Improving the Government of Canada's Response to Flooding Through the Inclusion of Pertinent Economic Information

by

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Declaration of Committee

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Abstract

At present, the methods by which costs of flood-related damages are estimated vary significantly across Canada, resulting in widely different and often incomplete quantification of these costs. I use the comprehensive flood-costing methodology that I co-developed in Adeel et al. (2020) to assess the economic impacts of flooding in Canada during 2013 – 2017. This methodology is meant to facilitate flood-planning investments by governments at different levels and allocation of resources to support real-time flood monitoring and response. Public Safety Canada, Indigenous Services Canada, and Natural Resources Canada should standardize and integrate pertinent economic information into existing disaster-response mechanisms, using the methodology proposed herein. Indigenous approaches for evaluating flood damages and losses must also be incorporated. Doing so would standardize the process of post-disaster assessments, facilitate enhancement of local resilience against flood impacts, and improve allocation of resources by the Government of Canada in response to flooding.

Keywords: comprehensive flood-costing methodology; floods; flood damages and losses; post-disaster reconstruction; disaster management; disaster risk reduction

Dedication

To Mum & Bubz.

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First and foremost, I respectfully acknowledge that this research took place on unceded land; the traditional territories of the xʷməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), Səl̓ílwətaɬ (Tsleil-Waututh), and kʷikʷəƛ̓əm (Kwikwetlem) Nations.

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List of Acronyms

ALAE	Allocated Loss Adjustment Expenses
CatIQ	Catastrophe Indices and Quantification Inc.
CDD	Canadian Disaster Database
CEC	Commission for Environmental Cooperation
CGE	Computable General Equilibrium
CWN	Canadian Water Network
DFA	Disaster Financial Assistance
DFAA	Disaster Financial Assistance Arrangements
E^3ID	Extreme Events Economic Impact Database
EGS	Emergency Geomatic Services
EMAP	Emergency Management Assistance Program
ECCC	Environment and Climate Change Canada
FDRP	Flood Damage Reduction Program
FEMA	Federal Emergency Management Agency
FERP	Federal Emergency Response Plan
FNIGC	First Nations Information Governance Centre
GIS	Geographic Information System
GOC	Government Operations Centre
IBC	Insurance Bureau of Canada
IPCC	Intergovernmental Panel on Climate Change
ISC	Indigenous Services Canada
NDMP	National Disaster Mitigation Program
NRCan	Natural Resources Canada
PBO	Parliamentary Budget Officer
PCS	Property Claims Services
PDAP	Provincial Disaster Assistance Program
PSC	Public Safety Canada
RMS	Risk Management Solutions Inc.
SPI	Smart Prosperity Institute
UN ECLAC	United Nations Economic Commission for Latin America and the Caribbean
UN ISDR	United Nations International Strategy for Disaster Reduction

Chapter 1. Introduction

1.1 Introduction

Flooding constitutes Canada's costliest extreme weather events (Office of the PBO, 2016; Davies, 2020). Because of increased population and more exposed assets in hazard-prone areas, more devastating and costly flooding are expected in the future. Changes in climate patterns are likely to exacerbate this trend, bringing heavier rainfall events, sea level rise, increased flooding from more intense hurricanes, and coastal erosion (IPCC, 2012; Seneviratne et al., 2012; Hodgkins et al., 2017).

Federal Disaster Financial Assistance Arrangements (DFAA) costs resulting from floods from 1970 – 2014 are estimated at $6.52 billion and represent 78% of DFAA's weather-related expenditures (Office of the PBO, 2016). These high costs are driven by lack of overland flood insurance availability in Canada, in addition to regulatory challenges (Office of the PBO, 2016). Another important consideration is interprovincial coordination of flood response and management (Office of the PBO, 2016). Although this has been shown to be an effective way to respond to flooding in other countries, much like flood insurance, the potential of interprovincial coordination has yet to be fully realized in Canada (Office of the PBO, 2016). This aspect is significant in the prairies, where many rivers and their tributaries span multiple provinces (Office of the PBO, 2016).

Not only is the financial burden of flooding placed on the Canadian taxpayer through the DFAA system, but insured losses also cover a significant proportion of the overall costs of flooding in Canada (Office of the PBO, 2016; Davies, 2020), in addition to provincial and municipal expenses. From 1983 to 2016, insurance covered 58% of the total recorded costs of extreme weather events (Davies, 2020). In contrast, the combined cost of federal DFAA and provincial disaster financial assistance (DFA) amounted to 21%, with the remaining 21% being spent by federal, provincial and municipal government departments on their own disaster-related expenses (Davies, 2020).

The Insurance Bureau of Canada (IBC) provides data on insured losses due to extreme weather events every year, from 1983 through 2019 (Canadian Underwriter, 2020).

Those losses (excluding adjustment expenses) amounted to an estimated $38.4 million in 1983 and $39.1 million in 1984 (Canadian Underwriter, 2020). In 2018 and 2019, the figures were $2 billion and $1.4 billion, respectively (Canadian Underwriter, 2020). The Canadian insurance industry was averaging approximately $400 million a year in catastrophic insured losses from 1983 through 2008 (Canadian Underwriter, 2020). Since 2009, the annual average has quintupled to nearly $2 billion; the majority of these losses have been flood related (Canadian Underwriter, 2020).

To improve disaster prevention, emergency responses, and recovery strategies, however, it is first necessary to better understand the consequences of floods on local and regional economies, and to develop methodologies to estimate the comprehensive cost of such disasters (Allaire, 2018). At present, the methods by which costs of flood damages are estimated vary significantly among federal and provincial jurisdictions across Canada, resulting in widely different quantification of these costs (McGrath, 2015; Davies, 2016).

The Commission for Environmental Cooperation (CEC)[1], an intergovernmental organization created by the governments of Canada, Mexico and the United States, recognized information gaps in estimating economic impacts of floods and has initiated in 2019 a collaborative research project in response. The work presented in this report includes insights and research findings from Canada as part of an international project led by the CEC entitled "Costing Floods and Other Extreme Events[2]," which brings together governmental agencies, academic institutions, and stakeholders from the private sector and communities. The overall objective of this project is to formulate a standardized methodology for assessing the cost of extreme floods in the US, Mexico, and Canada. This methodology is presented in Appendix A and is referred to as the "CEC Flood Costing Methodology." The CEC Flood-Costing Methodology has been developed in close cooperation between interested government agencies, Indigenous community representatives, private sector partners, and domain experts. The

[1] The Commission for Environmental Cooperation – established in 1994 through the North American Agreement on Environmental Cooperation – facilitates collaboration and public participation to foster conservation, protection and enhancement of the North American environment for the benefit of present and future generations, in the context of increasing economic, trade, and social links among Canada, Mexico, and the United States.

[2] https://www.sfu.ca/pwrc/research-and-projects/costing-floods-and-other-extreme-events.html

composition of this group includes the end-users of this methodology and data generated from it, particularly those designing infrastructure investments, enhancements to community resilience, and long-term planning. Such integrated and standardized methods do not exist at this time.

1.2 Research Questions

The purpose of this report is to address three broad research questions:

1) What is the added value of a standardized and comprehensive flood-costing methodology?
2) What are the potential roadblocks in implementing a standardized and comprehensive flood-costing methodology, and how can they be overcome?
3) What policy transformations need to occur for the Government of Canada to improve its response to flooding through the inclusion of pertinent economic information?

1.3 Report Organization

This report is organized into eight chapters. Chapter 1 introduces the research and guiding research questions. Chapter 2 explains the research methods used for this report. Chapter 3 identifies the role of the federal government in responding to flooding. Chapter 4 analyzes the existing methods for measuring the economic impacts of flooding. Chapter 5 highlights Indigenous perspectives on flood damages and losses. Chapter 6 shows the results of the spatial and temporal analysis of flood costs in Canada for the 2013-2017 period. Chapter 7 offers broader discussion, policy recommendations, and areas of future research based on the results. Chapter 8 presents the conclusion of the research.

Chapter 2. Research Methods

2.1 Systematic Review

A systematic review to identify the role of the federal government in responding to floods, existing flood-costing methods, and Indigenous perspectives on costing flood damages and losses in Canada was conducted. Systematic reviews have been widely used in synthesizing research evidence (O'Connor & Sargeant, 2015). More broadly, systematic reviews can be described as a type of research that is conducted by review groups with specialized skills. Reviewers try to identify and retrieve evidence that refers to particular questions and synthesize the results of this search to inform practice, policy, and in some cases, further research (Munn et al., 2018). Systematic reviews may be conducted on any piece of written evidence, including grey literature. Systematic reviews should attempt to be transparent about the decisions being made, and how evidence is synthesised to be replicable (Gough et al., 2012).

In co-developing the CEC Flood-Costing Methodology, I first went through a process of identifying the role of the federal government in responding to floods, existing flood-costing methods, and Indigenous perspectives on costing flood damages and losses in Canada. In the early review process, I defined the searching keywords and conducted a Title & Abstract search. Data collection consisted of a search of electronic literature databases to identify sources, including peer-reviewed articles, grey literature (e.g., government reports, policy statements, and issue papers), and books.

In identifying existing flood-costing methods, a full text screening to identify publications that met one or more of the following criteria was conducted:

- Criterion 1: The studies had to focus on the economic damages and indirect losses caused by floods in Canada (studies that did not include economic impacts were not considered further)
- Criterion 2: The publications evaluated governmental approaches for assessing economic impacts of floods.
- Criterion 3: The publications evaluated the approaches for economic assessment and risk analysis used by the insurance sector.

For the existing flood-costing methods, information on challenges in measuring flood impacts, approaches used for overcoming those challenges, and gaps in data collection approaches was analyzed. Case studies that highlight the effectiveness, challenges encountered, and limitations of applying flood-costing methods in various Canadian cities was a central element of the literature review. The academic literature on existing flood-costing methods in Canada was found to be vast and interdisciplinary. Information on these methods was found in disaster management, water resources and economic policy journals. Open-access data and information from national government agencies such as the Parliamentary Budget Office (PBO), Public Safety Canada (PSC), and Statistics Canada were also reviewed. Private-sector information found in many Insurance Bureau of Canada and Swiss Re[3] online reports was considered.

2.2 Database Design

I presented my research findings on existing flood-costing methods, and Indigenous perspectives on costing flood damages and losses at two international workshops (Sep 2019, Jul 2020) led by the CEC for multi-stakeholder analysis.

At the First CEC Expert Workshop in September 2019, participants from Canada, Mexico, and the United States comprised representatives from relevant government agencies, Indigenous organizations, insurance sector, research and academia, and other enterprises. Workshop participants critically reviewed the existing methods used in the three countries and offered their perspectives on challenges, opportunities, and possible next steps. In formulating the CEC Flood-Costing Methodology, workshop participants agreed that the centralized flood-costing methodology used in Mexico provided an effective and important starting point. The CEC Flood-Costing Methodology is based on the United Nations Economic Commission for Latin America and the Caribbean (UN ECLAC) methodology, which has been effectively used in the evaluation of the impact of disasters in Mexico and elsewhere (Zapata & Madrigal, 2009). A number of enhancements and modifications to this standardized methodology were recognized.

[3] Swiss Reinsurance Company Ltd, commonly known as Swiss Re, is a reinsurance company based in Zurich, Switzerland. It is the world's largest reinsurer.

Limitations of applying the CEC Flood-Costing Methodology and challenges in implementation within all three countries were further discussed. The conceptual design of the CEC Flood-Costing Methodology has been published in the International Journal of Disaster Risk Reduction (Adeel et al., 2020).

The CEC Indigenous Perspectives Workshop was a virtual workshop held in July 2020 via Zoom[4]. The overall objectives of the CEC Indigenous Perspectives Workshop were to: 1) incorporate Indigenous perspectives in the proposed methodology; 2) identify and build partnerships around shared aims; and 3) discuss ongoing collaboration. The workshop participants from Canada, Mexico, and the US comprised representatives from different Indigenous communities, relevant government agencies, research and academia, and other enterprises. There were a number of key modifications and recommendations made for the CEC Flood-Costing Methodology at the Indigenous Perspectives Workshop. Among these include the addition of a new category and sub-categories specifically for Indigenous communities to capture the intangibles and tangibles with different data types (e.g., videos, pictures of the event, and descriptive text), and a new flexible component that would allow for case-by-case inclusion of community-specific information.

The CEC Flood-Costing Methodology functions as a relational database, which I used to populate flood costs in Canada from 2013 – 2017. It is called the Extreme Events Economic Impact Database (E^3ID). The CEC Flood-Costing Methodology and the related database have the advantage of being flexible, in terms of the categories that could be included according to the time and resources available. The CEC Flood-Costing Methodology includes 105 indicators that cover the social sector, economic sector, infrastructure, emergency assistance, and categories specifically for Indigenous communities to capture the intangible and tangible damages and losses caused by floods. The E^3ID is comprised of eight tables. Figure 1 presents a brief description of each table.

[4] Zoom Video Communications, Inc. is an American communications technology company that provides videoconferencing and online services through a cloud-based software platform, and is used for teleconferencing, telecommuting, distance education, and social relations. Retrieved from https://zoom.us/

Figure 1: Brief descriptions of the eight tables that comprise the Extreme Events Economic Impact Database (E^3ID)

1. **Location table**: This table provides information about the locations that were affected by flooding (or other extreme events) from 2013 to 2017 in Canada
2. **Flood event table**: This table provides information about floods by year, start and end dates from 2013 to 2017 in Canada
3. **Flood-event location attributes**: This table provides support information about the event location (e.g., population).
4. **Direct damage table**: This table provides 55 indicators about direct damages caused by floods from 2013 to 2017 in Canada
5. **Indirect effect table**: This table provides 15 indicators about the indirect effects caused by floods from 2013 to 2017 in Canada
6. **Additional cost table**: This table provides 35 indicators about additional costs caused by floods from 2013 to 2017 in Canada
7. **Indigenous communities flood damage table:** This table provide information about the damages caused by floods in Indigenous communities in Canada from 2013 to 2017, including the intangible and tangible damages or losses with different data types (e.g., videos, pictures of the event, and descriptive text). However, data collection in this table needs to work in collaboration with Indigenous representatives to be sure of the specific data types, indicators, categories, and perspectives
8. **Data source table**: This table provides information about the data source and level of data aggregation that reflects a statistical view of the collected data points

For Canada, the spatial resolution of the E^3ID is initially based on the census level for insured values and municipal/township level for uninsured values. The E^3ID is composed of a GIS layer (e.g., shapefile) linked to a relational attribute database in Microsoft Access. While these two components are separate data files, they are linked by GIS software (e.g., ArcGIS products) for conduction of spatial and temporal analyses. The E^3ID attribute database provides information on direct damages, indirect effects, and additional costs caused by flood events.

2.3 Data Sources

The data used in the E^3ID are secondary data that have been gathered previously by another person or entity. Advantages of secondary data include that it is less expensive and more quickly available than primary data (Mulhern, 2010). However, disadvantages of secondary data include their selection and quality, the methods of their collection, which are not under the control of the researcher, and that they are sometimes impossible to validate. Table 1 shows a complete list of the sources used in tabulating the economic impacts of flooding in Canada.

Table 1: Data sources of the Extreme Events Economic Impact Database (E^3ID) in Canada

Country	Data sources
Canada	Canadian Disaster Database (CDD), Public Safety Canada (PSC)
	Catastrophe Indices and Quantification Inc. (CatIQ)
	The 2016 Census Program, Statistics Canada
	Provincial Disaster Assistance Program (PDAP), Government of Saskatchewan
	Disaster Financial Assistance (DFA) Program, Government of New Brunswick

PSC maintains the Canadian Disaster Database (CDD) which contains disaster related information — where and when a disaster occurred, the number of injuries, evacuations, and fatalities, and an estimate of the costs — for more than 1,000 events that occurred since 1900 that have directly impacted Canadians. In order to identify flood events in Canada from 2013 – 2017 and gather a sense of their scale, I consulted the CDD. This process is further explained in Section 2.4.1.

Catastrophe Indices and Quantification Inc. (CatIQ) delivers analytical and meteorological information on Canadian catastrophes through combining insured loss and exposure indices for the insurance industry, public sector, and other stakeholders (CatIQ, 2020). In order to tabulate insured losses, a dataset along with flood footprints from CatIQ was obtained. This process is further explained in Section 2.4.2

In addition to the federal DFAA program, each province and territory has their own disaster recovery program. There are differences across provinces in the design and intent of these programs, eligible groups, maximum amount covered, and relevant legislation, policy and guidelines (MNP, 2015). In order to tabulate uninsured losses, reports from Saskatchewan's Provincial Disaster Assistance Program (PDAP) and New Brunswick's Disaster Financial Assistance (DFA) program were obtained. This process is further explained in Section 2.4.2

Open-access population data from the 2016 Census Program was obtained from Statistics Canada in order to conduct a population-based weighting method to distribute economic costs of flooding at the census level. This process is further explained in Section 2.4.3.

2.4 Data Collection & Processing

Data from the CDD, CatIQ, and the selected provincial governments are compiled. These data are collated and georeferenced. These datasets are being used to determine the temporal and spatial trends of the economic impacts of floods across Canada. The data collection and management process in Canada was predicated on a high level of engagement from both the public and private sector. Government agencies at the national level (e.g. PSC, NRCan, and Statistics Canada), provincial level (e.g. Saskatchewan's PDAP and New Brunswick's DFA program), and the insurance industry (e.g. IBC and CatIQ) played a key role in facilitating the data collection process. Developing and applying the CEC Flood-Costing Methodology through the E^3ID in Canada is an ongoing and constantly evolving process. For this reason, approaches to data collection, processing and analysis needed to be flexible, adaptable and resilient to change.

The data collection process in Canada was divided into three stages. The first stage was to determine the costliest flood events in Canada from 2013 - 2017 based on open-access information in the CDD. The second stage involved collecting data on insured and uninsured losses. The third and final stage was to process the data on insured losses and populate the CEC project database.

2.4.1 Preliminary Selection of Events

Prior to collecting data on insured and uninsured costs of flooding, I went through a preliminary selection of events to determine the costliest flood events in Canada from 2013 – 2017. The CDD served as an effective starting point in the data collection process. After running a query on the CDD, the results showed that there were 22 flood events in Canada from 2013 – 2017 across every province. The CDD also produces a geospatial view of these 22 flood events, which perhaps provides some indication of the spatial trends.

There were 3 events listed for 2017. Furthermore, 10 of the 22 events listed did not include a cost estimate and are referred to as “unknown”. The values in the CDD for these events are a combination of federal DFAA and insurance payments, the former of which are distributed by PSC. Insured losses cover a significant proportion of the overall costs of flooding in Canada (Office of the PBO, 2016; Davis, 2020). For the purposes of this project, it is therefore essential that the data collection process sufficiently captures these losses.

The CDD fulfilled its role as an easily accessible and user-friendly database that lists and maps major flood events and their estimated costs. Though unsuitable for data collection purposes, the CDD was useful in identifying the costliest Canadian flood events on record and providing a sense of their scale. Moreover, the CDD does not employ a standardized guideline for collecting cost and loss data related to disasters, making it unsuitable for analytical and comparative purposes.

2.4.2 Data Collection on Insured and Uninsured Losses

The CatIQ dataset contains eight significant flood events and three sub-events from 2013 – 2017 across nine provinces. Information on these events can also be found in the CDD. The dataset includes estimated catastrophic insured losses (not adjusted for inflation) by province and line of business (personal, commercial, auto), broken down into physical and non-physical damage. ‘Personal non-physical damage’ represents adjusted living expenses, ‘commercial non-physical damage’ are the insured losses from business interruption, and ‘allocated loss adjustment expenses (ALAE)’ includes losses not related to the policy holder due to third party intervention (e.g., administrative costs such as legal fees, cost of auditors, etc.). The dataset does not indicate which economic sector claimed the loss with insurance, and data are represented at the provincial level. Footprints that depict the spatial coverage for each of these flood events and sub-events were also provided (in the form of .kml files).

Included in the report from Saskatchewan are seven events total; four identified as spring flooding, and the other three as heavy rain. Each tab represents a specific event in each year and includes the designated locations, date range, private claims, municipal claims, municipal projects and actual amount paid by the PDAP. The claimants are categorized as boards/cooperatives, charitable organization, displacement/ temporary relocation, First Nations, municipal, primary agricultural enterprise, principal residence, regional park authority, renter, small business, or other. The report does not display the amount each claimant received.

In the New Brunswick DFA report, there are three events total; two of which are heavy rain, and the other is a spring flood event. The report outlines the cost of DFA for different sectors that have completed a claim, including homeowners, small businesses, agriculture, mitigation, municipalities and provincial departments. Administrative, response and other costs include payouts to adjusters, auditors, appraisals, legal fees, engineers, and emergency responders. An important detail that separates the New Brunswick DFA program from the other data sources used is that the report specifies the amount given to each municipality that completed a claim. This demonstrates that the province of New Brunswick uses a relatively high level of granularity and transparency in reporting the costs of flooding.

2.4.3 Database Population

Due to lack of standardized disaster damage reporting, a decades-old issue in disaster database management is accounting for costs at the municipal, or at least, census level, the input data lacks a sufficient level of granularity (Bakkensen et al., 2017; Downton & Pielke, 2005; Wirtz et al., 2012). Since the values in the CatIQ dataset reflect insured losses at the provincial level, and the datasets from Saskatchewan and New Brunswick do not indicate the amount each municipality received, the spatial resolution of these data are not always suitable for the E^3ID. In addressing this concern, current estimates of flood damages at the census level are based on a simple method that involves disaggregating insured and uninsured flood costs at the provincial level according to census level population density. There are three steps to assign flood damages into each census subdivision:

1. Sum the total population affected by flood events;
2. Calculate the percentage of the total population of census subdivisions most affected by flood events;
3. Weigh flood damages based on the percentage of the affected population.

These estimated values are highlighted in the E^3ID. Population data are supplied by Statistics Canada at pre-defined units in the form of 2016 Census Data. A key assumption in performing this population-weighted assessment is that the epicentre of all flood damages and losses are in densely populated areas. However, this may not always be the case. Though disaggregating the data in this manner produces a number of limitations, uncertainties and assumptions, similar methods have been used in studies that integrate disaster databases (Bakkensen et al., 2017; Wirtz et al., 2012) or that highlight the importance of population-density in flood management (Smith et al., 2019; Calka et al., 2017.)

The definitions of the indicators used in the CatIQ and provincial datasets do not always align with those described in the CEC Flood-Costing Methodology. For example, the indirect commercial effects are exemplified as “decreased credit scores and bond downgrades for businesses” in the E^3ID, though the CatIQ data refers to this as “business interruption.” However, both represent an indirect effect to commerce. In initially processing the datasets from CatIQ, Saskatchewan and New Brunswick, I ensured that the terminology, categories, indicators and descriptions used align with those outlined in the E^3ID by confirming with their representatives. Table 2 highlights the differences in descriptions of damage indicators used by CatIQ, New Brunswick’s DFA program, and PDAP in Saskatchewan, and how these data should be processed under the indicators and categories that comprise the E^3ID.

Table 2: Data processing of insured and uninsured losses under the categories and indicators that comprise the E^3ID

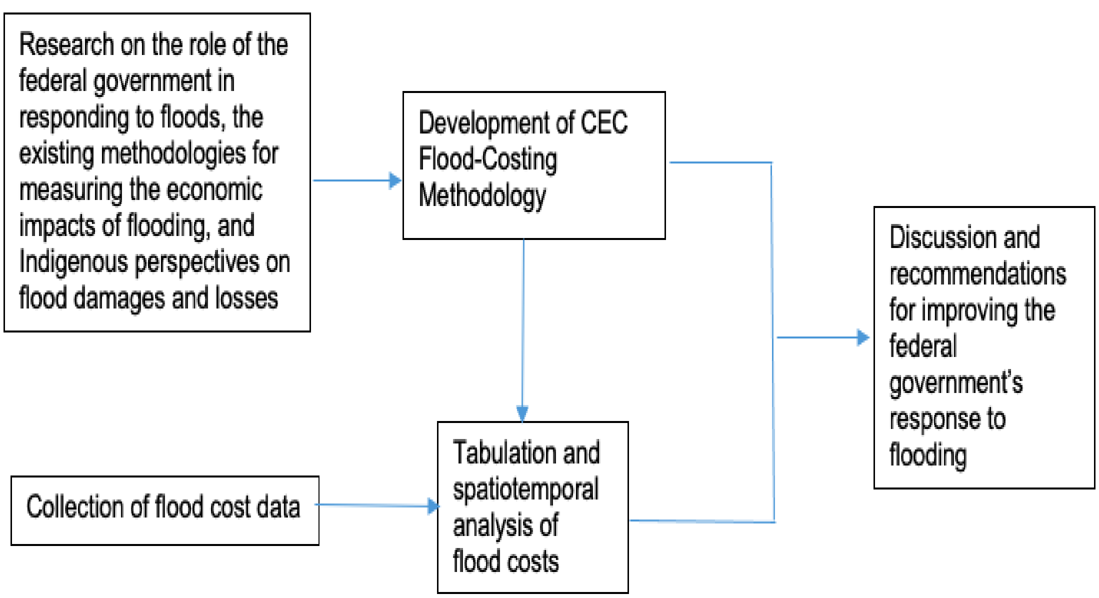
CEC Categories	CEC Sub-Categories	CEC Flood-Costing Indicator Description	CatIQ Dataset Indicator Description	Saskatchewan PDAP Dataset Indicator Description	New Brunswick DFA Dataset Indicator Description
Housing	Household items (Direct damage)	Cost of the total or partial destruction of furniture, electric appliance, sanitary facility, and other equipment	Auto Damage		
	Dwelling (Direct damage)	Cost of the total or partial destruction of dwellings or properties	Personal Physical Damage	Principal Residence	Homeowners
	Temporary accommodation (Additional cost)	Costs of the provision of temporary accommodation for persons whose homes were destroyed or had to be abandoned	Personal non-physical damage/adjusted living expenses	Displacement / Temporary Relocation	
Commerce	Building and facility (Direct damage)	Cost of the total or partial destruction of buildings, facilities and furniture	Commercial physical damage	Small Business	Small Business
	Credit (Indirect effect)	Decreased credit scores and bond downgrades for businesses	Commercial non-physical damage/business interruption		
Agriculture	Infrastructure used in farming (Direct damage)	Involved in the total or partial destruction of infrastructure used in farming		Primary Agricultural Enterprise	Agriculture
Cultural Resources	Recreation area (Direct damage)	Involved in the total or partial destruction of recreation areas		Regional Park Authority	

Local Government	Local infrastructure and services (Direct damage)	Involved in the damages of local infrastructure and services provided by the local government		Municipal	Municipal

2.5 Report Methodology

As illustrated in Figure 2, there are two methodologies used in this report. The first involves research on the role of the federal government in responding to floods, the existing methods for measuring the economic impacts of flooding, and Indigenous perspectives on flood damages and losses, which led to the development of the CEC Flood-Costing Methodology. The second involves collecting, tabulating, and analyzing flood cost data from 2013 – 2017, in order to pilot-test the CEC Flood-Costing Methodology. By the end of this report, the combination of the desk-based research to develop the CEC Flood-Costing Methodology, and pilot-testing of the CEC Flood-Costing Methodology will allow for a broader discussion and recommendations on improving the Government of Canada's response to flooding through the inclusion of pertinent economic information.

Figure 2: Report methodology



Chapter 3. Role of Federal Government in Responding to Floods

3.1 Introduction

The Government of Canada has many important roles and responsibilities in responding to floods, though their capacity to do so in an effective manner remains unclear. These are outlined in relevant legislation, in addition to the existing policies, programs, plans and initiatives led by federal government agencies.

3.2 Legislation

Some legislation can lay the groundwork for the federal government's capacities to respond to flooding, including the Indian Act (1876), the Canada Water Act (1970), and the Emergency Management Act (2007).

3.2.1 Indian Act (1876)

The Indian Act is an act of Parliament that involves registered Indigenous peoples,[5] their bands, and the system of Indigenous reserves. It was passed in 1876 and is still in force. The Indian Act is an important document which defines how the Government of Canada interacts with the First Nations, Métis and Inuit.[6] It outlines how reserves and bands should operate, which has affected on-reserve flood management activities, as the federal government have jurisdiction under this Act. It consists of many rules for governing reserves and describes the ways in which bands can be created. One goal of

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[5] "Indigenous peoples are commonly defined as those who are descendants of a geographic location or territory; those present before a new, dominant population arrived. Indigenous peoples retain social, economic, political and cultural characteristics of their descendants. Indigenous peoples determine their beliefs and keep knowledge and language systems, and it has been noted that identifying rather than defining Indigenous peoples is a more productive means to successful description." United Nations. Retrieved from "Indigenous People Indigenous Voices Fact Sheet

[6] The term "First Nation" is used to describe Aboriginal peoples of Canada who are ethnically neither Métis nor Inuit. The term "Métis" refers to a collective of cultures and ethnic identities that resulted from unions between Aboriginal and European people in what is now Canada. The term "Inuit" refers to the Indigenous peoples of the Arctic. https://indigenousfoundations.arts.ubc.ca/terminology/

this legislation is to determine who is, and who is not acknowledge as Indigenous by Crown Law.

The Indian Act serves as a major marker of colonialism in Canada and is argued to be an invasive law that continues to control the livelihoods of Indigenous peoples (Coates, 2008). The purpose of this Act is to allow Indigenous peoples to adopt the same values as mainstream Canadian life. This Act constrained the relationship of Indigenous peoples to the land and waters. There have been attempts to rectify the Indian Act, although the success and effectiveness of these attempts remain unclear. Section 35 of the Constitution Act, 1982 recognizes that Indigenous peoples have an inherent right to self-government. However, flood response and management activities for Indigenous peoples in Canada still operate under a colonial governance framework. The Indian Act has changed very little over the years, and destroys the cultural, socio-economic and political well-being of Indigenous peoples.

3.2.2 Canada Water Act (1970)

The Canada Water Act was introduced in 1970 and is a statute of the Government of Canada. It defines a framework for collaborating with provinces and territories to develop and use Canada's water resources. An important component of this Act is the research, planning and implementation of water-related programs. Part I of the Act establishes federal-provincial/territorial arrangements that have resulted in intergovernmental agencies which govern water resource management (ECCC, 2016). Part II authorizes federal-provincial/territorial management agreements where water quality has become a matter of urgent national concern. The implementation of alternative approaches and programs has resulted in Part II never having been used. Part III calls for regulating the concentration of nutrients in cleaning agents and water conditioners, though was later repealed and incorporated into the Canadian Environmental Protection Act in 1988. Part IV lays out the requirements for administrating the Act, which includes annual reporting to Parliament, inspection and enforcement, and allows the Minister to undertake public information programs.

The Canada Water Act reflects the paradigm shift by resource managers, policymakers, and the public with regards to their concerns over the management of water resources across Canada (ECCC, 2013). Prior to this Act, many uses of water were not covered, and federal assistance was given on the basis of a rigid cost-sharing formula. The Canada Water Act embodies the idea that non-structural alternatives should be considered for effective water resources management, and that planning should take place at the watershed level. Flood management called for a new approach, beyond the traditional one of employing structural works and paying disaster assistance. This paradigm shift was sparked by the overall disappointment with many characteristics of the structural approach; the problem of income transfer from the public to the minority of floodplain dwellers; and perhaps most importantly, the rise in flood damage costs even with the implementation of control structures. In response, the federal government evaluated its programs and policies, in order to develop a new national strategy to address the issue of flood damage. Canada's Flood Damage Reduction Program (FDRP) was launched in 1975. It sparked a national shift away from reliance on structural flood mitigation measures such as dams to the use of non-structural measures, including floodplain mapping (de Loë & Wojtanowski, 2001).

3.2.3 Emergency Management Act (2007)

Arguably the most important piece of legislation that defines the Government of Canada's capacity to respond to flooding is the Emergency Management Act. In 2007, the Emergency Management Act replaced the Emergency Preparedness Act, which was passed in 1988. The main objective of the Emergency Management Act is to develop and implement an integrated approach to emergency management planning, which includes better prevention/mitigation of, preparedness for, response to, and recovery from emergencies (PSC, 2012). The Act declares the Minister of Public Safety and Emergency Preparedness as its enforcer, who is responsible under the Act for conducting exercises and providing education and training related to emergency management. This piece of legislation helps to identify the risks that are within or related to the responsibilities of the federal government. This includes those related to critical infrastructure. These responsibilities must be carried out in accordance with the policies, programs and other measures established by the Minister. The policy requirements under this act involve responding to emergencies, such as flooding, in a manner that is consistent with areas of responsibility, the departmental response plan, and existing arrangements. Under this act, post-incident analysis is undertaken, and lessons learned and best practices are incorporated into emergency management plans.

Using Public Safety Canada (PSC) guidelines, this Act has helped develop emergency management plans related to the federal government's area of responsibility to address mitigation/prevention, preparedness, response and recovery. These plans also address the risks to strengthen the protection of critical infrastructure within or related to the areas of responsibility. Inherent within federal emergency management plans are facilitation and collaboration, both within and across sectors. Emergency management plans also include any measure to assist provincial/territorial and local governments.

3.3 Public Safety Canada

PSC was created in 2003 and ensures coordination across all federal departments and agencies responsible for the safety of Canadians (PSC, 2019a). Their mandate is to keep Canadians safe from a range of risks such as natural disasters; their mission is to build a safe and resilient Canada; and their vision is to achieve a safe and secure Canada with strong communities. An important role of PSC is to support the Minister's responsibility for all matters related to public safety and emergency management. Leadership is exercised at the national level for national security and emergency preparedness. PSC supports the Minister's responsibility for the coordination of entities within the Public Safety Portfolio. The Public Safety Portfolio calls for an integrated approach to Canada's security. PSC partner agencies have an annual budget of over $9 billion.

Under PSC, the Government Operations Centre (GOC) leads and supports response coordination of events of national interest (PSC, 2016). The GOC provides an all-hazards integrated federal emergency response to events (potential or actual, natural or human-induced, accidental or intentional) of national interest. It provides round-the-clock (24/7) monitoring and reporting, national-level situational awareness, warning products and integrated risk assessments, as well as national-level planning and whole-of-government response management. The GOC implements integrated government response management activities. Response management is the coordinated implementation of plans to ensure a harmonized response to the event. The Federal Emergency Response Plan (FERP) ensures a coordinated federal response to crises. The FERP is designed to harmonize federal emergency response efforts with those of the provinces/territorial governments, non-governmental organizations, and the private sector (PSC, 2018). The FERP consists of national and regional-level components, providing a framework for integration of effort through the federal government.

The Government of Canada provides financial assistance to provincial and territorial governments through the DFAA program, administered by PSC in the event of a natural disaster (PSC, 2020a). When response and recovery costs surpass what provinces or territories could reasonably be expected to bear on their own, the DFAA provides equitable means of assisting provincial and territorial governments. Assistance is paid to the province or territory, but not directly to affected individuals, businesses or communities. A financial assistance request is processed following receipt of the required documentation of provincial/territorial expenditures and a review by federal auditors. The provincial or territorial governments design, develop and deliver DFA. The amounts and types of assistance that will be provided to those that have experienced losses are decided by the province or territory. The DFAA does not restrict provincial or territorial governments in this regard. There is subnational freedom to implement the DFA appropriate to the particular disaster and the circumstances. The DFAA set out what costs will be eligible for cost-sharing with the federal government.

It has been postulated that there are two main policy concerns regarding the federal DFAA program that need to be addressed (Davies, 2020). The first is whether the federal government should consider making adjustments to the DFAA system in order to control its disaster related liabilities and to give provinces stronger incentives to mitigate and adapt to flooding and other extreme events. The second considers what the federal government can do to provide flood insurance for the 700,000 high flood risk homes in Canada and to encourage planned retreat from these susceptible areas.

PSC works directly with the affected province or territory to review requests for financial assistance of eligible response and recovery costs. A province or territory may request financial assistance when eligible expenditures surpass an established threshold. This is based on provincial or territorial population (see Table 3). Eligible expenses include, but are not limited to, evacuation operations, restoring public works and infrastructure to their pre-disaster condition, as well as replacing or repairing basic, essential personal property of individuals, small businesses and farmsteads (see Figure 3).

Table 3: Federal and provincial/territorial cost-sharing for a disaster in a province with a population of 1 million under DFAA guidelines

Eligible Expenditures	Provincial or Territorial Government	Government of Canada	Federal Share (%)
First $3.25 per capita	$3,250,000	$0	0
Next $6.51 per capita	$3,255,000	$3,255,000	50
Next $6.51 per capita	$1,627,500	$4,882,500	75
Remainder	$373,000	$3,357,000	90
TOTAL	**$8,505,500**	**$11,494,500**	

Source: (PSC, 2020a)

Figure 3: Examples of eligible and ineligible provincial/territorial expenses for cost-sharing under DFAA guidelines

Examples of provincial/territorial expenses that may be eligible for cost-sharing under the DFAA:
Evacuation, transportation, emergency food, shelter and clothing;
Emergency provision of essential community services;
Security measures including the removal of valuable assets and hazardous materials from a threatened area;
Repairs to public buildings and related equipment;
Repairs to public infrastructure such as roads and bridges;
Removal of damaged structures constituting a threat to public safety;
Restoration, replacement or repairs to an individual's dwelling (principal residence only);
Restoration, replacement or repairs to essential personal furnishings, appliances and clothing;
Restoration of small businesses and farmsteads including buildings and equipment; and
Costs of damage inspection, appraisal and clean up.

Examples of expenses that would NOT be eligible for cost-sharing:
Repairs to a non-primary dwelling (e.g. cottage or ski chalet);
Repairs that are eligible for reimbursement through insurance;
Costs that are covered in whole or in part by another government program (e.g. production/crop insurance);
Normal operating expenses of a government department or agency;
Assistance to large businesses and crown corporations;
Loss of income and economic recovery; and
Forest firefighting.

Source: (PSC, 2020a)

Davies (2020) advocates for overland flood insurance to be a required component of home insurance in all areas of Canada that are susceptible to flooding. He argues that in high-risk areas, the flood insurance component should be subsidized. Replacing DFA compensation by insurance for individuals, farmers and small business is a necessary reform. PSC will be undertaking a review of the DFAA program in order to evaluate and improve its viability (PSC, 2020b).

PSC leads an interdisciplinary Task Force on Flood Insurance and Relocation. To reduce financial and physical vulnerability to flooding, the task force will create a new, low-cost national flood insurance program to protect homeowners at high risk of flooding and without adequate insurance protection (PSC, 2020b). A national action plan to assist homeowners with potential relocation for those at the highest risk of repeat flooding is expected to be developed. Federal, provincial and territorial government officials, the insurance industry and stakeholders vulnerable to flooding make up the task force. Indigenous Services Canada (ISC) is working with Indigenous partners on a Steering Committee on First Nations Home Flood Insurance to analyze the exceptional context on reserves. There is space for information-sharing between the Task Force and Steering Committee, and they will collaborate to engage with various partners, including Indigenous communities and organizations.

As mentioned, PSC maintains the CDD, which contains disaster related information — where and when a disaster occurred, the number of injuries, evacuations, and fatalities, and an estimate of the costs — for more than 1,000 events that occurred since 1900 that have directly impacted Canadians. It tracks significant disaster events that meet one or more of the following criteria: 10 or more people killed; 100 or more people affected, injured, infected, evacuated or homeless; an appeal for national/international assistance; historical significance; and, significant damage/interruption of normal processes such that the community affected cannot recover on its own. However, the CDD does not employ a standardized guideline for collecting cost and loss data related to disasters, making it unsuitable for analytical and comparative purposes.

The United Nations International Strategy for Disaster Reduction (UN ISDR) coordinates international efforts in disaster risk reduction, and guides, monitors and reports on the progress of the implementation of the Sendai Framework for Disaster Risk Reduction

(PSC, 2019b). Canada is a signatory to the global framework, which PSC is leading as federal department responsible for domestic implementation. In October of 2018, British Columbia announced it would adopt the Sendai Framework to align and improve its approach to all phases of emergency management.

3.4 Natural Resources Canada

When floods occur over large areas, emergency responders and municipal governments require up-to-date information to make fast and rational decisions. It is critical that they have an understanding of where to send emergency workers, equipment and supplies; when and where to issue advisories, and road closures; whether to shut down or relocate services like hospitals; and whether to evacuate homes (NRCan, 2018). In order to facilitate this understanding, they must know where and how quickly floodwaters are rising, in addition to deciding which buildings, bridges and roads are at greatest risk.

Natural Resources Canada (NRCan) conducts flood research and mapping. Their Emergency Geomatics Services (EGS) team provides critical, near real-time information to the GOC, municipalities and other emergency responders during ice break-up and flood events (NRCan, 2020). Through the use of satellite imagery, EGS actively monitors spring ice break-up and flooding. They create real-time river ice state and flood extent maps to support flood response activities in Canada and for international flood events.

NRCan is also developing the Federal Flood Mapping Guidelines Series to standardize flood mapping activities across Canada. This approach will improve the accuracy of flood maps to support planning and flood response. Increasing the knowledge base around floods and improving the ability of authorities to predict and manage flood risk is of top concern to NRCan. Many parts of the country are missing updated flood maps that outline flood zones, which can be a useful tool for flood risk planning and mitigation. An important component of NRCan's mandate is to work with the provinces, territories and Indigenous peoples to complete flood maps in Canada.

With regards to climate change adaptation, NRCan's Adaptation to Climate Change Program enables the advance and exchange of the information and tools needed to implement pragmatic adaptation measures that increase the resilience of Canadian communities and industry to more frequent and intense flood events.

3.5 Indigenous Services Canada

Indigenous peoples across Canada face significant risks from annual flooding, which may include property damage, disrupted livelihoods, deteriorated health, and psychological trauma associated with prolonged and repeated evacuations (Thistlethwaite et al., 2020). In Canada, Indigenous reserve lands are disproportionately exposed to flooding, with 22% of residential properties at risk of a 100-year flood. Indigenous nations have limited information about flood defences, critical infrastructure assets and emergency services. This impedes comprehensive flood risk assessment for the affected communities.

The main goals of ISC are to improve quality of life of First Nations, Inuit and Métis, and facilitate the path to self-determination in all sectors (ISC, 2019). ISC officials work directly with First Nations at risk of flooding (ISC, 2020a). They also collaborate with their partners to ensure emergency response plans are effectively implemented, in addition to funding necessary flood response measures. ISC reports flood hazard events to PSC via coordinated situational awareness reports. ISC provides funding for flood mitigation, including upgrade of flood infrastructure. Crown-Indigenous Relations and Northern Development Canada has committed $25 million to reduce long-term flood risk, including support for flood mapping. ISC works directly with First Nations to support structural mitigation projects that protect communities from flooding. Projects may include dikes, sea walls and erosion-control measures. 57 structural mitigation projects have been launched and 25 have been completed. 65 First Nations communities have benefitted from these projects, serving approximately 81,000 people.

The source of federal funding to reimburse on-reserve emergency management activities, including for flood mitigation, preparedness, response and recovery is the Emergency Management Assistance Program (EMAP), administered by ISC (ISC, 2020b). The program provides funding to provinces, territories, and NGOs to support on-reserve response services. Moreover, the Building Back Better Strategy for implementing EMAP offers support to reduce First Nation communities' vulnerability and strengthen resilience in response and recovery to flooding. However, the level of meaningful engagement with Indigenous communities in these programs remains unclear.

3.6 Summary

Though the affected local community is the first line of defense in the wake of a flood, the Government of Canada carries out many diverse and complex roles and responsibilities in mitigating the impacts of flooding. Perhaps the most important pieces of legislation that dictate the federal government’s ability to respond to flooding are the Indian Act (1876), the Canada Water Act (1970), and the Emergency Management Act (2007). Moreover, federal government agencies such as PSC, ISC and NRCan carry out duties that attempt to quickly and effectively respond to floods. In improving the federal government’s response to flooding, there is room to integrate pertinent economic information into existing initiatives, programs, plans, policy and legislation.

Chapter 4. Existing Methods for Measuring the Economic Impacts of Flooding

4.1 Introduction

There are considerable differences in quantifying the costs of flooding and other extreme events at the national, provincial, and municipal level, in addition to harmonizing and integrating pertinent economic impact information across space and time. This national variability leads to information gaps when prioritizing development investments, for example, for infrastructure renewal, institutional development, or community enhancements. There also are significant data gaps in uninsured economic impacts of flooding (Allaire, 2018). These information gaps limit joint responses between multiple levels of government, particularly when encountering floods that impact multiple jurisdictions. Policymakers need accurate flood loss data for decisions about disaster assistance, policy evaluation, and scientific research priorities (Downton & Pielke, 2005). However, flood loss estimation can be difficult to conduct in a post-flood situation, and many secondary and tertiary impacts are seldom evaluated.

4.2 Flood-Costing Methods Used at Various Levels

The current methods for measuring the economic impacts of flooding in Canada are insufficient in accurately reflecting the financial burden placed on flood-prone communities and the wider economy. Though there are a range of methods by which we can determine the costs of flooding, there are also significant gaps in the data that informs these methods. Measuring flood impacts is by no means a simple process. The methods for measuring the economic impacts of flooding in Canada encounter significant challenges in data retrieval, presentation and analysis. All must deal with their associated uncertainties, assumptions and limitations. The ways in which these inherent uncertainties and assumptions are accounted for, and the approaches used in overcoming challenges in measuring the economic impacts of flooding is a testament to the effectiveness of that method.

These methods involve running model simulations, which requires basic input data. Input data tends to be provided in the form of a government or private insurance sector report. Key data holders tend to be associated with national government agencies, as well as private insurers. The wide range of flood-costing methods used in Canada are all being informed by similar sources and may not capture the full array of economic impacts encountered. The limited availability and accessibility of useful input data are common across the flood-costing methods used in Canada. There is a collection of literature on these flood-costing methods. However, the literature focuses mainly on methods that account for market costs and direct impacts such as building damage, as indirect and long-term impacts such as those inflicted on business and industry are less well understood. After carrying out a systematic review of publications and reports, I identified three key flood-costing methods used in Canada that have been accepted by government, industry (notably, the insurance sector), and researchers to varying degrees.

4.2.1 Parliamentary Budget Officer's (PBO) Methodology

The PBO estimated the average annual cost of the DFAA program over a five-year period (2016-2020) due to extreme weather events (Office of the PBO, 2016). Data for estimated future insured losses due to hurricanes, convective storms, and winter storms are obtained from Risk Management Solutions Inc.[7] (RMS), and the future flood residential property loss data are obtained from IBC. The estimate of future flood losses by IBC is then increased to include total commercial and public infrastructure losses, using the proportion of public sector and commercial fixed assets measured by Statistics Canada (Office of the PBO, 2016). For example, the categories of health care and social assistance, educational services, and government sector are included in public infrastructure. The DFAA payment for flood-related costs on an annual basis is then calculated as a fraction of total losses, based on the historic estimates of the ratio between uninsured economic impacts and total losses over a ten-year period (2005-2014) (Office of the PBO, 2016). The PBO forecasted that DFAA payments would average $902 million in the years 2016 – 2020 (Office of the PBO, 2016).

[7] Risk Management Solutions Inc. (RMS) is a catastrophe modeling firm contracted by the PBO to estimate future annual losses for hurricanes, convective storms and winter storms

4.2.2 Hazus

Created by the United States Federal Emergency Management Agency (FEMA), Hazus standardizes how public safety agencies assess hazards, including models for estimating potential losses from earthquakes, floods, and hurricanes (FEMA, 2019). It uses Geographic Information Systems (GIS) to estimate physical, economic, and social impacts of disasters. The Hazus model estimates risk by calculating the exposure to a particular hazard (e.g., river flooding) within a selected area and combining that information with the intensity of the hazard's impact on the exposed area, using this information to calculate potential losses (FEMA, 2018). Hazus offers a robust approach to flood loss estimation that is gradually being adopted by governments and organizations worldwide (Hastings et al., 2017).

Though initially developed in the United States, the use of Hazus as a tool to measure the economic impacts of flooding has many practical applications for a variety of Canadian sectors, including insurance, geotechnical engineering, emergency management, and municipal planning (Hastings et al., 2017). Hazus Canada is a tool that provides municipalities, regional districts, provinces or consultants with a standards-based approach to various aspects of emergency planning, including planning for mitigation, response and recovery (Hastings et al., 2017). Using Hazus Canada, Canadian jurisdictions can also better identify areas at risk from flood hazards that may require changes in land use (Hastings et al., 2017).

There have been many examples of effective application of the Hazus flood model specifically – which includes both coastal and riverine flooding (Nastev and Todorov, 2013; McGrath et al., 2014; McGrath et al., 2015). Fredericton, New Brunswick has served as a useful case study location for implementation of the Hazus flood model, though these studies also highlight its practical limitations and challenges (McGrath et al., 2014; McGrath et al., 2015). The Canadian application of Hazus includes modifications to the built environment by including geographic boundaries used by Census Canada and to the demographic data by using those distributed by Statistics Canada via the Census Program (Hastings et al., 2017). Nastev and Todorov (2013) note that development of consistent strategies for collecting, updating and maintaining the input inventory and hazard data remains a challenge for Canada. This challenge, among many others related to lack of community participation and education, has prevented widespread uptake of Hazus by the government and industry in Canada.

4.2.3 Computable General Equilibrium (CGE) Models

Computable General Equilibrium (CGE) models use a series of equations to summarize market dynamics that are calibrated by empirical economic data to estimate how an economy might respond to changes in policy, technology or other conditions. CGE models are one of the most utilized tools globally for development planning and macro policy analysis (Mitra-Khan, 2008) and evaluating economic impacts of flooding (Carrera et al, 2015; Davies, 2016; Gertz & Davies, 2015).

A dynamic CGE framework for modeling the economic impacts of flooding in Vancouver, British Columbia, was devised in 2015; the underlying purpose of the exercise was to better understand the future severity of damages and losses associated with the increased frequency and intensity of flooding and severe storms as a consequence of anthropogenic climate change (Gertz & Davies, 2015). Though damages and losses are typically calculated by totalling insurance claims or surveying flood victims, the loss of economic activity caused by a flood is typically not included in the calculation. Under this CGE framework, the initial damage is modelled as a shock to capital stock, and recovery requires rebuilding that stock. This method accounts for the many economic impacts that occur as a result of flooding, including private consumption, government consumption, DFA, investment, imports, exports, taxes, and damages by economic sector – all the while applying these impacts to different potential damage scenarios. The method thus goes beyond the direct economic impacts (such as property and infrastructure damage) and applies a more comprehensive framework to measure the economic impacts of flooding over time (Gertz & Davies, 2015). However, much like Hazus, it has not seen broad uptake in Canada as a comprehensive flood-costing methodology.

4.3 Common Features of Methods

It is important to determine common features and identify key differences between the three key flood-costing methods. Certain methods may be useful to different levels of government (municipal, provincial, national), to different sectors and at different time scales. Some are better at capturing the full range of economic costs – both direct damage and additional losses; and some methods produce more accurate outputs/models than others as well. There are far more differences than similarities among these methods, demonstrating a high level of variation.

All methods, to some degree, rely on the quality and accuracy of input data. These input data often come in the form of government or private insurance reports. Therefore, a significant commonality is that all methods are informed by similar sources. Provincial and national governments seem to be the key data holders, as municipal government reports are less available and more difficult to access – though would serve as a useful source of information. The data generated from insurance companies are usually based on the number of claims paid, and only reflect a portion of economic damage as a result of flooding. While all the methods gather data from either government or insurance sector reports, they also involve the use of their own input data as well. Methods which impute more unique user-created data will not necessarily yield more accurate outputs. There are shared limitations among these methods, including challenges in obtaining useful data, and gaps in data collection approaches. The ways in which these challenges are overcome differ among the methods. Perhaps the most noteworthy similarity is the problems encountered with regards to data availability and accessibility. These methods could all be improved by collecting and analyzing more useful datasets that are essential to the given framework, yet this has shown to be difficult to obtain.

The outputs of all methods often come in the form of model simulations, graphs and tables. Simulations are carried out under each method, though for different purposes. Scenarios that account for factors such as climate change, population growth, mitigation measures and damage levels may be of consideration under these simulations. Accounting for uncertainty and assumptions is also a shared process among the flood-costing methods used in Canada. However, uncertainty may be more inherent in some methods than others, and the ways in which uncertainty is dealt with also varies across methods. Uncertainty and assumptions may even arise as a consequence of the methods used, including ineffective data collection and analysis procedures. A common method of data analysis to account for uncertainty and assumptions are sensitivity analyses, which are carried out in case studies involving the use of Hazus (McGrath et al., 2014; McGrath et al., 2015) and CGE models (Gertz & Davies, 2015).

All methods discuss in great detail the primary economic impacts of flooding such as property damage. It is clear that some methods are better at addressing indirect impacts such as how flooding affects various economic sectors (the CGE framework, namely). However, none of the methods fully address all direct impacts and additional losses. Lastly, basic principles of flood damage such as depth-damage ratios, velocity, duration and return intervals serve as the underlying theories for measuring the direct economic impacts among methods. It is evident that there are shared strengths and weaknesses among the flood-costing methods used in Canada.

4.4 Key Differences in Methods

There are considerable differences in the function of each of the three key flood-costing methods; the PBO's methodology captures the costs of historical events, Hazus is a model for future and current events, and CGE models are economic models. To compare, CatIQ combines insured loss and exposure indices with other related information to reach an estimate of insured losses (CatIQ, 2020). Each of these flood risk tools carry out their own functions and fulfill their own specific purposes.

Although the three key flood-costing methods are based on similar principles, data sources, and may carry out comparable data presentation and analysis procedures, the differences seem to be more substantial. Identifying which of the methods are most useful to different levels of government is important for effective implementation of planning and policy measures.

The PBO's methodology would be most useful at the national/international level. This is because it is the only methodology that assesses and aggregates the economic impacts of multiple flood events over many years for an entire country. The other methods measure the economic impacts of flooding on a much smaller scale. The PBO's methodology has international relevance because other countries that have a similar type of DFA program may look to use an adapted version of this methodology to measure their national economic costs.

The Hazus method is most useful at the local level but could also be carried out at a more provincial/regional scale for smaller sized provinces. CGE models as a flood-costing method could be carried out at any level, as there are many different approaches to developing the models. However, a Vancouver case study demonstrates that other urban Canadian cities can apply a similar framework, and that dynamic CGE models are a useful way to measure the economic impacts of flooding at the municipal level (Gertz & Davies, 2015). On a local scale, both the Hazus and CGE methods could be effectively used, but not the PBO's methodology. On a national scale, the PBO's methodology is most effective and useful, while the Hazus methodology and CGE models would be ineffective. Elected officials at the local, provincial and national level have considered applying these methods to assess the economic impacts of past, current or potential flooding.

Some methods examine the economic impacts of one flood event rather than multiple ones. As mentioned, the PBO's methodology determines the economic impacts of many flood events that have accrued over time, of which there is existing data on. It uses the total value and proportion that is covered by DFAA to determine the estimated future annual cost of DFAA for flooding and other extreme weather events.

Contrastingly, Canadian case studies under the Hazus and CGE methods make use of existing data on one real-life past flood event as a baseline to estimate an annual cost of a similar or more intense flood event under different scenarios or potential damage levels. The CGE framework uses far more data inputs than the others because it accounts for a multitude of potential economic impacts and policy adjustments such as tax rates across sectors, trade, and financial assistance, to name only a few (Gertz & Davies, 2015). Only the PBO's methodology examines many flood events over a broad time scale to reach an estimation, whereas the others are concerned with the economic impacts of one real-life flood event and may use it as a baseline to assess potential scenarios of a future event of similar or greater magnitude.

Different methods may be more useful to certain economic sectors than others. It can be argued that the PBO's methodology is not applicable to any economic sector with the exception of the insurance industry. This is because it is only concerned with insured/uninsured losses and public-sector losses. However, estimating the annual cost of flooding in terms of insurance claims and government spending is perhaps indirectly beneficial to all economic sectors. With the exception of the insurance industry, it does not prove to be more useful to one economic sector/industry than the other.

The Hazus method can also be applied to any economic sector. Because some economic sectors may be more vulnerable to the impacts of flooding than others, there is useful information for the agricultural, insurance, transportation and real-estate industries – all of which can use Hazus to their benefit.

The CGE method can be applied to any economic sector. This is because data on each economic sector was manipulated for the dynamic CGE framework in the Vancouver case study, and some industries showed to be more affected than others (Gertz & Davies, 2015). Therefore, the information in this methodology may be most useful to the transportation and warehousing sector of Vancouver. When applied to other cities, it will show that other economic sectors may be more heavily impacted by potential flooding, thus serving as more useful to those economic sectors. It is difficult to determine which methodology is most beneficial to a specific economic sector, as this would vary on a case-by-case basis.

The ways in which economic costs are defined and calculated varies significantly among the three key flood-costing methods. The input data are reflective of what constitutes an economic impact under each methodology. The PBO’s methodology considers economic costs to be the aggregate of insured, uninsured, residential, commercial and public infrastructure losses. From this, an estimation on the average total annual DFAA payments is reached. This ignores many other categories of economic impacts such as additional costs, long-term costs, as well as any cost to the individual/household. Much of the insurance data under this methodology is generated by probabilistic catastrophe loss models, whereby the output is an estimation of average annual losses calculated from a set of events that are used to create a loss distribution.

The Hazus method is largely concerned with depth-damage ratios as an indicator of economic impact, where a greater depth of residential flooding corresponds to greater damage and consequent repair costs. There are many disadvantages to these input-output models such as its linearity, rigidity and lack of behavioural content. They do not allow for substitution between different goods in consumptions, or between capital and labour in production. Any attempt to simulate a real-market economy and incorporate behavioural content or other features in input-output models would require ad hoc assumptions that do not conform to its underlying theory, ultimately muddying the results.

It is for these reasons that there has been a recent surge of the CGE method, which considers a multitude of potential economic costs across sectors and between various governments. CGE models are considered much more accurate than depth-damage functions or other input-output models. Hazus can use a combination of input-output and CGE modelling to estimate direct and indirect economic impacts. However, we see that in practise, the Canadian version of the Hazus Flood Model tends to be used more for basic input-output modelling and analysis such as depth-damage functions, as this measure is useful for the Canadian insurance industry. It is clear that there are significant differences in what constitutes an economic impact and how it should be calculated under the given methodology. None of the methods are capable of fully addressing all the possible economic impacts of flooding, allowing for inconsistent and inaccurate estimates, and overall ineffectiveness.

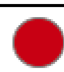
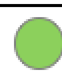
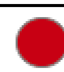
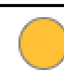
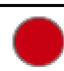
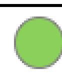
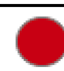
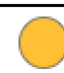
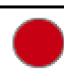
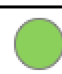
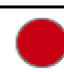
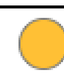
By comparing and contrasting the flood-costing methods used in Canada, we find that all have their associated advantages, limitations, uncertainties and assumptions which are not always well accounted for. There are different circumstances where some methods should be favoured over others. Knowing when to use which methodology can be complex and hinders effective decision-making. Comparatively analyzing these flood-costing methods demonstrates the need for the commonly-agreed-upon and comprehensive flood-costing methodology in Adeel et al. (2020).

4.5 Data Availability and Key Data Holders

A key factor in the success or failure of any methodology is the availability of, quality of, and access to data and metadata (such as location/coordinates, areal extent, and time period of the data) needed to undertake an assessment of damages and losses related to a flooding event. The data requirements the existing flood-costing methods also vary considerably, depending on the level of comprehensiveness required. Each of the methods have been subjectively qualified in accordance with the following criteria: data collection (frequency and comprehensiveness), data analysis and presentation, data availability and access, and the overall effectiveness and acceptability in developing estimates of damages and losses.

I followed established approaches for collecting and presenting expert opinion, such as those used for natural hazard management (Scheuer & Haase, 2012), hydrology (Antonetti & Zappa, 2018), and remote sensing (Arvor et al., 2019). I also duly recognize the limitations of such expert opinion, which might evolve over time or lead to different outcomes in different institutional settings. A broad-brush overview of how robust a costing method is or where the major data-driven challenges lie nonetheless provides useful and usable information for further research. For ease of presentation, my opinion is presented through a "traffic light approach," ranging from green (good) to yellow (moderate) to red (poor). Assumptions, uncertainties and gaps in data contribute to the ineffectiveness of the methods. Table 4 presents a summary of this opinion.

Table 4: An overview of the flood-costing methods in use in Canada, with respect to data collection, availability, accessibility, analysis, and presentation

Method	**Key Data Holders**	**Data Collection**	**Data Analysis & Presentation**	**Data Availability & Accessibility**	**Overall Effectiveness & Acceptability**
Canadian Methods					
Parliamentary Budgetary Office Method	Federal & provincial agencies; Insurance companies				
Hazus	Default inventory data (census-derived); User-derived data				
Computable General Equilibrium Models	Federal & provincial agencies				

A green light represents complete usefulness and effectiveness in approaches to data; a yellow/amber light represents somewhat usefulness and/or effectiveness; and a red light indicates unacceptability and ineffectiveness.

For the three key flood-costing methods, there is a generally acceptable level of data analysis and presentation, whereas availability and accessibility of data borders on inadequate. In most instances, data are presented in a clear and understandable format, but the level of detail required for input to the various methods is absent. Overall, there is a moderate level of effectiveness and acceptability with regards to the data that inform these methods.

Among the three key flood-costing methods, key data holders are government agencies, and the insurance sector. Scholarly peer-reviewed academic literature does not serve as a data holder, but still is commonly used as a source of valuable information under each of the methods.

The key data holders under the PBO's methodology are mostly insurance companies, some of which are even contracted by the Office of the PBO. Key data holders under this methodology include insurance and risk assessment companies such as IBC, Swiss Re, RMS, JBA Risk Assessment[8] (contracted by IBC), and Verisk Analytics Inc[9] (and its subsidiary, Property Claims Services (PCS)). A combination of insurance sector reports and data from national government agencies was used as input data for the PBO's methodology. Key data holders also include PSC and Statistics Canada. Government data came in the form of reports, spreadsheets and graphs showing annual expenditures. The history of DFAA payments from 2005-2014 are also obtained from PSC and Statistics Canada data reports. For the insurance companies, the data used to inform the PBO's methodology include annual reports and reviews that reveal expenditures and total claims paid. The results from probabilistic catastrophe models and other risk models are also collected for the methodology. Insured losses and total losses were retrieved from IBC, Swiss Re and PSC where available. Estimated future

[8] JBA Risk Assessment are global leaders in flood risk management, providing flood maps, catastrophe models, analytics and consultancy services to organisations around the world.
[9] Verisk Analytics, Inc. is an American data analytics and risk assessment firm based in Jersey City, New Jersey, with customers in insurance, natural resources, financial services, government, and risk management sectors

average annual insurance loss is obtained from RMS catastrophe models. The Office of the PBO met directly with some Canadian insurance industry representatives to retrieve useful information for their methodology.

A common feature among the flood-costing methods used in Canada is the unacceptable level of data availability and accessibility. Though under the PBO's methodology the majority of government data are open and easily accessible to the public (i.e. PSC data), important pieces of information such as historical records of total losses are untracked. The majority of insurance sector data are inaccessible to the public. With regards to availability of insurance sector data, IBC and Swiss Re Reports had numerous major flood events excluded, in addition to many small flood events. Due to only 10 years of Swiss Re reports being available, and a $50 million cost cut-off applied in order for a flood event to be listed, necessary data points were unobtained. Under the PBO's methodology, the challenges in data collection resulted in problems associated with data manipulation.

It is clear that use of the Hazus method in Canada involves the default GIS inventory data built into the Hazus Canada software. Canadian users have two options for inventory definition: a default Hazus inventory database aggregated on a census block level, or refined exposure information and supplied local inventory data – whereby each building is given its own latitude, longitude, construction type, etc. Local data are of much better quality, especially with regards to building and content replacement cost, occupancy and square footage, as shown through the Fredericton case study (McGrath et al., 2014; McGrath et al., 2015). The Flood Information Tool in the Hazus flood model provides a more sophisticated analysis of the flood hazard, as frequency, discharge and elevation are used to model the extent and velocity of flooding. There is uncertainty in input parameters. The Fredericton case study demonstrated the limitations of the default inventory data built into the Hazus software (McGrath et al., 2014; McGrath et al., 2015). It is possible for users to import their own local data based on a multitude of derived sources suited for the given analysis. These data can potentially be of much better quality, but are contingent on the ability of the user to access them.

Unavailability and inaccessibility of data are also problematic under the Hazus method, especially with regards to default inventory data. The reason default inventory data are aggregated is so that Hazus can perform an area-weighted assessment of damages and losses. It assumes that the inventory is evenly distributed across each census block, and damage and losses are computed proportionally to the flood depth distribution computed for the census block (i.e. 50% of a given census block that is flooded with 3 m of water corresponds to 50% of the inventory being flooded under 3 m of water). The default data that comes with the Hazus software may be readily available, but not of good quality, as demonstrated through the Fredericton case study (McGrath et al., 2014; McGrath et al., 2015).

The CGE framework requires real-life economic data, such as sector-specific inputs. For the Vancouver dynamic CGE model, we see that it is calibrated to the Metro Vancouver economy assuming a balanced growth path (Gertz & Davies, 2015). Statistics Canada's 2010 B.C. input-output table and their 2006 census data, in addition to B.C. Stats are key data holders. The symmetric B.C. input-output table is made up of 25 private business sectors, 6 governments and 1 non-profit sector, and provides spending on labour income, capital income, taxes and subsidies. It is useful for constructing the social accounting matrix, and deriving Metro Vancouver local input-output, final demand and trade tables. Data on employment at the municipal level was obtained from the 2006 census. BC stats provides employment data (labour market statistics) that is used to adjust the employment by sector for the year 2010. Some key parameters are fixed across sectors and are set exogenously, namely the growth rate, rate of depreciation and elasticity parameters.

Much like the PBO's and Hazus methods, there is a moderate level of acceptability with regards to who holds the data and how that data are to be collected under the CGE framework. With regards to data availability and accessibility, Statistics Canada and BC Stats input data may be accessible to the public, but there are many important numbers missing from their datasets, including figures on direct taxes. This data-gap resulted in numbers to be scaled and imputation procedures applied.

For each of the identified flood-costing methods used in Canada, the level of data availability and accessibility is unacceptable, and could lead to ineffective and inaccurate outputs. The insurance industry and federal/provincial government agencies seem to be the key holders of data, and each of the methods apply data collection approaches that also may yield unproductive results.

4.6 Summary

Among the flood-costing methods used in Canada, the ways in which assumptions, uncertainties, limitations and gaps in data are accounted for is largely ineffective. Although the data are often analyzed and presented in a clear and accurate manner, the overall effectiveness and level of acceptability of the flood-costing methods in Canada is hindered by three factors especially: data unavailability/inaccessibility; ineffective data collection approaches; and methods of addressing consequent or inherent assumptions, uncertainties, limitations and gaps in the data.

Chapter 5. Indigenous Perspectives on Flood Damages and Losses

5.1 Introduction

I assert that Indigenous perspectives for costing flood damages and losses in Canada need to be integrated into existing flood-costing methods, in addition to federal flood management policy, plans, programs and legislation. Doing so offers ways forward for how the federal government can improve their response to flooding among Indigenous peoples in Canada.

There are an estimated 1.7 million Indigenous people across Canada, which amounts to about 5% of the overall population (Statistics Canada, 2016). Indigenous peoples across Canada comprise the First Nations, Métis and Inuit. For centuries, Indigenous peoples have developed their traditional knowledge to connect with nature (Berkes, 2017). Traditional knowledge contributes to understanding many disciplines, such as natural resource conservation, climate change adaptation, social-ecological resilience, and natural hazards and disaster risk mitigation (Berkes, 2017; Sangha et al., 2018; Shea & Thornton, 2019). Currently, traditional knowledge is increasingly being recognized by academics and policymakers worldwide (Berkes, 2017; Parsons et al., 2019; Mohamed Shaffril et al., 2020). Indigenous peoples are engaging in national and international knowledge exchanges with other communities to help find solutions and increase resilience for various complex environmental problems (e.g., Shea & Thornton, 2019; Mohamed Shaffril et al., 2020). Supporting traditional knowledge to manage natural systems provides alternative paradigms in comparison to the economic-based approaches. There is evidence highlighting that traditional knowledge is helpful to better manage our natural resources (Berkes, 2017; Salmon, 2000).

A growing body of research has been conducted in flood-prone Indigenous communities from different perspectives, such as flood risk perception, insurance perception, livelihood sustainability, and climate change-related vulnerabilities (e.g., Newton, 1995; Black & McBean, 2017; Khalafzai et al., 2019; Thistlethwaite et al., 2020). These studies have highlighted the importance of integrating traditional knowledge and western technical and scientific approaches into the development of flood risk mitigation.

Different types of Indigenous knowledge have also proven to be valuable in flood risk management. However, the level of Indigenous peoples' engagement in flood risk mitigation remains unclear. The understanding and application of traditional knowledge require meaningful and long-term cross-institutional exchanges, partnerships, and processes involving Indigenous and non-Indigenous groups to understand how different knowledge systems can be blended in support of environmental stewardship goals (Whyte, 2013). Evidence has shown that most of the participation of Indigenous peoples or communities depends on a case-by-case, site-by-site, or project-by-project basis (Black & McBean, 2017; Natcher, 2001). Meanwhile, it might be questionable if the direct use of traditional knowledge is applied to places other than its origin because this knowledge typically differs from one community to another (Berkes, 2017; Zhang & Nakagawa, 2018). There is still a lack of a clearly conceptual framework demonstrating how local-based Indigenous knowledge may be integrated into scientific knowledge to reduce flooding risk at a national scale.

5.2 Water as a Living Entity

The relationship between water and Indigenous peoples across Canada is unique, reciprocal and sacred (Assembly of First Nations, 2020). Indigenous peoples across Canada were able to thrive under the given geographic and climatic conditions through engaging in a dynamic process of reciprocity and mutual respect with the living and non-living. Water is of significant cultural importance to Indigenous communities across Canada. Water has many uses including in ceremonies, to grow medicines, for transportation, drinking, cleansing and purification. Water is regarded as synonymous with life and needs to be respected. Water is a gift that sustains and connects all living beings. Water functions as the home of many living things and contributes to the well-being of everything not in the water. Water is the provider of all life, and without clean water all life will perish. Water is fundamental for the well-being of the individual and community, as well as for sustaining ecological integrity. Indigenous epistemologies recognize water as a living spiritual entity with life-giving forces. For Indigenous communities in Canada, water quantity and quality are not only ecological and health issues but are also contributors to a holistic perspective that understands all aspects of life to be interconnected (Cave & McKay, 2016). Much like all living entities, water is honoured and nurtured by Indigenous peoples across Canada.

Indigenous women in particular hold a sacred connection to the spirit of water and have special responsibilities to protect and sustain water. Water is provided by Mother Earth, and mothers create children in water (amniotic fluid). Indigenous women are regarded as the knowledge holders and carriers of water (Anderson et al., 2013). In Canada, there has been a movement within Indigenous communities to rebuild the connections that have been lost through colonialism, beginning with re-establishing the bonds that are shared with water (Cave & McKay, 2016). Indigenous women are leading these efforts, as they have traditionally been the caretakers of water. Maintaining the sacred relationship between women and water is a challenge. Re-empowering and supporting Indigenous women in Canada in their role as water stewards and in water governance is a process that involves addressing existing inequities as a result of colonialism.

Indigenous peoples across Canada strongly identify with water (Stefanovic & Atleo, 2021). The notion of relationality with water, recognized as a spiritual force with agency, is meant to guide ethical behaviour. The Anishinaabe of the Great Lakes region regard themselves as “water people.” Many Indigenous peoples navigate their territories through water and established strong canoeing cultures. Indigenous waterscapes provide food to be harvested such as fish, shellfish, whales, rice and seaweed. The practical connections to water are of cultural significance, including the reliance on waterways for transport, and the fact that rice, a beloved staple of many Indigenous peoples including the Ojibwe, is food that grows directly on water. There may be a strong relationship between Indigenous peoples and both freshwater and saltwater. On the coast of British Columbia, Indigenous peoples may refer to themselves as “saltwater people,” reaffirming their attachments to the water that sustains their livelihoods.

Among many Indigenous peoples across Canada, water is regarded as a being with its own spirit. Water is a relative that is alive and endowed with spirit and agency (McGregor, 2012). It deserves, respect, care and attention. One speaks to water as one would a relative, with care and compassion. Water is not a commodity. Water is revered and treated with respect and dignity. Yazzie & Baldy (2018) note that to be a water protector is to be a good relative, and that we will have no future if we are bad relatives. Appropriate water use should be based on respect and recognize that water is a living spiritual force (McGregor, 2012). However, when Indigenous peoples become alienated from water, they may begin to see their relations less as relatives and equals, worthy of respect and more as resources, to be exploited and sold (Stefanovic & Atleo, 2021).

5.3 Indigenous Approaches for Dealing with Flood Damages

Indigenous peoples have developed and utilized traditional knowledge that was accumulated over thousands of years through observations and experiences with their environment (Berkes, 2017). However, the ways in which Indigenous communities express their own place-based knowledge system varies, allowing for heterogeneity in managing flood damages (Berkes, 2017; Zhang & Nakagawa, 2018).

Indigenous methods for managing flood damages in Canada offer an alternative way of thinking about disaster management. There is a growing awareness of the value of traditional knowledge and its use in disaster risk reduction (Mercer et al., 2009). Traditional knowledge has the potential to increase our understanding of floods (Khalafzai et al., 2019). Bridging the gap between western science and traditional knowledge can be accomplished through integrating both in environmental decision-making processes that reduce community vulnerability to flooding. Much of the academic literature on Indigenous approaches for dealing with flood damages in Canada are based on mixed methods of research, which applies qualitative and quantitative measures, multiple types of approaches, and sources of information under creative, reflexive and participatory techniques.

Indigenous approaches for dealing with flood damages may involve the use of traditional knowledge and practices (Khalafzai et al., 2019; McNeill et al., 2017); individual, communal or governmental response activities (Newton, 1995); or community-based initiatives to effectively prepare, respond, recover and mitigate flooding (Montesanti et al., 2019). Moreover, ISC regional officials work closely with First Nations at risk of flooding, such as supporting funding for flood mitigation and recovery (e.g., EMAP) and structural mitigation projects (e.g., dikes) (ISC, 2020a). Through three brief case studies across Canada, the variety of ways in which Indigenous communities manage flood damages can be assessed.

5.3.1 Community-Based Responses

The Siksika First Nation implemented a holistic and social-ecological approach to mitigate the impacts of the flood in southern Alberta in June 2013 (Montesanti et al., 2019). The Siksika First Nation exhibited a fast and strategic community-based response to the June 2013 floods. They applied the Siksika Peacetime Emergency Plan, which was previously developed in 2005. This plan includes traditional knowledge about the history of the river and community capacities in emergency planning. The Siksika Emergency Team coordinated the evacuation of residents in the response phase, placing them in temporary emergency shelters. The team established a call centre and set up a Facebook page to coordinate relief efforts, donations, and volunteers. With funding from Alberta Health, the Siksika also developed and implemented a Community Wellness Plan to address the health and social concerns following the flood. Much like the planning and response phases, the Siksika Nation was able to implement effective post-flood recovery strategies by setting up programs that focus on the health and social effects, and not necessarily purely economic impacts.

Important to recovery and mitigation strategies is the recognition of traditional ways of life and cultural protocols. The role of spiritual Elders to help the Siksika Nation heal from disaster is valuable (Montesanti et al., 2019). There is a need to have a community engagement process in provincial and federal disaster and emergency planning that respects traditional knowledge and includes meaningful involvement in decision-making. The flood responses of the Siksika First Nation demonstrates that even for the most severe floods, community control over service provisions improves the planning, response and recovery phases, and effective flood management approaches led by Indigenous peoples can be successfully implemented. The Siksika First Nation has a robust governance system. Experienced members were available to take on the role of coordinator when needed. Transparent financial management and reporting took place, despite financial decisions being contentious. Although the Siksika Nation was open to external assistance, there was an effort to limit outsider access who may view the emergency as an opportunity to benefit more than Siksika members themselves. There is a shared belief that managing the June 2013 flood was an opportunity presented by the Creator to build on community strengths and increase adaptive capacity into the future. Under self-determination, this future would be designed and implemented by the Siksika First Nation.

5.3.2 Traditional Knowledge

Perspectives of the Kashechewan First Nation demonstrate that spring flooding has occurred seasonally over many generations and has not increased significantly over time (Khalafzai et al., 2019). The timing and extent of spring flooding has shifted in recent times with warming temperatures in the region. Members of the Kashechewan First Nation observe the impacts of climate change firsthand through detection of an earlier spring, more snowmelt, and rapid runoff. They also noticed that these impacts are being exacerbated by resource and landscape developments and inadequate infrastructure, including a substandard ring-shaped dike wall, and downriver winter ice road. Development in the region has increased the frequency and scale of spring ice breakup and ice jams. As a result, ecological changes have increased the risk of flooding for the community of Kashechewan.

Before the 1920s, the Cree of the James Bay Lowlands did not have permanent settlements (Khalafzai et al., 2019). They coped with floods by moving to higher ground in the spring. The established permanent settlements have increased their exposure to flood risk. 89% of band members voted in favor of relocating from Kashechewan to relatively higher and safer ground, mainly because they do not wish to lose their ancestral lands and valuable natural resources.

Conventional flood management approaches such as dam/dike construction, non-structural measures and technological solutions are perceived as infeasible when applied to the cultural and socio-economic context of the Kashechewan First Nation (Khalafzai et al., 2019; McNeill et al., 2017). Due to poor infrastructure and community planning, the Kashechewan First Nation is losing flood related traditional knowledge. Members of the Kashechewan First Nation explain that traditional flood management practises such as preparing canoes with supplies and preparing a camp at a safer place for temporary relocation are disappearing due to overreliance on dike construction and maintenance. The federal government has spent millions in constructing and maintaining a substandard dike for the community after failed relocation attempts. Approaches for dealing with flood damages among the Kashechewan First Nation consider ways to identify risk under the observed regional impacts of climate change. After seven events of flood risk since 2012, it is clear that none of the conventional flood management approaches have been effective for the Kashechewan First Nation. Due to dike failure, Kashechewan residents have been evacuated twelve times because of actual flooding or flood risks since 2004. It is now time for decisionmakers to embrace the “last resort” option of relocation, as this is perceived as a necessary way forward by and for the Kashechewan First Nation.

5.3.3 Northern Indigenous Communities

Northern Indigenous communities are in transition from a traditional lifestyle to a new condition that incorporates characteristics of Euro-Canadian and Indigenous society (Newton, 1995). These changes have influenced the ability of northern Indigenous communities to cope with flood damages. As demonstrated through isolated northern Indigenous communities, traditional management strategies and coping mechanisms have been eroded by the influence of modern society. There are four stages in the ways in which isolated northern Indigenous communities, their residents and governments cope with flood hazards: 1) perception of risk; 2) emergency preparedness; 3) local response; and 4) recovery. The fourth stage represents a body of literature that may entail social work and community recovery in the aftermath of a flood event.

With regards to perception, local understandings of the dynamics of flooding are based on local identification of important factors from the interaction of geologic, atmospheric, hydrologic, and morphologic processes (Newton, 1995). Awareness of these signs is essential to understanding flooding as an infrequent, though integral, part of life in many northern Indigenous communities. However, there are a number of discrepancies in how these northern Indigenous communities prepare for flooding. There are six factors that influence their preparedness for flooding: 1) warnings; 2) past experience; 3) time since the last flood; 4) actions/opinions of others; 5) weather, water, and ice conditions; and 6) frequency of flooding. The influence of these factors varies among communities, along with personal experience, and responsibilities of individuals. At each operational level – individual, communal, or governmental, there are differences in preparation based on perception of the warnings they may receive. In northern Indigenous communities, flood preparedness at different operational levels is based on the perception of flood warnings to design a response that mitigates the impact of flooding.

Individual, communal or governmental flood response is an extension of preparedness activities that ensures safety and survival (Newton, 1995). For isolated northern Indigenous communities, additional assistance in responding to floods is not readily available and may not arrive when needed. In light of this reality, there is a necessity to coordinate a community-wide first response, which shows a high level of self-sufficiency. As floods intensify, responsibility for survival shifts from individuals to community groups and government agencies. As a result, coping with flood damages is becoming increasingly complex and more dependent on external assistance. The transition from individual actions to mobilization of communities and governments reveals a shift of responsibility. The scope of activities and actors changes in response to the mobilization of communal and governmental responsibilities. There has been a reduction in local resilience and capability to cope with episodes of flooding for these northern Indigenous communities.

Adoption of a non-traditional lifestyle has countered the inherent capabilities of northern Indigenous communities to be resilient and reduce vulnerability to flooding (Newton, 1995). Euro-Canadian norms of community living have been imposed on Indigenous settlements to varying degrees, and this has influenced their ability to cope with episodes of flooding. Furthermore, there is a dependency on external sources for assistance, rather than taking individual and communal responsibility. Isolated northern Indigenous communities will undoubtedly continue to evolve and adapt their flood preparedness and response activities to a range of shifting socio-economic, political and environmental influences.

5.4 Flood-Related Challenges in Indigenous Communities

Flooding poses a threat to Indigenous communities across Canada, bringing severe socio-economic consequences due to community isolation, lack of infrastructure and inadequate supply of resources (McNeill et al., 2017). Between January 2006 and November 2016, 67 First Nations communities in Canada experienced almost 100 flood events, half of which occurred in Manitoba and Ontario. Over 25% of these communities experienced multiple floods, with more than 10% having experienced three or more floods during this time period (McNeill et al., 2017). Approximately half of the Indigenous population reside in remote communities on reserves, in northern territories, or rural areas. These small and isolated communities are more vulnerable to the socioeconomic consequences of flooding partly because of substandard living conditions as a result of inaccessibility to adequate food and water resources. Also, Indigenous communities were disrupted by evacuations due to flood warnings, while damage to property and infrastructure, disruptions to education and medical services and mental health issues served as socio-economic implications of this high flood risk (McNeill et al., 2017). Because of these evacuations, education is interrupted along with access to other important community services.

Indigenous communities usually face a higher flood risk than non-Indigenous peoples**.** Annual flooding creates direct, indirect, and additional damages for Indigenous peoples, including property damage, interrupted livelihoods, loss of cultural practices and sacred sites, deteriorated physical health, and psychological trauma caused by repeated evacuation (McNeill et al., 2017). Many Indigenous communities have been placed on marginal land or in remote areas of residence, which makes them particularly vulnerable to the impacts of flooding. Many Indigenous peoples face numerous challenges within their communities, including extreme poverty, unemployment, and chronic health issues. At the same time, a lack of adequate and reliable infrastructure places Indigenous peoples in more flood risky situations. Many Indigenous communities lack adequate safe housing, piped water or sewage, and road access. Moreover, most Indigenous communities lack the authority, capacity, and resources, including funding, staffing, data, and information to access federal assistance and address flooding. These factors further limit an Indigenous community's resiliency to flood events

As shown in Table 5, flooding in Indigenous communities is influenced by a variety of natural or anthropogenic factors. Anthropogenic factors contribute more to flood risk in Indigenous communities in comparison to natural factors. Flooding might be caused by natural occurrences. However, anthropogenic factors (e.g., inappropriate dam construction project) augment the magnitude and frequency of floods. Moreover, Indigenous communities are one of the most vulnerable populations to flood, due to several unresolved political and social-economic issues (e.g., colonization and unclear jurisdiction).

Table 5: Factors contributing to flood risk in Indigenous communities

Natural Factors	Hydrological conditions	Ice thickness Depth of snowpack River flow rate Water/sea level
	Geographical conditions	Location Population density Elevation
	Climate conditions	Precipitation Temperature Climate change Extreme weather events
Anthropogenic Factors	Management level	Community drainage design Flooding infrastructure Infrastructure maintenance Non-Indigenous construction project Land drainage Wastewater management
	Technological support	Data availability Level of sophistication of tools Use of flood forecasting
	Socioeconomic status	Available funds for Indigenous community Average income Colonization history Education rate Self-government/ determination Social isolation Social support mobilization Willingness to participate in water project

Sources: (McNeill et al., 2017; Marshall et al., 2018)

A significant proportion of Indigenous peoples have gone for years and years without safe drinking water**.** Many Indigenous communities experienced health status and water quality below that of non-Indigenous peoples (Bradford et al., 2016). For decades, Indigenous peoples have sought to have a voice in the safety of drinking water. Water quality continues to be considered as a serious health concern in many Indigenous communities. Thousands of Indigenous peoples have difficulty accessing clean drinking water and sanitation in Canada (Marshall et al., 2018). The lack of safe drinking water can be caused by a lack of infrastructure, resources, technical expertise as well as pollution from industry.

As a result of colonization, First Nations communities in Canada are disproportionately affected by undrinkable water and inadequate access to sanitation services. There are 61 active drinking water advisories remaining in effect throughout Canada (ISC, 2020c). Water resources management in First Nation communities has been conducted by state-led authorities (Baijius & Patrick, 2019). There has been limited engagement of First Nations in water management and governance decision-making. Local knowledge holders, and Indigenous perspectives on relations with the land, have always been ignored. This has resulted in the perpetuation of substandard housing, poor drinking water and sanitation services and crumbling infrastructure that is too expensive for Indigenous communities to maintain. In the absence of community control, substandard infrastructure is maintained, and inappropriate land use practices continue regardless of the health and socio-ecological implications of these colonial practices. The colonial and imperialist state-driven system continues to restrict Indigenous governance, disempower and dispossess Indigenous peoples.

Top-down water-related policies or programs lack cultural recognition among Indigenous communities, thus; Indigenous communities are often excluded in these policies/programs. It should be noted that many federal or provincial water protection programs have been designed to involve Indigenous communities. However, a lack of choice and ownership over the planning process has restricted the participation of these Indigenous communities (Marshall et al., 2018). For example, in Ontario, 27 of the 133 First Nations have been included in the provincial source water protection framework. However, only three First Nations have joined this provincial source water protection framework due to a range of logistical, political, jurisdictional, and economic issues (Collins et al., 2017). As for flood mitigation, local ecological conditions and settlement patterns require different solutions than those provided by provincial and federal agencies. Moreover, there is an information gap between the chief and band council, on one hand, and community members, on the other (White, 2012). As a few Indigenous communities have participated in water-related programs, Indigenous peoples played a limited role in these programs.

Data gaps on coping strategies to floods in Indigenous communities exist. More specifically, there are historic gaps with western hydrologic data (Norton-Smith et al., 2016), and Indigenous knowledge systems and adaptation strategies provide a holistic understanding of long-term meteorological changes, streamflow, and flood impacts (Wilson et al., 2015).

Indigenous communities recognize that data and information sharing are challenging because western governance processes remain inequitable and do not respect Indigenous knowledge systems and worldviews (Williams & Hardison, 2013). As sovereign nations, Indigenous peoples have the governance authority to control and manage Indigenous data, and the federal government has a trust responsibility to ensure Indigenous communities have the resources to protect the welfare of their communities. There is, however, a history of distrust between Indigenous peoples and federal, provincial, and local government agencies regarding Indigenous data collection, dissemination, and use.

Indigenous data collection and management is costly, and many Indigenous communities do not have adequate financial resources and capacity to develop and support programs. This can result in Indigenous communities having insufficient data for planning and decision making, and in many cases, they must rely on data from outside entities. The reliance on outsiders may involve compromises over the control of data, and therefore data sovereignty. Emerging from these concessions are important questions regarding from whom data are to be collected, the content of the data, the purposes for which the data are to be used, and who will control access to this data.

Moreover, Indigenous communities are often disadvantaged when preparing for and responding to flood events because they are making decisions based on insufficient and outdated data and information. To support effective response and recovery, flood impact evaluation needs involve data analysis from multiple sources to further understand flood risk to Indigenous peoples and prioritize mitigation measures. Governments have access to geospatial, social, economic, health and administrative data that could be incorporated to better assess and visualize affected areas. Indigenous communities also have a wealth of traditional knowledge that needs to be integrated as an important source of information for flood management. As a result of improved data governance, Indigenous communities will have a more reliable foundation on which to make informed decisions about their flood-related goals and objectives.

Literature lacks Indigenous-inclusive studies that emphasize flood assessment. There is a lack of peer-reviewed studies about Indigenous communities' flood defense, essential infrastructure resources, and emergency services, which considerably restricts a comprehensive flood risk assessment and mitigation for Indigenous peoples (Thistlethwaite et al., 2020). Also, there is very little in-depth research that integrates Indigenous perspectives into flood impact assessments. Access to grey literature is variable, and their quality is hard to assess. Many studies reported that factors constraining water-related programs/policies tend to be institutional and jurisdictional rather than technical or scientific (de Loë & Kreutzwiser 2005; Patrick, 2011). Case studies analyzed the challenges of water-related programs involving Indigenous peoples, but few provide clear solutions (Marshall et al., 2018). Several studies also indicated that the participation of Indigenous communities in federal and provincial water-related programs has proven to be difficult (e.g., McGregor, 2012; Collins et al., 2017). Nevertheless, few studies suggested the integration of ecological/economic outcomes, Indigenous knowledge, and governance approaches (Marshall et al., 2018).

A culturally appropriate framework for flood assessment, management, and mitigation in Indigenous communities is lacking. Although many research programs have been designed with the involvement and oversight of Indigenous communities, in numerous instances the whole process is still guided by researchers. Qualitative methods have been widely used to integrate Indigenous knowledge into water-related programs. In-depth or semi-structured interviews and surveys, focus groups, and participant observations are widely used to collect data. Questions were used throughout the interviews to develop discussion. In many cases, researchers can be in a position of power, as it is the researcher who designs the interview questions, analyzes the data, and presents interpretations to the academic community (Wright et al., 2012). Also, there are still challenges to further integrate Indigenous knowledge into scientific knowledge, such as inadequate communication, distrust, and ideology conflicts (Davidson, 2019). Moreover, many of these articles are written by non-Indigenous researchers analyzing Indigenous communities and values — though some are written by Indigenous scholars and integrate their perspectives directly. It means Indigenous perspectives were collected and then explained by non-Indigenous scholars. There is a distinction to be made between research done with an Indigenous context using Western methods, and research done using Indigenous methods that integrate Indigenous perspectives (Louis, 2007). Language bias and extraction of this knowledge is an inherent part of the research and broader academic understanding of Indigenous perspectives.

There are numerous tools and models to manage flood risk and evaluate impacts. Information-based measures, such as flood maps and visualizations, will provide Indigenous communities with additional resources to increase their understanding of the risks and impact of flooding, which ultimately encourages preparedness. The application of economic instruments, such as grants and subsidies, is dependent on the results of the flood impact evaluation and can encourage flood protection. Similarly, the application of regulatory tools, such as codes and standards, emerge from the results of flood impact evaluation, which increases the quality and durability of new or retrofitted structural defences. Because Indigenous communities are geographically and culturally unique, meaningful engagement and deep consultation with Indigenous communities should be a requirement. Indigenous peoples should determine the use of their knowledge and data and be involved in each stage of research programs. This would mobilize traditional knowledge to mitigate flood risk, provide effective impact evaluation and implement long-term solutions.

5.5 Summary

Traditional knowledge has proven to be an effective tool for reducing risk from natural hazard-related disasters in Canada. Anthropogenic factors contribute more to flood risk in Indigenous communities in comparison to natural factors. The common Indigenous approaches for dealing with flood damages include observation of natural phenomena; regular movement or relocation; reliance on community social networks and the sharing of resources and information; collaboration with federal/local governments and non-governmental organizations; integrating traditional knowledge into emergency planning and Internet services technology; Indigenous technologies; and joining water-related projects to address flooding. The common flood-related challenges in Indigenous communities tend to be knowledge, research, institutional, and data gaps. In particular, Indigenous communities usually face a higher flood risk than non-Indigenous peoples, due to several unresolved issues, such as colonial history, jurisdiction, and institutional inequities. A significant proportion of Indigenous peoples have gone for many years without safe drinking water. Top-down water-related programs lack cultural recognition among Indigenous communities, thus; Indigenous communities are often excluded in these programs. Literature lacks Indigenous-inclusive studies that emphasize on flood assessment. Data gaps on coping strategies to floods in Indigenous communities exist. There is a need to design and implement non-Indigenous government programs (e.g., EMAP) to align with Indigenous-based water policies and programs.

Chapter 6. Results

6.1 Overview of Insured Flood Damages and Losses

Figure 4 shows the spatial distribution of the eight CatIQ events. All provinces are covered except for British Columbia. None of the territories are included. Prairie provinces such as Alberta, Saskatchewan, and Manitoba suffered multiple flood events during the period of interest (2013-2017). Flooding also occurred in the population-dense St. Lawrence Lowlands, in addition to the Maritimes.

Table 6 shows the total estimated insured losses for the eight CatIQ events. The 2013 Southern Alberta Flood was by far the costliest event at approximately $1.54 billion. This event accounts for 45% of the total estimate insured costs for all eight events and was almost twice as damaging as the next costliest event, which was the 2013 Toronto Flood at approximately $890 million. The least expensive flood event in the CatIQ dataset are the 2016 Prairies and Northern Ontario flood at $37 million. The total estimated insured cost of these 8 flood events is $3.4 billion, and the average cost is $425 million. According to the CatIQ dataset, no significant flood events occurred in 2015. The only 2017 event is Quebec and Ontario Spring Flooding. Four of the eight events occurred in 2016. However, the costliest year was 2013, which comprises 71% of the total cost of all eight events from 2013 – 2017. Flood events occurred from May to October.

Figure 4: Spatial distribution of eight major flood events in Canada (2013 – 2017)

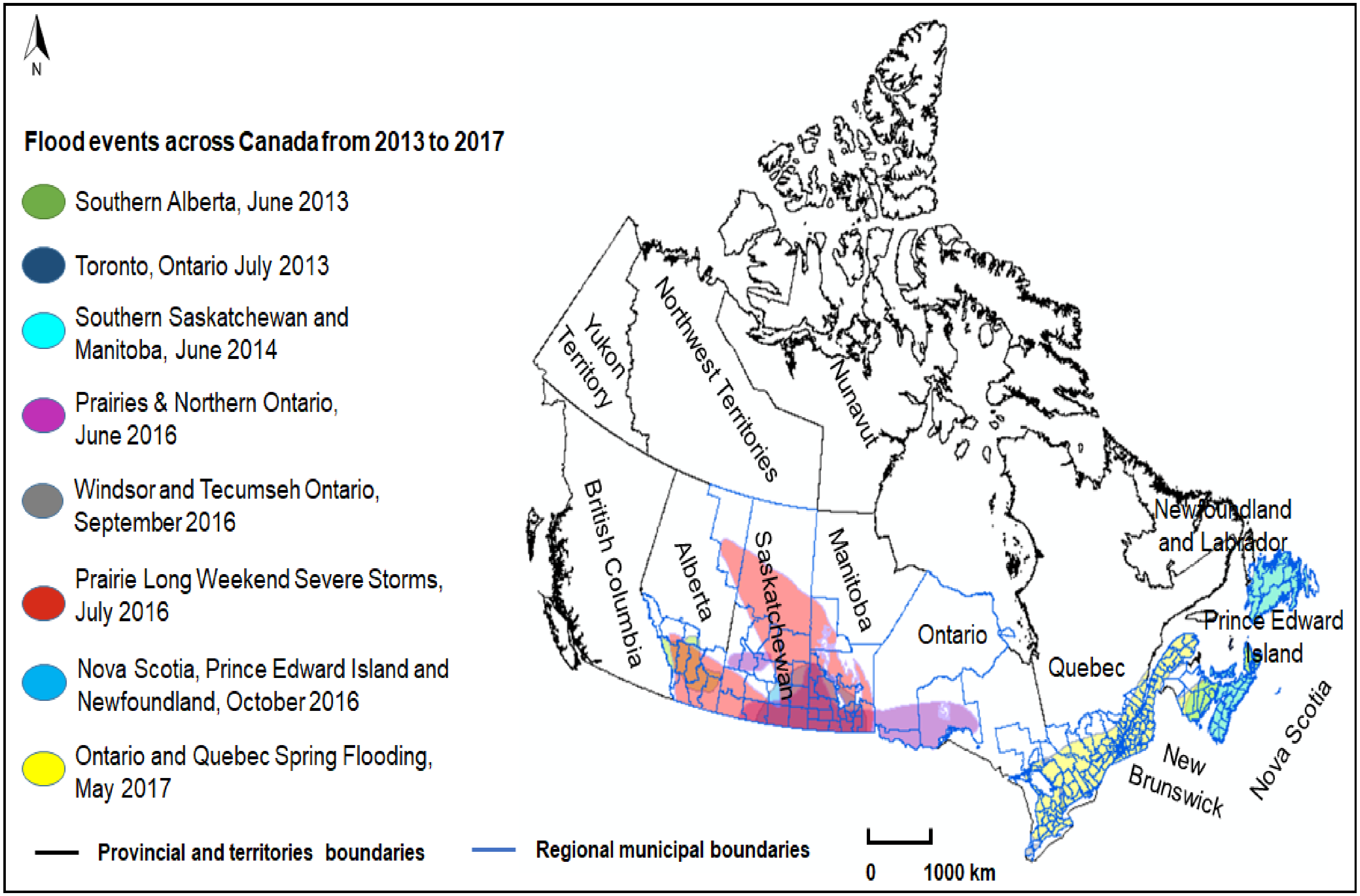


Table 6: Total estimated insured losses (unadjusted for inflation, excluding ALAE) of eight major flood events in Canada (2013 – 2017)

Location	**Month**	**Year**	**Description**	**Total estimated insured losses (CAD) (unadjusted for inflation, excluding ALAE)**
Southern Alberta	June	2013	Persistent rain due to stationary system	1,541,691,000
Toronto, Ontario	July	2013	Thunderstorm/ Flash Flooding	889,695,000
Southern Saskatchewan and Manitoba	June	2014	Persistent rain due to stationary system	120,781,000
Prairies and Northern Ontario	June	2016	Thunderstorm/ Flash Flooding	37,763,000
Windsor and Tecumseh, Ontario	September	2016	Thunderstorm /Flash Flooding	153,461,000
Prairie Long Weekend Severe Storms	July	2016	Persistent rain due to stationary system	443,302,000
Nova Scotia, Prince Edward Island and Newfoundland	October	2016	Hurricane Matthew	104,179,000
Ontario and Quebec Spring Flooding	May	2017	Melting snow and ice	113,866,000
Total				3,404,738,000

As mentioned, the CatIQ dataset contains five categories that align with the CEC Flood-Costing Methodology indicators, and there are eight events listed. For this reason, there are dozens of maps that show the spatial distribution of the cost of each damage indicator for all eight events. It is therefore necessary to zoom in on four specific events to reveal the spatial distribution of insured costs of flooding. In assessing these insured damages and losses, I will present the findings of Ontario and Quebec Spring Flood, May 2017 (section 6.2); Prairies & Northern Ontario Flood, June 2016 (section 6.3);

Toronto Flood, July 2013 (section 6.4); and Windsor & Tecumseh Flood, September 2016 (section 6.4).

6.2 Ontario and Quebec Spring Flood (May 2017)

I choose to report on the findings from this particular event because it spans four provinces (Ontario, Quebec, New Brunswick, and Nova Scotia), hundreds of census subdivisions, and is the most recent event included in the CatIQ dataset.

Figure 5 illustrates the spatial distribution of household item damages caused by Ontario and Quebec Spring Flooding, May 2017. This is described as ‘the cost of the total or partial destruction of furniture, electric appliance, sanitary facility, and other equipment’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘auto damage’ in the CatIQ dataset. The estimated insured losses for this category are highest in population-dense areas such as Québec City, Montreal, Outaouais, Ottawa, and Toronto, where damages are as high as $100,000. Damages in areas with much smaller populations do not exceed $15,000.

Figure 6 depicts the spatial distribution of dwelling damages caused by Ontario and Quebec Spring Flooding, May 2017. This is described as ‘the cost of the total or partial destruction of dwellings or properties’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘personal physical damage’ in the CatIQ dataset. Much like household item damages, census subdivisions with higher populations receive the most damage. In these areas, dwelling damages can be as high as $1.1 million. The dwelling damages in areas with much smaller populations do not exceed $50,000.

Figure 7 shows the spatial distribution of commerce building and facility damages caused by Ontario and Quebec Spring Flooding, May 2017. This is described as ‘the cost of the total or partial destruction of buildings, facilities and furniture’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘commercial physical damage’ in the CatIQ dataset. Commerce building damages are most severe in Québec City, Montreal, Outaouais, and Toronto, where costs can be as high as $4.4 million. The commerce building damages in areas with much smaller populations do not exceed $50 thousand.

Figure 8 shows the spatial distribution of commerce credit losses caused by Ontario and Quebec Spring Flooding, May 2017. This is described as ‘decreased credit scores and bond downgrades for businesses’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘commercial non-physical damage/business interruption’ in the CatIQ dataset. Commerce credit losses are most severe in Montreal, where costs can be as high as $180 thousand. Commerce credit losses in areas with much smaller populations do not exceed $3,000.

Figure 9 displays the spatial distribution of temporary accommodation costs caused by Ontario and Quebec Spring Flooding, May 2017. This is described as ‘the cost of the provision of temporary accommodation for persons whose homes were destroyed or had to be abandoned’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘personal non-physical damage/adjusted living expenses’ in the CatIQ dataset. Temporary accommodation costs are most severe in Montreal and Toronto, where costs can be as high as $52,000. The temporary accommodation costs in areas with much smaller populations do not exceed $1,000.

Table 7 lists the estimated insured losses (unadjusted for inflation, excluding ALAE) caused by Ontario and Quebec Spring Flooding, May 2017. It is clear that the vast majority of flood damages and losses occurred in Ontario and Quebec (99%), while New Brunswick and Nova Scotia were not nearly as affected. Insured flood damages and losses are split somewhat evenly between Ontario and Quebec (48% and 51%, respectively). In both New Brunswick and Nova Scotia, 3 out of the 5 indicators had 0 cost, including temporary accommodation and commerce credit losses. Of the 5 indicators, estimated insured losses for dwelling damage cover the majority of flood damages and losses (75%). For this event, total temporary accommodation costs only amounted to $411,000, which covers a very small fraction of the total cost (0.3%). Estimated insured losses are much higher for direct damages (99%) than indirect effects, and losses and additional costs.

Table 7: Estimated insured losses (unadjusted for inflation, excluding ALAE) caused by Ontario and Quebec Spring Flooding, May 2017

Province	**Dwelling damages (CAD)**	**Temporary accommodation costs (CAD)**	**Commerce building damages (CAD)**	**Commerce credit losses (CAD)**	**Household item damages (CAD)**	**Total by province (CAD)**
Ontario	49,068,000	232,000	4,601,000	174,000	952,000	55,027,000
Québec	35,893,000	179,000	17,278,000	699,000	3,871,000	57,920,000
New Brunswick	875,000	0	0	0	12,000	887,000
Nova Scotia	10,000	0	22,000	0	0	32,000
Total by indicator (CAD)	85,846,000	411,000	21,901,000	873,000	4,835,000	**113,866,000**

Figure 5: Spatial distribution of household item damages caused by Ontario and Quebec Spring Flooding, May 2017

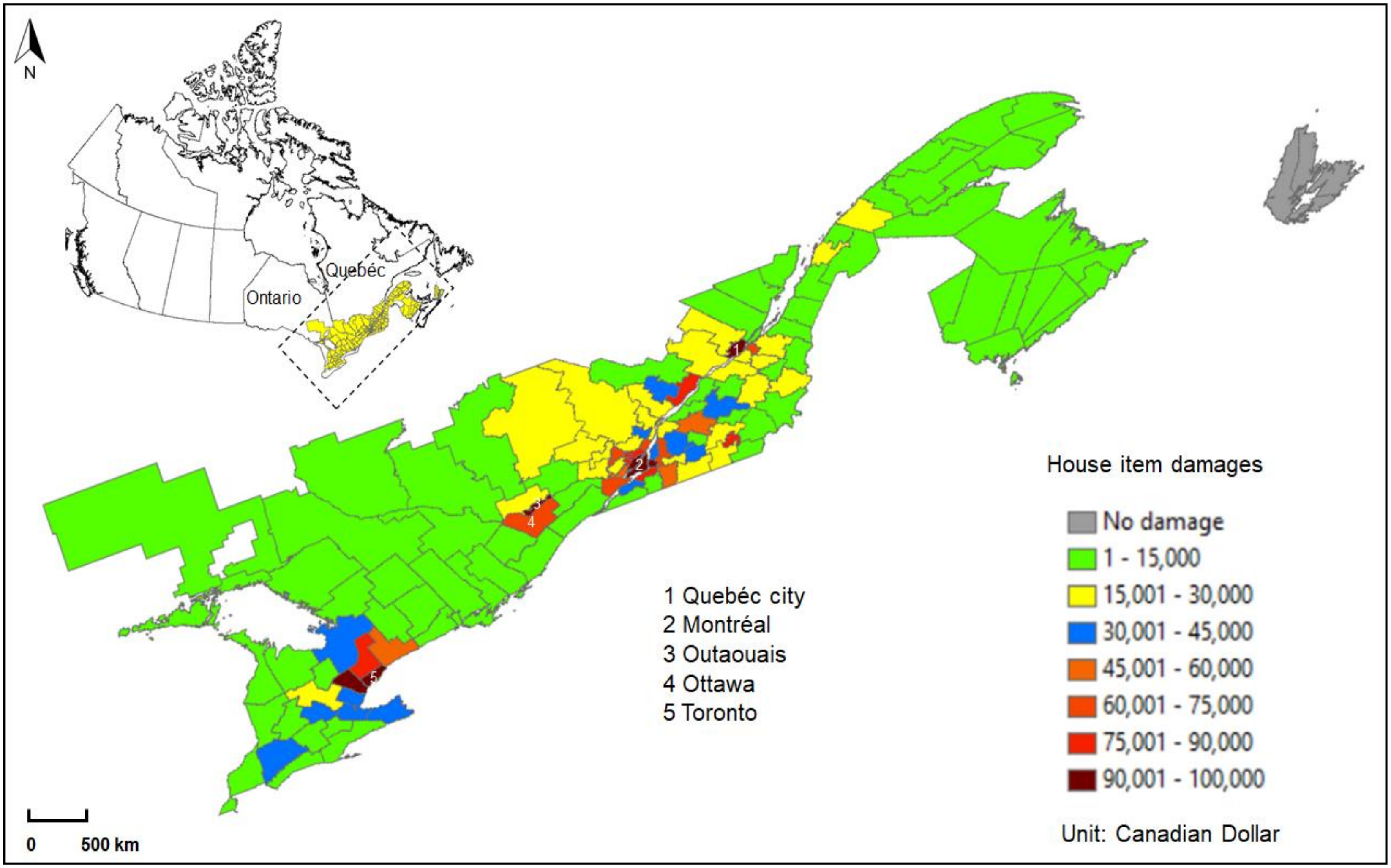


Figure 6: Spatial distribution of dwelling damages caused by Ontario and Quebec Spring Flooding, May 2017

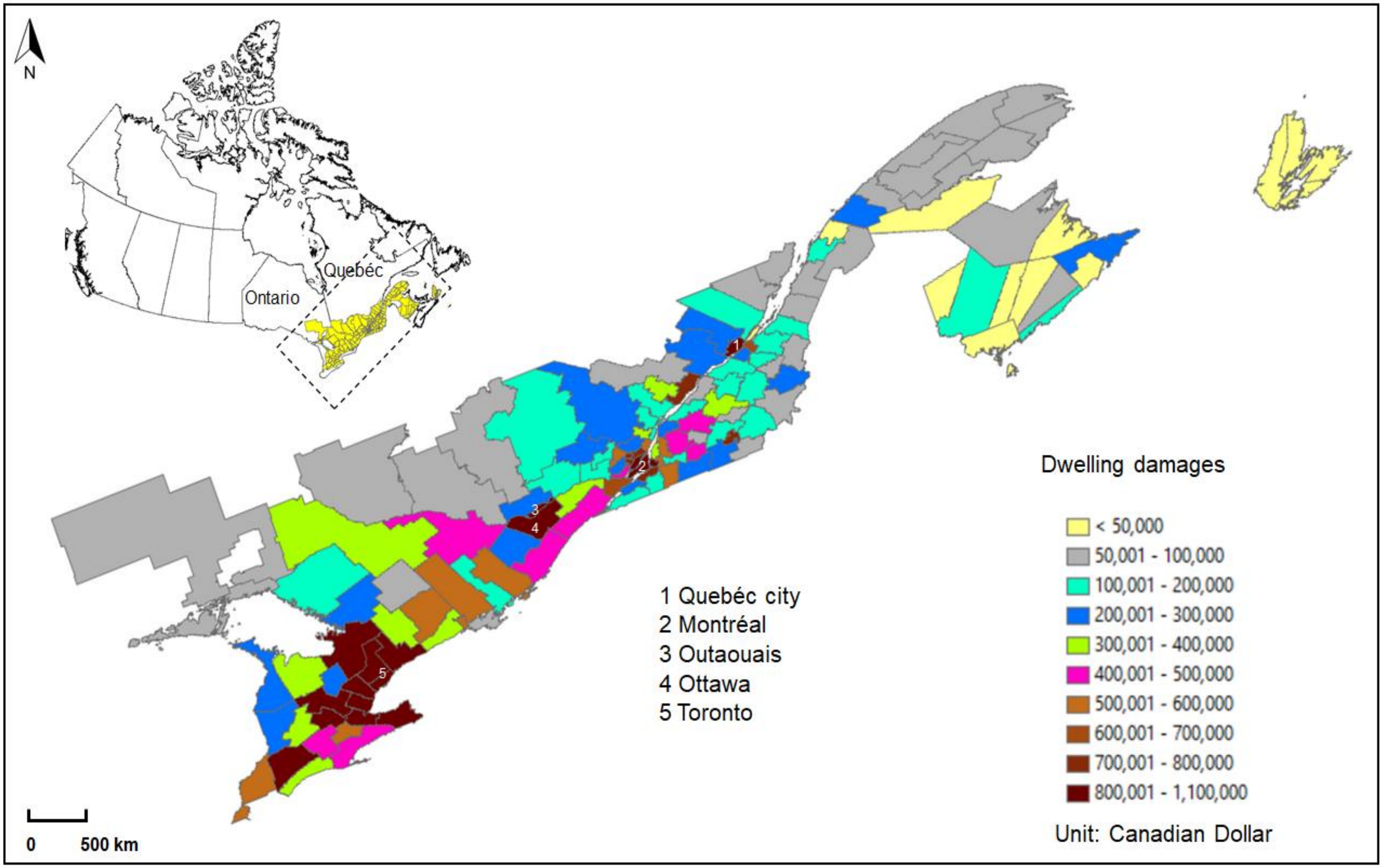


Figure 7: Spatial distribution of commerce building damages caused by Ontario and Quebec Spring Flooding, May 2017

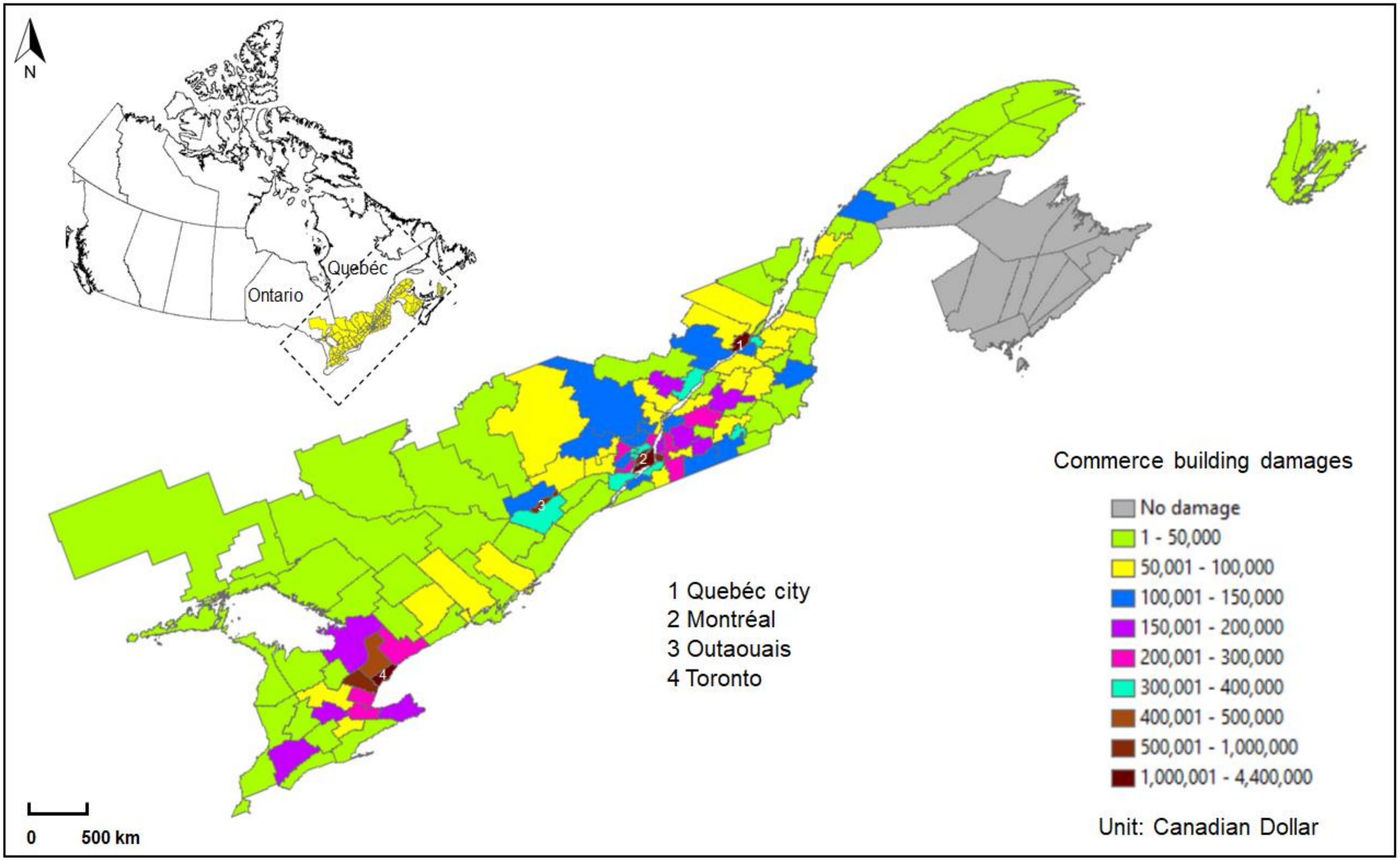


Figure 8: Spatial distribution of commerce credit losses caused by Ontario and Quebec Spring Flooding, May 2017

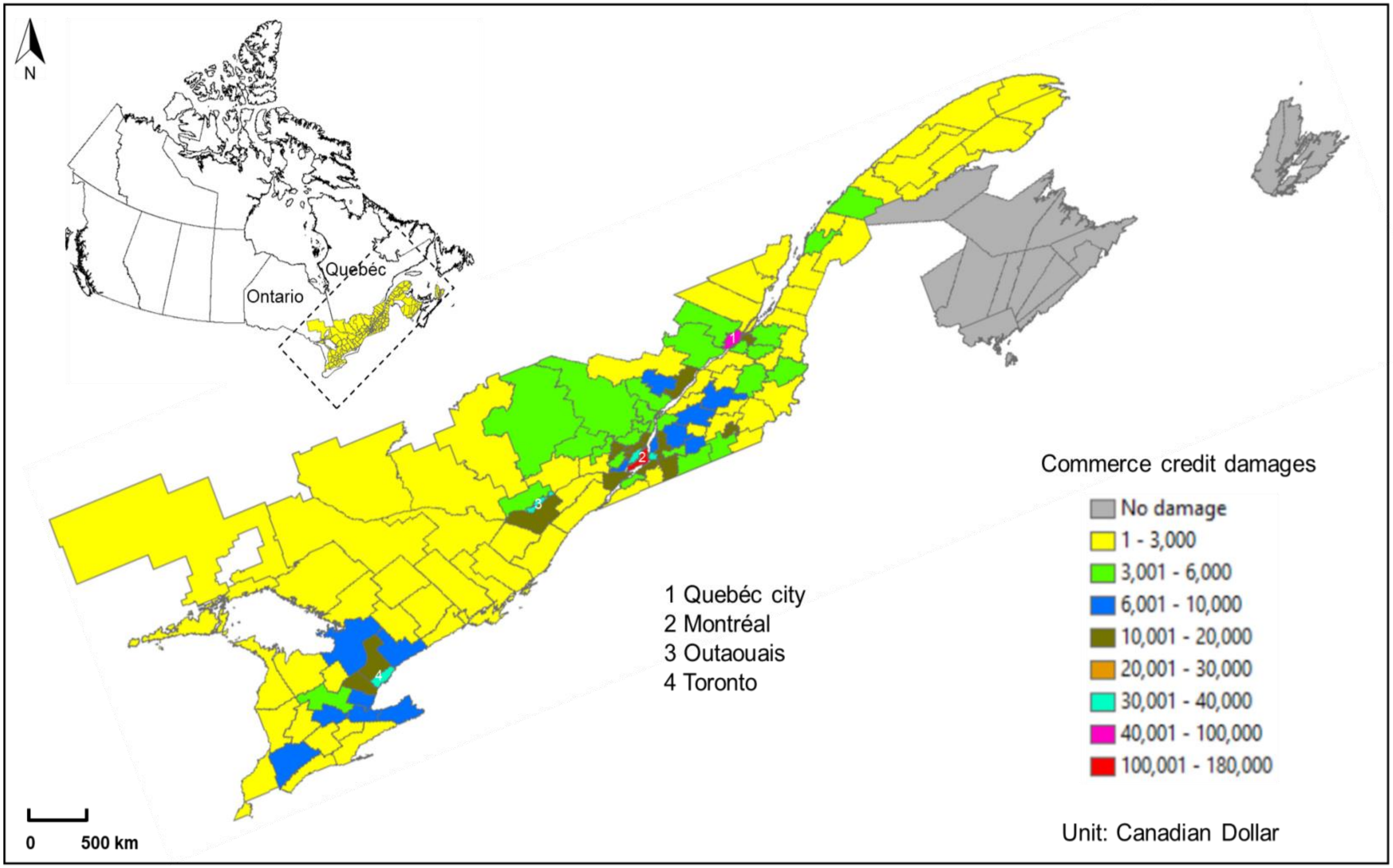
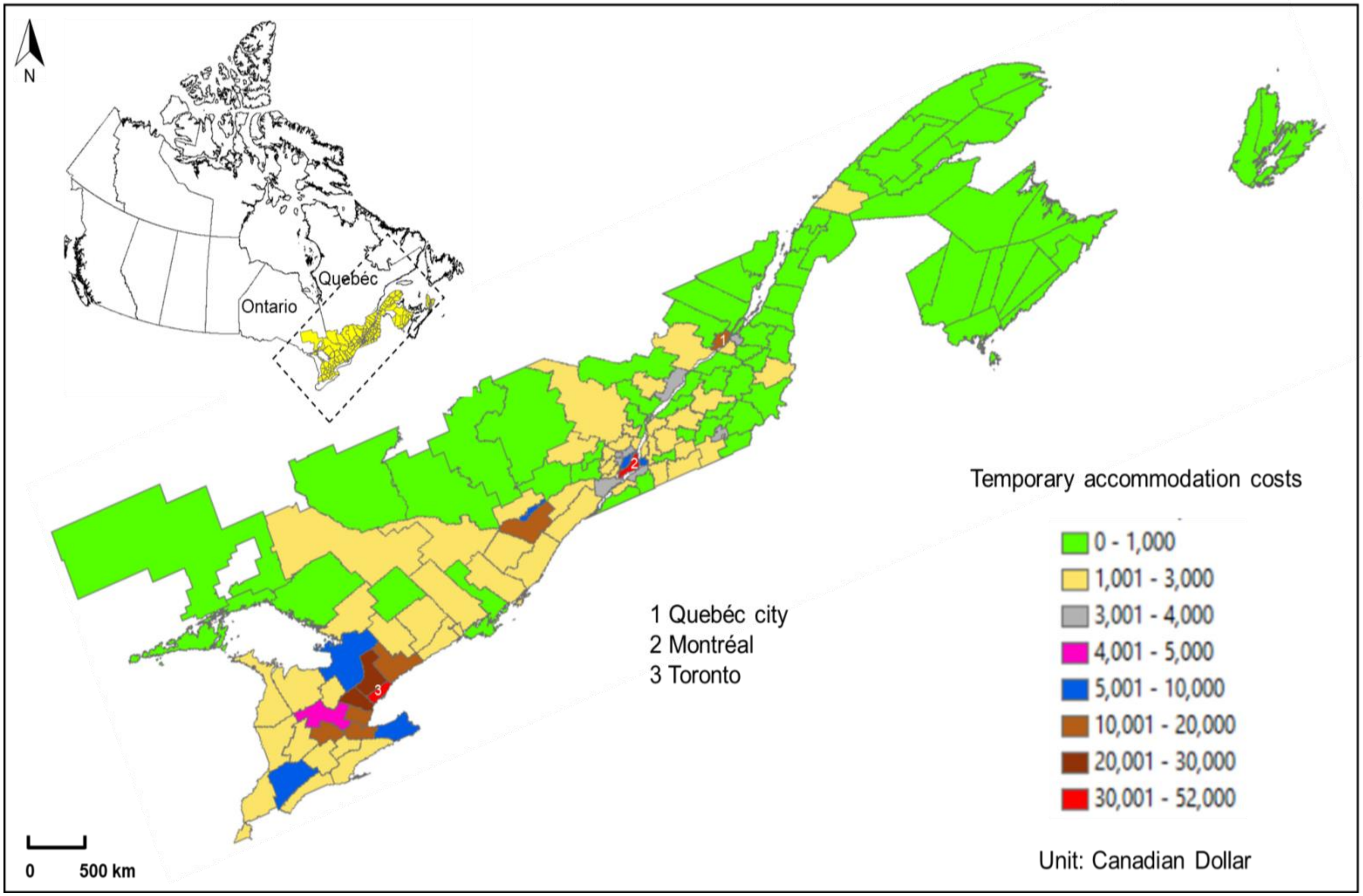


Figure 9: Spatial distribution of temporary accommodation costs caused by Ontario and Quebec Spring Flooding, May 2017



6.3 Prairies and Northern Ontario Flood (June 2016)

I choose to report on the findings from this particular event because it spans three provinces (Ontario, Manitoba, and Saskatchewan), several census subdivisions, and is the least costly event included in the CatIQ dataset.

Figure 10 illustrates the spatial distribution of household item damages caused by the Prairies and Northern Ontario Flood, June 2016. This is described as ‘the cost of the total or partial destruction of furniture, electric appliance, sanitary facility, and other equipment’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘auto damage’ in the CatIQ dataset. The estimated insured losses for this category are highest in population-dense areas such as Winnipeg, where damages are as high as $4.5 million. Damages in areas with much smaller populations, such as Southern Saskatchewan, do not exceed $50,000.

Figure 11 depicts the spatial distribution of dwelling damages caused by the Prairies and Northern Ontario Flood, June 2016. This is described as ‘the cost of the total or partial destruction of dwellings or properties’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘personal physical damage’ in the CatIQ dataset. Much like household item damages, census subdivisions with higher populations receive the most damage, such as Winnipeg and Thunder Bay. In these areas, dwelling damages can be as high as $8 million. The dwelling damages in areas with much smaller populations, such as Southern Saskatchewan, do not exceed $50,000.

Figure 12 shows the spatial distribution of commerce building and facility damages caused by the Prairies and Northern Ontario Flood, June 2016. This is described as ‘the cost of the total or partial destruction of buildings, facilities and furniture’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘commercial physical damage’ in the CatIQ dataset. Commerce building damages are most severe in Thunder Bay, where costs can be as high as $1 million. Winnipeg, Kenora and Rainy River subdivisions all received between $100,000 and $500,000 worth of commerce building damage. The commerce building damages in areas with much smaller populations, such as parts of Saskatchewan and Manitoba, do not exceed $5,000.

Figure 13 shows the spatial distribution of commerce credit losses caused by the Prairies and Northern Ontario Flood, June 2016. This is described as ‘decreased credit scores and bond downgrades for businesses’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘commercial non-physical damage/business interruption’ in the CatIQ dataset. Commerce credit losses are most severe in Thunder Bay, where costs were almost $220,000. Commerce credit losses in Kenora was nearly $100 ,000, and in Rainy River, over $30,000. For this event, there were no commerce credit losses in Saskatchewan and Manitoba, only in Ontario.

Figure 14 displays the spatial distribution of temporary accommodation costs caused by the Prairies and Northern Ontario Flood, June 2016. This is described as ‘the cost of the provision of temporary accommodation for persons whose homes were destroyed or had to be abandoned’ under the CEC Flood-Costing Methodology and E^3ID. This is referred to as ‘personal non-physical damage/adjusted living expenses’ in the CatIQ dataset. Temporary accommodation costs are most severe in Thunder Bay, where costs can be as high as $150,000. The temporary accommodation costs in Manitoba and most of Saskatchewan were under $1,000.

Table 8 lists the estimated insured losses (unadjusted for inflation, excluding ALAE) caused by the Prairies and Northern Ontario Flood, June 2016. It is clear that the vast majority of flood damages and losses occurred in Ontario and Manitoba (87%), while Saskatchewan was not nearly as affected. Insured flood damages and losses are split somewhat evenly between Ontario and Manitoba (39% and 48%, respectively). In Manitoba and Saskatchewan, commerce credit losses had 0 cost. Of the 5 indicators, estimated insured losses for dwelling damage cover the majority of flood damages and losses (65%). For this event, total temporary accommodation costs only amounted to $246,000, which covers a very small fraction of the total cost (0.6%). Estimated insured losses are much higher for direct damages (98%) than indirect effects, and losses and additional costs.

Table 8: Estimated insured losses (unadjusted for inflation, excluding ALAE) caused by the Prairies and Northern Ontario Flood, June 2016

Province	Dwelling damages (CAD)	Temporary accommodation costs (CAD)	Commerce building damages (CAD)	Commerce credit losses (CAD)	Household item damages (CAD)	Total by province (CAD)
Ontario	12,201,000	232,000	1,437,000	348,000	693,000	14,910,000
Manitoba	10,271,000	1,000	563,000	0	7,197,000	18,032,000
Saskatchewan	2,080,000	13,000	147,000	0	2,581,000	4,821,000
Total by indicator (CAD)	24,552,000	246,000	2,147,000	348,000	10,471,000	**37,763,000**

Figure 10: Spatial distribution of household item damages caused by the Prairies and Northern Ontario Flood, June 2016

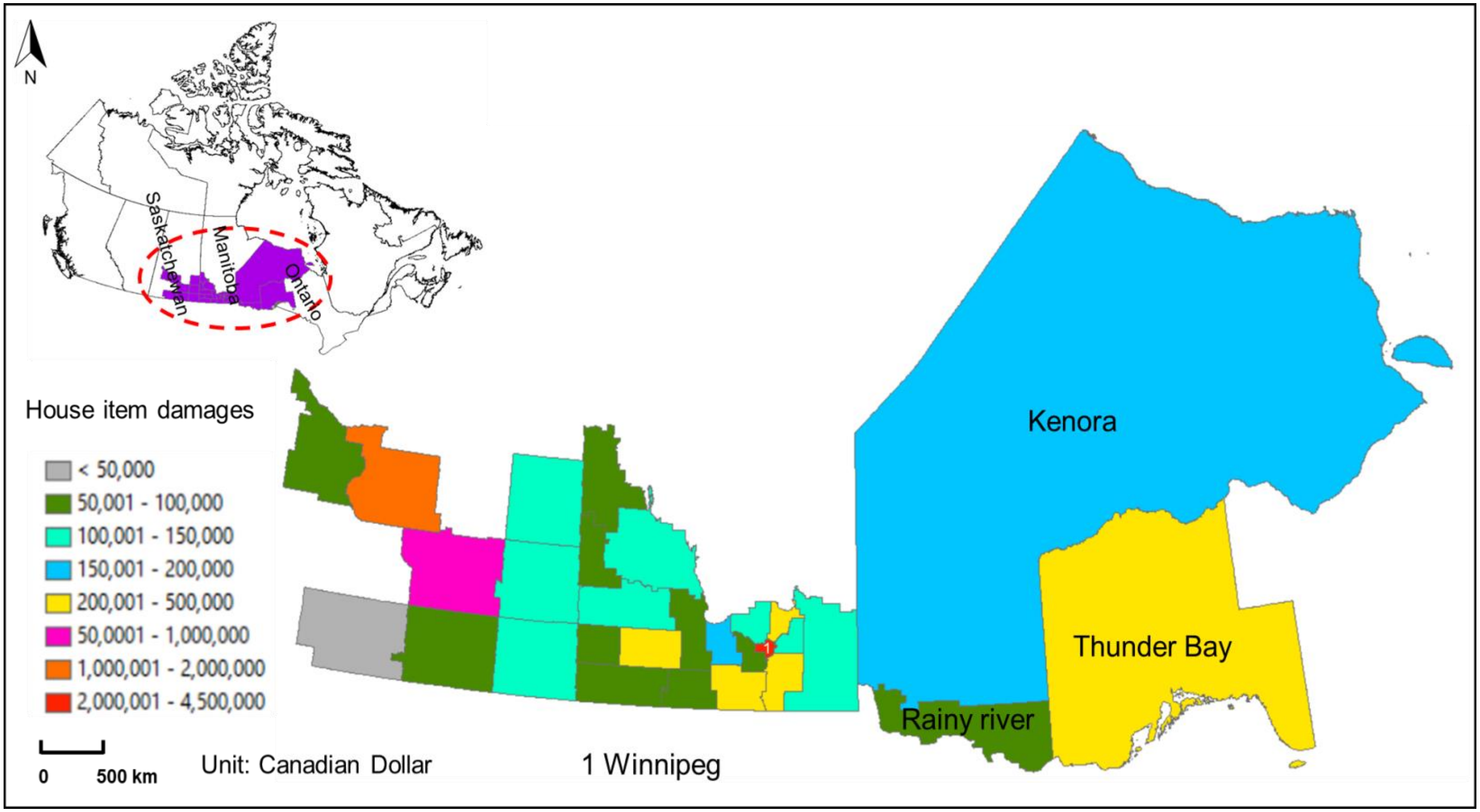


Figure 11: Spatial distribution of dwelling damages caused by the Prairies and Northern Ontario Flood, June 2016

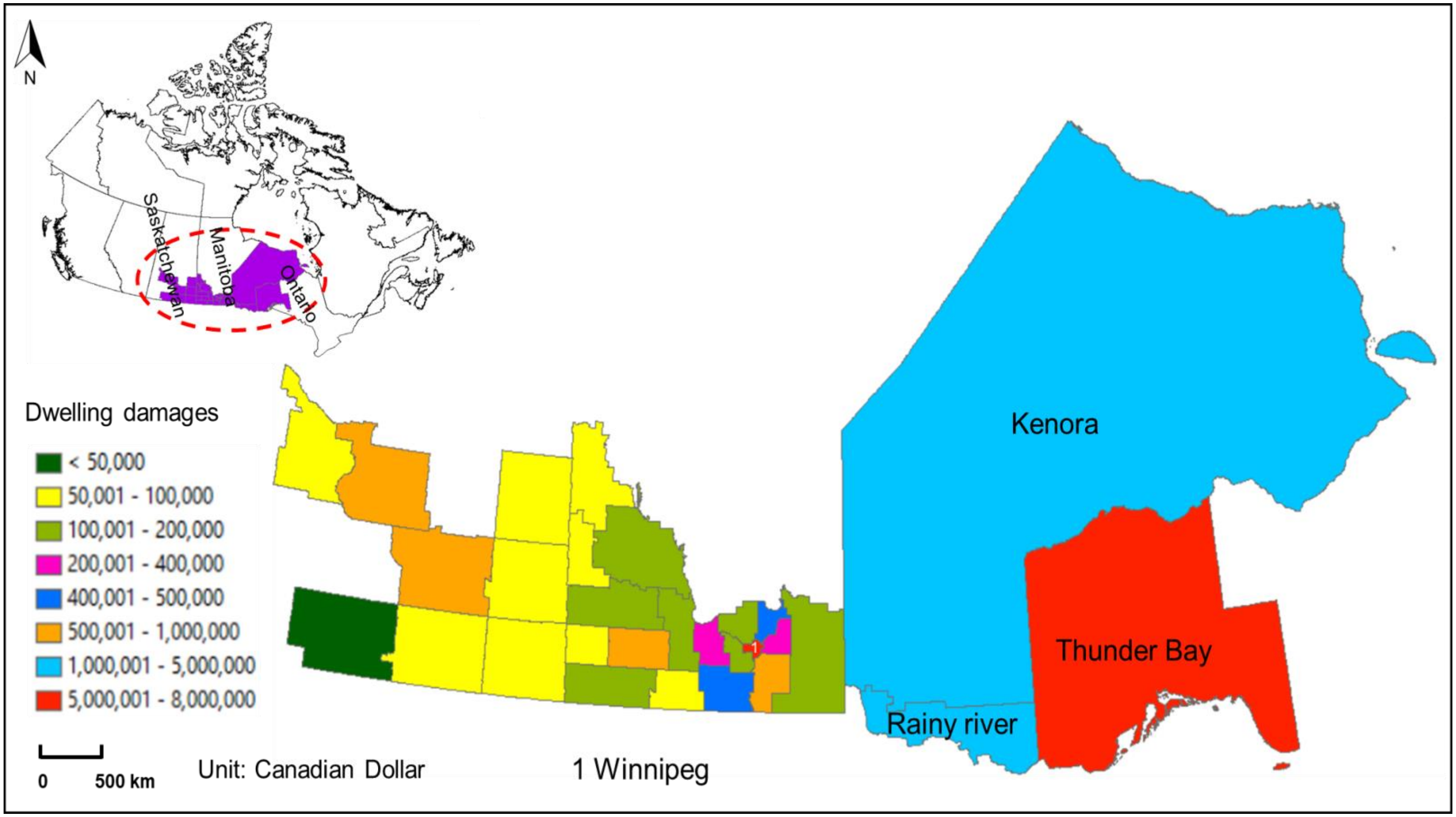


Figure 12: Spatial distribution of commerce building damages caused by the Prairies and Northern Ontario Flood, June 2016

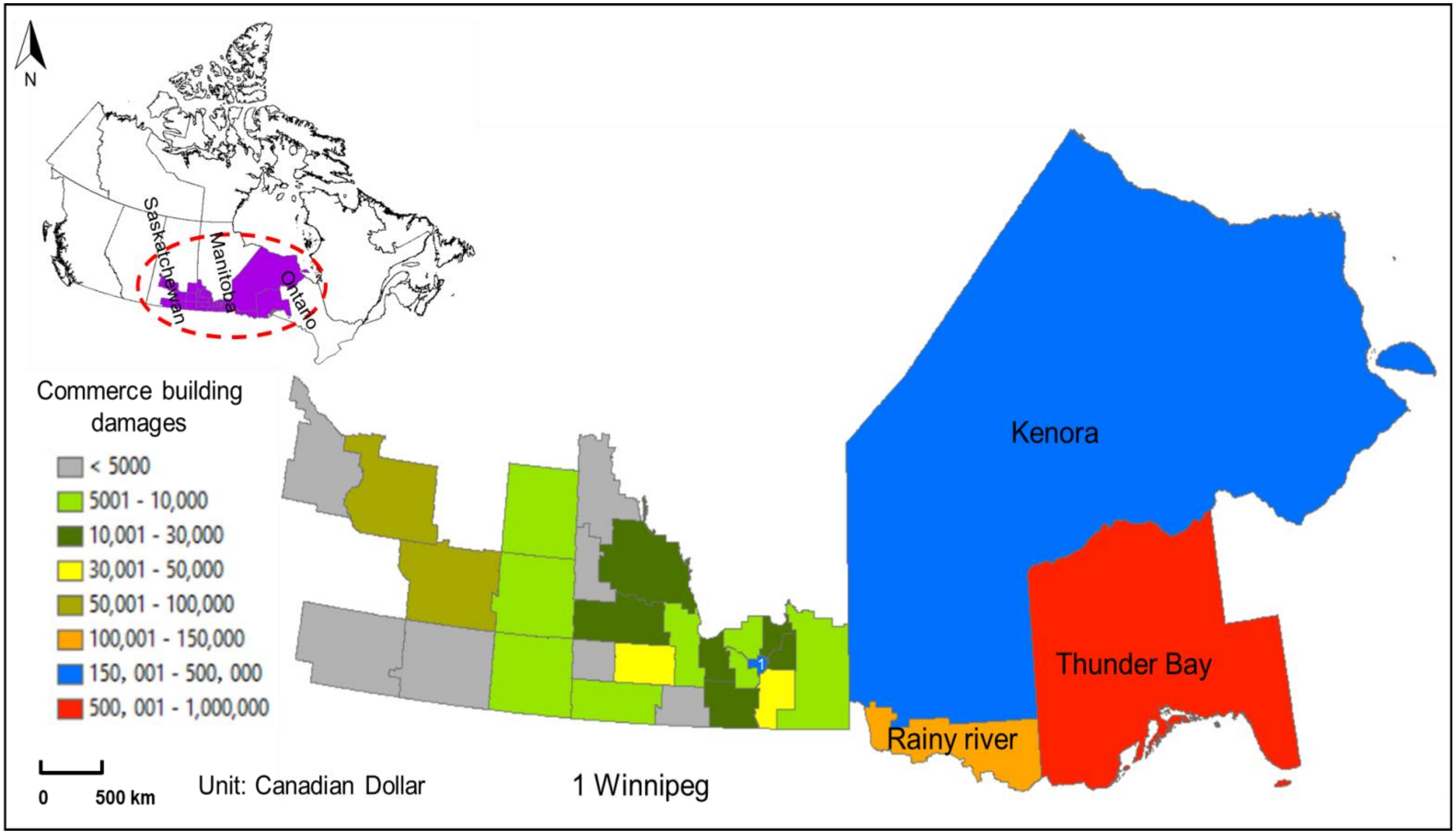


Figure 13: Spatial distribution of commerce credit losses caused by the Prairies and Northern Ontario Flood, June 2016

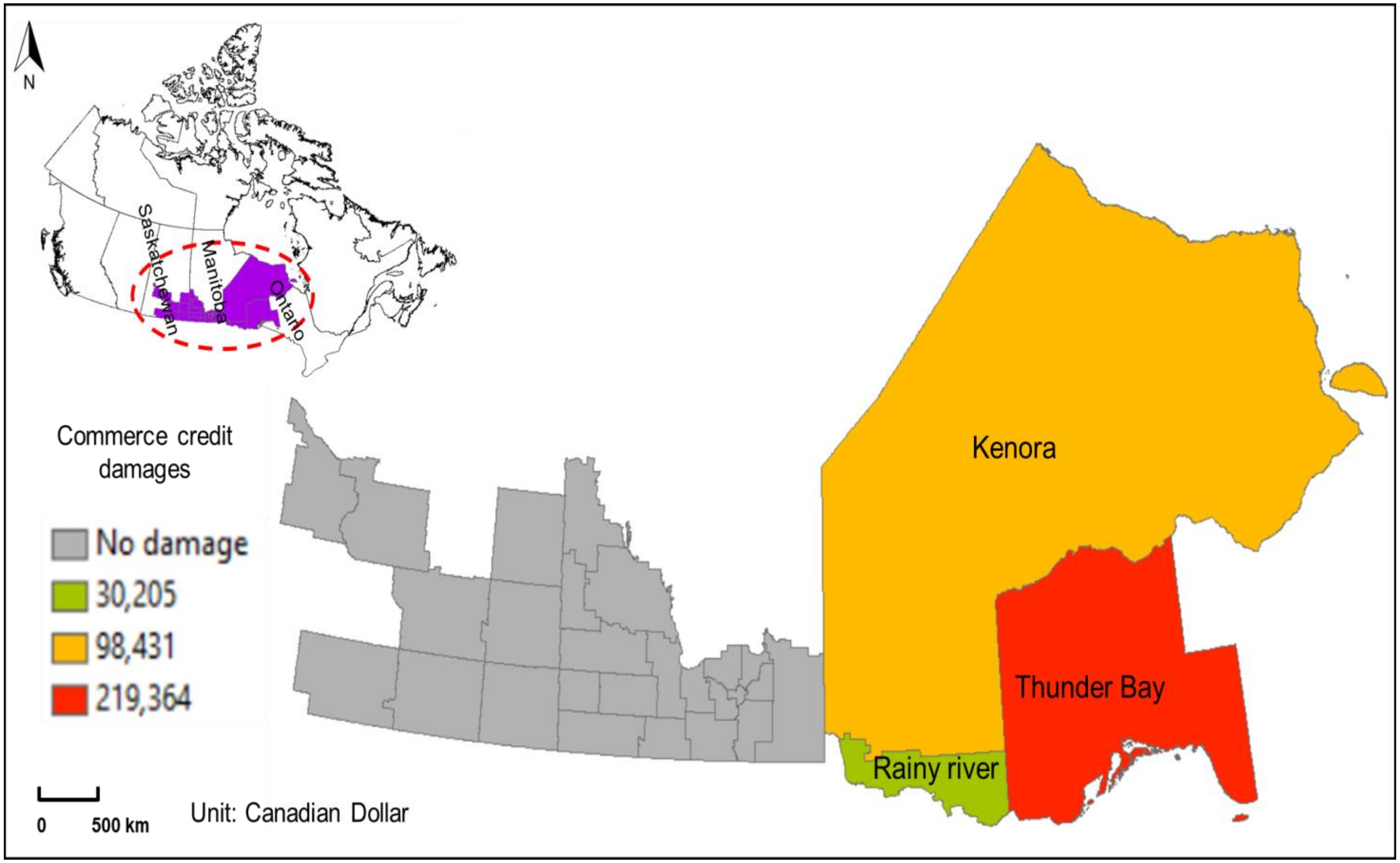
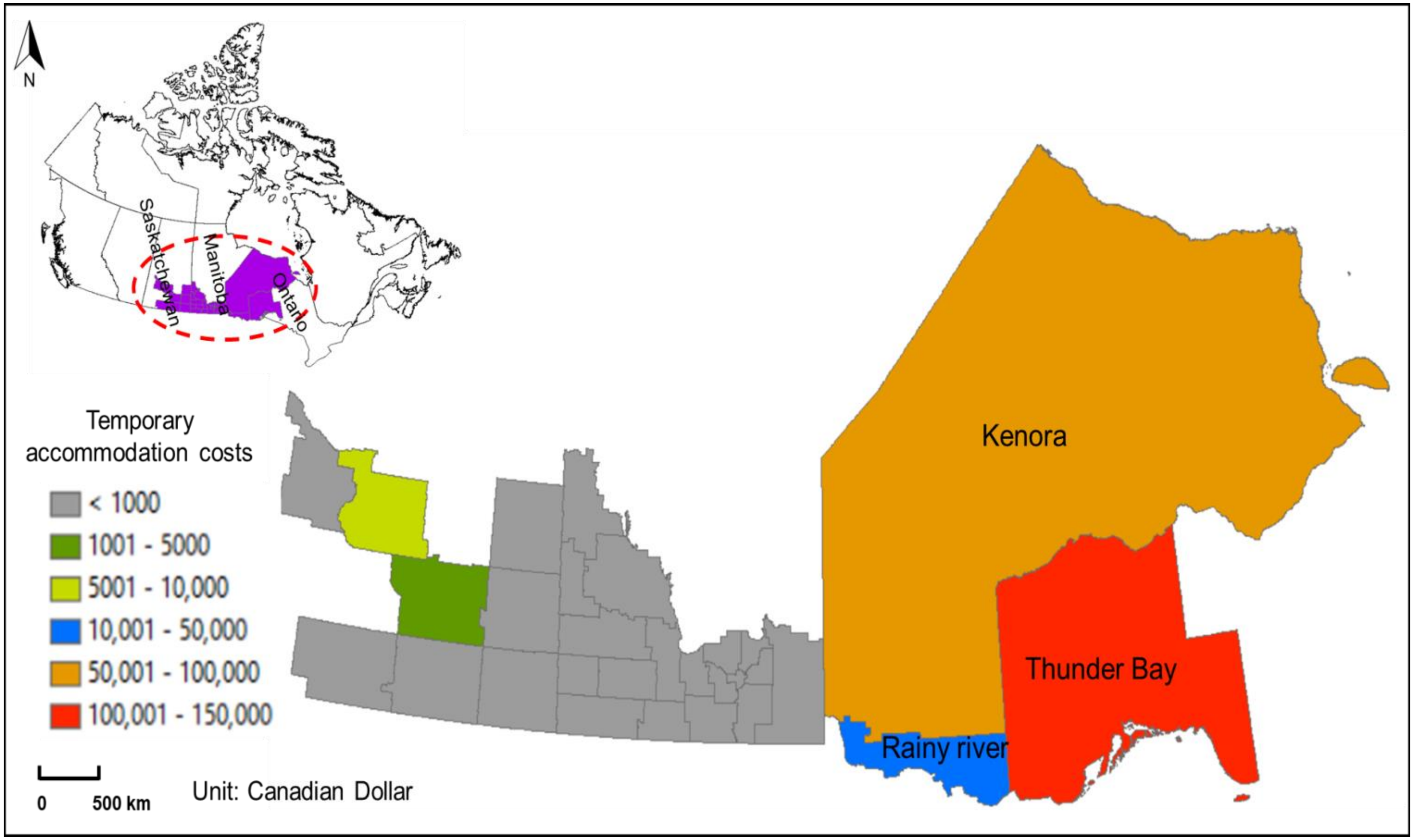


Figure 14: Spatial distribution of temporary accommodation costs caused by the Prairies and Northern Ontario Flood, June 2016



6.4 Toronto Flood (July 2013) and Windsor & Tecumseh Flood (September 2016)

I choose to report on the findings from these two events because they both serve as useful examples of costly and localized pluvial flash flooding in a major metropolitan area.

Figure 15 shows the spatial distribution of the Toronto Flood (July 2013) and Windsor & Tecumseh Flood (September 2016). For the Windsor & Tecumseh Flood, the two affected subdivisions are Essex and Chatham-Kent. For the Toronto Flood, the three affected subdivisions are Peel, Toronto, and York.

Table 9 reveals estimated insured losses caused by the Toronto Flood (July 2013) and Windsor & Tecumseh Flood (September 2016). For the Windsor & Tecumseh Flood, the majority (80%) of damages and losses occurred in Essex. Much like most of the other events in the CatIQ dataset, dwelling damages are the costliest indicator for the Windsor & Tecumseh Flood, comprising 92% of total damages. Temporary accommodations are the least costly, making up a very small fraction of the total cost of flooding.

For the Toronto Flood, the spread of damages and losses between the three affected subdivisions is relatively more even. 52% of estimated insured damages and losses occurred in Toronto, 26% in Peel, and 22% in York. 73% of all damages and losses are attributed to dwelling damage, and 20% are attributed to commerce building damage.

Figure 15: Spatial distribution of the Toronto Flood (July 2013) and Windsor & Tecumseh Flood (September 2016)

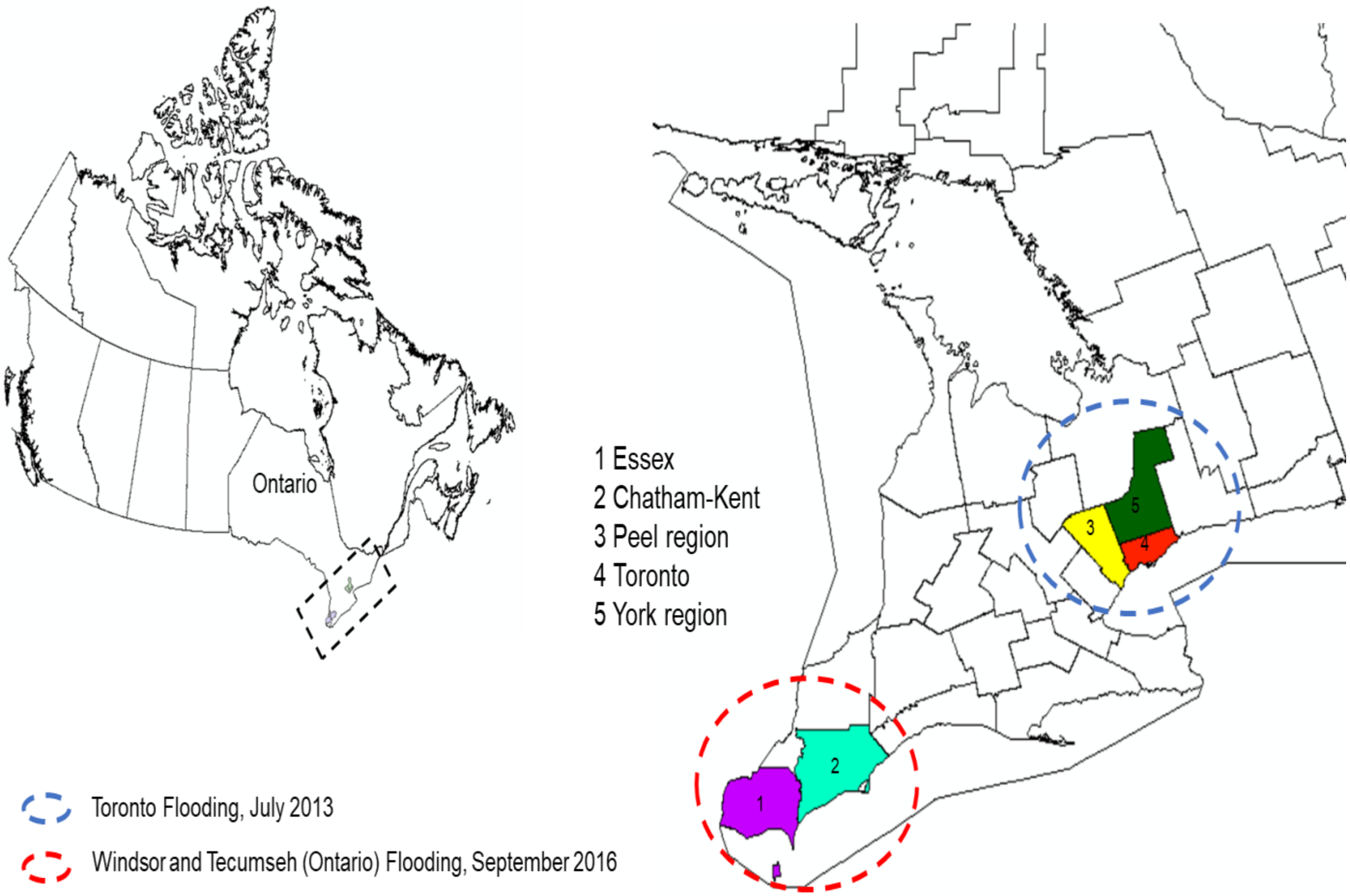


Table 9: Estimated insured losses (unadjusted for inflation, excluding ALAE) caused by the Toronto Flood (July 2013) and Windsor & Tecumseh Flood (September 2016)

Flood event	Affected area	Household item damage (CAD)	Dwelling damage (CAD)	Commerce building damage (CAD)	Commerce credit losses (CAD)	Temporary accommodation cost (CAD)	Total by affected area (CAD)
Windsor & Tecumseh Flood (September 2016)	Chatham-Kent	365,807	28,687,938	1,109,030	1,087,440	6,721	31,256,936
	Essex	1,430,193	112,161,062	4,335,970	4,251,560	26,279	122,205,064
Total by indicator (CAD)		1,796,000	140,849,000	5,445,000	5,339,000	33,000	**$153,462,000**
Toronto Flood (July 2013)	Peel	8,726,838	171,138,250	46,511,305	7,074,800	1,906,789	235,357,982
	Toronto	17,252,157	338,324,589	91,948,575	13,986,229	3,769,546	465,281,096
	York	7,010,004	137,470,161	37,361,120	5,682,972	1,531,665	189,055,922
Total by indicator (CAD)		32,989,000	646,933,000	175,821,000	26,744,000	7,208,000	**$889,695,000**

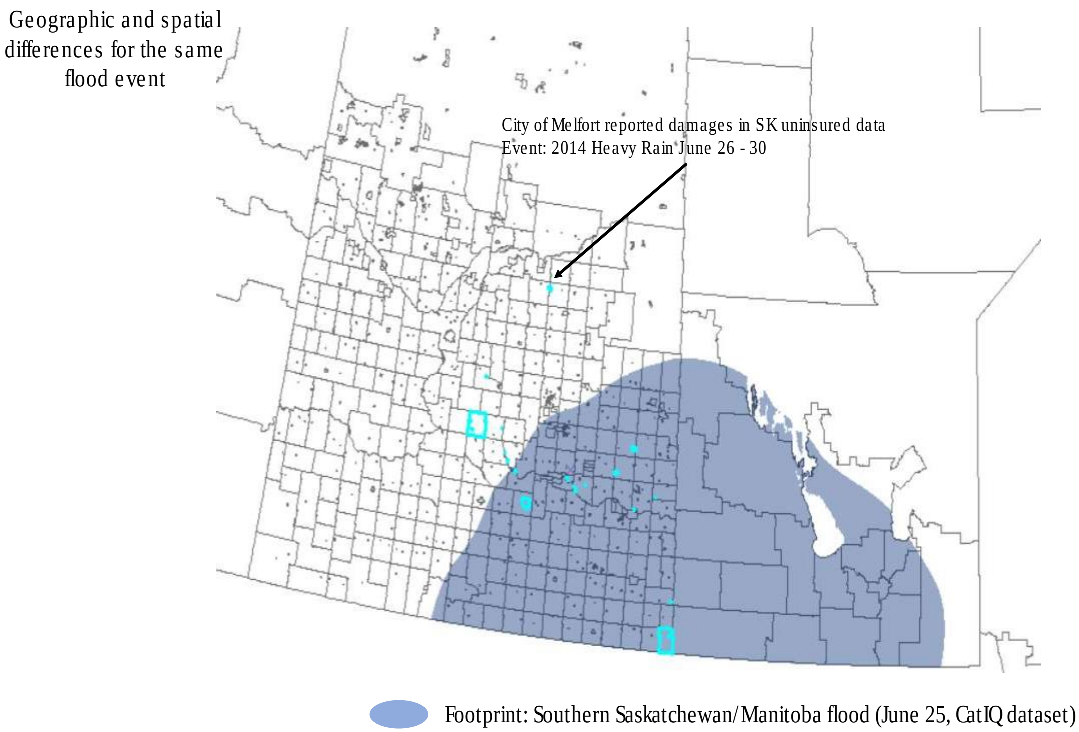
Chapter 7. Discussion & Recommendations

7.1 Challenges in Populating Provincial Data

My attempts to populate the uninsured provincial data from Saskatchewan and New Brunswick increased the unreliability of the results. This is due to differences in scale and coverage between the insured data from CatIQ and uninsured provincial data from Saskatchewan and New Brunswick. For example, there are spatial and temporal discrepancies between the CatIQ footprint, and the affected municipalities reported by the Province of Saskatchewan for the Southern Saskatchewan and Manitoba Flood (June 2014) (see Figure 16).

The Government of Saskatchewan data shows that there are some municipalities (e.g. Melfort) that were affected by flooding, though they fall outside the CatIQ footprint. There are several possible reasons as to why this is the case (L. Twidle, personal communication, February 2, 2021). It is likely that insurance coverage was not widely offered in the locations reported by the Province of Saskatchewan (e.g., Melfort). The insurance industry only began to offer overland flood insurance in 2015. Floods caused by rivers overflowing in 2014 would not have been covered (by insurance). Therefore any, or most, of the financial support for those affected would have come from the government. This may also be a reason for the lack of events in British Columbia. It is also possible that there were not as many claims as the other places included, and CatIQ only highlighted the main hotspots/dates. Moreover, there could be differences due to internal catastrophe dates and/or insurance/reinsurance treaties.

Figure 16: Spatiotemporal differences between insured and uninsured data sources for the Southern Saskatchewan and Manitoba Flood (June 2014)



Given that a number of ad-hoc assumptions were made in populating the CatIQ data, such as downscaling the data from provincial to census level, upscaling the uninsured provincial data from municipal to census level, and blending these two datasets together, adds to the existing limitations and inconsistencies. For this reason, I have inserted only the insured data into our database, based on the CatIQ data inputs. However, the provincial data are presented in raw form in Appendix B (Saskatchewan PDAP dataset) and C (New Brunswick DFA dataset), without trying to process it by upscaling. This helps further demonstrate the inconsistencies in the current set-up. Though not ideal, one should be able to judge the total magnitude of an event by tallying up the insured and uninsured costs.

The total census subdivision population was calculated for the CatIQ dataset. For the PDAP dataset, the population of the affected municipalities needed to be calculated. Likewise, although a growing number of studies have highlighted that population density plays a key component of flood risk calculations and management (e.g., Smith et al., 2019; Calka et al., 2017), flood damage is influenced by various hydrological, hydraulic, and socioeconomic factors. It is difficult to accurately estimate flood damages only depending on a single factor. Given these uncertainties, only CatIQ datasets are added into our database.

In explaining the spatial discrepancies between the provincial and CatIQ datasets, it is important to note that the CatIQ footprints are based on available meteorological, damage and loss information. There are no guarantees regarding the accuracy or completeness of the CatIQ footprints. As such, care was administered when relying on them. There may have been damages in areas outside of the CatIQ footprint, in addition to the circumstance that not every municipality inside the footprint underwent any damages.

In this approach, I acknowledge that despite mutual inconsistencies, there are some uninsured and insured data available for Canada. This approach also demonstrates that the magnitude of impact of these flood events is quite significant and demands policy attention to build resilience against future events. Moreover, it calls for additional investment into research, in order to achieve a deeper understanding the Canadian flood cost data issues.

7.2 Key Information and Data Gaps for the Existing Methods

It is important to note the difference between financial and economic impacts, since flood damages are often assessed through either a financial or economic impact approach (NRCan, 2021). Financial impacts are calculated by aggregating financial losses experienced by individuals or organizations as a result of a flood. At a much larger scale, economic impacts are calculated by aggregating individual financial losses to model losses for an entire region. There are inconsistencies in evaluating both the economic and financial impacts of flooding in Canada.

The costs of direct impacts are generally easier to quantify than indirect costs. Indirect impacts may last for months and even years after a flood event (Merz et al., 2010). Flood impact assessments are performed on different spatial scales, depending on the method used. On a micro-scale, impacts are calculated for each affected object (building, infrastructure, etc.). On a meso-scale, the assessment is based on spatial aggregations such as residential areas or postal code, while macro-scale impact estimation typically involves municipalities, provinces, or countries (Merz et al., 2010). Overall, considerable variability exists in these assessment methods on both micro- and meso-scales in Canada.

The assessment of existing literature points to a number of challenges related to data availability, access, quality, and spatial coverage. The existing flood-costing methods in Canada all seem to have some shortcomings in terms of the inclusiveness and comprehensive coverage of economic impacts across all sectors, as well as expansive assessment of losses over extended periods of time. These shortcomings emphasize the need for a standardized and comprehensive methodology for evaluating economic impacts of flooding.

The ways in which the input data are analyzed and presented, and the level by which assumptions and uncertainties are accounted for speaks to the overall of effectiveness and level of acceptability of the flood-costing method. The PBO, Hazus, and CGE methods all deal with inherent uncertainties, assumptions and limitations. However, some of these assumptions may be a function of data unavailability/inaccessibility, lack of useful input data, or ineffective methods in data collection. In the case studies illustrating the Hazus and CGE methods, we see the use of sensitivity analyses to account for these assumptions and uncertainties. Gaps in data are a common feature throughout each of the methods. The ways in which these gaps are addressed varies, and also serves as a testament to the effectiveness and overall acceptability of the flood-costing methodology. It is clear that among the flood-costing methods, there is an acceptable level of data analysis and presentation. However, the ways in which assumptions, limitations, and uncertainties are dealt with is for the most part ineffective. The overall level of effectiveness for each of the methods is deemed somewhat acceptable.

The PBO's methodology emphasizes the limitations of catastrophe models, such as the over-reliance on the quality and accuracy of input data to generate useful and accurate outputs (Office of the PBO, 2016). Much like the CGE method, due to data unavailability and inaccessibility, numbers were scaled, and imputation procedures of unobtainable values carried out. The main challenges in the PBO's methodology stem from data collection, resulting in consequent issues relation to data manipulation and analysis. Attempts to address gaps in the data used to inform the methodology were carried out to the best of the PBO's abilities, given the practical limitations of what constitutes total economic loss. The data were presented as graphs (mostly pie charts) and tables revealing clear cost estimates, including an estimate of annual cost of DFAA, estimates scaled to include total economic loss, estimates calculated by RMS and IBC, cumulative losses, DFAA liabilities and annual transfers, DFAA payments by catastrophe and by province/territory.

A combination of historical total insurance claims paid and DFAA costs are scaled to reach estimates. Data were inflated using nominal GDP and was useful in ultimately estimating the proportion that DFAA pays and annual average peril total loss. This methodology is only effective at measuring the economic impacts of flooding on a national scale. This approach may be widely accepted by government officials and representatives, but its results are not completely reliable, and overlook many other economic impacts, particularly over longer term, that have occurred as a result of flooding.

The Hazus method and Fredericton case study reveals the limitations and disadvantages of depth-damage functions and the use of pre-programmed assumptions about a local economy (McGrath et al., 2014; McGrath et al., 2015). This is perhaps what has hindered Hazus' effectiveness and level of acceptability as a flood-costing method. Under its default data, it assumes inventory to be evenly distributed across each census block, in order to produce an assessment of damages and losses. This is illustrated and analyzed under depth-damage cures, resulting in quantitative estimates of the damage to buildings and infrastructure. Indirect losses are more difficult for the user to determine, but Hazus is capable of producing estimates for secondary and tertiary impacts. The Fredericton case study emphasized the limitations of depth-damage functions, as there are other factors beyond depth that may contribute to damages, such as velocity and duration, which is considered a more sophisticated analysis (McGrath et al., 2014; McGrath et al., 2015).

Flood loss estimation under the Hazus software relies on a combination of factors that all result in uncertainty. These uncertainties need to be dealt with early in the process, and local, user-derived data can help produce better results. In contrast to how assumptions and uncertainties are dealt with, data presentation under the Hazus methodology is clear and user-friendly. The Hazus flood model takes data on the hazard (e.g. riverine or costal flood), multiplied by the inventory (e.g. demography, general building stock), multiplied by the vulnerability (e.g. depth-damage functions) to calculate the risk (e.g. economic loss, repair and replacement cost, building content loss, crop loss). Hazus presents the results as visual risk maps, summary reports with totals for each building type over the study region, and tabular or graphic outputs for individual buildings, or at the census block level. Assumptions, uncertainties, limitations and gaps in data are not always properly dealt with under the Hazus methodology, despite being capable of carrying out effective data analysis and presentation.

The CGE framework and Vancouver case study reveals a number of significant gaps in the data that were attempted to be addressed through assumptions and imputations (Gertz & Davies, 2015). Some of these assumptions and limitations were accounted for in a sensitivity analysis (namely, the constant growth rate, rate of depreciation and elasticity parameters), but others are inherent to the methodology and are only made for modelling purposes. The Vancouver case study estimates each sector’s capital stock across municipalities from assuming that sectoral capital-employment ratios are constant across municipalities. With regards to modelling flooding, each sector’s capital is exposed at the same rate within a municipality. In reality, the exposure is heterogeneous across sectors due to different distributions of capital across municipalities. Data presentation and analysis was carried out effectively and clearly under the Vancouver case study. Census data are used to estimate distribution of capital stock across municipalities, and to produce bar graphs illustrating capital exposed in percentage and value across various economic sectors. Simulations for each of the variables over time are run and expressed as line graphs. Different damage levels are also applied to the model, and aggregate output losses for different damage scenarios are tabularized.

With regards to the overall effectiveness and level of acceptability of CGE modelling as a flood-costing methodology, we see that it is widely accepted and utilized across the world for development planning and policy analysis. However, the CGE framework for Vancouver emphasizes the limitations and criticisms of CGE models (Gertz & Davies, 2015). It serves as an example of how they may be too flexible. A wide range of costs were accounted for, and this CGE framework makes a strong attempt to accurately simulate and fully capture the real-life economic impacts of a severe flood event for Metro Vancouver. Evidently, this can complicate the procedure and negatively alter the composition of the output data. This framework would have to be applied to a very sophisticated CGE model, as there are many variables that need to be endogenized. The choice to use different damage levels was strong, as well as analysis on the state of the economy decades after the flood occurs.

The state of existing flood-costing methods in Canada is concerning. It is evident that the economic impacts of flooding in Canada are not always well accounted for. None of the methods consider all potential impacts, and it is difficult to address secondary and tertiary impacts. For this reason, the direct damages and additional impacts need to be categorized. Though the majority of sectors are covered, it is clear that additional losses and indirect consequences across many of these sectors are not considered in the flood-costing methods used in Canada. Furthermore, the economic costs of flooding to Canada's vital ecosystems are not of significant concern to the flood-costing methods. Perhaps standardizing the impacts of flooding may lead to the coordinated decision-making and effective mitigation measures that the existing flood-costing methods are not sufficiently informing.

Analysis of the flood-costing methods used in Canada has emphasized the importance of understanding the economic risks associated with flooding. The existing methods for measuring the economic impacts of floods in Canada are not adequate in helping to achieve this understanding. They are driven by similar sources of information that may provide unproductive data, and often neglect many important economic impacts that need to be accounted for. Consistent throughout these methods is a lack of meaningful input data, gaps in the data, and significant challenges in obtaining and manipulating the data. Overcoming these challenges and effectively accounting for impacts, uncertainty and assumptions is difficult for decision-makers and scientists alike. Furthermore, these methods are difficult to interpret and use for a non-specialist audience and may not be fully applicable to every Canadian community. In summary, analysis of the existing flood-costing methods used in Canada demonstrates the need for the commonly-agreed-upon and comprehensive flood-costing methodology introduced in Adeel et al. (2020). In implementing this integrated methodology, we become more resilient to the consequences of climate change such as flooding and improve on the decision-making processes by which we tackle the range of economic impacts.

7.3 Implications of Results

El Niño–Southern Oscillation (ENSO) involves periodic variations in sea surface temperatures over the eastern Pacific Ocean, regulating the climate of much of the tropics and subtropics (Shabbar, 2006). The warming phase is called El Niño and the following cooling phase is known as La Niña, both typically lasting over several months. Across much of North America, ENSO affects the location of the jet stream, which causes changes in precipitation patterns across the West, Midwest, and Southeast. The shift in the jet stream causes shifts in the occurrence of severe weather, such as flooding.

The ENSO phenomenon is a possible explanation as to why 2016 ended up being a flood-prone year and the Canadian Prairies was the most frequently flooded region. 2016 was a La Niña year. During a La Niña year, snowfall tends to exceed the annual average across the Prairies and Western Ontario (Shabbar, 2006). The increased snowpack over much of the Canadian prairies due to La Niña, coupled with a seasonal shift in temperatures, partially explains the high frequency of 2016 events. The October 2016 Nova Scotia, Prince Edward Island and Newfoundland flood was caused by remnants of Hurricane Matthew. During La Niña, the jet stream (and consequently, severe weather) is likely to occur farther north than normal. Due to changes in winds caused by variations in the ENSO cycle, there is greater likelihood of a North Atlantic hurricane hitting the Maritimes during La Niña conditions than during El Niño conditions.

This suggests that increasing the Government of Canada's capacity to respond to floods is especially crucial during La Niña years.

The findings in this report also demonstrate that reliance on existing datasets is not fully sufficient to provide a comprehensive and inclusive picture, considering there are spatial, temporal, and sectoral gaps. The CEC Flood-Costing Methodology is used as a benchmark for the information needed to make a comprehensive and credible assessment of flood-related costs. The findings in this report show that databases on flood-related costs in Canada somewhat align with the CEC Flood-Costing Methodology. Only 5 out of 105 indicators were populated in the E^3ID (dwelling damage, commerce building damage, commerce credit losses, and temporary accommodation costs). Direct damages were more commonly found than indirect effects, and losses and additional costs. Flood cost data on specific economic sectors was left unpopulated in the E^3ID, in addition to other indicators, such as damages and losses to education, cultural resources, physical/psychological health, and the environment. Furthermore, the cost values reported include all damages and losses of the entire event, as they are not separated by peril. For example, the value of $443,302,000 for the Prairies Long Weekend and Severe Storms event (July 2016) encompasses the total cost of the event, which includes damages attributed to flood, wind, and hail across the event footprint. In order to more accurately assess the cost of flooding, these damages need to be separated by peril.

The main research findings also indicate that the CEC Flood-Costing Methodology is both adaptable and flexible, as it is applicable to many types of flooding, on many different scales, and in a variety of settings. There are results on the costs of pluvial flash flooding in major urban areas, spring flooding that spanned four provinces, and prairie flooding. This emphasizes the argument for a standardized, comprehensive, and robust framework for conducting post-flood cost assessments, while also highlighting the importance of flood mitigation measures and nature-based solutions, including increased investment in green infrastructure, in both urban and rural settings.

Furthermore, there are common limitations between application of the CEC Flood-Costing Methodology, CGE models, and Hazus, including their use of census data, and lack of rigidity leading to ad-hoc assumptions that do not conform to any underlying theory. The Hazus flood model produces an area-weighted assessment and assumes homogenous distribution of damages and losses. Similar to this concept, use of the CEC Flood-Costing Methodology performs a population-weighted assessment. Much like the criticisms of CGE models and Hazus, application of the CEC Flood-Costing Methodology in Canada serves as an example of how it may be too flexible, allowing for general inconsistencies in collecting and processing flood cost data, in addition to the inconsistencies in the design of the CEC Flood-Costing Methodology.

A range of methods were invoked, at least initially, to fill the data gaps encountered while populating the E^3ID. For example, obtaining data on payouts and take-up rates from insurance companies proved to be a difficult process, as this information is often proprietary and confidential. Downscaling the CatIQ data from provincial to the census-level through a population-weighted assessment swayed the results. For this reason, estimates in some census subdivisions may be conservative while others could be overvalued. Ensuring comparable quality of data from different sources proved to be challenging as well. In the long run, it can be envisioned that monitoring and data collection in Canada can be modified such that those data become readily available and reliance on model-based methods such as CGE models or Hazus is minimized or eliminated.

Perhaps the most significant challenge in data collection was to tackle the systemic data vacuum on flood damages and losses in Canada. In the long run, this research is meant to address this gap. Throughout the data collection process, obtaining granular data on flood damages and losses at the municipal level proved to be a challenge. Much of the existing flood cost data are aggregated by province and categories are generalized. This challenge was addressed through analytic techniques (population weighting adjustment) and the use of software (ArcGIS) to disaggregate the data. Furthermore, quantifying uninsured losses, in order to comprehensively represent the cost of flooding, was also challenging. For the purposes of this project, the CDD is not a high-quality source of flood cost data. Engagement with the private sector proved to be a productive route. A high level of engagement with CatIQ helped in alleviating data collection challenges, mainly through their function as a reliable source of catastrophe loss information in Canada.

In order to more effectively curate and leverage flood cost data in Canada, the data generated through application of the CEC Flood-Costing Methodology in Canada can also be developed to improve the state of municipal climate change adaptation, if it used in tandem with existing initiatives led by non-profit organizations. For example, with the support of IBC, Canadian Water Network (CWN) and Smart Prosperity Institute (SPI) have generated recommendations on the successful structuring of the Canadian Centre for Climate Information and Analytics, as an authoritative source of climate information and decision analysis (CWN, 2020). As discussed in this report, municipalities, provincial and federal levels of government, and the insurance sector hold key elements of the knowledge base needed to effectively identify and prioritize areas requiring action. CWN generated objectives for improved data and information, knowledge sharing and curation that is useful for municipalities to improve flood risk evaluation. In line with this initiative, the CEC Flood-Costing Methodology and E^3ID could potentially be used as a tool for improved flood cost data curation, to significantly enhance municipal flood risk evaluation, monitoring, trade-offs and infrastructure investments.

As mentioned, existing generic flood preparedness and response plans are not meeting the needs of the diverse Indigenous populations. There is limited knowledge of what an Indigenous flood response plan should include. Public health impacts of floods on the well-being of Indigenous peoples in Canada need closer attention. Data are sparse, especially from remote regions. Data unavailability hinders effective flood mitigation, response and recovery, as many Indigenous communities across Canada are isolated. Agencies do not always share data and use different definitions. There are key observations missing as a result of sparse data. There is no standard protocol for collecting environmental, climate and disaster-impact data. There are many ways of tracking monetary impacts, loss of life and livelihoods in Canada. These gaps are preventing the development of a systematic framework or methodology for evaluating the impacts of flooding on Indigenous communities.

The findings show that the CEC Flood-Costing Methodology has the potential to help capture the impact of floods on Indigenous communities. There is a need for an inclusive, flexible, and adaptable methodology for Indigenous communities that recognizes Indigenous rights and sovereignty and reflects the unique cultures, geographies, socio-political experiences, and damage impacts and losses. However, institutional inequities and data gaps are a primary barrier for many Indigenous communities. The capacity and resources to calculate flood losses and damages in displaced and remote communities is particularly problematic. The establishment of new partnerships and other opportunities for collaboration and knowledge sharing could help address existing inequities and data gaps.

The results highlight the need for engagement in ongoing and meaningful consultation with Indigenous peoples so that methods are consistent with the impacts felt, in addition to developing collective processes on knowledge exchange and consultation as part of the process, to ensure this is carried out in a non-extractive manner. Spirituality is a factor that needs to be captured, though including this in assessing flood damages and losses comes with many challenges. There must be emphasis on ensuring the narrative elements of collecting data (e.g., videos from the community, pictures of the event, and descriptive text) are included, not just quantities, in documenting the cost of floods. Much like any methodology, the effectiveness of the CEC Flood-Costing Methodology eventually lies with its utility to various stakeholders, including the insurance industry, businesses, government agencies, academia and Indigenous organizations. Inclusion of representatives and perspectives from these stakeholders, as was the case for the First CEC Expert Workshop and Indigenous Perspectives Workshop, is an effective way of ensuring that the outputs generated from the CEC Flood-Costing Methodology are usable and useful.

7.4 Overcoming Roadblocks to Implementation

Overall, the results indicate that the CEC Flood-Costing Methodology can play an important role in enhancing resilience in at-risk communities and allocation of resources for monitoring. When applied to Canada, this methodology has the potential to enable systematic investments by national government agencies to enhance resilience to extreme floods, reduce the economic impact of future events, and support real-time monitoring and flood response. The CEC Flood-Costing Methodology could enable regional collaboration in applied and targeted research on future impacts of extreme events, operations for mitigating impacts of extreme events, analysis of social disparities in flood costs and relief efforts and coordinated policymaking within Canada. It also could allow tracking of costs over time and space for analysis of trends.

Although there are clear benefits to establishing a shared methodology deployed across Canada, roadblocks to its implementation remain. Political leadership, high-level officials from all levels of government, and multiple agencies must agree to gathering data and metadata accurately and then to further develop the E^3ID into a framework or information warehouse to share those data in a timely fashion. This level of coordination requires planning and allocation of both financial and human resources. To be successful in this endeavor, the E^3ID will need to undergo proper security, data quality checks, easy-to-use interface, etc., and requires further development, testing, and implementation, with appropriate training across multiple agencies and jurisdictions.

In view of increasing levels of threats from flooding, there needs to be a commitment from policymakers at the municipal, provincial and federal levels to collect and share comprehensive data. As discussed, such incremental investment into data gathering and maintaining the E^3ID for its dissemination is critical to ensure that timely, comprehensive, and inclusive data and corresponding pertinent information are available to both policy makers and the at-risk general public. Seeing as how this methodology is shared between Canada, Mexico, and the US, I anticipate that the establishment of any such information warehouse might be subject to tri-national governmental negotiations and intense public scrutiny. Vigorous policy debates, based on findings from applying the CEC Flood-Costing Methodology in Canada, can help draw a contrast between benefits of community-level resilience-building through investments into infrastructure and better preparedness approaches, and the total costs a community accrues due to flooding. Such debates around trade-offs between short-term gains and long-term protection can help set priorities at community- and national-levels.

7.5 Policy Recommendations

Given that there is a need for a comprehensive and standardized flood-costing methodology, and that challenges and ways to overcome them have been identified, in this section I offer the policy transformations that need to occur to improve the federal government’s response to flooding through the inclusion of pertinent economic information. My primary recommendation is for PSC, ISC, and NRCan to fully adopt and implement the CEC Flood-Costing Methodology. However, some challenges to its implementation need to be overcome before PSC, ISC, and NRCan can fully adopt this methodology. Doing so would standardize the process of post-disaster assessments for enhanced flood-cost data gathering and management, formulation of recommendations to enhance local resilience against flood impacts, and allocation of resources and investments to improve the Government of Canada's response to flooding. My recommendations for PSC, ISC, and NRCan are directly linked to some of the ongoing flood-related initiatives outlined in Chapter 3 and can also be extended to cover other types of disasters – both natural and manmade. Further recommendations are presented in Sections 7.5.1, 7.5.2, and 7.5.3.

7.5.1 Public Safety Canada

With regards to allocation of resources and investments, there needs to be increased investments and funding in national flood prevention, preparedness and mitigation programs, including the National Disaster Mitigation Program (NDMP), administered by PSC. Budget 2014 earmarked $200 million from 2015 to 2020, to establish the NDMP as part of the Government of Canada's commitment to build more resilient communities (PSC, 2021). Given the severity of flood costs from 2013 - 2017, to help offset Canada's rising flood costs, funding from 2020 to 2025 should increase. Other programs that would require increased funding include the FDRP. There also needs to be improved technologies and resources for flood prevention, in addition to increased investments in public education and outreach initiatives for flood preparedness, response and recovery, including FloodSmart Canada.

Given the severity of insured losses due to personal damages highlighted in the results, I also suggest that PSC's Interdisciplinary Task Force on Flood Insurance and Relocation creates a low-cost national flood insurance program to protect homeowners at high risk of flooding and without adequate insurance protection (PSC, 2020b). A national action plan to assist homeowners with potential relocation for those at the highest risk of repeat flooding needs to also be developed. Much like the conclusions of Davies (2020), I recommend that flood insurance should be a mandatory component of home insurance in all flood-vulnerable areas. For very high-risk areas, such as floodplains, flood insurance should be subsidized at a generous rate, initially. With success of this endeavor, these rates should decrease gradually into the future. The insurance industry and federal government need to work together in determining high-risk areas, whereby insurance premiums would be too expensive to be provided and need to be subsidized, which also highlights the importance of updated flood maps. However, better access to flood insurance for individuals, farmers and small businesses implies decreased national, provincial and local government financial assistance in the long run.

I also recommend that the data generated from the CEC Flood-Costing Methodology and E^3ID are used to inform PSC's CDD as a source of disaster loss information. For flood events from 2013 – 2017, the CDD revealed that 10 out of the 22 events are "unknowns," meaning they do not include a cost estimate. Given that insured losses have been obtained from CatIQ, those gaps can now be filled in for the Prairies and Northern Ontario event, and Windsor & Tecumseh event, if given access to the CDD. I assert that the CDD needs to be updated to include missing data, some of which has already been generated by the CEC Flood-Costing Methodology.

Political and ethical considerations regarding confidentiality of data can be facilitated through blockchain technology. Blockchain technology is a data storage structure that consists of a network connected through nodes (Investopedia, 2020). In this case, these nodes would be owned by public agencies, rather than being open to the public. In the current information era, blockchain is an emerging technology with many advantages. It is highly secure, as it employs a digital signature feature, which makes it impossible to corrupt or alter data by other users. Blockchain also functions as a decentralized system that is designed to be undertaken by mutual agreement among its users, resulting in smooth, safe and fast communication. As mentioned, the CDD does not employ a standardized methodology in collecting disaster-related information and is open-access. Standardizing the CEC Flood-Costing Methodology and securing it through Blockchain technology could help in addressing these limitations.

7.5.2 Indigenous Services Canada

In validating the CEC Flood-Costing Methodology through integration of Indigenous perspectives, there needs to be recognition that the desire for one universal method is connected to western science paradigms to generalize theories and does not reflect Indigenous worldviews. Capacity building to encourage Indigenous control of data collection and dissemination also needs to occur. For example, ISC should organize a meeting to invite community members and Indigenous organizations to participate in a flood policy discussion. There needs to be improved dialogue with community leaders in order to incorporate their perspectives to guide policy making and respond to floods, in addition to consideration of not only traditional academic work, but also videos and other media in tandem.

Due to substandard infrastructure in many flood-devastated Indigenous communities, ISC should directly engage Indigenous communities and organizations to develop a national policy for disaster recovery funding, to also improve resilience of Indigenous communities, rather than return them to their pre-disaster state. ISC should directly engage Indigenous communities to establish an expansive network of on-reserve evacuation centres that function as culturally appropriate sites for evacuated Indigenous communities to provide support to its members. This could reduce the cost and detrimental socio-economic impacts of federal government-led flood evacuations.

ISC plays a unique role in responding to floods for Indigenous communities. However, their initiatives could be better coordinated with the work already being undertaken by other federal government agencies. As mentioned, NRCan's EGS team provides critical, near real-time information to the GOC, which is maintained by PSC. This federal inter-agency coordination is crucial in ensuring that floods can be responded to quickly and effectively. There is an opportunity for ISC to play a key role in ensuring that real-time flood loss information generated through Indigenous stakeholders are communicated to the GOC. Although ISC already reports flood hazard events to PSC via coordinated situational awareness reports, there is an opportunity for these situational awareness reports to capture flood loss information, which can then be communicated to the GOC. This is of particular importance for remote and/or displaced Indigenous communities, where delivering timely flood response activities can be difficult.

7.5.3 Natural Resources Canada

In terms of building resilience, NRCan should build capacity for households, businesses, and local governments to prepare for, respond to and recover from floods through the development and implementation of a national strategy for post-flood resilience-building.

This would imply increased investments in disaster risk reduction for resilience through strategic allocation of resources for monitoring and preparedness, and to ensure disaster risk reduction initiatives are in place across stakeholders.

As mentioned, NRCan also has developed the Federal Flood Mapping Guidelines Series to standardize flood mapping activities across Canada, in order to improve the accuracy of flood maps to support planning and flood response. In line with this initiative, the main findings in this report suggest more funding to carry out flood mapping studies that better illustrate the costs of flooding across space and time. As was attempted in this research, data compiled from flood cost data sources such as CatIQ, all levels of government, Indigenous organizations and NGOs can be mapped, to more precisely understand where and when an economic impact occurred.

7.6 Areas of Future Research

There is no clear consensus emerging on the notion of what constitutes an "extreme flood." For example, CatIQ defines a catastrophe as an event that causes $25 million worth of insured damage or more (CatIQ, 2020), which may be different than the threshold or factors employed by certain government agencies. This is part of the reason the eight flood events obtained from CatIQ range from approximately $37 million (2016 CAD) to $1.5 billion (2013 CAD). To contrast, the costliest event in the New Brunswick DFA report is approximately $7.5 million (2014 CAD), and there is even an event below $1 million. Such a definition has important consequences for mobilization of resources and support at national and subnational levels. Extremeness can be defined by the natural environment (e.g., amount of precipitation over a certain time period, flood return period, etc), societal factors (e.g., number of people impacted), economic impacts (e.g., magnitude of damages and losses), or a combination of all of them. Developing a definition for extreme flooding, including identification of hydrological, societal and economic thresholds, will require detailed dialogue with government agencies to achieve a consensus, and further research and examination of published literature as well.

The 2013- 2017 window of time is sufficient in duration to discern some regional and temporal trends about where the flooding is occurring, and when and how worst economic impacts take place. There is, however, an argument for extending this window in time to a ten-year period (say, 2007-2017), particularly to better analyze the temporal trends. Such an extended approach, although beyond the scope of this report, would better evaluate the applicability and robustness of the CEC Flood-Costing Methodology.

It is also recommended that a full cost-benefit and trade-off analysis of the events analyzed in this report is undertaken. This would help government agencies, Indigenous communities, and the private sector determine how to maximize profit while preserving savings; infrastructure and institutional investments; and, allocation and mobilization of resources for data collection, monitoring, preparedness, response, and recovery.

Future research should also seek to better quantify indirect effects, damages and losses to various economic sectors, and broader social impacts, such as health costs. Given that uninsured costs were not processed, there is also a need to establish a mechanism for blending uninsured and insured data, and to address spatiotemporal discrepancies between multiple data sources, using the CEC Flood-Costing Methodology. Doing so would allow for a more complete picture of flood costs.

Flood cost data in isolated communities and Indigenous reserves is scarce. More work needs to be done to engage directly with affected Indigenous communities, such that they are benefitting from the findings and recommendations generated from application of the CEC Flood-Costing Methodology, which is outside the time and financial resources available for this research. Future research should better understand the perspectives of flood-affected Indigenous communities for costing flood damages and losses, such that Table 7 of the CEC Flood-Costing Methodology on community-specific information can be populated. Correct protocols for engaging with Indigenous communities and how to collect information for mutual benefits need to be implemented.

Moreover, the economic impacts of cascading multi-hazards (for example, dry season > forest fires > floods > landslides) are not well documented. Current research is being undertaken to demonstrate how the CEC Flood-Costing Methodology can also inform future methods for determining the economic impacts of other types of extreme events. Such an approach would enable a more realistic analysis of the costs associated with a broader range of extreme events, including hurricanes, tornadoes, forest fires, landslides, etc. Proof-of-concept application of the CEC Flood-Costing Methodology is being developed through a specific case study of a cascading event in Canada.

Chapter 8. Conclusions

Based on the development and application of the CEC Flood-Costing Methodology in Canada, four final conclusions have been reached:

First, though the affected local community is the first line of defense in the wake of a flood, the Government of Canada carries out many diverse and complex roles and responsibilities. Perhaps the most important pieces of legislation that dictate the federal government's ability to respond to flooding are the Indian Act (1876), the Canada Water Act (1970), and the Emergency Management Act (2007). Moreover, federal government agencies such as PSC, ISC and NRCan carry out duties that attempt to quickly and effectively respond to floods. In improving the federal government's response to flooding, there is room to integrate pertinent economic information into existing initiatives, programs, plans, policy and legislation, through adoption and implementation of the CEC Flood-Costing Methodology.

Second, the state of existing flood-costing methods in Canada is concerning. It is evident that the economic impacts of flooding in Canada are not always well accounted for. None of the methods consider all the potential impacts, and it is difficult to address secondary and tertiary impacts. For this reason, the direct damages and additional impacts need to be categorized. Though the majority of sectors are covered, it is clear that additional losses and indirect consequences across many of these sectors are not considered in the flood-costing methods used in Canada. Furthermore, the economic costs of flooding to Canada's vital ecosystems are not of significant concern to the flood-costing methods. Perhaps standardizing the impacts of flooding, as can be done through adoption and implementation of the CEC Flood-Costing Methodology, may lead to the coordinated decision-making and effective mitigation measures that the existing flood-costing methods are not sufficiently informing.

Third, Indigenous perspectives for costing flood damages and losses in Canada need to be integrated into existing flood-costing methods, in addition to federal flood management policy, plans, programs and legislation. Traditional knowledge has proven to be an effective tool for reducing risk from natural hazard-related disasters in Canada.

The common Indigenous approaches for dealing with flood damages include observation of natural phenomena; regular movement or relocation; reliance on community social networks and the sharing of resources and information; collaboration with federal/local governments and non-governmental organizations; integrating traditional knowledge into emergency planning and Internet services technology; Indigenous technologies; and joining water-related projects to address flooding. The common flood-related challenges in Indigenous communities tend to be knowledge, research, institutional, and data gaps. In particular, Indigenous communities usually face a higher flood risk than non-Indigenous peoples, due to several unresolved issues, such as colonial history, jurisdiction, and institutional inequities. Data gaps on coping strategies to floods in Indigenous communities exist. There is a need to design and implement non-Indigenous government programs (e.g., EMAP) to align with Indigenous-based water policies and programs. Although further engagement with affected Indigenous communities is needed, the CEC Flood-Costing Methodology partly functions as a culturally appropriate framework for Indigenous communities to document flood-related damages and losses.

Lastly, PSC, ISC, and NRCan have much to gain from adoption and implementation of the CEC Flood-Costing Methodology. Doing so would address the challenges and impacts felt by Indigenous communities, while improving the current state of existing flood-costing methods and federal government responsibilities. By offering a standardized framework for how post-disaster assessments should be conducted, the CEC Flood-Costing Methodology has the potential to address data gaps and deficiencies with regards to flood costs, leading to enhanced flood-cost data gathering and management, formulation of recommendations to enhance local resilience against flood impacts, and allocation of resources and investments to improve the Government of Canada's response to flooding. The findings in this report demonstrate that although further research is needed, the CEC Flood-Costing Methodology serves as an effective tool that can improve the Government of Canada's response to flooding through the inclusion of pertinent economic information.

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Appendix A. The CEC Flood-Costing Methodology

Category	Direct Damages	Indirect Effects	Losses & Additional Costs
Social Sectors			
Housing	*Household items.* Cost of the total or partial destruction of furniture, electric appliance, sanitary facility, and other equipment.	*House rental.* Rent increases due to the housing shortage.	*Temporary accommodation*. Costs of the provision of temporary accommodation for persons whose homes were destroyed or had to be abandoned.
	Dwelling. Cost of the total or partial destruction of dwellings or properties.		*Relocation*. Cost of migration and permanent relocation of communities.
	Cleaning. Cost of cleanup and mud removal. Total or irreversible structural damage, in which case all the costs of demolition and rubble removal.		
Education	*Building*. Cost of the total or partial destruction of buildings.	*Missing workdays* due to school closure.	*Temporary classroom.* Rental of mobile classrooms.
	Classroom. Cost of the total or partial destruction of classrooms, also included furnishings, tables, cupboards, desk and chairs, and textbooks.		Reset service. Outlays needed to restore the education service.
	Cleaning. Cost of cleanup and mud removal. Total or irreversible structural damage, in which case all the costs of demolition and rubble removal.		
Health	*Death toll.* Count of people died directly by the flood event.	*Patient*. Increase the number of patients in the emergency room	*Post-disaster epidemic.* Cost of actions not planned prior to the disaster.

	Physical damage. Damage to physical infrastructure can involve structural elements (beams, pillars, structural flooring, load-bearing walls, foundations, etc.) as well as non-structural or architectural elements (partitions, doors, windows, non-structural roofing and floors, interior and exterior walls, perimeter fences and so forth).	*Workdays lost.* Missing workdays due to psychological impacts, stress, and anxiety (or PTSD).	*Hospital-related costs*. Additional services to account for the increase of health issues/costs of treating diseases (i.e. respiratory disease) as a result of flooding
	Medical equipment. Cost of the losses of vital service connections or medical equipment (e.g. water, electricity, gas, oxygen).		*Structure-related costs.* Cost of post-disaster health concerns, such as removal of black mold
Water and Sanitation	*Storage tank*. Cost of the total or partial destruction of storage tanks.		*Temporary water needs.* Reduction in sales of water. Use of tanker trucks, trailers, or makeshift carriers to distribute water.
	Distribution network / treatment plant. Cost of the total or partial destruction of distribution network treatment plants.		
	Rebuilding. Cost of rebuilding water infrastructure and reconstruction of dams and levees.		
Cultural Resources	*Place of worship.* Cost of the total or partial destruction of places of worship.		*Revenue* (cultural resources) Loss of revenue to religious/cultural organizations.
	Recreation area. Cost of the total or partial destruction of recreation areas.		*Recreation.* Loss of recreation services (non-market values).
	Sacred burial place. Cost of the total or partial destruction of sacred burial places.		
	Cultural artifact. Cost of the total or partial destruction of cultural artifacts (e.g., building) in landscapes.		

	Museum collection. Cost of the total or partial destruction of museum collections and artifacts in buildings.		
	Culturally-relevant historic structure. Cost of the total or partial destruction of non-market value (as in public infrastructure).		
	Damaged zone. Cost of the total or partial destruction of zones.		
Local Government/ Community	*Local infrastructure and services*. Cost of the damages of local infrastructure and services provided by the local government /municipality.	*Workdays lost.* Unemployment increases.	*Revenue*. Loss of tax revenue
			Loans and bonds. Cost to recover (taking out loans and bonds).
			GDP. Loss of Gross Domestic Product (GDP) to municipalities
Infrastructure			
Transportation	*Railroad*. Cost of the total or partial destruction of railroads.	*Revenue* (port). Loss of revenue at ports.	*Cost for transporting freight.* Partial or total road closures imply greater distances and longer travel times for users, as well as higher vehicle operating costs.
	Airport. Cost of the total or partial destruction of airports.		*Loss of tolls*
	Port. Cost of the total or partial destruction of ports.		Cost for passengers Partial or total road closures imply greater distances and longer travel times for users, as well as higher vehicle operating costs.
	Road. Cost of the total or partial destruction of roads and highways.		*Additional costs for crews*. Additional costs associated with the deployment and mobilization of crews for damage repair

	Protection wall/dyke. Cost of constructing protection walls and dykes for roads and highways.		
	Restore the infrastructure. Cost of the work needed to restore the infrastructure to pre-disaster conditions.		
	Restore the services. The rehabilitation works required to restore service (i.e. to make a road accessible and passable), as well as the replacement works needed to return the infrastructure to its original state.		
Energy & Utilities	*Power generation plant.* Cost of the total or partial destruction of power generation plants.	*Spills damage*. Environmental damage caused by spills.	*Revenue* forgone by electric power utilities during the period of disruption.
	Substation. Cost of the total or partial destruction of substations of electricity and natural gas.		*Rehabilitation/ reconstruction.* Cost of supplying power needs temporarily during rehabilitation and reconstruction of the installations affected
	Transmission line and distribution grid. Cost of the total or partial destruction of transmission lines, gas pipelines, and distribution grids.		
	Dispatch center. Cost of the total or partial destruction of dispatch centers of electricity and natural gas.		
Technology & Communications	*Service tower*. Cost of the total or partial destruction of service towers.	*Revenue (manufacturing).* Loss of revenue from manufacturing due to a lack of communication services.	
	Communication infrastructure. Cost of the total or partial destruction of communication infrastructure.	*Revenue (commerce).* Loss of revenue from commerce due to a lack of communication services.	

Public infrastructure		*Non-market value* of public space	*Cleaning*. Involved in cleanup and mud removal
			Rescheduling public events' costs
Economic Sectors			
Agriculture	*Road or bridge.* Cost of the total or partial destruction of roads or bridges within the farm property.		
	Storage space. Cost of the total or partial destruction of buildings and installations for the storage of equipment.		*Market value of crop.* Lower yields than normal for the crops.
	Infrastructure used in farming. Cost of the total or partial destruction of infrastructure used in farming.		*Income*. Lesser harvest production means lower incomes for producers.
	Infrastructure used in livestock. Cost of the total or partial destruction of infrastructure used in livestock.		*Market value of livestock*. Reduction in physical productivity or lower yields than normal for the species of livestock.
	Infrastructure used in poultry. Cost of the total or partial destruction of infrastructure used in poultry.		*Market value of poultry*. Reduction in physical productivity or lower yields than normal for the species of poultry.
	Infrastructure used in private forestry activity. Cost of the total or partial destruction of infrastructure used in private forestry activities.		*Market value of private forest product* Lower yields than normal for private forest products.
Fisheries	*Storage space*. Cost of constructing tanks, cages, and other installations for the cultivation of fish and crustaceans. Silos, stalls, corrals, troughs, and pens for raising fish or crustaceans.		*Market value of fish*. Reduction in physical productivity or lower yields than normal for fish.

			Market value of crustaceans. Reduction in physical productivity or lower yields than normal for crustaceans.
			Income. Lesser harvest production means lower incomes for producers.
Manufacturing	*Building and facility.* Cost of the total or partial destruction of buildings, facilities and furniture.	*R&D impacts.* Loss of R&D prototypes, documentation, software	
	Machinery and equipment. Cost of the total or partial destruction of machinery and equipment.	Loss of wages, including temporary jobs, of workers due to shutting down of manufacturing facilities.	
	Inv*entory of goods.* Cost of the total or partial destruction of inventories of goods being processed, finished goods, raw materials and spare parts.		
Commerce	*Building and facility.* Cost of the total or partial destruction of buildings, facilities and furniture.	*Credit.* Decreased credit scores and bond downgrades for businesses.	
	Machinery and equipment. Cost of the total or partial destruction of machinery and equipment.		
	Inv*entory of goods.* Cost of the total or partial destruction of inventories of goods being processed, finished goods, raw materials and spare parts.		
Tourism	*Tourism area*. Cost of the total or partial destruction of tourism areas.	Loss of wages, including temporary jobs, of workers in the tourism sector.	*Service flow*. Damage sustained by tourism establishments located in a disaster area will have a negative impact on the provision of service flows.
	Property. Cost of the total or partial destruction of properties.		

Public Forest	*Employee*. The number of people whose activities rely on forests in the area affected.	*Workday lost*. Cost of people unable to work.	*Market value*. The types of forest products and the quantity in a given period.
	Road or bridge. Cost of the total or partial destruction of roads or bridges in parks.		
	Infrastructure used in the park. Cost of the total or partial destruction of Infrastructure used in parks.		
Environment	*Erosion and sedimentation.* Cost of the damages of erosion and sedimentation.		
	Wildlife and aquatic species health. Cost of the damages of wildlife and aquatic species.		
	Dispersal of nutrients and pollutants. Floodwater can contain debris (e.g., trees, stones, and pieces of houses) and pollutants (e.g., pesticides). Sedimentation and turbidity can give rise to algae and aquatic plant growth that jeopardize water quality.		
	Local landscapes and habitats. Cost of the damages of local landscapes and habitats.		
Emergency Assistance			
Emergency Response			*Transporting the wounded or other emergency evacuations.* The additional cost of emergency transportation by land or through air.
			Equipment. The rent or purchase of equipment used for emergency care work.
			Temporary shelters. The installation of temporary shelters
			Search for people. Costs generated by the search and rescue operations for people.

Appendix B. Saskatchewan PDAP (Uninsured) Dataset

Event: 2013 Spring Flooding April 13 - August 27

Claim Category	Number of Private Claims	Number of Municipal Claims	Number of Municipal Projects	Actual Paid
Boards / Cooperatives	1			316,411.32
Charitable Organization	4			61,297.18
Displacement/ Temp Relocation	23			103,107.02
First nations		7	47	217,256.49
Municipal		149	3181	20,442,679.93
Other	8			13,934.29
Primary Agricultural Enterprise	124			1,155,174.95
Principal Residence	328			2,179,950.70
Regional Park Authority		2	3	6,870.53
Renter	11			18,390.77
Small Business	35			307,981.87
Private Claim Total	534			4,156,248.10
Municipal Claim Total		158	3231	20,666,806.95
Private & Municipal Claim Total	534	158	3231	$24,823,055.05

Event: 2014 Spring Flooding April 7 - May 5

Claim Category	Number of Private Claims	Number of Municipal Claims	Number of Municipal Projects	Actual Paid
Displacement/ Temp Relocation	2			14,924.06
Municipal		25	879	7,702,027.97
Other	1			0.00
Primary Agricultural Enterprise	23			218,541.38
Principal Residence	35			176,377.06
Regional Park Authority		1	5	24,250.70
Renter	1			759.99
Small Business	2			1,057.45
Private Claim Total	64			411,659.94
Municipal Claim Total		26	884	7,726,278.67
Private & Municipal Claim Total	64	26	884	$8,137,938.61

Event: 2014 Heavy Rain June 18 - 21

Claim Category	Number of Private Claims	Number of Municipal Claims	Number of Municipal Projects	Actual Paid
Charitable Organization	1			4,244.53
Displacement/ Temp Relocation	8			35,250.67
Municipal		37	768	3,020,965.29
Other	2			0.00
Primary Agricultural Enterprise	35			666,541.73
Principal Residence	156			2,285,032.95
Regional Park Authority		1	3	7,768.36
Renter	1			456.00
Small Business	16			113,395.33
Private Claim Total	219			3,104,921.21
Municipal Claim Total		38	771	3,028,733.65
Private & Municipal Claim Total	219	38	771	$6,133,654.86

Event: 2014 Heavy Rain June 26 - 30

Claim Category	Number of Private Claims	Number of Municipal Claims	Number of Municipal Projects	Actual Paid
Boards / Cooperatives	4			239,781.29
Charitable Organization	51			726,714.96
Displacement/ Temp Relocation	121			538,820.15
First nations		13	144	415,789.93
Municipal		220	4332	39,981,079.98
Other	43			303,472.05
Primary Agricultural Enterprise	370			3,756,860.61
Principal Residence	2893			18,808,680.51
Regional Park Authority		7	78	1,449,566.65
Renter	237			268,405.39
Small Business	273			1,217,920.68
Private Claim Total	3992			25,860,655.64
Municipal Claim Total		240	4554	41,846,436.56
Private & Municipal Claim Total	3992	240	4554	$67,707,092.20

Event: 2015 Spring Flooding March 7 - May 4

Claim Category	Number of Private Claims	Number of Municipal Claims	Number of Municipal Projects	Actual Paid
Boards / Cooperatives	2			90,930.11
Charitable Organization	2			613.02
Displacement/ Temp Relocation	9			55,639.04
First nations		1	4	15,079.28
Municipal		52	1577	16,371,293.97
Other	3			3,892.63
Primary Agricultural Enterprise	46			495,970.80
Principal Residence	55			243,133.00
Small Business	6			210,459.42
Private Claim Total	123			1,100,638.02
Municipal Claim Total		53	1581	16,386,373.25
Private & Municipal Claim Total	123	53	1581	$17,487,011.27

Event: 2016 Spring Flooding March 1 - May 14

Claim Category	Number of Private Claims	Number of Municipal Claims	Number of Municipal Projects	Actual Paid
Municipal		12	126	2,530,867.20
Primary Agricultural Enterprise	4			43,178.20
Principal Residence	1			920.08
Small Business	1			0.00
Private Claim Total	6			44,098.28
Municipal Claim Total		12	126	2,530,867.20
Private & Municipal Claim Total	6	12	126	$2,574,965.48

Event: 2016 Heavy Rain July 10 - 13

Claim Category	Number of Private Claims	Number of Municipal Claims	Number of Municipal Projects	Actual Paid
Boards / Cooperatives	2			16,456.69
Charitable Organization	8			269,248.38
Displacement/ Temp Relocation	14			29,461.55
Municipal		15	308	2,952,838.34
Other	1			0.00
Primary Agricultural Enterprise	28			201,903.27
Principal Residence	271			1,134,823.66
Regional Park Authority		2	12	28,523.54
Renter	15			6,193.86
Small Business	47			119,497.63
Private Claim Total	386			1,777,585.04
Municipal Claim Total		17	320	2,981,361.88
Private & Municipal Claim Total	386	17	320	$4,758,946.92

Appendix C. New Brunswick DFA (Uninsured) Dataset

***DFA REPORT** (As of Oct 6, 2020)*

EVENT	SECTORS	# OF CLAIMS	# NOT ELIGIBLE	COMPLETED	OUTSTANDING	AMOUNT SPENT ($ to date)	ADMIN, RESPONSE & OTHER COSTS	Actual Costs Paid to-date	TOTAL EXPENDTURES TO-DATE
							Adjusters	645,407	
Spring 2014	Homeowners	517	111	406	-	$ 4,236,355	Appraisals	3,540	
	Small Business	58	13	45	-	$ 449,967	Auditors	264,994	
	Agriculture	12	7	5	-	$ 31,073	Legal Fees	5,681	
	Mitigation					$ 333,553	Engineers	120,570	
	Municipalities	9	-	9	-	$ 1,343,535	Red Cross	111,872	
	Provincial Departments	6	-	5	1	$ 1,108,634	EMO	318,705	
		602	131	470	1	$ 7,503,117	**TOTAL**	1,470,768	$ 8,973,885
Heavy Rain Dec. 2014	Homeowners	127	87	40	-	$ 407,329	Adjusters	107,959	
	Small Business	8	5	3	-	$ 66,923	Appraisals	3,565	
	Agriculture	4	4	-	-	$ -	Auditors	21,050	
	Mitigation					$ 119,192	Legal Fees	4,360	
	Municipalities	7	1	6	-	$ 115,709	Engineers	4,764	
	Provincial Departments	2	-	-	2	$ -	EMO	25,068	
		148	97	49	2	$ 709,153	**TOTAL**	166,767	$ 875,920
Heavy Rain September 201	Homeowners	77	18	59	-	$ 998,396	Adjusters/appriasals	33,564	
	Small Business	8	1	7	-	$ 169,968	Auditors	60,763	
	Agriculture	5	-	5	-	$ 242,345	Legal Fees	4,360	
	Mitigation					$ 125,857	Engineers	91,231	
	Municipalities	11	5	6	-	$ 488,847	Red Cross	4,953	
	Provincial Departments	5	-	4	1	$ 2,140,488	EMO	346,235	
		106	24	81	1	$ 4,165,902	**TOTAL**	541,106	$ 4,707,008