Climate Change Vulnerability & Risk Assessment

June 2022

National Capital Commission
Commission de la capitale nationale

Executive Summary

People are feeling the impacts of climate change globally and locally. Research predicts these impacts will intensify and affect the National Capital Region for decades to come. As such, the region will experience more extreme weather events like floods, wildfires, droughts, heatwaves, freeze-thaw spells and tornadoes.

The National Capital Commission (NCC) is vulnerable to these hazards. They magnify existing stressors or challenges, such as aging infrastructure, and will create new ones. Like other cities and organizations across Canada, the NCC must adapt to these inevitable changes.

In this study, the NCC has evaluated its vulnerability to climate change within business lines. It assessed the potential impacts of 27 climate hazards for 8 sectors:

1. Agriculture
2. Infrastructure & Operations
3. Natural Resources & Parks
4. Archaeology
5. Buildings, Housing & Real Estate
6. Corporate Services (IT, Security, HR, Procurement, Communications, Legal)
7. Recreation, Education, Tourism & Cultural Heritage
8. Land Use, Development & Planning

Findings

Priority climate hazards

If the NCC doesn't take further adaptive actions, the following climate hazards should present the most significant risks to the delivery of its mandate:

- hotter and more humid summers,
- short duration/high intensity and sustained precipitation events, and
- extreme events (e.g., ice storms, freezing rain, etc.).

These hazards already have a high probability of occurrence in the baseline period (1981-2010). They should increase in frequency over the next 80 years and have important environmental, social and economic consequences.

Priority impacts

This study found a total of **124 potential impacts** on NCC business lines. Of these, 61 need immediate action, 38 need a plan to address the risk, and 25 need minor controls and monitoring. Of those that need immediate action, 3 have very high vulnerability and very high risk, 23 have high risk and high vulnerability, and the remaining 35 have a medium/medium-high vulnerability and risk rating.

The following NCC sectors have the greatest number of **total** risks:

- Infrastructure and Operations: 22%
- Natural Resources and Parks: 19%
- Recreation and Culture: 14%
- Building, Housing and Real Estate: 12%

The following NCC sectors have the greatest number of **priority** risks:

- Infrastructure & Operations (13 of 27 total risks for this sector)
- Natural Resources & Parks: (13 of 23 total risks for this sector)
- Buildings (12 of 15 total risks for this sector)
- Agriculture (9 of 15 total risks for this sector)

Of the 61 potential climate impacts that need immediate action, approximately 36% of the risks are related to extreme heat, 36% are related to changes to precipitation, and 20% are related to extreme weather events, including but not limited to extreme blizzards, ice storms, extreme winds, etc., and a small percentage (8%) are related to seasonable variability.

Impacts on lands

The study has found that the NCC's assets within the 100-year flood plain are already at risk of extreme and long-duration precipitation events. This risk will increase as the probability of high precipitation events increases. This will impact assets like shorelines, contaminated sites, and archeological sites.

Major events may also impact poorly functioning ecosystems. However, the extent to which this is the case is unclear without a more detailed assessment. We expect extreme heat, drought-like conditions and the cascading effects that result from seasonal changes to increase stress on ecosystems. These changes will make it increasingly difficult for the NCC to maintain the tree canopy and achieve its tree-planting targets.

Impacts on infrastructure

Heritage buildings and structures are at the greatest risk of extreme temperatures and precipitation as they were not designed to handle the projected climate conditions, Extreme heat, seasonal changes, heavy snow and long-duration precipitation events already impact them.

The Crown Collection, a collection of ~4,000 pieces of fine and decorative art that furnish and adorn the interiors of Canada's official residences, is also at risk. NCC staff actively manage the collection to avoid heat and humidity damage by not putting items in areas without air conditioning, ensuring that there are screens on windows, etc. But, unless at-risk heritage assets get upgraded, this task is likely to get increasingly difficult.

For at-risk infrastructure, intense and long precipitation is the most damaging and costly kind of hazard. Hotter summers and droughts speed up the degradation of infrastructure. They soften and rut asphalt roads and damage steel structures like bridges and rail systems. Winter freeze-thaw

damages roads, sidewalks and shallowly buried infrastructure. They cause thermal cracks, frost heave, potholes, and rutting.

These impacts can result in health and safety hazards, localized flooding and property damage. Many of the impacts have cascading effects on operations, costs, and users. With many of the NCC's pathways already in a poor condition, this likely means more complaints, slip, trip and fall-related liabilities.

Impacts on programs

Changes to parkways and road conditions could impact programming like the Weekend Bikedays program. Warmer and shorter winters should shorten the cross-country skiing and snowshoeing season in Gatineau Park and the Greenbelt and on urban ski trails as well as the skating season on the Rideau Canal Skateway. Adapting these programs over time will add pressure on already limited operations, maintenance, staff, and budgets.

NCC's ability to react to impacts

We can trace some of the risks to built assets back to age, design and construction materials. But, other factors limit the NCC's ability to react to the potential impacts of climate change. The NCC is in a situation where assets reach near-critical condition before we can intervene to bring them back up to a functional level. Because of the pressing nature of these interventions, there is no time or mechanism to build in measures to mitigate the effects of climate change.

The organization is still working to fix the damage from prior flooding events. In the NCC's current situation, the costs associated with climate impacts are going to be higher as events occur more frequently and with greater intensity. This will make it increasingly difficult for the NCC to meet its organizational mandate.

The NCC and its partners have commissioned a comprehensive climate change projections study for the National Capital Region, which this study used. But, the NCC doesn't have formal policies calling for use of that data in corporate and operational decisions or design criteria. Plus, climate change has low priority in funding decision frameworks.

The NCC needs a concerted and organized corporate effort to course correct. This will include:

- more funding and resources, or more creative and efficient use of existing resources;
- a senior-level commitment to embed climate change and sustainable development into all aspects of the organization;
- policies and programs that mandate the use of climate risk assessments to inform decisions at key points in time; and
- a monitoring and reporting program for accountability and to evaluate and report on progress.

Next Steps

The NCC is at the beginning of its climate adaptation planning process. Although this study notes the risks and vulnerabilities as current gaps, the NCC can address them in the upcoming climate adaptation strategy.

To develop this strategy, the NCC will engage with staff to identify and prioritize actions. All 124 impacts identified in this study will move forward.

The strategy will focus on lessening NCC's vulnerability to the effects of climate change by increasing resilience. It intends to create a comprehensive document that will enable NCC service area leads to:

- begin implementing adaptation measures;
- identify other studies needed to further understand climate risks; and
- identify adaptation measures for specific assets.

The NCC will start developing its strategy in Fall 2022. It will circulate the first draft for public input in Summer 2023. The draft will include an implementation plan that identifies responsibilities, resource requirements, and timelines.

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1.0 Introduction

1.1 Context for Climate Adaptation

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 "human influence has warmed the atmosphere, ocean and land, widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred, and 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."[1] To substantially reduce the risks and effects of climate change, and limit global warming to 1.5°C, scientists and policy makers have agreed that global society must dramatically reduce GHG emissions by 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 of addressing climate change, the Government of Canada (including the National Capital Commission (NCC)[2]) and 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 two metres 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 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

[1] https://www.ipcc.ch/assessment-report/ar6/
[2] Per the *Federal Sustainable Development Act*, the NCC must achieve net-zero operations by 2050 for real property, fleet, procurement and staff business travel and commuting. 40% reduction in emissions from real property and fleet by 2025 with 10% decrease every five years thereafter.
[3] sciencebasedtargets.org/news/more-than-1000-companies-commit-to-science-based-emissions-reductions-in-line-with-1-5-c-climate-ambition
[4] https://www.ipcc.ch/site/assets/uploads/2018/11/pr_181008_P48_spm_en.pdf

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. Depending on physical geography many locations will be impacted more than others as was noted by Environment and Climate Change Canada (ECCC) who concluded that Canada is warming at twice the rate of the rest of the world.[5] ECCC's climate models project that this warming trend will materialize as an increase in precipitation in the winter, spring and fall seasons with a decrease in summer, warmer and more acidic oceans, and more extreme heat events that last longer in duration.

The National Capital Region (NCR) is already experiencing the outcome of these changes with the weather becoming more variable and unpredictable. For example, the floods of 2017 and 2019 had significant impacts on the multi-use pathway network. The tornadoes in 2018 impacted trees on NCC-managed lands in Ottawa and Gatineau. The extreme heat episodes in the summer of 2018 impacted crops in the Greenbelt, and increased energy demand to cool buildings. Climate change has also negatively disrupted popular programs such as cross-country skiing in Gatineau Park and skating on the Rideau Canal. The impact of these events ranged in economic magnitude, but included service disruption to users, damage to, and loss of, physical and natural assets, reduced service life for asset components and assets themselves, and increased stress on NCC staff, policies, procedures, and operations.

1.2 Responding to the Impacts of Climate Change

Although it is no longer possible to avoid the impacts of climate change, it is possible to reduce the severity and cost of climate change to some extent. There are two responses to climate change: 1. Mitigation (efforts to reduce greenhouse gas emissions taken at global, national, sub-national and organizational levels) and 2. Adaptation (acknowledgement that climate change is happening and adopting measures to respond to changes that are irreversible and already underway). 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 to new or changing environments (Figure 1). Most importantly, climate adaptation is now an essential aspect of managing assets and infrastructure.

[5] https://cca-reports.ca/wp-content/uploads/2019/07/Report-Canada-top-climate-change-risks.pdf

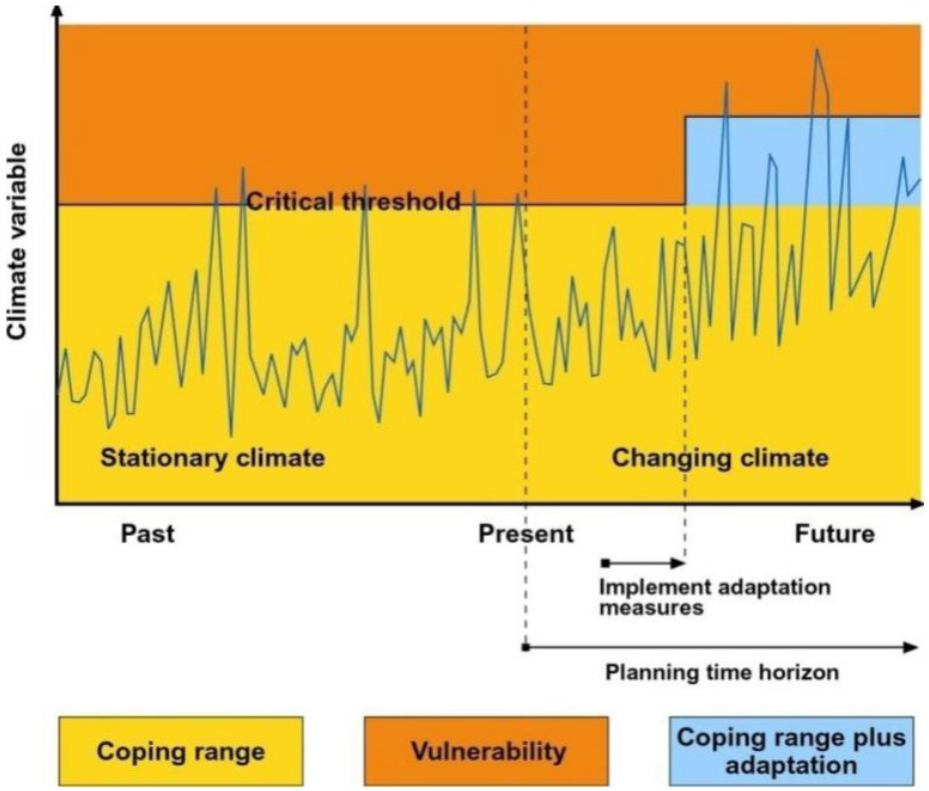

Figure 1. Adaptation Aims to Reduce Vulnerability by Increasing Coping Ranges6

Adaptation and mitigation are not mutually exclusive and can sometimes result in co-benefits and synergies when carefully considered and planned for. For instance, green roofs can improve on-site stormwater management, increase biodiversity in the area, improve the thermal retention of the roof and reduce summer cooling energy use, and reduce GHG emissions as a result. However, the window of opportunity for co-benefits is closing as the concentration of GHG emissions released into the atmosphere increase.[7]

There will also be cases of conflict or trade-offs between mitigation and adaptation measures where one measure will become the priority over the other. In such cases, other decision criteria like lifecycle avoided cost and cost-benefit assessments will need to come into play to support decision making. For example, adaptive upgrades to infrastructure, like the installation of additional stormwater infrastructure to account for more extreme rainfall events, are expected to avoid or reduce the flooding impacts and avoid the costs of damage and repair which has a GHG impact; however, are likely to result in GHG emissions because of construction. Over time, there will be more occasions where there are mitigation versus adaptation tradeoffs and the NCC will need to consider how it wants to manage these tradeoffs in terms of its commitments and decision-making.

Proactive adaptive action can result in significant cost-benefits as reported by the National Round Table on the Environment and the Economy who concluded that under a high GHG emissions

[6] www.erm.com/en/insights/feature-articles/a-changing-climate-for-the-extractives-sector/
[7] https://data.fcm.ca/documents/reports/investing-in-canadas-future-the-cost-of-climate-adaptation.pdf

scenario (i.e., RCP 8.5)[8], the benefit-to-cost ratio of proactive adaptation is 38:1; while under a lower GHG emissions scenario, the same benefit-to-cost ratio falls to 9:1.[9] Similar studies have also shown that every $1 proactively invested in resilient infrastructure could avoid $6 of losses resulting from climate change.

1.3 Costs of Climate Change

If global GHG emissions targets are not met and the upward trajectory continues (i.e., RCP 8.5), scientists estimate that global temperatures could rise by an average of 4 to 6°C globally this century, yield up to two metres of sea level rise and result in significant social, environmental, and economic costs to society. While the costs of extreme weather events depend on multiple factors, climate change is already increasing the intensity of storms, floods, droughts, and other severe weather events in Canada. Since the 1980s, catastrophic losses from weather-related events have been growing (Figure 2). In Canada 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).[10]

More concerning is that the catastrophic losses from natural disasters are expected to grow from about $5 billion in 2020 to between $30 billion and $62 billion in Canada per year by 2050.[11] In the worst-case GHG emissions scenario (RCP 8.5), there is a 5% chance that costs could exceed $113 billion per year.

[8] 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.

[9] http://nrt-trn.ca/wp-content/uploads/2011/09/paying-the-price.pdf

[10] Tip-of-the-Iceberg-_-CoCC_-Institute_-Full.pdf (climatechoices.ca)

[11] Canada in a Changing Climate: National Issues Report – Costs and Benefits of Climate Change Impacts and Adaptation (nrcan.gc.ca)

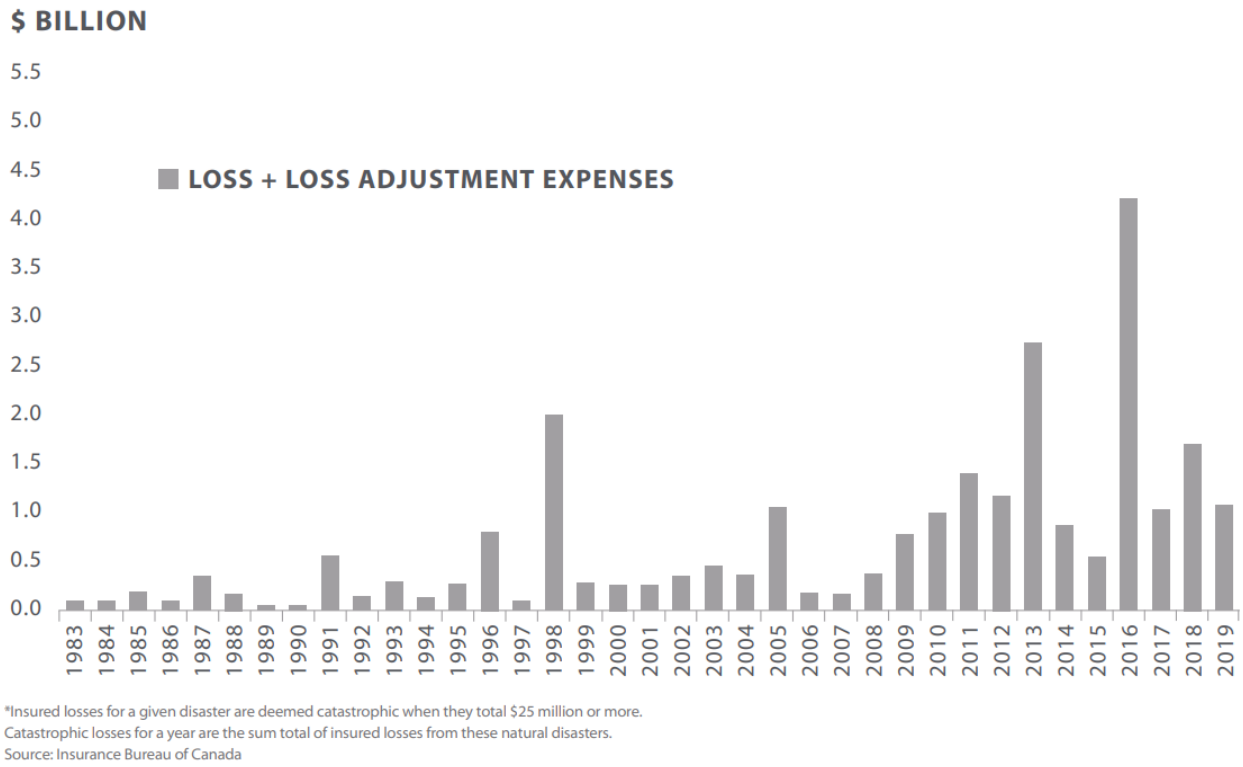

Figure 2. Catastrophic Losses from Natural Disasters in Canada ($ Billions, 1983–2019)[12]

The NCC has already experienced several destructive and costly climate-driven events – the 1998 ice storm, the 2018 extreme heat event and tornadoes, and the 2017 and 2019 floods. Additional smaller scale events also have caused major damages to NCC's assets (e.g. high short-duration precipitation at Philippe Lake in 2011). The impact of these events ranged in economic magnitude, but also included service disruption to users, damage and loss of physical and natural assets, increased capital and operational costs, the diversion of resources to emergency response and repairs, delay of planned projects, and increased stress on NCC staff, systems, and operations. While the NCC has been able to respond and recover from the impacts, there are residual impacts that are not always quantified - higher repair and maintenance costs, accelerated deterioration and reduced asset value (Figure 3), lost productivity, and as it relates to NCC park users, the delay or cancellation of programs, and temporary or permanent closures of park areas because of environmental hazards. Recent extreme events have highlighted the need for the NCC to plan ahead.

[12] assets.ibc.ca/Documents/Disaster/The-Cost-of-Climate-Adaptation-Report-EN.pdf, Figure 1

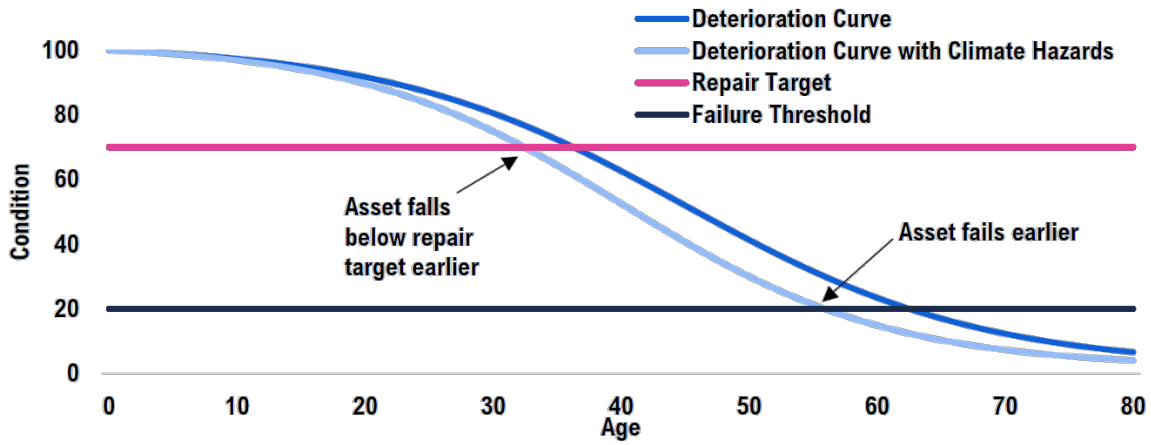

Figure 3. Typical Asset Deterioration Curve with Climate Hazards[13]

1.4 Purpose of this Climate Change Vulnerability And Risk Assessment

The projected effects of climate change – i.e., more intense, frequent, and longer in duration events - will magnify existing stressors or challenges, like aging infrastructure, and are expected to create new ones, as the risks of more frequent and severe climate-related hazards intensify over time. The inevitability of these climatic changes to increase in both frequency and intensity has prompted the NCC to commit to evaluating the risk of climate change impacts on NCC assets, programs and services in its 2018-2023 Sustainable Development Strategy. The NCC is also a designated entity under the *Federal Sustainable Development Act* which means that it is required to contribute to and report on progress toward the Federal Sustainable Development Strategy and the Greening Government Strategy. Under these strategies, the NCC is required to "take action to improve understanding of the risks posed by the impacts of climate change to federal assets, services and operations" and "take action to reduce climate change risks to assets, services and operations".

This climate change vulnerability and risk assessment (CVRA) has been completed to meet these requirements and expand the NCC's understanding of its vulnerability to climate change within and across business lines and identify ways in which the organization can reduce vulnerability and increase resiliency to the impacts of climate change. This involved utilizing a robust set of climate projections for the National Capital Region and Geographic Information System (GIS) data to assess climate-related vulnerabilities and risks to NCC operations and built and natural infrastructure to

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identify the highest climate hazards and sectoral risks to the NCC. The assessment of the impacts was organized by the 8 following NCC sectors:

1. Agriculture (includes the planning, management, maintenance and renewal of all agricultural assets and leases).
2. Infrastructure & Operations (includes the planning, management, maintenance and renewal of non-building related assets – i.e., roads, bridges, pedestrian and cycling infrastructure, stormwater infrastructure, parking lots, fleet, facilities, snow removal, and road maintenance).
3. Natural Resources & Parks
4. Archaeology
5. Buildings, Housing & Real Estate (includes the planning, management, maintenance and renewal of all building assets and leases).
6. Corporate Services (e.g., all corporate systems and operations – i.e., HR, IT, Security, Procurement, Legal, and Communications)
7. Recreation, Education, Tourism & Cultural Heritage (includes Crown Collection and associated assets)
8. Land Use, Development & Planning (includes contaminated sites)

Internal processes have also been examined as these can be a significant source of vulnerability and are therefore worth examining alongside assets. By identifying priority risks and organizational vulnerabilities, the NCC can take the next step to identify adaptation pathways, implement the strategies needed to reduce the consequence of climate-driven events, and better respond to and recover from climatic events when they occur. This will be captured in the climate adaptation strategy which will be developed in 2022-23.

2.0 Methods

A 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 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 helps to prioritize these potential problems or vulnerabilities by assessing the probability of the climate hazard occurring and estimating what social, economic and environmental consequences may occur should the climate hazard interact with the population, asset, system or sector in question. To determine the probability of a hazard occurring, the annual frequency of a climate hazard is compared to the historical climate trends and a probability score is assigned. Climate risks are identified and prioritized as a result of the confluence of vulnerability, probability, and consequence. The overall risk rating serves to prioritize impacts as requiring immediate action, developing a plan, identifying controls and monitoring changes, or continuing to manage. Impacts requiring immediate action will be carried forward to the adaptation planning stage of the project.

2.1 Methodology Overview

The NCC's CVRA process is based on ICLEI's Building Adaptive & Resilient Communities (BARC) protocol, ISO 14090-92 standards and NCC's Enterprise Risk Management framework which is based on the ISO 31000 risk management standard. This hybrid approach enabled the NCC to utilize climate vulnerability and risk information generated by the Ville de Gatineau and the City of Ottawa who are utilizing the BARC approach but was specific enough to assess the broad range of physical infrastructure, assets, operations and programs (i.e., natural systems, recreational programs) managed by the NCC. This process is depicted in Figure 4.

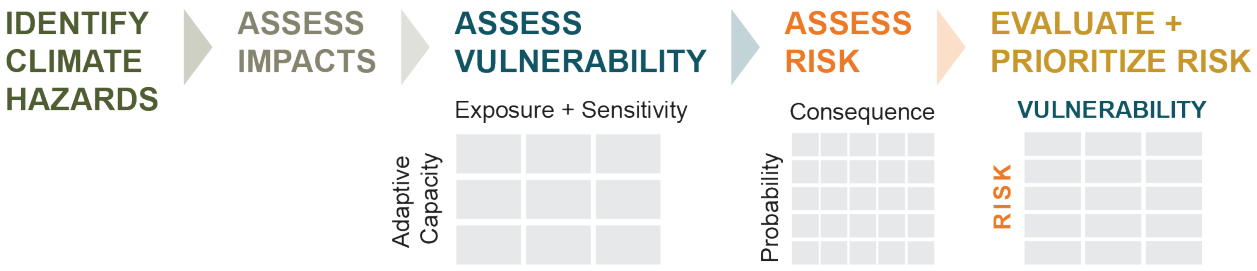

Figure 4. Climate Vulnerability & Risk Assessment Framework

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

2.1.1 Staff Engagement

NCC staff were engaged at three pivotal points during the assessment in the Fall of 2021: individual and group interviews, a vulnerability workshop and vulnerability validation, and consequence rating workshop. The majority of findings described in this report were reported by staff via these workshops and interviews.

2.1.2 Climate Hazard & Impact Identification

The first step in the climate change risk and vulnerability assessment process begins with using climate change projections for the NCR 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, in partnership with the City of Ottawa and Environment and Climate Change Canada, developed and released a comprehensive climate change projection study called "Climate Projections for the National Capital Region". 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 1981-2010 baseline. The 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 what changes may occur (i.e., no noticeable change, warmer and drier summer, more frequent and intense storm events, fewer frost days, change in growing degree days, etc.), a preliminary analysis of the climate hazards and impacts for each sector was completed. Once complete, the possible range of impacts were described in concise "impact statements" that outline 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:

1. A climatic hazard (i.e., increase in freezing rain events; warmer summer temperatures)
2. The outcome of the climatic hazard (i.e., damage to trees and electrical infrastructure; heatwaves)
3. The impact associated with this outcome (i.e., power outages; specific health impacts)

As a result of this work, 27 primary climate indices were used to identify a total of 124 impact statements for the NCC.

It is important to note that there are only 92 distinct impact statements, however several impacts appear more than once because they received different risk scores depending on the sector.

The full list of impact statements ranked according to risk level and the level of intervention required can be found in Appendix A, grouped by NCC sector in Appendix B, and grouped by climate hazard in Appendix D0.

2.1.3 Vulnerability Assessment

For each impact statement identified, a vulnerability assessment was completed with NCC staff in a workshop setting. 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 5).

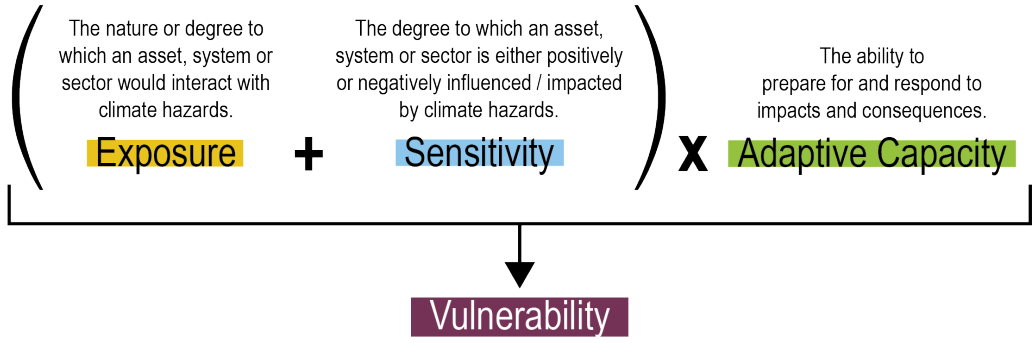

Figure 5. Basis of Vulnerability

2.1.4 Risk Assessment

Following the completion of the vulnerability assessment, the next step was to determine the relative risk posed by each climate hazard by calculating a risk score. To calculate the risk scores, it was

necessary to assess both the probability of each climate hazard's occurrence and its potential consequences. Risk is commonly calculated by multiplying the probability score by the total consequence score (Figure 6).

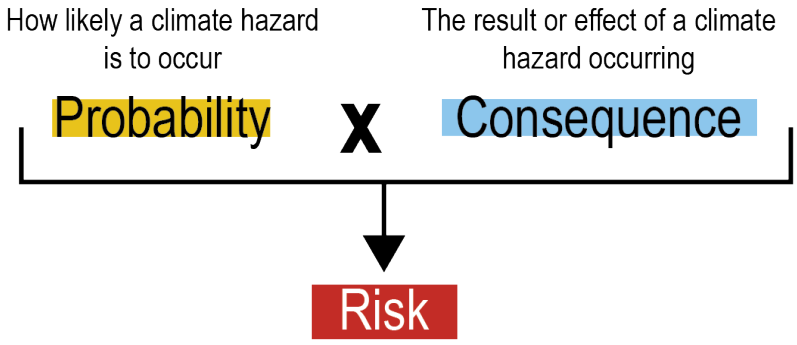

Figure 6. Basis of Risk

The probability ratings were based on the NCR climate projections data which used climate science/climate models to determine the probability 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 social, economic and environmental consequences of the described impacts were assessed by NCC staff in sector-based workshops.

2.1.5 Evaluating Priority Risks

The CVRA methodology evaluated risks for all future periods (Baseline (1981-2010), 2021-2050, 2041-2070, and 2071-2100) 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 was utilized to determine the level of intervention required (Figure 7).

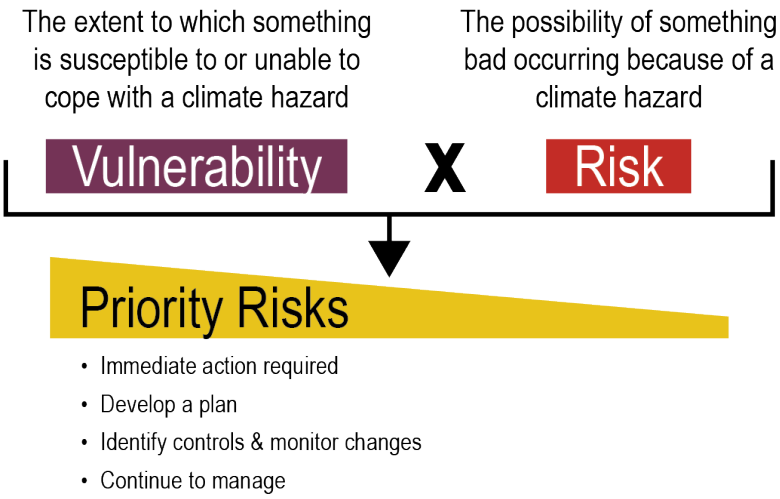

Figure 7. Basis of Assessing Priority Risks

The intent of this task was 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.

2.2 Limitations of the CVRA

Like any vulnerability and risk assessment, the CVRA assessment is subject to some uncertainty and limitations – these include uncertainty surrounding climate projections and parameters, particularly for non-temperature climate variables such as precipitation and extreme events, limitations in asset and geospatial data, staff perception of consequence and the timing of the impacts (see Appendix C.2.6 for details). While there are limitations with any risk assessment process, completing a risk assessment represents a major step forward in terms of understanding what actions are needed to decrease the impacts of climate change on the organization.

3.0 Projected Climate Change Hazards

To understand anticipated future climate conditions in the National Capital Region, the NCC and the City of Ottawa released a comprehensive set of climate change projections for the NCR in 2020. This involved analyzing current and historical data from regional ECCC weather stations in relation to projected global climate trends. Future climate conditions were projected based on IPCC global Representative Concentration Pathways (RCPs), while current and historical weather data was retrieved from ECCC records from local weather stations. From this data, localized climate projections for the NCR were developed and used to general long-term patterns and trends that could be expected to be experienced in the NCR by the 2030s (2021-2050), 2050s (2041-2070) and 2080s (2071-2100) under the different RCP scenarios.

The different RCPs reflect varying GHG emissions futures ranging from business as usual (i.e., RCP 8.5) where emissions continue to increase until the year 2100 to the best-case scenario (RCP 2.6) where global GHG emissions are reduced significantly and global warming is kept below 1.5°C. 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. 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. A summary of the potential changes under RCP 8.5 as compared to the 1981-2010 baseline is presented in Figure 8.

	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 8. Climate Projections for the National Capital Region[14]

In order to build a shared understanding of how climate change will impact the NCC, the following sections outline the climatic changes expected for the NCR between now and 2100 and the potential impacts on NCC assets, programs and operations. Refer to the Climate Projections for the National Capital Region Report for additional information. The full table of impacts by climate hazard and parameter is presented in Appendix D.

The following sections are organized by climate hazard theme:

- Extreme heat, drought and humidity
- Seasonal variability and change
- Precipitation volume and intensity
- Extreme weather events

3.1 Extreme Heat, Drought & Humidity

3.1.1 Projected Changes to Average Temperatures

In 2018, the Canadian Centre for Climate Services reported that between 1948 and 2016 the average annual temperature in Canada rose by 1.7ºC.[15] Using data collected at the local weather stations, the NCR is also warming and is projected to continue warming in all seasons over the next century. The climate models project that the annual mean temperatures in the NCR will be 2–3°C

[14] https://ncc-website-2.s3.amazonaws.com/documents/Climate-Projections-for-the-NCR_Volume-1_Final.pdf
[15] www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR-Chapter4-TemperatureAndPrecipitationAcrossCanada.pdf

warmer by the mid-century and potentially 3–5°C warmer by as early as 2071. This means warmer seasons and fewer cold extreme events.

While the general warming of all seasons may be viewed as a positive change as there is likely to be a longer construction, crop growing, and active transportation season, 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.

3.1.2 Projected Changes in the Warm Extremes & Heat Warnings

In addition to an increasing average temperature, 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. The number of warm extremes is expected to increase to approximately 25–28 days in 2021-2050, 32–43 days in 2041-2070 and 36–72 days by 2071-2100. Because of this change, the number of extreme heat warnings is also expected to increase. Extreme heat warnings are issued when the daytime temperature exceeds 31°C and the nighttime temperature remains over 20°C.

The increase in warm extremes will pose health risks to users, staff, and contractors and put a strain on some ecosystem types and functions. In terms of other impacts, hotter summers can increase cooling demands in buildings and increase GHG emissions, accelerate the degradation of built assets like asphalt roads, place stress on terrestrial and aquatic ecosystems (e.g., increased forest mortality, algae blooms, and increased recreational use and damage), increase the incidence of wildfire and smoke (local and national), and increase ground-level ozone levels resulting in health and safety hazards. Extreme heat warnings result can be mechanical and electrical failures and in people, severe and at times, fatal health outcomes as the nighttime temperature does not fall significantly and thus does not provide mechanical and electrical systems, animals and people with a reprieve and opportunity to cool down and rest.

3.1.3 Projected Changes in Humidex

Humidex - an index calculation based on both temperature and humidity - is also projected to increase over the next century in the NCR. 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 2 days of humidex >40°C is expected to increase from approximately 1 day in the baseline to approximately 4 days in 2021-2050, 5–6 days in 2041-2070, and 6–9 days in 2071-2100. 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 serious implications for human health and safety, especially for outdoor workers, recreation enthusiasts, and those with no access to air conditioning or who have existing medical conditions are likely to result in park and recreation programming delays or extensions, modifications to outdoor activities and events, and lost revenues to the NCC. Humidity also has damaging impacts on antiques and heritage assets as they are typically wood and oil-based products.

3.1.4 Wildfires

Wildfires are part of natural ecological processes that while destructive, allow for the renewal and regeneration of the impacted ecosystems. Wildfires clear 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. However, wildfires also pose a risk when the fire is near rural and urban populations as they can destroy property and infrastructure, and result in a loss of life. Extreme wildfires can also leave a lasting impact where intense fire scorches the organic layer to the point that the post-fire regrowth cycle is less successful. Wildfires also result in reduced air quality both locally and regionally, and can significantly impact vulnerable populations (children, athletes, individuals with existing health conditions, people who are experiencing homelessness and those who are under-housed, etc.).

Wildfires are the result of a variety of elements which include but are not limited to temperature change, drought-like conditions, precipitation patterns, human and non-human interactions (e.g., increasing population, expansion of urban areas into wildlands and lightning respectively), and 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.[16]

3.2 Seasonal Variability & Change

3.2.1 Projected Seasonal Changes

As average temperatures across all seasons increase, the typical characteristics of the seasons will also change. By 2071-2100, 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. These changes are already occurring and have forced the NCC to adapt the Tulip Festival planting and programming (i.e., the timing of tulip emergence and blooming). Warming across all seasons will have implications for ecosystems, watersheds, outdoor workers, and recreational enthusiasts and will require changes to NCC planting regimes and programs. 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 increasing human health and safety risks (e.g., West-Nile, Lyme Disease, etc.), the permanent alteration of natural habitats, loss of at-risk species due to the loss of habitat and increased management costs to the NCC.

As a result of warming and shifting seasons, a warmer and shorter winter season is also projected. Typically, cold temperature extremes will be, on average, less severe and less frequent. In particular, the number of days where the daily minimum temperature is less than -10°C is projected to decrease from approximately 71 cycles of cold weather extremes in the baseline to approximately

[16] https://nrc-publications.canada.ca/eng/view/ft/?id=3a0b337f-f980-418f-8ad8-6045d1abc3b3

59–57 cycles in 2021-2050, 53–46 cycles in 2041-2070 and 48–28 cycles in 2071-2100. While this change may be welcomed by some, the cascading impacts will be significant. For example, without a period of extreme cold temperature periods, invasive species populations may not be kept in check and are likely to spread. The warming and shorter winter trend is expected to shorten the cross-country skiing and snowshoeing season in Gatineau Park and the Greenbelt and on urban ski trails (such as the Kichi Sibi Winter Trail), as well as the skating season on the Rideau Canal Skateway (RCS).

As it relates to the RCS, the NCC recently conducted a climate change risk assessment to understand how warming temperatures and increased temperature variability, shorter winter seasons, and changes in winter precipitation patterns would affect the operations, equipment, and infrastructure. The assessment concluded that the NCC should expect to open the RCS one to two weeks later than average and that the NCC should prepare for skating seasons that last between 20 and 40 days. Under a high GHG emissions scenario (RCP 8.5), there is a 73% probability that there will be at least 20 skating days, a 13% probability that there will be 40 skating days and only a 1% probability that there will be 60 skating days by 2071-2100.[17]

3.2.2 Projected Changes to Annual & Winter Freeze-Thaw Occurrences

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 2021-2050, 17–14 cycles per season in 2041-2070 and 16–8 cycles per season in 2071-2100.

While the number of spring and fall freeze-thaw cycles is projected to decrease, the number of winter freeze-thaw cycles is projected to increase. The number of winter freeze-thaw events is predicted to increase from 24 days in the baseline (1981–2020) to approximately 28–27 days in 2021-2050, 30–32 days in 2041-2070 and 32–37 days in 2071-2100. Winter freeze-thaw events are particularly damaging to vegetation health (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), water supply infrastructure, and masonry assets like heritage walls.

3.3 Precipitation Volume & Intensity

Warmer winters will 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.

[17] National Capital Commission – Standards Council of Canada Report Number: 201-10298-00. Risk Assessment Of The Effects Of Climate Change On The Rideau Canal Skateway - Analysis And Recommendation Options

3.3.1 Projected Changes to Annual Precipitation

In the NCR, total annual precipitation is expected to increase between 3%-5% in 2021-2050, 6%-8% in 2041-2070 and 7%-12% in 2071-2100. Future climate projections for the NCR 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% increase by 2071-2100.

More importantly, the short duration-high intensity (SDHI) rainfall events – i.e., a rainfall of 50 mm or more in 1 hour – are expected to increase in annual probability. SDHI events are more likely to result in riverine flooding as stream banks are overtopped and inland flooding as stormwater infrastructure is overwhelmed by the sheer volume of water being deposited. Inland and overland flooding, like the events in 2017 and 2019, have resulted in significant financial and resource consequences to the NCC with some repairs still ongoing. A projected increase in more intense precipitation events is expected to have long-lasting impacts on the NCC as inland, sewer, and riverine flooding result in damage to natural and built infrastructure (roads, buildings), damage or loss of heritage assets, temporary or permanent park closures, damage to archaeological sites, and exposure of contaminated sites which create health and safety hazards to NCR residents, staff and contractors.

3.3.2 Projected Changes to Winter Precipitation

While total precipitation is expected to increase, the total monthly snowfall is expected to decline in all months, with the greatest absolute decreases projected to occur in the months that currently have the most snow (December, January, February, and March). The number of days with snow cover is also projected to decrease from approximately 115 days in the baseline to approximately 95–94 days in 2021-2050, 90–72 days in 2041-2070 and 78–43 days in 2071-2100.

Less snowfall and a shorter snow season will directly impact winter outdoor recreational activities, like skating, snowshoeing, fat biking, and cross-country skiing, and will increase operational costs in the short term to maintain these program offerings. Over the longer term, the NCC will need to evaluate the cost-benefit ratio of offering these programs considering a changing climate and potentially reimagine their format, location, and timing.

3.4 Extreme Weather Events

Extreme weather is identified as a weather event that is significantly different from the usual or average weather pattern. In the NCR, these tend to materialize as freezing rain, ice storms, extreme wind events and tornadoes, and extreme snow and blizzards which can produce disproportionate amounts of damage to the natural and built environment and pose significant health and safety risks to populations in the areas that these events occur.

There is a lower degree of certainty when it comes to climate projections for the NCR related to extreme weather events and several extreme weather phenomena are the result of multiple converging climate factors such as temperature, humidity and wind speed and local geography.

3.4.1 Freezing Rain & Ice Storms

Freezing rain falls as a liquid but freezes on contact with roads and sidewalks, power lines and trees and is one of the most damaging and costly weather events that occur in Canada.[18] The projected increase in near-freezing temperatures in the NCR suggests that there will be an increase in freezing rain occurrence. This assessment aligns with a freezing rain study completed by ECCC who predicts that freezing rain will increase about 40% in December, January and February in Southern Canada.[19] These events damage vegetation, overhead wires, and agriculture crops due to ice accumulation, create dangerous driving and walking conditions, increase road salt use (further harming ecosystems – e.g., trees along confederation boulevard), and accelerate the degradation of heritage assets (e.g., stone walls).

3.4.2 Extreme Snow & Blizzards

Extreme snow and blizzards can have a wide range of impacts on the population, built and natural environment in the NCR. Such events can result in stress and injury to the population (e.g., slips and falls, isolation, car accidents), severe damage to trees, building envelops or roofs collapsing due to the weight of the snow, localized flooding from storm drain blockages, power outages and impede emergency services. The climate projections for the NCR suggest that with the warming of the winter seasons, more snow is expected to fall as rain.

3.4.3 Extreme Wind & Gusts

High winds can result in considerable damage to infrastructure, properties, power lines, and trees resulting in significant social and economic 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 2041-2070. High straight-line wind gust events where the winds exceed 80 km/hour are projected to remain steady at ~1-2 times per year.

3.4.4 Tornadoes

Eastern Ontario and Western Quebec have historically been subject to periodic significant tornado events, including the recent September 21, 2018, event and a similar event that occurred in the region on June 26, 1978. The June 1978 outbreak included a tornado affecting Masson-Angers, Quebec of remarkably similar intensity, size, and track length to the Dunrobin-Gatineau tornado of September 2018. It is conservatively estimated annual probability of an EF1+ tornado (winds of 138-177 km/h) occurring within the region could increase from 14.6% to 18.2% by 2041-2070. Although the probability of a tornado event occurring remains low over the next century, a tornado can result in considerable damage to infrastructure as was observed during the September 2018 event when six tornadoes hit the NCR. Many trees were knocked over requiring replanting.

[18] www.tandfonline.com/doi/full/10.1080/07055900.2011.555728
[19] www.tandfonline.com/doi/full/10.1080/07055900.2011.555728

4.0 Results

The CVRA process examined how changes to 27 climate parameters could result in climate hazards and impact each of the NCC sectors. This resulted in the generation of 124 “impact statements” that described a range of possible climate-related impacts on the NCC.

Recall that there are only 92 distinct impacts, however, several impacts appear more than once because they were scored differently depending on the sector, resulting in a total of 124 impacts.

During the vulnerability and risk assessment stages, each impact statement was assessed in terms of the NCC’s ability to respond to the impact should it occur, how the impact would affect the asset’s or program’s functionality – i.e., the ability to provide services, complete daily activities, etc. and what the social, economic and environmental consequences would be.

Once the vulnerability and risk stages were completed for each sector, the overall risk and vulnerability ratings were reviewed to identify the level of intervention required to address each impact (see Figure C.5 in Appendix C). The CVRA found that:

- 49% of impacts require immediate action (n = 61),
- 31% of impacts require a plan to be developed (n = 38), and
- 20% of impacts require minor controls and monitoring (n = 25).

Of the 61 impacts requiring immediate action, 3 have very high vulnerability and very high risk, 23 have high risk and high vulnerability, and the remaining 35 have a medium/medium-high vulnerability and risk rating. The impacts ranked by risk level and level of intervention required are presented in Appendix A. Impacts categorized as requiring immediate action will hereafter be referred to as “priority impacts”.

The following sections present these results, first by climate hazard and then by NCC sector.

4.1 Priority Climate Hazards

Based on the CVRA, if no further adaptive actions are taken, the climate-related hazards associated with hotter and more humid summers, short-duration/high-intensity and sustained precipitation events, and extreme events (e.g., ice storms, freezing rain, etc.) are expected to present as significant risks to NCC staff, residents and visitors in the Capital Region, the construction, operation and maintenance of NCC infrastructure, the delivery of recreational programs and services, and the natural function of ecosystems. These climate hazards already have a high probability of occurrence in the baseline period (1981-2010), are expected to increase in frequency over the next 80 years and have significant environmental, social and economic consequences. Extreme wind events and wildfires are at an elevated risk rating due to their high consequence but rate lower due to their lower probability of occurrence.

The baseline period (1981-2010) and future period (2021-2100) climate hazard risks are presented in Figure 9 and Figure 10 to provide a visual representation of the risk related to each of the climate

hazards over time. The figures show that the probability of nearly all the climate hazards increases over the next 80 years.

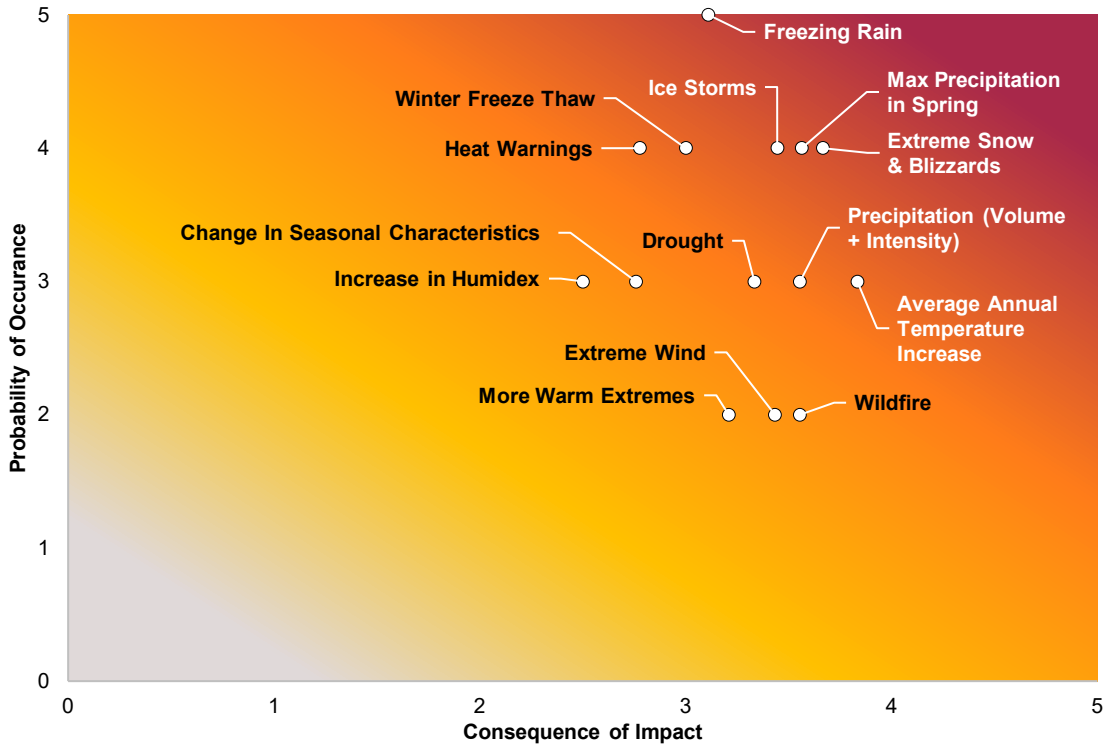

Figure 9. Climate Hazard Risks in the Baseline Period (1981-2010)

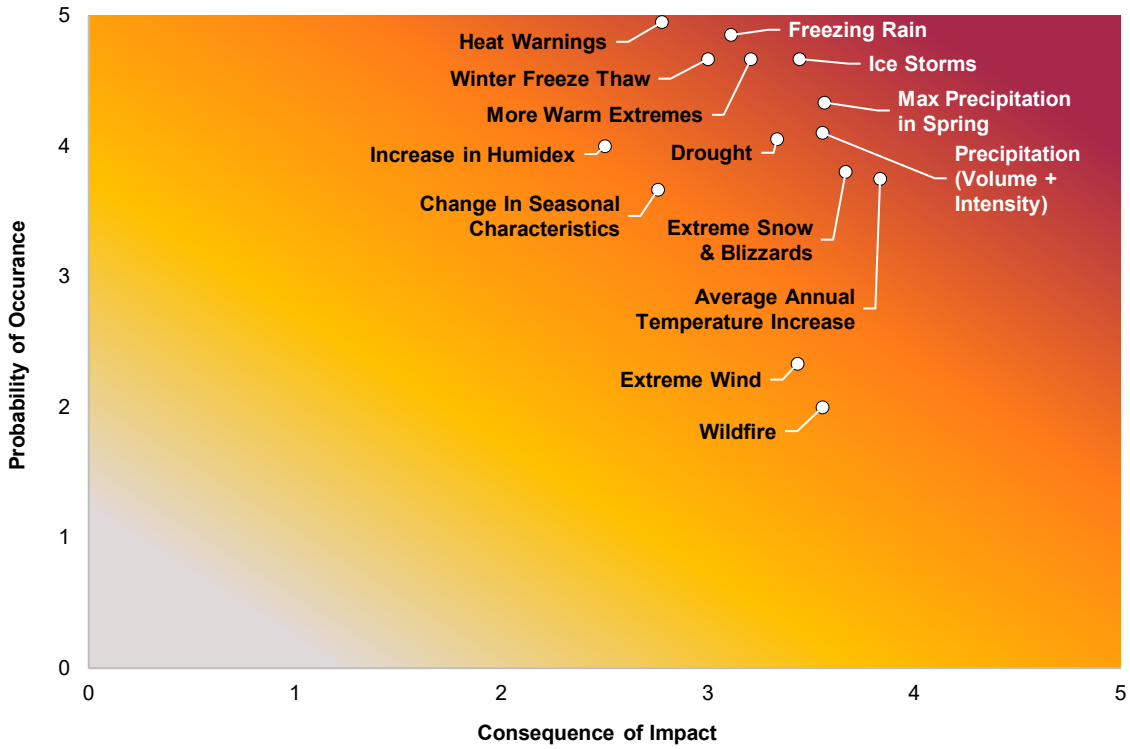

Figure 10. Climate Hazard Risks for the 2021-2100 period

Figure 9 and 10 show that the probability of the various climate hazards increases more so than the direct consequence of the hazards. However, an increased occurrence of climate hazards can have significant consequences for the NCC as more frequent occurrences will shorten the life and robustness of assets to withstand impacts, and result in more expensive repairs and earlier replacements.

Of the 61 impacts that require immediate attention over the 2021-2100 period, approximately 36% of the risks are related to extreme heat, 36% are related to changes to precipitation, 20% are related to extreme weather events, including but not limited to extreme blizzards, ice storms, extreme winds, etc., and a small percentage (8%) are related to seasonable variability (Figure 11).

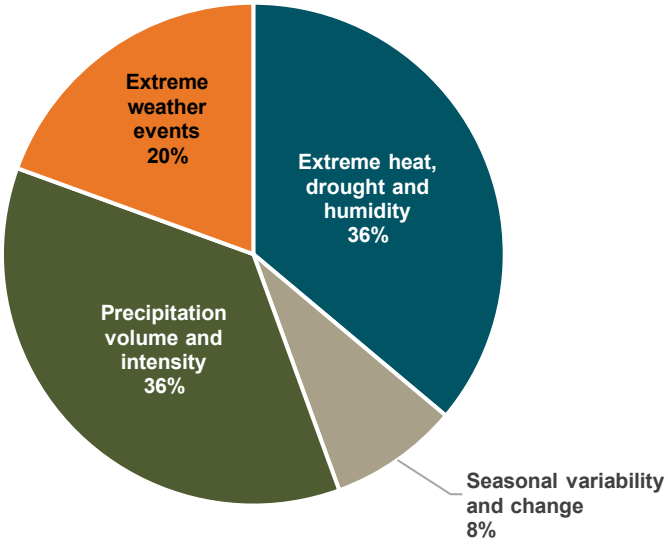

Figure 11. Breakdown of 61 Impacts Requiring Immediate Action by Climate Hazard

Figure 12 presents these priority impacts by climate hazard and NCC sector. As noted previously, the bulk of the priority risks stem from extreme heat and precipitation changes. Note that there were no impacts requiring immediate action for the Corporate services sector therefore it does not appear in the table below.

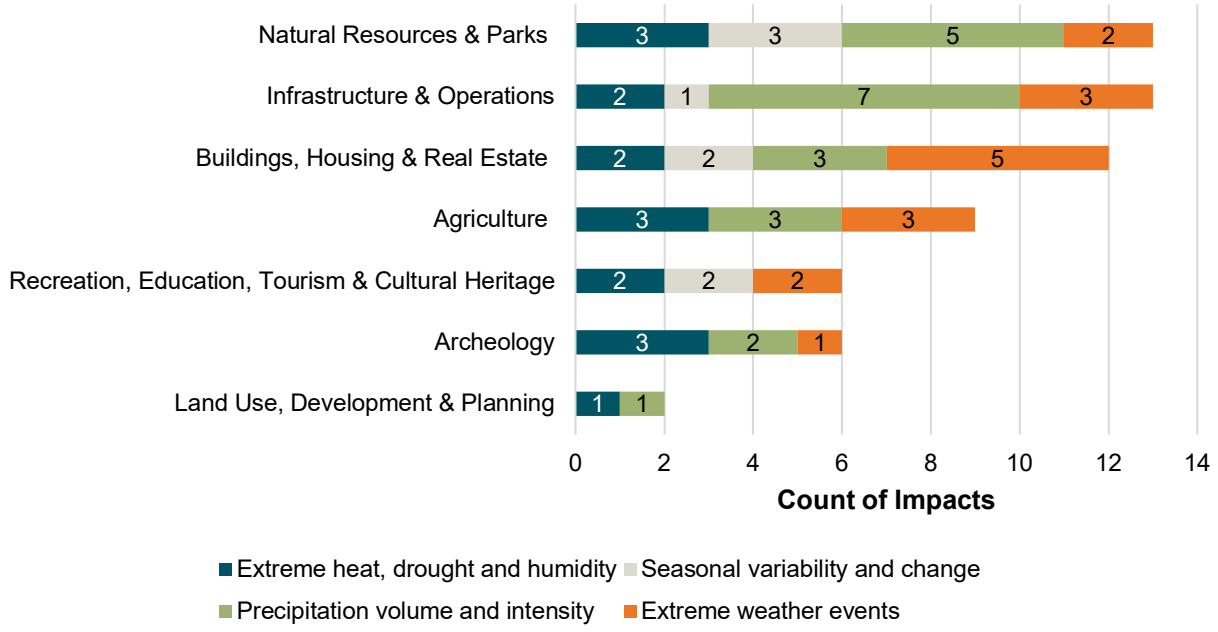

Figure 12. Summary of the 61 Impacts Requiring Immediate Action by Climate Hazard for NCC Sectors.

4.2 Priority Impacts by NCC Sector

The CVRA methodology evaluated risks for all future periods (Baseline, 2021-2050, 2041-2070 and 2071-2100) and took an average of the 2021-2100 period to inform the prioritization process. Where there were duplicate or similar impact statements due to different NCC sectors evaluating the same impacts, the highest risk rating was applied.

As previously noted, 61 priority impacts (i.e., those requiring immediate action) were identified.

Other than the Corporate Services sector, these 61 priority impacts are showing up in all NCC sectors with Natural Resources & Parks, Infrastructure & Operations and Buildings, Housing & Real-Estate accounting for two-thirds of the risks (21%, 21% and 20% respectively - Figure 13).

The risk profiles for each of the NCC sectors are presented in Figure 14 below. The Archaeology and Agriculture sectors have the greatest proportion of their sector-specific impacts requiring immediate action (86% each) followed by the Buildings, Housing & Real Estate sector (80%), Natural Resources & Parks sector (57%), and the Infrastructure & Operations sector (48%). Based on the risk profiles, these five NCC sectors have the most significant risks. The Corporate Services sector was found to have the fewest impacts requiring immediate action.

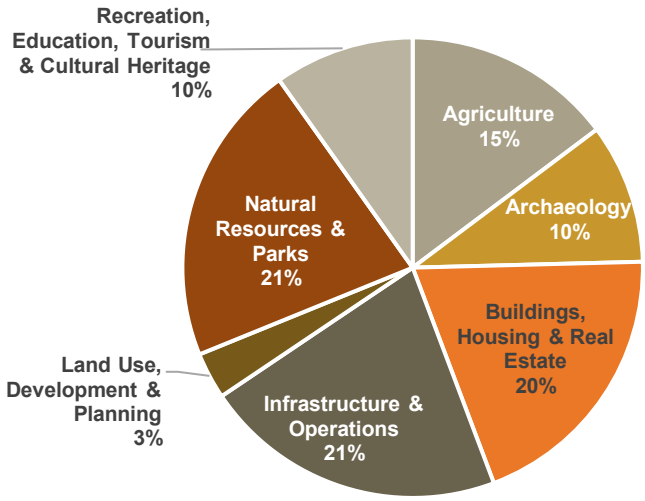

Figure 13. Percentage of 61 Impacts Requiring Immediate Action by Sector

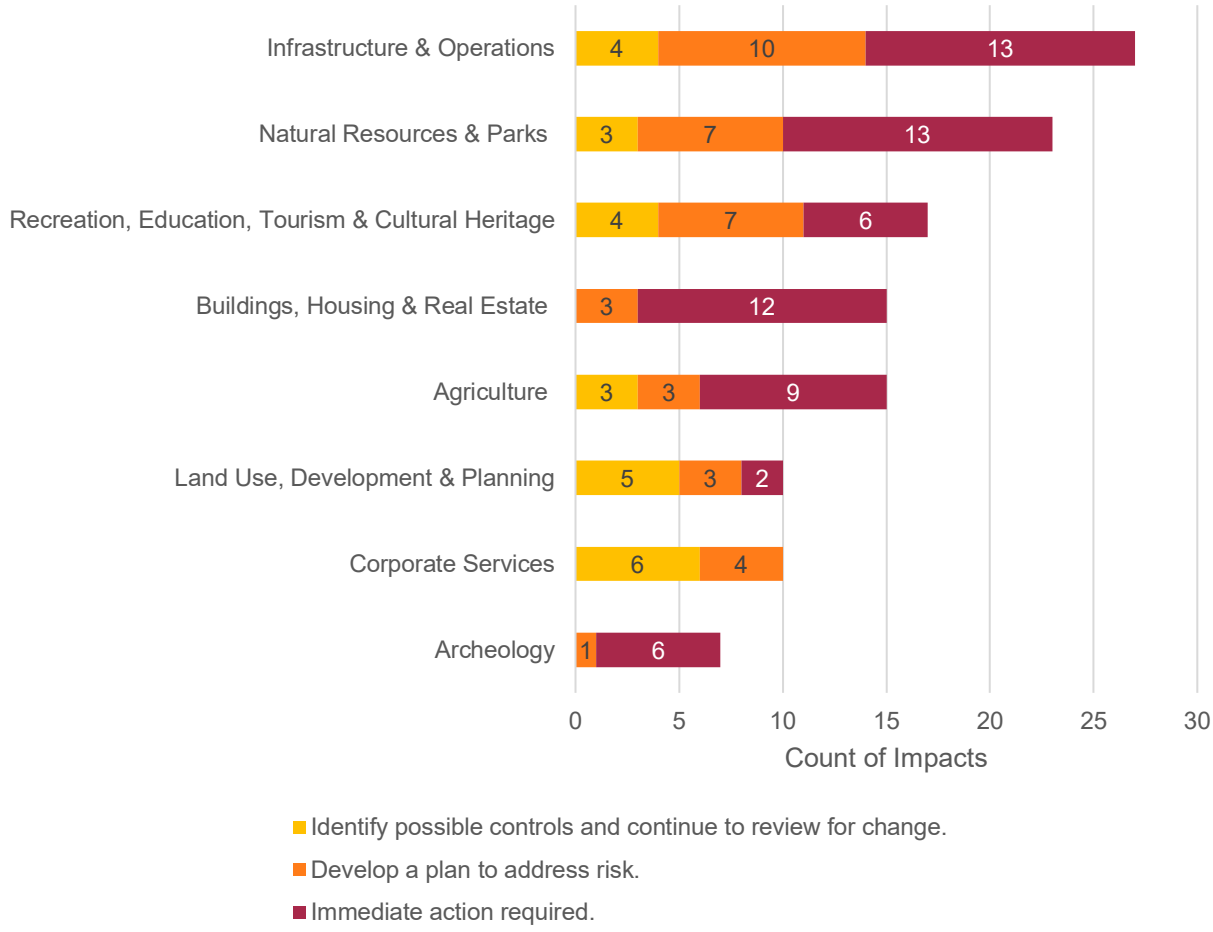

Figure 14. NCC Sector Risk Profile.

The following sections examine these priority risks by NCC sector.

4.2.1 Infrastructure & Operations

Of the 27 impact statements considered for the Infrastructure & Operations sector, 13 require immediate attention based on the vulnerability and risk assessment, 10 require a plan to be developed to mitigate the risk over time, and 4 are noted for monitoring. The priority impacts are presented in Table 1 by climate hazard. The full list of medium-to-high risks for this sector can be found in Appendix B.

Table 1. Infrastructure & Operations Impacts Requiring Immediate Action

Climate Hazard	Impacts
Extreme Heat, Drought and Humidity	• Delay of regularly scheduled maintenance programs, procedures and construction windows. • Algae blooms in water systems resulting in reduced water quality and impact NCC programs (e.g., Lake Philippe campground, Rideau Canal).
Seasonal Variability and Change	• Slippery roads and trails, resulting in reduced park/facility access, increased risks to users and increased maintenance activity (snow clearing, etc.) • Damaged vegetation and increased slope stability issues in susceptible areas, resulting in public safety issues and temporary/permanent closures of park areas. • Damaged communication systems and electricity grids, impacting infrastructure monitoring and backup systems.
Precipitation Volume and Intensity	• Wash-out of pathways, boardwalks, staircases, and roads, resulting in temporary/permanent closures of transportation systems, and more frequent repairs and renewals • Overtopping of damns and weirs resulting in damage to assets, uncontrolled downstream flows, and more frequent repairs and renewals. • Shoreline erosion, damage to assets (e.g., bridges, dams), reduced asset lifespan, and more frequent repairs and renewals. • Scouring, erosion, side-slope failure, and foundation settlement of bridges, resulting in temporary/permanent closures of transportation systems and more frequent repairs and renewals. • Flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up). Refer to the section on geographic risk. • Damaged stormwater infrastructure (e.g., increased sediment and material transport leading to blockages and clogging of conveyance systems) and culverts, resulting in reduced run-off capture, localized flooding, and more frequent repairs and renewals.
Extreme Weather Events	• Reduced capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).

The NCC manages over 11% of the lands in the NCR (537 km^2) and has custodial responsibilities that extend to a large and diverse portfolio of built and natural assets worth an estimated $2.2 billion[20]. This includes managing and maintaining assets such as roads, bridges, pathways, parkways as well as above and below-ground infrastructure (stormwater, water, wastewater systems), communication towers, etc. Beyond typical vulnerabilities due to age, condition, and design, the NCC's infrastructure systems are notably vulnerable to the effects of a changing climate because of the deferred maintenance cycle the organization is locked into, the associated resource challenges, and the fact that the organization is still working to fix the damage from prior flooding events.

In terms of impacts, hotter summers and droughts are already accelerating the degradation of infrastructure like asphalt roads (e.g., softening and rutting), causing heat-related damage to steel structures (e.g., bridges and rail systems), increasing the frequency and extent of algae blooms in water systems, and contributing to the increased spread of invasives. Many of the impacts have cascading impacts on operations, costs and users. For instance, algae blooms in the canal have impacted RCS operations by reducing ice surface quality and have resulted in the jamming of water pumps. While the NCC has been adapting to these heat-related impacts – such as using a rubber-based sealant on roads – the extent of the damage and repairs will increase exponentially, as will complaints. For instance, during the workshops, staff noted that the projected number of heat days would reduce road lifespans by half and require the NCC to explore the use of more resilient materials, which tend to have a higher cost. Increased infrastructure maintenance and repair with limited resources will mean increased delays all of which will impact users.

There is the potential during heatwaves for stormwater management facilities to lose significant volumes of retained water which could result in pond vegetation dying off resulting in debris movement during the next precipitation event, clogging the downstream conveyance system and resulting in localized flooding. Hotter summers and droughts also increase the probability that wildfires will occur in the NCR which can have devastating impacts on all aspects of infrastructure.

Winter freeze-thaw events are particularly damaging to roads and sidewalks (e.g., thermal cracking, frost heave, potholes, and rutting), and shallowly buried infrastructure (e.g., ice dams). These impacts can result in health and safety hazards, localized flooding and property damage. With many of the NCC's pathways already in a poor condition, an increase in the frequency of winter freeze-thaw events will likely result in an increased number of complaints, slip, trip and fall-related liabilities, and could impact programming (e.g., Weekend Bikedays program).

During the workshops, NCC staff noted that intense and long-duration precipitation events are the most damaging and costly kind of climate-related event to at-risk infrastructure systems. For example, the 2017 floods were significant and resulted in extensive shoreline erosion, damaged segments of the Ottawa River Pathway and the Voyageurs Pathway, and damaged underground infrastructure, which resulted in extended park closures, and detours. The 2019 floods impacted many of the same NCC assets and infrastructure (e.g., Portage Bridge). Both floods cost tens of millions of dollars to repair. The impacts from these historical events demonstrate the NCC's vulnerability to extreme precipitation events and offer insight into the potential near- and long-term

[20] https://ncc-website-2.s3.amazonaws.com/documents/natural_capital_economic_value_ncc_green_network_final_dec_1_web.pdf

consequences like cascading infrastructure failures and the increasing costs associated with reactively addressing the impacts of climate change.

As presented via the maps in Section 4.3 Geographic Risks, many of the NCC's assets are located within the 100- and 350-year flood plain and thus during such an event could be stranded and/or significantly damaged. Bridges and shorelines are at the greatest risk due to the constant exposure and interaction (i.e., scouring, erosion, foundation settlement, etc.) with running water and waves as well as debris that is washed into the watercourse. Precipitation events also increase ground infiltration which can result in an increase in road damage (e.g., sinkholes) and place stress on bridge joins. During the workshops, staff noted that some pedestrian bridges are at risk due to not being properly anchored (or at all) and older bridges are now undersized for future water levels.

Similar to bridges, staff also noted that many culverts are at the edge of failure and failures are anticipated with large rainfall, and are undersized for future precipitation conditions. It was also noted that some dam and weir structures are old and outdated and at higher risk of failure due to weaknesses that may exist in the dam/weir design or construction. These weaknesses are due to a combination of increased erosion, more extreme fluctuations in water levels, changes in vegetation and prolonged drying during hot weather, and most importantly, increased upstream development which increases the volume of stormwater.

These impacts on transportation and stormwater infrastructure can have cascading impacts in terms of localized and downstream flooding, closure of transportation systems and parks, and result in health and safety issues. For instance, the Lac Philippe campground experienced heavy rainfall on June 24th, 2011. As a result, the wastewater treatment lagoons accumulated too much stormwater and could not hold additional sewage. The campground was then closed to prevent overflow of the wastewater system and campers were evacuated. The Lac Phillipe wastewater lagoons are noted to be quite sensitive to intense rainfalls (but not from stream overflows) as they already receive stormwater and thus there is a risk that the lagoons can overflow.

In terms of precipitation, a key vulnerability brought forward by NCC staff was that the NCC does not have a good handle on how the water balance in each of the sub-watersheds is expected to change with climate change and upstream development. Another key vulnerability is that the NCC's asset condition assessments do not factor in the possible effects of climate change when considering the future condition and lifespan of the asset. Therefore, assets may be perceived to have a longer lifespan than what may realistically be the case.

Extreme weather events like freezing rain, ice storms and wind are expected to be the most damaging and disruptive to this sector due to the nature of the impacts. These events place a great strain on the operational capacity to clean up debris or material, remove trees, place sand/gravel, and repair damaged infrastructure.

The NCC is also subject to external vulnerabilities outside of its control. In particular, the NCC is exposed to vulnerabilities in the electrical and communication systems, as well as upstream development. For example, between 10% and 25% of power outages are typically due to transmission system interruptions from high wind events, wildfires, ice storms, invasive species, and lightning.

4.2.2 Natural Resources & Parks

Of the 26 impact statements considered for the Natural Resource & Parks sector, 13 require immediate action based on the vulnerability and risk assessment, 7 require a plan to be developed to mitigate the risk over time, and 3 are noted for monitoring. The impacts requiring immediate action are presented in Table 2 by climate hazard. The full list of impacts for this sector can be found in Appendix B. It should be noted that many of these priority impacts are shared with the Recreation, Education, Tourism & Cultural Heritage Sector (discussed in the next section).

Table 2. Natural Resource & Parks Impacts Requiring Immediate Action

Climate Hazard	Impacts
Extreme Heat, Drought and Humidity	• Reduced aquifer recharge, which may result in lower baseflow to streams and degraded aquatic habitat. • Extended park seasons, increased park use, and increased operational demands. • Increased public demand for shaded areas especially on surfaces that exacerbate the urban heat island effect. • Park and recreation programming delays, modification to outdoor activities/events, and lost revenues.
Seasonal Variability and Change	• Intensification of existing disease vectors, and the migration of new disease vectors and illnesses resulting in health and safety risks to park users and NCC staff. • Shortened winter/outdoor park season requiring changes to programming and facilities and increased capital/maintenance costs. • Increased road salt use and could accelerate the susceptibility/mortality of heritage landscapes and damage to aquatic ecosystems
Precipitation Volume and Intensity	• Overland flooding resulting in the temporary/permanent closure of trails and park lands, and increased maintenance activity (repairing/replacing infrastructure and clean-up). • Nutrient loading of aquatic ecosystems (soil erosion and run-off). • Shoreline erosion and landslides in inhabited or built-up areas resulting in temporary/permanent closures, and increased maintenance activity (repairing/replacing infrastructure and clean-up). • Exposure or destabilization of contaminated park lands resulting in regulatory and financial liabilities for the NCC
Extreme Weather Events	• Reduced capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).

As noted previously, the NCC manages over 11% of the lands in the NCR (537 km^2) and has custodial responsibilities that include managing, conserving, and protecting 39,600 ha of forested lands and 2,500 ha of wetlands and 23 urban parks.

In terms of impacts on natural resources and parks, extreme heat days and droughts will place additional stress on already stressed terrestrial and aquatic ecosystems resulting 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 ecosystems are at a greater risk of wildfires which can have a direct impact on the region (i.e., destruction of assets, 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 vulnerable populations. While 74% of NCC-managed lands are covered with trees, the urban forest is very susceptible to persistent drought-like conditions, winter freeze-thaw events, road salt, intensive recreational use, and invasive species. NCC staff noted that Gatineau Park's large population of conifer trees has a heightened risk of wildfires (human or natural caused). An issue related to this is that the NCC has not yet updated its tree and vegetation species planting list (a commitment under its Forest Strategy) and thus many of the trees being planted may not be capable of adapting to the projected changes in temperatures and precipitation.

With the NCC's recent commitment to plant 100,000 trees, additional resources will be required to maintain this existing resource in a functional state. Even more resources will need to be allocated for the planting and management of additional trees because of the effects of climate change. Using GIS data to map the urban island heat effect and existing forest cover can identify potentially hot areas where tree planting activities could be focused (Figure 15[21]).

[21] The maps shows that 74% of NCC-managed lands are covered with trees resulting in only small pockets of non-building areas being exposed to areas where there is a Land Surface Temperature (LST) greater than 30°C. Nevertheless, these small areas should be planted if possible.

Figure No.

15

Title

Tree Canopy and Urban Heat above 30°C

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 2,800 5,600 metres

(At original document size of 11x17)
1:148,400

- Urban Heat > 30°C
- Tree Canopy Cover (Only those that overlap with Heat > 30°C)

PORTFOLIO

- Gatineau Park
- Greenbelt
- Official Residences
- Ontario Urban Lands
- Quebec Urban Lands

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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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 programs. For instance, increases in year-round temperatures over time are expected to increase the potential for vector-borne disease transmission, the intensification of existing invasive and noxious species (e.g., Emerald Ash Borer, Wild parsnip, poison ivy) and the migration of new invasive species increasing human health and safety risks (e.g., West-Nile, Lyme Disease, etc.), the permanent alteration of natural habitats, loss of at-risk species due to the loss of habitat and shifts in the seasonality for wildlife and habitat functioning.

There is already an increasing trend of reported wildlife encounters with domestic pets and humans involving bite injuries and rabies assessments – these are expected to increase as seasons change, ecosystems shift in ecology, and animal food sources migrate or change. In terms of ecosystem and park management, these impacts are expected to result in substantial resource demands as new invasives emerge, existing plant and animal species become more invasive (e.g., possums, beavers, etc.) and it takes more effort to maintain existing and establish additional tree canopy and parks (e.g., increased grass mowing to minimize tick populations). Loss or significant changes to ecosystems can also have significant social, spiritual and health impacts on the community - e.g., loss of tree species for cultural practices (e.g., birchbark) and could require the provision of 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.) (Figure 16).

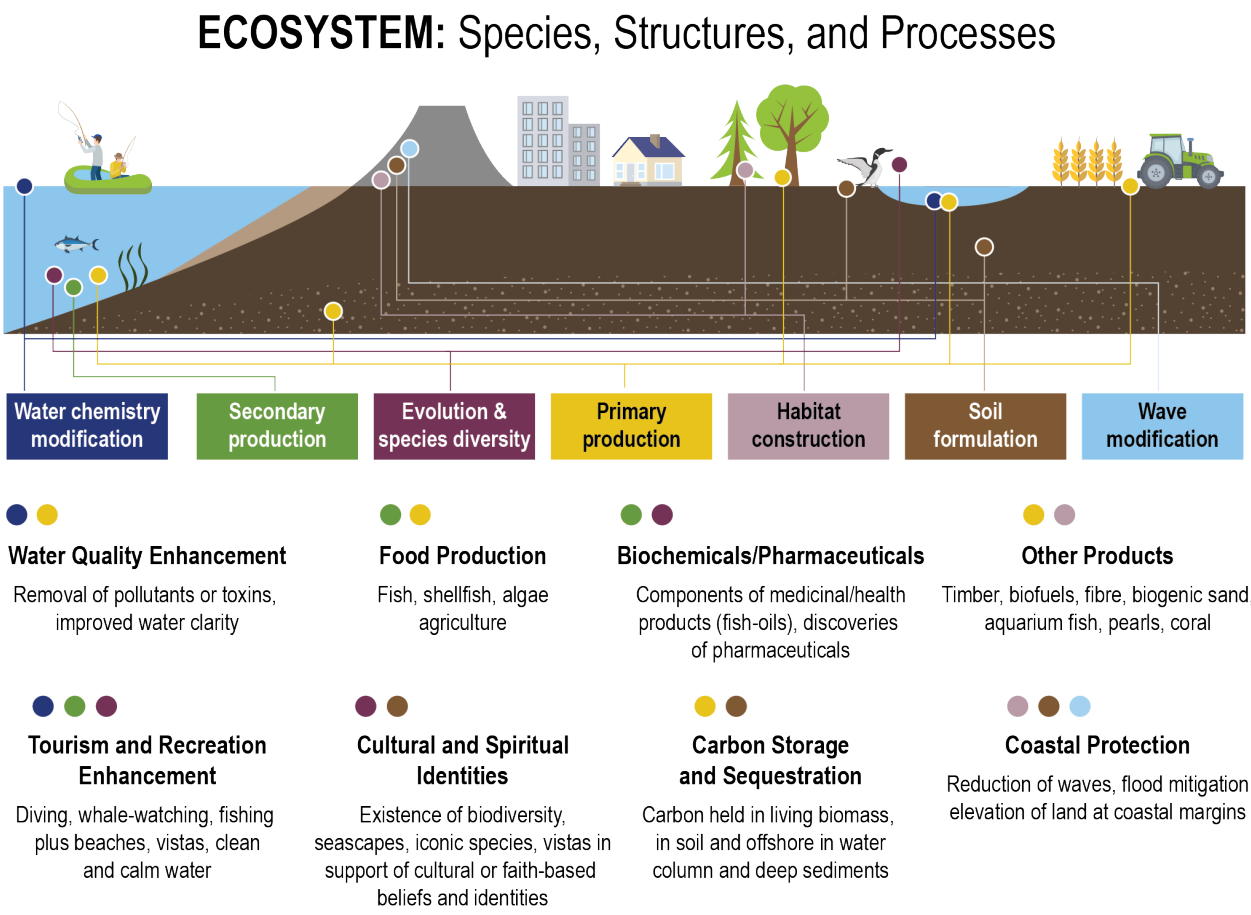

Figure 16. Overview of Ecosystem Goods and Services[22]

Seasonal variability will increase the erratic occurrences of later spring and early fall frosts which can result in disruption to soils, and significant damage to understory vegetation and trees. These impacts can increase the ecosystems' vulnerability to invasive species and high precipitation events. Shorelines with sensitive marine clay are expected to be at the greatest risk (i.e., hotter and drier in the summer and then saturation in other seasons resulting in destabilization). Similarly, very moist-to-wet forest communities and their component tree species in floodplains and around wetlands and water bodies may be vulnerable to stress when summer soil moisture levels fall below their threshold of tolerance. These same forest stands may also be vulnerable to tree mortality from increased flooding within increased precipitation in the fall and winter.

Winter freeze-thaw events are expected to result in the increased use of road salt which has a detrimental impact on vegetation and trees exposed to it. Road salt has a huge impact on the likelihood that urban trees can reach maturity, and chloride levels can be toxic to aquatic species and exceed water quality thresholds. Trees along Confederation Boulevard were noted to be at significant risk from road salt impacts. Road salt impacts are also noticeable in existing shallow wells

[22] https://oceanwealth.org/ecosystem-services/

(and some deep wells) in hydrogeological sensitive environments (i.e., thin soil over bedrock, karstic aquifer, highly permeable aquifers). It is not clear if this is an issue for NCC lands/tenants.

Precipitation patterns can significantly damage shorelines, waterways and streams and result in riverine flooding – this is typically due to stormwater discharge volumes into the receiving environment. For example, increased stormwater runoff (volume and speed) can result in an extreme variation in water level and flow, making the stream vulnerable to erosion and pollutants (i.e., sediment and road salt/pollutants in winter vs fertilizers, animal wastes, garbage in the summer, etc.). Increased upstream development will worsen this condition/risk. During the workshops, NCC staff noted that there are gaps in terms of the management of creeks and ravines and this gap would need to be addressed to understand the impacts that climate change could have on the watershed.

In terms of interactions, the mapping assessment showed that the following high-to-exceptionally high value natural ecosystems and habitats are located within the 100-year floodplain, and most are situated in the 350-year floodplain (those within both the 100- and 350-year flood plain are denoted with an *):

- Shirleys Bay*
- Mer Bleue Bog
- Green's Creek*
- Black Rapids Creek*
- Leamy Lake
- Mud Lake*
- Champlain Bridge and Lemieux Islands*
- Rockcliffe Park*
- Airbase Woods*
- Rideau River, Hog's Back*
- McCarthy Woods*

This interaction is presented in Figure 17 and Figure 18[23].

[23] This map is for Ontario only as Quebec does not have maps for the 350-year floodplain publicly available.

Figure No.

17

Title

High Value Natural Ecosystems and Habitats in the 100-Year Floodplain

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 1,100 2,200 metres

(At original document size of 11x17)
1:63,000

100 year Floodplain (ON) / Ville de Gatineau Flood Plain

NCC Lands

Valued Habitat

- Exceptional
- Very High
- High

Valued Ecosystem

- Exceptional
- Very High
- High
- Unknown

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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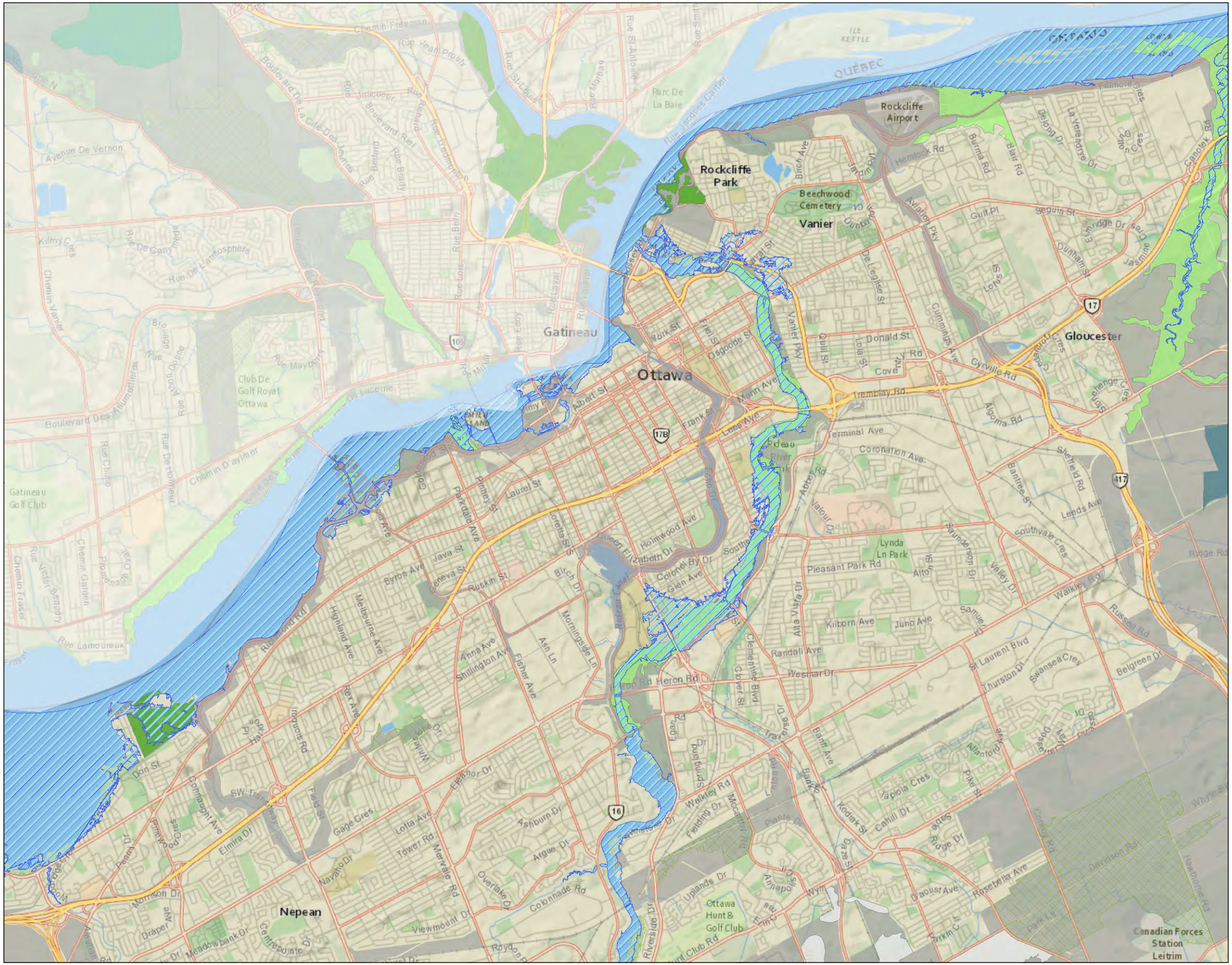

Figure No.

18

Title

Valued Ecosystems and Habitats - Flooding (350 year Floodplain)

Client/Project 123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 1,200 2,400 metres

(At original document size of 11x17)
1:63,000

- 350 year Floodplain (Ontario Only)
- NCC Lands

Valued Habitat

- Exceptional
- Very High
- High

Valued Ecosystem

- Exceptional
- Very High
- High
- Unknown

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Stantec

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Without an evaluation of each ecosystem's functional condition, it is not possible to estimate the extent to which these ecosystems could respond to and recover from extreme precipitation events. Given the reported concern around shoreline erosion by NCC staff and the proximity of the high-value natural ecosystems and habitats, it is highly probable that these valuable ecosystems will be damaged from such an extreme event and remain exposed to invasives and other factors. Ultimately, without some form of active management before and after a flood event, there is a high risk that the functionality and value of the ecosystems will be reduced.

Extreme events, like ice storms, freezing rain and extreme winds can result in significant damage to forests, however, the impacts tend to be more severe in urban areas.

4.2.3 Recreation, Education, Tourism & Cultural Heritage

Of the 14 impact statements considered for the Recreation, Education, Tourism & Cultural Heritage sector, 6 require immediate action based on the vulnerability and risk assessment, 7 require a plan to be developed to mitigate the risk over time, and 1 is noted for monitoring. The impacts requiring immediate action are presented in Table 3 by climate hazard. The full list of impacts for this sector can be found in Appendix B.

Table 3. Recreation, Education, Tourism & Cultural Heritage Impacts Requiring Immediate Action

Climate Hazard	Impacts
Extreme Heat, Drought and Humidity	• Reduced water quality at beaches and natural outdoor swimming areas can result in health and safety risks to users. • Park and recreation programming delays, modification to outdoor activities/events, and lost revenues.
Seasonal Variability and Change	• Intensification of existing invasive species and diseases, the migration of new invasive species, and the alteration of natural habitats. • Shortened winter/outdoor park season requiring changes to programming and facilities (e.g., Rideau Canal Skateway, cross country skiing, etc.) and increased capital/maintenance costs.
Extreme Weather Events	• Damage to and irreplaceable loss of the Crown Collection resulting in a loss of culturally and historically significant assets. • Reduced capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding). • Reduced staff morale, increased turnover, and a loss of organizational knowledge.

The NCC provides recreational opportunities to residents and over 10 million users that visit the region annually. This includes offering programs and events including cross-country skiing and snowshoeing, ice skating on the RCS, swimming at Gatineau Park beaches and Leamy Lake, camping, hiking, trail running and mountain biking in Gatineau Park and the Greenbelt, walking or biking on urban multi-use pathways, a winter carnival for newcomers to the Capital to discover the joys of winter, Weekend Bikedays, the Tulip Festival, Fall Rhapsody, and archaeological digs, amongst many others.

In terms of impacts on recreation, extreme heat days and droughts will place additional pressure on already stressed terrestrial and aquatic ecosystems which are expected to result in the expansion of invasive species, pests and vector-borne diseases and algae blooms. Recreational beaches and lakes, such as Lac Phillipe, are at risk of blue-green algae blooms which can result in closures due to health and safety concerns thus resulting in increased use/pressure on other beaches (i.e., overcrowding), reduced or cancelled recreational activities, boating and fishing activities (i.e., kills small fish and hazards for eating fish). Hotter and drier summers are also expected to result in increased demand for the provision of additional cooling areas (shade structures, trees to provide shade in open areas), pressure on the NCC to improve water quality and water fountain availability, increased demand for docks and water access, and increased staffing requirements. Extreme heat events can result in park and recreation programming delays, modification to outdoor activities/events and lost revenues to the NCC.

Warmer winters, while welcomed by many, are already impacting and shortening the cross-country skiing and snowshoeing season in Gatineau Park and the Greenbelt, and on urban ski trails as well as the skating season on the RCS. While the average number of frost-free days will be longer, there are likely to be more erratic occurrences of later spring and early fall frosts which can result in significant damage to vegetation and vegetation-based programs like the Tulip Festival and Fall Rhapsody. In response, NCC staff have already been adapting programming. For example, NCC staff have adjusted the types of tulips being planted to accommodate the changes in spring seasonal characteristics. Those in charge of the ski trails have been utilizing machinery to maintain ski tracks on a very shallow snow cover on winter trails in Gatineau Park.

The trend of warming and shorter winters will also harm RCS operations in that warmer winters can result in warm and salt-infused stormwater being sent to the Rideau Canal via storm water outflows. This is an issue as the water tends to have high concentrations of calcium which lowers the freezing point and results in ice integrity issues. As noted previously, warmer winters and lengthening spring and fall seasons are expected to reduce the number of skating days significantly by 2071-2100. NCC staff have been beginning to adjust operational practices to increase ice thickness and quality after the formation of the initial ice cover. However, continuing to maintain and adapt these programs as the winter season shortens will place increased pressure on operation and maintenance programs, staff, and budgets, which are already constrained.

NCC staff expect that there will be increased demands for washroom availability and usage, increased programming and amenities, increased operational demands to keep parks groomed and repaired (more users going off of official trails), and increased effort to maintain the RCS (more maintenance, materials, and energy), all of which will divert funds away from maintaining assets and will constrain operational budgets. An extended and shifting recreation season may make it increasingly difficult for the NCC to recruit staff as many summer staff are students.

An increased number of freeze-thaw events will impact pathways and roads in terms of damage and the creation of icy surfaces. This will increase the risks to the health and safety of active transportation users, the use of road salt, and in more extreme cases, temporary closure of pathways and roads. As noted previously, the increased use of road salt has a detrimental impact on vegetation and trees exposed to it. Road salt is also extremely damaging to mortar-based assets, like stone walls and buildings, near roads (e.g., Maple Lawn Gardens). The increased use of salts during these events to reduce health and safety risks will also increase the maintenance costs

(requires the use of specialist contractors) and increase the already large number of public complaints related to NCC's management of heritage assets.

As noted during the review of other sectors, riverine flooding in 2017 and 2019 has significantly impacted the operation of parks, resulting in temporary closures. The NCC must soon weigh these costs and public benefits as the risks of flooding increase over time.

Extreme events can result in significant damage to NCC assets, topple structures (e.g., monuments), and result in significant disruption to operations and daily life. Strong winds or gusts, freezing rain and heavy snow can damage and bring trees down and damage private property, disrupt power and communication systems, and in more extreme cases, cause injury and loss of life. Wind and water erosion is having an extremely damaging impact on outdoor monuments, public art and heritage structures.

4.2.4 Buildings, Housing & Real Estate

Of the 15 impact statements considered for the Buildings, Housing and Real-Estate sector, 12 require immediate action based on the vulnerability and risk assessment, and 3 require a plan to be developed to mitigate the risk over time. The priority impacts are presented in Table 4 by climate hazard. The full list of medium-to-high risks for this sector can be found in Appendix B.

Table 4. Buildings, Housing & Real-Estate Impacts Requiring Immediate Action

Climate Hazard	Impacts
Extreme Heat, Drought and Humidity	• Increased cooling demands, requirements to improve building performance, and increased capital costs to the NCC.
Seasonal Variability and Change	• Increased damage to buildings, reduced asset life expectancy, and more frequent repairs and renewals to buildings. • Increased operational demands to accommodate mechanical systems to the varying temperatures.
Precipitation Volume and Intensity	• Flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up). • Increased water ingress and damage, compromised building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up). • Increased basement flooding damage and mould-related illnesses to NCC tenants and staff, if not addressed.
Extreme Weather Events	• Damage to building roofs (ice and snow load), compromised building integrity, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up). • Reduced capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding). • Increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change. • Supply chain instability and/or market failures impacting the availability of fuels and other goods required to maintain operations. • Increased health and risks to NCC contractors and staff.

The NCC manages approximately 1,600 properties in its real estate portfolio in the NCR. This includes approximately 560 properties leased in Ottawa - Gatineau for residential, agricultural, institutional, recreational and commercial purposes. Similar to many buildings in Ontario and Quebec that need to function in an extreme range of temperatures, the NCC's buildings are at the greatest risk from extreme heat, seasonal change (winter freeze-thaw), precipitation and extreme events.

In terms of impacts, extreme heat can result in damaged or compromised buildings (e.g., mechanical systems not being able to keep buildings cool, or buildings without A/C), increased cooling demands on buildings and reduced indoor air quality, especially in older buildings. This can result in significant health and safety issues for the individuals that occupy the buildings – especially in cases where buildings do not have adequate insulation or air conditioning systems which is often the case for heritage buildings. Humidity is already a major issue of concern for heritage buildings and those without mechanical systems that house Crown Collection items. Many of the systems within these buildings are struggling to maintain the necessary conditions to preserve Crown Collection items (the ~4,000 pieces of fine and decorative art used to furnish and adorn the interiors of Canada's official residences). Wood and paper-based items are most vulnerable to temperature and humidity. While NCC staff in charge of the Crown Collection are actively managing the collection to avoid heat and humidity damage (e.g., not putting items in areas without air conditioning, ensuring that there are screens on windows, etc.), this task is likely to get increasingly difficult unless more work is done to upgrade at-risk heritage assets. While the most direct response is to upgrade the building envelopes, materials and mechanical systems to be more resilient to these effects and reduce energy consumption and GHG emissions, many of the at-risk buildings are heritage or have heritage elements. These buildings need to be assessed on a case-by-case basis to identify what alterations are appropriate and compatible with a building's heritage characteristics and their importance to the NCC. As noted by NCC staff, in many cases, the NCC will need to decide which competing priorities matter more – i.e., heritage protection vs resiliency vs GHG emission reductions.

Seasonal variability is expected to increase the number of winter freeze-thaw events which can result in foundational damage, premature deterioration of concrete, damage to porous and masonry materials, damage to roofs due to ice dams (due to poor thermal insulation), moisture damage (due to poor moisture barriers), the freezing and breaking of pipes (due to poor thermal insulation) and result in hazards to building occupants (ice overhangs on copper and cedar roofs). According to NCC staff, at least 50-60% of heritage buildings are composed of heritage masonry which means increased repair, maintenance and upkeep costs as the number of winter freeze-thaw events increase. Seasonal variability can also be hard on typical building mechanical systems and a challenge for building managers. For instance, the Sussex st buildings are run on steam (boiler and ground source system) and as a result, there are only two options for temperature management which results in staff bringing in personal space heaters and portable air conditioners. This issue can result in circuits being overloaded, other electrical issues, and increases in operational GHG emissions. The buildings that are most vulnerable to extreme heat and seasonal change tend to be heritage assets due to the lack of insulation, materials used, and construction practices.

Lastly, extreme events like windstorms can result in power and communication outages, damage to the building envelope and mechanical systems and result in health and safety issues.

While the vulnerability of buildings to these climate hazards is affected by several factors, the main factors that influence their vulnerability include age, composition, design and condition. As many of

the assets within NCC's building portfolio are heritage buildings, there is already an inherent vulnerability to many of the noted climate hazards, but these are further exacerbated by the following organizational vulnerabilities:

- A static budget to plan, manage and maintain federal lands and assets. This has resulted in widespread critical asset deterioration forcing NCC asset managers to defer maintenance of assets, until critical thresholds are met, or there is an influx of capital. It has also resulted in the discarding of resilience measures to save costs without consideration for the cascading effects to project operations in a changing climate.
- There are no processes to assess, manage or report on climate risks and how they change in the asset management and corporate risk systems.
- While the NCC's asset managers tend to be very adept at what they do, considering the resources available to them, the asset management system is limited and not as functional as needed (e.g., it is not connected to asset condition assessments and is more often used to deposit documentation).
- In terms of the development of new projects (new construction or renovation), there is limited integration between the environmental teams and the Process for Project Management and the asset management system, which has, at times, resulted in climate change hazards not being factored into decision making.
- A lack of organizational knowledge on the effects and hazards of climate change to NCC assets has likely contributed to the construction, maintenance and rehabilitation of assets that are not resilient to the effects of climate change, and the rebuilding of assets and infrastructure in high-risk areas.

4.2.5 Agriculture

Of the 15 impact statements considered for the Agricultural Sector, 9 require immediate attention based on the vulnerability and risk assessment, 3 require a plan to be developed to mitigate the risk over time, and 3 require monitoring. The priority impacts are presented in Table 5 by climate hazard. The full list of impacts for this sector can be found in Appendix B.

Table 5. Agriculture Priority Impacts

Climate Hazard	Priority Impacts
Extreme Heat, Drought and Humidity	• Increased cooling demands, requirements to improve building performance, and increased capital costs to the NCC. • Increased potable water demands by agricultural tenants on wells (particularly east end) and increased costs to the NCC. • Increased occurrence of algal blooms that can reduce the availability of water safe for growing food and agricultural operations. • More volatile growing conditions.
Precipitation Volume and Intensity	• Saturation or flooding of agricultural lands, reduced production and lost effectiveness of fertilizer and soil improvements. • Nutrient loading of nearby aquatic ecosystems, increased buffer requirements, reduced lands available for agriculture, and a lost revenue source to the NCC. • Flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).

Climate Hazard	Priority Impacts
Extreme Weather Events	• Damage to agricultural buildings (snow load), compromised building integrity, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up). • Increased health and safety risk to agricultural workers. • Reduced capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts.

Extreme heat, drought, precipitation, and extreme weather events are the greatest climate hazards to the agricultural sector. Those most vulnerable to these hazards are farmers operating with losses or low margins, farmers who do not have robust equipment, and those who do not live beside their operations (and thus cannot respond quickly).

Extreme heat and drought can result in health and safety impacts on residents and workers, increased land management and operational costs (e.g., greater pressure for farmers to invest in adaptive measures and technologies), dry wells, reduced food and agricultural production and increase the risk of insolvency from farms (from increased fluctuations in farming incomes). The increased risk of insolvency from farms can have a cascading impact on the NCC, as it invests capital and inducement funding in agricultural properties. This funding may need to increase as the risks to agricultural operations increase. For example, there are already several properties with dry wells which require the NCC to deliver potable water for consumption (but not irrigation). However, if more wells run dry and/or irrigation source waters decline, there may be a demand for irrigation water as well as having a well as an asset to a farm. Farmers have been installing ponds to support irrigation, but these could be at risk of pathogens due to the stagnation of the water and the depth in light of increasing average temperatures and extreme heat events. It is also worth noting that monocropping is the dominant approach to farming in the Greenbelt and is more heat resilient and less water reliant. However, this activity is not in line with the NCC's objectives of increasing sustainable food cultivation which requires a stable climate, dry fields and access to water.

More frequent or intense precipitation can result in increased soil and nutrient run-off (which increases farming costs), increased demands for the NCC to install tile drain systems (where there are none) and associated costs, and possibly, the loss of arable lands with increased land-buffer requirements. Historically, the NCC has also received calls from concerned community members about agricultural run-off when there are algae blooms nearby. With the increased occurrence of extreme heat days and droughts, there are likely to be more algae blooms (as water levels are lower resulting in higher concentration levels) and more reports by concerned community members.

Extreme events, like heavy snow, blizzards, wind gusts, and freezing rain are also a significant risk to the health and safety of workers and NCC assets (e.g., the collapse of a riding arena due to wind). Agricultural buildings like barns and storage sheds are expected to be at a higher risk of these extreme events as they are less likely to be maintained and may not be built to code (for instance, many sheds are not anchored to the ground). While climate change may create some perceived positive opportunities such as longer seasons for agriculture, the warmer weather, variable seasonality and changing precipitation patterns are expected to negate these benefits, increase the risk of failed crops, and increase the risk that invasives and vector-borne diseases spread. Ultimately, these hazards could result in the underperformance of NCC's strategic objectives as it relates to agriculture.

4.2.6 Land Use, Development & Planning

Of the 10 impact statements considered for the Land Use, Development & Planning sector, 2 require immediate action based on the vulnerability and risk assessment, 3 require a plan to be developed to mitigate the risk over time, and 5 are noted for monitoring. The impacts requiring immediate action are presented in Table 6 by climate hazard. The full list of impacts for this sector can be found in Appendix B.

Table 6. Land Use, Development & Planning Impacts Requiring Immediate Action

Climate Hazard	Impacts
Extreme Heat, Drought and Humidity	• Increased public demand for shaded areas especially on surfaces that exacerbate the urban heat island effect.
Precipitation Volume and Intensity	• Exposure or destabilization of contaminated park lands resulting in regulatory and financial liabilities for the NCC.

The NCC is the main federal urban planner in the NCR. To guide land use and planning the NCC has developed 4 master plans – Gatineau Park, Capital Urban Lands, Greenbelt and the Core Area – each of which guides the long-term planning, use and management of the NCR. Each plan is in effect for approximately 10 years. As these plans are updated, they take into account international best practices for the management of natural environments and infrastructure.

As presented in the other NCC sectors, climate change hazards are likely to impact the NCC's assets, operations and programs in one way or another. As land-use planning takes a longer-term focus, the potential impacts can be planned for and integrated into new land use plans and standards. In terms of risk exposure, the main risks to the sector are related to changes in heat and precipitation.

The projected changes in climate and its cascading impacts will have a direct impact on public health and well-being and should be factored into project design and long-range planning to minimize impacts on vulnerable populations including infants, children, older adults, people who work and exercise outside, people experiencing homelessness, those with existing health conditions, and those without good access to air conditioning. For example, with the increasing number of extreme heat days projected for the next century, the NCC will need to ensure that there is enough space for trees alongside shaded amenities, shade sails or structures, and adequate and functioning water fountains, etc. Likewise, cool roofs and air conditioning can help people stay cool indoors. As the NCR has an aging population, and growing rates of inequality, including housing precarity and homelessness, there will be an ever-increasing number of people impacted by extreme heat and will seek low to no-cost supports to remain safe (e.g., going to, or living in, the park to be in shaded areas). A socio-economic status and heat map is presented in Figure 19 – it shows areas where adaptation measures could be /prioritized as part of NCC planning exercises.

Figure No.

19

Title

Urban Heat above 30°C and Socioeconomic Status

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 2,800 5,600 metres

(At original document size of 11x17)
1:148,400

- Buildings
- Urban Heat > 30°C*
- NCC Lands

Socioeconomic Status (2017)

- 1 - least vulnerable
- 2
- 3
- 4
- 5 - most vulnerable
- No Data Available

*NOTE: Extreme urban heat data is from July 18, 2019. Data source is Environment and Climate Change Canada

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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In addition to extreme heat, other climate impacts will disproportionately impact vulnerable populations including poor air quality from wildfires, water-borne illnesses following extreme heat events, flooding, and vector-borne diseases.

While many of these impacts may seem to be outside of the NCC's realm of responsibility, risks to users must be accounted for and cannot be delegated to other jurisdictions. In addition, the NCC can adapt existing plans and work with stakeholders like the Ville de Gatineau and the City of Ottawa to develop programs and partner on infrastructure projects to reduce the likelihood that these impacts occur.

As noted previously, the NCC manages 537 km^2 of land – some of which is contaminated. As part of the Federal Contaminated Sites Action Plan, the NCC has been cleaning up the highest-priority sites on NCC-managed lands. However, many sites remain and are exposed to extreme precipitation events that can erode soil and dislodge materials into the environment. The GIS mapping exercise shows that many of the contaminated sites are within the 100- and 350-year floodplains and thus are at risk of extreme and long-duration precipitation events. This is presented in Figure 20 and Figure 21[24].

[24] This map is for Ontario only as Quebec does not have maps for the 350-year floodplain publicly available.

Figure No.

20

Title

Contaminated Sites in the 100-year Floodplain

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 1,600 3,200 metres

(At original document size of 11x17)
1:84,412

Contaminated Site Affected By Flood Scenario

Contaminated Site

100 year Floodplain

PORTFOLIO

Gatineau Park

Greenbelt

Official Residences

Ontario Urban Lands

Quebec Urban Lands

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N

2. Data Sources:

3. Background: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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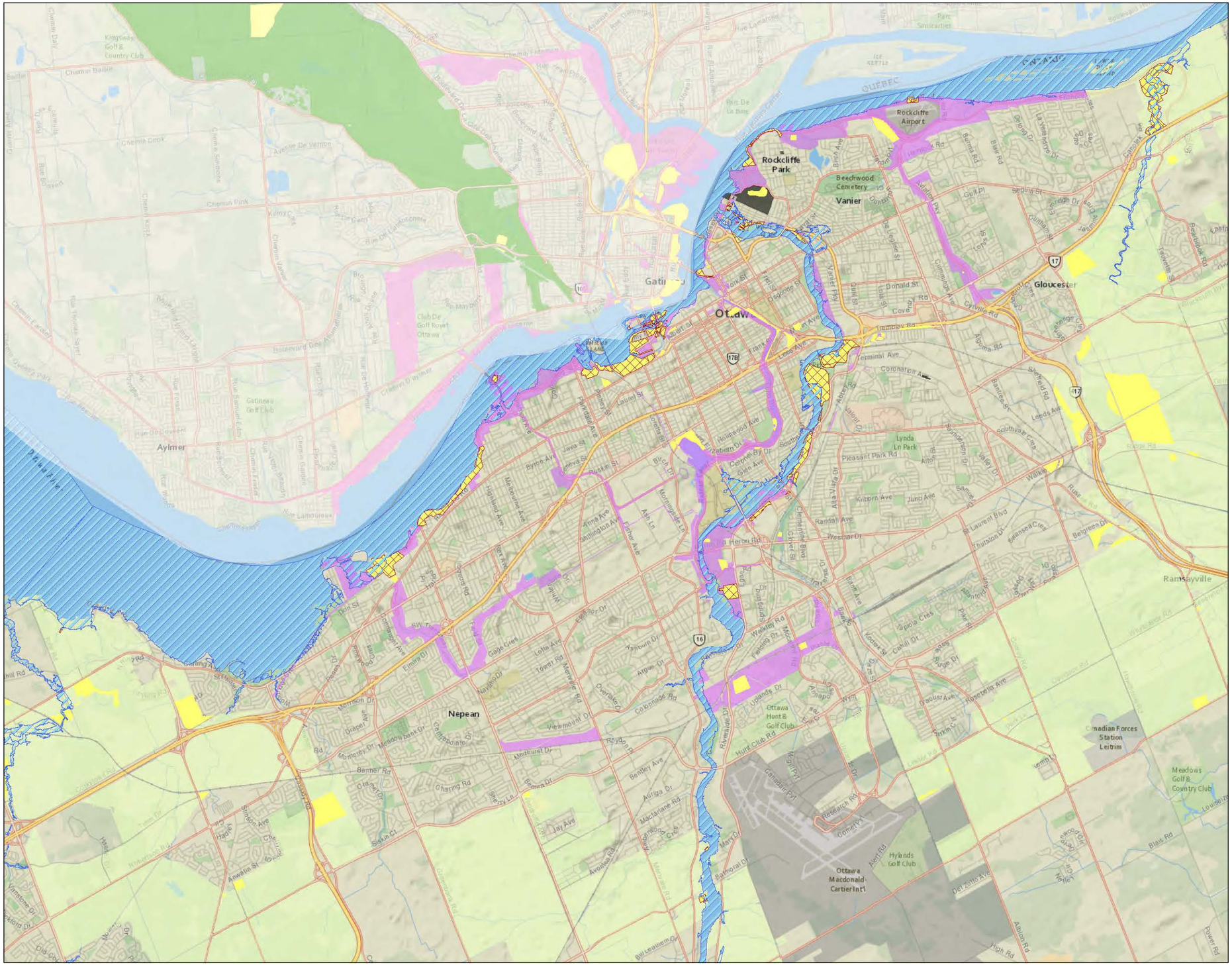

Figure No.

21

Title

Contaminated Sites in the 350-year Floodplain

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 1,600 3,200 metres

(At original document size of 11x17)
1:84,412

- Contaminated Site Affected By Flood Scenario
- Contaminated Site
- 350 year Floodplain (Ontario Only)

PORTFOLIO

- Gatineau Park
- Greenbelt
- Official Residences
- Ontario Urban Lands
- Quebec Urban Lands

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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As a result of flooding, there will likely be increased access restrictions and land access requests which can place increased pressure on the environment. This will have an impact on the coordination between land use groups and will require realigning and applying updated design standards to assets and areas at risk from flooding.

4.2.7 Corporate Services

The Corporate Services sector encompasses the Information Technology (IT), Human Resources (HR), Communications, Finances & Procurement, and Legal departments of the NCC which were deemed to be potentially impacted by climate change. Due to the nature of the Corporate Services sector, it can be directly and indirectly impacted by all of the identified climate hazards; however, none of the impacts were considered an immediate priority which was due to most of the impacts having a medium to low overall vulnerability and low consequence ratings. Of the 10 impact statements identified for this sector, 4 impacts require a plan to be developed to mitigate the risk over time and 6 require ongoing monitoring of the risks. As there were no impacts requiring immediate action, no summary table is provided here. The full list of risks for this sector can be found in Appendix B.

The climate hazards that require a plan to be developed are all related to extreme events and the associated disruptions to staff, infrastructure monitoring, communication (e.g., the 2-way radio system), IT systems, security and emergency backup systems. Considering the nature of the sector, this makes sense as extreme events are the most likely to increase the risks related to NCC and stakeholder health and safety. For instance, during the workshops, it was noted that NCC has been through many extreme weather impacts so there is increased organizational confidence in terms of its ability to respond to future events. It was noted that NCC has a strong organizational culture and willingness to succeed which is contrary to other organizations that suffer from significant resource constraints, isolated management and operational systems and moderate to high turnover like the NCC. Because of the strong culture at the NCC, staff can band together and respond quickly to extreme events.

While the current collective “can-do” culture increases the organizations' ability to respond and adapt when climate events occur, there remains a risk that climate change is already reducing organizational capacity and capability. With a static budget, current processes and procedures, and the probability that more frequent, intense and compound events occur, this ability to respond could erode quickly and the risk may be understated. Equally important is that an increase in extreme weather events can exacerbate underlying systematic vulnerabilities across the NCC which could result in a significant disruption to business continuity and material financial losses/obligations as the NCC has to increase the investment required to maintain existing assets and does not have insurance to cover the cost of damages (except for the vehicle fleet). It should also be noted that risks in other NCC sectors can carry over to the corporate services sector. For example, climate hazards that result in slips, trips and falls on NCC lands can result in related lawsuits and financial liabilities to the NCC.

4.2.8 Archaeology

Of the 7 impact statements considered for the Archaeology sector, 6 require immediate action based on the vulnerability and risk assessment, and 1 requires a plan to be developed to mitigate the risk over time. The impacts requiring immediate action are presented in Table 7 by climate hazard. The full list of impacts for this sector can be found in Appendix B.

Table 7. Archaeology Impacts Requiring Immediate Action

Climate Hazard	Impacts
Extreme Heat	• Increased water-based recreational activity and park use resulting in disruption and damage to archaeological sites (e.g., boat wakes, shoreline gatherings and parties, digging pits and creating mud windbreaks for campfires, displacing logs and rocks for seats, etc.). • Increased risk of heat-related health and safety risks to NCC archaeologists, staff and contractors.
Seasonal Variability and Change	• Increased damage to vegetation (freeze-thaw), adversely impacting clay and silt sediments and increase slope instability in susceptible areas, resulting in damage to archaeological sites.
Precipitation Volume and Intensity	• Accelerated shoreline erosion, damage to archaeological sites and a permanent loss of archaeological resources. • Increased ground heave, and subsidence resulting in damage to archaeological sites.
Extreme Weather Events	• Increased damage to vegetation (ice storms), adversely impacting clay and silt sediments and increase slope instability in susceptible areas, resulting in damage to archaeological sites.

Extreme heat, seasonal variability, precipitation, and extreme weather events are the greatest climate hazards to the Archaeology sector. Of all the hazards, intense precipitation events that result in overland and/or riverine flooding is expected to have the most direct and damaging consequences to the sector as these events can simply erode and wash away archeological sites, and with them, cultural knowledge and heritage. For example, the following maps (Figure 22) present archaeological artifact locations at risk from water level changes along the Ottawa River. These maps show a comparison between low water levels when artifacts are exposed and high-water levels when they are completely submerged. Each findspot represents a “concentration” of artifacts recovered within a diameter of 2 to 3 metres. Since 2018, the NCC has collected at least 55,000 pre-contact artifacts from this shoreline alone and many kilometers have not yet been assessed.

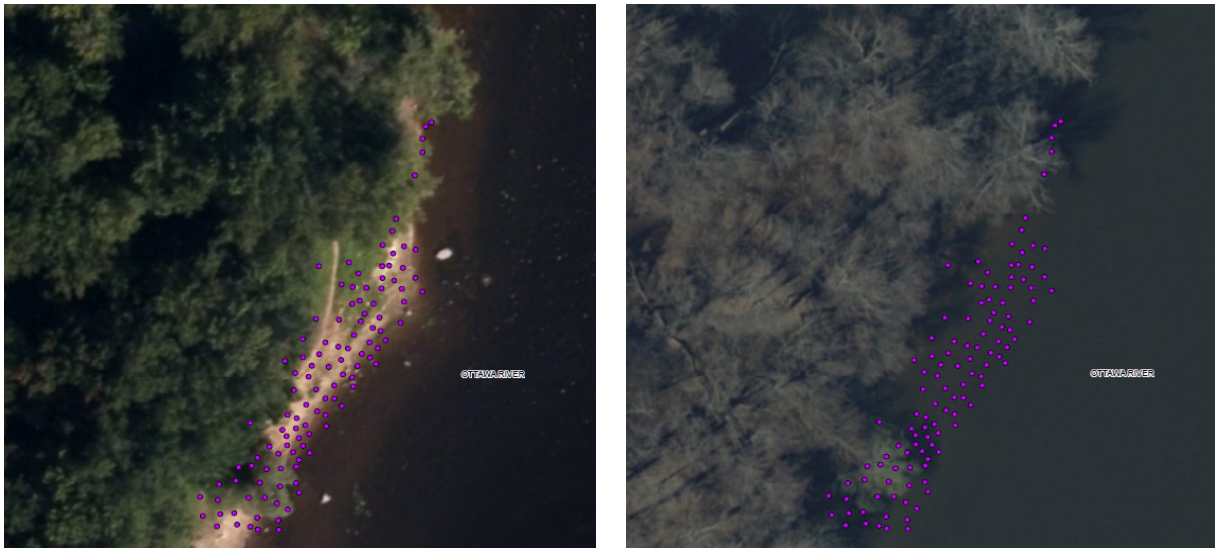

Figure 22. Identified Artifact Sites Low Water (Left) and High Water (Right)

Because of the dams upstream and downstream, an artificially high-water level in the Core Area stretch of the Ottawa River is maintained during spring, early summer and late fall which is a major influence on the erosion of archaeological resources on the river's shorelines. Controlling the water level in response to climate change variables will harm these resources, but this sits outside of NCC's control. While archeological sites in the flood plain are at the greatest risk, those not in the flood plain may also be at risk due to slope failure during high precipitation events.

Unlike precipitation and water levels, the impacts from heat and seasonal change are more indirect but can be equal in terms of consequences. A lengthening spring and fall season combined with a warmer summer is likely to result in increased water-based recreational activity and park use which can (and has) resulted in disruption and damage to archaeological sites (e.g., boat wakes, shoreline gatherings and parties, digging pits and creating mud windbreaks for campfires, displacing logs and rocks for seats, etc.).

Of the 26 impact statements at the organizational level identified to have a high vulnerability and high or very-high risk, 5 of these (21%) are from the Archaeology sector which is due to several notable vulnerabilities:

- Insufficient staff and funding resources to:
    - determine the degree of the cultural heritage value of archaeological resources on NCC lands (e.g., only 17 km of the Ottawa River shoreline has been studied, out of 75 km managed by the NCC (22.6%)).
    - collect and process archaeological resources for transferring to appropriate stakeholders.
- Stakeholders do not have the capacity to receive and store archaeological assets; therefore, the NCC stores the assets.
- Increased public recreational activities (especially on the shoreline) are resulting in stress and damage to archaeological sites (e.g., digging campfires, making mud walls, etc.).
- There are limited resources available to enforce and monitor what the public does on NCC lands.

4.3 Geographic Risks

4.3.1 Flood Maps

In addition to engaging with NCC staff through interviews and workshops, GIS maps and other data sets were made available by the NCC to identify the proximity of NCC assets to some climate hazards (e.g., assets in the 100-year and 350-year flood plain, extreme heat exposure, proximity to slopes, etc.). The GIS mapping exercise shows that the NCC's shorelines, contaminated sites, archeological sites, and buildings and infrastructure assets within the 100- and 350-year floodplains are already at risk of extreme and long-duration precipitation events. According to NCC staff, residential buildings are at the greatest risk of flooding. Increased precipitation can also result in overland flooding if stormwater systems are overwhelmed, water ingress into buildings (roof, window and foundational) and can result in sewer backups. This is a notable issue with residential buildings.

The maps show that cultural assets, water wells, lift stations, fuel storage tanks, septic tanks, and as expected, recreational pathways and areas would be impacted by major flood events (i.e., a 100-year flood or greater) which aligns with recent experiences with flooding in these areas. This is presented in Figure 23, Figure 24 and Figure 25. It should be noted that while these maps present the risk of riverine flooding to assets, there is also the risk of overland flooding (which occurs when storm sewer systems are overwhelmed) which can also damage assets.

Flood mitigation and response measures could potentially be prioritized according to the socio-economic status (i.e., in more vulnerable areas – see Figure 26).

Figure No.

23

Title

Greenbelt Assets in the 350-year floodplain

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

2,800 5,600 metres

(At original document size of 11x17)
1:146,940

- 350 year Floodplain (Ontario Only)
- Greenbelt

Impacted Asset (by Type)

- Septic Tank
- Water Well
- Recreational Path
- Recreational Area

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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Figure No.

24

Title

Ontario Urban Lands Assets in the 350-year floodplain

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 1,300 2,600 metres

(At original document size of 11x17)
1:69,730

- 350 year Floodplain (Ontario Only)
- Ontario Urban Lands
- Impacted Asset (by Type)
  - Cultural
  - Fuel Storage Tanks
  - Lift Station
  - Recreational Path
  - Recreational Area

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N

2. Data Sources:

3. Background: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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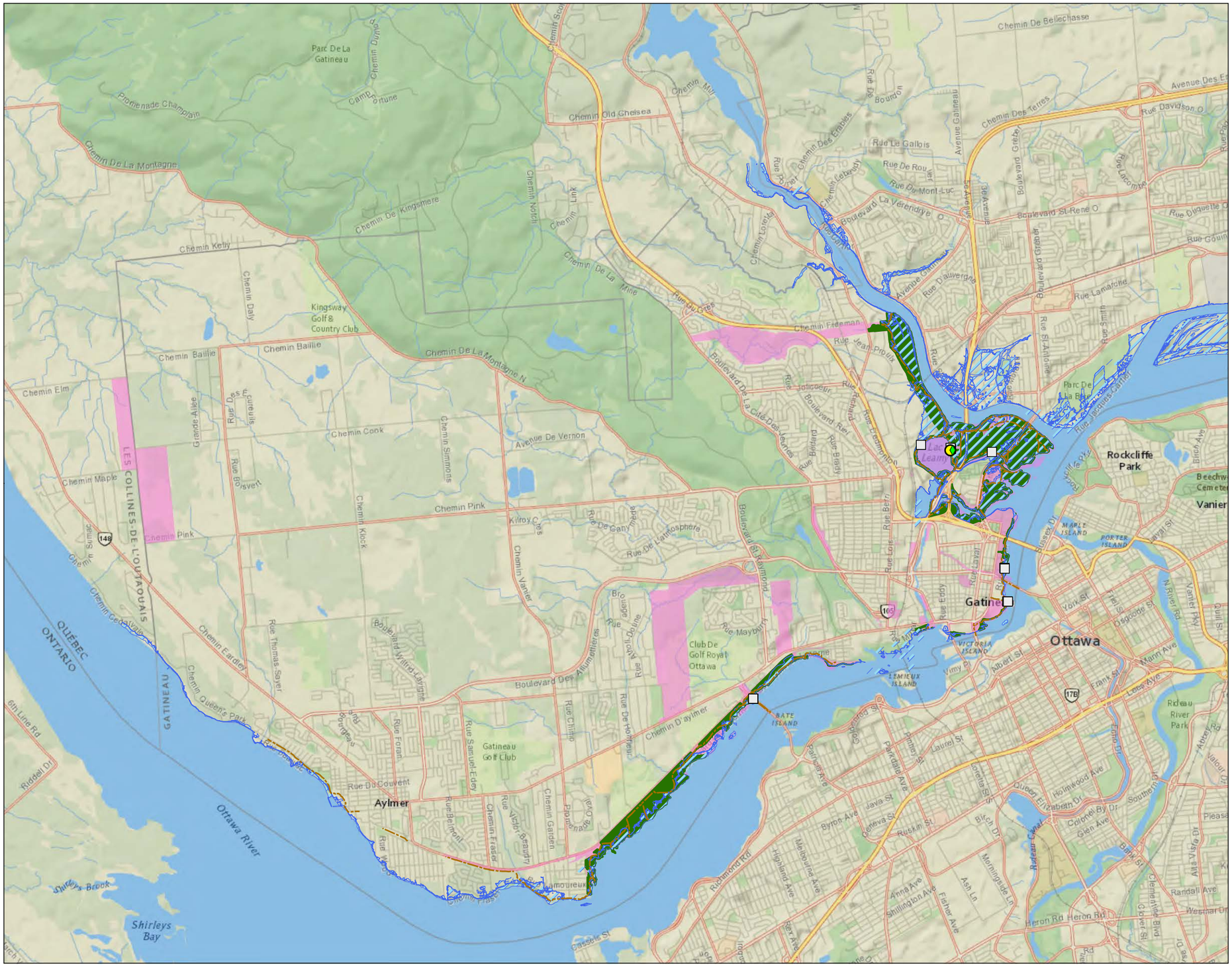

Figure No.

25

Title

Quebec Urban Lands Assets in the 100-year Floodplain

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 1,300 2,600 metres

(At original document size of 11x17)
1:69,730

- 100 year Floodplain
- Quebec Urban Lands

Impacted Asset (by Type)

- Cultural
- Fuel Storage Tanks
- Septic Tank
- Recreational Path
- Recreational Area

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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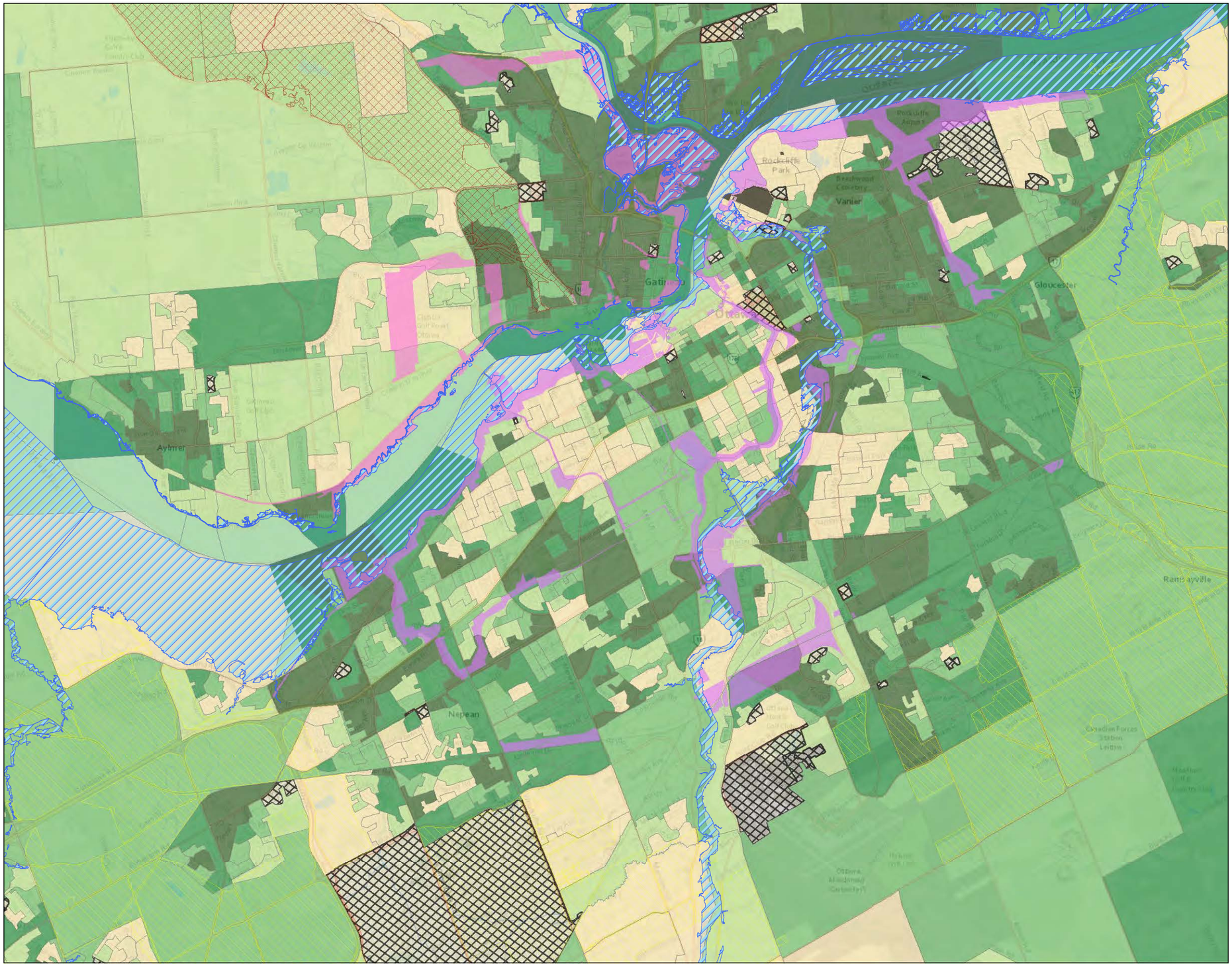

Figure No.

26

Title

100-year Floodplain and Socioecnomic Status

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 1,600 3,200 metres

(At original document size of 11x17)
1:84,412

100 year Floodplain (ON) / Ville de Gatineau Flood Plain

NCC Lands

- Gatineau Park
- Greenbelt
- Official Residences
- Ontario Urban Lands
- Quebec Urban Lands

Socioeconomic Status (2017)

- No Data Available
- 1 - least vulnerable
- 2
- 3
- 4
- 5 - most vulnerable

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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4.3.2 Slope Maps

Similar to the flood mapping exercise, the NCC's assets were mapped against areas with a slope that is greater than 15%. Any asset within 10 meters could be subject to some form of subsidence or landslide during prolonged precipitation events. Similar to the flooding assessment, many of the NCC assets that could be impacted include water wells, lift stations, fuel storage tanks, septic tanks, recreational pathways and cultural assets. Many of the assets identified on the maps presented in Figure 27 to Figure 31 are also located in the 1-year and 350-year floodplains and should be considered priority assets before further risk assessment.

Figure No.

27

Title

Gatineau Park Assets Near Steep Slopes

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 3,100 6,200 metres

(At original document size of 11x17)
1:166,900

- Gatineau Park

Impacted Asset (by Type)

- Cultural
- Fuel Storage Tanks
- Lift Station
- Septic Tank
- Water Well
- Recreational Path

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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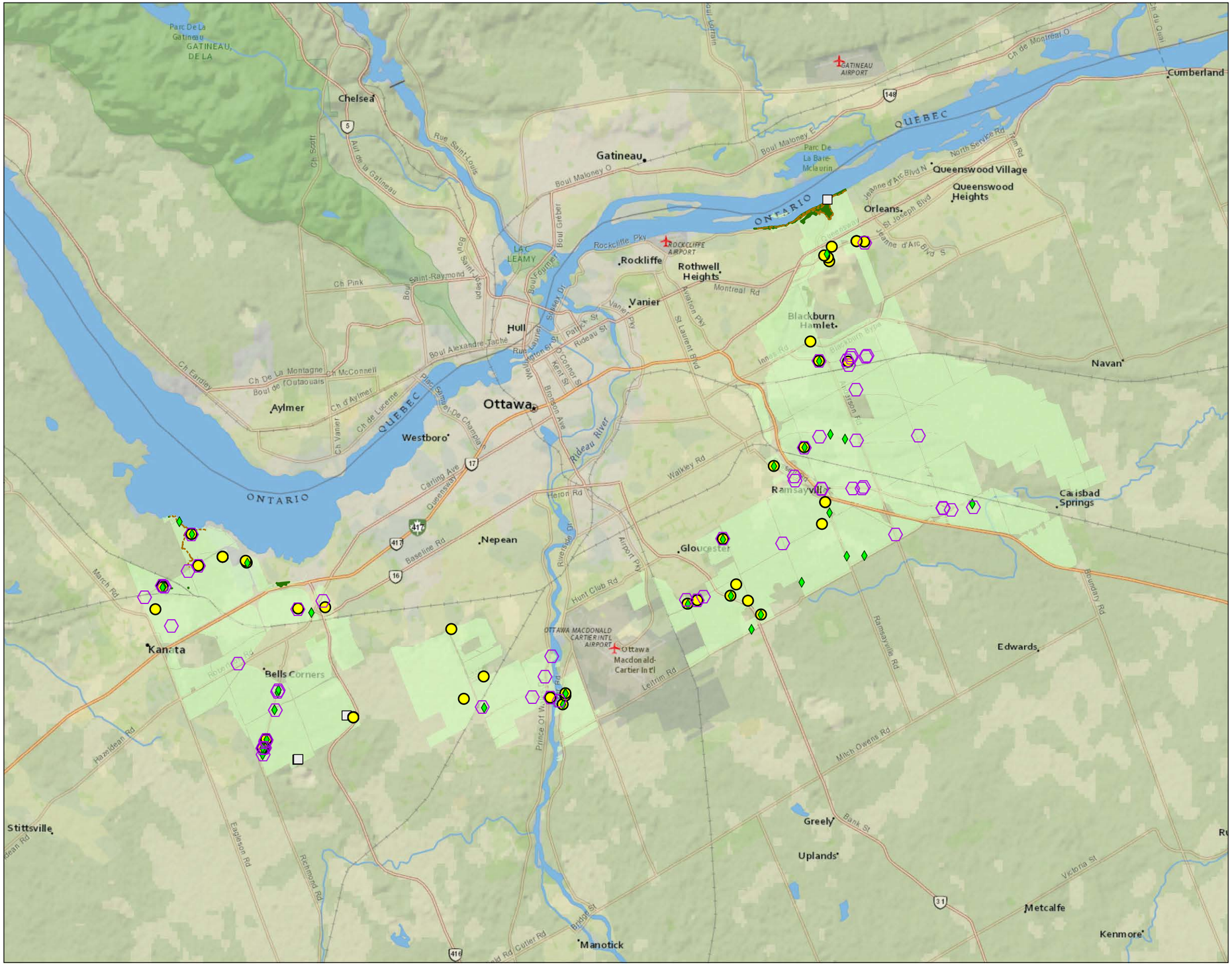

Figure No.

28

Title

Greenbelt Assets Near Steep Slopes

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 2,800 5,600 metres

(At original document size of 11x17)
1:148,400

Greenbelt

Impacted Asset (by Type)

- Cultural
- Fuel Storage Tanks
- Septic Tank
- Water Well
- Recreational Path
- Recreational Area

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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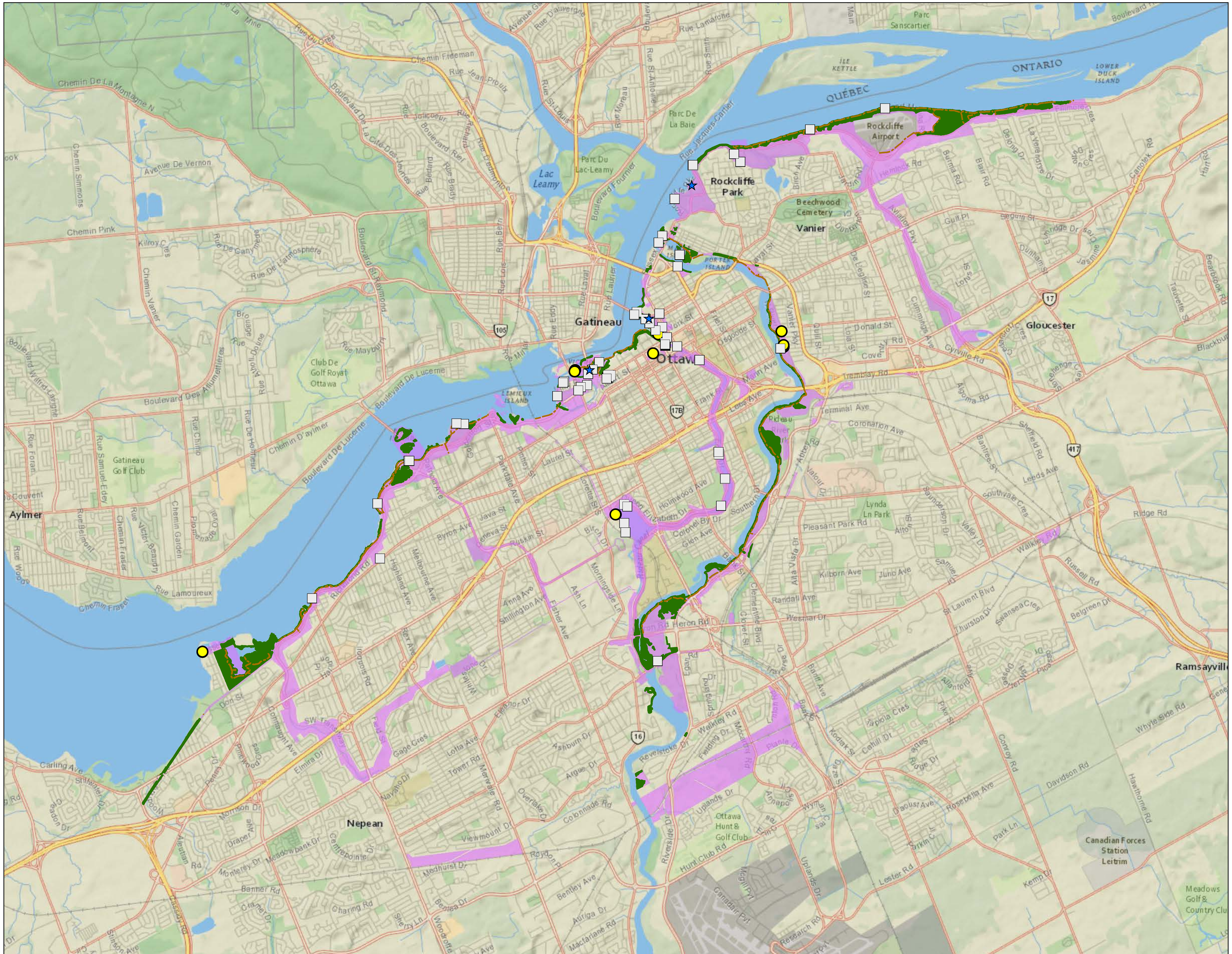

Figure No.
29

Title
Ontario Urban Lands Assets Near Steep Slopes

Client/Project
123221923_001

National Capital Commission
CVRA

Project Location
Ottawa, ON / Gatineau, QC

N

0 1,300 2,600 metres
(At original document size of 11x17)
1:72,800

- Ontario Urban Lands
- Impacted Asset (by Type)
  - Cultural
  - Fuel Storage Tanks
  - Lift Station
- Recreational Path
- Recreational Area

Notes
1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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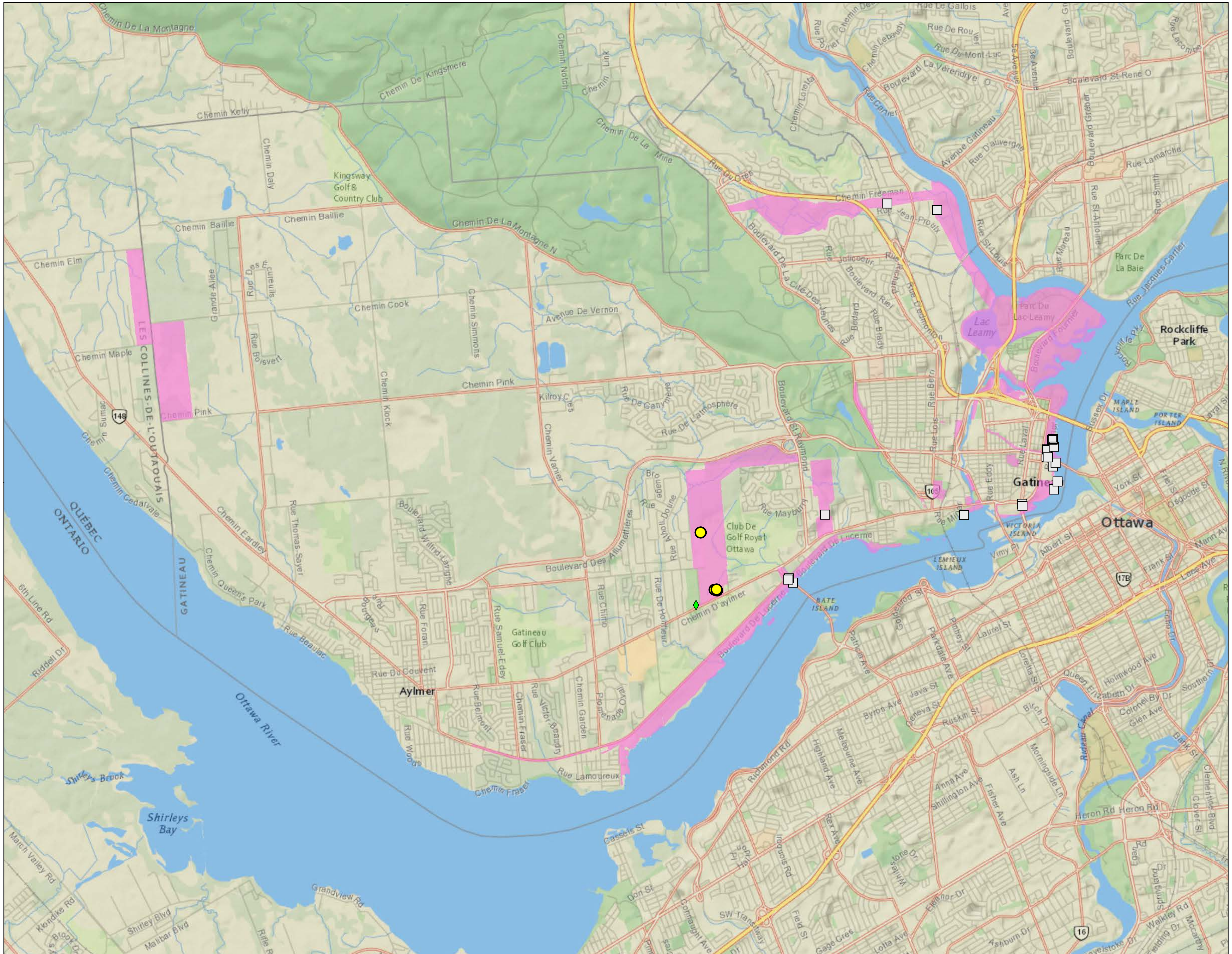

Figure No.

30

Title

Quebec Urban Land Assets Near Steep Slopes

Client/Project 123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 — 1,250 — 2,500 metres

(At original document size of 11x17)
1:67,100

Quebec Urban Lands

Impacted Asset (by Type)

- Cultural
- Fuel Storage Tanks
- Septic Tank
- Recreational Path

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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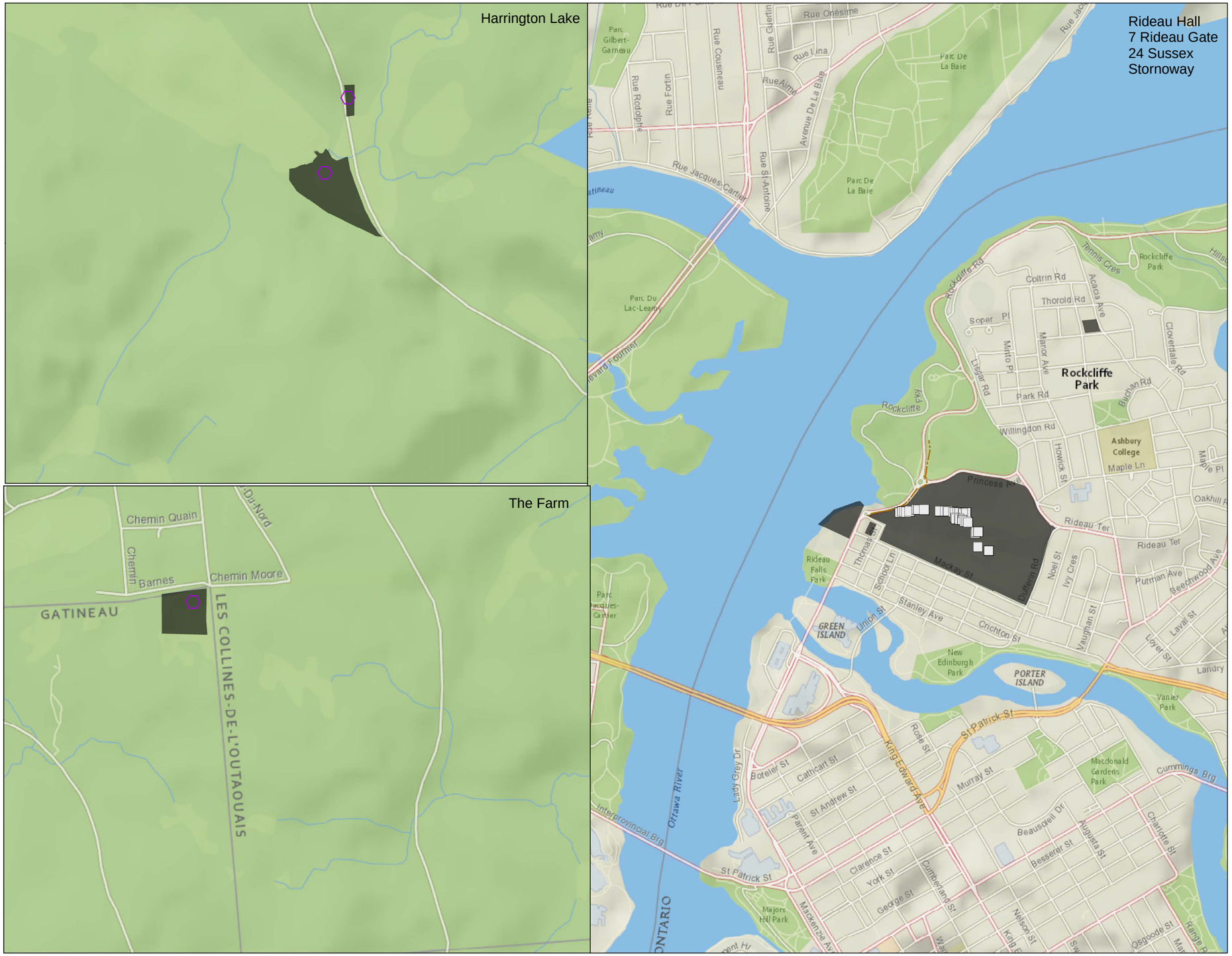

Figure No.

31

Title

Official Residences Assests Near Steep Slopes

Client/Project

123221923_001

National Capital Commission
CVRA

Project Location

Ottawa, ON / Gatineau, QC

N

0 280 560 metres

(At original document size of 11x17)
1:15,000

Official Residences

Impacted Asset (by Type)

- Cultural
- Water Well
- Recreational Path

Notes

1. Coordinate System: NAD 1983 UTM Zone 18N
2. Data Sources:
3. Background: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

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5.0 Key Findings

Under a changing climate over the next century, many of the NCC's climate vulnerabilities and risks are going to be exacerbated, and with no action to mitigate them, could result in significant economic, environmental, and social impacts on the organization. The results of the risk assessment show where attention is needed around key internal structures and processes in order to improve resilience. If climate risks are not proactively managed, the NCC will need to seek more funds, decrease service level standards, and/or abandon assets and programs.

Based on their vulnerability and risk, this study found that out of a total of 124 impacts, 61 require immediate action, 38 require a plan to be developed, and 25 require minor controls and monitoring. Of the 61 impact statements requiring immediate action, 3 have very high vulnerability and very high risk, 23 have high risk and high vulnerability, and the remaining 35 have a medium/medium-high vulnerability and risk rating.

The following climate-related hazards associated are expected to present the most significant risks to NCC's delivery of its mandate:

- hotter and more humid summers,
- short duration/high intensity and sustained precipitation events, and
- extreme events (e.g., ice storms, freezing rain, etc.).

Of the 61 potential impacts that require immediate action, approximately 36% of the risks are related to extreme heat, 36% are related to changes to precipitation, with 20% of the potential risks are associated with extreme weather events (8%) related to seasonable variability. These climate hazards already have a high probability of occurrence in the baseline period (1981-2010), are expected to increase in frequency over the next 80 years and have significant environmental, social and economic consequences.

The Natural Resources & Parks, Infrastructure & Operations, and Buildings, Housing & Real-Estate sectors account for the greatest number of priority risks (21%, 21% and 20% respectively). The risk profiles for each of the NCC sectors was presented in Figure 14 in Section 4.2. The Archaeology sector has the greatest proportion of its sector-specific impacts requiring immediate action (86%) followed by the Buildings, Housing & Real Estate sector (80%), Agriculture (60%), Natural Resources & Parks sector (57%), and Infrastructure & Operations sector (48%). Based on the risk profiles, these five NCC sectors have the most significant risks. The Corporate Services sector was found to have the fewest impacts requiring immediate action.

In terms of geographic risk, the CVRA has found that the NCC's shorelines, contaminated sites, archeological sites, and assets within the 100-year flood plain are already at risk of extreme and long-duration precipitation events. This risk will increase as the probability of high precipitation events increases. Heritage buildings and structures (e.g., monuments, walls, etc.) are at the greatest risk during extreme temperatures and precipitation, as they were not designed to handle the projected climate conditions and are already being impacted by extreme heat, seasonal changes, heavy snow and long-duration precipitation events (e.g., water ingress). Although NCC staff in charge of the Crown Collection are actively managing the collection to avoid heat and humidity

damage (e.g., not putting items in areas without air conditioning, ensuring that there are screens on windows, etc.), this task is likely to get increasingly difficult unless more work is done to upgrade at-risk heritage assets.

In addition to evaluating vulnerabilities related to sectors and assets, the CVRA evaluated several aspects of the NCC's internal/organizational structure. These findings are based on staff workshops, interviews and corporate documents. The following factors (in no particular order) increase the organization's vulnerability and show where attention is needed around key internal structures and processes to improve resilience:

Small and static federal appropriation – The NCC receives approximately $24 million annually for capital expenditures and $68 million annually for operating expenditures and has not received any permanent increases in funding since 2009–2010, despite facing increased financial pressures, and the number of assets (or value of acquired assets) under its control has consistently increased. The investment required to properly maintain the NCC's extensive asset base and meet the corporation's responsibilities on an ongoing basis substantially exceeds its regular parliamentary appropriations. Because of static funding and resources, the deferred maintenance of assets is prolonged until capital injections are made available. Without the impact of climate change, the deferral of maintenance is already a risk and liability for the NCC. To help address the deteriorating condition of the NCC's assets, the Government of Canada has made a significant capital investment of $228.6 million over five years (2018–2019 to 2022–2023). This investment has allowed the corporation to begin the long process of revitalizing assets in need of critical repair, although there is considerable deferred maintenance work remaining unfunded. Because of the static funding level, NCC asset managers must compete for limited funds via the Multi-year Capital Program (MYCP) based on the criticality of the assets they manage. This results in some assets not receiving funding which furthers the deferred maintenance loop. In addition, there have been instances where other corporate priorities have taken precedence over asset management in budget decisions. The current funding level and limited operating funds to support ongoing asset operation and maintenance, even as new assets are acquired, constructed, and transferred into the NCC's care, hinders the NCC's ability to proactively address climate change and maintain assets in a safe and climate-resilient condition.

Deferred maintenance positive feedback loop – Because of the vast number of assets managed by the NCC and the duration to which deferred maintenance has been going on, the NCC is now in a deferred maintenance positive feedback loop where an asset degrades to a near-critical condition and emergency interventions are made to bring the asset condition up to a functional level. When emergency interventions are made, there is a varying degree to which climate risk is incorporated into planning and design. As capacity constraints and asset deterioration are not quantified, this information is not used to inform asset acquisition or the planning, design and construction of new assets and programs.

Short time horizons result in missed adaptation opportunities - Current decision-making frameworks often reject projects or project elements with a payback longer than 3–4 years, to keep costs low. However, in several cases, this cost-saving approach has ended up costing the NCC more as some projects had to be modified to install the adaptation measure after the project was built because the adaption (or mitigation) measure was deemed essential to the building function. This issue has likely contributed to the construction, maintenance and rehabilitation of assets that are not resilient to the effects of climate change.

Underutilization of the Enterprise Asset Management System - The NCC's asset managers are very adept at what they do, however the enterprise asset management system (Dynamics AX Enterprise Asset Management) is not used to its fullest capacity to manage assets across the organization in a coordinated manner. While some staff use it for work planning, work completion tracking, and cost tracking the current system is more of a repository of asset condition reports, and the bulk of the knowledge remains with asset managers. Also, many types of infrastructure do not have asset numbers (e.g., wastewater treatment system/lagoons, or pumping stations), only very general ones, which makes them hard to evaluate. Given the size of the corporation's portfolio of assets a systems-based asset management approach is needed to facilitate information-sharing and decision-making.

Limiting internal structures – There is an absence of a climate lens in nearly all organizational processes, including asset inspection and management, the Process for Project Management, Impact Assessment, Federal Land Use, Design And Transaction Approval, and risk management which creates an organization-wide vulnerability. The MYCP scoring and Strategic Environmental Assessment processes include a high-level climate lens; however, there is significant room for improvement. In addition, there is limited integration between the Sustainable Development & Environmental Services division and the Process for Project Management and the asset management system, which has, at times, resulted in missed opportunities to integrate climate resilience. Furthermore, internal structures and systems prevent operational staff from using management techniques like "low-regret" decision-making and incrementalism to adapt to climate change in the short and mid-term.

Corporate culture, capability, and capacity – The NCC has a strong organizational culture and willingness to succeed which is contrary to other organizations that suffer from significant resource constraints, siloed management, and operational systems and moderate to high turnover like the NCC. While the current collective "can-do" culture increases the organizations' ability to respond and adapt when climate events occur, there is a significant risk that climate change is already reducing organizational capacity and capability. Given the organization's limited funds, personnel and other resources, as more frequent, intense, and compound events occur, this ability to respond will erode quickly.

Climate change not highlighted in corporate risk management framework – Climate change is already impacting the NCC's bottom line, but it has not been raised as a corporate risk even after the historical flooding and tornado events. As such, climate change and events are handled on a case-by-case basis rather than under an organization's systems view. The NCC does not track the costs of climate change which limits the organization's ability to understand and prioritize the impacts.

Approach to climate change has been ad hoc – Until recently, climate change has been a bottom-up priority which has resulted in maladaptive decisions/approaches being made across the organization resulting in missed opportunities to mitigate and adapt to the effects of climate change. Adapting and mitigating the effects of climate change will require a significant investment in assets, systems and staff and will also require a modification to financial and capital decision frameworks that realize the economic value of long-term investments.

Lack of data – The NCC does not currently collect data about the cost of extreme events so it is difficult to forecast how much it has cost in recent years and how much proactive adaptation measures could save the organization.

External vulnerabilities - The NCC is also subject to vulnerabilities outside of its control. In particular, the NCC is exposed to vulnerabilities in the electrical and communication systems, as well as upstream development. The NCC will need to work with stakeholders like Hydro Ottawa, Hydro-Québec, the City of Ottawa, and the Ville de Gatineau to understand how these vulnerabilities are being managed by stakeholders and work in concert with them.

The NCC is at the beginning of its climate adaptation planning process, so while the risks and vulnerabilities are noted as current gaps, the NCC has the opportunity to address them in the upcoming climate adaptation strategy. Indeed, it is by incorporating climate risk into internal processes, rather than focusing strictly on individual assets, that the NCC will become a resilient organization.

To ensure that the organization can continue delivering on its mandate, and meet new climate-related risk disclosure requirements of the Federal Government, a concerted effort will be required, including more funding and resources, a senior-level commitment to embedding climate change and sustainable development considerations into all aspects of the organization (including finance, for instance), the implementation of policies and programs that require the use of climate risk assessments to inform decisions at pivotal junctures and to establish a monitoring and reporting program to establish accountability systems and evaluate and report on progress.

6.0 Path Forward

The development of the climate adaptation strategy (CAS) will involve engagement with NCC staff to identify, assess, and prioritize actions focused on minimizing the NCC's vulnerability to the effects of climate change by increasing resilience. These actions and the timing of their implementation will be based on the vulnerabilities and gaps identified in the CVRA. Impacts identified as requiring "immediate action", "a plan be developed" and "monitoring and control" will move forward to the CAS. The timelines associated with these three categories will be defined in the next phase of the project (adaptation planning).

Actions and strategies included in the CAS may be categorized into the following action types:

- No regret – Actions that are cost-effective and justified regardless of whether a climate event occurs or not.
- Low regret – Low-cost options for which the benefits, although primarily realized under projected future climate change, may be relatively large.
- Win-win – Actions that minimize the impacts of future climate events and have other social, environmental or economic benefits.

- Flexible – Incremental adaptation options rather than undertaking large-scale adaptation actions all at once.
- Large-scale – initiatives requiring significant time and or resources.

The CAS intends to create a comprehensive document that will enable NCC service area leads to begin implementing adaptation measures, understand what additional studies are needed to further understand climate risks, and identify adaptation measures for specific assets. It is expected that the development of the CAS will begin in Fall 2022, with a first draft circulated for public input in Summer 2023. It will include an implementation plan that identifies responsibilities, resource requirements and timelines.

7.0 Glossary

Adaptation	Acknowledgement that climate change is happening and adopting measures to respond to changes that are irreversible and already underway.
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.
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.
Mitigation	A measure taken to reduce the probability of a risk occurring or the impact of negative consequences if it does occur; often referred to as a control

	measure. In the context of climate change, mitigation commonly refers to efforts to reduce greenhouse gas emissions at global, national, sub-national or organizational levels.
Opportunity	Beneficial outcome – can be treated/evaluated in a similar manner as consequence.
Outcome	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 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: Impacts Ranked by Level of Intervention Required

The following table lists all 124 impacts identified through this study, ranked in order of the level of intervention required, from the highest level of intervention to the lowest. Recall that there are only 92 distinct impact statements, however, several impacts appear more than once because they were scored differently depending on the sector. As a reminder, each impact statement has three components:

1. A climatic hazard (i.e., increase in freezing rain events; warmer summer temperatures)
2. The outcome of the climatic hazard (i.e., damage to trees and electrical infrastructure; heatwaves)
3. The impact associated with this outcome (i.e., power outages; specific health impacts)

The matrices defining the vulnerability, risk, and level of intervention required ratings can be found in Figure C.4, Figure C.5 and Figure C.6. in Appendix C.

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Archaeology	Hotter summers will result in increased water-based recreational activity resulting in the disruption and damage to archaeological sites (e.g., boat wakes, shoreline gatherings and parties).	High Vulnerability	Very High Risk	Immediate action required
Buildings, Housing & Real Estate	Hotter summers may increase cooling demands and associated costs to the NCC and tenants.	High Vulnerability	Very High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in the volume and intensity of precipitation may result in flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Very High Risk	Immediate action required
Agriculture	An increase in the volume and intensity of precipitation may result in saturation or flooding of agricultural lands.	High Vulnerability	High Risk	Immediate action required
Agriculture	An increase in the volume and intensity of precipitation may result in nutrient loading of nearby aquatic ecosystems, increased buffer requirements, reduced lands available for agriculture, and a lost revenue source to the NCC.	High Vulnerability	High Risk	Immediate action required

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Agriculture	An increase in extreme winter weather events, like freezing rain and heavy snow, may result in damage to agricultural buildings (snow load), compromised building integrity, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	High Risk	Immediate action required
Agriculture	An increase in climate-related events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	High Risk	Immediate action required
Archaeology	Hotter summers and seasonal variability will result in increased NCC park use resulting in the disruption and damage to archaeological sites (e.g., digging pits and creating mud windbreaks for campfires, displacing logs and rocks for seats, etc.).	High Vulnerability	High Risk	Immediate action required
Archaeology	An increase in the frequency, volume and intensity of rainstorms and flooding, will lead to accelerated shoreline erosion, damage to archaeological sites and a permanent loss of archaeological resources.	High Vulnerability	High Risk	Immediate action required
Archaeology	An increase in the frequency, volume and intensity of precipitation, will lead to increased ground heave, and subsidence resulting in damage to archaeological sites.	High Vulnerability	High Risk	Immediate action required
Archaeology	An increase in shoulder season events, like increased winter freeze-thaw cycles and ice storms, will damage vegetation, adversely impacting clay and silt sediments and increase slope instability in susceptible areas, resulting in damage to archaeological sites.	High Vulnerability	High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in shoulder season events, like increased freeze-thaw cycles may result in damage to buildings, reduced asset life expectancy, and more frequent repairs and renewals to buildings.	High Vulnerability	High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in the volume and intensity of precipitation may impact building roof and foundation drainage systems resulting in water ingress and damage, compromised building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in the volume and intensity of precipitation resulting in overland flooding may result in basement flooding damage and mould-related illnesses to NCC tenants and staff, if not addressed.	High Vulnerability	High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in extreme winter weather events, like freezing rain and heavy snow, may result in damage to building roofs (ice and snow load), compromised building integrity, health and safety risks to tenants, and	High Vulnerability	High Risk	Immediate action required

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
	increased maintenance activity (repairing/replacing infrastructure and clean-up).			
Buildings, Housing & Real Estate	Global climate change may cause supply chain instability and/or market failures impacting the availability of fuels and other goods required to maintain operations.	High Vulnerability	High Risk	Immediate action required
Infrastructure & Operations	An increase in shoulder season events, like freezing rain, may lead to slippery roads and trails, resulting in reduced park/facility access, increased risks to users, and increased maintenance activity (snow clearing, etc.).	High Vulnerability	High Risk	Immediate action required
Infrastructure & Operations	An increase in the volume and intensity of precipitation, high snowpack and/or warmer springs may result in the wash-out of pathways and roads and sinkholes, resulting in temporary/permanent closures of transportation systems, and more frequent repairs and renewals.	High Vulnerability	High Risk	Immediate action required
Infrastructure & Operations	An increase in the volume and intensity of precipitation may result in the wash-out of boardwalks and staircases, resulting in temporary/permanent closures of active transportation systems and more frequent repairs and renewals.	High Vulnerability	High Risk	Immediate action required
Infrastructure & Operations	An increase in the volume and intensity of precipitation may lead to the overtopping of damns and weirs resulting in damage to assets, uncontrolled downstream flows, and more frequent repairs and renewals.	High Vulnerability	High Risk	Immediate action required
Infrastructure & Operations	An increase in the volume and intensity of precipitation may lead to shoreline erosion, damage to assets (e.g., bridges, dams), reduced asset lifespan, and more frequent repairs and renewals.	High Vulnerability	High Risk	Immediate action required
Natural Resources & Parks	An increase in the volume and intensity of precipitation may result in overland flooding resulting in the temporary/permanent closure of trails and park lands, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	High Risk	Immediate action required
Recreation, Education, Tourism & Cultural Heritage	Hotter summers may lead to reduced water quality at beaches and natural outdoor swimming areas (e.g., algal blooms) and result in health and safety risks to users.	High Vulnerability	High Risk	Immediate action required

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Recreation, Education, Tourism & Cultural Heritage	Hotter summers and/or high humidex periods may result in park and recreation programming delays, modification to outdoor activities/events, and lost revenues.	High Vulnerability	High Risk	Immediate action required
Recreation, Education, Tourism & Cultural Heritage	An increase in seasonal temperatures may lead to the intensification of existing invasive species and diseases, the migration of new invasive species, and the alteration of natural habitats.	High Vulnerability	High Risk	Immediate action required
Recreation, Education, Tourism & Cultural Heritage	An increase in extreme weather events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	High Risk	Immediate action required
Agriculture	An increase in summer temperatures may result in algal blooms that can reduce the availability of water safe for growing food and agricultural operations.	High Vulnerability	Medium-High Risk	Immediate action required
Agriculture	An increase in the volume and intensity of precipitation may result in flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium-High Risk	Immediate action required
Buildings, Housing & Real Estate	Hotter summers may increase cooling demands, requirements to improve building performance, and increased capital costs to the NCC.	High Vulnerability	Medium-High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in shoulder season temperature variability may result in more operational demands to accommodate mechanical systems to the varying temperatures.	High Vulnerability	Medium-High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	High Vulnerability	Medium-High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in extreme weather events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	Medium-High Risk	Immediate action required

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Infrastructure & Operations	An increase in the volume and intensity of precipitation may result in the scouring, erosion, side-slope failure, and foundation settlement of bridges, resulting in temporary/permanent closures of transportation systems and more frequent repairs and renewals.	High Vulnerability	Medium-High Risk	Immediate action required
Infrastructure & Operations	An increase in the volume and intensity of precipitation may result in flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium-High Risk	Immediate action required
Infrastructure & Operations	An increase in the volume and intensity of precipitation may lead to damaged stormwater infrastructure (e.g., increased sediment and material transport leading to blockages and clogging of conveyance systems) and culverts, resulting in reduced run-off capture, localized flooding, and more frequent repairs and renewals.	High Vulnerability	Medium-High Risk	Immediate action required
Infrastructure & Operations	An increase in climate-related events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	Medium-High Risk	Immediate action required
Land Use, Development & Planning	Hotter summers and/or high humidex periods may increase public demand for shaded areas, especially on surfaces that exacerbate the urban heat island effect.	High Vulnerability	Medium-High Risk	Immediate action required
Land Use, Development & Planning	An increase in the volume and intensity of precipitation may lead to the exposure or destabilization of contaminated park lands resulting in regulatory and financial liabilities for the NCC.	High Vulnerability	Medium-High Risk	Immediate action required
Natural Resources & Parks	Hotter summers may result in reduced aquifer recharge, which may result in lower baseflow to streams and degraded aquatic habitat.	High Vulnerability	Medium-High Risk	Immediate action required
Natural Resources & Parks	An increase in seasonal variability may result in park seasons being extended in duration, increased park use, and increased operational demands.	High Vulnerability	Medium-High Risk	Immediate action required
Natural Resources & Parks	An increase in seasonal temperatures may lead to the intensification of existing disease vectors, and the migration of new disease vectors and illnesses resulting in health and safety risks to park users and NCC staff.	High Vulnerability	Medium-High Risk	Immediate action required
Natural Resources & Parks	Warmer, shorter winters and reduced snowfall may result in a shortened winter/outdoor park season requiring changes to programming and facilities (e.g., Rideau Canal Skateway, cross country skiing, etc.) and increased capital/maintenance costs.	High Vulnerability	Medium-High Risk	Immediate action required

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Natural Resources & Parks	An increase in the volume and intensity of precipitation, high snowpack and/or warmer springs may result in nutrient loading of nearby aquatic ecosystems (soil erosion and run-off).	High Vulnerability	Medium-High Risk	Immediate action required
Natural Resources & Parks	An increase in the volume and intensity of precipitation may lead to shoreline erosion, damage to assets (e.g., bridges, dams), reduced asset lifespan, and more frequent repairs and renewals.	High Vulnerability	Medium-High Risk	Immediate action required
Natural Resources & Parks	An increase in the volume and intensity of precipitation may lead to the exposure or destabilization of contaminated park lands resulting in regulatory and financial liabilities for the NCC.	High Vulnerability	Medium-High Risk	Immediate action required
Natural Resources & Parks	An increase in climate-related events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	Medium-High Risk	Immediate action required
Recreation, Education, Tourism & Cultural Heritage	Warmer, shorter winters and reduced snowfall may result in a shortened winter/outdoor park season requiring changes to programming and facilities (e.g., Rideau Canal Skateway, cross country skiing, etc.) and increased capital/maintenance costs.	High Vulnerability	Medium-High Risk	Immediate action required
Agriculture	Hotter summers may increase cooling demands, requirements to improve building performance, and increased capital costs to the NCC.	Medium Vulnerability	High Risk	Immediate action required
Agriculture	Hotter summers and variable precipitation may result in dry wells increasing potable water demands by agricultural tenants on wells (East end) and in increased costs to the NCC.	Medium Vulnerability	High Risk	Immediate action required
Agriculture	An increase in extreme weather events may result in a health and safety risk to agricultural workers.	Medium Vulnerability	High Risk	Immediate action required
Archaeology	Hotter summers and/or high humidex periods will place NCC archaeologists, staff and contractors at greater risk of heat-related health and safety risks.	Medium Vulnerability	High Risk	Immediate action required
Buildings, Housing & Real Estate	An increase in extreme weather events and the stresses that it places on the organization may negatively impact staff morale resulting in increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change.	Medium Vulnerability	High Risk	Immediate action required
Infrastructure & Operations	Hotter summers and/or high humidex periods may result in the delay of regularly scheduled maintenance programs, procedures and construction windows.	Medium Vulnerability	High Risk	Immediate action required

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Infrastructure & Operations	Hotter summers may increase the occurrence of algae blooms in water systems resulting in reduced water quality and impact on NCC programs (e.g., Lake Philippe campground, Rideau Canal).	Medium Vulnerability	High Risk	Immediate action required
Infrastructure & Operations	An increase in shoulder season events, like increased freeze-thaw cycles, may result in the accelerated degradation of roads, pathways and bridge infrastructure, temporary closures of transportation systems, and more frequent repairs and renewals.	Medium Vulnerability	High Risk	Immediate action required
Infrastructure & Operations	An increase in shoulder season events, like increased freeze-thaw cycles and freezing rain, may damage vegetation and increase slope stability issues in susceptible areas, resulting in public safety issues and temporary/permanent closures of park areas.	Medium Vulnerability	High Risk	Immediate action required
Natural Resources & Parks	Hotter summers and/or high humidex periods may increase public demand for shaded areas, especially on surfaces that exacerbate the urban heat island effect.	Medium Vulnerability	High Risk	Immediate action required
Natural Resources & Parks	Hotter summers and/or high humidex periods may result in park and recreation programming delays, modification to outdoor activities/events, and lost revenues.	Medium Vulnerability	High Risk	Immediate action required
Natural Resources & Parks	An increase in the volume and intensity of precipitation may result in landslides in inhabited or built-up areas resulting in temporary/permanent closures, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	Medium Vulnerability	High Risk	Immediate action required
Natural Resources & Parks	An increase in extreme winter weather events, like freezing rain, may increase road salt use and could accelerate the susceptibility/mortality of heritage landscapes (trees along confederation boulevard) and damage to aquatic ecosystems	Medium Vulnerability	High Risk	Immediate action required
Recreation, Education, Tourism & Cultural Heritage	An increase in extreme weather events and the stresses that it places on the organization may negatively impact staff morale resulting in increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change.	Medium Vulnerability	High Risk	Immediate action required
Agriculture	Hotter summers and variable precipitation may threaten the success of agricultural operations, result in a decline of agricultural tenants on NCC lands and a lost revenue source to the NCC.	Low Vulnerability	High Risk	Develop a plan to address risk

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Natural Resources & Parks	An increase in shoulder season events, like increased winter freeze-thaw cycles and ice storms, may result in the accelerated degradation of park trails and associated infrastructure, temporary/permanent closures and increased maintenance activity (repairing/replacing infrastructure).	Low Vulnerability	High Risk	Develop a plan to address risk
Agriculture	Hotter summers and seasonal variability may result in reduced agricultural yields (drought, pollinator lifecycle changes, pests, invasive species) and loss of revenue to the NCC.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Agriculture	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Archaeology	An increase in climate-related events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Corporate Services	An increase in extreme weather events may exacerbate underlying systematic vulnerabilities across the NCC which could result in a significant disruption to business continuity and material financial losses/obligations.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Corporate Services	An increase in extreme weather events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Infrastructure & Operations	Hotter summers and UV exposure may deteriorate asphalt and concrete-based surfaces (rutting, potholes), place stress on bridge joints, result in temporary closures of transportation systems and more frequent repairs and renewals.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Infrastructure & Operations	Hotter summers may increase cooling demands and associated costs to the NCC and tenants.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Infrastructure & Operations	An increase in shoulder season events, like increased winter freeze-thaw cycles, may lead to ice accumulation in shallow-buried stormwater infrastructure, resulting in reduced runoff capture, localized flooding, and more frequent repairs and renewals.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Infrastructure & Operations	An increase in the volume and intensity of precipitation may impact building roof and foundation drainage systems resulting in water ingress and damage, compromised building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Infrastructure & Operations	An increase in the volume and intensity of precipitation may result in increased hazards (accidents) on roads with improper crowning, sloping, and ditching.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Infrastructure & Operations	An increase in the volume and intensity of precipitation may lead to increased infiltration and inundation (I&I) and exceedance of wastewater treatment capacity resulting in a reduced level of service, reduced water quality to the receiving environment, non-compliance with regulatory requirements, and more frequent repairs and renewals.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Infrastructure & Operations	An increase in extreme winter weather events, like heavy snow, may result in damage to building roofs (snow load), compromised building integrity, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Infrastructure & Operations	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Land Use, Development & Planning	Hotter summers and/or high humidex periods may require modifications to existing master plans, and the restriction/closures of certain land uses.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Land Use, Development & Planning	An increase in the volume and intensity of precipitation resulting in riverine flooding may require modifications to existing master plans, and the restriction/closures of certain land uses.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Land Use, Development & Planning	An increase in extreme weather events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Natural Resources & Parks	Hotter summers may lead to reduced water quality at beaches and natural outdoor swimming areas (e.g., algal blooms) and result in health and safety risks to users.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Natural Resources & Parks	An increase in seasonal temperatures may lead to the intensification of existing invasive species, the migration of new invasive species, and the alteration of cultural landscapes.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Recreation, Education, Tourism & Cultural Heritage	Hotter summers and/or high humidex periods may increase the number and severity of heat-related health and safety issues, particularly for NCC staff, first responders, priority populations and those with existing health conditions.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Recreation, Education, Tourism & Cultural Heritage	An increase in seasonal variability may result in higher incidences of human and wildlife interactions resulting in health and safety risks to park users and NCC staff.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Recreation, Education, Tourism & Cultural Heritage	An increase in seasonal temperatures and/or stagnant waters from flooding may lead to the intensification of existing disease vectors, and the migration of new disease vectors and illnesses resulting in health and safety risks to park users and NCC staff.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Recreation, Education, Tourism & Cultural Heritage	An increase in extreme winter weather events, like freezing rain, may result in the increased use of road salt resulting in the accelerated degradation of heritage assets (e.g., stone walls).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Recreation, Education, Tourism & Cultural Heritage	An increase in climate-related events may result in the damage to and irreplaceable loss of the Crown Collection resulting in a loss of culturally and historically significant assets.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
Buildings, Housing & Real Estate	An increase in extreme weather events may result in trees falling causing damage to buildings and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium Risk	Develop a plan to address risk
Buildings, Housing & Real Estate	An increase in extreme wind events (micro-storms, strong winds or tornadoes) may result in damages to building envelopes and roof-top mechanical systems, compromised building functionality, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium Risk	Develop a plan to address risk
Buildings, Housing & Real Estate	An increase in extreme wind events (micro-storms, strong winds or tornadoes) may increase the number of extended power outages affecting building and facility operations.	High Vulnerability	Medium Risk	Develop a plan to address risk
Corporate Services	An increase in extreme weather events may result in damage to communication systems and electricity grids, impacting infrastructure monitoring, communication, security and emergency backup systems.	High Vulnerability	Medium Risk	Develop a plan to address risk

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Corporate Services	An increase in extreme weather events and the stresses that it places on the organization may negatively impact staff morale resulting in increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change.	High Vulnerability	Medium Risk	Develop a plan to address risk
Infrastructure & Operations	Hotter summers may increase the probability of wildfires resulting in damage to infrastructure (e.g., boardwalks, ecosystems) resulting in temporary/permanent closures of park and transportation systems.	High Vulnerability	Medium Risk	Develop a plan to address risk
Infrastructure & Operations	An increase in extreme wind events (micro-storms, strong winds or tornadoes), may result in damage to communication systems and electricity grids, impacting infrastructure monitoring and backup systems.	High Vulnerability	Medium Risk	Develop a plan to address risk
Natural Resources & Parks	Hotter summers may increase the probability of wildfires resulting in damage to park lands and place additional strain on forest management/wildfire suppression programs and resources.	High Vulnerability	Medium Risk	Develop a plan to address risk
Natural Resources & Parks	Hotter summers may result in the reduction of grounder water recharge and the shifting of ecosystems (wetland to upland) which may conflict with organizational priorities or land-use plans.	High Vulnerability	Medium Risk	Develop a plan to address risk
Natural Resources & Parks	An increase in seasonal variability may result in a longer but inconsistent growing season (e.g., impact to Tulip festival, planting of new trees, etc) resulting in increased maintenance requirements (e.g., irrigation demands, invasives management, etc.)	High Vulnerability	Medium Risk	Develop a plan to address risk
Natural Resources & Parks	An increase in extreme wind events, like micro-storms, strong winds or tornadoes, may result in damage to park infrastructure and trees resulting in temporary/permanent closures of trails and parks, increased risks to users, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium Risk	Develop a plan to address risk
Recreation, Education, Tourism & Cultural Heritage	An increase in extreme wind events, like micro-storms, strong winds or tornadoes, may result in damage to park infrastructure and trees resulting in temporary/permanent closures of park areas and outside event spaces, cancellation of outdoor activities/events, and lost revenues.	High Vulnerability	Medium Risk	Develop a plan to address risk
Recreation, Education, Tourism &	An increase in extreme wind events (micro-storms, strong winds or tornadoes) may accelerate the degradation of outdoor monuments, public art and heritage structures.	High Vulnerability	Medium Risk	Develop a plan to address risk

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Cultural Heritage				
Infrastructure & Operations	Increased winter freeze-thaw events may result in ice flows resulting in damage to shoreline assets and increased maintenance activity (repairing/replacing damaged infrastructure).	High Vulnerability	Medium-High Risk	Identify controls and monitor changes
Corporate Services	Hotter summers and/or high humidex periods may result in the delay of regularly scheduled maintenance programs, procedures and construction windows.	Low Vulnerability	Medium-High Risk	Identify controls and monitor changes
Infrastructure & Operations	Hotter summers and UV exposure may result in thermal expansion of wood-based infrastructure (warping, swelling, shrinkage) resulting in hazards to infrastructure users and more frequent repairs and renewals.	Low Vulnerability	Medium-High Risk	Identify controls and monitor changes
Infrastructure & Operations	Extreme winter weather events, like cold extremes combined with minimal snow cover, may lead to deeper frost resulting in water main breaks (cast iron water mains are particularly vulnerable) and hydrant leakage, and more frequent repairs and renewals.	Low Vulnerability	Medium-High Risk	Identify controls and monitor changes
Agriculture	An increase in extreme wind events (storms, strong winds or tornadoes) may disrupt operations and result in damage to crops and lands.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Agriculture	An increase in extreme wind events (micro-storms, strong winds or tornadoes) may result in damage to agricultural assets managed by the NCC (e.g., house and barn roofs).	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Corporate Services	Hotter summers may increase the probability of wildfires resulting in damage to infrastructure, temporary/permanent closures of NCC assets and disruptions to corporate services	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Corporate Services	Hotter summers and extreme weather availability may result in the damage and loss of IT systems resulting in operational delays, and more frequent repairs and renewals.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Corporate Services	Global climate change may cause supply chain instability and/or market failures impacting the availability of fuels and other goods required to maintain operations.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Infrastructure & Operations	An increase in multi-day ice storms may result in damage to communication systems and electricity grids, impacting infrastructure monitoring and backup systems.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Land Use, Development & Planning	Hotter summers and/or high humidex periods may result in park and recreation programming delays, modification to outdoor activities/events, and lost revenues.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Land Use, Development & Planning	An increase in seasonal variability may result in park seasons being extended in duration, increased park use, and increased operational demands.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Land Use, Development & Planning	Warmer, shorter winters and reduced snowfall may result in a shortened winter/outdoor park season requiring changes to programming and facilities (e.g., Rideau Canal Skateway, cross country skiing, etc.) and increased capital/maintenance costs.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Land Use, Development & Planning	An increase in extreme weather events and the stresses that it places on the organization may negatively impact staff morale resulting in increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Natural Resources & Parks	An increase in seasonal variability may result in higher incidences of human and wildlife interactions resulting in health and safety risks to park users and NCC staff.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Natural Resources & Parks	An increase in extreme winter weather events, like ice storms, may result in damage to park infrastructure and trees resulting in temporary/permanent closures of trails and parks, increased risks to users, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Natural Resources & Parks	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Recreation, Education, Tourism & Cultural Heritage	Hotter summers and high humidex periods may increase the strain on the mechanical systems and building infrastructure that houses the Crown Collection and could result in degradation and damage to wood-based Crown Collection items.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Recreation, Education, Tourism & Cultural Heritage	An increase in seasonal variability may result in park seasons being extended in duration, increased park use, and increased operational demands.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes

Sector	Impact Statement	Vulnerability Rating	Risk Rating	Level of Intervention Required
Recreation, Education, Tourism & Cultural Heritage	An increase in seasonal variability may result in a longer but inconsistent growing season (e.g., impact on Tulip festival, planting of new trees, etc) resulting in increased maintenance requirements (e.g., watering, invasives management, etc.) and costs.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Recreation, Education, Tourism & Cultural Heritage	An increase in seasonal temperatures may result in increased unauthorized encampments on lands and increased operational demands on NCC staff.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
Agriculture	An increase in summer temperatures may result in additional health and safety risks for outdoor agricultural workers.	Low Vulnerability	Medium Risk	Identify controls and monitor changes
Corporate Services	Hotter summers and seasonal variability may result in higher incidences of human and wildlife interactions resulting in health and safety risks to park users and NCC staff.	Low Vulnerability	Medium Risk	Identify controls and monitor changes
Corporate Services	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	Low Vulnerability	Medium Risk	Identify controls and monitor changes
Land Use, Development & Planning	An increase in extreme weather events may require modifications to existing master plans, and the restriction/closures of certain land uses resulting in a loss of land area available for future development and use.	Low Vulnerability	Medium Risk	Identify controls and monitor changes

Appendix B: Impacts grouped by NCC Sector

The following tables include a summary of the impact statements for each of the eight sectors:

1. Infrastructure & Operations
2. Natural Resources & Parks
3. Recreation, Education, Tourism & Cultural Heritage
4. Buildings, Housing & Real Estate
5. Land Use, Development & Planning
6. Agriculture
7. Corporate Services
8. Archaeology

Each impact statement has three components:

1. A climatic hazard (i.e., increase in freezing rain events; warmer summer temperatures)
2. The outcome of the climatic hazard (i.e., damage to trees and electrical infrastructure; heatwaves)
3. The impact associated with this outcome (i.e., power outages; specific health impacts)

Each table shows the vulnerability rating, average risk rating and recommended risk response for each impact statement. These have been organized from highest to lowest priority based on the required risk response.

B.1 Infrastructure & Operations

Table B.1. Infrastructure & Operations Impact Statements (IS# = Impact Statement number)

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
11	An increase in shoulder season events, like freezing rain, may lead to slippery roads and trails, resulting in reduced park/facility access, increased risks to users, and increased maintenance activity (snow clearing, etc.).	High Vulnerability	High Risk	Immediate action required
14	An increase in the volume and intensity of precipitation, high snowpack and/or warmer springs may result in the wash-out of pathways and roads and sinkholes, resulting in temporary/permanent closures of transportation systems, and more frequent repairs and renewals.	High Vulnerability	High Risk	Immediate action required

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
15	An increase in the volume and intensity of precipitation may result in the wash-out of boardwalks and staircases, resulting in temporary/permanent closures of active transportation systems and more frequent repairs and renewals.	High Vulnerability	High Risk	Immediate action required
19	An increase in the volume and intensity of precipitation may lead to the overtopping of damns and weirs resulting in damage to assets, uncontrolled downstream flows, and more frequent repairs and renewals.	High Vulnerability	High Risk	Immediate action required
20	An increase in the volume and intensity of precipitation may lead to shoreline erosion, damage to assets (e.g., bridges, dams), reduced asset lifespan, and more frequent repairs and renewals.	High Vulnerability	High Risk	Immediate action required
1	Hotter summers and/or high humidex periods may result in the delay of regularly scheduled maintenance programs, procedures and construction windows.	Medium Vulnerability	High Risk	Immediate action required
4	Hotter summers may increase the occurrence of algae blooms in water systems resulting in reduced water quality and impact on NCC programs (e.g., Lake Philippe campground, Rideau Canal).	Medium Vulnerability	High Risk	Immediate action required
7	An increase in shoulder season events, like increased freeze-thaw cycles, may result in the accelerated degradation of roads, pathways and bridge infrastructure, temporary closures of transportation systems, and more frequent repairs and renewals.	Medium Vulnerability	High Risk	Immediate action required
9	An increase in shoulder season events, like increased freeze-thaw cycles and freezing rain, may damage vegetation and increase slope stability issues in susceptible areas, resulting in public safety issues and temporary/permanent closures of park areas.	Medium Vulnerability	High Risk	Immediate action required
16	An increase in the volume and intensity of precipitation may result in the scouring, erosion, side-slope failure, and foundation settlement of bridges, resulting in temporary/permanent closures of transportation systems and more frequent repairs and renewals.	High Vulnerability	Medium-High Risk	Immediate action required
17	An increase in the volume and intensity of precipitation may result in flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium-High Risk	Immediate action required

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
18	An increase in the volume and intensity of precipitation may lead to damaged stormwater infrastructure (e.g., increased sediment and material transport leading to blockages and clogging of conveyance systems) and culverts, resulting in reduced run-off capture, localized flooding, and more frequent repairs and renewals.	High Vulnerability	Medium-High Risk	Immediate action required
27	An increase in climate-related events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	Medium-High Risk	Immediate action required
5	Hotter summers may increase the probability of wildfires resulting in damage to infrastructure (e.g., boardwalks, ecosystems) resulting in temporary/permanent closures of park and transportation systems.	High Vulnerability	Medium Risk	Develop a plan to address risk
25	An increase in extreme wind events (micro-storms, strong winds or tornadoes), may result in damage to communication systems and electricity grids, impacting infrastructure monitoring and backup systems.	High Vulnerability	Medium Risk	Develop a plan to address risk
3	Hotter summers and UV exposure may deteriorate asphalt and concrete-based surfaces (rutting, potholes), place stress on bridge joints, result in temporary closures of transportation systems and more frequent repairs and renewals.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
6	Hotter summers may increase cooling demands and associated costs to the NCC and tenants.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
8	An increase in shoulder season events, like increased winter freeze-thaw cycles, may lead to ice accumulation in shallow-buried stormwater infrastructure, resulting in reduced runoff capture, localized flooding, and more frequent repairs and renewals.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
12	An increase in the volume and intensity of precipitation may impact building roof and foundation drainage systems resulting in water ingress and damage, compromised building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
13	An increase in the volume and intensity of precipitation may result in increased hazards (accidents) on roads with improper crowning, sloping, and ditching.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
21	An increase in the volume and intensity of precipitation may lead to increased infiltration and inundation (I&I) and exceedance of wastewater treatment capacity resulting in a reduced level of service, reduced water quality to the receiving environment, non-compliance with regulatory requirements, and more frequent repairs and renewals.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
22	An increase in extreme winter weather events, like heavy snow, may result in damage to building roofs (snow load), compromised building integrity, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
26	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
23	Increased winter freeze-thaw events may result in ice flows resulting in damage to shoreline assets and increased maintenance activity (repairing/replacing damaged infrastructure).	High Vulnerability	Medium-High Risk	Identify controls and monitor changes
10	An increase in multi-day ice storms may result in damage to communication systems and electricity grids, impacting infrastructure monitoring and backup systems.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
2	Hotter summers and UV exposure may result in thermal expansion of wood-based infrastructure (warping, swelling, shrinkage) resulting in hazards to infrastructure users and more frequent repairs and renewals.	Low Vulnerability	Medium-High Risk	Identify controls and monitor changes
24	Extreme winter weather events, like cold extremes combined with minimal snow cover, may lead to deeper frost resulting in water main breaks (cast iron water mains are particularly vulnerable) and hydrant leakage, and more frequent repairs and renewals.	Low Vulnerability	Medium-High Risk	Identify controls and monitor changes

B.2 Natural Resources & Parks

Table B.2 Natural Resources Impact Statements (IS# = Impact Statement number)

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
15	An increase in the volume and intensity of precipitation may result in overland flooding resulting in the temporary/permanent closure of trails and park lands, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	High Risk	Immediate action required
2	Hotter summers may result in reduced aquifer recharge, which may result in lower baseflow to streams and degraded aquatic habitat.	High Vulnerability	Medium-High Risk	Immediate action required
7	An increase in seasonal variability may result in park seasons being extended in duration, increased park use, and increased operational demands.	High Vulnerability	Medium-High Risk	Immediate action required
11	An increase in seasonal temperatures may lead to the intensification of existing disease vectors, and the migration of new disease vectors and illnesses resulting in health and safety risks to park users and NCC staff.	High Vulnerability	Medium-High Risk	Immediate action required
12	Warmer, shorter winters and reduced snowfall may result in a shortened winter/outdoor park season requiring changes to programming and facilities (e.g., Rideau Canal Skateway, cross country skiing, etc.) and increased capital/maintenance costs.	High Vulnerability	Medium-High Risk	Immediate action required
14	An increase in the volume and intensity of precipitation, high snowpack and/or warmer springs may result in nutrient loading of nearby aquatic ecosystems (soil erosion and run-off).	High Vulnerability	Medium-High Risk	Immediate action required
16	An increase in the volume and intensity of precipitation may lead to shoreline erosion, damage to assets (e.g., bridges, dams), reduced asset lifespan, and more frequent repairs and renewals.	High Vulnerability	Medium-High Risk	Immediate action required
18	An increase in the volume and intensity of precipitation may lead to the exposure or destabilization of contaminated park lands resulting in regulatory and financial liabilities for the NCC.	High Vulnerability	Medium-High Risk	Immediate action required
23	An increase in climate-related events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	Medium-High Risk	Immediate action required
3	Hotter summers and/or high humidex periods may increase public demand for shaded areas, especially on surfaces that exacerbate the urban heat island effect.	Medium Vulnerability	High Risk	Immediate action required

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
4	Hotter summers and/or high humidex periods may result in park and recreation programming delays, modification to outdoor activities/events, and lost revenues.	Medium Vulnerability	High Risk	Immediate action required
17	An increase in the volume and intensity of precipitation may result in landslides in inhabited or built-up areas resulting in temporary/permanent closures, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	Medium Vulnerability	High Risk	Immediate action required
21	An increase in extreme winter weather events, like freezing rain, may increase road salt use and could accelerate the susceptibility/mortality of heritage landscapes (trees along confederation boulevard) and damage to aquatic ecosystems	Medium Vulnerability	High Risk	Immediate action required
5	Hotter summers may increase the probability of wildfires resulting in damage to park lands and place additional strain on forest management/wildfire suppression programs and resources.	High Vulnerability	Medium Risk	Develop a plan to address risk
6	Hotter summers may result in the reduction of grounder water recharge and the shifting of ecosystems (wetland to upland) which may conflict with organizational priorities or land-use plans.	High Vulnerability	Medium Risk	Develop a plan to address risk
8	An increase in seasonal variability may result in a longer but inconsistent growing season (e.g., impact to Tulip festival, planting of new trees, etc.) resulting in increased maintenance requirements (e.g., irrigation demands, invasives management, etc.)	High Vulnerability	Medium Risk	Develop a plan to address risk
19	An increase in extreme wind events, like micro-storms, strong winds or tornadoes, may result in damage to park infrastructure and trees resulting in temporary/permanent closures of trails and parks, increased risks to users, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium Risk	Develop a plan to address risk
1	Hotter summers may lead to reduced water quality at beaches and natural outdoor swimming areas (e.g., algal blooms) and result in health and safety risks to users.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
10	An increase in seasonal temperatures may lead to the intensification of existing invasive species, the migration of new invasive species, and the alteration of cultural landscapes.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
13	An increase in shoulder season events, like increased winter freeze-thaw cycles and ice storms, may result in the accelerated degradation of park trails and associated infrastructure, temporary/permanent closures and increased maintenance activity (repairing/replacing infrastructure).	Low Vulnerability	High Risk	Develop a plan to address risk

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
9	An increase in seasonal variability may result in higher incidences of human and wildlife interactions resulting in health and safety risks to park users and NCC staff.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
20	An increase in extreme winter weather events, like ice storms, may result in damage to park infrastructure and trees resulting in temporary/permanent closures of trails and parks, increased risks to users, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
22	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
5	An increase in seasonal variability may result in park seasons being extended in duration, increased park use, and increased operational demands.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
6	An increase in seasonal variability may result in a longer but inconsistent growing season (e.g., impact to Tulip festival, planting of new trees, etc.) resulting in increased maintenance requirements (e.g., watering, invasives management, etc.) and costs.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
11	An increase in seasonal temperatures may result in increased unauthorized encampments on lands and increased operational demands on NCC staff.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes

B.3 Recreation, Education, Tourism & Cultural Heritage

Table B.3 Recreation, Education, Tourism & Cultural Heritage Impact Statements (IS# = Impact Statement number)

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
1	Hotter summers may lead to reduced water quality at beaches and natural outdoor swimming areas (e.g., algal blooms) and result in health and safety risks to users.	High Vulnerability	High Risk	Immediate action required
2	Hotter summers and/or high humidex periods may result in park and recreation programming delays, modification to outdoor activities/events, and lost revenues.	High Vulnerability	High Risk	Immediate action required
8	An increase in seasonal temperatures may lead to the intensification of existing invasive species and diseases, the migration of new invasive species, and the alteration of natural habitats.	High Vulnerability	High Risk	Immediate action required
16	An increase in extreme weather events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	High Risk	Immediate action required
17	An increase in extreme weather events and the stresses that it places on the organization may negatively impact staff morale resulting in increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change.	Medium Vulnerability	High Risk	Immediate action required
10	Warmer, shorter winters and reduced snowfall may result in a shortened winter/outdoor park season requiring changes to programming and facilities (e.g., Rideau Canal Skateway, cross country skiing, etc.) and increased capital/maintenance costs.	High Vulnerability	Medium-High Risk	Immediate action required
13	An increase in extreme wind events, like micro-storms, strong winds or tornadoes, may result in damage to park infrastructure and trees resulting in temporary/permanent closures of park areas and outside event spaces, cancellation of outdoor activities/events, and lost revenues.	High Vulnerability	Medium Risk	Develop a plan to address risk
14	An increase in extreme wind events (micro-storms, strong winds or tornadoes) may accelerate the degradation of outdoor monuments, public art and heritage structures.	High Vulnerability	Medium Risk	Develop a plan to address risk
3	Hotter summers and/or high humidex periods may increase the number and severity of heat-related health and safety issues, particularly for NCC staff, first responders, priority populations and those with existing health conditions.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
7	An increase in seasonal variability may result in higher incidences of human and wildlife interactions resulting in health and safety risks to park users and NCC staff.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
9	An increase in seasonal temperatures and/or stagnant waters from flooding may lead to the intensification of existing disease vectors, and the migration of new disease vectors and illnesses resulting in health and safety risks to park users and NCC staff.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
12	An increase in extreme winter weather events, like freezing rain, may result in the increased use of road salt resulting in the accelerated degradation of heritage assets (e.g., stone walls).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
15	An increase in climate-related events may result in damage to and irreplaceable loss of the Crown Collection resulting in a loss of culturally and historically significant assets.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
4	Hotter summers and high humidex periods may increase the strain on the mechanical systems and building infrastructure that houses the Crown Collection and could result in degradation and damage to wood-based Crown Collection items.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes

B.4 Buildings, Housing & Real Estate

Table B.4. Building, Housing and Real Estate Impact Statements (IS# = Impact Statement number)

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
2	Hotter summers may increase cooling demands and associated costs to the NCC and tenants.	High Vulnerability	Very High Risk	Immediate action required
5	An increase in the volume and intensity of precipitation may result in flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Very High Risk	Immediate action required
3	An increase in shoulder season events, like increased freeze-thaw cycles may result in damage to buildings, reduced asset life expectancy, and more frequent repairs and renewals to buildings.	High Vulnerability	High Risk	Immediate action required
6	An increase in the volume and intensity of precipitation may impact building roof and foundation drainage systems resulting in water ingress and damage, compromised building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	High Risk	Immediate action required
7	An increase in the volume and intensity of precipitation resulting in overland flooding may result in basement flooding damage and mould-related illnesses to NCC tenants and staff, if not addressed.	High Vulnerability	High Risk	Immediate action required
9	An increase in extreme winter weather events, like freezing rain and heavy snow, may result in damage to building roofs (ice and snow load), compromised building integrity, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	High Risk	Immediate action required
14	An increase in extreme weather events and the stresses that it places on the organization may negatively impact staff morale resulting in increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change.	Medium Vulnerability	High Risk	Immediate action required
15	Global climate change may cause supply chain instability and/or market failures impacting the availability of fuels and other goods required to maintain operations.	High Vulnerability	High Risk	Immediate action required
1	Hotter summers may increase cooling demands, requirements to improve building performance, and increased capital costs to the NCC.	High Vulnerability	Medium-High Risk	Immediate action required

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
4	An increase in shoulder season temperature variability may result in more operational demands to accommodate mechanical systems to the varying temperatures.	High Vulnerability	Medium-High Risk	Immediate action required
12	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	High Vulnerability	Medium-High Risk	Immediate action required
13	An increase in extreme weather events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	Medium-High Risk	Immediate action required
8	An increase in extreme weather events may result in trees falling causing damage to buildings and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium Risk	Develop a plan to address risk
10	An increase in extreme wind events (micro-storms, strong winds or tornadoes) may result in damages to building envelopes and roof-top mechanical systems, compromised building functionality, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium Risk	Develop a plan to address risk
11	An increase in extreme wind events (micro-storms, strong winds or tornadoes) may increase the number of extended power outages affecting building and facility operations.	High Vulnerability	Medium Risk	Develop a plan to address risk

B.5 Agriculture

Table B.5. Agriculture Impact Statements (IS# = Impact Statement number)

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Risk Response
7	An increase in the volume and intensity of precipitation may result in saturation or flooding of agricultural lands.	High Vulnerability	High Risk	Immediate action required
9	An increase in the volume and intensity of precipitation may result in nutrient loading of nearby aquatic ecosystems, increased buffer requirements, reduced lands available for agriculture, and a lost revenue source to the NCC.	High Vulnerability	High Risk	Immediate action required
12	An increase in extreme winter weather events, like freezing rain and heavy snow, may result in damage to agricultural buildings (snow load), compromised building integrity, health and safety risks to tenants, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	High Risk	Immediate action required
15	An increase in climate-related events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	High Vulnerability	High Risk	Immediate action required
2	Hotter summers may increase cooling demands, requirements to improve building performance, and increased capital costs to the NCC.	Medium Vulnerability	High Risk	Immediate action required
3	Hotter summers and variable precipitation may result in dry wells increasing potable water demands by agricultural tenants on wells (East end) and in increased costs to the NCC.	Medium Vulnerability	High Risk	Immediate action required
13	An increase in extreme weather events may result in a health and safety risk to agricultural workers.	Medium Vulnerability	High Risk	Immediate action required
4	An increase in summer temperatures may result in algal blooms that can reduce the availability of water safe for growing food and agricultural operations.	High Vulnerability	Medium-High Risk	Immediate action required
8	An increase in the volume and intensity of precipitation may result in flooding of buildings, stranded assets in floodplains, compromised facility/building functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up).	High Vulnerability	Medium-High Risk	Immediate action required
1	Hotter summers and seasonal variability may result in reduced agricultural yields (drought, pollinator lifecycle changes, pests, invasive species) and loss of revenue to the NCC.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
14	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Risk Response
6	Hotter summers and variable precipitation may threaten the success of agricultural operations, resulting in a decline of agricultural tenants on NCC lands and a lost revenue source for the NCC.	Low Vulnerability	High Risk	Develop a plan to address risk
10	An increase in extreme wind events (storms, strong winds or tornadoes) may disrupt operations and result in damage to crops and lands.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
11	An increase in extreme wind events (micro-storms, strong winds or tornadoes) may result in damage to agricultural assets managed by the NCC (e.g., house and barn roofs).	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
5	An increase in summer temperatures may result in additional health and safety risks for outdoor agricultural workers.	Low Vulnerability	Medium Risk	Identify controls and monitor changes

B.6 Land Use, Development & Planning

Table B.1. Land-Use, Development and Planning Impact Statements (IS# = Impact Statement number)

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
2	Hotter summers and/or high humidex periods may increase public demand for shaded areas, especially on surfaces that exacerbate the urban heat island effect.	High Vulnerability	Medium-High Risk	Immediate action required
7	An increase in the volume and intensity of precipitation may lead to the exposure or destabilization of contaminated park lands resulting in regulatory and financial liabilities for the NCC.	High Vulnerability	Medium-High Risk	Immediate action required
1	Hotter summers and/or high humidex periods may require modifications to existing master plans, and the restriction/closures of certain land uses.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
6	An increase in the volume and intensity of precipitation resulting in riverine flooding may require modifications to existing master plans, and the restriction/closures of certain land uses.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
9	An increase in extreme weather events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
3	Hotter summers and/or high humidex periods may result in park and recreation programming delays, modification to outdoor activities/events, and lost revenues.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
4	An increase in seasonal variability may result in park seasons being extended in duration, increased park use, and increased operational demands.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
5	Warmer, shorter winters and reduced snowfall may result in a shortened winter/outdoor park season requiring changes to programming and facilities (e.g., Rideau Canal Skateway, cross country skiing, etc.) and increased capital/maintenance costs.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
10	An increase in extreme weather events and the stresses that it places on the organization may negatively impact staff morale resulting in increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
8	An increase in extreme weather events may require modifications to existing master plans, and the restriction/closures of certain land uses resulting in a loss of land area available for future development and use.	Low Vulnerability	Medium Risk	Identify controls and monitor changes

B.7 Corporate Services

Table B.7. Corporate Services Impact Statements (IS# = Impact Statement number)

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
5	An increase in extreme weather events may result in damage to communication systems and electricity grids, impacting infrastructure monitoring, communication, security and emergency backup systems.	High Vulnerability	Medium Risk	Develop a plan to address risk
9	An increase in extreme weather events and the stresses that it places on the organization may negatively impact staff morale resulting in increased turnover, and a loss of organizational knowledge on how to adapt the organization to the effects of climate change.	High Vulnerability	Medium Risk	Develop a plan to address risk
7	An increase in extreme weather events may exacerbate underlying systematic vulnerabilities across the NCC which could result in significant disruption to business continuity and material financial losses/obligations.	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
8	An increase in extreme weather events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk
1	Hotter summers may increase the probability of wildfires resulting in damage to infrastructure, temporary/permanent closures of NCC assets and disruptions to corporate services	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
3	Hotter summers and extreme weather availability may result in the damage and loss of IT systems resulting in operational delays, and more frequent repairs and renewals.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
10	Global climate change may cause supply chain instability and/or market failures impacting the availability of fuels and other goods required to maintain operations.	Medium Vulnerability	Medium Risk	Identify controls and monitor changes
2	Hotter summers and/or high humidex periods may result in the delay of regularly scheduled maintenance programs, procedures and construction windows.	Low Vulnerability	Medium-High Risk	Identify controls and monitor changes
4	Hotter summers and seasonal variability may result in higher incidences of human and wildlife interactions resulting in health and safety risks to park users and NCC staff.	Low Vulnerability	Medium Risk	Identify controls and monitor changes
6	An increase in climate-related events may result in an increase in health and risks to NCC contractors and staff.	Low Vulnerability	Medium Risk	Identify controls and monitor changes

B.8 Archaeology

Table B.8. Archaeology Impact Statements (IS# = Impact Statement number)

IS#	Impact Statement	Sector Vulnerability Rating	Average Risk	Vulnerability & Risk Response
3	Hotter summers will result in increased water-based recreational activity resulting in disruption and damage to archaeological sites (e.g., boat wakes, shoreline gatherings and parties).	High Vulnerability	Very High Risk	Immediate action required
1	Hotter summers and seasonal variability will result in increased NCC park use resulting in the disruption and damage to archaeological sites (e.g., digging pits and creating mud windbreaks for campfires, displacing logs and rocks for seats, etc.).	High Vulnerability	High Risk	Immediate action required
4	An increase in the frequency, volume and intensity of rainstorms and flooding will lead to accelerated shoreline erosion, damage to archaeological sites and a permanent loss of archaeological resources.	High Vulnerability	High Risk	Immediate action required
5	An increase in the frequency, volume and intensity of precipitation will lead to increased ground heave, and subsidence resulting in damage to archaeological sites.	High Vulnerability	High Risk	Immediate action required
6	An increase in shoulder season events, like increased winter freeze-thaw cycles and ice storms, will damage vegetation, adversely impacting clay and silt sediments and increase slope instability in susceptible areas, resulting in damage to archaeological sites.	High Vulnerability	High Risk	Immediate action required
2	Hotter summers and/or high humidex periods will place NCC archaeologists, staff and contractors at greater risk of heat-related health and safety risks.	Medium Vulnerability	High Risk	Immediate action required
7	An increase in climate-related events may reduce the capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding).	Medium Vulnerability	Medium-High Risk	Develop a plan to address risk

Appendix C: Methodology

A 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 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 helps to prioritize these potential problems or vulnerabilities by assessing the probability of the climate hazard occurring and estimating what social, economic and environmental consequences may occur should the climate hazard interact with the population, asset, system or sector in question. In determining the probability of the occurrence of a hazard, the annual frequency of a climate hazard is compared to the historical climate trends and a threshold relevant to the population, asset, system or sector being considered. Priority climate risks arise as a result of the confluence of vulnerability, probability, and consequence. The overall risk rating serves to prioritize impacts for adaptation planning and risk reduction measures.

C.1 Engagement

NCC staff were engaged at three pivotal points during the CVRA assessment: group interviews, a vulnerability workshop and a vulnerability validation and consequence rating workshop. Many/majority of findings described in this report were reported by staff via these workshops.

In the first interaction, group interviews, organized by NCC sector, were completed in October 2021 to engage with staff on the purpose of the project and to discuss how climate change has impacted the sector, how the NCC responded, and what challenges the staff perceive as barriers to adapting to the effects of climate change. The information and follow-up data collected from these interviews were used to inform the development of 124 impact statements and the vulnerability assessment.

During the vulnerability workshops, held in late October and early November 2021, NCC staff were presented with the draft impact statements applicable to their sector and asked to provide input as to whether any impacts were missed or if the impact statements required modification. During these sectoral workshops, participants were asked to rate the sensitivity and adaptive capacity for each impact statement and the average results were provided back to the group in real-time to facilitate discussion about the scoring rationale and to discuss vulnerabilities. Following the workshops, workshop summary reports were prepared and distributed to participants for feedback and comments. The workshop summaries contained updated impact statements based on participant feedback, draft vulnerability ratings, and a description of the vulnerabilities for each impact statement at the sector and organizational level.

The third and final round of workshops, held in late November 2021, focused on validating the vulnerability ratings and getting workshop participants to rate the potential social, environmental and economic consequences for each of the impact statements. Like the vulnerability workshops,

participants were able to see the average group rating in real-time to facilitate discussion about their scoring rationale. Following the workshops, workshop summary reports were prepared and distributed to participants for feedback and comments. These workshop summaries presented the final vulnerability rating, climate probabilities, draft risk ratings for each climate period, an overall risk and assessment rating for each impact statement.

NCC staff were given the opportunity to review and comment on this document prior to finalization. Two rounds of reviews were completed.

C.2 Methodology Overview

NCC's CVRA process is based on ICLEI's Building Adaptive & Resilient Communities (BARC) protocol, ISO 14090-92 standards and NCC's Enterprise Risk Management (ERM) framework which is based on the ISO 31000 risk management standard. This hybrid approach enabled the NCC to utilize climate vulnerability and risk information generated by the Ville de Gatineau and the City of Ottawa who are utilizing the BARC approach but was specific enough to assess the broad range of physical infrastructure, assets, operations and programs (i.e., natural systems, recreational programs) managed by the NCC. This approach is depicted in Figure C.1.

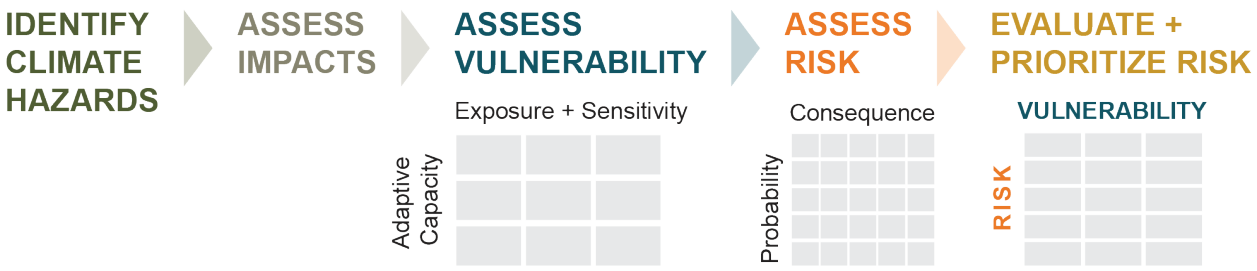

Figure C.1. Climate Vulnerability & Risk Assessment Framework

C.2.1. Variances from the BARC Protocol

The objective of the BARC protocol is to identify how projected climatic changes could affect service areas/sectors in a community or organization, 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 NCC CVRA method built on the methods of the BARC protocol, but made some important adjustments:

- 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 BARC protocol suggests using the vulnerability assessment as a form of triage to reduce the number of impact statements that go through the risk assessment stage. The NCC methodology evaluated the vulnerability and risks for all impact statements to inform the prioritization process. The intent of this change was to avoid overlooking an impact with a low vulnerability but very

high risk, which would, at a minimum, require a plan developed to mitigate the risk to the organization.

- The NCC 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 NCC's ERM framework to align with the NCC's current risk evaluation and management system.
- The NCC methodology risk matrix and prioritization tables are taken from the NCC's ERM framework to align with the NCC's current risk evaluation and management system.
- The NCC methodology evaluated risks for all future periods (Baseline,2021-2050, 2041-2070, and 2071-2100) 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 sectors, assets and programs managed by the NCC, the selection of one period may result in the incorrect prioritization of risk.

C.2.2. Climate Hazard & Impact Identification

The first step in the climate change risk and vulnerability assessment process begins with using climate change projections for the NCR 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 NCR, the NCC and the City of Ottawa released a comprehensive climate change projection study for the NCR 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 for the NCR 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 C.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.[25]

[25] Global Warming of 1.5 ºC — (ipcc.ch)

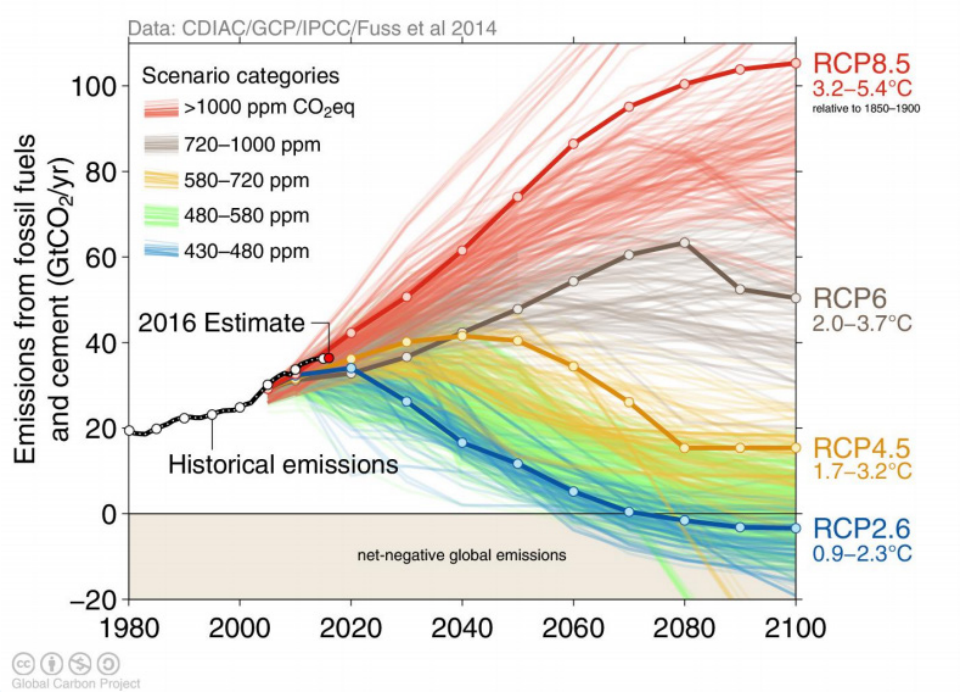

Figure C.2. Representative Concentration Pathway (RCP) Emissions Scenarios [26]

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

1. A climatic hazard (i.e., increase in freezing rain events; warmer summer temperatures)
2. The outcome of the climatic hazard (i.e., damage to trees and electrical infrastructure; heatwaves)
3. The impact associated with this outcome (i.e., power outages; specific health impacts)

This step involved engaging with NCC staff to identify past impacts and current challenges to their sector, using information prepared by the City of Ottawa (e.g., impact statements), and the Ville de Gatineau, reviewing relevant internal policy and process information provided by the NCC and the reported climate impacts to organizations within the study area. GIS maps and other data sets made available by the NCC and stakeholders were also used to identify climate interactions. The GIS data that was made available to complete this analysis included:

- Flood depth from The Rideau Valley Conservation Authority in Ottawa
- Ontario floodplains (100 Year and 350 Year)
- Contaminated site records

[26] Source: Global Carbon Project, 2016

- Lands owned or managed by the NCC
- The Gatineau Park boundary
- The Greenbelt boundary
- Digital Elevation Model
- Tree canopy data
- Socio-economic Status data
- Land surface temperature
- Provincial fire data
- NCC Valued Natural Ecosystems and Habitat data

Through this work, 27 climate indices were used to generate a total of 124 impact statements for the NCC. It is important to note that there are actually only 92 distinct impact statements, however several impacts appear more than once because they received different risk scores depending on the sector.

The following sections examine these priority risks by NCC sector. The full list of impact statements ranked according to risk level and the level of intervention required can be found in Appendix A and the same impacts grouped by NCC sector can be found in Appendix B.

C.2.3. Assessing Vulnerability

For each impact statement identified, a vulnerability assessment was completed with NCC staff in a workshop setting. Vulnerability is the measure of the extent to which a segment of the population, asset, system or sector (as described in the impact statement) is susceptible to, or unable to cope with, the impacts of a changing climate. Vulnerability is based on the following 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 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 an organization's 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 or sector is susceptible to, and/or unable to cope with, the hazards of climate change, including climate variability and extreme weather conditions. This is depicted in Figure C.3.

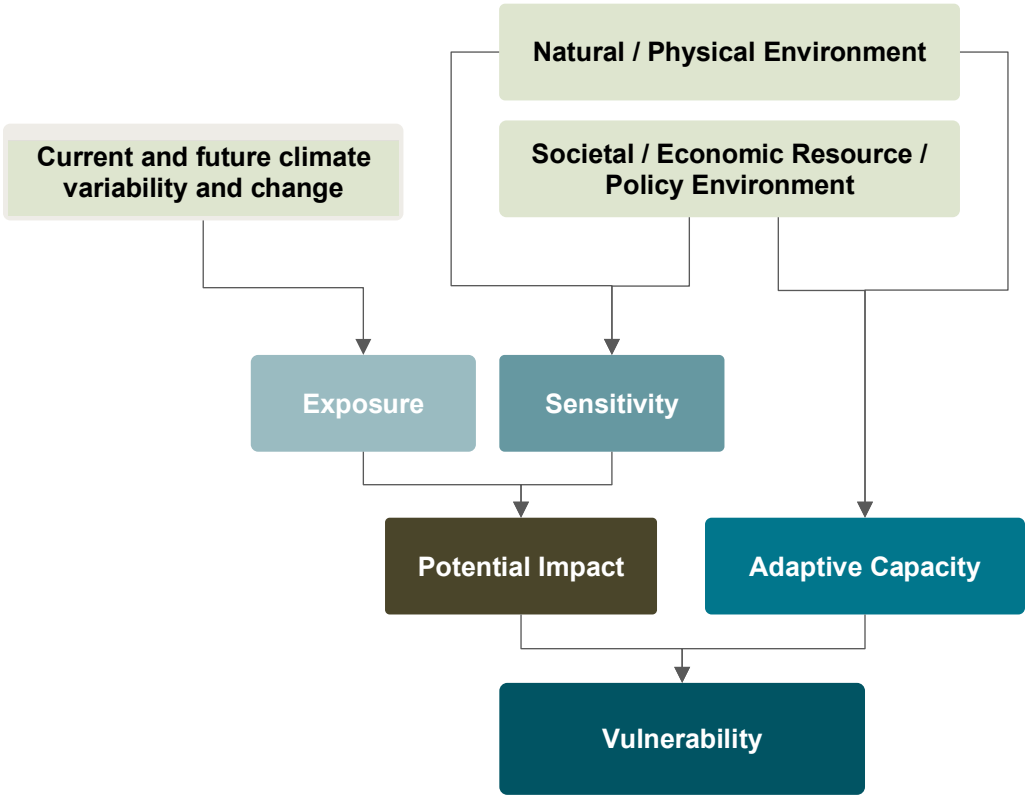

Figure C.3. Components of Vulnerability

Assessing Exposure & Sensitivity

The first step in assessing sensitivity is to assess whether a sector 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 sector subject to existing stresses?
- Are there current climate hazards that result in impacts to the sector?
- Does the sector have limiting factors that may be affected or exacerbated by climate change?
- How would a climate impact affect the ability of the sector to function[27]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?

[27] 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).

Sensitivity was assessed using a 3-point scale based on how the functionality of the NCC department /sector will be affected (as presented in Table C.1).

Table C.1. 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 socio-economic influences on adaptive capacity. To determine adaptive capacity, the impacts will be assessed on the level of effort and intervention required by the NCC to adjust to the impact. When assessing adaptive capacity, NCC staff were 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 C.2).

Table C.2. 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 sector, the vulnerability rating was determined using the following matrix (Figure C.4). The NCC sectors 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.

Adaptive Capacity	Impact Rating (Sensitivity + Exposure)		
	S1	S2	S3
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 C.4. Vulnerability Matrix

In addition to engaging with NCC staff where available, asset location data, flood maps, and geospatial data were used to identify the proximity of NCC assets to physical impacts (e.g., assets in the 100-year and 350-year flood plain, heat exposure, proximity to slopes, etc.).

C.2.4. 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 (Figure C.5). The CVRA methodology evaluated risks for all future periods (Baseline, 2021-2050, 2041-2070 and 2071-2100) and took an average of the 2021-2100 period to inform the prioritization process. Where there were duplicate or similar impact statements due to different NCC sectors evaluating the same impacts, the highest risk rating was applied.

Probability/Likelihood	Consequence				
	Very Low 1	Low 2	Medium 3	High 4	Very High 5
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

Figure C.5. Risk Matrix

The probability ratings were based on the NCR 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 relied on a 5-point scale where 1 is 'rare' and 5 is 'almost certain' the event will occur (Table C.3). The climate variables and probability ratings used in the analysis are presented in Table C.4.

Table C.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

Probability Table

The following table presents the climate probability ratings used in the CVRA assessment.

Table C.4. Climate Probability Ratings

Climate Hazard Theme	Parameter	Climate Indicator Threshold	Probability Rating			
			(Baseline)	(2021-2050)	(2041-2070)	(2071-2100)
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
		# of days with Max T > 30C (summer)	4	4	5	5
		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

Climate Hazard Theme	Parameter	Climate Indicator Threshold	Probability Rating			
			(Baseline)	(2021-2050)	(2041-2070)	(2071-2100)
	Shift in Freeze-Thaw Cycles	Annual Freeze-Thaw Cycles [Number of Days]	3	3	4	4
	Seasonal Average Temperature in Winter	Winter mean Temperature based on -6 ℃	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
	5 Day Max Total Precipitation in Spring	Monthly 5-day Spring Max Precipitation (MAM)	4	4	4	5
	Decrease in Total Snowfall	Annual Total Snowfall [cm]	5	4	4	3
	Shorter Snow Season	Number of Days with Snowfall [Number of Days]	5	5	4	4
	High Variability in Extreme Snow	Number of Days with Snowfall >= 10 cm/day [Number of Days]	4	4	3	3
Wind	Reduced Wind Chill	Number of Days Wind Chill is between -35°C and -25°C [Number of Days]	5	5	4	4
Humidity	Increase in Humidex	Number of Days Humidex > 40°C [Number of Days]	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

Climate Hazard Theme	Parameter	Climate Indicator Threshold	Probability Rating			
			(Baseline)	(2021-2050)	(2041-2070)	(2071-2100)
	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
	Lightning	Occurrence of lightning events	4	4	4	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 average value of the economic, social and environmental consequence ratings was used as the final consequence rating. The following consequence rating scale is based on the NCC’s Corporate Risk Framework.

Table C.5. Consequence Rating Scale

	Impact Areas		
Rating	**Social**	**Economic**	**Environment**
Extreme (5)	• Loss of life • All strategic objectives are unmet • Significant complaints on most programs and assets • Media requesting the dissolution of the organization • Extensive and sustained reputational damage and widespread public criticism in the media • Extensive legal or compliance issues	• Damage of more than $5M • Cost overrun of more than 50% on an important project • Loss of a significant landmark	• Major loss of environmental amenity (includes air, water, soil, vegetation, natural heritage and ecological functions) and irrecoverable damage
Major (4)	• Severe injury to employee or member of public • Underperformance on many strategic objectives • Major public complaints concerning many programs or assets • Media requesting the departure of a high-ranking member of the organization	• Damage between $1M and $5M • Cost overrun between 25% and 50% on an important project • Loss of an important and irreplaceable asset	• Severe and widespread loss of environmental amenity and danger of continuing environmental damage
Moderate (3)	• Injury to employee or member of public • Underperformance on many operational or strategic objectives • Public complaint conserving a program or asset • Substantial amount of unfavourable media reports	• Damage between $100K to $1M • Cost overrun between 10 and 25% • Loss of an important, but replaceable asset	• Isolated but significant instances of environmental damage that could be reversed with intensive efforts

	Impact Areas		
Rating	**Social**	**Economic**	**Environment**
Minor (2)	• Minor injury to employee or public • Slight underperformance on a few operational objectives • Minor complaint from the public concerning a program or asset • A few unfavourable media reports	• Damage between $10K and $100K • Cost overrun between 5 and 10% • Limited loss of assets	• Minor instances of environmental damage that could be reversed
Insignificant (1)	• Little or no injuries • Slight underperformance on an operational objective • Few public complaints concerning a program or asset • Few or no unfavourable media reports	• Damage of less than $10K • Cost overrun under 5% • Minimal loss of assets	• Minimal and temporary damage to the environment

Similar to the vulnerability assessment stage of the CVRA, NCC staff were engaged in a workshop setting to qualitatively assess the possible economic, social and environmental consequences of the impacted areas (as determined by the impact statement).

C.2.5. Determining Level of Intervention

As a sector-level assessment was completed, the NCC methodology evaluated risks for all future periods (Baseline (1981-2010),2021-2050, 2041-2070, and 2071-2100) 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 sectors, assets and programs managed by the NCC, the selection of one period may result in the incorrect prioritization of risk, such as overlooking an impact with a low vulnerability but very high risk, which would, at a minimum, require a plan developed to mitigate the risk to the organization. Once the vulnerability and risk ratings were assessed, a risk and vulnerability matrix was utilized to determine the timing of the action required (Figure C.6).

	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

Figure C.6. Level of Intervention Matrix

C.2.6. Limitations of the Vulnerability & Risk Assessment

Like any vulnerability and risk assessment, this 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 given the limited time for society to evolve. However, it is exceedingly 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, the uncertainty associated with the probability of climate hazards will increase the longer the time horizon that is considered. Climate models will be updated and improved as new data becomes available. Reviewing new future climate data on a regular basis will provide NCC 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 parameters, 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 users from using this information. More information about uncertainty related to climate projections can be found in the Climate Projections for the National capital Region Report.

Mapping Data

The geospatial analysis was limited to what data was available. For example, 350-year flood maps were available for the Ottawa region, but only 100-year flood maps were available for the Quebec region which may therefore understate the flood risks to the NCC assets located in Quebec.

Vulnerability & Consequence Ratings

NCC staff were engaged in sector-specific workshops to provide their ratings of sensitivity, adaptive capacity, consequences. 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 on the horizon, then perceptions tend to be more pessimistic. The same applies to threats/hazards that are thought to be uncontrollable. To minimize the risk of individual perceptions skewing the results, during the risk workshops, each participant

rated the sensitivity, adaptive capacity and consequence, and then were shown the average group results in real-time. Where there was divergence in assessments or ratings, NCC staff were asked to discuss the rationale behind their ratings.

Asset-Specific Assessments

This high-level risk assessment is a first step-the CVRA examined NCC elements at a sector level and not at a service, component or program delivery level (as was done in the Rideau Canal Skateway (RCS) CVRA) and thus did not consider infrastructure system age, condition, operation and the impact of compounding events. Nevertheless, some asset and hazard GIS data were made available by the NCC and stakeholders, and climate interactions were identified.

Upstream Impacts to NCC Assets Downstream

This assessment did not examine how upstream risks (e.g., development in the Ottawa River watershed) may impact the NCC assets downstream with climate change. This is a knowledge gap that was identified by NCC staff during workshops.

While there are limitations with any risk assessment process, the development of this CVRA process is the most important result of this project. Continuing to use the CVRA process with staff will not only provide useful information about changing vulnerabilities and risks, but will also build the NCC's understanding of the impacts of climate change on assets, programs and users, and how to take a systematic approach to climate change risk management at the corporate and operational levels. The input to the CVRA process and supporting documentation will need to be updated and adjusted as new information becomes available.

Appendix D: Table of Potential Impacts by Climate Hazard

Table D.1. Potential Climatic Changes & Impacts under a changing climate to NCC Elements

Climate Hazard Theme	Parameter	Potential Impacts
Extreme Heat, Drought & Humidity	More Warm Extremes	• Reduced water quality at beaches and natural outdoor swimming areas (e.g., algal blooms) • Health and safety risks to users • Increased park use • Disruption and damage to archaeological sites (e.g., digging pits and creating mud windbreaks for campfires, displacing logs and rocks for seats, etc.). • Increased cooling demands in buildings and GHG emissions • Requirements to improve building performance • Decreased asset life (HVAC) and greater repair/renewals • Modifications to existing master plans • Restriction/closures of certain land uses • Deterioration of asphalt and concrete-based surfaces (rutting, potholes) • Increased stress on bridge joints • Temporary closures of transportation systems • More frequent repairs and renewals of infrastructure systems • Increased occurrence of algae blooms impacting NCC programs (e.g., Lake Philippe campground, Rideau Canal) • Reduced availability of water safe for growing food and agricultural operations
	Increase In Humidex	• Increased strain on the mechanical systems and building infrastructure that houses the Crown Collection • Degradation and damage to wood-based Crown Collection items • Hotter summers and high humidex periods may increase the strain on the mechanical systems and building infrastructure that houses the Crown Collection and could result in degradation and damage to wood-based Crown Collection items. • Thermal expansion of wood-based infrastructure (warping, swelling, shrinkage) • Hazards to infrastructure users • More frequent repairs and renewals
	Heat Warnings	• Increased water-based recreational activity resulting in disruption and damage to archaeological sites (e.g., boat wakes, shoreline gatherings and parties) • Increased park use

Climate Hazard Theme	Parameter	Potential Impacts
		• Increase cooling demands, GHG emissions, requirements to improve building performance, and increased capital costs to the NCC • Increased number and severity of heat-related health and safety issues • Damage and loss of IT systems resulting in operational delays • Delay of regularly scheduled maintenance programs, procedures and construction windows • Increased public demand for shaded areas especially on surfaces that exacerbate the urban heat island effect. • Park and recreation programming delays, modification to outdoor activities/events, and lost revenues • Health and safety risks for NCC staff and contractors • Failure of exposed, outdoor electrical equipment (e.g., transformers) • Shortened road and infrastructure construction/repair operational windows • Issues with curing and shrinkage of concrete pours leading to weakened concrete structures and cracking that requires repair
	Drought	• Reduced agricultural yields (drought, pollinator lifecycle changes, pests, invasive species) • Decline of agricultural tenants on NCC lands and a lost revenue source to the NCC • Reduced aquifer recharge • Lower baseflow to streams and degraded aquatic habitat • Longer but inconsistent growing season • Increased maintenance requirements (e.g., irrigation demands, invasives management, etc.) • Reduction of ground water recharge and the shifting of ecosystems (wetland to upland) • Increased incidence of dry wells and potable water demands by agricultural tenants
	Wildfires	• Damage to park lands and infrastructure • Strain on forest management/wildfire suppression programs and resources • Disruptions to corporate services • Temporary/permanent closures of park and transportation systems • Extended power outages • Increased urban/rural fire interface/vegetation management • Smoke/air quality impacts resulting in health and safety risks
Seasonal Variability & Change	Change In Seasonal Characteristics	• Increased building operational demands to accommodate mechanical systems to the varying temperatures • Intensification of existing invasives and disease vectors • Migration of new invasives, disease vectors and illness • Health and safety risks to park users and NCC staff • Higher incidences of human and wildlife interactions • Increased unauthorized encampments on lands and increased operational demands on NCC staff

Climate Hazard Theme	Parameter	Potential Impacts
	Seasonal Winter Freeze-Thaw	• Longer but inconsistent growing season • Park seasons being extended in duration • Increased park use • Increased operational demands. • Damage to buildings (frost decay/deterioration of porous masonry materials, roof damage due to ice dams, and moisture damage) • Damage and breaking of underground irrigation systems • Premature deterioration of concrete in bridges and reduced load capacity • Shortened winter/outdoor park season requiring changes to programming and facilities (e.g., Rideau Canal Skateway, cross country skiing, etc.) • Ice flows and damage to shoreline assets • Ice accumulation in shallow-buried stormwater infrastructure • Reduced run off capture and localized flooding • Accelerated degradation of roads, pathways and bridge infrastructure • Temporary closures of transportation systems • Watermain breaks (cast iron watermains are particularly vulnerable) and hydrant leakage • Increased slope instability in susceptible areas (clay areas) • Damage to archaeological sites • Accelerated degradation of park trails and associated infrastructure • Temporary closures
	Increase In Average Temperatures	• Intensification of existing invasives and disease vectors • Migration of new invasives disease vectors and illnesses • Health and safety risks to park users and NCC staff • Increased park use • Alteration of natural habitats

Climate Hazard Theme	Parameter	Potential Impacts
Precipitation Volume & Intensity	5 Day Max Total Precipitation in Spring	• Accelerated shoreline erosion • Damage to archaeological sites and a permanent loss of archaeological resources • Flooding of buildings and compromised functionality, and increased maintenance activity (repairing/replacing infrastructure and clean-up) • Stranded assets in floodplains • Exposure or destabilization of contaminated park lands • Temporary/permanent closure of trails and park lands • Wash-out of boardwalks and staircases • Temporary/permanent closures of active transportation systems • Modifications to existing master plans and the restriction/closures of certain land uses • Scouring, erosion, side-slope failure, and foundation settlement of bridges • Overtopping and damage to damns and weirs • Uncontrolled downstream flows • Increased risk of critical events (road washout, bridge failures, landslides affecting roads, bridges, etc.) • Weakened or washed-out soil resulting in sinkholes
	More Intense Precipitation	• Saturation or flooding of agricultural lands • Increased ground heave, and subsidence resulting in damage to archaeological sites • Basement flooding damage and mould-related illnesses to NCC tenants • Water ingress and damage, compromised building functionality, and increased maintenance activity • Damaged stormwater infrastructure and culverts • Reduced run off capture, localized flooding • More frequent repairs and renewals • Wash-out of pathways and roads and sinkholes • Temporary/permanent closures of transportation systems • Increased hazards (accidents) on roads with improper crowning, sloping, and ditching • Increased infiltration and inundation (I&I) and exceedance of wastewater treatment capacity • Reduced water quality to the receiving environment • Weakened or washed-out soil resulting in sinkholes
	Increase In Total Precipitation	• Increased nutrient loading of nearby aquatic ecosystems (soil erosion and run-off). • Increased buffer requirements and reduced land available for agriculture • Increased shoreline erosion • Increased incidence of landslides in inhabited or built-up areas • Temporary/permanent park closures • Increased maintenance activity

Climate Hazard Theme	Parameter	Potential Impacts
Extreme Weather Events	Multi-Day Ice Storm	• Damage to communication systems and electricity grids, impacting infrastructure monitoring and back-up systems • Damage to park infrastructure and trees • Temporary/permanent closures of trails and parks • Increased maintenance activity (repairing/replacing infrastructure and clean-up)
	Freezing Rain	• Damaged vegetation and trees • Increased use of road salt • Accelerated degradation of heritage assets (e.g., stone walls) • Accelerate the susceptibility/mortality of heritage landscapes (trees along confederation boulevard) • Damage to aquatic ecosystems • Slippery roads and trails • Reduced park/facility access, increased risks to users • Increased maintenance activity (snow clearing, etc.)
	Extreme Snow and Blizzards	• Damage to agricultural and heritage buildings • Compromised building roof • Health and safety risks to tenants • Increased maintenance activity (repairing/replacing infrastructure and clean-up)
	Extreme Wind/ Tornadoes	• Damage to agricultural crops and lands • Damages to building envelope and roof-top mechanical systems • Flying debris or trees falling on buildings resulting in damage • Compromised building functionality (e.g., increase or decrease cooling loads due to air leakage and impacts to air handling systems, etc.) • Increased maintenance activity • Damage to and loss of urban trees • Extended power outages affecting building and facility operations • Disruptions to infrastructure monitoring, communication, security and emergency back-up systems • Accelerated degradation of outdoor monuments, public art and heritage structures • Damage to park infrastructure and trees • Temporary/permanent closures of park areas and outside event spaces, cancellation of outdoor activities/events, and lost revenues • Increased wind loads on raised structures, such as bridges, and structural wear • Wind-induced damage to sign poles and light poles • Lifting of building roof materials, cladding, and attached equipment • Health and safety risks to NCC users, staff and contractors from blowing debris

Climate Hazard Theme	Parameter	Potential Impacts
	Climate Change/Extreme Conditions	• Damage to and irreplaceable loss of the Crown Collection resulting in a loss of culturally and historically significant assets • Supply chain instability and/or market failures impacting the availability of fuels and other goods • Reduced capacity for NCC and its contractors to respond to compounding events or recover from prior climate impacts (e.g., flooding) • Negative impact on staff morale, increased turnover, and a loss of organizational knowledge • Disruption of business continuity and material financial losses/obligations • Modifications to existing master plans and the restriction/closures of certain land uses • Increase in health and risks to NCC contractors and staff • Increase in health and safety risk to tenants