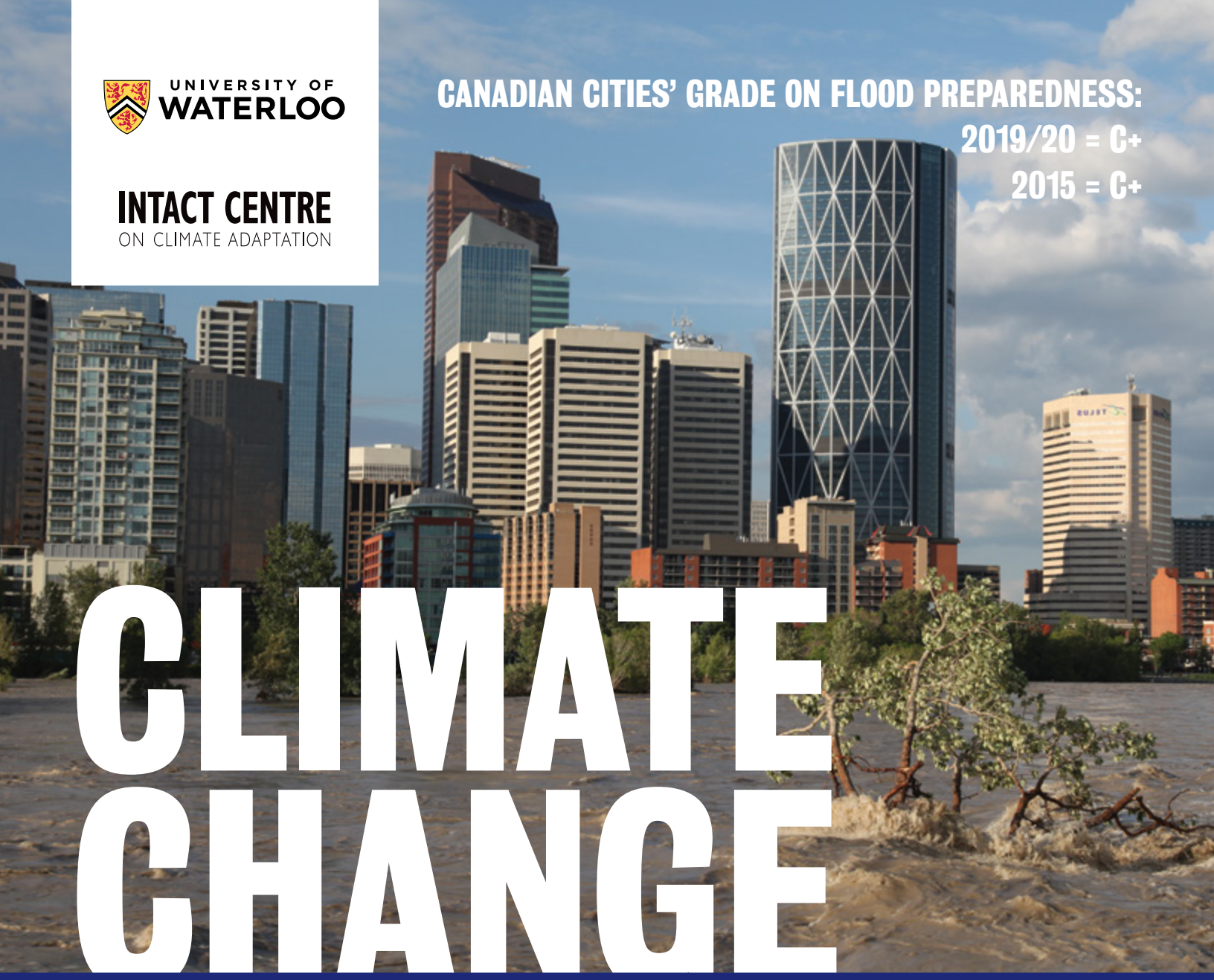
UNIVERSITY OF WATERLOO

INTACT CENTRE
ON CLIMATE ADAPTATION

CANADIAN CITIES' GRADE ON FLOOD PREPAREDNESS:
2019/20 = C+
2015 = C+



CLIMATE CHANGE

AND THE PREPAREDNESS OF 16 MAJOR CANADIAN CITIES TO **LIMIT FLOOD RISK**

SUPPORTED BY:

[intact]

Dr. Blair Feltmate
Marina Moudrak

February 2021



"The value of quantifying the flood preparedness of Canada's major cities cannot be overstated. Cities profiled in this report – and even those not considered – should be able to learn from one another regarding means to advance flood readiness going forward, which in turn will benefit all Canadians."



Veronica Scotti
Chairperson, Global Partnerships at Swiss Re

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The Intact Centre on Climate Adaptation (Intact Centre) is an applied research centre at the University of Waterloo. The Intact Centre was founded in 2015 with a gift from Intact Financial Corporation, Canada's largest property and casualty insurer. The Intact Centre helps homeowners, communities and businesses to reduce risks associated with climate change and extreme weather events. For additional information, visit: www.intactcentreclimateadaptation.ca

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“FLOODING *has become the most widespread and costly natural disaster across Canada”*

EACH YEAR, SEVERE WEATHER EVENTS INCLUDING FLOODS, wildfires, windstorms, droughts, hail and destructive thunderstorms, pose a serious risk to cities across Canada. These events are growing in frequency and intensity, causing an impact in terms of insurance claims, economic losses, mental/psycho-social stress, and in some cases, fatalities. Although each city faces a unique combination of climate change related challenges, flooding has become the most widespread and costly natural disaster across Canada (IBC 2019).

In Canada, flood management is the responsibility of the provinces and territories, however, this responsibility is often legislatively delegated to municipal goverments. Therefore, flood management activities including mapping, planning, preparation, response and recovery are typically executed at the local rather than at the provincial, territorial, or federal level. As such – and as a complement to the report **Climate Change and the Preparedness of Canadian Provinces and Territories to Limit Flood Risks** (Feltmate et al. 2020), that addressed the preparedness of provincial and territorial governments to address flood risk – this report instead focuses on how the municipal governments of 16 major Canadian cities self-assess their efforts to reduce the severity of flood impacts on their jurisdictions and citizens.

The flood preparedness of fourteen cities spread across the ten Canadian provinces was evaluated relative to criteria 1-7 presented in **Table 1**, while two cities located within two territories, namely, Yellowknife in the Northwest Territories and Iqaluit in Nunavut, were evaluated relative to 5 factors (viz., these two cities determined that *Flood Risk Assessment and Residential Property Risk Mitigation* were not applicable to their communities). Each of the criteria was self-assessed by the jurisdictions using a five-point scale, ranging from 'A' for a high state of flood preparedness, 'E' for a low state of preparedness, and with the good, significant, and incipient states of preparedness denoted as 'B', 'C' and 'D', respectively (see Appendix A for a detailed description of the scoring protocol). **Response scores were determined and recorded during interviews with designated representatives of municipal governments (e.g., City Managers, Directors, Senior Planners, etc.) and in some cases with the representatives of public utilities and conservation authorities, who had appropriate expertise relative to the specific criterion under consideration**. In total, **53 interviews** were conducted with such representatives starting in November 2018.

TABLE 1: Criteria utilized to assess the flood preparedness of selected Canadian cities

No.	Criteria	Description
1	Flood Risk Assessment	Flood risk assessments define the probability that floods occur in a given area and the consequences of flooding for people, properties, and infrastructure.
2	Land Use Planning	Land use planning manages development activities to minimize the risk of flooding to life, property, and infrastructure.
3	Urban Drainage Assessment	Urban drainage assessments evaluate the risk-based performance in terms of the reliability, resiliency, and vulnerability of an urban drainage system.
4	Residential Property Risk Mitigation	Residential flood mitigation measures include the assessment of existing risk factors and the implementation of flood risk protection actions.
5	Critical Infrastructure Risk Mitigation	Critical Infrastructure (CI) flood risk mitigation measures include the identification of vulnerabilities of existing CI to flooding and the implementation of actions to enhance their flood resilience.
6	Public Health and Safety	Public Health and Safety assessments focus on the flood risks affecting healthcare facilities, chemical facilities and dams.
7	Emergency Management	Emergency management assessments focus on flood risks affecting emergency response and recovery operations including contingency planning for businesses and infrastructure owners/operators.
8	Chief Resilience Officer	A Chief Resilience Officer is a top-level advisor responsible for establishing and activating a city's risk resilience strategy.

An additional 8th level of evaluation focused on the presence (or absence) of a Chief Resilience Officer (or equivalent), as a top-level advisor overseeing city resiliency.

On the basis of the above criteria, the average score of 16 major Canadian cities on flood preparedness for 2019/20 was C+, with the highest score being B+, and the lowest score being D (**see Figure 1**).

2019/20 Canadian Cities Average C+



FIGURE 1. **Flood Preparedness Scores of 16 Major Canadian Cities, 2019/20.**

These results presented in **Figure 1** are roughly comparable to those found in a study conducted in 2015 (Feltmate and Moudrak, 2015), whereby the flood preparedness score of 15 major Canadian cities was also C+, with the highest score being A-, and the lowest score being D (**see Figure 2**).

2015 Canadian Cities Average C+



FIGURE 2. **Flood Preparedness Scores of 15 Major Canadian Cities, 2015.**

Average flood preparedness scores were calculated for cities within the western and central provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, and Quebec) as distinct from the cities located within the Atlantic provinces (New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador) (**see Figure 3**). As the government of Whitehorse, located within the Yukon Territory, declined to participate, the average flood preparedness score for the territorial capital cities was not calculated. Therefore, Northern Canada is represented by two cities, namely, Yellowknife in the Northwest Territories and Iqaluit in Nunavut.

The three groupings (Western and Central, Atlantic, and Northern regions) were in part based on (1) direction from the city governments of the Atlantic provinces, that stated that their flood risk factors are unique due to their proximity to the Atlantic Ocean, as well as (2) the territorial cities declaring that their climate risks are influenced by a unique set of climate change related factors relative to the rest of Canada.

FIGURE 3 a–n. Flood Preparedness Scores of Canadian Cities, 2019/20.

FIGURE 3a

Vancouver, British Columbia C

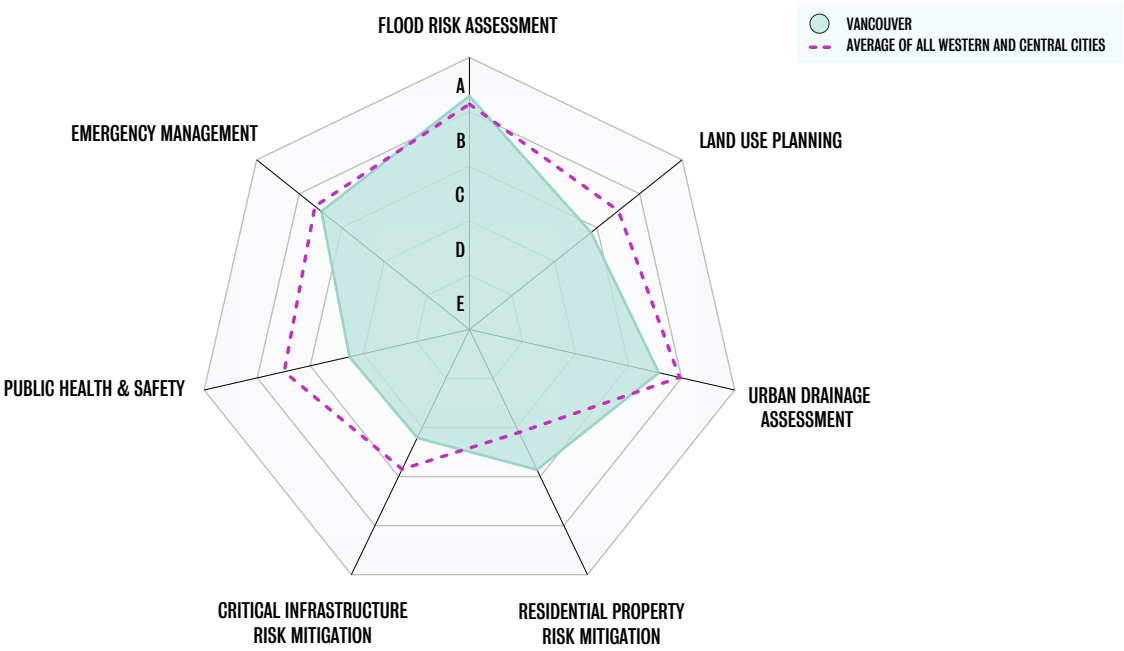


FIGURE 3b

Surrey, British Columbia B–

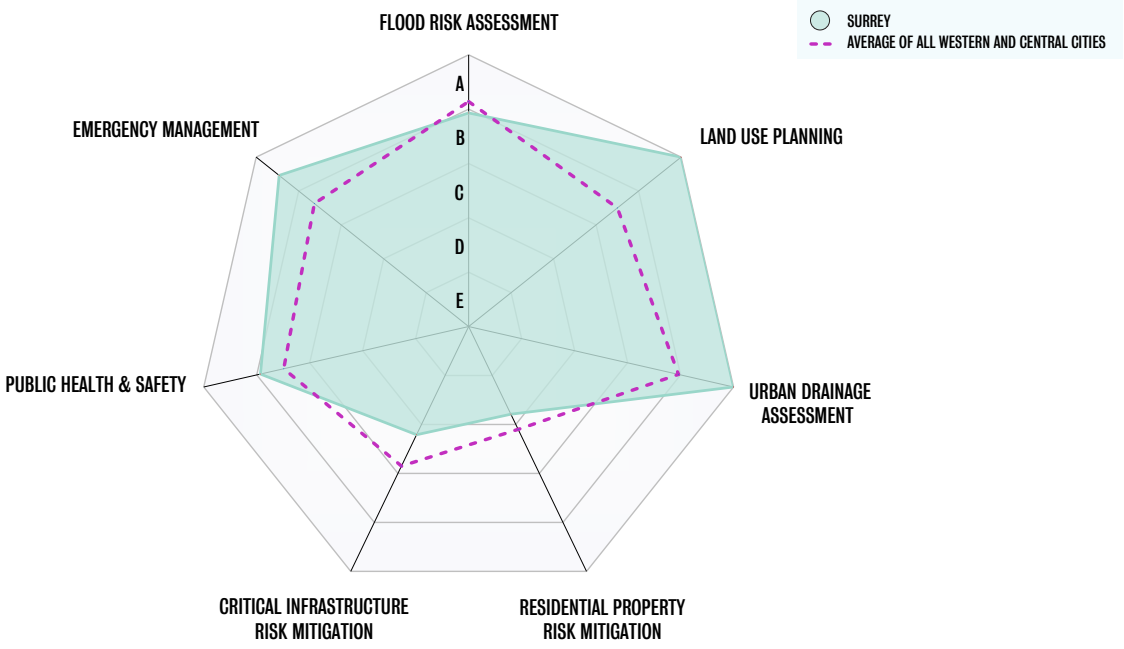


FIGURE 3c

Calgary, Alberta B–

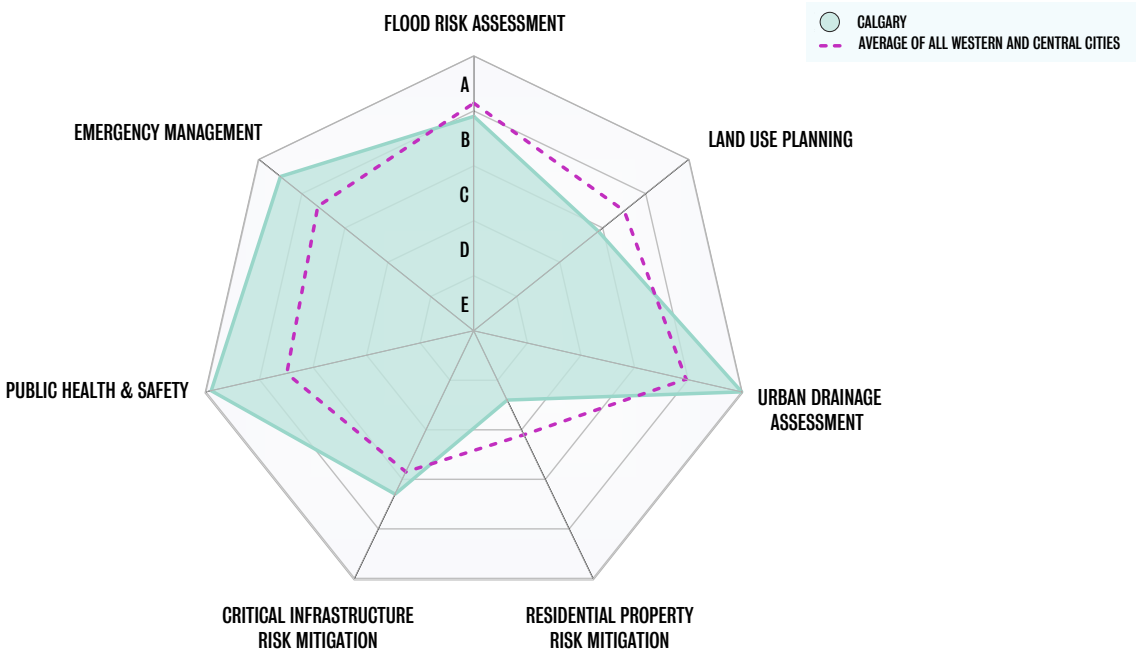


FIGURE 3d

Edmonton, Alberta B+

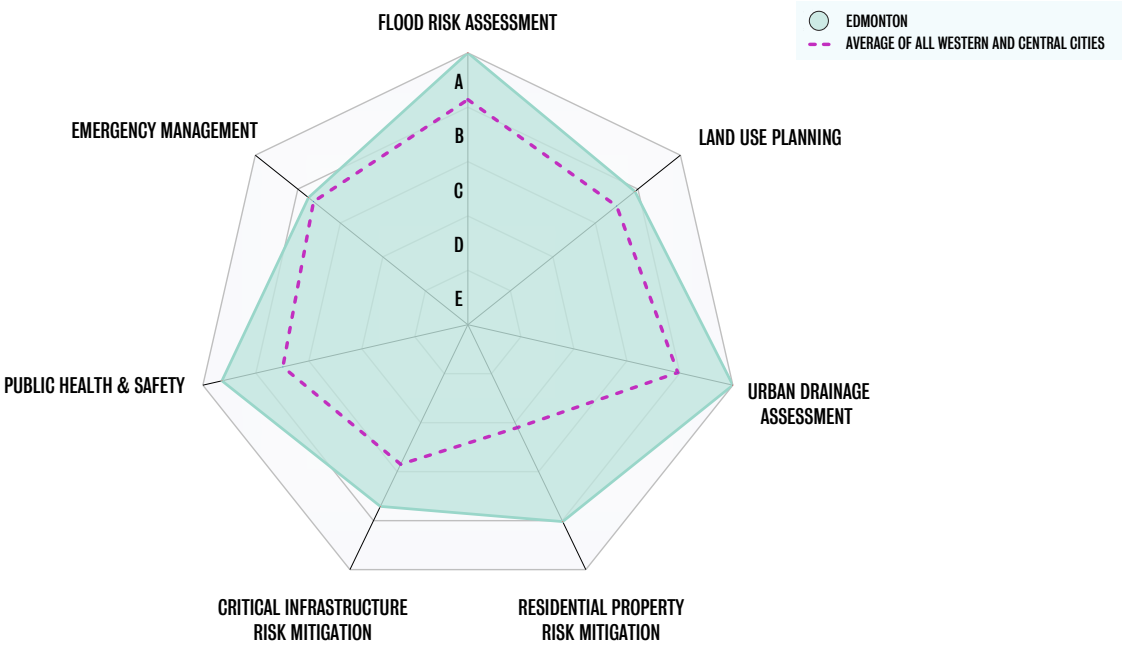


FIGURE 3e

Regina, Saskatchewan B+

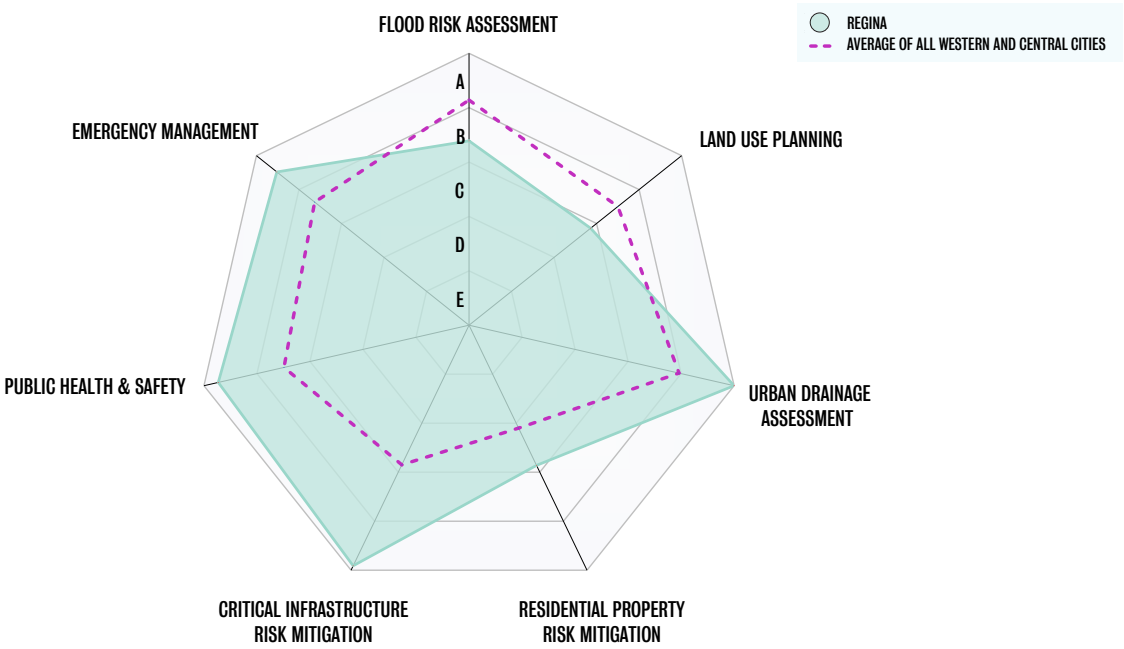


FIGURE 3f

Winnipeg, Manitoba D

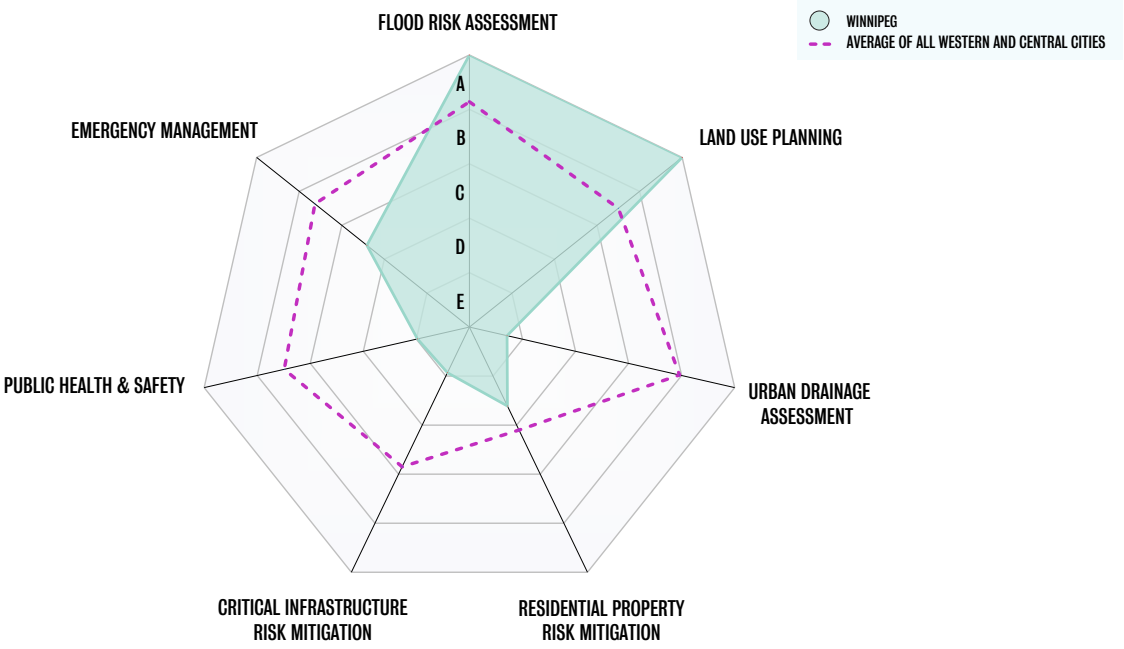


FIGURE 3g

Toronto, Ontario B+

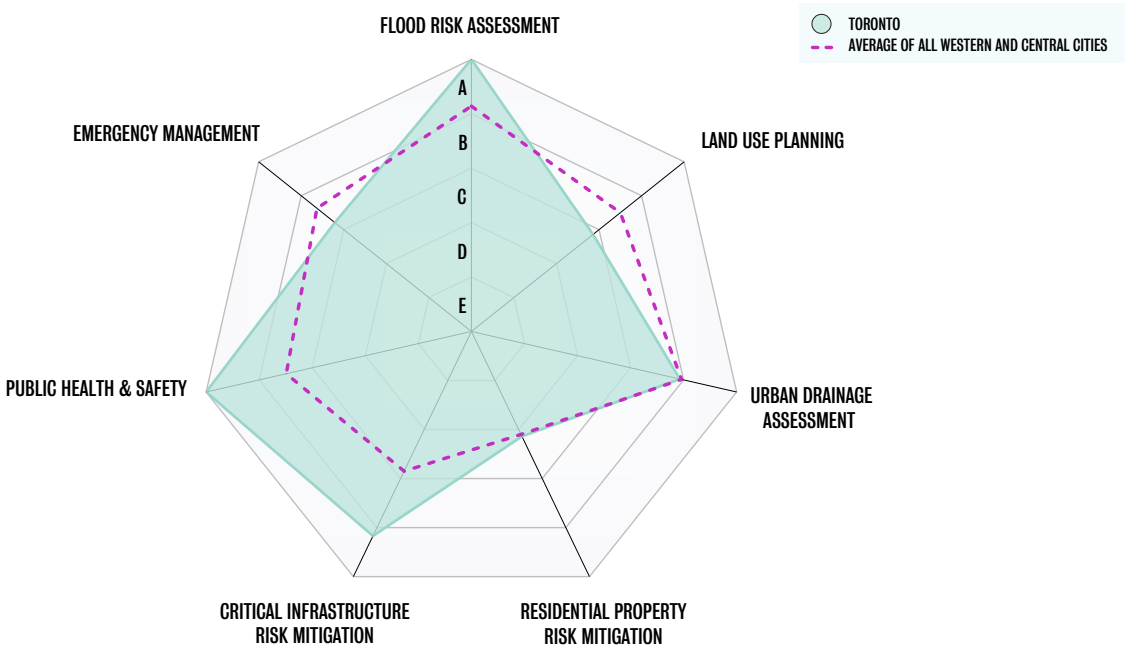


FIGURE 3h

Ottawa, Ontario B–

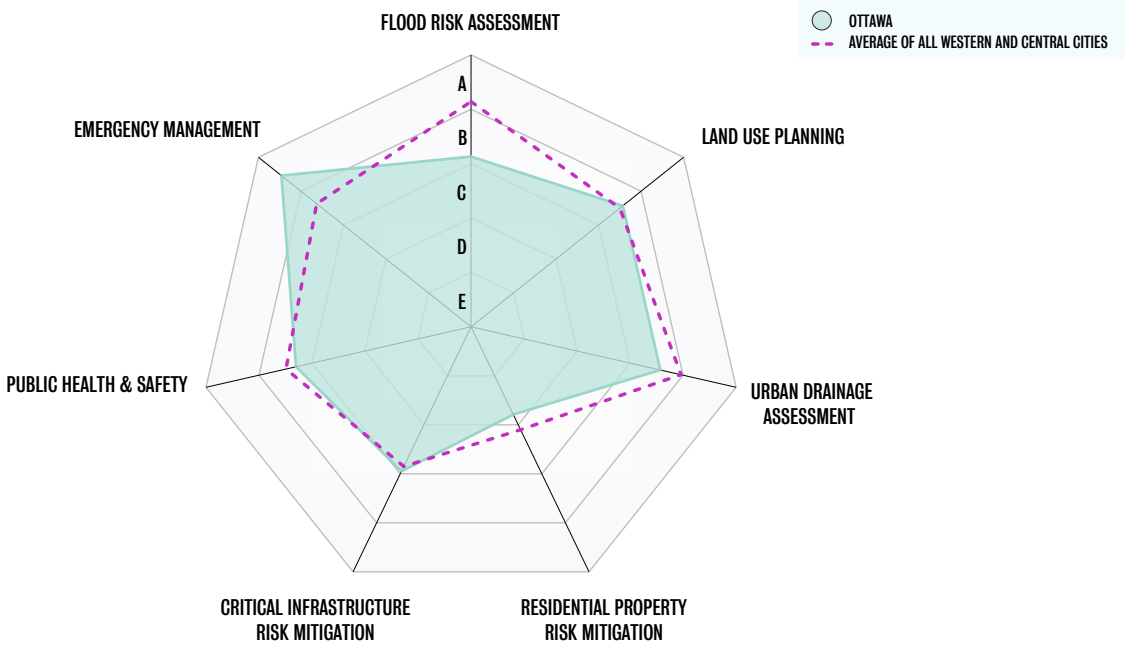


FIGURE 3i

Montréal, Quebec C

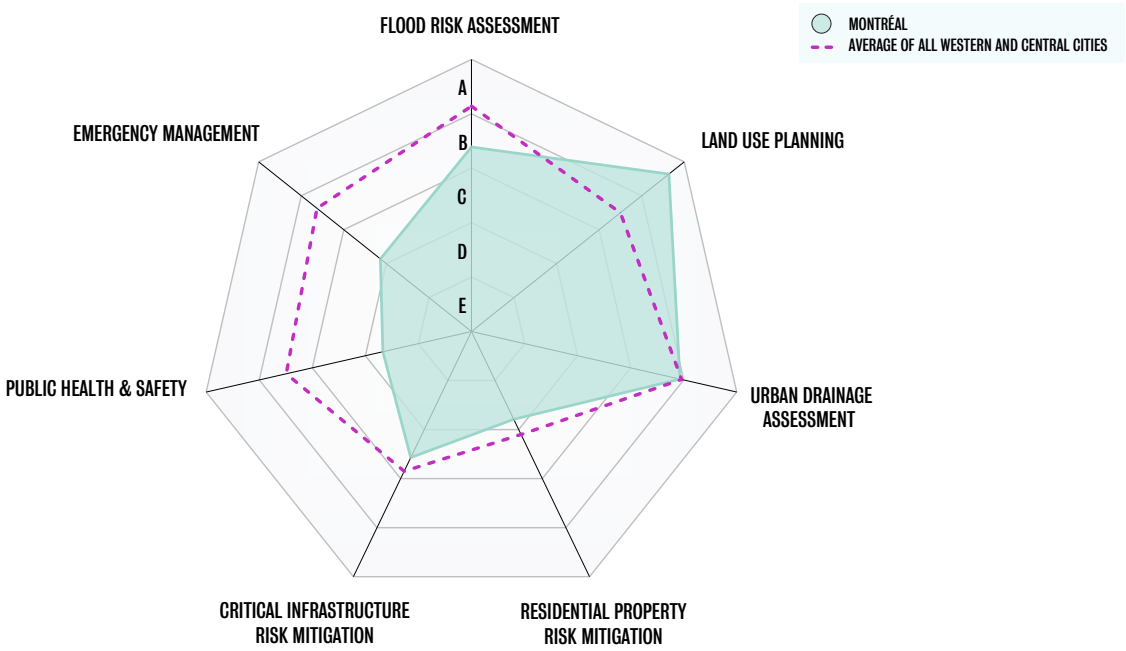


FIGURE 3j

Québec City, Quebec C+

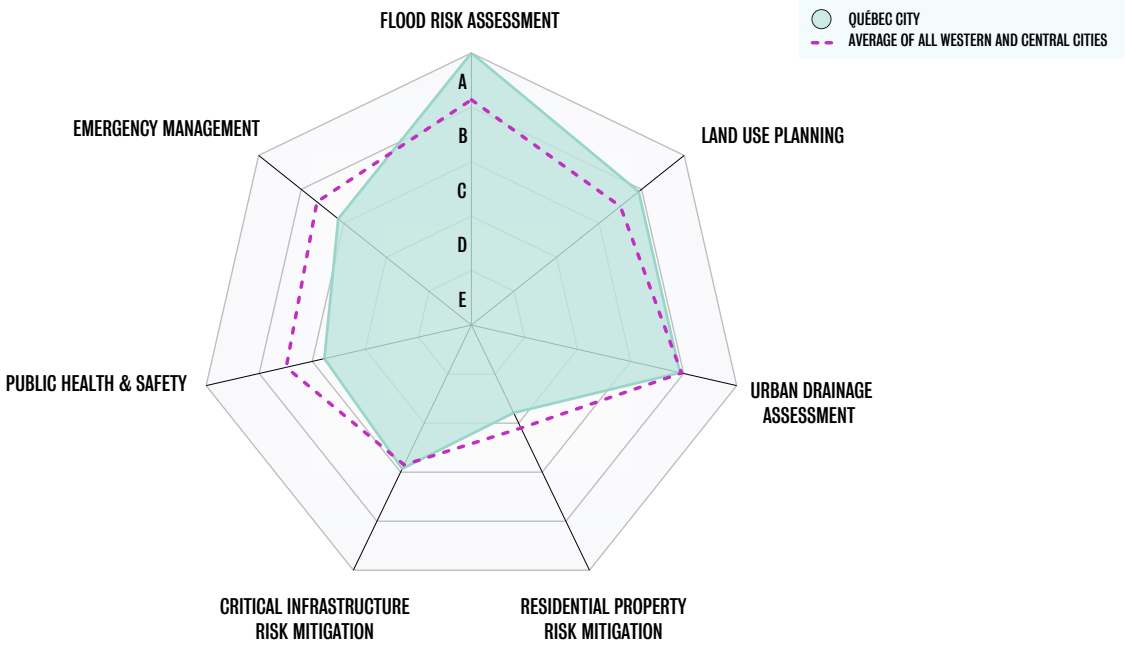


FIGURE 3k

Fredericton, New Brunswick B-

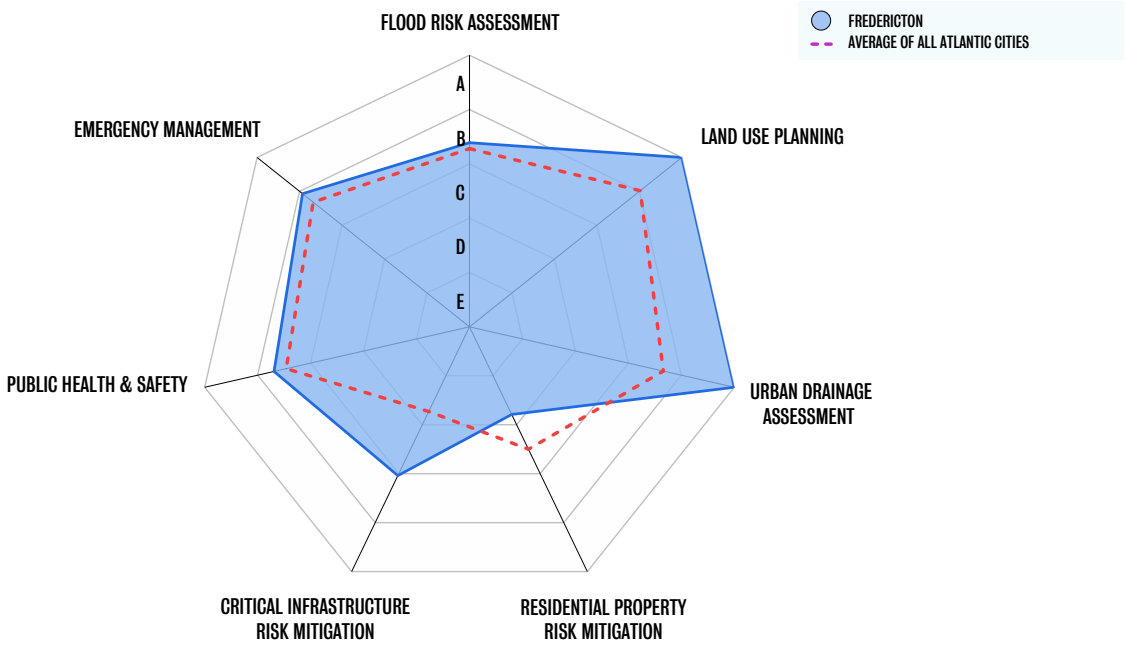


FIGURE 3l

Halifax, Nova Scotia B-

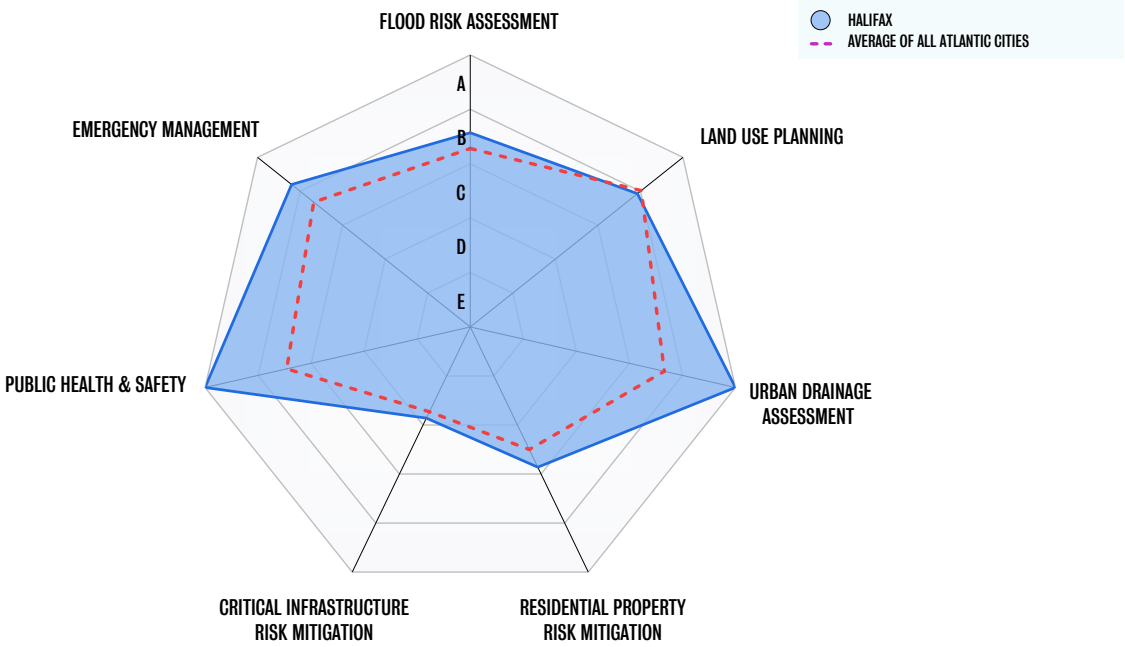


FIGURE 3m

Charlottetown, Prince Edward Island D+

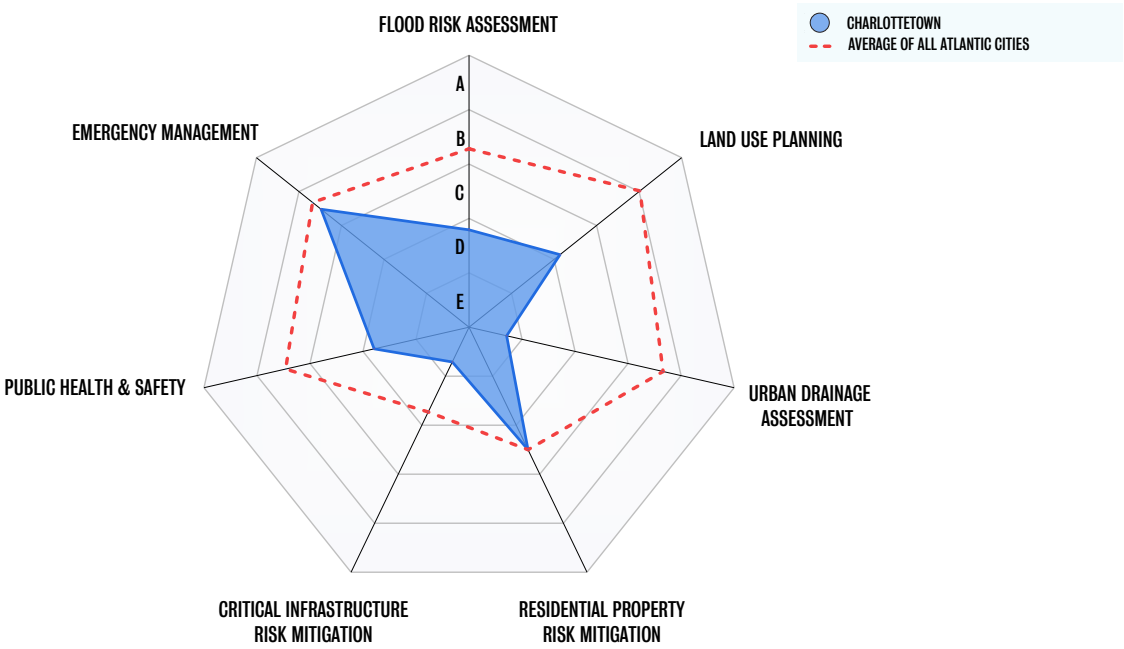
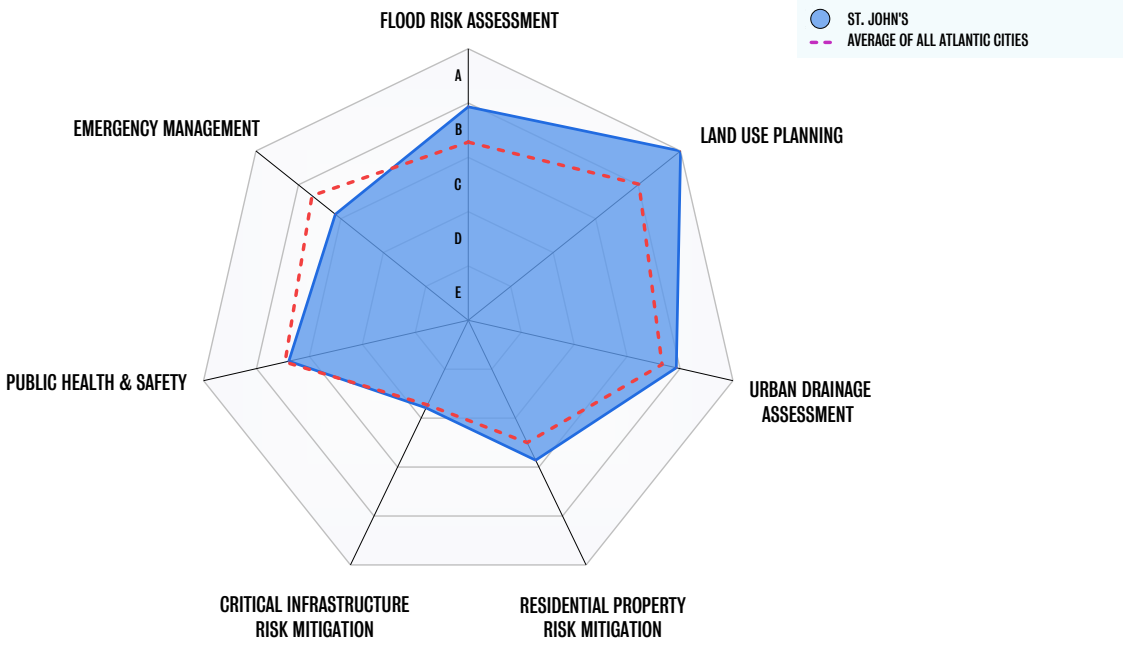


FIGURE 3n

St. John's, Newfoundland and Labrador C+



Note: As Whitehorse, Yukon, declined to participate in this study, an average score for the cities located in Northern Canada was not calculated. The scores for Yellowknife, Northwest Territories, and Iqaluit, Nunavut, are presented in **Figure 3.3.1.**

While the Canadian average score on flood preparedness has not changed since 2015 – and remains **C+** in 2019/20 – all surveyed cities recognized the need to prepare for pending climate change and associated extreme weather events.

Notably, Vancouver, Surrey, Fredericton and Halifax conducted risk assessments to identify areas that are most at risk from riverine and/or coastal flooding, and where applicable took into account climate change and sea level rise. Despite the fact that nearly all cities demonstrated strengths in flood risk assessment related to riverine and/or coastal flooding, only half of the cities reviewed – namely Vancouver, Edmonton, Toronto, Ottawa, Montréal, Québec City, Halifax, and St. John's – reported assessing risk of pluvial (e.g., sewer back-up) flooding.

In addition, nearly all surveyed municipal governments reported a similar level of strength with respect to their Urban Drainage Assessment efforts, including the amendment of engineering standards to meet performance expectations under increasingly challenging climatic conditions as well as initiatives focused at rebuilding and upgrading stormwater infrastructure.

Representatives of municipal governments reported that they utilize many instruments to govern land use planning, including bylaws, codes, policies, plans, standards and guidelines. However, as noted by many survey respondents, Canadian cities are under the obligation to comply with provincial or territorial land use regulations, and therefore, it is necessary for municipalities to request the Provincial legislature to pass applicable amending legislation before the municipality can enact any meaningful changes within their own jurisdictional governing tools (Van Der Brink 2016). In Canada, as the provinces/territories exercise exclusive control over their cities and municipalities, the powers that each municipality possesses depends almost entirely on the powers the province/territory deems necessary to grant. Therefore, only a few of the studied cities, namely Ottawa, Iqaluit, Fredericton, and St. John's, stated that new development is actually prohibited within their respective floodplains, or within the 20-year flood zone

"All surveyed cities recognized the need to prepare for pending climate change and associated extreme weather events"

in the case of Montréal and Québec City. Significantly, even those cities that did report having designated floodplains, noted that their designation was based on floodplain standards established provincially and that were delegated down to cities and municipalities. For example, Ottawa reported that its Official Plan and Zoning By-law prohibits development within the one-hundred-year flood plain. Therefore, even when the results of conducted risk assessments identified areas that are at risk of flooding that are outside of presently regulated floodplains, cities have no legal power to update their formal floodplain regulations and thereby enforce adherence to updated, risk-based standards.

Municipal governments reported moderate strength in emergency management relative to flood risk, and more specifically in maintaining the continuity of fuel supply and emergency communications. However, only a few cities, specifically Surrey, Ottawa, Fredericton and Halifax, demonstrated strength in the operation and maintenance of alert/warning systems, and indicated that they are currently in the process of updating their existing emergency alert/warning systems to include the provision of services for people with special needs based on social vulnerability studies.

In regard to municipally owned Critical Infrastructure (CI) Risk Mitigation, the survey results indicated strength across cities only in the domains of Critical Electrical-Powered Infrastructure and Water Infrastructure and Services. Conversely, the survey results revealed a prevalent limitation in the ability of municipalities to mitigate the flood vulnerability of existing Critical Telecommunication-Reliant Systems, Food Systems and Financial Services. This pattern of weakness coincides with what was demonstrated by the provinces and territories in the 2019 study *Climate Change and the Preparedness of Canadian Provinces and Territories to Limit Flood Risks* (Feltmate et al. 2020), particularly regarding assessment of infrastructure interdependencies.

The primary vulnerability consistently demonstrated by the studied cities was risk exposure of residential properties to flooding. Of the 16 studied cities, only Edmonton reported significant strength in this important domain of flood preparedness. While most cities indicated that they provide information to their residents to allow them to determine whether their property is located in a riverine and/or coastal flood-prone area, **only Edmonton** stated that it **provides free home flood assessments for any homeowner through its municipally owned utility, EPCOR**.

Although most cities perceived the risk of pluvial flooding (which may include storm and sanitary sewer back-up flooding) as significant, only Edmonton indicated the highest level of preparedness relative to this factor. Regina, Halifax, Charlottetown and St. John's reported that they provide information to residents to allow them to determine whether their property may be at risk of pluvial flooding, but stated that they do not subsidize home flood assessments. The remaining cities reported that they are only in the process of considering different approaches to inform residents on pluvial flood prevention and recommended maintenance activities.

Basement flood mitigation is another key aspect of reducing the risk exposure of residential properties. Installation of backwater valves can reduce the risk of sewer back-up water flowing into a house during extreme precipitation events for properties that are connected to combined sanitary and storm sewer systems.

Table 2 below presents a summary of municipal responses to the following question: "*For newly constructed homes, does your city mandate the installation of backwater valves?*"

TABLE 2: Backwater Valve Installation for New Homes. Responses to the question: *For newly constructed homes, does your city mandate the installation of backwater valves?*

City	Backwater Valves for New Homes
Calgary, AB	Yes
Charlottetown, PE	For some
Edmonton, AB	Yes
Fredericton, NB	For some
Iqaluit, NU	No
Halifax, NS	Yes
Montréal, QC	Yes
Ottawa, ON	Yes
Québec City, QC	Yes
Regina, SK	Yes
St. John's, NL	Yes
Surrey, BC	No
Toronto, ON	Yes
Vancouver, BC	Yes
Winnipeg, MB	Yes
Yellowknife, NT	No



Table 3 below presents a summary of municipal responses to the following question: "*For existing homes, does your city offer a financial subsidy for the installation of backwater valves?*"

Yellowknife stated that the use of back flow preventers is highly problematic in the North and their use has historically caused issues when they have failed or when they were incorrectly installed. In short, the extreme temperatures that are endemic to this part of Canada severely impact the effectiveness of this equipment. Simultaneously, the city noted that as it does not have combined sewer systems, thus the risk of stormwater infiltration into the wastewater system is relatively low.

Iqaluit stated that almost all houses in Nunavut, including within Iqaluit, are constructed on steel pile systems that are drilled into the permafrost or bedrock layer, with water and sewer services provided by either shallowly buried insulated piping, or by means of tanker truck. Although the city stated that it recognizes the sensitivity of its sewer pipes to permafrost thawing, it nevertheless does not enforce the installation of backwater valves.

Another key challenge for resilience efforts of Canadian cities is the trend of rapid growth. As urbanization progresses across Canada, it is important for city governments to consistently improve their ability to deal with stresses, including flooding.

In 2013, The Rockefeller Foundation (New York, USA) launched the 100 Resilient Cities (100RC) program that offered a $100 million USD prize that was split between 100 cities around the world that agreed to establish a Chief Resilience Officer (CRO) position. Vancouver, Calgary, Toronto and Montréal each established this position within their respective city governments, to lead each city's resilience efforts, funded by the aforementioned program which ended in 2019.

TABLE 3: Backwater Valve Installation for Existing Homes. Responses to the question: *For existing homes, does your city offer a financial subsidy for the installation of backwater valves?*



City, Province/Territory	Financial Subsidy for Backwater Valve Installation, Existing Homes
Calgary, AB	No
Charlottetown, PE	No
Edmonton, AB	For some
Fredericton, NB	For some
Iqaluit, NU	No
Halifax, NS	No
Montréal, QC	No
Ottawa, ON	Yes
Québec City, QC	Yes
Regina, SK	For some
St. John's, NL	No
Surrey, BC	No
Toronto, ON	Yes
Vancouver, BC	No
Winnipeg, MB	No
Yellowknife, NT	No

Over half of major Canadian cities employ an individual or a group of individuals charged with ensuring the safety of their respective communities and their risk adaptability, even if there is no formal Chief Resilience Officer designation.

For a more formal assessment of oversight regarding resilience, **Table 4** (below) presents responses of participating cities to the following question: "*Does your city have a full-time "Chief Resilience Officer" (or equivalent)?*"

On average, the state of flood preparedness of Canada's major 16 cities was not materially better or worse over the time frame 2015 to 2019/20. However, individual cities (notably Edmonton, Regina, Fredericton, and Halifax) did show strong improvement and overall preparedness to address flooding over this four year time frame – as such, other Canadian cities may wish to consider some of the actions of these cities as described in the body of this report.

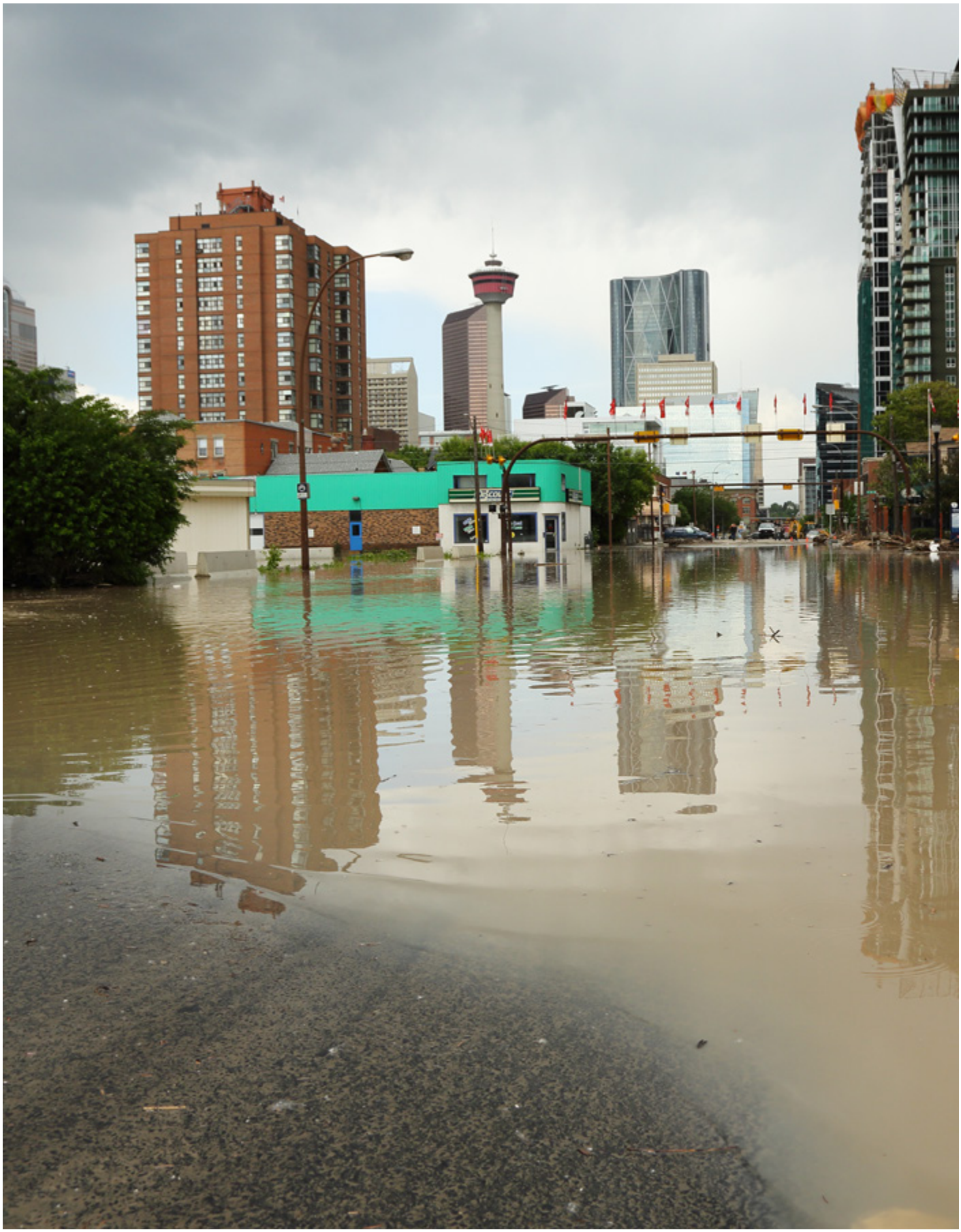
The rate at which Canadian cities address flood risk must improve, considering the wide range of stressors to which they are exposed – including the evolving risk of climate change, loss of natural infrastructure, population growth, and aging municipal and housing infrastructure, amongst others. **The good news for Canada is that flood risk mitigation guidelines and standards are well established** and thus, with appropriate resolve to deploy flood risk mitigation practices, a score of "A" is within reach for most – if not all – Canadian cities.

TABLE 4: Chief Resilience Officer Positions. Responses to the question *Does your city have a full-time "Chief Resilience Officer" (or equivalent)*?

City	Chief Resilience Officer (or equivalent)
Calgary, AB	Yes
Charlottetown, PE	No
Edmonton, AB	No
Fredericton, NB	No
Iqaluit, NU	No
Halifax, NS	Equivalent
Montréal, QC	Yes
Ottawa, ON	Equivalent
Québec City, QC	Equivalent
Regina, SK	Equivalent
St. John's, NL	Equivalent
Surrey, BC	Equivalent
Toronto, ON	Yes*
Vancouver, BC	Yes
Winnipeg, MB	No
Yellowknife, NT	Equivalent

* While the City of Toronto reported that at time of survey that they did employ a CRO, the position was since eliminated.

"On average, the state of flood preparedness of Canada's major 16 cities was not materially better or worse over the time frame 2015 to 2019/20."





CHAPTER 1
INTRODUCTION

This chapter provides an introduction to the preparedness of major Canadian cities to address the impacts of flooding and climate change risks.

1.1

Background

The purpose of this report is to quantify the state of flood preparedness of 16 major Canadian cities, and in so doing provide guidance that may alleviate current and future flood risk. As of 2019, according to Statistics Canada, 88% of all Canadians live in municipalities with populations of 5,000 or greater, while slightly over half of Canadians (55%) live in cities with a population of 100,000+. As such, the importance of flood preparedness to the economic, social and environmental well-being of Canadian cities, and Canada, cannot be overstated.

Although the risks to which individual cities are exposed are diverse in nature, flooding remains one of the costliest perils for communities across Canada, thus rendering it the subject of this report. Subjected to increasing demand for infill development, city governments face increasing pressures to grant development permits within flood-prone areas. This trend, along with changes in the frequency and intensity of extreme flood events, is increasing the risk of significant disruptions to economic activity, physical damage to residential and commercial properties, and losses of critical infrastructure and essential services, while also posing a threat to the health and well-being of city populations (Moudrak and Feltmate 2019).

According to the National Working Group on Financial Risk of Flooding, flooding accounts for roughly three quarters of federal Disaster Financial Assistance (DFAA) payments, "with residential losses accounting for 5-15% of that total while a greater portion by far, perhaps as much as 70%, is spent on the recovery of public infrastructure." Notably, DFAA payments cover only a portion of the costs incurred due to natural disasters. An overview of the escalating costs of extreme events is illustrated in **Figure 4**, which profiles insurable losses for Canadian catastrophic (CAT) events between 1983 and 2020. There is a discernable upward trend in losses covering the period, with a material proportion of growing costs attributable to flooding. The upward trend in claims is not solely attributable to extreme weather – for example, loss of natural infrastructure, aging municipal infrastructure, and housing construction practices that did not incorporate flood resiliency also contributed to escalating claims (Moudrak and Feltmate 2019).

Insured Catastrophic Losses in Canada

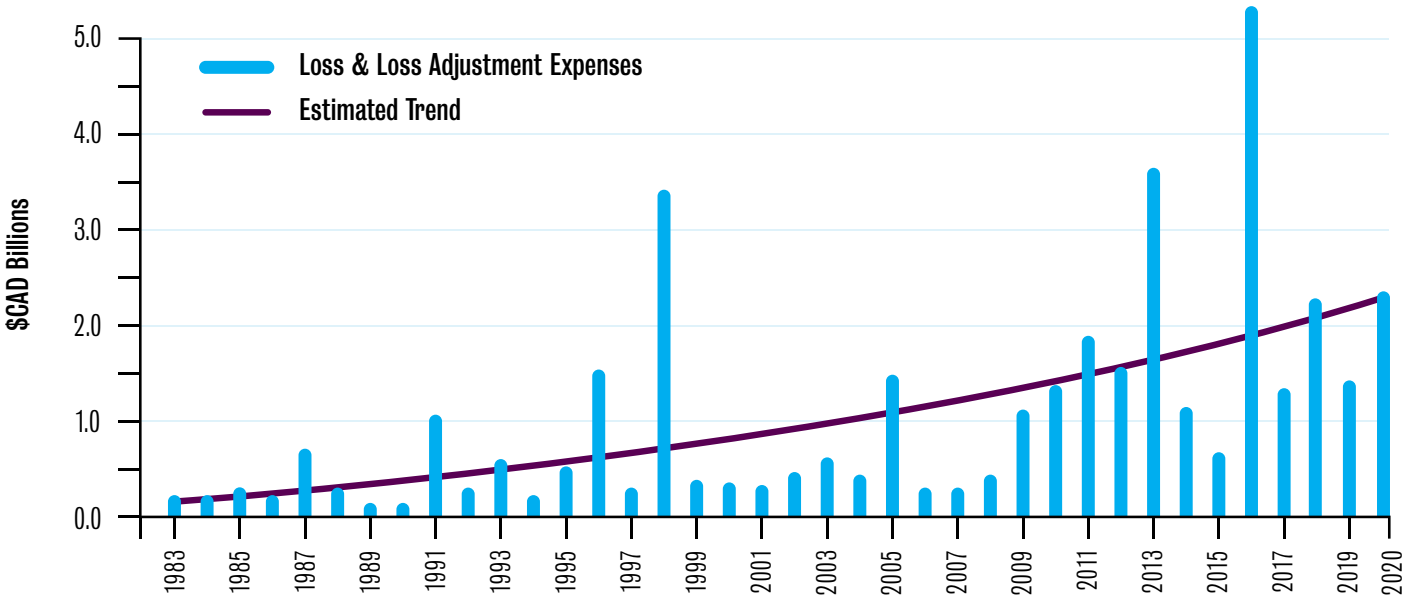


FIGURE 4: Catastrophic insured loss payments, Canada, 1983 – 2020. Total losses are normalized for inflation ($2020 CAN) and per-capita wealth accumulation, as of November 2020. Source: CatIQ, PCS, IBC Facts Book.

Cities across Canada are exposed to different types of floods, including coastal, fluvial, pluvial, surface water floods, glacial lake outburst floods and floods caused by dam failure. The complex interrelated processes that cause and influence floods can lead to compounding flood risks, thereby resulting in increased flood damages. Moreover, populations of modern cities are becoming highly dependent on the resiliency of an increasingly complex and highly interconnected system that is composed of critical infrastructures (CIs) including water, information and telecommunications, energy, transportation, banking and finance, and emergency services. Disruption of a single infrastructure during flooding can produce ripple effects of disruption in interdependent infrastructures, resulting in significant and adverse economic, social, and environmental impacts within a community – for example, power outages can trigger failures of communication systems. Accordingly, the report examines flood vulnerability from a systems failure/interdependencies perspective. The stress of system failures related to flood risk is manifesting in an increasing number of flood-related lawsuits involving homeowners, developers, municipal governments, conservation authorities, Indigenous people, provinces, and private businesses (Moudrak and Feltmate 2019).

Each city examined in this report should take solace in areas where flood preparedness is well developed, while simultaneously striving to remedy areas of weakness relative to flood preparedness.

With this purpose in mind, the structure of this report is as follows:

- **Chapter 2** defines the scope of the study;
- **Chapter 3** presents the findings for each criterion and its components across the municipal governments;
- **Chapter 4** profiles recommendations and next steps that may be taken to limit future flood risk in Canada; and
- **Appendix A** provides a copy of the study questionnaire.

"Disruption of a single infrastructure during flooding can produce ripple effects of disruption in interdependent infrastructures, resulting in significant and adverse economic, social, and environmental impacts within a community"



CHAPTER 2
PURPOSE AND SCOPE

The areas of focus of the study reflected the core themes of the United Nations Sendai Framework for Disaster Risk Reduction (DRR), to which Canada is a signatory. DRR is a systematic, whole-of-society approach to identifying, assessing, and analyzing the causal effects of disasters and reducing the resultant risks and impacts on the basis of risk assessments.

Most emergencies in Canada are managed by municipalities and communities, or at the provincial or territorial level (PSC 2019). This study was administered over an eight-month period (starting in November 2018), with the intention to gain insight into the efforts of municipal governments to minimize the negative consequences of current and future floods, and to reduce climate-related risks in the Northern region of Canada. During this period, a series of phone interviews were conducted with representatives from municipal governments, conservation authorities, and public utilities who were responsible for the management of flood and climate-related risks, as well as with emergency management personnel.

The areas of focus of the study reflected the core themes of the United Nations Sendai Framework for Disaster Risk Reduction (DRR), to which Canada is a signatory. DRR is a systematic, whole-of-society approach to identifying, assessing, and analyzing the causal effects of disasters and reducing the resultant risks and impacts on the basis of risk assessments. The framework highlights the need for an integrated, all-hazard, and multi-sectoral approach to disaster risk management (PSC 2017) relative to four key pillars:

1) Understanding disaster risk;

2) Strengthening disaster risk governance to manage disaster risk;

3) Investing in disaster risk reduction for resilience; and

4) Enhancing disaster preparedness for effective response and to "Build Back Better" through recovery, rehabilitation, and reconstruction (Canada 2017).

The criteria utilized within this study were not exclusively derived from the DRR, but also drew from the Canadian Emergency Management Framework (PSC 2017), which outlines the roles and responsibilities of Canadian governments.

" The areas of focus of the study reflected the core themes of the United Nations Sendai Framework for Disaster Risk Reduction, to which Canada is a signatory."

2.1

Study Design and Methodology

The flood preparedness criteria utilized in the current study were informed, in part, by a 2015 study of the preparedness of 15 Canadian cities to limit flood damage (Feltmate and Moudrak 2015). Some of the criteria and their components were redesigned for the present study, to reflect the evolution toward proactive prevention and mitigation efforts in emergency management practices, and to incorporate the efforts of municipal governments to adapt to climate change.

The criteria designed to assess the flood-related commitments of municipal governments are presented in Table 5. Some criteria consisted of a single dimension (e.g., Land Use Planning) whereas other factors consisted of sub-components (e.g., Flood Risk Assessment).

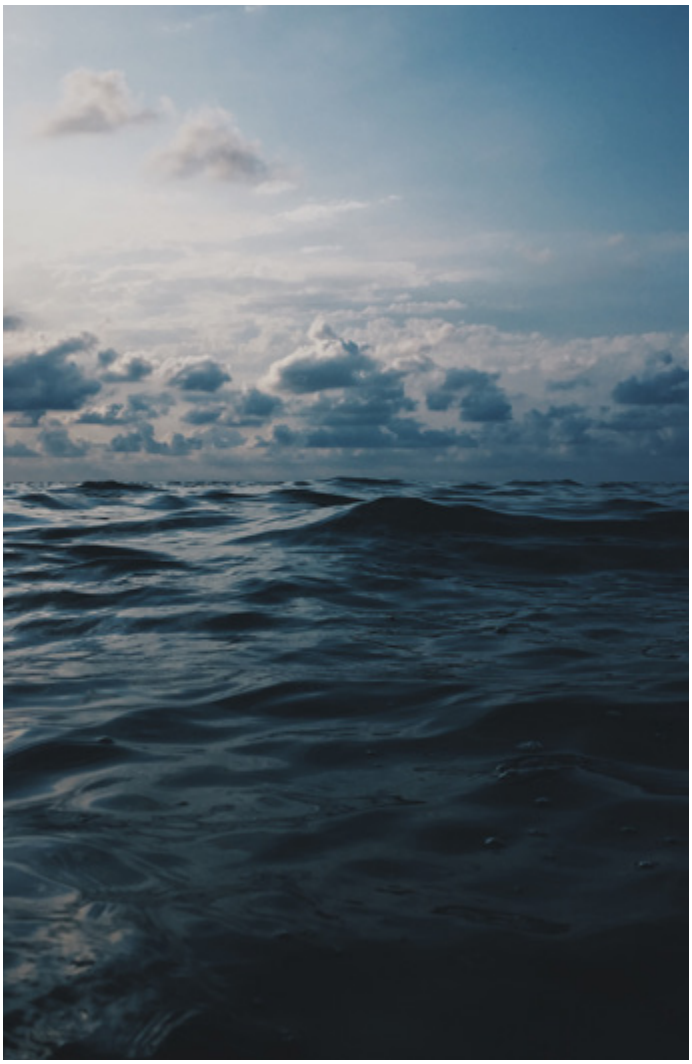


TABLE 5: Key Flood Assessment Criteria Designed to Assess Municipal Governments (Canada)

No.	Criteria	Identifier	Sub-Components
1	Flood Risk Assessment	1a	Riverine and/or Coastal
		1b	Pluvial
		1c	Failure of Flood Protection and Water Retaining Infrastructure
		1d	Incorporation of Social and Economic Vulnerability Assessments
2	Land Use Planning	2	N/A
3	Urban Drainage Assessment	3	N/A
4	Residential Property Risk Mitigation	4a	Riverine and/or Coastal
		4b	Pluvial
		4c	Backwater Valve Installation – New Homes
		4d	Backwater Valve Installation – Existing Homes
5	Critical Infrastructure Risk Mitigation	5a	Electrical-Powered Infrastructure
		5b	Telecommunication-Reliant Infrastructure
		5c	Transportation Infrastructure
		5d	Water Infrastructure
		5e	Food Services
		5f	Financial Services
6	Public Health and Safety	6a	Healthcare Sector
		6b	Chemical Sector
		6c	Dams Sector
7	Emergency Management	7a	Emergency Response Operations
		7b	Continuity of Electricity Supply
		7c	Continuity of Fuel Supply
		7d	Continuity of Emergency Communications
		7e	Public Alerting
8	Chief Resilience Officer	8	N/A

Note. N/A (Not Applicable) indicates that the specific criterion is standalone and therefore does not have any components.

Data/information regarding the criteria identified in **Table 5** was collected in a similar manner as in a prior flood preparedness study (Feltmate and Moudrak 2016). Specifically, the data was primarily collected utilizing telephone interviews with key government officials. Prior to the initiation of each phone interview, all study participants were informed that their personal judgements or opinions were not sought in regard to the adequacy of the flood preparedness efforts of their respective jurisdictions. Instead, the stated goal of the phone interviews was to collect information on the specific measures, practices, and policies that were in place within each jurisdiction. **Responses were only considered final/accurate after written confirmation by study participants**.

2.2

Study Questionnaires

Study questions for the municipal governments were formulated relative to the criteria specified in Table 5. Moreover, to enable complementarity between the present study and the provincial and territorial flood assessments conducted in 2019 (Feltmate et al. 2020), the questions and response options were consistent in design.

Several preliminary interviews were conducted with municipal officials to ensure interview questions were clear and unambiguous.

Similar to the prior study conducted in 2015 (Feltmate and Moudrak 2015), the present survey was designed using questions that were primarily quantitative in nature. However, the study also incorporated qualitative techniques to enable a detailed understanding of the state of municipal flood preparedness. The municipal questionnaire consisted of a total of 24 questions. These questions were split into sections on the basis of the various flood preparedness criteria to which they corresponded.

All 24 survey questions that were presented to city officials are included in Appendix A. A sample survey question is provided in Section 2.4 Data Analysis.

2.3

Sample Population

Participants in this study represented the municipal governments of 16 major Canadian cities, which included the capital cities of all provinces and two territories (the city of Whitehorse, Yukon, declined to participate) as well as 4 additional major cities which demonstrated high risks of flooding, whether coastal, riverine or pluvial.

Researchers established a database of 117 municipal contacts, all of whom held responsibilities related to climate change and flood risk adaptation efforts, including emergency management representatives. Initial invitations were sent to city managers, chief resilience officers, chief planners and/or other senior city staff.

Following conveyance of initial invitations, city officials appointed representatives to collect information from within their departments. Appointed officials included city managers, as well as the heads of departments of planning, community development, public works, transportation, engineering, emergency management, and public health. In addition, several interviews were conducted with representatives of conservation authorities and public utilities who were responsible for the management of municipal water, wastewater and stormwater systems.

Interviews were conducted with 53 jurisdictionally designated representatives (see Table 6 for a breakdown of the number of interviewees per city).



TABLE 6: Number of Municipal Officials Interviewed Throughout the Study

City	Number of Conducted Interviews
Calgary, AB	3
Charlottetown, PE	2
Edmonton, AB	4
Fredericton, NB	3
Iqaluit, NU	1
Halifax, NS	4
Montréal, QC	8
Ottawa, ON	8
Québec City, QC	3
Regina, SK	2
St. John's, NL	2
Surrey, BC	3
Toronto, ON	5
Vancouver, BC	2
Winnipeg, MB	2
Yellowknife, NT	1
TOTAL	**53**

Note. Whitehorse, Yukon, declined to participate in the study. Therefore, the ratio of the cities who agreed to take part to the total number of cities contacted was 16/17 = 94%.

"Several preliminary interviews were conducted with municipal officials to ensure interview questions were clear and unambiguous."

2.4

Data Analysis

To enable comparability between the municipal flood preparedness scores that were obtained in the present study vs. the aforementioned study conducted in 2015, identical methods were applied to data collection and analysis in both studies.

The survey utilized closed-form questions, each of which had five response options ranging from optimal ('A') to the low ('E'), with the good, significant and incipient options in between, respectively. During interviews, respondents were asked to self-report which option out of the five response options best captured the level of preparedness of their respective jurisdiction. For example, in order to gauge the level of involvement of municipal governments in the development and regular update of riverine and coastal flood risk assessments, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

How does the city develop and update riverine and/or coastal flood risk assessments? (Select between the following options):

- *A - The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of riverine and/or coastal flooding (considering impacts of climate change on identified flood hazards). On the basis of this assessment, the city updates flood risk maps and flood mitigation strategies and implements mitigation projects as needed.*

- *B - The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of riverine and/or coastal flooding (considering impacts of climate change on identified flood hazards). On the basis of this assessment, the city updates flood risk maps and flood mitigation strategies for flood-prone areas and is currently developing mitigation plans.*
- *C - The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of riverine and/or coastal flooding (considering impacts of climate change on identified flood hazards). The city has updated flood risk maps and is in the process of developing flood mitigation strategies.*
- *D - The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of riverine and/or coastal flooding (considering impacts of climate change on identified flood hazards). The city is currently in the process of updating flood risk maps.*
- *E - The city is currently in the process of conducting a flood risk assessment of riverine and/or coastal flooding.*

For data analysis, the selected response options were codified through the assignment of a numerical value for each respective option: A=5, B=4, C=3, D=2, and E=1. In some instances, respondents chose to utilize the non-applicable option instead of any of the above letter grades. In such cases, no numeric value was assigned to such responses. Data analyses were then performed by calculating means/averages for each participating jurisdiction. Criteria means were calculated by summing the response options selected for each component divided by the number of component questions within the criterion.

Criteria means were subsequently transcribed by converting numeric values to letter grades. However, no data transformation was performed and consequently the resultant values represent the jurisdiction's own judgments in reference to their respective levels of preparedness. Finally, average scores were calculated for cities located in Atlantic Canada, in Western and Central Canada, and for Canada as a whole, by summing the individual preparedness values and dividing by the number of jurisdictions in each respective geographical category. No average score was calculated for the cities located in Northern Canada as Whitehorse declined to participate and therefore only two cities were assessed.

The commentary provided by study participants was also analyzed with a qualitative lens. Qualitative data analyses were performed primarily to validate the collected data and to ensure the accuracy of the quantitative data scoring.

The study incorporated several open-ended questions, to allow for additional input on flood mitigation efforts – exercised by municipal governments, conservation authorities and public utilities – that might be overlooked based on quantitative analyses alone. Data that was obtained using qualitative data collection methods was neither coded nor scored and was consequently included in text format in Chapter 3.



CHAPTER 3
MUNICIPAL FINDINGS

This chapter provides an overview of the major findings pertaining to the state of preparedness of Canadian cities relative to flood and climate-related risks.

To effectively present the performance of municipal governments, the report made use of the following three jurisdiction groupings:

The Cities of Western and Central Canada, encompassing 10 major cities, located in the Provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec;

The Cities of Atlantic Canada, encompassing the capital cities of the Provinces of Newfoundland and Labrador, New Brunswick, Prince Edward Island and Nova Scotia; and

The Cities of Northern Canada, encompassing the city of Yellowknife, Northwest Territories, and Iqaluit, Nunavut (Whitehorse, Yukon, declined to participate).

The following uniting factors explain each geographic grouping of cities.

The cities of Western and Central Canada have an important similarity in that nearly all have high population densities, ranging from 5,492 people per square kilometre in Vancouver to 1,173 people per square kilometre in Québec City. Only Ottawa has a significantly lower population density with only 335 people per square kilometre.

It is projected that future population increases will continue to be concentrated largely in the major urban areas of Canada. This will lead to a continued rise in built-up areas and dwelling densities, while also causing a decrease in the size of metropolitan area ecosystems. The continual transformation of the natural environment into the built environment in highly populated cities negatively impacts hydrological and ecological systems and thereby exacerbates the pre-existing flood vulnerability of these areas.

Similarly, the cities of Atlantic Canada share unique geographical specifics which make all of them susceptible to the impacts of climate change ((Natural Resources Canada 2015). It is expected that due to rising sea level and the increasing frequency of storm events, storm surge events may become more frequent and more extreme in Atlantic Canada. Taken as a whole, the contributing factors of sea level rise, storm surge and King Tides will increase the risks of flooding, erosion and other related negative impacts, thereby stressing Atlantic communities, infrastructure and ecosystems.

The most noteworthy uniting factor for the cities of Northern Canada is that climate change is already significant and manifests itself through the reduction of sea ice, degradation of permafrost, changing precipitation levels, and increasing frequency of ice-jam floods.

Based on the above factors that highlight natural groupings of cities, the major findings of the study are presented in the following three subsections:

Subsection 3.1 profiles the findings for the cities of Western and Central Canada;

Subsection 3.2 profiles the findings for the cities of Atlantic Canada; and

Subsection 3.3 profiles the findings for the cities of Northern Canada.

3.1

Selected Cities within the Provinces of Western and Central Canada

Population increases across Western and Central Canada are projected to occur primarily within existing major urban centres, with Ontario, Quebec, British Columbia, and Alberta already being the most populous provinces in Canada, ordered by their respective population size (Statistics Canada 2019). Population growth will lead to an increase in built-up areas and dwelling densities, while simultaneously causing metropolitan area ecosystems to decrease in size. In addition, the population growth in the major cities increases the number of persons that could be potentially affected by floods. Notably, urban flooding is one of the costliest types of flooding in Canada, with damages including both insured and uninsured property damage, damage to public infrastructure, as well as productivity and business losses.

This section presents an overview of the responses provided by the municipal officials of the cities of Vancouver and Surrey (British Columbia), Calgary and Edmonton (Alberta), Regina (Saskatchewan), Winnipeg (Manitoba), Toronto and Ottawa (Ontario), and Montréal and Québec City (Quebec).

Cities were selected for inclusion in the study based on their population and/or jurisdictional, economic or legislative importance.

TABLE 7: Population of Cities Studied for Flood Resiliency (Western and Central Canada)

City	Province	City Population	City Population Density per Square Kilometre, 2016	Proportion (%) of Provincial Population Residing in City, 2016
Vancouver*	British Columbia	631,486	5492	13.6%
Surrey		517,887	1636	11.1%
Calgary	Alberta	1,239,220	1501	30.5%
Edmonton		932,546	1360	22.9%
Regina	Saskatchewan	215,106	1195	19.6%
Winnipeg	Manitoba	705,244	1518	55.2%
Toronto	Ontario	2,731,571	4334	20.3%
Ottawa		934 243	334	6.9%
Montréal	Quebec	1,704,694	4662	20.9%
Québec City		531,902	1173	6.5%

Note. Data from StatsCan 2016. * – this statistic denotes the population of the City of Vancouver and not the population of the Greater Vancouver area.

Vancouver, British Columbia C

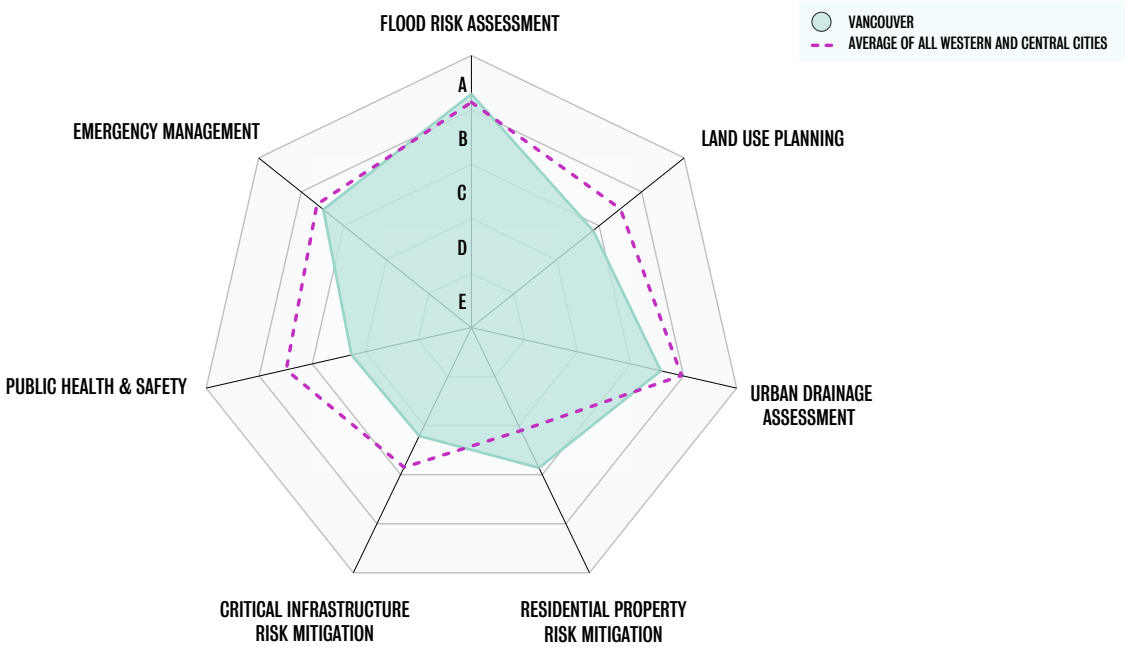


Figure 3.1.1. Flood Preparedness for Vancouver. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Vancouver.

As shown in **Figure 3.1.1**, Vancouver demonstrated strength in flood preparedness, specifically in terms of Flood Risk Assessment, Urban Drainage Assessment and Emergency Management.

Regarding Flood Risk Assessment, Vancouver reported that it had conducted its first flood risk assessment in 2013-2014, which included the impacts of climate change. The city also remarked that this assessment had a major impact on the city's subsequent policy and emergency planning efforts. The assessment was last updated in 2016 and included both social and economic factors.

Relative to Urban Drainage Assessment, the City stated that it uses future projections in terms of rain projections and Intensity, Duration and Frequency (IDF) curves, in anticipation of future redevelopment of its shoreline areas. Moreover, Vancouver stated that it is planning to reconfigure its stormwater drainage infrastructure to ensure that this infrastructure does not have a confounding effect on existing shoreline infrastructure.

In terms of Vancouver's Emergency Management, the city reported that it has conducted risk assessments, and on the basis of their results found that there is no critical emergency response infrastructure within city flood zones. Vancouver stated that it has no major transportation routes within its flood risk areas. Moreover, the city operates its own gas stations and owns fuel tanks which thereby allows the city to continue operating generators at critical facilities across Vancouver during emergency events.

Vancouver is involved in the Public Safety Broadband Network (PSBN) initiative and stated that it is currently discussing emergency management prioritization on the Bell telephone network. Presently, the city's first responders have access to a dedicated resilient public safety radio network which is run by E-Comm 911. The city also has a formalized relationship with VECTOR, which is an emergency communications amateur radio society that was created as a joint initiative between the City and Vancouver Police. Additionally, the city performs joint emergency response exercises with VECTOR and provides them with space and tools within the city's Emergency Operations Centre.

The city has conducted flood modelling city-wide to understand the potential impacts of flooding across Vancouver for both coastal and riverine flooding.

The city's current plans include the dissemination of information through the use of regular and social media. Additionally, the city has some planning in place regarding some of its homeless populations which are of significant size in areas of Vancouver, such as in East Hastings. Also, the city is engaged in expanding its alerting capability and reported that it will be leveraging the new AlertReady system once the Province includes the ability for local governments to issue alerts, which is something that is expected to be available in 2020/2021. The city's police and fire departments are also able to deliver additional notifications through the use of their field units.

Conversely, Vancouver's performance was found to be beneath the regional average in terms of its initiatives in the areas of Land Use Planning, Critical Infrastructure (CI) Risk Mitigation, and Public Health and Safety.

In regard to Land Use Planning, the city stated that it presently allows both redevelopment and development on floodplains, although it does require higher flood construction levels for developments within these areas. **More concerning, Vancouver reported that British Columbia is currently constructing a hospital in the city's floodplain**.

To mitigate risk to its CI, Vancouver stated that it is in the early stages of understanding CI interdependencies and has redundancies in place for some of its electrical system components, but not for its wastewater systems. The city's efforts in relation to mitigating the flood risk of its telecommunications systems is limited to preliminary discussions. Vancouver has also not yet secured funding to assess the flood risk of its transportation systems.

With regard to Public Health and Safety initiatives, Vancouver reported that although it does engage with the owners and operators of healthcare facilities, it only collaborates with them and has no capability to require them to conduct any specific efforts. In terms of preventing the release of harmful chemicals, the owners of most potential releasing sites are federally controlled and are therefore outside of the city's jurisdiction – accordingly, the city is unable to mandate safety reviews. The city also reported that a great deal of hazardous materials come through the Port of Vancouver, noting that it is not able to regulate this site and how flood risk and hazardous waste might convey compounding and pervasive risk.

Surrey, British Columbia B-

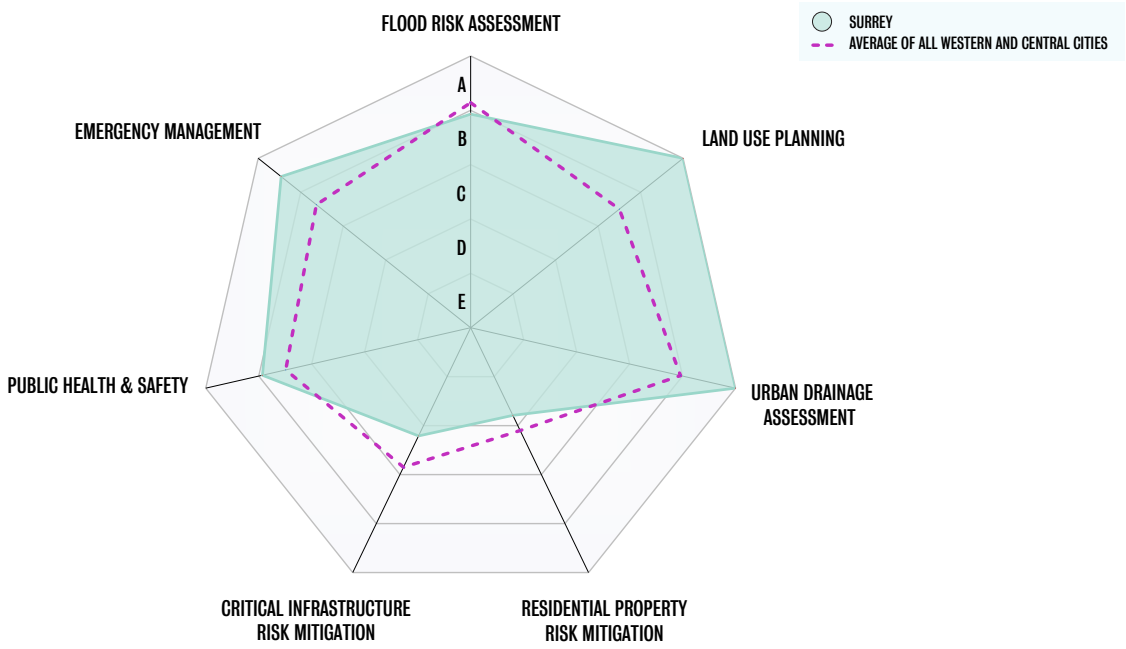


Figure 3.1.2. Flood Preparedness for Surrey. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Surrey.

Surrey was amongst the first cities in Canada to adopt a Climate Adaptation Strategy that included an initiative to increase the community's resilience to future flood risks, including the risks of coastal and riverine flooding. Accordingly, the City developed floodplain maps for future conditions, incorporating climate change projections and land-use changes for 2040, 2070, 2100 and 2200 time horizons. When compared to other Canadian municipalities, Surrey is at the forefront of implementing a multifaceted climate adaptation plan that includes both structural and non-structural flood mitigation measures.

As **Figure 3.1.2** demonstrates, Surrey reported strengths in several domains of its flood preparedness, specifically in terms of Land Use Planning, Urban Drainage Assessment, Public Health and Safety and Emergency Management.

With regard to its Land Use Planning policies, the city stated that no new residential developments are permitted within the city's flood-prone areas. Developers are responsible for building to the flood construction level per the Floodplain Management Bylaw requirement, and only city council has the power to override this requirement.

Another notable achievement is that Surrey's forward-thinking land-use regulation policy has ensured that floodplain areas largely contain agricultural lands rather than high density developments. The city has invested considerable effort to bring low-lying coastal areas and river floodplains, which are primarily agricultural lowlands, to acceptable flood protection standards.

Regarding Urban Drainage Assessment, the city noted that it is implementing a $25 million comprehensive Stormwater Management Strategy for Crescent Beach to help prepare the community for the increased risk of coastal floods.

With respect to Public Health and Safety, Surrey reported that the responsibility for healthcare facilities lies with the Fraser Health Authority and moreover that most healthcare facilities are located outside of floodplain areas. The city also stated that it has a hazardous materials team and that Surrey has an all-hazards response and

evacuation plan that is focused on preventing the release of hazardous materials. In terms of dam safety, the city reported that it monitors dams, reviewing and updating action items annually.

In regard to its Emergency Management efforts, the city stated that it has developed new LIDAR mapping and is consequently aware of the availability of emergency routes within its territory and also stated that there is only a small flood-impacted area within the city.

Pertaining to the continuity of fuel supply, Surrey noted that it has established relationships with fuel contractors and that it conducts annual reviews and business continuity exercises with them. The city also has a biofuel facility that provides Surrey with renewable natural gas as an alternative fuel for many of its vehicles.

Surrey reported that it is heavily involved in the development of the Public Safety Broadband Network (PSBN) and had co-written a letter that urged further development of this project. The city also conducts monthly testing of its emergency communications networks and participates in workshops to develop the PSBN.

Finally, the city has conducted a vulnerability assessment throughout its food section. It noted that its Agriculture Enhancement and Protection Strategy manages some of the risks of extreme weather by ensuring reliable connections and relationships between agriculture and urban residents.

Conversely, Surrey's performance was found to be beneath the regional average for initiatives in relation to Flood Risk Assessment, Residential Property Risk Mitigation, and Critical Infrastructure Risk Mitigation.

In reference to Flood Risk Assessment, Surrey reported that it develops so-called "unofficial maps." These maps are not verified by the province of British Columbia as the city does not apply to the province to have these maps formalized. Surrey stated that this is because it "does not recognize the benefit of doing this." Surrey also reported that its city council has not enclosed the creeks within the residential parts of its territory which give rise to flooding.

Regarding Residential Property Risk Mitigation, Surrey reported it has areas within the city where there are large quantities of flood-vulnerable historical residential developments. In addition to this, Surrey remarked that some of the floodplains within the city remain less protected than others, and moreover that some parts of the City are sinking. Surrey does not mandate the installation of backflow prevention valves for new homes and lacks a subsidy program for existing homes.

Finally, in regard to Surrey's Critical Infrastructure, the city stated that its traffic signals can be vulnerable to power loss and that it also has limited ability to mitigate this issue as the lighting and power supply systems are owned by an independent hydro utility. The city went on to state that there are key railways from the United States as well as numerous infrastructure corridors of regional, provincial and national significance that go through the floodplain adjacent to the city. For example, BC Hydro's main transmission line goes through the floodplain adjacent to the city en route to the United States, and as Surrey confirmed, this infrastructure is not flood-proofed. Although Surrey has repeatedly asked to adjust the line's route, the city reported that the Utility has repeatedly strongly opposed this request.

"Surrey does not mandate the installation of backflow prevention valves for new homes and lacks a subsidy program for existing homes."

Calgary, Alberta B–

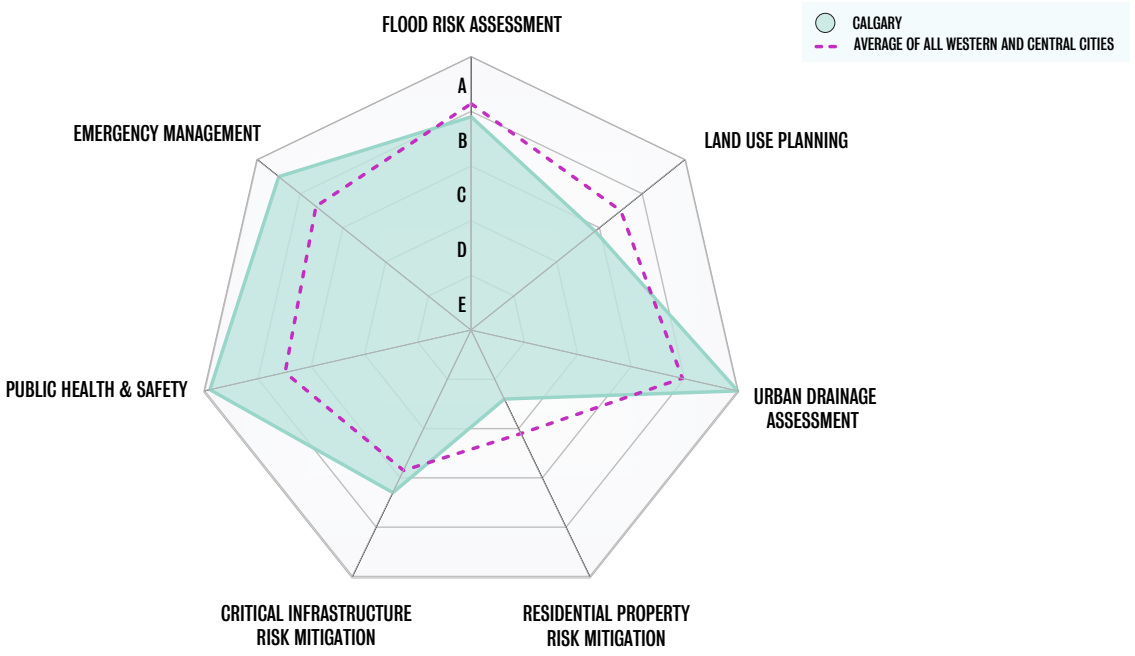


Figure 3.1.3. Flood Preparedness for Calgary. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Calgary.

As shown in **Figure 3.1.3**, Calgary reported areas of strength in terms of its flood preparedness, primarily in the domains of Urban Drainage Assessment, Critical Infrastructure Risk Mitigation, Public Health and Safety, and Emergency Management.

Regarding Urban Drainage Assessment initiatives, Calgary operates a Community Drainage Improvement Program to assess and provide flood-related infrastructure upgrades to older neighborhoods that require them.

In reference to Critical Infrastructure (CI), Calgary reported that it cooperates with electrical utility providers in ensuring that electrical infrastructure is waterproof.

In addition, Calgary reported that it has assessed infrastructure interdependencies.

In terms of telecommunications systems, most pieces of CI of this type have back-up systems in place with multiple redundancies. Calgary's critical response infrastructure is thoroughly protected which allows the city's emergency response operations to continue to operate even during internet and electrical outages.

Additionally, Calgary has redundant communications systems in place, which were used in 2013 when the city lost power causing a telecommunications outage.

In relation to Calgary's food systems, the city reported that it had completed a macro-level all-risk assessment in addition to flood-specific risk assessments for all critical food infrastructure that is located within the city's flood hazard area.

Calgary regulates the elevations of key transportation infrastructure that passes through flood zones. The city builds resilience into such infrastructure as well, for instance by installing flood-proof doors for subterranean subway stations.

In regard to Calgary's Public Health and Safety initiatives, the city reported that it prevents the construction of new healthcare facilities in zones at risk of flooding, although some existing institutions are located in borderline areas and therefore have evacuation plans in place. Moreover, the design standards for new buildings must meet stringent guidelines that are above the 1:500-year flood event mark.

The city has a dedicated program that aims to prevent hazardous chemical releases, with procedures to identify, characterize and abate associated risks. Regarding dam safety, Calgary reported that dams in Alberta are regulated provincially with a discrete and extensive set of requirements.

In reference to Emergency Management policies, Calgary stated that it has developed a detailed flood emergency manual which is updated annually, and which specifies the actions and operations that are to be undertaken during flood events of varying extremes. The city is also conducting work to protect its river flood risk zones, and has secured funds and established planning for most of its critical areas.

Conversely, the City of Calgary's efforts were below the regional average with respect to several domains of flood preparedness. Specifically, these gaps were found in the City's Land Use Planning and Residential Property Risk Mitigation policies.

In terms of Land Use Planning, Calgary stated that it does not prohibit development on floodplains, allowing development to proceed in the flood fringe, provided that such developments are flood-proofed.

In regard to Residential Property Risk Mitigation, the city stated that there are no home flood assessments conducted on a property-specific level, although there is a flood preparedness program that includes self-assessments and educational programs. The City also identified basement damages as a significant risk and is planning to implement regulations that eliminate the development of below grade space, and that will require the installation of sump pumps and sewer backflow preventers in all flood prone areas. Calgary also reported that the development of a property-level mitigation and flood risk awareness program is underway as part of an overall flood resilience strategy, but the City is currently placing primary importance on the installation of structural components.

Edmonton, Alberta B+

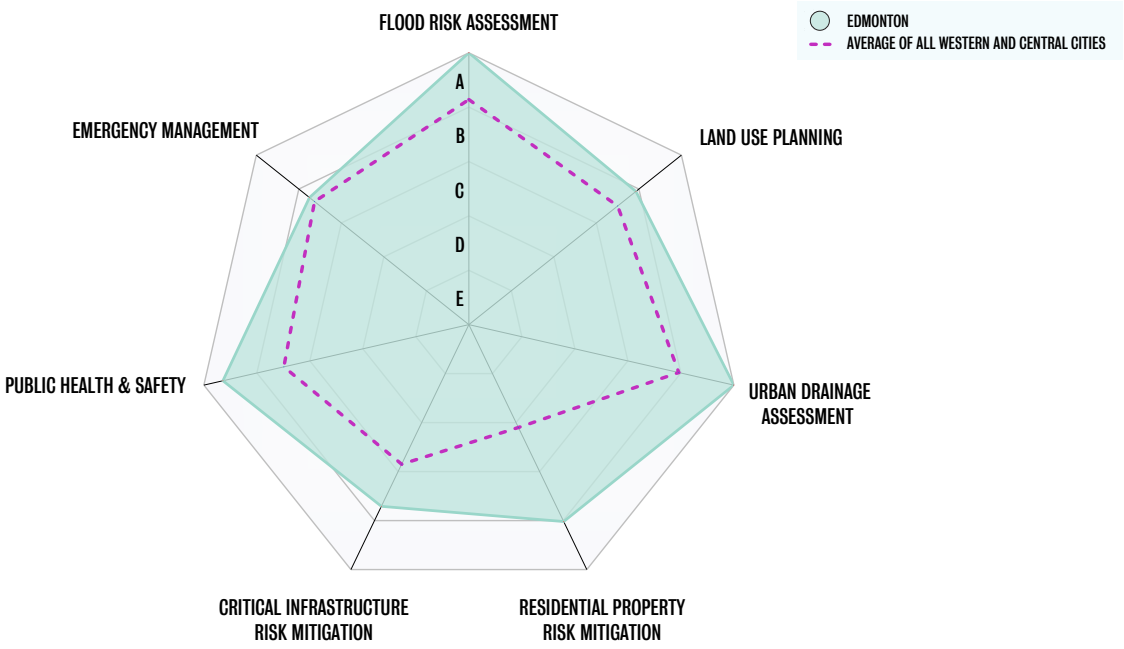


Figure 3.1.4. Flood Preparedness for Edmonton. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Edmonton.

As indicated in **Figure 3.1.4**, Edmonton demonstrated strength in terms of all domains of its flood preparedness, thereby earning it one of the highest scores of any city in Canada.

Relative to Flood Risk Assessment initiatives, Edmonton reported that it had assessed flood risks with a project that was conducted by EPCOR (Edmonton Power Corporation). The city also completed a full safety assessment from the standpoint of public safety and the risk of drowning. Edmonton's risk framework considers health, safety and the environment, as well as financial and social/service impacts.

In reference to Land Use Planning policies, the city has enacted zoning bylaws which designated parts of its territory as floodplains. Edmonton is updating its zoning bylaws which may lead to new or altered restrictions in regard to development within the city's designated floodplain zones.

In regard to Urban Drainage Assessments, Edmonton has completed a stormwater infrastructure assessment as part of its recent city-wide risk assessment. The results of this assessment subsequently led to the City prioritizing certain city areas for future mitigative actions.

In terms of Residential Property Risk Mitigation, Edmonton stated that it had assessed property risk mitigation efforts recently and that since 1998, the city's bylaws have required all new homes to install backwater valves. Moreover, EPCOR has a backwater valve subsidy program to financially assist the city's residents on installing this type of equipment.

Regarding the City's risk mitigation efforts for its Critical Infrastructure (CI), Edmonton reported that it has received grant funding toward mitigating its electrical infrastructure. The city's water treatment plants have received funding for mitigating their electrical equipment and to harden their infrastructure and move equipment where necessary. **The City conducted a supplementary pluvial flooding assessment for all of its electrical substations.** Edmonton is actively engaged with the owners and operators of its power and water treatment plants to continue the process of hardening CI throughout the city.

In regard to Public Health and Safety initiatives, Edmonton reported that the ownership of healthcare facilities had been recently transferred to the Province of Alberta. However, EPCOR has developed a plan called the Source Water Protection Plan which included the evaluation of risks to the water supply of the city. Edmonton also reported that it closely cooperates with the oil and gas sectors, reviewing plans on an annual basis and conducting various joint exercises. The city also reported that there are no dams located immediately within the city.

Finally, with respect to its Emergency Management initiatives, Edmonton reported that it has developed maps which indicate riverine risk in terms of the continuity of access to parks, hospitals, emergency shelters and fire stations. Currently, the city is outfitting its emergency response stations with additional flood protection infrastructure. The City also has fuel continuity plans and mutual aid agreements in place.

"The City conducted a supplementary pluvial flooding assessment for all of its electrical substations."

Regina, Saskatchewan B+

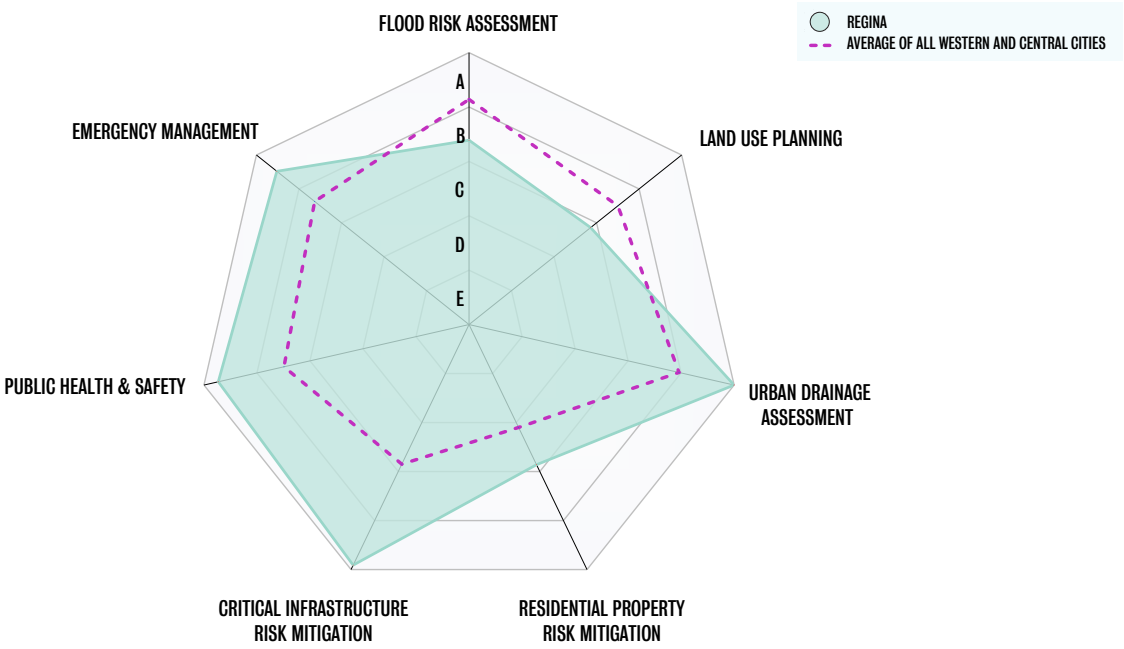


Figure 3.1.5. Flood Preparedness for Regina. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Regina.

As shown in **Figure 3.1.5**, Regina demonstrated strength in multiple domains of flood preparedness, specifically in terms of Urban Drainage Assessment, Critical Infrastructure Risk Mitigation, Public Health and Safety, and Emergency Management.

In reference to Flood Risk Assessment, Regina reported that it has developed flood risk maps and that it is currently completing a full upgrade of its Drainage System Model. This upgrade will include 2D modelling to identify overland flows and underground pipes city-wide. The City has also upgraded its drainage systems to enable them to handle more extreme events.

In regard to Urban Drainage Assessments, Regina reported that it has invested substantially into upgrading its drainage and stormwater systems, performing between one to two projects annually in this regard. Also, the city has created new detention ponds, has moved some of its drainage infrastructure, and has installed new culverts.

In terms of city-owned Critical Infrastructure, the city reported that it has performed vulnerability assessments of its water infrastructure and has focused on increasing the resiliency of electrical supply to its water treatment plants. Moreover, the city stated that all key telecommunications infrastructure within Regina is located well away from any flood zones. The city also has agreements in place with amateur radio operators for assistance during major disasters.

The city has agreements in place with the Canadian Red Cross and is therefore able to provide emergency shelter for its citizens when necessary. The city also has agreements with contractors to assist with the supply of food. Finally, Regina has an all-encompassing, non-flooding-specific plan in place for its transportation system.

In regard to Public Health and Safety initiatives, Regina reported that it regularly improves its healthcare facilities to make them more flood resilient. The city has also conducted two joint full-scale exercises with oil companies that focused on dealing with potential releases of toxics into water bodies.

Regarding Emergency Management, Regina stated that it has developed a flood response plan which is updated annually. The city also has its own radio system and works with the Provincial Public Safety Telecommunications Network operated by the province of Saskatchewan. Moreover, Regina utilizes a municipal mass notification system and distributes information through the city's website as well as through other social media platforms.

Regina's efforts were below the regional average relative to Land Use Planning and Flood Risk Assessment.

In reference to Regina's Land Use Planning policies, the city reported that mechanisms exist through which developers can apply to create developments on floodplains. Such developments may require flood-proofing measures, but development on floodplains is not explicitly prohibited in Regina, in contrast to what is mandated in some other Canadian jurisdictions.

In relation to the risk mitigation of its residential properties, Regina reported that it has no comprehensive subsidy program for the installation of backflow prevention valves, except for within a small area of the city which was identified as being at high risk of flooding.

Winnipeg, Manitoba D

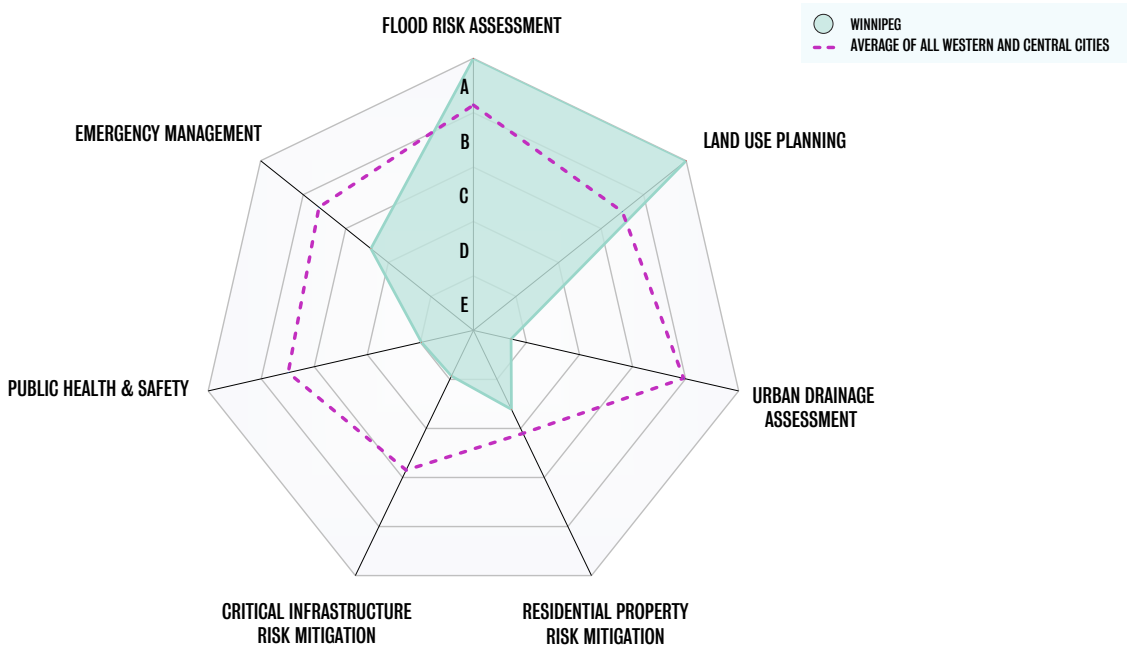


Figure 3.1.6. Flood Preparedness for Winnipeg. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Winnipeg.

As indicated in **Figure 3.1.6**, Winnipeg demonstrated strength in some domains of flood preparedness, particularly in reference to Land Use Planning. More specifically, Winnipeg stated that although it reviews relevant Land Use Planning plans regularly, there are no city-specific land-use related bylaws, with regulations instead stemming directly from the province of Manitoba. If a building is found to be within the flood fringe, Winnipeg either builds dykes or extends primary dykes to isolate the area within which the structure is located. In brief, the city stated that it restricts new development through legislation enacted provincially.

Regarding Flood Risk Assessments, Winnipeg reported that riverine flood risk mapping is conducted by the Province of Manitoba rather than by the city, and indicated N/A options for most components of the Flood Risk Assessment criterion.

Alternatively, Winnipeg's performance was found to be below the regional average regarding Urban Drainage Assessment, Residential Property Risk Mitigation, Critical Infrastructure (CI) Risk Mitigation, Public Health and Safety, and Emergency Management Initiatives.

For Urban Drainage Assessments, Winnipeg reported that it has limited capacity to address issues identified for existing developments within the city. Moreover, Winnipeg reported that it has not conducted any assessments on its stormwater infrastructure within the last five years.

The city also stated that it currently has no active program for the installation of backflow prevention valves for existing homes, although such a program did exist in the past.

Regarding the risk mitigation of its CI, Winnipeg reported that it has not conducted any specific work on its food systems to address their potential vulnerability to flooding. The city also reported that although some work has been performed in terms of assessing its financial sector, this work has not been specific to flood risk.

In terms of Public Health and Safety, Winnipeg stated that it generally lacks policies regarding the release of hazardous chemicals as well as in relation to dam safety.

Relative to Emergency Management efforts, Winnipeg reported that it has not factored the impacts of climate change into its discussions in regard to risk assessments. Moreover, Winnipeg's emergency fuel supply plans were not developed to deal with the risk of flooding.

Finally, Winnipeg stated that it maintains a public safety radio network for emergency responders with mitigative measures for hazard situations, including anticipated flood impacts. In addition, the city partners with an amateur radio operator society to provide emergency communications if required.

Toronto, Ontario B+

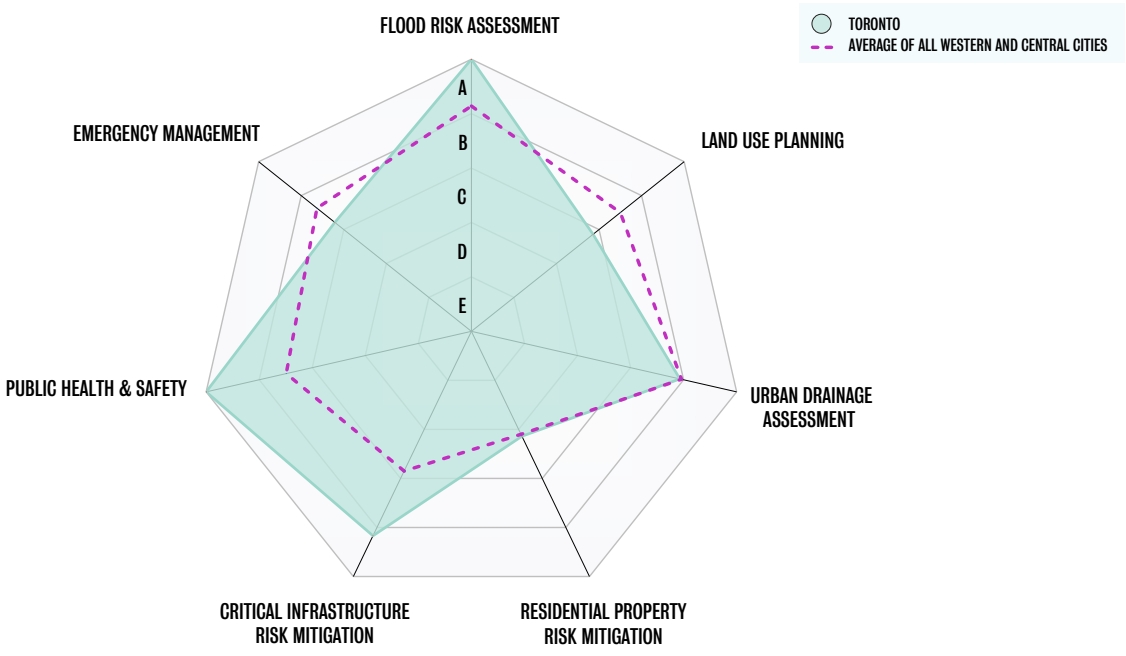


Figure 3.1.7. Flood Preparedness for Toronto. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Toronto.

As shown in **Figure 3.1.7**, Toronto demonstrated strength in some domains of flood preparedness, specifically Flood Risk Assessment, Critical Infrastructure (CI) Risk Mitigation, and Public Health and Safety.

Regarding Flood Risk Assessment, Toronto reported that it updated its G. Ross Lord Dam Emergency Preparedness Plan, which analyzed the state of a dam that could impact the city substantially if it were to fail. Toronto also conducts social vulnerability assessments which consider the economic and social impacts of flooding.

In terms of risk mitigation of CI, Toronto reported that it assessed the potential of flooding for its critical water facilities. The city has also installed dual power feeds to its most critical electrical-powered infrastructure, with standby generators. Toronto is upgrading its water plants to reduce their exposure to flood risk.

Toronto also reported that it had conducted a high-level vulnerability assessment of its food systems relative to the impacts of climate change. As part of this process, Toronto analyzed three types of extreme weather events, specifically: significant rain and flooding events, extended heatwaves, and major winter ice storms. Toronto is working with stakeholders to disseminate the results of its vulnerability assessments and is developing a food resilience coordination plan.

Relative to its transportation network, Toronto is developing plans, and prioritizing actions, to ensure the integrity of it transport system in anticipation of major flood events.

In regard to Toronto's Public Health and Safety initiatives, Toronto reported that it has developed a thorough plan through Toronto Water to deal with hazardous chemical releases. The city responds to such releases by setting up booms and other interception devices to attempt to remove harmful substances from watercourses. For the cases when owners cannot be immediately identified, Toronto stated that it responds itself. In some instances, the public-at-large may also be notified. In addition to this, Toronto has a Source Protection Plan that was developed to mitigate potential threats to the city's drinking water intakes. Toronto also has established emergency preparedness plans for its dams.

Conversely, the performance of the city was found to be lower than the regional average in terms of its initiatives in relation to Residential Property Risk Mitigation and Emergency Management.

In regard to the mitigation of risk to residential properties, Toronto reported that it has no clear legislative requirements in relation to riverine flooding, and that this responsibility is delegated to the Toronto and Region Conservation Authority (TRCA).

Finally, in relation to Emergency Management, Toronto stated that it was not certain whether the development of Emergency Routes for the City had been completed. The City also stated that its efforts in terms of developing flood warning systems are presently limited.

"The performance of the city was found to be lower than the regional average in terms of its initiatives in relation to Residential Property Risk Mitigation and Emergency Management."

Ottawa, Ontario B–

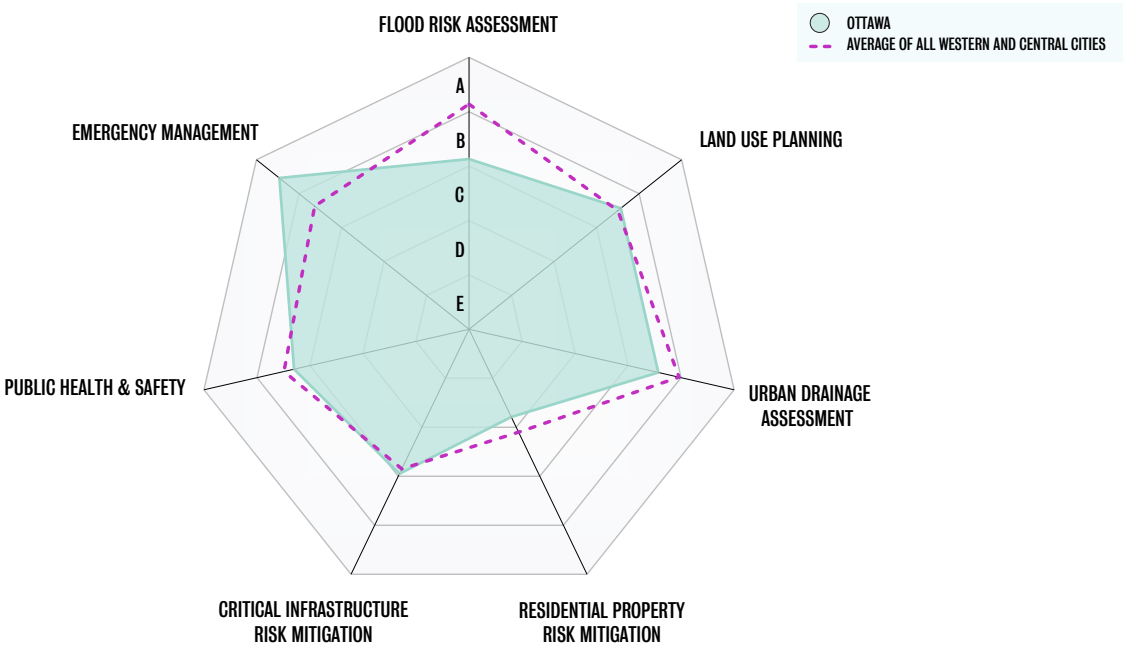


Figure 3.1.8. Flood Preparedness for Ottawa. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Ottawa.

As shown in **Figure 3.1.8**, Ottawa demonstrated strength in some domains of its flood preparedness, specifically in terms of Land Use Planning, Critical Infrastructure Risk Mitigation, and Emergency Management.

In regard to Land Use Planning, Ottawa reported that its policies conform with Ontario's Provincial Policy Statement (PPS), and are more comprehensive than those required by the PPS. Specifically, the city's zoning bylaw prohibits all development within the floodplain**,** except for minor forms of development such as small additions (subject to size limitations). Ottawa also has a separate set of policies and zoning provisions for areas at reduced risk, while prohibiting lot creation in both types of areas.

In reference to Critical Infrastructure, the city has conducted some work on mitigating flood risk relative to electrical infrastructure. Ottawa also reported that it has established plans to ensure redundancy for the generating capacities of some telecommunications facilities. The city has also reviewed some vulnerabilities for its food systems, and has assessed parts of its road network.

Regarding Emergency Management initiatives, Ottawa reported that none of its emergency response resources are at significant risk of flooding. The city mentioned that it has a just-in-time fuel supply system and is discussing the deployment of the Public Safety Broadband Network (PSBN) within the city. Ottawa also stated that it cooperates with local amateur radio providers and operates a P25 public safety radio system that includes all first responders and city agencies. Finally, the city's flood warning system is based on the AlertReady system.

Conversely, the performance of the city was found to be lower than the regional average in relation to the domains of Flood Risk Assessment, Urban Drainage Assessment, and Public Health and Safety.

Regarding Flood Risk Assessment, Ottawa reported that the remediation portion of its flood risk initiatives is not in place, as the entire area of the city had not yet been fully assessed, ranked and prioritized – however, these efforts are in progress. The city's assessments do not include the economic impacts of flooding.

Relative to Urban Drainage Assessment, the city reported that not all areas are analyzed to the same extent.

In regard to Public Health and Safety initiatives, Ottawa stated while the risk assessments that the City carries out do encompass its healthcare facilities, funding and planning are under the jurisdiction of the Province, although the city does collaborate with the province on planning initiatives.

Finally, Ottawa reported that it is not confident about the exact extent of the dam failure mapping for city-adjacent dams, as this mapping is performed by the operators of the dams rather than by the City itself.

Montréal, Quebec C

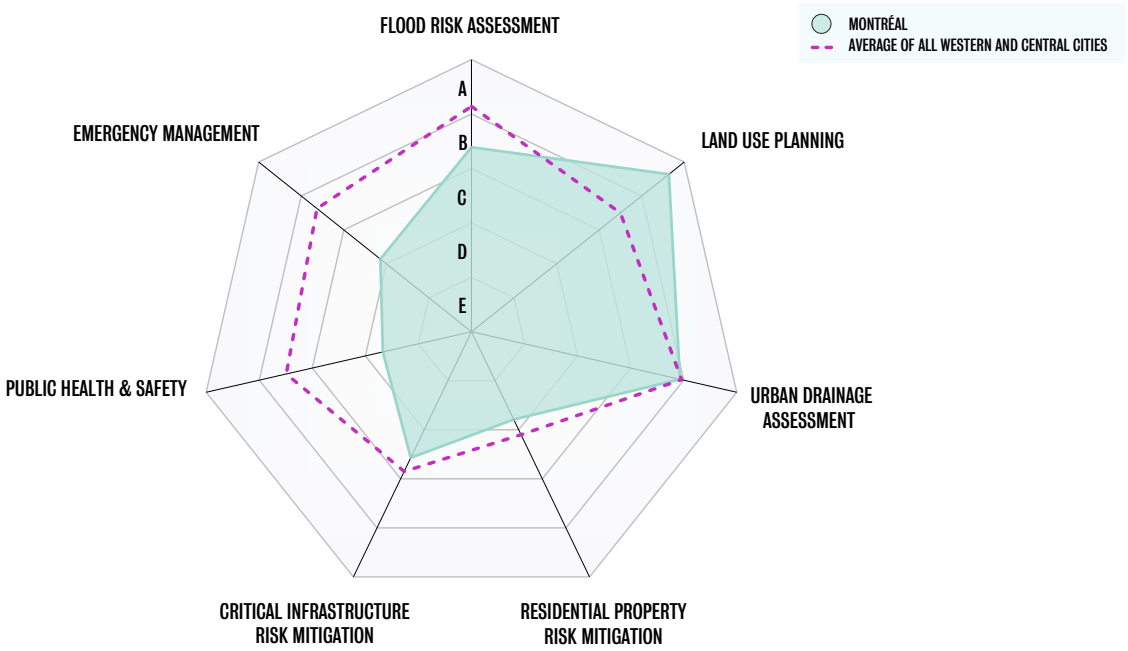


Figure 3.1.9. Flood Preparedness for Montréal. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Montréal.

As shown in **Figure 3.1.9**, Montréal demonstrates strength in some domains of its flood preparedness, specifically in terms of Flood Risk Assessment, Land Use Planning, and Urban Drainage Assessment.

In reference to Flood Risk Assessments, the city reported that it uses aerial and ground surveys for risk assessments and has validated information collected during the 2017 Montréal floods. Moreover, the risks of flooding are incorporated in its planning initiatives and the city is currently reviewing and analyzing its drainage, sewer and land use plans. Montréal also stated that there are very few floodplain areas within its territory and therefore the City has no flood protection infrastructure.

Regarding Land Use Planning, the city's policies fall under a provincial regulation Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains (PPLRI). This policy was incorporated into city bylaws, and includes a minimal regulatory framework that all municipalities within Quebec must apply. As directed by this policy, existing buildings can be maintained in the 0 to 20-year flood zone, however they cannot be rebuilt following a flood disaster. In addition, new construction would be prohibited in the flood zone. Non-protected construction is prohibited within the 20-to-100-year flood zone.

Relative to Urban Drainage Assessment, Montréal reported that it is currently conducting work on its stormwater infrastructure from the perspective of improving and adapting to the effects of climate change. All new designs for stormwater infrastructure within Montréal are based on new rainfall conditions that consider the impacts of climate change.

Montréal's efforts were found to be below the regional average with respect to several domains of flood preparedness. Specifically, these weaknesses were found relative to Residential Property Risk Mitigation, Critical Infrastructure Risk Mitigation, Public Health and Safety, and Emergency Management.

In terms of Residential Property Risk Mitigation, Montréal provides information on a case-by-case basis to residents who apply for building permits, but otherwise is not involved in riverine flood mitigation initiatives. The city also lacks a subsidy program for the installation of backflow prevention valves for existing homes.

In regard to gaps in the city's risk mitigation initiatives relative to its CI, Montréal stated that it has not conducted any risk assessments on its electrical and food systems. Also, the city has no risk assessment, action plan, nor discussion regarding vulnerability of the city's financial sector – interventions with respect to this sector are made on an ad-hoc basis.

Regarding its Public Health and Safety initiatives, Montréal stated that it lacks a comprehensive plan in reference to the potential releases of hazardous chemicals. Similarly, the city stated that it does not have the power to mandate the owners or operators of dams to conduct risk monitoring activities.

Finally, Montréal reported that in terms of its Emergency Management policies, the integration between the forecasting and flood warning systems operated by Quebec and those operated by the city are ongoing. This integration is a necessary and important initiative as the St. Lawrence River watershed that could affect the city is material.

Québec City, Quebec C+

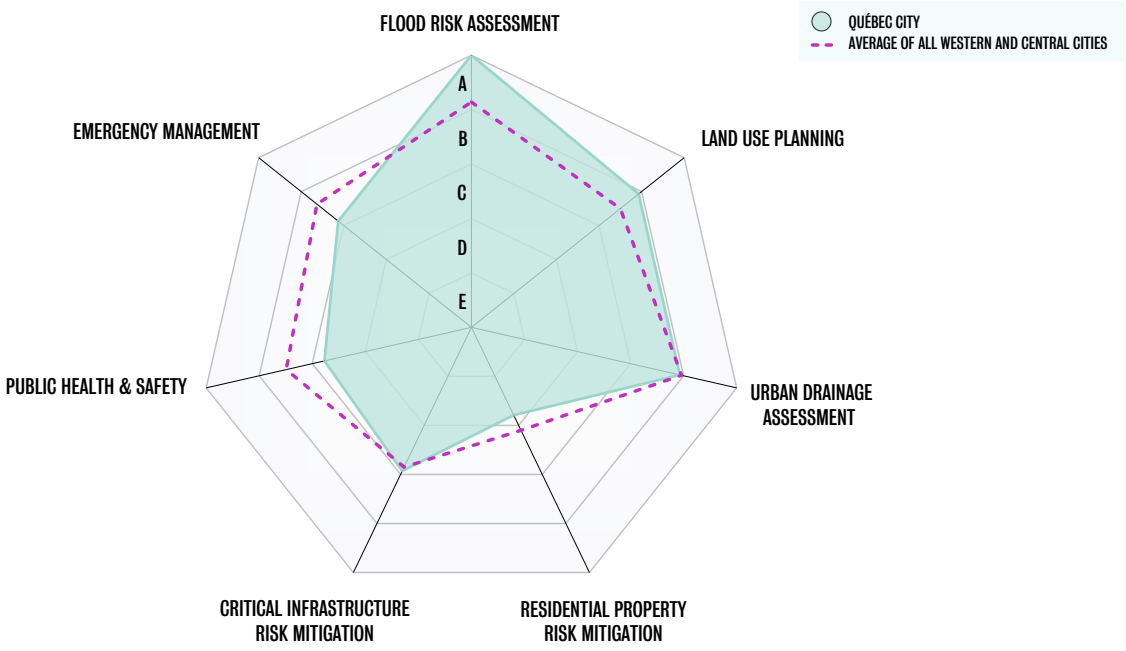


Figure 3.1.10. Flood Preparedness for Québec City. The benchmark score, calculated as the average of the results of all major cities of Western and Central provinces (viz. Vancouver, Surrey, Calgary, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montréal, and Québec City) is depicted with a dashed line. The green area depicts the preparedness score of Québec City.

As shown in **Figure 3.1.10**, Québec City demonstrates strength in some domains of its flood preparedness, specifically with respect to Flood Risk Assessment, Land Use Planning, Urban Drainage Assessment, and Critical Infrastructure (CI) Risk Mitigation.

Relative to Flood Risk Assessment, Québec City stated that it has conducted risk mitigation projects, such as the reconstruction of bridges and the construction of water retention structures for the Lorette River.

Regarding Land Use Planning, the city stated that, similar to Montréal, it is obligated to incorporate the provincial Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains (PPRLPI) into its land use planning bylaws. However, Québec City reported that certain exceptions to this policy are possible, although they are difficult to obtain and require several authorizations.

Relative to Urban Drainage Assessment, the city mandates the application of Future Climate IDF curves for all civil engineering projects (since 2007 onward).

In reference to the city's Critical Infrastructure, Québec City stated that all of its existing essential electrical infrastructure has been equipped with redundancy systems such as back-up generators and that all such infrastructure is elevated above the flood level. Furthermore, a risk assessment of this infrastructure is ongoing. The city also has a Civil Security Plan (CSP) which includes redundancy measures for its telecommunication systems. On the other hand, Québec City indicated that its financial institutions are treated in the same manner as all other buildings during disaster events.

Finally, with respect to the city's transportation network, Québec City stated that its CSP includes a Road Network Management activity, which addresses the transportation of people and goods.

Conversely, the city's efforts were found to be below the regional average in terms of Residential Property Risk Mitigation, Public Health and Safety, and Emergency Management.

For instance, Québec City indicated that it has no grant programs to support home protection assessments.

In terms of Public Health and Safety, the city stated that it does not have any significant policies in relation to the potential releases of hazardous chemicals.

Finally, in regard to Emergency Management initiatives, Québec City has incorporated renewable energy aspects for some, but not all, of its administrative units with respect to the continuity of fuel supply. The city stated that it has not adapted its flood warning system to address the heightened need and concerns of vulnerable populations.



3.2

Selected Cities within the Provinces of Atlantic Canada

The cities of Atlantic Canada share unique geographical specifics which makes them all susceptible to the impacts of climate change. It is predicted that the region will experience more frequent storm events, increasing intensity of storms, rising sea levels, storm surges, coastal erosion and more frequent flooding due to climate change (Lemmon et al. 2016).

This section provides an overview of the responses provided by the municipal officials of the cities of Fredericton (New Brunswick), Halifax (Nova Scotia), Charlottetown (Prince Edward Island) and St. John's (Newfoundland and Labrador).

The cities which are located within these provinces were selected for the study on the basis of their population and/or jurisdictional, economic and/or legislative importance.

TABLE 8: Populations of Studied Cities in Atlantic Canada

City	Province	City Population	City Population Density per Square Kilometre, 2016	Proportion of Provincial Population Residing in City, 2016
Fredericton	New Brunswick	58,220	439	7.8%
Halifax	Nova Scotia	403,131	73	43.7%
Charlottetown	Prince Edward Island	36,094	814	25.3%
St. John's	Newfoundland and Labrador	108,860	244	21.0%

Note. Source: StatsCan 2016.



Fredericton, New Brunswick B-

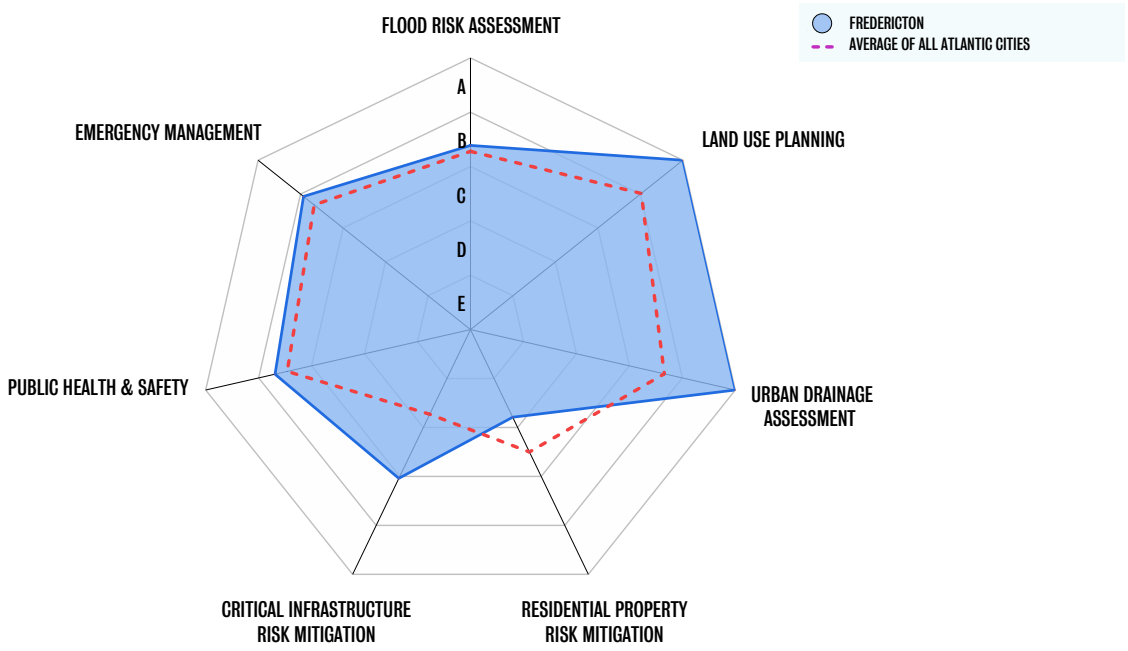


Figure 3.2.1. Flood Preparedness for Fredericton. The benchmark score, calculated as the average of the results of all capital cities of the Atlantic provinces (viz. Charlottetown, Fredericton, Halifax and St. John's) is depicted with a red dashed line. The blue area depicts the preparedness score of Fredericton.

As demonstrated in **Figure 3.2.1**, Fredericton has areas of strength in flood preparedness, particularly in the domains of Flood Risk Assessment, Land Use Planning, Urban Drainage Assessment and Critical Infrastructure Risk Mitigation.

Fredericton was built on the banks of the Saint John River, which effectively splits the city through its downtown area. In reference to Flood Risk Assessment, Fredericton reported that although the Saint John River watershed is being studied by the province of New Brunswick, the city also conducts independent flood assessments. The city is working on pluvial flood risk assessments and has identified a number of infrastructure issues. The city follows a management system based on identifying problems, resolving them, and then moving back to the identification step. Utilizing this process, the city has elevated some key roadways and is continuing to identify areas where there could be long-term impacts of continual flooding.

The city created Environmental Open Space zoning to protect low lying or flood prone areas from being developed. In response to Urban Drainage Assessment, the city stated that it added an additional 20% to its 1-in-100-year flood preparedness standard for culverts and bridge replacements. There is also a minor storm sewer system that the city is constructing to a 10-year standard.

In regard to Critical Infrastructure Risk Mitigation, the city reported that it addresses the risks of its electrical, telecommunications, food, financial and transportation systems. Fredericton is working on protecting its electrical infrastructure through an infrastructure renewal project which includes upgrading city roads and lift stations. Additionally, the city has completed assessments of what specific pieces of telecommunication infrastructure would be impacted by flooding. Fredericton has also installed SCADA systems that provide monitoring data for its water systems, and allow the city to manually update traffic signals during telecommunications disruptions.

Fredericton has installed back-up power for its food storage facilities, and has a partnership in place with the Salvation Army which had constructed a shelter to provide temporary food and hospitality services during

emergencies. The city also noted that there are no financial institutions within its immediate floodzone.

In terms of Fredericton's transportation network, the city has identified areas that are vulnerable to flood risk – in response, as these areas are upgraded during the normal course of refurbishment, an elevated level of resilience will be met.

Fredericton was below the regional average regarding Residential Property Risk Mitigation. The city reported that it has no property-specific program in place to convey flood-proofing information to home owners. Also, the city does not mandate the installation of backwater valves for residential housing.

Halifax, Nova Scotia B-

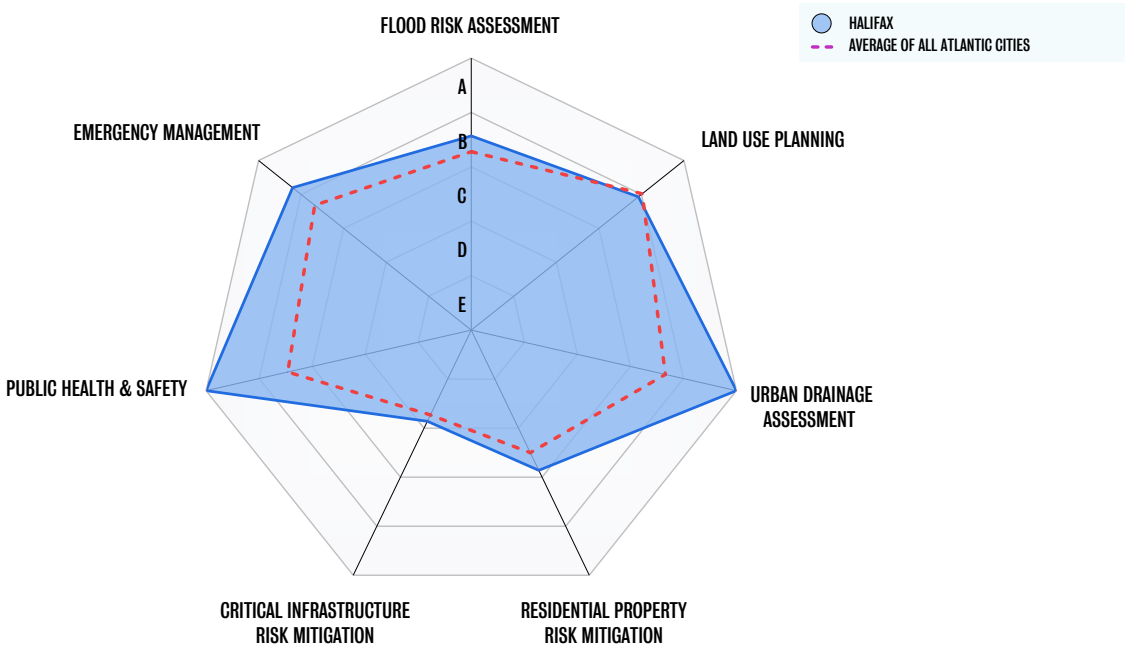


Figure 3.2.2. Flood Preparedness for Halifax. The benchmark score, calculated as the average of the results of all capital cities of the Atlantic provinces (viz. Charlottetown, Fredericton, Halifax and St. John's) is depicted with a red dashed line. The blue area depicts the preparedness score of Halifax.

As demonstrated in **Figure 3.2.2**, Halifax reported areas of strength regarding flood preparedness, particularly in the domains of Flood Risk Assessment, Urban Drainage Assessment, Residential Property Risk Mitigation, Public Health and Safety and Emergency Management.

Regarding Flood Risk Assessment initiatives, Halifax reported that it regularly conducts hydrological assessments of its developed areas, and based on findings, reviews and amends zoning plans as appropriate. The city has identified ten priority areas as being at risk from riverine, coastal and other forms of flooding.

In reference to Urban Drainage Assessment, Halifax reported that it is amending its engineering standards to account for the impacts of climate change – this information factors into asset and infrastructure management plans that are updated every five years.

The city's Residential Property Risk Mitigation initiatives are comprehensive in comparison to the regional average.

Halifax provides advice to its residents on how they can best protect their homes against the adverse impacts of flooding. The city has planning designations in some areas that delineate flood-prone properties, and the city has introduced mandatory setbacks from watercourses. Finally, the city mandates flood protection for all fixtures located below street-level.

Regarding Public Health and Safety, Halifax collaborates with local hospitals and healthcare facilities. The city also stated that while it has no dams within its limits, a dam safety assessment was conducted on dams that are located well outside the city.

Relative to Emergency Management efforts, Halifax stated that it has installed a joint communications system and reported that the testing of the Public Safety Broadband Netwwork (PSBN) remains on-going. Halifax has conducted a social vulnerability assessment for its citizens and utilizes its AlertReady system in addition to the 3-1-1 system to distribute messaging to residents.

Conversely, the Critical Infrastructure Risk Mitigation initiatives of Halifax were weak in terms of its overall preparedness. Halifax has not yet conducted a complete flood risk assessment on all of its critical electrical infrastructure, and moreover, the city lacks a formalized approach to address this area of potential vulnerability. Similarly, the city conducts risk assessments of its telecommunications networks on an *ad hoc* basis.

Halifax reported that it has not focused on the flood vulnerability of its food supply systems. The city also stated that financial infrastructure is outside of the municipal mandate in Nova Scotia, and is therefore not considered by the city. Overall, Halifax noted that the authority and mandate of all municipalities within the Province of Nova Scotia is very limited.

Charlottetown, Prince Edward Island D+

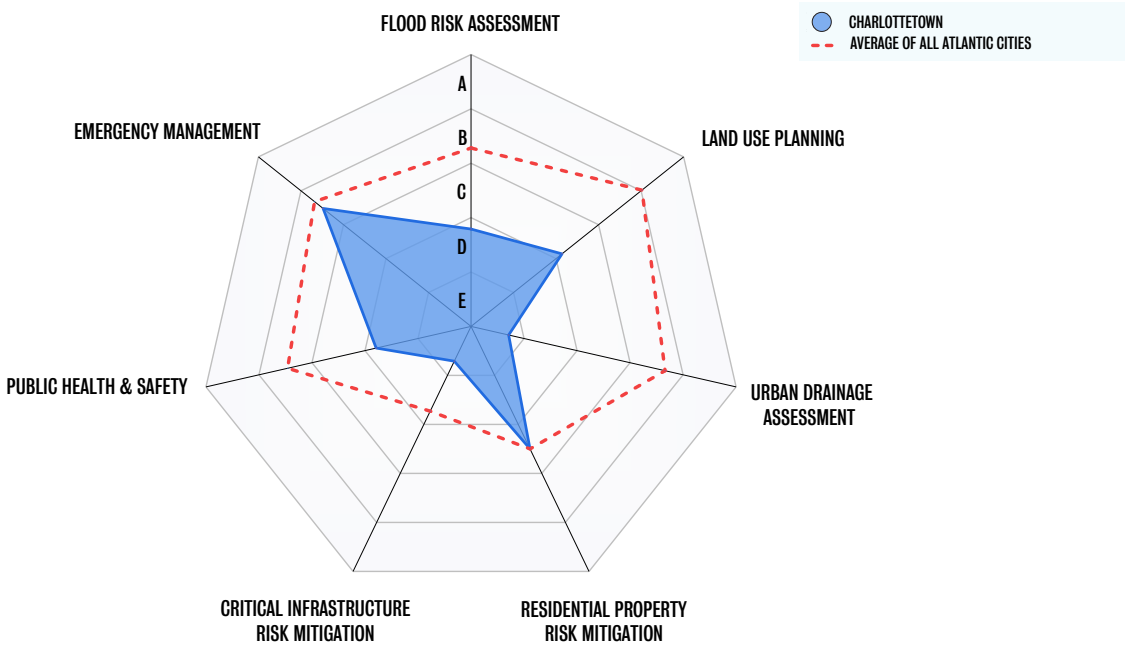


Figure 3.2.3. Flood Preparedness for Charlottetown. The benchmark score, calculated as the average of the results of all capital cities of the Atlantic provinces (viz. Charlottetown, Fredericton, Halifax and St. John's) is depicted with a red dashed line. The blue area depicts the preparedness score of Charlottetown.

As **Figure 3.2.3** demonstrates, Charlottetown reported areas of strength with respect to its flood preparedness in the domain of Residential Property Risk Mitigation and Emergency Management.

Specifically, Charlottetown reported that it has emergency response plans in place to ensure the continuity of access during emergencies. The city has established agreements to ensure continuity of fuel supply during flood events. The city also reported that it is aware of the general capabilities of the local fuel supply industry. Charlottetown has direct agreements with Esso Fuels to supply the city during emergencies.

The city stated that it has ensured that emergency responders, including the RCMP, municipal police, fire department, provincial ambulances, and the provincial EMO, all have 2-way radio systems to allow for the continuity of communications during emergencies. The city operates its own mass notification and alert system that it uses to provide the public with emergency information. The city has also developed and deployed a digital radio network. Finally, Charlottetown mentioned that riverine flooding is not a significant concern. The city reported that it relies on weather service forecasts as well as sanitary pump alarms for forecasting flood emergencies.

Conversely, Charlottetown's performance was found to be below the regional average with respect to certain domains of flood preparedness. Specifically, its performance was found to be lower than the regional average in terms of Flood Risk Assessment, Urban Drainage Assessment, Residential Property Risk Mitigation, Critical Infrastructure Risk Mitigation, and Public Health and Safety.

In reference to Flood Risk Assessments, Charlottetown stated that it does not formally assess pluvial flood risk, but does perform *ad hoc* evaluations. The city reported that it has not completed calculations on the potential economic and social impacts of flooding. Similarly, Charlottetown stated that it has never conducted a formal assessment in relation to its stormwater infrastructure, but rather relies on the "working knowledge" of its vulnerable areas.

Regarding Residential Property Risk Mitigation, Charlottetown stated that it provides neither educational materials nor subsidies to its residents. Moreover, city residents are required to install backflow prevention valves only if they have services below ground level. Charlottetown advises its citizens to use backflow prevention, but neither mandates this nor conducts inspections of whether its residents complete this action. The city also lacks a subsidy program for the installation of backflow prevention valves for existing homes.

In terms of Critical Infrastructure Risk Mitigation, Charlottetown reported that it has never conducted a risk assessment on its electrical infrastructure and is also not involved in assessing its food supply networks. Additionally, the city has not directed attention to its financial sector and is involved with mitigating the risk to its transportation networks only in an unofficial capacity.

Finally, in regard to Public Health and Safety initiatives, Charlottetown stated that it does not guide the development of emergency plans for private agencies in reference to the prevention of hazardous chemical releases.

"The city reported that it relies on weather service forecasts as well as sanitary pump alarms for forecasting flood emergencies."

St. John's, Newfoundland and Labrador C+

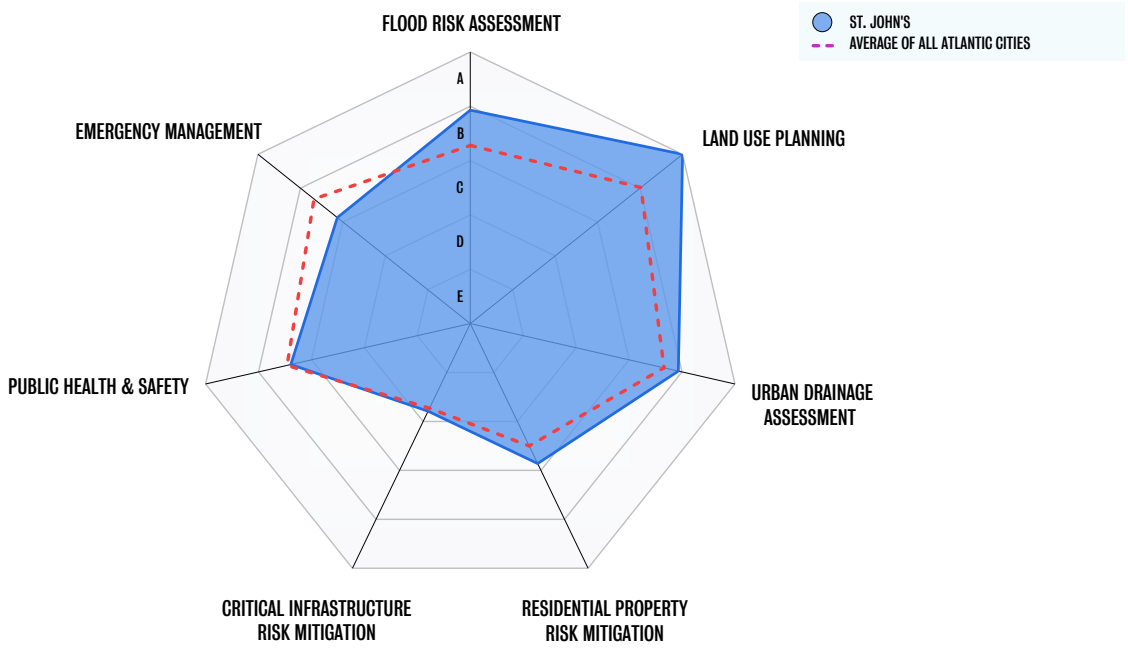


Figure 3.2.4. Flood Preparedness for St. John's. The benchmark score, calculated as the average of the results of all capital cities of the Atlantic provinces (viz. Charlottetown, Fredericton, Halifax and St. John's) is depicted with a red dashed line. The blue area depicts the preparedness score of St. John's.

As demonstrated in **Figure 3.2.4**, St. John's has strength regarding flood preparedness, primarily in the areas of Flood Risk Assessment, Land Use Planning and Residential Property Risk Mitigation.

Regarding Flood Risk Assessment, the city reported that the province has recently updated flood risk mapping, and all new developments are required to use the new floodplain mapping where applicable. In addition, the city independently conducts dam break analyses on nearby dam infrastructure, incorporating social and economic impacts of failures. The city reported that the Province of Newfoundland and Labrador completes other types of flood risk assessments province-wide and shares that data with the city.

In regard to Land Use Planning, St. John's stated that it prohibits new developments within flood hazard and flood risk areas.

In reference to mitigating the risk to its Critical Infrastructure (CI) facilities, the city reported that it has conducted a comprehensive risk assessment on its electrical infrastructure as part of Emergency Business Continuity plans that were established for all electrical facilities.

In terms of Public Health and Safety, St. John's provides advice to regional and provincial healthcare authorities in reference to flood risk, has mitigation policies in place to prevent the release of hazardous chemicals, and is generally well-prepared in regard to dam safety.

Conversely, St. John's reported weaknesses with respect to food system and financial service risk mitigation and Emergency Management efforts.

For Residential Property Risk Mitigation, the city reported that it lacks a subsidy program for the installation of backflow prevention valves for existing homes.

Finally, in regard to the city's Emergency Management efforts, St. John's reported that its involvement in providing flood warning services for its residents is limited. However, the city has agreements in place with a group of amateur radio operators, specializing in emergency communications. These volunteers can provide direct radio communications links to evacuation centres and backup communications at the emergency operations centre and operational command centres as required.

3.3

Selected Cities within the Northern Canada

Northern Canada is comprised of three territories: Northwest Territories, Nunavut and Yukon. Climate change is one of the most serious environmental, economic and political issues affecting residents of Northern Canada.

This section provides an overview of the responses provided by the municipal officials of Yellowknife (Northwest Territories) and Iqaluit (Nunavut). Whitehorse (Yukon) declined to participate in the study.

This study investigated and compared Yellowknife and Iqaluit relative to their flood risk management initiatives and flood risk reduction capacities. These cities were selected based on their large population (relative to northern communities) and jurisdictional, economic and legislative importance.

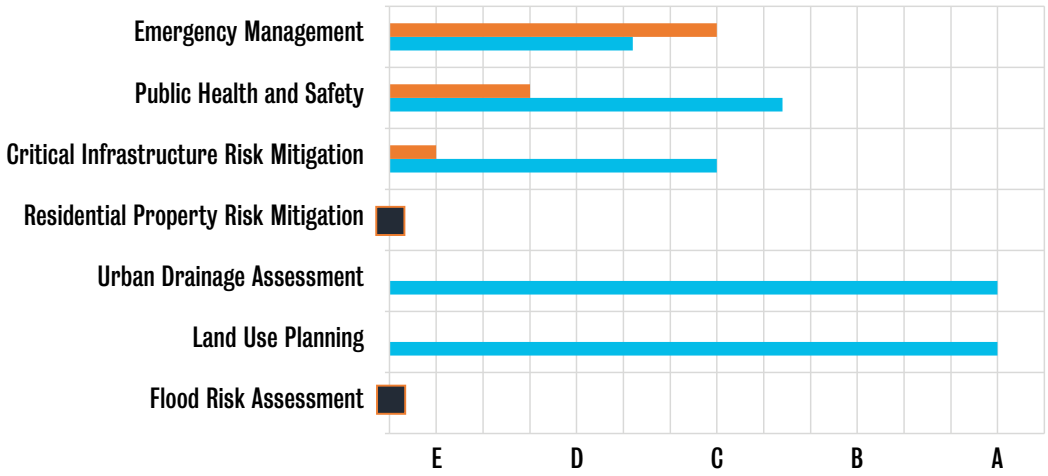
TABLE 9: Populations of Studied Cities in Northern Canada

City	Territory	City Population	City Population Density per Square Kilometre, 2016	Proportion of Territorial Population Residing in City, 2016
Yellowknife	Northwest Territories	19,569	185.5	46.8%
Iqaluit	Nunavut	7,740	147.4	21.5%

Note. Source: StatsCan 2016.

Recognizing that the government of Whitehorse (Yukon) declined to participate in the study, average scores for cities of Northern Canada were not calculated, and Figure 3.3.1 presents only responses provided by the governments of two cities, Yellowknife and Iqaluit.

Figure 3.3.1. Flood Preparedness of Yellowknife and Iqaluit. The orange and blue bars indicate the scores for Yellowknife and Iqaluit, respectively.



Note: Both cities selected the N/A response option in response to the Flood Risk Assessment and Residential Property Risk Mitigation survey questions. Yellowknife selected the N/A response option in response to the Land Use Planning and Urban Drainage Assessment survey questions.

Yellowknife, Northwest Territories D

One of Canada's most contaminated industrial sites, Giant Mine, is located close to Yellowknife, about 5 km from city centre. There are eight open pits located within the central valley where Baker Creek flows, two of which are in close proximity to Yellowknife Bay, on which Yellowknife is located. These open pits pose risks to the safety of the public as well as to the environment, given the possibility that Baker Creek may flood the area, affecting underground arsenic chambers. These chambers are filled with 237,000 tonnes of arsenic trioxide in a frozen state, while an additional 95-hectare surface site is polluted with 13.5 million tonnes of arsenic-contaminated tailings.

The Giant Mine Remediation Project considers flood protection measures to mitigate the potential of inundation and uncontrolled flows to the underground mine during extreme weather events. The city stated that a Qualitative Risk Assessment (QRA) is being completed by the Giant Mine Remediation Team evaluating not only flood risk, but all scenarios that could result in a breach of the tailings ponds and/or underground arsenic containment areas. One of these scenarios includes flooding of the various mine components. As Yellowknife reported, if the mine's storage chambers were ever to be flooded, thus causing a thawing of the frozen arsenic trioxide, this could lead to a release of the substance which would result in its infiltration into Yellowknife's groundwater supply as well as lead to contamination of the water within Great Slave Lake which is the tenth largest lake in the world. This is a particularly important concern considering the fact that arsenic trioxide is a highly water-soluble substance and is also odorless, tasteless, and transparent. **The City stated that the quantity of arsenic trioxide that is currently contained within the chambers of Giant Mine would be sufficient to eliminate the entire world's population several times over**.

As demonstrated in Figure 3.3.1, the City of Yellowknife possesses certain areas of strength in terms of its flood preparedness, primarily in the domain of Emergency Management.

Yellowknife reported that it has considered the community's vulnerability to various hazards, particularly as they may be exacerbated by the impacts of climate change. Yellowknife deals with its Critical Infrastructure (CI) facilities, such as hospitals, as dictated by the circumstances of a given threat. Yellowknife has planned work with fuel and other suppliers and has established arrangements to ensure business continuity. The city also has its fuel supply while its local hospital has its own arrangements and sources. Yellowknife also services its own radio systems and therefore ensures a level of robustness in maintaining public communication during extreme events.

Yellowknife's Emergency Management department is planning to collaborate with amateur radio volunteers to help with the provision of some emergency communications services. Cellular service communications providers are also part of the city's emergency communications arrangements as is the territorial utility. Yellowknife confirmed that it has participated in national emergency public alerting exercises.

Yellowknife was not designated as a flood risk community under the defunct Flood Damage Reduction Program, and therefore does not consider itself to be flood prone in regard to riverine events. However, the city reported that it can be exposed to hazards caused by overland and spring flooding, as well as potential high-water levels in Great Slave Lake and other large bodies of water in its vicinity. The city also stated that periodically, significant changes in water levels do occur, a factor that can damage or disrupt the city's infrastructure and its provision of services.

Conversely, Yellowknife's performance was found to be limited in regard to Critical Infrastructure Risk Mitigation as well as Public Health and Safety initiatives.

For Public Health and Safety, the city reported that it is aware of some facilities within its territory that utilize hazardous chemicals such as chlorine. In regard to dam safety, Yellowknife stated that a failure at one of the hydroelectric facilities that are located close to the city could have a significant impact city-wide – the city is built close to the Yellowknife River which would receive increased flow volumes following a dam breach. The city reported that it has no regulatory authority over the local power utility.

In terms of its Critical Infrastructure, Yellowknife reported that it does not regulate power generation or distribution within its territory. Alternatively, the city has installed backup power for 12 out of its 14 lift stations.

In regard to the city's telecommunications sector, Yellowknife is not involved in regulating the businesses that operate within it. The city expects business owners and operators to address their own vulnerabilities but has no specific regulatory role that mandates that this takes place. Yellowknife also reported that no flood mitigation work has been conducted on its community garden plots and that grocers are likewise responsible for their own safety provisions.

Although Yellowknife has no jurisdiction over local banking and financial institutions, there have been efforts to focus on emergency planning and business continuity of the local financial system.

With regard to the City's transportation sector, Yellowknife is in the early stages of assessing its transportation vulnerabilities from the perspective of flood risk.

The city has considered the vulnerability of its water supply to flood risk, and as a consequence has submitted a request for a major capital project to replace the submarine water line which is currently the source of the city's drinking water. Arsenic trioxide stored in above ground tailings ponds and underground storage chambers in the abandoned site at Giant Mine poses a significant threat for any municipal water source in Yellowknife, given the mine's proximity to the city.

Iqaluit, Nunavut C+

As demonstrated in Figure 3.3.1, Iqaluit has significant areas of strength in terms of its flood preparedness, primarily in Urban Drainage Assessment and Land Use Planning.

With respect to Urban Drainage Assessments, Iqaluit reported that it has completed a master drainage plan spanning its territory.

In terms of Land Use Planning, Iqaluit stated that flood policies that apply throughout its area stem from the territorial government rather than from the city. Iqaluit reported that the federal government also plays a role in the development of these policies.

Conversely, Iqaluit's performance was found to be limited in regard to Critical Infrastructure Risk Mitigation, Public Health and Safety and Emergency Management.

In terms of Critical Infrastructure Risk Mitigation, Iqaluit is installing a back-up generator to power City Hall, and emergency services to provide continuity of services during power outages. Iqaluit's power generation and distribution systems have built-in redundancies and the city itself has back-up sources of power.

In regard to Iqaluit's food supply sector, food retailers maintain warehouses for the storage of food, and the city also has a small greenhouse used to grow lettuce. Iqaluit collaborates closely with its food supply sector, particularly during emergencies. The city's food suppliers have their own supply chains which are independent from one another, which implies that food can be delivered to Iqaluit from different locations rather than being reliant on a single route.

In terms of Iqaluit's financial sector, the city has conducted some discussions in regard to business continuity planning. Iqaluit has also conducted risk assessments for flood disasters that could result in lengthy power outages, major storms and dam breaks. The city's dam break risk assessments are updated every few years. In terms of the city's transportation systems, by-pass options and detours exist for most of its roads. Iqaluit is working on a transportation master plan.

Regarding Public Health and Safety, Iqaluit reported that it participates in interagency group discussions applied to the emergency management of healthcare facilities. Additionally, regional hospitals have their own emergency management plans. The development and update of these plans is supported by funding from the territorial government, as the responsibility for hospitals lies with Nunavut. In relation to the prevention of the release of hazardous chemicals, the city has performed some mitigation work by utilizing retention ponds to store run-off. In regard to dam safety, Iqaluit conducts regular inspections and has detailed evacuation plans.

Finally, in terms of Emergency Management, the city reported that it does not yet have a formal flood alert system, and lacks the ability to distribute text messages to its citizens – Iqaluit is working to remedy this issue.

CHAPTER 4
EMERGING TRENDS AND CONCLUSIONS

The purpose of this study, and its 2015 analogue, was to determine the state of flood preparedness of 16 Major Canadian cities.



The findings of this study indicate that **there has been no significant progress in terms of the flood preparedness of Canadian cities over the period 2015 to 2019/20 – the Canadian average score on flood preparedness has not changed and remains C+ as of 2019/20**.

Areas of strength in terms of city flood preparedness include Flood Risk Assessment, Urban Drainage Assessment, Flood Risk Mitigation for Drinking and Wastewater Infrastructure, Public Health and Safety (specifically in the Dams Sector), and Emergency Management (specifically in the domains of Continuity of Fuel Supply and Continuity of Emergency Communications).

Areas of weakness in city flood preparedness initiatives include Flood Risk Mitigation for Residential Property (specifically in the domain of Pluvial Flooding), Critical Infrastructure Risk Mitigation (particularly in the Food and Financial Sectors), and Public Health and Safety (particularly in the Chemical Sector).

Although most Canadian cities have made progress in identifying areas vulnerable to flood risk, most indicated an inability to prohibit or restrict development in high risk areas, as this responsibility fell under provincial control. Even when municipal governments had developed their own floodplain maps – that incorporate climate change projections, sea level rise and land-use changes – they often lack the ability to restrict development within areas at risk of flooding, and could only offer advice on flood protection strategies.

Another limitation that characterized many cities pertained to the flood vulnerability of Critical Infrastructure (CI) and essential services. As was demonstrated in the 2019 study (Feltmate et al. 2020), nearly all provincial and territorial governments indicated that they are not involved in mitigating the risk exposure of electrical, telecommunications, and pipeline infrastructure. At the same time, cities indicated that they were largely powerless to halt infrastructure development in known areas of high flood risk. Importantly, many cities reported difficulties in discussing required protection measures with owners of CI, built on floodplains, located within or close to cities.

The broad findings of this study indicated that to limit the adverse effects of ongoing flood damage, Canadian cities need to make significant improvements in three areas of flood preparedness:

- **Risk Mitigation for Residential Property**
- **Critical Infrastructure Risk Mitigation, and**
- **Public Health and Safety**

Risk Mitigation for Residential Property

Of the 16 studied cities in this report, only Edmonton reported that its utility, EPCOR, provides information to residents to allow them to determine if their property is located in a flood-prone area – subsequently, upon request, home owners may request a complimentary home flood assessment. Most other cities indicated that they only provide high-level information for residents to allow them to learn whether their property is located in a riverine and/or coastal flood-prone area, and generally less information is available pertaining to urban or pluvial flood assessment.

Despite the fact that urban/pluvial flooding is becoming increasingly frequent – and its impact in terms of damage, disruption, and threat to life is escalating – most cities reported that they do little in terms of addressing this risk, with the exception of Edmonton. The cities of Regina, Halifax, Charlottetown and St. John's reported that they provide information to residents to allow them to learn whether their property may be at risk of pluvial (urban) flooding, but stated that they do not subsidize home flood assessments.

Although many survey respondents indicated that while most cities offer educational programs to residents living in floodplains and in areas at high risk of flooding, **during real estate transactions there is no legal requirement to disclose information that a given property had experienced, or is at risk of experiencing, flood damage.** Real estate transactions are regulated by provincial governments, thus the specific rules governing such disclosures vary across Canada. While some Canadian provinces, including Manitoba, Quebec and New Brunswick do query property sellers on whether a given property had sustained prior damage due to flooding, only Ontario's Seller Property Information Statement includes a specific question about the current flood exposure of the property. Notably, for all provinces, sellers are not legally obligated to provide property flood disclosure statements to buyers, even if requested (Henstra and Thistlethwaite 2018). In short, there is a gap in provincial policy, across Canada, which should be addressed to protect property buyers and reduce the financial and social costs of flooding.

Critical Infrastructure Risk Mitigation

Critical Infrastructure (CI) is the foundation upon which daily life of Canadians is built – accordingly, flood damage to energy systems, transportation networks, telecommunication systems, water supply and wastewater systems, as well as other lifeline infrastructure systems, has far-reaching societal impacts.

Most Canadian cities showed substantial flood resilience in reference to maintaining the integrity of Water Infrastructure and Services. Conversely, many cities are striving to limit flood risk of Electrically Powered Infrastructure and Transportation Infrastructure. More concerning, survey results indicated a prevalent limitation in city efforts to mitigate the flood vulnerability of existing Critical Telecommunication-reliant Systems, Food Systems and Financial Services. Notably, out of the 16 cities reviewed, only Edmonton, Regina and Toronto reported strength in addressing the vulnerability of city food supply systems to flooding. Toronto conducted a high-level vulnerability assessment of climate change impacts on its food system in 2018, which allowed the city to identify the most significant risks to food processing, distribution and access. The city also stated that it is working with community-based organizations to develop community food resilience action plans for its vulnerable neighborhoods.

The pattern of weakness in the domains of risk mitigation to CI coincides with the findings of a prior study (Feltmate and Moudrak 2020), the results of which indicated the presence of significant gaps throughout Canada in terms of addressing CI flood risks, including interdependencies.

Additionally, many cities reported that there are significant numbers of rail lines, highways and utility corridors of regional, provincial and national importance – as well as critical assets such as hospitals, electric power substations and communication facilities – that are located within floodplains inside city boundaries. While cities are making efforts to communicate flood risk information to CI owners, they reported a lack of a mutual desire to minimize the flood risk exposure of CI. Notably, while some cities reported their involvement in discussions with the owners and operators of CI on how to mitigate the vulnerability of CI to flooding, most responders indicated that measures to protect individual CI sectors, systems

or assets would be the responsibility of the individual owners and operators of CI, and that they would assume no involvement.

Simultaneously, while cities stated that they recognize the importance of avoiding the placement of any additional CI within floodplains, the majority of responders indicated that municipalities are powerless to halt infrastructure development within risk areas. For instance, a healthcare facility is being built on a city floodplain, as decided by the province, and the city was powerless to stop it.

Public Health and Safety

Naturally, the Canadian health sector plays a significant role in the response and recovery efforts that take place during and following natural and manmade disasters. However, although most cities indicated that they provide advice to regional and provincial authorities regarding vulnerabilities of the healthcare sector to floods, they hold no formal authority over them.

Additionally, cities reported weak performance to address the vulnerability of their populations to hazardous chemical releases. Chemical spills from refineries, wastewater treatment plants and hospitals during floods can directly lead to the contamination of drinking water sources, wherein the prompt coordination of actions would be required to protect the health and safety of the public. Notably, out of the 16 studied cities, only Calgary, Edmonton, Regina and Toronto demonstrated significant strength in planning for, and managing, potential spills of hazardous materials. While all cities indicated that the responsibility for a spill/discharge of hazardous waste lies with the owner of the facility from which the discharge originates, only four aforementioned cities reported that they are engaged with owners of facilities to identify, characterize and abate associated risks.

Conclusions

With the average flood preparedness score for Canada's major cities remaining C+ over the period 2015 to 2019/20, it is evident that there is considerable margin for improvement in flood preparedness for most of the surveyed jurisdictions.

Recognizing that climate change is effectively irreversible (ECCC 2019), which in turn will exacerbate future extreme weather, Canadian cities must elevate their resolve to mitigate flood risk. On a positive note, Edmonton, Regina and Toronto scored well in terms of their efforts to limit the impacts of flooding, which could guide, and perhaps serve as a model for, other cities to emulate their efforts where appropriate.

A key factor that many cities identified to limit flood risk was the need for provinces/territories to incentivize municipal actions to reduce current exposure, and to limit risks linked to new development and re-development in low-lying coastal areas and on floodplains.

Cities indicated that they can only limit development within provincially-defined risk areas in accordance with the provincially-defined regulatory flood standard. Even where municipal governments developed floodplain maps which incorporated climate change projections, sea level rise, and land-use changes, they lack the ability to restrict development within identified risk areas, and can only offer advice regarding flood protection strategies.

Ironically, while the prime statutory responsibility of municipal policymakers is supposed to be to consider the well-being and interests of their community, one study participant noted that "in a cost-benefit analysis of flood risk, the only [parties] that win are the ones who put a lot of people in the floodplain." This participant, along with

"A key factor that many cities identified to limit flood risk was the need for provinces/territories to incentivize municipal actions to reduce current exposure, and to limit risks linked to new development and re-development in low-lying coastal areas and on floodplains."

several others, noted that municipalities are exposed to backward incentives in relation to the topic of floodplain mapping – municipalities are often incentivized to not create flood maps, as this thereby enables them to avoid financial and political accountability when flooding does occur. Instead of restricting the municipalities which fail to develop floodplain mapping from receiving funds following a flood, municipalities without flood maps often find it easier to apply for, and consequently receive, federal recovery funding. Therefore, it is currently the case that municipalities directly and immediately benefit from not developing floodplain maps and thus clearly have little to no incentive to develop and keep them up-to-date. To redress this limitation, **survey respondents recommended that up-to-date and comprehensive flood maps be made a requirement to receive federal recovery support following catastrophic flooding events.**

Lack of appreciation for the interdependencies of critical infrastructure systems– where one failure may cascade to another, and another beyond that – was also an area highlighted as a point of concern by survey respondents. The potential for cascading impacts may prove more challenging in the future, as Canada is continuing to experience increasing urbanization that will convey higher concentrations of population and economic activity within cities. As such, a failure or degradation of essential services provided by critical infrastructure, that can often be located outside cities, could affect the health, safety, security, and economic well-being of communities. Some survey respondents suggested that future analysis to identify and protect against system level failures might be the purview of such organizations as the **Big City Mayors' Caucus** and/or the **Federation of Canadian Municipalities.**

This study demonstrates that municipal governments must build upon generalized messaging on flood mitigation, to provide more detailed localized hazard information, as well as develop 'flood literacy' by fostering local knowledge about flooding. For example, there is both a need and a means by which home owners can protect their homes from flooding: that is by adopting home flood protection measures. **The implementation of home flood protection is relatively inexpensive (generally less than a few hundred dollars per home), is technically straightforward, and is generally quick to deploy. As such, respondents suggested that concerted efforts to promote home flood protection offered a readily available option to mitigate flood risk for which there was only an upside.**

Recognizing that the costs of flooding are on the rise for virtually all Canadian cities, some respondents suggested that citizens themselves demand action by mayors and councilors to be more pro-active in promoting flood risk mitigation. Survey participants suggested that "as much as it is the duty of Canadian governments to inform their citizens, it is equally the duty of every citizen to demand to be informed [on flood risk mitigation]".

A recurring theme highlighted by the 53 city managers, directors, and senior officers interviewed for this report was **the need for cities to move more aggressively to prepare for flood risk.** As climate change and the associated risk of flooding increases, **stasis on flood preparedness, as indicated by an unchanged average score of C+ over the time frame of 2015 to 2019/20, is not acceptable.** Canadian cities must therefore move much quicker to prepare for flood risk, by building on the momentum of such leaders as, but not limited to, Edmonton, Regina and Toronto. As suggested by survey participants, it is not possible to cheat on flood preparedness – to do so will result in management by disaster scenarios. Canadian cities must draw upon the momentum of leaders who not only understand the importance of flood preparedness, but also the need to act with **urgency**.

"Stasis on flood preparedness, as indicated by an unchanged average score of C+ over the time frame of 2015 to 2019/20, is not acceptable."

APPENDIX A

This appendix provides a description of criteria used to assess the flood-related commitments of municipal governments, along with the questionnaire.

A.1 Flood Risk Assessment

The extensiveness of the consequences of a flood depends on a variety of factors including how exposed a given community is to floods as well as how vulnerable its people, property, and infrastructure are to the adverse impacts of flooding.

Risk assessments identify the social, economic, and environmental impacts that flood events can have on a given community, including identifying the specific flood hazards, compounding hazards, community and infrastructure vulnerabilities, risk tolerance or "risk threshold," in addition to the overall flood risk profile for said community.

For cities with increasing population densities which commonly experience significant pressure to continue development in high-risk areas, flood risk assessments play an important role in increasing public awareness, thereby helping people make informed decisions on where to live and which preventive actions to take. Mapping the extent and depth of flooding associated with current and future flood scenarios is a key component in assessing the vulnerability of people, buildings, infrastructure, and the economy to flood events.

Historically, flood risk management in Canada has mainly concentrated on river, coastal, and ice related flooding, yet there are also other significant sources of flooding such as pluvial, stormwater, sewer, groundwater flooding, as well as flooding caused by the failure of artificial water retention structures.

The present study assesses the declared commitments of municipal governments pertaining to the following components of Flood Risk Assessment criteria:

- Riverine and/or Coastal;
- Pluvial; and
- Flooding due to potential structural failures or breaches of flood protection and water retaining infrastructure.

To address these criteria, participants from municipal governments were asked to select the most appropriate option (or combination of options) in response to the following questions:

1a How does the city develop and update riverine and/or coastal flood risk assessments?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of riverine and/or coastal flooding (considering impacts of climate change on identified flood hazards). On the basis of this assessment, the city updates flood risk maps and flood mitigation strategies and implements mitigation projects as needed.
B	The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of riverine and/or coastal flooding (considering impacts of climate change on identified flood hazards). On the basis of this assessment, the city updates flood risk maps and flood mitigation strategies for flood-prone areas and is currently developing mitigation plans.
C	The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of riverine and/or coastal flooding (considering impacts of climate change on identified flood hazards). The city has updated flood risk maps and is in the process of developing flood mitigation strategies.
D	The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of riverine and/or coastal flooding (considering impacts of climate change on identified flood hazards). The city is currently in the process of updating flood risk maps.
E	The city is currently in the process of conducting a flood risk assessment of riverine and/or coastal flooding.

1b How does the city develop and update pluvial flood risk assessments?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of pluvial flooding (considering the impacts of climate change and extreme weather events). On the basis of this assessment, the city updates flood risk maps, develops flood mitigation strategies for flood-prone areas, and implements mitigation projects as needed.
B	The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of pluvial flooding (considering the impacts of climate change and extreme weather events). On the basis of this assessment, the city updates flood risk maps, develops flood mitigation strategies, and is currently developing mitigation plans.
C	The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of pluvial flooding (considering the impacts of climate change and extreme weather events). The city has updated flood risk maps and is in the process of developing flood mitigation strategies.
D	The city has recently (within the past 5 years) conducted a flood risk assessment identifying areas at risk of pluvial flooding (considering the impacts of climate change and extreme weather events). The city is currently in the process of updating flood risk maps.
E	The city is currently in the process of conducting a flood risk assessment for pluvial flooding.

1c How does the city develop and update flood risk assessments for flood protection and water retaining infrastructure (including flood walls, sea walls, flood damage mitigation reservoirs, dams, dikes, etc.)?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment that identified the areas that are at risk of flooding due to potential structural failures or breaches of flood protection and water retaining infrastructure (considering the impacts of climate change, storm surges, and extreme weather events). On the basis of this assessment, the city updates flood risk maps, develops flood mitigation strategies, and implements mitigation projects as needed.
B	The city has recently (within the past 5 years) conducted a risk assessment that identified the areas that are at risk of flooding due to structural failures or breaches of flood protection and water retaining infrastructure (considering the impacts of climate change, storm surges, and extreme weather events). On the basis of this assessment, the city updates flood risk maps, develops flood mitigation strategies, and is currently developing mitigation plans.
C	The city has recently (within the past 5 years) conducted a risk assessment that identified the areas that at risk of flooding due to structural failures or breaches of water retaining and flood protection infrastructure (considering the impacts of climate change, storm surges, and extreme weather events). The city has updated flood risk maps and is in the process of developing flood mitigation strategies.
D	The city, in partnership with the province, and/or conservation/watershed authorities, has recently (within the past 5 years) conducted a risk assessment that identified the areas that are at risk of flooding due to structural failures or breaches of flood protection and water retaining infrastructure (considering the impacts of climate change, storm surges, and extreme weather events). The city is currently in the process of updating flood risk maps.
E	The city is currently in the process of conducting an assessment to identify the risk of flooding due to structural failures or breaches of flood protection and water retaining infrastructure.

1d While developing and updating flood risk assessments, does the city include social and economic vulnerability assessments?

ANSWER KEY	
	☐ Both Social & Economic Vulnerability Assessments
	☐ Economic Vulnerability Assessments, such as insurable losses, temporary/permanent loss of wages, etc.
	☐ Social Vulnerability Assessments, such as fear of future flooding, stress of the flood itself, etc.
	☐ Limited Incorporation of Either Factor
	☐ Neither

A.2 Land Use Planning

Land use planning is a critical component of an integrated approach to flood risk management. It offers many opportunities to reduce the impacts of floods such as through the prohibition of development in high-risk areas and the accommodation and incentivization of urban growth and expansion in flood-safe areas.

The Intact Centre on Climate Adaptation (ICCA) report released in 2019 indicated that "due to changing planning policies across Canada, which have the objective of reducing urban sprawl, increasing development efficiencies, and reducing infrastructure-servicing costs, many municipalities are increasing population densities within their urban limits. This approach, over time, can lead to [the] intensification of development and re-development in within, or in close proximity to, floodplains, exacerbating neighbourhood exposure to flood risk." (Moudrak and Feltmate 2019).

Although cities across Canada have traditionally managed their exposure to flood risk through the use of regulatory instruments such as zoning regulations and building codes, the aforementioned changes in planning policies can have the unintended effect of increasing, rather than decreasing, the flood vulnerability of Canadian communities.

The Sendai Framework for Disaster Risk Reduction 2015–2030 underscores the importance of land use planning and policy to address rapid urbanization, poor land management, and weak enforcement of land use regulations. Therefore, Canadian cities have a responsibility to incorporate said recommendations in their regulations and policies to reduce their existing exposure to flood risk as well as to prevent the creation of new risks that are linked to infill, intensification, and the re-development of low-lying coastal areas and floodplains.

To address this criterion, participants from municipal governments were asked to select the most appropriate option (or combination of options) in response to the following question:

2 Relative to land use planning, how does the city regulate floodplain and/or coastal encroachment including infill, intensification, and re-development?

ANSWER KEY	
A	Through legislation enacted by the province, the city prohibits new development and re-development within regulatory (designated) floodplains.
B	The city has enacted bylaws that designate lands as floodplains, prohibit new development and re-development within regulatory (designated) floodplains and has an established enforcement framework for these bylaws.
C	The city has zoning regulations that restrict new development and re-development within regulatory floodplains, subject to some exemptions.[1]
D	The city has policies that support the restriction of new development and re-development in regulatory floodplains.
E	Currently, the city does not have bylaws prohibiting or restricting new development and re-development within regulatory floodplains.

[1] In some communities, there are designated SPAs (Special Policy Areas), within which development that encroaches on the floodplain and/or coastal areas can still proceed, subject to certain flood proofing/protection measures. Such measures may include mandates that require elevated building openings, raising electrical and mechanical systems above the regulatory flood level, the installation of backflow valves, and the use of flood damage resistant materials in basements.

A.3 Urban Drainage Assessment

Across Canada, tremendous urban development has taken place in various watersheds and in coastal areas. Drastic land use changes due to the removal of vegetation and soil, gradation of the land surface, and the construction of drainage networks increase water runoff to streams due to rainfall and snowmelt. As a result, the peak discharge, volume, and frequency of floods increases in nearby streams. Moreover, permeable soil is replaced by impermeable surfaces such as roads, roofs, parking lots, and sidewalks that store little water, reduce the infiltration of water into the ground, thereby producing higher peak-flows in drainage channels.

The most common consequences of urban development are increased peak discharges and more frequent floods. Despite studies that have supported the link between the trend of urbanisation and the increasing risk of flooding, developments and re-developments within, or in close proximity to floodplains continues to take place at a rapid rate, consequently exposing communities to increasing flood hazards (Nirupama and Simonovic 2006)

Urban stormwater management systems are typically designed to meet performance standards that are based on historical climate events. However, if precipitation patterns continue to change, the historically reliable designs developed on the basis of probabilistic models may cease to be adequate in the future, and stormwater management systems within the built environment will therefore need to meet performance expectations under climatic conditions that are significantly different from the historically-experienced climate in a given area.

In order to reduce their exposure to the risk of flooding, cities need to develop and implement integrated stormwater management and urban drainage strategies that consider the impacts of climate change, population growth, and future land cover changes.

To address this criterion, participants from municipal governments were asked to select the most appropriate option (or combination of options) in response to the following question:

3 Regarding the upgrading and rebuilding of stormwater infrastructure, how does the city address the impacts of climate change?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk-based performance assessment of stormwater drainage infrastructure that identified the impacts of climate change on identified flood hazards. Based upon the developed/updated long-term city flood mitigation strategy, a number of flood mitigation projects have been implemented or are scheduled for implementation throughout the city.
B	The city has recently (within the past 5 years) conducted a risk-based performance assessment of stormwater drainage infrastructure that identified the impacts of climate change on identified flood hazards. Based upon the updated long-term city flood mitigation strategy, a number of flood mitigation projects are under consideration for implementation in the flood-prone areas of the city.
C	The city has recently (within the past 5 years) conducted a risk-based performance assessment of stormwater drainage infrastructure that identified the impacts of climate change on identified flood hazards. The city is currently in the process of developing/updating a long-term flood mitigation strategy.
D	The city has recently (within the past 5 years) conducted a risk-based performance assessment of stormwater drainage infrastructure that identified the impacts of climate change, on identified flood hazards. The city is currently in the process of developing/updating short-term site-specific mitigation strategies for flood-prone areas.
E	The city has recently (within the past 5 years) conducted a risk-based performance assessment of stormwater drainage infrastructure and is planning to improve its performance. However, the city has limited capacity to address the identified issues.

A.4 Flood Risk Mitigation for Residential Property

As the Intact Centre on Climate Adaptation (ICCA) report indicated, "in recent years, the financial and social costs of natural catastrophes in Canada have escalated beyond historical levels. Residential flooding has been a key driver behind this trend, which has led to upward pressure on residential insurance premiums, mental health stress for homeowners impacted by flooding, potential increases in residential mortgage defaults, and lawsuits directed to builders and municipalities that fail in their fiduciary duty to anticipate and mitigate flood risk." (Moudrak and Feltmate 2019).

It is widely agreed that effective and ongoing communication of flood information to residents is an essential component of any initiative aimed at reducing flood losses over the long term. A particularly important time when potential flood risk needs to be communicated is during real-estate transactions. Disclosing hazard information to potential buyers can reduce the odds that an individual or a family would be caught by surprise and would be unprepared if and when their homes were to be flooded or damaged.

Programs addressing the risks of residential properties to flooding are increasingly being implemented throughout Canadian municipalities, including educational programs that aim to inform residents on flood prevention and recommended maintenance activities. It is especially important that the general public has quick and easy access to user-friendly flood risk maps and other risk-related information. An increased awareness of flood risks amongst the general population can also lead to an increase in flood-resilience initiatives that are undertaken by residents in existing communities, particularly for more economical solutions that are dependent on active and enthusiastic homeowner participation and support.

The present study assesses the declared commitments of municipal governments pertaining to the following components of Flood Risk Mitigation for Residential Property criteria:

- Risk Assessments; and
- Backwater Valve Installation.

The following four subsections present how the level of engagement of municipal governments is assessed in terms of their engagement in programs addressing the risks of residential properties to flooding.

Residential Property Risk Mitigation: Riverine and/or Coastal Flooding

To address this criterion, participants from municipal governments were asked to select the most appropriate option (or combination of options) in response to the following question:

4a How does the city mitigate the vulnerability of existing residential property to riverine and/or coastal flooding?

ANSWER KEY	
A	The city provides information for residents to allow them to learn whether their property is located in a flood-prone area and subsidizes home flood assessments for residents who desire such assessments.
B	The city provides information for residents to allow them to learn whether their property is located in a flood-prone area and subsidizes home flood protection assessments for only those properties that are located in flood-prone areas.
C	The city provides information for residents to allow them to learn whether their property is located in a flood-prone area but does not provide subsidies for home flood assessments.
D	The city is currently developing a program that would allow residents to assess riverine and/or coastal flood risk at a property-specific level. The city also provides guidance and educational materials on flood risk and prevention to homeowners.
E	The city provides guidance and educational materials on flood prevention to homeowners.

Residential Property Risk Mitigation: Pluvial Flooding

Thousands of Canadians have experienced flooding, including those who reside far away from bodies of water. This is the case because flooding can occur in any urban area, even in higher elevation areas that lie above coastal and river floodplains. A pluvial flood, sometimes referred to as an urban flood in this context, takes place when heavy rainfall causes a flood event to occur, unrelated to the overflow of a water body. It has been suggested that pluvial floods may become increasingly frequent due to the effects of climate change.

Pluvial flooding effects can include street flooding, basement flooding, as well as flooding in low-lying areas caused by the overflow of local drainage systems. Throughout Canada, the responsibility for managing this type of flooding falls to the municipalities, where such exist. In other areas which may lack municipalities, the responsibility for managing these floods may fall to the provincial government but regulation with respect to this issue is typically scant.

While almost any structure located within urban areas is at some risk of experiencing damages from extreme precipitation and sewer backups, much of this damage can be prevented by interventions that can be implemented by municipalities, utilities, and other relevant authorities in order to reduce flood risk for communities in Canada.

Pluvial flooding often occurs in conjunction with coastal and fluvial floods and can therefore lead to significant and compounded property damages. The development of risk mitigation strategies, including strict building codes and restrictive zoning laws, can help prevent such losses, provided that these codes are adhered to and relevant laws enforced.

To address this criterion, participants from municipal governments were asked to select the most appropriate option (or combination of options) in response to the following question:

4b How does the city mitigate the vulnerability of existing residential property to pluvial flooding?

ANSWER KEY	
A	The city provides information for residents to allow them to learn whether their property is at risk of pluvial flooding and subsidizes home flood assessments for residents who desire such assessments.
B	The city provides information for residents to allow them to learn whether their property is at risk of pluvial flooding and subsidizes home flood protection assessments for only those properties that are at a high risk.
C	The city provides information for residents to allow them to learn whether their property is at risk of pluvial flooding but does not provide subsidies for home flood assessments.
D	The city is currently developing a program that would allow residents to assess pluvial flood risk at a property-specific level. The city also provides guidance and educational materials on flood prevention to homeowners.
E	The city provides guidance and educational materials on flood prevention to homeowners.

Backwater Valve Installation

When heavy rainstorms flush debris into the mainline storm and sanitary sewers operated by communities, these sewers consequently can back up into homes and businesses, particularly if these systems are not designed with sufficient capacity. A mainline backwater valve (i.e., backflow prevention devices) on storm and/or sanitary sewer laterals can help prevent sewer water from backflowing into the basements of city residents.

The National Building Code of Canada developed by the National Research Council of Canada requires every new Canadian home to have a Backwater Valve (BWV) installed on both the storm and sanitary sewer service laterals. However, it should be noted that it is a codified best practice and therefore, Canadian municipalities are not mandated to adhere to it, instead following their own respective provincial building codes. In some provinces, the installation of BWVs for new homes is optional rather than mandatory. For municipalities, the requirement for the installation of backwater valves is defined in the City's Sewer Design Guidelines and/or applicable bylaws, if either exist.

To address Backwater Valve Installation criteria, participants from municipal governments were asked to select the most appropriate option (or combination of options) in response to the following questions:

4c For newly constructed homes, does your city mandate the installation of backwater valves?

ANSWER KEY	
	☐ Yes
	☐ No
	☐ For some homes, dependent on the location of the home and its consequent exposure to flood hazards

4d For existing homes, does your city offer a financial subsidy for the installation of backwater valves?

ANSWER KEY	
	☐ Yes
	☐ No
	☐ For some homes, dependent on the location of the home and its consequent exposure to flood hazards

A.5 Flood Risk Mitigation for Critical Infrastructure and Essential Services

According to Public Safety Canada, Critical Infrastructure (CI) refers to the "processes, systems, facilities, technologies, networks, assets, and services [that are] essential to the health, safety, security, or economic well-being of Canadians and the effective functioning of government."

The loss of CI components such as those within energy systems, transportation networks, telecommunication systems, water supply and wastewater systems, as well as other lifeline infrastructure systems can have far-reaching societal impacts, and damage to these critical assets may well have significant impacts on emergency response and recovery efforts. Therefore, it is very important that cities regularly review the vulnerability of municipal CI systems and services to flooding.

Perhaps the most important aspect of assessing Critical Infrastructure and essential services is identifying and analyzing the dependencies and interdependencies of CI. Failing to consider the interconnected nature of infrastructure and consequent interdependencies will result in ineffectiveness in terms of emergency response to disasters.

The present study assesses the declared commitments of municipal governments pertaining to the identification of vulnerabilities including infrastructure interdependencies for the following types of Critical Infrastructure and essential services:

- Electrical-Powered Infrastructure;
- Telecommunication-Reliant Infrastructure;
- Food Systems;
- Financial Services;
- Transportation Infrastructure; and
- Water Infrastructure.

The following six subsections present how the level of preparedness of municipal governments is assessed in terms of their ability to deal with the disruption of Critical Infrastructure and subsequently ensuring the continual stable delivery of essential services.

Electrical-Powered Infrastructure

The functional continuity of the electrical grid is critical to the operations of emergency and human safety systems, since almost all critical infrastructure sectors are directly dependent on electricity and a loss of power would instantly affect a wide range of key power-reliant infrastructure operations. A serious degradation of electrical power can produce interdependent failures across a variety of CI sectors, a phenomenon generally referred to as a "ripple effect."

To address these criteria, participants from municipal governments were asked to select the most appropriate option (or combination of options) in response to the following questions:

5a How does the city mitigate the vulnerability of existing critical electrical-powered infrastructure (such as wastewater plants, water treatment plants, pumping stations, etc.) to flooding, including the vulnerability to infrastructure interdependencies?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of the existing critical infrastructure to flooding including the vulnerability to infrastructure interdependencies. The city has subsequently secured funding and developed plans to protect key infrastructure and services to a desired level if deemed necessary.
B	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of the existing critical infrastructure to flooding including the vulnerability to infrastructure interdependencies. In collaboration with the owners/operators of electrical infrastructure, the city is currently developing plans to protect key infrastructure and services to a desired level.
C	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of the existing critical infrastructure to flooding. In collaboration with the owners/operators of electrical infrastructure, the city plans to assess infrastructure interdependencies as related to flood vulnerability.
D	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of the existing critical infrastructure to flooding. Engagement with the owners/operators of electrical infrastructure is currently limited to preliminary discussions.
E	The city addresses the vulnerability of critical infrastructure to flooding on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

Telecommunication-Reliant Infrastructure

Communications infrastructure, which includes terrestrial, satellite, and wireless transmission systems is critical for the continued operation of all businesses, public safety organizations, and governments. It is closely linked to other CI systems, among them emergency services, which depends on communications for the direction of resources, the coordination of emergency response, the operation of public alert and warning systems, and the ability to receive emergency calls.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

5b How does the city mitigate the flood vulnerability of existing critical telecommunication-reliant systems (such as monitoring of critical infrastructure, emergency communications, traffic signals, etc.), including the vulnerability to power loss?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of existing telecommunication-reliant systems to flooding including the vulnerability to infrastructure interdependencies. It has subsequently secured funding and developed plans to protect key infrastructure and services to a desired level if deemed necessary.
B	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of existing telecommunication-reliant systems to flooding including the vulnerability to infrastructure interdependencies. The city has subsequently engaged with stakeholders to secure funding to protect key infrastructure and services to a desired level.
C	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of existing telecommunication-reliant systems to flooding. In collaboration with the owners/operators of telecommunication infrastructure, the city plans to assess infrastructure interdependencies as related to flood vulnerability.
D	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of existing telecommunication-reliant systems to flooding. Engagement with the telecom sector is currently limited to preliminary discussions.
E	The city addresses the vulnerability of telecommunication-reliant systems to flooding on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

Food Systems

Food systems include all processes and infrastructure components that ensure that city populations continue to have access to food. These systems include growing, processing, storing, transporting, and disposing of food. Extreme weather events including flooding can cause significant damages and disruptions to this type of Critical Infrastructure, especially in terms of the transportation, storage, and processing of food. In addition, the access of citizens to food can also be impaired due to supply shortages and disruptions of transportation networks.

Moreover, the ability of citizens to access food can be limited due to a variety of failures in other types of CI such as electrical, telecommunication, transportation, and water systems. Therefore, planning in relation to the continuity of the food supply sector must include preparedness initiatives, communications during and after emergency events, and food inspections that occur throughout and following such events.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

5c How does the city mitigate the flood vulnerability of food systems (encompassing transportation and food supply networks) including the vulnerability to power loss?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of the city's food supply systems to flooding. It has subsequently secured funding and developed plans to enhance the flood resilience of the food systems if deemed necessary.
B	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of the city's food supply systems to flooding. It has subsequently engaged with stakeholders to develop food supply resilience plans and to secure funding for new, diverse ways of growing food.
C	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of the city's food supply systems to flooding. In collaboration with the food supply sector, the city plans to assess flood vulnerabilities related to the dependency of food supply systems on other critical infrastructure systems.
D	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of the city's food supply systems to flooding. Engagement with the food supply sector is currently limited to preliminary discussions.
E	The city addresses the vulnerability of the city's food systems to flooding on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

Financial Services

The Financial Services sector represents a vital component of Canada's Critical Infrastructure. This sector comprises of thousands of depository institutions, investment product providers, insurance companies, financing institutions, as well as the providers of the critical financial utilities and services that support the continual functioning of these various organizations.

Extreme weather events, including flooding, can cause damages to buildings that house financial/banking services in some cases. However, the dependency of this sector on computer, telecommunication, and wireless networks can lead to the immediate degradation and/or interruption of services following disruptions of the electrical grid and telecommunication networks, a problem which is exacerbated when back-ups to these services are not established. For example, large swaths of Northern Canada rely solely on satellite communication and when this is disrupted, which occurs quite often, financial systems are commonly rendered inoperable as well.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

5d How does the city mitigate the vulnerability of the financial sector to disruptions of critical financial services caused by flooding, including the vulnerability to infrastructure interdependencies?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of this sector to disruptions of critical financial services caused by flooding. It has subsequently engaged with relevant stakeholders to outline their flood resilience plans.
B	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of this sector to disruptions of critical financial services caused by flooding. The city is engaged with relevant stakeholders in emergency and business continuity planning.
C	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of this sector to disruptions of critical financial services caused by flooding. In collaboration with the relevant stakeholders, the city plans to assess flood vulnerabilities related to the dependency of the financial sector on other critical infrastructure systems.
D	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of this sector to disruptions of critical financial services caused by flooding. Engagement with the financial sector is currently limited to preliminary discussions.
E	The city addresses the vulnerability of this sector to disruptions of critical financial services caused by flooding on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

Transportation Infrastructure and Services

The accurate assessment of risk is critical to efficient flood management, particularly within the transportation sector. Floods, and the physical response of channels and floodplains to them, constitutes a primary hazard of concern. Floodwaters and other flood-related hazards may severely damage transportation infrastructure (i.e. bridges and roadway embankments), thereby diminishing the ability of emergency responders to deliver services in addition to reducing the ability of the public to leave dangerous areas in the event of extreme rain events, coastal or riverine flooding, or flooding caused by the failure of dams or other flood protection infrastructure.

Flooding of roads, especially in low-lying areas (e.g. underpasses), is a special area of concern for first responders and emergency services, particularly during telecommunication disruptions as communicating information about the accessibility of emergency routes can become difficult or impossible.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

5e How does the city mitigate the vulnerability of existing transportation infrastructure and service systems to flooding (including public transit and road networks)[2]?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of its transportation infrastructure to flooding including the vulnerability to infrastructure interdependencies. It has subsequently secured funding and developed plans to protect key transportation infrastructure and services to a desired level if deemed necessary.
B	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of its transportation infrastructure to flooding including the vulnerability to infrastructure interdependencies. It has subsequently engaged with stakeholders to develop plans and to secure funding in order to protect key transportation infrastructure (including bridges, culverts, and underpasses) to a desired level.
C	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of its transportation infrastructure to flooding. The city plans to assess infrastructure interdependencies as related to flood vulnerability.
D	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of its transportation infrastructure to flooding. The city is presently engaged with stakeholders to develop a framework in order to assess and prioritize flood adaptation measures for key transportation infrastructure and services.
E	The city addresses the vulnerability of its transportation infrastructure to flooding on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

[2] Provincial highways, airports, CN/CP railways, and maritime transportation are out of the scope of this study.

Water Infrastructure and Services

Canadians depend on provincially regulated municipal water and wastewater facilities for their household water supplies and waste removal. Water and wastewater facilities are critical infrastructure and their potential for failure as a consequence of any hazard has emergency preparedness implications.

Both drinking water and wastewater infrastructure can be significantly impacted by extreme precipitation events. The impacts to such infrastructure can include power losses, severe asset damage, and dangerous conditions for the personnel of these facilities. As extreme weather events become more frequent and intense and as sea levels continue to rise, flooding will remain an ongoing challenge for drinking water and wastewater utilities.

Water systems are dependent on and interdependent with many other sets of CI. Specifically, drinking water facilities depend on an uninterrupted supply of electricity and chemicals in order to maintain the supply of potable water to citizens. Similarly, the wastewater system depends on utilities including gas, water, electricity, telecommunications, and chemical/equipment suppliers.

Disruptions within water systems or in the infrastructure with which water infrastructure is interdependent creates a complex system of impacts, and in some cases can magnify costs to human life, health, and welfare. Therefore, the analysis of interdependencies between the water sector and other sectors of CI is crucially important.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

5f How does the city mitigate the vulnerability of existing drinking and wastewater infrastructure and services to flooding?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of drinking and wastewater infrastructure to flooding including the vulnerability to infrastructure interdependencies. It has subsequently secured funding and developed plans to protect key infrastructure and services to a desired level if deemed necessary.
B	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of drinking and wastewater infrastructure to flooding including the vulnerability to infrastructure interdependencies. It has subsequently engaged with stakeholders in order to develop plans and to secure funding to protect key infrastructure and services to a desired level.
C	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of drinking and wastewater infrastructure to flooding. The city plans to assess infrastructure interdependencies as related to flood vulnerability.
D	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of drinking and wastewater infrastructure to flooding. The city is presently engaged with stakeholders to develop the framework in order to assess and prioritize flood adaptation measures for key water infrastructure and services.
E	The city addresses the vulnerability of drinking and wastewater infrastructure to flooding on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

A.6 Public Health & Safety

"Disasters resulting from natural hazards such as floods can cause severe environmental and infrastructural disruption and significant economic losses. Disasters can also directly affect human health through injuries, death and disease outbreaks, and longer-term impacts may include non-communicable diseases, psychiatric morbidity and disabilities" (World Health Organization 2018). Natural hazards can trigger chemical releases as well as dam incidents, significant water releases, or significant changes in releases.

The integration of disaster risk management into municipal emergency planning becomes ever more important as the frequency and unpredictability of extreme weather events continues to increase.

The present study assesses the declared commitments of municipal governments pertaining to understanding and mitigating risks posed by potential hazards to the following critical sectors:

- Healthcare;
- Chemical; and
- Dams Sector.

The following three subsections present how the level of preparedness of municipal governments is assessed in terms of their ability to deal with the disruption of these sectors and subsequently to minimise the physical and psychological impacts of such disruptions to communities, as well as to reduce private and public losses.

Healthcare Sector

The Canadian health sector naturally plays a significant role in the response and recovery efforts that occur during and following natural or manmade disaster events. Damages to health facilities not only cost lives, but also can cause disruptions to health systems, facilities, and services, critically leaving many without access to health care when it is most needed, that is during emergencies.

Understanding and mitigating the risks that are posed by potential hazards to the healthcare sector can greatly contribute to ensuring that the necessary capacity is put into place to safeguard the resilience of communities in regard to coping and recovering from the impacts of disasters, including floods.

Notably, the healthcare system is highly dependent on other CI systems for the continuity of its operations and service delivery, amongst them telecommunication, energy, transportation, water, and food systems.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

6a How does the city mitigate the vulnerability of existing healthcare facilities to flooding (such as hospitals, clinics, retirement homes, outpatient care centres, and assisted living facilities)?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of existing healthcare facilities and their dependencies to flooding. The city has subsequently secured funding and developed plans to protect healthcare facilities and services to a desired level if deemed necessary.
B	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of existing healthcare facilities and their dependencies to flooding. The city has subsequently engaged with stakeholders to develop resilience plans and to secure funding in order to protect healthcare facilities to a desired level.
C	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of existing healthcare facilities to flooding. In collaboration with the relevant stakeholders, the city plans to assess flood vulnerabilities related to the dependency of healthcare facilities on other critical infrastructure systems.
D	The city has recently (within the past 5 years) conducted a risk assessment to identify the vulnerability of existing healthcare facilities to flooding. Engagement with healthcare facilities is currently limited to preliminary discussions.
E	The city addresses the vulnerability of existing healthcare facilities to flooding on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

Chemical Sector

In addition to causing significant economic and social damages, floods can trigger technological disasters, exacerbating impacts on the environment and on human health due to the potential releases of hazardous materials, as well as the possibility of fires and explosions. The assessment of potential chemical release risks associated with floods affecting the chemical sector is critically important due to the potential of major accidents. The chemical sector encompasses a wide range of facilities that manufacture, store, use, and transport potentially dangerous chemicals upon which a wide range of other critical infrastructure sectors rely.

A technological accident can cause the release of dangerous chemicals from manufacturing facilities, oil and gas pipelines, storage sites, transportation links, waste sites, and mines. Large-scale releases are particularly likely to occur from pipelines and at fixed chemical installations, where underground and aboveground fuel, chemical tanks, and connecting pipes can be damaged by floods.

Chemical spills from refineries, wastewater treatment plants, and hospitals can directly lead to the contamination of drinking water sources, wherein the prompt coordination of actions would be required in order to protect the health and safety of people. Furthermore, the ability of local authorities and services to respond to such chemical releases can be severely curtailed due to the other impacts of flooding, including blocked, damaged, or flooded transportation routes as well as potentially overwhelming rescue demand. Moreover, chemical releases themselves may prevent or hinder rescue operations because of the additional risks posed to emergency-response personnel.

Disruptions in the chemical sector can create complex systems of impacts, and in some cases, can also magnify the costs to human life, health, and welfare. Therefore, the analysis of interdependencies between the chemical sector and other CI sectors is crucially important.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

6b How does the city mitigate the vulnerability of its population to hazardous chemical releases (such as oil spills and other chemical releases from pipelines carrying hazardous materials, industrial facilities, landfills, and water treatment plants) during floods?

ANSWER KEY	
A	In collaboration with the owners/operators of facilities that produce, transport, store, or use toxic chemicals, the city identifies potential chemical release risks associated with flooding; mandating, controlling, and validating mitigation efforts against any potential threat to the lives, health, and safety of its population.
B	The city provides guidance on flood risk assessment and management to the owners/operators of facilities that produce, transport, store, or use toxic chemicals, and subsequently approves the implementation of mitigation measures.
C	The city mandates the owners/operators of facilities that produce, transport, store, or use toxic chemicals to review and update their emergency response plans that address contamination risks during and following flood events.
D	In collaboration with the owners/operators of facilities that produce, transport, store, or use toxic chemicals, the city guides the development of emergency plans that address contamination risks during and following flood events.
E	The city coordinates emergency and response planning with the owners/operators of facilities that produce, transport, store, or use toxic chemicals to ensure the safety of its population.

Dams Sector

There are over 15 000 dams in Canada, of which 933 are categorised as 'large' dams as defined by the International Commission on Large Dams (ICOLD). Such dams may be owned by a variety of different organizations, including federal, provincial, and municipal governments, provincial or local utilities, industrial and mining companies, and even private individuals. Canadian hydroelectric and mine tailings dams are amongst the largest dams in the world, with some particularly large dams located in the Province of Quebec and used for hydroelectric purposes.

Unlike some other countries, Canada lacks a central regulatory authority to guide and develop requirements that would outline how dams are to be managed in a safe manner.

Significant dam failures lead to floods of varying extremity. Climate change, erosion, variations in volume and waterway flows due to precipitation changes and upstream development, as well as the increasing occurrence of extreme weather events can negatively affect the integrity of dams and lead to dam overtopping and dam breach emergencies. Moreover, dams are exposed to the risk of deliberate sabotage which would result in the most extreme consequences out of all possible dam-related emergencies.

The responsibility for emergency planning for dams lies primarily with dam owners and also local authorities. The former group has the duty to provide timely warnings, whereas downstream local authorities are responsible for their own emergency planning relative to dam-related emergencies. Inundation maps along with flood arrival details are to be prepared by dam owners so as to allow emergency responders to plan their own response actions. Local authorities must also ensure that local emergency plans include current, all-inclusive inundation maps, supported by the inundation maps provided by dam owners. These emergency plans should also include an inventory of impacts to the people and properties that are located within the inundation zone.

The term 'inundation zone' refers to the area that would be impacted downstream of the dam in the event of a dam failure or an uncontrolled release of water that is generally significantly larger than a normal river or stream flood event. Notably, this term is broader than a 'regulated flood area' (such as a 1-in-100-year flood) and keeping accurate stock of the extent of such zones is perhaps even more critically important than the routine update of regular floodplain maps. This is the case because floods caused by dam breaches or failures are typically more sudden and dangerous than regular flood events.

Nevertheless, the requirements of how inundation maps are kept up-to-date and how these are shared not only with emergency response agencies but also with the general public is inconsistent across the various Canadian jurisdictions. Inundation maps being publicly available is particularly important seeing as the consequence of such floods can include the flooding of major infrastructure and transportation routes, leading to difficulties with evacuations, if such become necessary.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

6c How does the city mitigate the vulnerability of its population to the negative impacts of controlled releases and/or dam failures that may occur during floods?

ANSWER KEY	
A	For dams that may affect the city during floods, the city in partnership with the province and/or conservation/watershed authorities carries out regular dam safety surveillance, water level monitoring, and other relevant activities that are related to dam pre-releases and extra discharges during heavy rainfall events. Dam failure inundation maps and/or evacuation maps, incorporating the impacts of climate change were recently (within the past 5 years) updated.
B	For dams that may affect the city during floods, the city in partnership with the province and/or conservation/watershed authorities carries out regular dam safety surveillance, water level monitoring, and other relevant activities that are related to dam pre-releases and extra discharges during heavy rainfall events. Dam failure inundation maps and/or evacuation maps, were updated more than 10 years ago.
C	For dams that may affect the city during floods, the city mandates the owners/operators of these dams to regularly (at least every 10 years) update dam failure inundation maps (for dams with high risks of failure) and/or evacuation maps as applicable, incorporating the impacts of climate change.
D	For dams that may affect the city during floods, the city mandates the owners/operators of these dams to regularly (at least every 10 years) update dam failure inundation maps (for dams with high risks of failure) and/or evacuation maps as applicable.
E	The city addresses the potential safety risks of controlled releases and/or dam failures during floods on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

A.7 Emergency Response

The mission of emergency response operators is to save lives, protect property and the environment, assist communities impacted by disasters, and aid recovery during emergencies.

Emergency operation assets include the Government Operations Centre, housed at Public Safety Canada as well as regional offices located in all of the provinces and in the North. Emergencies are managed first at the local level – for example, by first responders such as medical professionals and hospitals, fire departments, the police, and public works departments.

To ensure the safety of their residents, as well as the safety of emergency professionals and volunteers, municipal governments need to assess the vulnerability of their emergency services and assets so as to manage the assistance required for both the operation and protection of the assets and facilities that provide Emergency Social Services assistance during emergency events.

The emergency response sector has dependencies and interdependencies with multiple other Critical Infrastructure sectors and the analysis of interdependencies between this sector and the other CI sectors is crucially important for emergency management.

The present study assesses the declared commitments of municipal governments pertaining to the identification of vulnerabilities including infrastructure interdependencies for the emergency response sector focusing on the following domains:

- Emergency Response Operations;
- Continuity of Fuel Supply;
- Continuity of Emergency Communication; and
- Public Alerting.

The following four subsections present how the level of preparedness of municipal governments is assessed in terms of their ability to deal with emergency situations and subsequently ensuring the continual stable delivery of essential services.

Emergency Response Operations

Emergency services play a crucial role during the flood response process, as they are central to rescue and relief efforts. The resilience of critical response and recovery facilities, including police, fire, emergency health centres, and Emergency Social Services (ESS) reception centers plays a crucial role in emergency response and recovery activities.

The main target of the hazard risk and vulnerability assessments of emergency response operations is the prevention of injury and loss of life of emergency services personnel, members of volunteer organizations, and members of the public, as well as ensuring the ability of emergency services to respond efficiently and effectively during emergencies.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

7a How does the city mitigate the vulnerability of emergency response operations to flooding, including the accessibility of routes designated for first responders, as well as access to hospitals, emergency shelters, fire, police, and ambulance stations?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a risk assessment that incorporated the impacts of climate change to identify the vulnerability of emergency response operations and their dependencies to flooding. The city has subsequently secured funding and developed plans for flood emergencies and committed funding to protect emergency response operations to a desired level if deemed necessary.
B	The city has recently (within the past 5 years) conducted a risk assessment that incorporated the impacts of climate change to identify the vulnerability of emergency response operations and their dependencies to flooding. The city has subsequently engaged with key stakeholders in order to develop plans and to secure funding to protect emergency response operations to a desired level.
C	The city has recently (within the past 5 years) conducted a risk assessment that incorporated the impacts of climate change to identify the vulnerability of emergency response operations and their dependencies to flooding. The city is currently engaged with stakeholders in considering adaptation measures in order to protect emergency response operations to a desired level.
D	The city has recently (within the past 5 years) conducted a risk assessment that incorporated the impacts of climate change to identify the vulnerability of emergency response operations to flooding. The city has subsequently engaged with stakeholders in order to develop a framework to assess and prioritize flood adaptation measures for emergency response operations.
E	The city addresses the vulnerability of emergency response operations to flooding on an ad-hoc basis (e.g. following large flood events), but not on a regular basis.

Continuity of Fuel Supply

A fuel supply shortage ("fuel" refers to refined petroleum products, such as gasoline, diesel, jet fuel and heating oil but not crude oil) can be caused by failures in the distribution system (e.g. due to pipeline damage) and/or major disruptions to refinery operations (e.g. significant electrical outages or flooding). During a declared emergency, supplies of fuel may become a government-controlled commodity in order for communities and critical infrastructure (CI) sectors to maintain essential services.

The availability of fuel for emergency service backup generators is critical for continued operations of hospitals and emergency services, telecommunications systems and transportation hubs such as airports and public transportation services. During emergencies, the demand for fuel supply can increase dramatically, therefore, local business continuity planning should adopt measures in order to mitigate the effects of fuel shortages during flooding events.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

7b How does the city ensure the continuity of fuel supply (gas, oil, and diesel) including fuel supply for emergency coordination centres, emergency first response operations, and hospitals during flood events?

ANSWER KEY	
A	The city maintains designated emergency fuel depots and annually reviews emergency and business continuity plans to ensure the continuity of fuel supply during emergencies. The city has implemented renewable energy programs so as to diversify fuel supplies.
B	The city maintains designated emergency fuel depots and annually reviews emergency and business continuity plans to ensure the continuity of fuel supply during emergencies. The city is planning to implement renewable energy programs to diversify its fuel supply.
C	The city maintains designated emergency fuel depots and has mutual aid agreements with the owners/operators of critical infrastructure to mitigate the effects of fuel shortages during flooding events.
D	The city mandates the owners/operators of critical infrastructure to arrange agreements with fuel suppliers, validating and controlling the implementation of their business continuity plans.
E	The city provides guidelines and tools for emergency planning to assist the owners/operators of critical infrastructure in the development and implementation of their emergency fuel contingency plans.

Continuity of Emergency Communication

In a situation like a flood, the ability of first responders to communicate is of paramount importance, and continuity of communications is especially essential during emergency operations. The loss of communications, whether due to destruction or loss of service due to power failure, places the lives and safety of all people in a disaster-affected area at a significantly greater risk.

Emergency communications are defined as the ability of emergency responders to exchange information via data, voice, and video as authorized, to carry out their work, and to complete their missions. Unanticipated congestion on commercial wireless networks during unplanned events can result in degradation of service, thereby impeding the ability of emergency managers, local officials, residents, and businesses to make decisions on how to best respond to threatening conditions. Seeing as all telecommunication networks are extensively power-reliant, power outages immediately and directly impact the continuity of telecommunications services.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

7c How does the city ensure the continuity of communications between emergency response agencies and organizations during flood events?

ANSWER KEY	
A	The city actively participates in the testing of the public safety broadband network to enhance communications between emergency response agencies during flood events.
B	The city collaborates with cellular communication service providers to ensure the continuity of wireless priority service for communications between emergency response agencies during flood events.
C	The city collaborates with an amateur radio operator society to provide reliable communications between emergency response agencies during flood events.
D	The city has deployed a Public Safety Radio Network to provide reliable communications between emergency response agencies during flood events.
E	The city, in partnership with the province, and/or conservation/watershed authorities is working with providers to assess the provision of critical services and to understand the limitations of the current services.

Public Alerting

Public alerting in Canada, like all emergency management functions, is a collaborative initiative between federal, provincial, territorial, and municipal governments, as well as industry partners.

As the climate becomes increasingly variable, the ability of disaster management teams to anticipate the occurrence of extreme weather events will become ever more challenging. There may also be a trend of growth in the potential for disasters to occur with very little warning or with sudden, unanticipated intensities. Therefore, building a safe and reliable public alerting system empowers individuals and organizations to minimize disaster damages and losses of life by providing residents of disaster-prone areas with advance warning of possible emergency events.

Current methods for assessing social vulnerability to emergencies, including flooding, assume that social deprivation is a good proxy of vulnerability to a flood. For municipal governments, social vulnerability assessments are an important step in building robustness against emergency and flood risks. Mapping the distribution of social vulnerabilities is a beneficial add-on to existing emergency alert/warning systems as it allows planning efforts to include consideration for the inclusion of services for people with special needs (e.g., visually, hearing, or physically impaired, infirm, illiterate, individuals who do not speak the primary local language, etc.) residing in flood prone areas.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

7d How does the city ensure the accuracy, coverage, and timeliness of flood warnings?

ANSWER KEY	
A	The city has recently (within the past 5 years) conducted a social vulnerability assessment and has upgraded existing flood forecasting and emergency alert/warning systems to include services for people with special needs (e.g., visually, hearing, or physically impaired, infirm, illiterate, don't speak the primary local language, etc.) residing in flood prone areas if deemed necessary.
B	The city has recently (within the past 5 years) conducted a social vulnerability assessment and is in the process of developing a detailed business case and a budget request to undertake the required upgrade of existing flood forecasting and emergency alert/warning systems to include services for people with special needs (e.g., visually, hearing, or physically impaired, infirm, illiterate, don't speak the primary local language, etc.) residing in flood prone areas.
C	The city is currently upgrading existing flood forecasting and emergency alert/warning systems in order to expand forecasting and warning services to include overland, storm, and sanitary sewer back-up flooding; and is currently testing alert services for residents located in flood-prone areas.
D	The city relies on river flood forecasting and warning systems operated by the province or conservation (watershed) authorities and plans to expand forecasting and warning services to include overland, storm, and sanitary sewer back-up flooding, but this work has not yet been initiated.
E	The city relies on river flood forecasting and warning systems operated by the province or conservation (watershed) authorities and has no plans to provide new forecasting and warning services for overland, storm, and sanitary sewer back-up flooding.

A.8 Chief Resilience Officer

One of the evolving challenges for Canadian cities concerned about resilience and emergency preparedness is the trend of rapid population growth in most major Canadian metropoleis. As urbanization progresses across Canada, it is important for city governments to consistently improve their capacity to deal with various shocks and stresses resultant from a wide range of causal factors.

In 2013, The Rockefeller Foundation (New York, USA) launched the 100 Resilient Cities (100RC) program that offered a $100 million USD prize that was split between 100 cities around the world that agreed to establish a Chief Resilience Officer (CRO) position. In Canada, the cities of Vancouver, Calgary, Toronto, and Montréal had each established such a position within their respective city governments in order to lead each city's resilience efforts. These four cities formed the "Team Canada Committee," a working group on resilience best practices that collaborated on shared challenges "in public health, immigration, social resilience, and adaptation to climate change" (City of Montréal 2018).

The 100RC program ended in 2019, with all four participating Canadian cities launching their respective Resilient City Strategies and related action plans.

While many other communities across Canada may have an individual or a group of individuals that are responsible for the respective community's safety and capacity to adapt and/or react to risks, the titles held by such individuals may be different. Therefore, nearly all major Canadian communities do address the issue of resilience in some manner.

To address this criterion, participants were asked to select the most appropriate option (or combination of options) in response to the following question:

8 Does your city have a full-time "Chief Resilience Officer" (or equivalent)?

ANSWER KEY	
	☐ Yes
	☐ No
	☐ Equivalent

Definitions

A catastrophic event (CAT): an event that affects multiple policies and causes more than $25 million of insured damage.

Climate: the average weather, usually expressed in terms of the parameters temperature, precipitation, and wind.

Climate Change: a change in the mean and/or the variability of climate parameters over a period of time ranging from months to thousands or millions of years

Coastal Flooding: flooding associated with a defined shoreline along an ocean or a lake. Can occur due to a combination of high water levels, high tides, storm surges, waves, tsunamis, rising sea levels.

Disaster: essentially a social phenomenon that results when a hazard intersects with a vulnerable community in a way that exceeds or overwhelms the community's ability to cope and may cause serious harm to the safety, health, welfare, property or environment of people; this may be triggered by a naturally occurring phenomenon or by human action or error.

Emergency communications: the ability of emergency responders to exchange information via data, voice, and video as authorized, to carry out their work and complete their missions.

Floodplain: an area adjacent to a lake, river or coast, which can be expected to be regularly inundated or covered with water. It typically includes two zones:

Floodway: the channel of the river or stream and the adjacent land that must remain free from obstruction so that the regulatory flood can be safely conveyed downstream.

Flood Fringe: the remaining portion of the floodplain, where flood depths, flow velocities, or wave energies are relatively lower and some development may be permitted, if adequate levels of flood protection are provided. Flood Mechanisms: the condition, which causes a specific type of flood (e.g., blocked culvert leading to overland flooding).

Flood Mitigation: a sustained action taken to reduce or eliminate long-term risk to people and property from flood hazards and their effects. Mitigation distinguishes actions that have a long-term impact from those that are more closely associated with preparedness for, immediate response to, and short-term recovery from specific events.

Flood Risk: flood risk is a combination of the likelihood of occurrence of a flood event and the social or economic consequences of that event when it occurs.

Flood Risk Map: maps that contain the flood hazard or inundation delineations along with additional socio-economic values, such as potential loss or property vulnerability levels. These maps serve to identify the social, economic and environmental consequences to communities during a potential flood event.

Flood Protection: any combination of structural and non-structural improvements, additions, changes, or adjustments to structures, which reduce or eliminate risk of flood damage to real estate or improved real property, water and sanitation facilities, or structures with their contents.

Fluvial Flooding: excess stream flow in a watercourse, such that land outside the normal banks is submerged or inundated. Riverine flooding can be caused or exacerbated by extreme rainfall, snowmelt, physical conditions (e.g., ice, sediment and debris jams, watercourse configuration and capacity limitations), as well as elevated water levels in receiving waterbodies.

Hazard: a potentially damaging physical event, phenomenon, or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

Infill: development within urban boundaries not related to large-scale development plans, but rather smaller scale development in remnant vacant parcels.

Intensity-Duration-Frequency (IDF) curve: a graphical representation of the probability that a given depth of rainfall will occur, shown in rainfall intensity (e.g., in millimeters per hour) with respect to rainfall duration (e.g., hour). Lateral: any pipe from a building connected to the main sewer.

Peak Flow: the maximum flow rate occurring during a specified flood event measured at a given point in a river, overland, or in a pipe system.

Permafrost: rock or soil that remains below 0°C for at least two consecutive years. Surface conditions including vegetation, organic cover and snow thickness can influence permafrost temperatures. Permafrost thickness is related to the air temperature, soil characteristics and the geothermal gradient as well as the geological history of the area.

Pluvial Flooding: the inundation of the built environment by rainfall, overwhelming the capacity of stormwater management systems.

Re-development: conversion of existing urban uses of lower value and significance to other preferred uses per a community plan (e.g. brownfield redevelopment to residential uses).

Regulatory Flood: the defined flood event used to delineate areas prone to flooding for the purposes of regulating land use. The minimum regulatory flood criteria standard in Canada is the 100-year return period flood, which is the peak flood flow with a one percent chance of occurring in any given year. Some regions, provinces, and territories implement standards that are more stringent.

Resilience: capacity of people and systems to absorb negative impacts and respond to changing climate conditions.

Risk: a combination of the likelihood (probability of occurrence) and the consequences of an event.

Risk Management: a systematic approach to setting the course of action under conditions of uncertainty, by applying management policies, procedures, and practices to the analysis, evaluation, control, and communication about risk issues.

Runoff: the amount of water deriving from precipitation/ snowmelt, not otherwise evapotranspirated or stored, that flows across the landscape.

Sanitary Sewer: part of the public sewage works for the transmission of sanitary sewage (includes human and industrial waste, and septic waste, but not typically stormwater).

Stormwater: precipitation that washes off driveways, parking lots, roads, yards, rooftops, and other surfaces.

Stormwater Management: the planning, design and implementation of systems that mitigate and control the impacts of man-made changes to runoff and other components of the hydrologic cycle. Stormwater management is also referred to as "rainwater management" in much of the world.

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