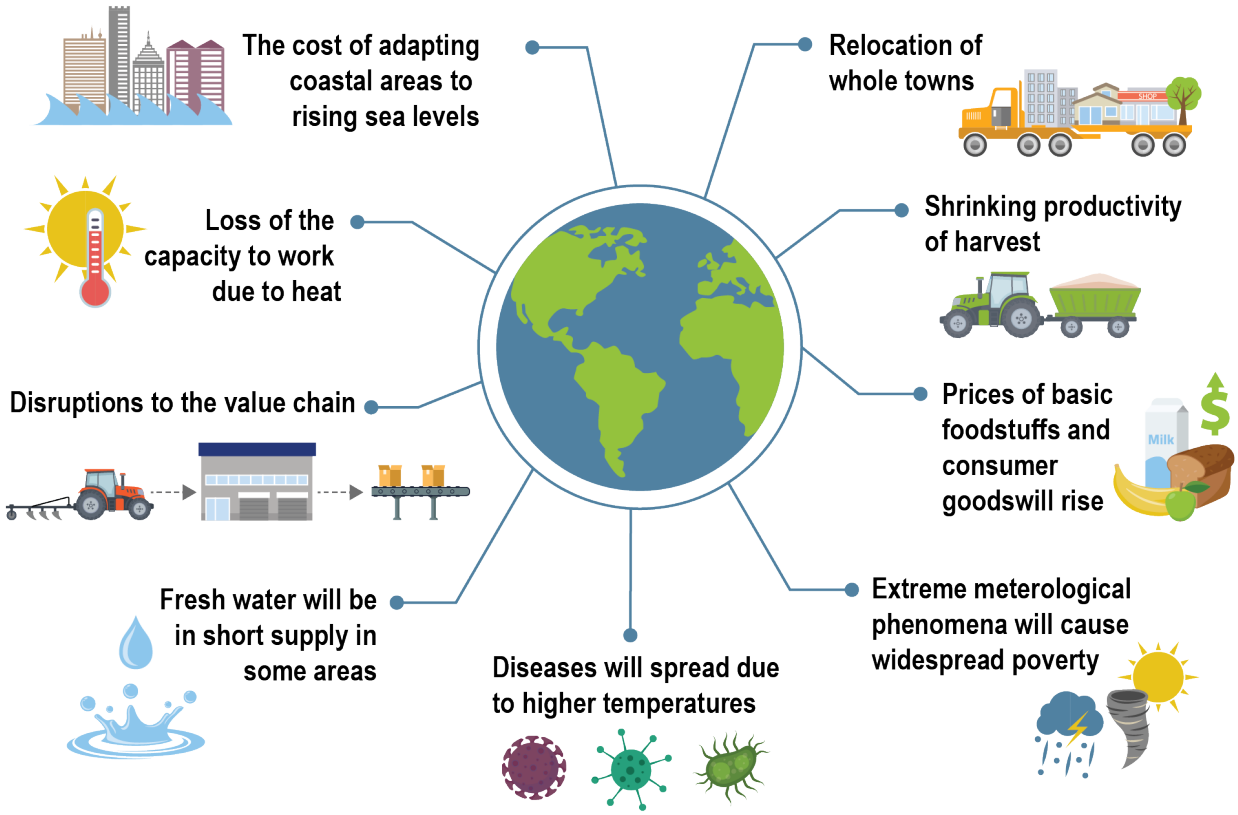


Figure 28. The impacts of a climate change under RCP8.5 scenario

In addition to direct climate impacts on local services and populations noted in the previous sections, Ottawa will be affected by global climate impacts primarily through supply chain disruptions and global migration (e.g. climate refugees). The impacts of climate change to the value chain and the economy could be highly disruptive and severe. At the global scale, an increase in the frequency and intensity of extreme weather events can damage factories, supply chain operations, transportation systems and result in reduced supply and an increase in costs. For example, flooding in Thailand in 2011 impacted Toyota and Ford's production facilities, costing more than a billion dollars in

[54] IPCC (2001). Climate Change 2001 Synthesis Report: Inertia in Climate Systems.

lost revenue).[55] More recently, the 2021 BC fires and flood events resulted in damage to both road and rails systems causing significant supply chain disruptions both locally and across Canada.[56]

An increase in heat waves and droughts could increase the cost of electricity (increased demand and production requirements) and water thereby impacting the cost of raw materials and the final cost of goods to consumers. The pricing of carbon to incent GHG reductions and the cost of adapting to the effects of climate change will also be passed along to consumers in high prices, or reduced quality of goods. Extreme weather events will also increase the uncertainty and magnitude of value chain disruptions creating longer delays and rising prices. While these changes will impact all consumers, they will be most felt by vulnerable and low-income members of the population furthering the already widening inequality divide. Global climate change is also expected to result in climate based migration and displacement. The World Bank estimates that if global climate change is left unchecked, more than 200 million people could be displaced by the impacts from climate change by 2050.[57]

4.6.2 Potential Impacts

While all Focus Areas will be impacted by value chain disruptions, the agriculture, local business, tourism, buildings, transportation, emergency management and community well-being sectors are expected to be harder hit. A summary presenting the possible range of global climate change related impacts and consequences are presented in Table 28.

[55] BBC News (2011). Toyota profits hit by floods in Thailand.
[56] Evans, P. (2021). CBC News: Stressed supply chains snarled anew as B.C. floods wash out rail lines, roads.
[57] World Bank Group (2021). Millions on the Move in Their Own Countries: The Human Face of Climate Change.

Table 28. Summary of Global Climate Change Impacts, Vulnerabilities and Possible Consequences

Focus Areas	Impacts	Noted Vulnerabilities / Considerations	Possible Consequences
Agriculture and Food Systems	• Disruptions to material and fuel supply chain reducing local production of food and agricultural • Disruptions to food supply chain	• Farmers operating with losses or low margins • Food industry sectors that rely on low-cost food sources / imports (e.g. secondary and restaurants, etc.) • Lack of small and medium scale food infrastructure in the region - abattoirs, commercial kitchens, warehousing, and root cellars – creates a supply chain vulnerability • Labour shortages exacerbate supply chain vulnerability at various stages of food production	• Higher food costs and reduced local food security • Higher risk of insolvency of farms • Reduced seed availability • Soil loss/reduced soil quality
Buildings and Facilities	• Increased material costs for construction • Disruptions to material and fuel supply chain	• Construction sector • Lower income populations	• Increased costs to long term projects and budgets • Delayed construction of City and community buildings due to cost increases which could lead to an increase in the deterioration of existing City building stock. • Increased capital costs may result in a scaling back of community programming
Economy	• Reduced business operations and economic development opportunities • Increased migration to Ottawa (climate refugees / immigrants)	• Product-based businesses most likely to be impacted • Development and construction sectors	• Development impacts (less construction starts – this could lead to an increase in the cost of housing) • Investment / business loss (as well as lost opportunity) • Closure of local businesses • Support systems would be placed under greater pressure with increased migration
Emergency Management, Community Well-Being and Health	• Supply chain breakdowns (e.g. food, fuel, other goods) causing increased costs • Increased migration to Ottawa (climate refugees / immigrants)	• Populations that depend on community services (e.g. food banks, social assistance) • Additional households/ families may require social assistance • Lack of capacity in social systems, especially for mental health and complex cases	• Increased pressure on community services including social housing, food banks, mental health or subsidized transit • Increased inequality and families pushed to poverty and homelessness • Increased costs may result in a scaling back of community programming • Emergency response to receive refugee populations that have been determined as a priority by the federal government
Transportation	• Increased material costs (e.g. asphalt) • Delayed projects • Increased cost of energy	• Exposure to increased costs, delayed material shipments, unavailability of critical parts for fleet or infrastructure etc. • Transitioning to non fossil fuel sources will be resource and cost intensive	• Increased costs • Delayed capital projects resulting in reduced level of service • Disruptions to goods movement. • Higher infrastructure project costs are ultimately borne by the community through higher property taxes and water/sewer rates • Increased fuel costs may support accelerated electrification and adoption of renewable energy sources
Water Wastewater Stormwater	• Increased material costs • Delayed projects	• Exposure to increased costs, delayed material shipments, unavailability of critical parts for fleet or infrastructure etc.	• Direct impact to the cost of construction materials and activities. • Delayed capital projects resulting in reduced level of service • Higher infrastructure project costs are ultimately borne by the community through higher property taxes and water/sewer rates

4.6.3 Adaptive Measures in Place

Throughout the CVRA, City staff and subject matter experts provided input on existing adaptive measures to reduce vulnerability and increase resilience to climate hazards, and what gaps remain. These adaptive measures were taken into consideration during the vulnerability rating step of the CVRA and are summarized in Table 29.

Table 29. Current or Planned City of Ottawa Adaptive Measures – Global Climate Change

Current or Planned City of Ottawa Adaptive Measures
• The City reviews its continuity of operations plans including stockpiling procedures and plans. • The City has systems in place to ensure proper fuel and diesel levels are maintained at City-owned fueling sites. • The City works with community partners such as Just Food to support community gardens and promote buy local campaigns. • The City is working with community partners to develop a Food Security Strategy to address access to local, affordable and culturally appropriate food. • The City's Human Needs Task Force ensures that social supports are in place for those most in need. • The City will develop a Poverty Reduction Strategy, as part of the Community Safety and Well-Being Plan. • The City has invested in the Ottawa Smart Farm which focuses on leveraging technology to help producers optimize their efforts and and manage risks associated with climate change.

4.6.4 Interpretation of Results

The CVRA identified several impacts to the City and community as a result of global climate change across all Focus Area. Similar to the extreme weather related event assessment, the risks will shift upwards as the probability that global climate change worsens in severity if GHG emissions are not reduced enough or not fast enough. This is presented in Figure 29.

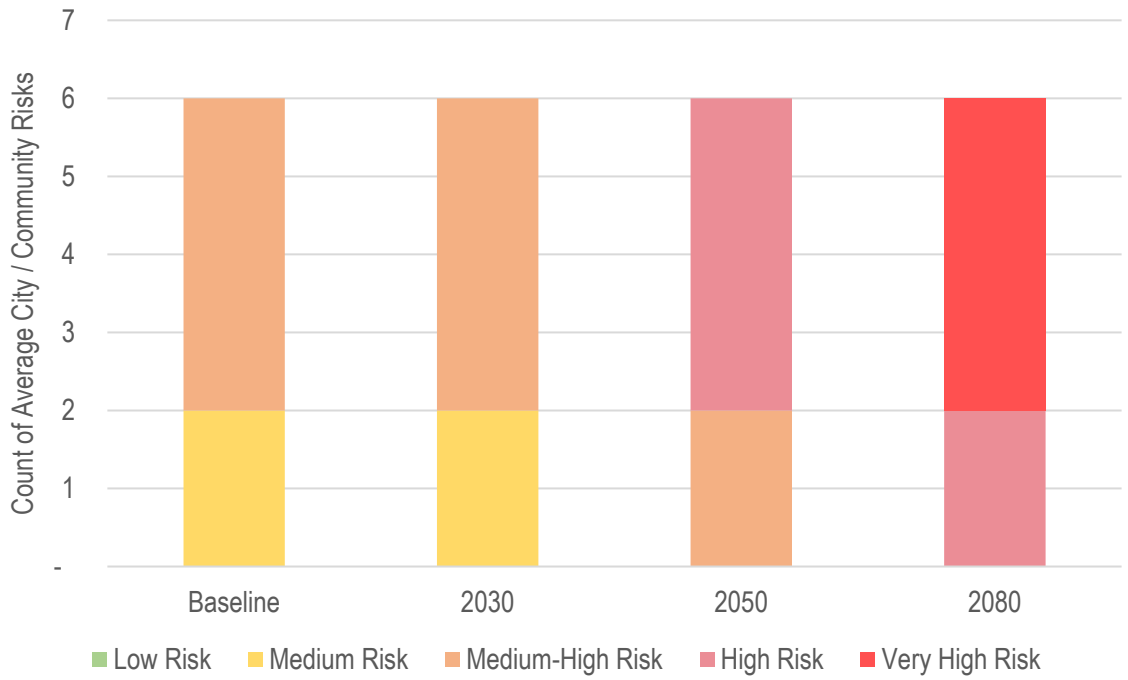


Figure 29. Count of Average Risks Related to Global Climate Change Between the Baseline and the 2080's

Currently, the world is on track with a high GHG emissions scenario (i.e. RCP 8.5). If that continues, global climate hazards will increase resulting in reduced business operations and economic development opportunities, more frequent and costly disruptions to all supply chains (fuel, material, food and other goods and services), increased material costs and delayed projects, greater pressure on disproportionately impacted populations and ultimately, greater pressure on community and emergency support services.

The CVRA shows that all Focus Areas exposed to global climate change will end up with high or very high risks by the 2080s. Those impacted most by global climate change will be those who are socially, economically, and possibly physically vulnerable (e.g. limited income, inadequate housing or living conditions, dependency on support services). While this segment of the population may appear to be small, it is likely underestimated with many being on the fringe of vulnerability. For example, a recent Consumer Debt Index reported that more than half of Canadians surveyed are $200 or less away from not being able to meet their monthly bills and debt obligations.[58]

[58] MNP (2022). Consumer Debt Index hits record low amid growing concern about debt and rising interest rates among Canadians.

4.6.5 Summary of Priority Risks Based on Vulnerability and Risk Ratings

The table that follows presents a consolidated summary of the impact statements rated in the CVRA and are organized by priority rating starting with those risks that require immediate action. Risks that require action will be used to inform the future Climate Resiliency Strategy (CRS). Appendix C: includes the priority impacts for all hazards. Appendix D presents the original impact statements, by Focus Area, where the changing risk in the 2030s, 2050s, and 2080s is noted.

The following impacts require actions to be identified and implemented within the next 1-3 years to begin to mitigate these risks.

Table 30. Global Climate Change Impacts That Require Immediate Action

Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
Supply chain instability and/or market failures impacting availability and the cost of energy, goods, and services.	Medium	High	High	High
Increased physical, emotional and mental harm to those experiencing poverty and those in precarious economic situations.	Medium	High	High	High
Reduced ability of the City, community service providers and social support systems to effectively provide services .	Medium	High	Medium-High	High

The following impacts were not evaluated at the risk stage due to them being deemed to be a low vulnerability or opportunity or not applicable:

- Increased migration to Ottawa as other regions become less inhabitable creating opportunities for economic development.

5.0 KEY GAPS

To fully understand how climate hazards might impact Ottawa, the CVRA considered the degree of exposure and sensitivity to the hazard, as well as the probable consequence or outcome. The assessment of vulnerability and risk also considered what adaptive capacity measures are already in place or are in the process of being implemented to reduce vulnerability and increase resilience to climate hazards, and what gaps remain. A summary of the gaps and proposed responses is presented below. In some cases, work is already underway or planned to address these gaps, for example through the ongoing development of the Infrastructure and Transportation Master Plans.

Table 31. Summary of Key Gaps and Proposed Responses

Information Gap	Proposed Response
The CVRA provides direction on the services and types of assets most at risk to climate hazards. Further analysis is needed to identify the specific assets that are most vulnerable or require mitigative action.	More specific spatial and asset analysis should be undertaken through the ongoing development of the Infrastructure, Transportation, Solid Waste, and Greenspace and Urban Forest Master Plans as well as Asset Management Plans.
Initial steps have been taken to identify climate risks in the City's asset management plans for water, wastewater, stormwater, and transportation services as per provincial regulations. More detailed analyses are required to assess climate risks to specific assets in all City services and identify activities and funding to support future levels of service.	Continue to develop and update Asset Management Plans as per provincial regulations. The Province of Ontario requires that by 2025 all local governments approve asset management plans for all municipal infrastructure assets that identify proposed levels of service, activities required to meet proposed levels of service, and a strategy to fund these activities.. As climate hazards are likely to influence and impact level of service metrics and targets, climate change considerations should be integrated into both asset and risk management frameworks and reflected in Long Range Financial Plans.
The new Official Plan includes policies to build resilience to known climate risks such as extreme heat and more severe flooding. The OP Implementation Plan identifies key steps to implement these policies through policy and planning tools.	Continue to review and revise relevant statutory and non-statutory policy and planning tools and procedures (e.g. Zoning By-law, High Performance Development Standard, Master Plans, design guidelines and standards etc.) to identify where and how climate risk and resilience measures could be integrated into planning and development.

Information Gap	Proposed Response
While flood forecasting of the Ottawa River is well understood and response plans are in place, flood forecasting and response plans are less well developed for the Rideau River and other smaller watercourses. There has also not been an assessment of existing flood control structures (berms, walls, pump stations etc.) along Rideau and Ottawa Rivers to determine their performance in more severe riverine flooding events.	Improve flood forecasting modelling and data for the Rideau River watershed. Assess existing flood control structures (berms, walls, pump stations etc.) along the Ottawa and Rideau Rivers to determine risks to nearby communities (e.g. Kingsview, Windsor Park etc.). Continue to improve site-specific flood response plans for flood vulnerable areas along the Ottawa and Rideau Rivers. Continue to update flood hazard mapping of watercourses through the flood mapping project with the Conservation Authorities and make the information publicly available.
There is a risk of wildfires occurring within Ottawa, but there was limited information to identify what areas would be most at risk. Fires beyond the City can also influence air quality and human health.	Complete a Wildland Fire Risk Assessment and Plan (a requirement of the Planning Act). This would involve mapping and ground truthing forested and grassland areas adjacent to urban areas to identify areas at risk and develop a plan to reduce the risk of wildfires occurring and spreading. Assess priority populations at risk of wildfires and wildfire smoke.
The CVRA process highlighted how climate change can disproportionately impact certain populations. More detailed analysis at the community scale is needed to identify specific communities or populations that may be at greater risk.	Continue to examine impacts on priority populations as part of OPH's climate change health vulnerability assessment and risk mitigation and adaptation plan. Continue to engage Indigenous Peoples and equity-seeking groups, as well as organizations and service agencies that work with them. Further examine the gender, race and intersectional lens. Identify which communities are more at risk to the priority climate impacts identified in this report. This would involve assessing specific physical infrastructure, social programs as well as socioeconomic indicators. This would enable the City to compare risks across Ottawa to prioritize which communities require immediate action.

Information Gap	Proposed Response
Public engagement in the CVRA focused on online information and surveys and a series of discussions with subject matter experts and key community stakeholders. More effort is required to raise awareness of residents, businesses, and organizations on climate risks and solutions, and encourage action to build community resilience.	Undertake community education on climate risks and engage in local-level adaptation planning. Continue to make information publicly available to enable residents, businesses, and organization to make informed climate risk management decisions.
This CVRA reflects an analysis of risks based on currently available information. A climate risk tolerance threshold or a monitoring system is needed to report when risks are changing.	Establish systems for monitoring, reporting, and evaluating climate risks and adaptation actions to better enable identification of when "tipping points" are close to being reached, or have been reached, and there is a need for transformational adaptation.
The City gathers information on additional costs incurred during extreme weather events but does not assess opportunity costs incurred due to re-deployment of staff or identify financial risks from future extreme weather events in long-term financial planning.	Continue to strengthen tracking and management of climate staffing and financial risks, including impacts on City services. Undertake cost-benefit analysis during the development and/or implementation of the Climate Resiliency Strategy and other City Plans to further inform the benefits of preventative actions. Research market standards for climate change related insurance policies.
More information is needed on impacts to privately owned infrastructure and services (such as private waste collection and management, community buildings etc.).	Continue to engage with community and private sector organizations to further assess risks and identify solutions.

6.0 CONCLUSION AND NEXT STEPS

The completion of the CVRA is a foundational step towards enhancing City and community resilience to climate change. The CVRA provides an assessment of the climate related hazards, impacts, most disproportionately impacted populations and highest risks to Ottawa. The findings of the CVRA can be used to identify opportunities and prioritize actions to build climate resilience into the City of Ottawa's policies and, programs, planning and operations, as well as partnerships with community agencies.

The CVRA process examined how climate change could impact programs, assets and populations in each of the 12 Focus Areas covering community, infrastructure, natural environment and economy. Based on the CVRA, if no further adaptive actions are taken, the climate related hazards associated with extreme heat, seasonal variability, precipitation, extreme weather events and global climate change are expected to present as significant risks to the:

- physical and mental health of City staff, residents and visitors,
- construction, operation and maintenance of City infrastructure,
- delivery of community, emergency and recreational programs and services,
- operation and development of the economy, and
- natural function of ecosystems.

While nearly all individuals within the City of Ottawa will be impacted in one way or another, there are specific segments of the population more vulnerable to the identified climate hazards. These include immigrants, older adults, persons with disabilities, persons living in poverty, racialized people, rural residents, women and youth.

The top risks identified in the CVRA will be the focus of the next phase of the project – to develop adaptation strategies as part of the Climate Resiliency Strategy (CRS). The CRS will identify a series of progressive and pragmatic actions focused on minimizing Ottawa's vulnerability to the effects of climate change by increasing resilience. Steps will be taken to address remaining information gaps through already planned City programs, such as the development of Master Plans and Asset Management Plans. The CRS will identify opportunities to embed climate resiliency considerations into key City plans, budget and risk assessment processes, and identify high-level gaps and resource needs. The development of the CRS will commence in 2022.

7.0 GLOSSARY

Term	Definition
Adaptation	Measures taken to respond to existing and 'locked in' climate changes.
Adaptive capacity	The ability to prepare for and respond to impacts and consequences (e.g. a system that is already under stress has lower adaptive capacity).
Climate change	Long-term changes in climate variables, as measured by temperature, precipitation, and frequency of events, differ significantly from the normal range of extremes for a particular region.
Climate hazard	Potential source of harm. Hazard comprises slow-onset developments (e.g. rising temperatures over the long term) as well as rapidly developing climatic extremes (e.g. a heatwave) or increased variability.
Climate impact	The resulting problem or opportunity to deal with a climate hazard (e.g. culvert failures, road washouts, flooding basements, etc.).
Climate parameter	A physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth' s climate (e.g. temperature).
Climate threshold	A measurable factor forming one of a set that defines a system (e.g. heatwave is defined as a number of days that exceed 35°C).
Climate variability	Natural changes in climate that fall within the normal range of extremes for a particular region. Climate variability can range over time and space and result in thunderstorms, tornadoes, etc.
Consequence	The result or effect of a climate impact. The effect on natural and human systems, including lives, health, ecosystems, economies, services and infrastructure. This can be positive or negative relative to the entity's related objectives.
Enterprise Risk Management	Enterprise Risk Management is the process of planning, controlling and acting on potential hazards and dangers to minimize their impact on an organization's operations and processes
Exposure	The nature or degree to which people, assets, systems or sectors would interact with a climate hazard – e.g. stormwater infrastructure is exposed to the effects of precipitation by design.
Impact Statement	A description of how a changing climate indices could affect community, infrastructure, natural environment and economy.

Mitigation	A measure taken to reduce the likelihood of a risk occurring or the impact of negative consequences if it does occur; often referred to as a control measure.
Opportunity	Upside risk – can be treated / evaluated in a similar as consequence.
Outcome	The intermediate effect as a result of exposure / interaction with a climate hazard (land and/or weather) (e.g. overland flooding).
Probability	Likelihood or chance an event that a climate hazard will occur. Expressed annually based on how often the risk event is likely to occur.
Protocol	Protocols provide a structured way to identify the issues, examine the possible impacts, and assess the urgency of action. Protocols are not regulations; rather, they provide guidance material to help investigators in this area follow a standardized sequential and logical process.
Resilience	The capacity to prevent, withstand, respond to and recover from climate trends and shocks.
Risk	The effect of uncertainty.
Risk assessment	The process of determining and evaluating risks. Assessments may be quantitative or qualitative and involve applying rating levels to prioritize risks needing mitigation.
Risk management	The identification, assessment, and response to risk to a specific objective. Integrated risk management is a systematic process for identifying, analyzing, evaluating, mitigating, communicating, documenting and monitoring/reassessing risks that would threaten the achievement of objectives.
Risk tolerance	The level of risk that an organization is willing to accept. Risk tolerance is also referred to as risk acceptability, risk appetite, and risk threshold.
Risk impact matrix	A scoring system used to identify the potential impact of a risk occurring by comparing the consequences of an event with the probability of the event occurring (can be quantified in dollars).
Sensitivity	The degree to which people or systems are either positively or negatively impacted by changing climate conditions.
Vulnerability	The propensity to be affected by change. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

APPENDICES

APPENDIX A: METHODOLOGY

A.1 Methodology Overview

The CVRA process deployed is based on ICLEI's Building Adaptive and Resilient Communities (BARC) protocol, ISO 14090-92 standards and the City's Enterprise Risk Management (ERM) framework which is based on the ISO 31000 risk management standard. This hybrid approach enabled the City to integrate findings from Ottawa's Hazard Identification and Risk Assessment (HIRA), the Health and Climate Vulnerability Assessment and the Public Infrastructure Engineering Vulnerability Committee (PIEVC) climate risk assessments that were conducted on wastewater, stormwater and drinking water assets. This is depicted in Figure A. 1.

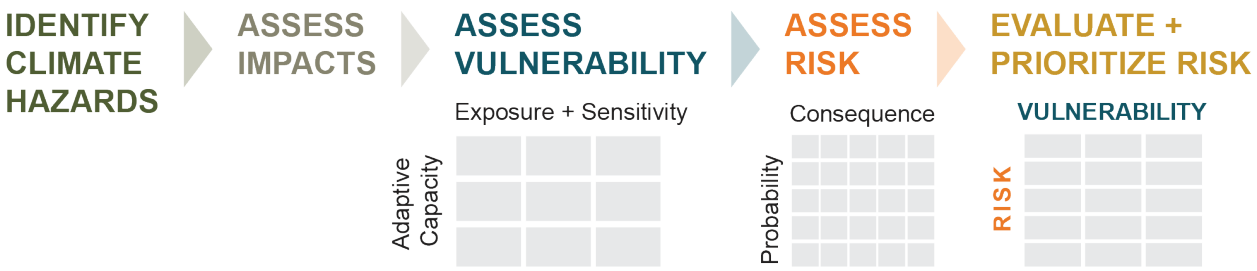


Figure A. 1. Climate Vulnerability and Risk Assessment Framework

A.1.1 Variances From the BARC Protocol

The objective of the BARC protocol is to identify how projected climatic changes could affect service areas / sectors in the City and the community, frame these interactions in terms of climate change impact statements, and assess the vulnerability and level of resulting risk associated with the climate-related impacts. The CCRA method built on the methods of the BARC protocol, but made some important adjustments:

- The CVRA adapted the findings from the extreme heat Health and Climate Vulnerability Assessment and the water, stormwater and wastewater Public Infrastructure Engineering Vulnerability Committee (PIEVC) assessments. As these assessments were led by City staff outside of the CVRA process, to which there were different probability and consequence scales being applied, the risk assessment findings from these studies had to be calibrated to the CVRA risk matrix.
- The BARC adaptive capacity and sensitivity ratings were adjusted from 5-point scales to 3-point (low, medium and high scale) to simplify the rating scale for users.
- The CVRA methodology assesses consequence on 3 dimensions - social, environmental and economic – rather than the 12 dimensions proposed by BARC. The consequence ratings were derived from the City's ERM framework as to align with its current risk evaluation and management system.
- Unlike BARC, the CVRA does not average the consequence rating across economic, social and environmental categories, but bases consequence rating based on the highest evaluation of consequence. For example, under the BARC methodology, an environmental consequence of 1 and a social consequence of 3, would result in a total consequence of 1.5, whereas the City's methodology would set the final consequence as a 3. While the

difference in final consequences may seem immaterial, when paired with a probability rating of 2, the risk rating shifts between a low under BARC and a medium under the City's methodology.

- The CVRA methodology risk matrix and prioritization tables are taken from the City's ERM framework as to align with its current risk evaluation and management system.
- The CVRA methodology evaluated risks for all future periods (Baseline, 2030's, 2050's and 2080's) and took an average of these risks to inform the prioritization process. The BARC protocol suggests selecting one period to evaluate risks, but considering the range of impacts and possible consequences, the selection of one period may result in the incorrect prioritization of risk or not factor in the degree to which risk changes between periods.
- Once the vulnerability and risk ratings were assessed, a risk and vulnerability matrix was utilized to determine the timing of the action required. The intent of this task is to avoid overlooking an impact with a medium vulnerability but very high risk, which would, at a minimum, require a plan developed to mitigate the risk. This also helped with identifying the priority risks where immediate action is required.

A.1.2 Climate Hazard and Impact Identification

The first step in the climate change risk and vulnerability assessment process begins with using climate change projections to assess which climate change hazards like extreme heat or freezing rain might materialize as impacts today and in the future. To understand anticipated future climate conditions in the National Capital Region, the NCC and the City of Ottawa released a comprehensive climate change projection study for the Region in 2020. This involved analyzing current and historical data from regional Environment and Climate Change Canada (ECCC) weather stations in relation to projected global climate trends. Future climate conditions were projected based on IPCC global Representative Concentration Pathways (RCPs) (see text box below), while current and historical weather data was retrieved from ECCC records from local weather stations. From this data, localized climate projections were developed and used to estimate potential extreme weather events and general long-term patterns and trends that could be expected to be experienced in the Region by the 2030s (2021-2050), 2050s (2041-2070) and 2080s (2071-2100).

Future climate conditions represented in this document are based on RCP 8.5 which the IPCC refers to as the 'business as usual' climate scenario (Figure A. 2). Under RCP 8.5 it is assumed global carbon emissions will continue to rise until 2100. Although some progress has been made in reducing global GHG emissions, current estimates of GHG emissions are still close to following the RCP 8.5 pathway.[59]

[59] IPCC (2018). Summary for Policymakers. In: Global Warming of 1.5°C

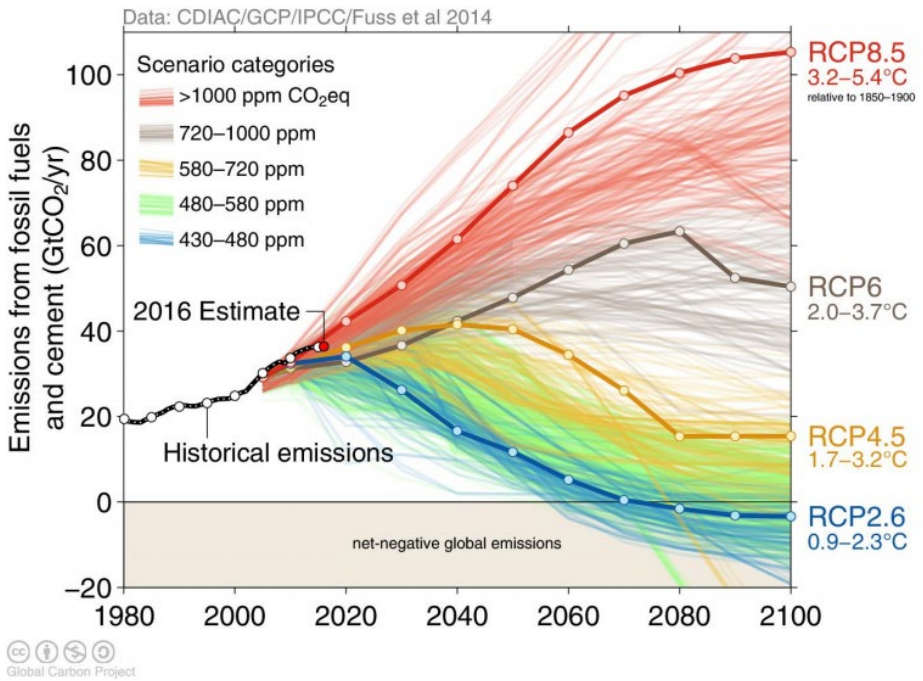


Figure A. 2. Representative Concentration Pathway (RCP) Emissions Scenarios [60]

Climate modeling uses various GHG emission scenarios, known as Representative Concentration Pathways (RCPs), to project future climate variables under different concentrations and rates of release of GHGs to the atmosphere.

Various future trajectories of GHG emissions are possible depending on the global mitigation efforts in the coming years. RCPs are established by IPCC, the international body for assessing the science related to climate change. The IPCC has established four RCPs based on different GHG emissions scenarios. RCP 8.5 is the internationally recognized most pessimistic - "business as usual" GHG emissions scenario. Other GHG emissions scenarios represent more substantial and sustained reductions in GHG emissions.(See Figure 38). RCP2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures. The RCP 2.6 emissions scenario may be achievable with extensive adoption of biofuels/renewable energy and large-scale changes in global consumption habits, along with carbon capture and storage. RCP 4.5 is considered the 'medium stabilization' scenario where global mitigation efforts result in intermediate levels of GHG emissions (IPCC, 2014).

By assessing what changes may occur (i.e. no noticeable change, warmer and drier summer, more frequent and intense storm events, less frost days, change in growing degree days, etc.), a preliminary analysis of the climate

[60] Source: Global Carbon Project (2016).

hazards and impacts for each focus area was completed. Once complete, the possible range of impacts were described in concise impact statements that outlined locally relevant projected threats and briefly described how those changes are expected to affect a particular area, asset or sector (in both positive and negative ways). Impact statements are intended to capture:

- A climatic hazard (i.e. increase in freezing rain events; warmer summer temperatures)
- The outcome of the climatic hazard (i.e. damage to trees and electrical infrastructure; heat waves)
- The impact associated with this outcome (i.e. electricity outages; specific health impacts)

This work involved reviewing climate related interview summaries prepared by City staff, reviewing the reported climate impacts to organizations and municipalities within and around the National Capital Region and using the prepared material to engage with City staff. By assessing what changes may occur (i.e. no noticeable change, warmer and drier summer, more frequent and intense storm events, less frost days, change in growing degree days, etc.), a draft set of impact statements were developed.

These impact statements were further refined through the completion of literature reviews, survey responses from Ottawa-based business and the general public, and meetings with City staff. As a result of this work, a total of 146 impact statements were identified for Ottawa.

Table A. 1 presents a sample of Agriculture and Food Systems impact statements that were derived from the desktop review and influence diagram and used in the analysis. The two drought-based impact statements at the City and community levels have been carried through the methodology section to provide additional context to the CVRA method summary.

The full list of impact statements, by focus area, is presented in Appendix B.

Table A. 1. Agriculture and Food Systems Impact Statements

Climate Hazard	Impact Statement
Drought	Drought like conditions may result in reduced agricultural yields.
	Hotter summers and variable precipitation may increase irrigation demands at food production and agricultural operations.
More Warm Extremes	Hotter summers and a prolonged growing season may create conditions that increase agriculture and food production opportunities.
	An increase in summer temperatures may result in additional health and safety risks for agricultural workers.
	Hotter and drier summers may increase the risk that agricultural materials stored in bulk (e.g. stored fertilizer, grain in silos, manure piles) catch fire.
Change In Seasonal Characteristics	Seasonal changes may disrupt pollinator lifecycles and increase the number of agricultural pests or invasive species resulting in reduced food production.
	Changes in weather patterns may result in more lands suitable for farming operations.
Less Cold Extremes	Warmer and shorter winters may result in less energy needed to heat buildings that house livestock and poultry.
Increase In Total Precipitation	Wetter winters and springs or an increase in the volume and intensity of precipitation may result in saturation or flooding of agricultural lands and reduce pasture availability / forage production or delayed planting/harvesting.
	Wetter winters and springs could result in natural wetland creation in areas where conditions were previously unsuitable.

Climate Hazard	Impact Statement
More Intense Precipitation	An increase in the volume and intensity of precipitation may cause increased run-off from agricultural lands resulting in nutrient loading of nearby aquatic ecosystems.
Extreme Events	An increase in extreme events (e.g. tornadoes, wildfires, ice storms, etc.) can negatively impact food production and agricultural operations and reduce local food security.

A.1.3 Assessing Vulnerability

This step involved using the impact statements to assess vulnerability. Vulnerability is the measure of the extent to which a segment or group of the population, asset, system or sector is susceptible to, or unable to cope with, the impacts as a result of a changing climate. In the case of this project, vulnerability is a function of the Focus Areas' exposure, sensitivity and adaptive capacity but also broader socioeconomic and environmental cross effects as well. Vulnerability is based on assessing three factors:

- **Exposure -** The nature or degree to which an asset, system or sector would interact with climate hazards. Exposure to climate-related hazards varies based on location and setting, design features, users, and other factors, which can change as climate hazards vary, interact and compound.
- **Sensitivity -** The degree to which an asset, system or sector is either positively or negatively influenced / impacted by climate hazards. The degree of sensitivity to climatic hazards depends not only on geographic conditions but also socio-economic factors such as population and infrastructure. Indicators of sensitivity can encompass geographical conditions, land use, demographic characteristics, etc.
- **Adaptive Capacity -** The ability to prepare for and respond to impacts and consequences. Adaptive capacity depends on physical resources, access to technology and information, varieties of infrastructure, institutional capability, and the distribution of resources. Indicators for adaptive capacity can compose economic capability, physical infrastructure, social capital and institutional capacity, etc. At an asset or asset component level, factors like, age, design setting, load, service levels, etc. come into consideration. Adaptive capacity may not be applicable or ratable in many cases, so at times, it may be excluded from vulnerability assessments.

In this context, vulnerability is the measure of the extent to which an asset, system, population within a focus area or sector is susceptible to, or unable to cope with, the hazards of climate change, including climate variability and extreme weather conditions. This is depicted in Figure A. 3.

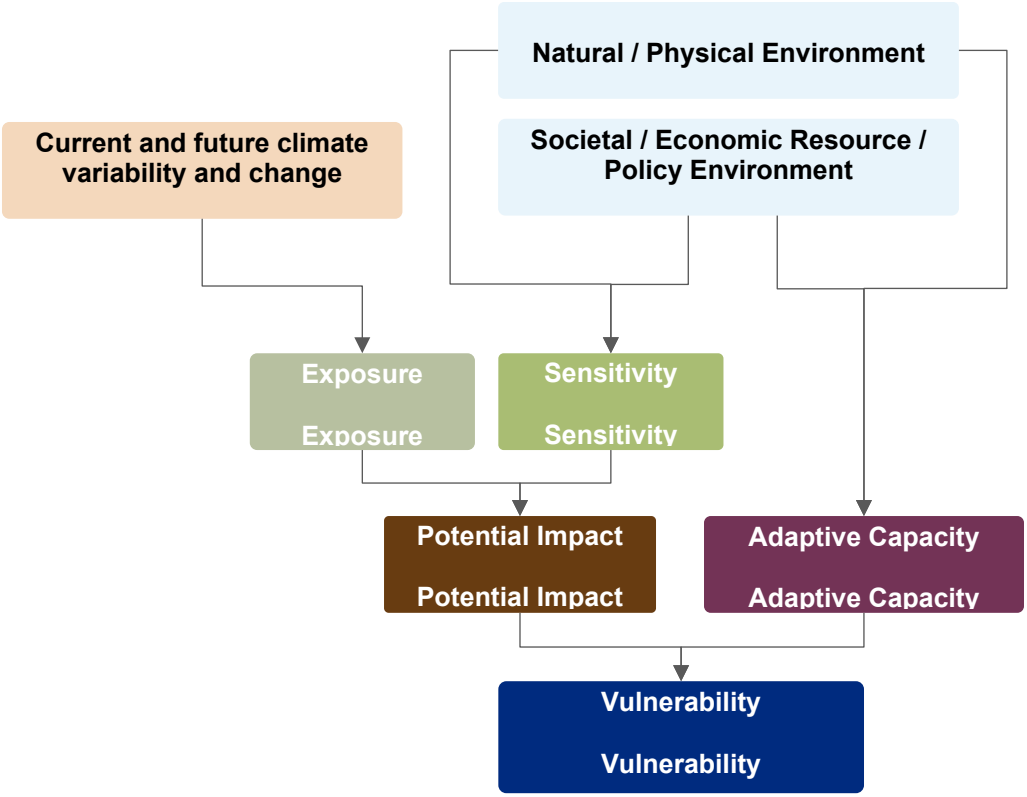


Figure A. 3. Components of Vulnerability

Assessing Exposure and Sensitivity

The first step in assessing sensitivity is to assess whether a focus area is subject to any existing stress and whether the climate hazard could exacerbate that stress – this is the level of exposure. Once an idea of exposure is developed, then a level of sensitivity can be determined. When assessing exposure and sensitivity, the following questions will be presented to stakeholders:

- Is the focus area subject to existing stresses?
- Are there current climate hazards that result in impacts to the focus area?
- Does the focus area have limiting factors that may be affected or exacerbated by climate change?
- How would a climate impact affect the ability of the focus area to function[61]if it occurred today? (e.g. will climate change cause the demand for a resource or service to exceed its supply or current abilities?)
- Are there measures that are presently in place that are able to provide a buffer against predicted climate hazards?

Sensitivity was assessed using a 3-point scale based on how the functionality of a City department or community will be affected (as presented in Table A. 2).

[61] Functionality: the ability to provide services or deliver product(s) from organizational perspective) or ability to carry out day-to-day activities (from individual or resident perspective). Collectively, these make up the functionality of the community as a whole.

Table A. 2. Sensitivity Rating Scale

Low: Functionality will stay the same or likely stay the same. Barely affected.	**S1**
Medium: Functionality is likely to get worse. Moderately affected.	**S2**
High: Functionality will become unmanageable. Significantly affected.	**S3**

Adaptive Capacity

In addition to understanding exposure and rating sensitivity, assessing vulnerability requires consideration of the main stressors, both climatic and non-climatic, as well as the socioeconomic influences on adaptive capacity. To determine adaptive capacity, the impacts will be assessed on the level of effort and intervention required by the City / community to adjust to the impact. When assessing adaptive capacity, stakeholders will be asked to consider the following questions:

- What is the ability of the current built, natural, or human systems in the community to accommodate changes, moderate potential damages, take advantage of opportunities, or cope with consequences?
- What current actions, plans, and policies are in place that could help mitigate the impacts?
- Are the current adaptive measures adequate?

Adaptive capacity is assessed using a 3-point scale (as presented in Table A. 3).

Table A.3. Adaptive Capacity Rating Scale

Low: Little or slight additional effort and intervention required.	**AC1**
Medium: Some effort and intervention required.	**AC2**
High: Significant or substantial effort and intervention required.	**AC3**

With the sensitivity and adaptive capacity ratings assigned to each of the impact statements for each Focus Area, the vulnerability rating was determined using the following matrix (Figure A. 4). The Focus Areas impact statements with a high impact rating and low adaptive capacity are highly vulnerable; whereas those with a low impact rating and high adaptive capacity have low vulnerability; and those that have a high impact rating and high adaptive capacity have a medium vulnerability.

		Impact Rating (Sensitivity + Exposure)		
		S1	**S2**	**S3**
Adaptive Capacity	**AC1**	Low Vulnerability (V1)	Low Vulnerability (V1)	Medium Vulnerability (V2)
	AC2	Low Vulnerability (V1)	Medium Vulnerability (V2)	High Vulnerability (V3)
	AC3	Medium Vulnerability (V2)	High Vulnerability (V3)	High Vulnerability (V3)

Figure A. 4. Vulnerability Matrix

For each impact statement identified, vulnerability surveys and workshops were used to engage with City staff to review and confirm the relevance of each impact statement applicable to their area of expertise and to rate the City and community's vulnerability. External subject matter experts were also engaged in workshop sectoral based workshops to help fill information gaps around vulnerabilities in the community.

The vulnerability assessment of the Agriculture and Food Systems drought based impact statements is presented in Table A. 4 and Table A. 5 below.

Table A. 4. Vulnerability Assessment of Agriculture and Food Impact Statements for Drought – City

Impact Statement	Sensitivity (S1-S3)	Adaptive Capacity (AC1-AC3)	Vulnerability Score (V1-V3)	Vulnerability Comments
Drought like conditions may result in reduced agricultural yields.	**Low (S1):** Functionality will stay the same or likely stay the same. Barely affected.	**Low (AC1):** Little or slight effort and intervention required.	Low Vulnerability (V1)	• The City's role with respect to agriculture is more policy setting and enforcement of policy requirements.
Hotter summers and variable precipitation may increase irrigation demands at food production and agricultural operations.	**Low (S1):** Functionality will stay the same or likely stay the same. Barely affected.	**Low (AC1):** Little or slight effort and intervention required.	Low Vulnerability (V1)	

Table A. 5. Vulnerability Assessment of Agriculture and Food Systems Impact Statements for Drought – Community

Impact Statement	Sensitivity (S1-S3)	Adaptive Capacity (AC1-AC3)	Vulnerability Score (V1-V3)	Vulnerability Comments
Drought like conditions may result in reduced agricultural yields.	**High (S3):** Functionality will become unmanageable. Significantly affected.	**High (AC3):** Significant or substantial effort and intervention required.	High Vulnerability (V3)	• Farmers with poor soil quality are at increased risk. • Increased irrigation demands and associated technology costs increase the pressure on farms. • Tile drains are a double edged sword in that they are great for wet seasons, but not helpful when farms need to retain moisture in soil during droughts. There are new technologies available to better manage water on the land and farmers are likely to explore new control structure technologies as droughts increase (but barriers will need to be addressed (e.g. access to technology and how to use).
Hotter summers and variable precipitation may increase irrigation demands at food production and agricultural operations.	**Medium (S2):** Functionality is likely to get worse. Moderately affected.	**Medium (AC2):** Some effort and intervention required.	Medium Vulnerability (V2)	

A.1.4 Assessing Risk

Risk can be expressed as a function where risk = probability x consequence. In this case, probability refers to the probability of a climate hazard materializing resulting in an impact, and consequence refers to the known or estimated outcomes of a particular climate change impact (Table A. 6).

Table A. 6. Risk Matrix

			Consequence				
			Very Low 1	Low 2	Medium 3	High 4	Very High 5
Probability / Likelihood	Rare	1	1 Low	2 Low	3 Low	4 Low	5 Medium
	Unlikely	2	2 Low	4 Low	6 Medium	8 Medium	10 Medium-High
	Possible	3	3 Low	6 Medium	9 Medium	12 Medium-High	15 High
	Likely	4	4 Low	8 Medium	12 Medium-High	16 High	20 Very High
	Almost Certain	5	5 Medium	10 Medium-High	15 High	20 Very High	25 Very High

The probability ratings were based on the National Capital Region climate projections data which used climate science/climate models to determine the likelihood a certain climate hazard will exceed the threshold assigned (i.e. 15 mm of freezing rain in four hours) as compared to the baseline. The probability ratings also relied on a 5-point scale where 1 is 'rare' and 5 is 'almost certain' the event will occur (Table A. 7).

Table A. 7. Probability Rating Based on Climate Event Occurrence

Occurrence	Qualitative Descriptor	Recurrent Event	Single Event	Rating
>1:50 year	Rare	Not likely to occur in the assessment period.	Negligible: probability very small, less than zero	1
1:30-50 year	Unlikely	Likely to occur at least once between 30-50 years	Unlikely but not negligible: probability noticeably greater than zero	2
1:10-30 year	Possible	Likely to occur at least once every 10 to 30 years	Less likely than not but still appreciable – probability less than 50% but still quite high	3
1: 1-10 year	Likely	Likely to occur at least once per decade	As likely as not – 50/50 chance	4
>1/year	Almost Certain	Likely to occur once or more annually	More likely than not- probability greater than 50%	5

The consequences of the described impacts were assessed using a five-point rating system ranging from "very low" to "very high" for each impact statement. For this risk assessment, the maximum value of the economic, social and environmental consequence ratings was used as the final consequence rating.

Table A. 8. Consequence Rating Scale

	Consequence Dimension		
Rating	**Social**	**Economic**	**Environment**
Very High (5)	• Large number of fatalities or serious injuries, permanent illness (physical or mental) or displacement of a large number of people. • Large disturbances leading to permanent changes in people's normal routines and way of life (> 1 month but causing daily changes) • Permanent decline in services, causing the city to be seen as unattractive, and not providing essential services to the community	• Regional decline leading to widespread business failure, loss of employment and hardship. • Catastrophic damage and costs incurred by the City / property owner ($$$$$)	• Major loss of environmental amenity (includes air, water, soil, vegetation, natural heritage and ecological functions) and irrecoverable damage
High (4)	• A low number of fatalities, serious injuries, or long-term illness (physical or mental) or displacement of people. • Severe decline in services and quality of life within the community • Large disturbances leading to prolonged changes in people's normal routines and way of life (> 1 month but not daily)	• Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth. • Major damage and costs incurred by the City / property owner ($$$$)	• Severe and widespread loss of environmental amenity and danger of continuing environmental damage
Medium (3)	• Small number of injuries, or cases of illness. • Some isolated instances of temporary displaced people. • Isolated but noticeable examples of decline in services. • Moderate disturbances leading to short-term changes in people's normal routines and way of life (1 week to 1 month)	• General reduction in economic performance relative to current forecasts. • Moderate damage and costs incurred by the City / property owner ($$$)	• Isolated but significant instances of environmental damage that could be reversed with intensive efforts

	Consequence Dimension		
Rating	**Social**	**Economic**	**Environment**
Low (2)	• Near misses or minor injuries. • Isolated instances of temporary displaced people in localized areas. • There would be minor areas in which the community is unable to maintain its current services • Minor and short-term changes to people's normal routines and way of life (<1 week)	• Isolated areas of reduction in economic performance relative to current forecasts. • Minor damage and costs incurred by the City / property owner ($$)	• Minor instances of environmental damage that could be reversed
Very Low (1)	• Appearance of a threat but no actual harm or displacement. • No changes to people's normal routine and way of life. • No real pressure on current services.	• No real impact to the local economy and growth. • No damage and costs incurred by the City / property owner ($)	• No real environmental damage
Notes: Positive consequences are assessed in the same manner as negative consequences, but the consequence descriptor is reversed and viewed in a positive light. For example, a positive impact to agriculture may be an increased growing period which could have an "isolated improvement in economic performance relative to current forecasts" thereby warranting a consequence rating of a 2.			

Similar to the vulnerability assessment stage of the CVRA, City staff were provided a survey to qualitatively assess the possible economic, social and environmental consequences of the impacted areas (as determined by the impact statement) deemed to be most vulnerable (e.g. medium and higher). Once the survey results were compiled and preliminary risk ratings determined, City staff were presented the findings in a workshop setting with the objective of validating, modifying the risk level (if needed) and providing feedback.

Continuing with the two Agriculture and Food Systems drought based impact statements, the severity of the consequences clearly depends on how the impacts play out. In the first impact statement, the drought like conditions would have a significant economic consequence to farmers due to unplanned loss of crops thus resulting in a very high social consequence rating. The second impact, while having a moderate social consequence has a higher economic consequence as the impact will have an impact on operations in terms of capital outlay and operational costs, but can be planned for, thereby resulting in a high economic consequence rating. Table A. 9 presents the consequence and climate period risk rating for these impact statements. It shows that the risks associated with droughts are already high and are expected to increase in magnitude by the 2050's (if not sooner). It should be noted that the City impact statements did not carry forward as the vulnerability rating was set to low.

Table A. 9. Consequence Assessment of Agriculture and Food Systems Impact Statements for Drought – Community

	PROBABILITY				CONSEQUENCE				RISK			
IMPACT STATEMENT	**Baseline**	**2030's**	**2050's**	**2080's**	**Soc**	**Eco**	**Env**	**Final Rating**	**Baseline**	**2030's**	**2050's**	**2080's**
Drought like conditions may result in reduced agricultural yields.	Possible (3)	Possible (3)	Likely (4)	Almost Certain (5)	Very High (5)	High (4)	Low (2)	Very High (5)	High Risk	High Risk	Very High Risk	Very High Risk
Hotter summers and variable precipitation may increase irrigation demands at food production and agricultural operations.	Possible (3)	Possible (3)	Likely (4)	Almost Certain (5)	Medium (3)	High (4)	Medium (3)	High (4)	Medium-High Risk	Medium-High Risk	High Risk	Very High Risk

A.1.5 Evaluating Priority Risks

As a sector level assessment was completed, the CVRA methodology evaluated risks for all future periods (Baseline, 2030's, 2050's and 2080's) and took an average of these risks to inform the prioritization process. Once the vulnerability and risk ratings were assessed, a risk and vulnerability matrix were utilized to determine the timing of the action required (Figure A. 5). The intent of this task is to avoid overlooking an impact with a medium vulnerability but very high risk, which would, at a minimum, require a plan developed to mitigate the risk. This also assisted with identifying the priority risks where immediate action is required.

	VULNERABILITY		
RISK	**High Vulnerability**	**Medium Vulnerability**	**Low Vulnerability**
Very High Risk	Immediate action required.	Immediate action required.	Develop a plan to address risk.
High Risk	Immediate action required.	Immediate action required.	Develop a plan to address risk.
Medium-High Risk	Immediate action required.	Develop a plan to address risk.	Identify possible controls and continue to review for change.
Medium Risk	Develop a plan to address risk.	Identify possible controls and continue to review for change.	Identify possible controls and continue to review for change.
Low Risk	Identify possible controls and continue to review for change.	Identify possible controls and continue to review for change.	Continue to manage through existing controls and procedures.

Figure A. 5. Vulnerability and Risk Matrix

For the two Agriculture and Food Systems drought based impact statements, due to the vulnerability and average risk ratings, both impacts are deemed to require immediate action. This assessment is presented in Table A. 10.

Table A. 10. Risk Prioritization Assessment of Agriculture and Food Systems Impact Statements for Drought – Community

Impact Statement	Vulnerability Rating	Average Risk	Assessment
Drought like conditions may result in reduced agricultural yields.	High Vulnerability (V3)	Very High Risk	Immediate action required.
Hotter summers and variable precipitation may increase irrigation demands at food production and agricultural operations.	Medium Vulnerability (V2)	High Risk	Immediate action required.

APPENDIX B: PROBABILITY TABLE USED IN THE CVRA

The following table presents the climate probability ratings for the key climate indices used in the risk assessment. Additional data on these and many other climate indices and thresholds can be found in the Climate projections report for the National Capital Region.[62]

Table B-1: Climate Probability Ratings

Climate Parameter	Climate Indices	Climate Indices Threshold	Probability Rating			
			Baseline	2030s	2050s	2080s
Temperature	Increase in Average Temperatures	Annual Average Temperature	3	3	4	5
	Less Cold Extremes	Number of days with Min Temperature < -28°C (winter)	5	4	3	2
	More Warm Extremes	Number of days with Max Temperature > 35°C (summer)	2	3	5	5
	Heat Warnings	Frequency of Warm Spells (1-day max T > 31 and min T > 20°C) [# Periods]	4	5	5	5
	Change in Seasonal Characteristics	Timing of First Fall Frost and Last Spring Frost	3	3	4	4
	Seasonal Average Temperature in Winter	Winter mean Temperature based on -6 deg C	1	2	3	4
	Seasonal Winter Freeze Thaw	Winter Freeze Thaw (based on historical 24 cycles per year)	4	4	5	5
Precipitation	Increase in Total Precipitation	Annual Total Precipitation [mm]	3	3	4	5
	More Intense Precipitation	Annual Max. 1-day Precipitation [mm]	3	3	4	5
	Riverine Flooding	Riverine Flooding Proxy based on current 1:100 riverine flood with moderate increases to reflect increased spring precipitation	3	4	4	5
	3 Day Snow Melt and More Intense Precipitation	Total 3 Day Snow Melt Plus Max Monthly 2 Day Precipitation	4	4	3	3
Humidity	Increase in Humidex	Number of Days Humidex > 40°C	3	3	4	5
Extreme Events	Seasonal Winter Freeze Thaw + Ice Storms	Freezing Rain events combined with Winter freeze thaw	4	4	5	5
	Freezing Rain	Number of Days with Daily Min Temperature <0°C and Winter (DJF) Precipitation	5	5	5	5
	Multi-Day Ice Storm	Ice Accretion of 25mm or more	2	2	2	2
	Extreme Snow and Blizzards	Number of Days with Snow Depth > 21 cm [Number of Days] and Number of Hours Wind Speed > 40 km/hour [Number of Hours]	4	4	4	4
	Extreme Wind/ Tornadoes	1 in 50 Year 3-Hourly Winds and 1 in 100 Year 3-Hourly Winds	2	2	2	3
	Drought	Water Scarcity Approximation (Based on Precipitation and Temperature) [Number of Days]	3	3	4	5
	Wildfires	Number of Days Chandler Burning Index (Fire Index) > 90 [Number of Days]	2	2	2	2
	Global Climate Change	City Derived Proxy based on probability of extreme weather globally	3	3	4	5

[62] National Capital Commission and City of Ottawa (2020). Climate Projections for the National Capital Region. *Volume 1: Results and Interpretation for Key Climate Indices*

APPENDIX C: PRIORITY RISKS (ALL HAZARDS)

C.1 Risks Requiring Immediate Action

Hazard	Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
	Reduced agricultural yields.	–	High	–	Very High
	Changing winter conditions may increase the number and severity of extreme cold-related health and safety issues (slips and falls, isolation, etc.).	Medium	High	Very High	Very High
	Increased spread of invasive species, agricultural pests, extinctions of local flora and fauna and reduced food production.	Medium	High	Very High	High
	Increased number and severity of heat-related health and safety issues to emergency responders, disproportionately impacted populations, active transportation users, and athletes or active recreation users.	Medium	Medium	Very High	Very High
	Less outdoor recreation and sports impacting overall physical and mental health of the community.	Medium	Medium	High	Very High
	Increased cooling demands, increased occurrence of inadequate indoor environmental conditions where no A/C, and increased demand / cost to upgrade buildings / facilities.	Medium	Medium	High	Very High
	Extreme winter events may increase winter maintenance needs and reduce asset life of roads, sidewalks, bridges, etc. thereby decreasing the availability of transportation systems and increasing the risks to users.	High	Medium	Medium-High	Very High
	Increased demand for shaded areas in parks and additional indoor and outdoor recreational facilities.	High	Medium	High	High
	Riverine flood related damage to / overwhelming of sewers, ditches, pumping stations and culverts located in the floodplains.	High	-	High	-
	Increased tree mortality and ecosystem instability and habitat loss requirements.	High	High	High	High
	Increased stormwater runoff or sewer overflows resulting in poor surface water quality, riverbank and ravine bank destabilization, erosion and loss of habitat.	High	High	High	High

Hazard	Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
	Increased water flows, erosion and sediment inflow into stormwater systems, resulting in a reduced level of service, localized flooding, basement flooding and more frequent repairs and renewals.	High	-	High	-
	Riverine flooding damages or overburdens berms and flood protection infrastructure along the Rideau and Ottawa Rivers resulting in localized flooding and more frequent repairs and renewals.	High	-	High	–
	Increased basement flooding and sewer overflows due to increased inflow and infiltration in wastewater collection systems and reduced capacity in pump stations or sewers.	High	-	High	–
	Riverine flood related damage to water treatment plant and reduced access. And contaminated private wells and compromised septic systems.	High	-	High	-
	Overwhelmed stormwater systems resulting in inland flooding resulting in damage to buildings.	High	Medium	High	High
	Riverine flood-related access issues to key roadways, property and infrastructure throughout the community, leading to isolation of residents and/or challenges for emergency services.	Medium	High	High	High
	Intensification of existing, and the migration of, new disease vectors and illnesses into the community.	High	High	High	Medium-High
	Increased settlement, heave and misalignment of surface or shallow stormwater infrastructure resulting in reduced run off capture, localized flooding, interruptions to transportation systems, and more frequent repairs and renewals.	High	–	High	–
	Increased settlement, heave, and misalignment of surface wastewater infrastructure such as maintenance holes and pump stations resulting in increased inflow and infiltration.	Medium	–	High	–
	Increased irrigation pressures at food production and agricultural operations.	–	Medium	–	High
	Riverine flood related damage to buildings.	High	High	Medium-High	High
	Supply chain instability and/or market failures impacting availability and the cost of energy, goods, and services.	Medium	High	High	High

Hazard	Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
	Increased physical, emotional and mental harm to those experiencing poverty and those in precarious economic situations.	Medium	High	High	High
	Reduced ability of the City, community service providers and social support systems to provide services.	Medium	High	Medium-High	High
	Disruption to business continuity, extended closures and wide range of financial impacts in the community.	Medium	High	Medium-High	High
	Reduced ability of the City, community service providers and social support systems to provide services and effectively respond to simultaneous and future events.	Medium	High	Medium-High	High
	Saturation or flooding of agricultural lands leading to delayed planting/harvesting and reduced pasture availability.	Medium	Medium	Medium	High
	Increased run-off from agricultural lands resulting in nutrient loading of nearby aquatic ecosystems.	-	Medium	–	High
	Damage and disruption to electrical and communication systems, impacting communication, transportation, building and emergency systems.	High	High	Medium-High	Medium-High
	More frequent repairs and renewals to buildings (freeze-thaw).	High	Medium	Medium-High	Medium-High
	Increased use of parks and associated damage / degradation from overuse.	High	Medium	Medium-High	Medium
	Seasonal winter freeze thaw may result in structural damage and increased maintenance to berms, levees and dykes	High	-	Medium-High	-
	Decreased use of active transportation and transit systems due to more extreme heat.	Medium	High	Medium-High	Medium-High
	Decline of winter tourism and recreation, some seasonal agritourism, and economic welfare.	Medium	High	Medium	Medium-High
	Heavy rains compromise roof and foundation drainage.	Medium	High	Medium-High	Medium-High
	Reduced / delayed delivery of essential services (e.g. electricity supply, food banks, mental health supports, etc.).	Medium	High	Medium-High	Medium-High

Hazard	Impacts	City Vulnerability	Community Vulnerability	City Risk (Average)	Community Risk (Average)
	Blockages and clogging of ditches and culverts from windborne debris resulting in damaged infrastructure and localized flooding.	High	-	Medium-High	–
	Reduced aquifer recharge, lower baseflow to streams and degraded aquatic habitat.	Medium	High	Medium-High	Medium-High
	Exposure of vulnerable segments of the population to physical injuries, respiratory, water-borne and food-borne illnesses, and mental health impacts from flooding.	Medium	High	Medium-High	Medium-High