Assessing the Use of Flood Risk Management in High Risk Zones in Canada

A Case Study in New Hamburg, Ontario

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Flooding is Canada's most significant source of natural disaster risk. Development in high risk areas, aging infrastructure and climate change all contribute to increasing frequency of flooding in Canada. The traditional methods to reduce flood impacts include expensive structural flood defences, and disaster assistance aid from government. These policies have encouraged development in high risk areas. To address these challenges, Canadian governments at all levels have embraced flood risk management (FRM). FRM involves the use of risk information and assessment to allocate responsibility for reducing risk among a diverse set of stakeholders and strategies. However, there is a lack of research on the implications of FRM adoption for existing flood management strategies in high risk areas. This is unfortunate as the demand for effective flood risk reduction is most pronounced in these areas. The purpose of this research is to address this gap through a case study designed to understand how FRM is changing flood management in the high-risk community of New Hamburg, Ontario, Canada. The case study conducted semi-structured interviews with local experts to evaluate whether flood policy is aligned with the strategies and goals of FRM. In addition, the analysis evaluated differences between provincial government and insurance flood maps to measure the extent to which risk information is used. The results reveal a partial adoption of FRM particularly through an emphasis on preparedness and the introduction of flood insurance. Based on the research findings, the adoption of FRM through coordination between federal government and insurance industry is critical, specifically through the efforts to share information on flood risk through mapping to design flood policy.

Keywords: Flood hazard management, flood risk management, flood insurance, flood maps, diversity of strategies

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Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

Flooding is a natural phenomenon that has posed a significant challenge for society. Water has played a crucial role in the development of cities, with many settlements being located near water bodies which provided access for commerce and migration (Bergkamp et al., 2010). Early civilizations practiced flood control measures in forms of locating critical infrastructure on elevated land, flood-sensitive land-use planning and various warning methods (Sayers et al., 2013). Globally, floods account for nearly one-third of all-natural disasters (Birkholz et al., 2014). Moreover, population growth and urbanization have led to development in floodplains, which has caused an increase in susceptibility of people to flooding (Nirupama & Simonovic, 2007; Suriya & Mudgal, 2012).

Traditionally, flood management has focused on providing flood control through structural defenses, such as river channelization, retention reservoirs, river diversions, dikes/berms, levees and dams. When those measures failed, government disaster aid was used for recovery (Palom et al., 2017). The use of structural defences has proven to be challenging because of maintenance and upgrading costs. Structural defences have also failed during extreme flood events because they only protect for a predetermined flood return period (Jonkman & Dawson, 2012). Additionally, studies have shown that the frequency of flood events has increased due to climate change (Schanze, 2006; Birkholz et al., 2014; Adikari &Yoshitani, 2006). Due to these challenges, a shift of the traditional flood management approach to a more holistic perspective of managing flood risk is needed (Schanze, 2006; Birkholz et al., 2014).

Canada is prioritizing a shift away from traditional flood management. Flooding is the most costly natural disaster in Canada. Historically, Canada has experienced more than 168 flood events, which resulted in over $2 billion in damages, displacement of 45,000 people and approximately 198 deaths (Chowdhury & Haque, 2011; Shrubsole, 2013). Flooding continues to be a significant public policy matter in Canada because of population growth, development in high-risk zones, urbanization and climate change.

Canada's flood management is rooted in a hazard-based model that uses the 1 in 100-year flood statistics to create flood maps and policy instruments like land-use planning, structural defences and disaster assistance aid. The justification for these policies, however, is weakening in response to the increasing costs associated with flooding. For example, the federal government has paid more than $5 billion in post-disaster assistance to help with response and recovery (Public Safety Canada, 2019).

Increasing costs have shifted management policies to target a reduction in the consequences, or risk of flooding. This approach is widely known as Flood Risk Management (FRM), which can be used to reduce risk to the economy, people, social well-being and ecosystem (Sayers et al., 2013) Despite the growing motivation to adopt FRM, there is little known about its implementation in practice. This research is designed to address this gap by exploring how FRM is being adopted in Canada to reduce flood risk.

FRM is defined with two broad characteristics. First, risk information is used to inform the design of flood management strategies. Flood mapping is an example of an information tool used to inform this design (Lindsay, 2012; Matczak et al., 2015). Historically, hazard data was the primary source of information for flood mapping. Flood maps are used to delineate floodplains and assist with land-use planning and zoning by-laws for communities. The use of hazard data, however, restricts flood mapping because it is based on a single return period (Jakob and Church, 2011). Since hazard data does not account for multiple return periods, it fails to address flood exposure and vulnerability (see section 2.1.2). By contrast, a risk-based approach expands the information used to inform flood mapping to emphasize exposure and vulnerability, which captures a much broader range of the consequences (e.g. damage) of flooding rather than just its extent and depth.

Second, rather than relying on a narrow set of policy instruments, such as structural defences, land-use and government disaster assistance, FRM embraces a diverse set of strategies and policies among a wide range of stakeholders (Lindsay, 2012; Matczak et al., 2015). These strategies include preparedness, mitigation, response and recovery (see section 2.1.2.2). Moreover, FRM policy instruments consist of risk-based land-use planning, which uses risk maps to prohibit development in the floodplain, and flood insurance. The use of flood insurance as a form of recovery is a risk-

based approach because it limits the reliance on government disaster aid. As a result, this management increases responsibility for the property owners and promotes the use of flood risk reduction measures (Henstra and Thistlethwaite, 2017).

Since FRM is a new concept, there is a lack of information on how risk-based strategies and policies are being adopted in high-risk areas. To address this gap, Chapter 2 will focus on defining FRM and its diverse strategies and policies that are successfully practiced internationally. Furthermore, Chapter 3 will identify the current flood management being used in Canada and assess if a risk-based approach is being used to inform the flood policies.

1.2 Research Question

Over the last decade in Canada, flooding has become the most frequent and expensive natural disaster (Oulahen, 2014; Henstra & Thistlethwaite, 2017). There is evidence that Canada is shifting to an FRM based approach (as explained in chapter 3). But little is known about its implementation in practice. It is essential to understand how FRM is being adopted in Canadian communities. This gap justifies the following research questions:

1. How is flood risk management being used to reduce flooding in high risk areas?
   1a. What flood risk management strategies are being used in Canada?
   1b. How is risk information being used to design flood policy?

To address these questions, the research uses a case study in New Hamburg, Ontario, to explore the existing approach to flood management and investigate the evolution of FRM in a high-risk area in Canada, which is described in Chapter 4. To guide this research, a mixed methods approach was adopted. First, qualitative research was conducted using semi-structured interviews with 14 decision-making stakeholders. Second, a geospatial analysis (quantitative research) was generated to understand how risk information is being used to inform flood mapping.

These findings contribute to the broader study of flood management policy and increasing risk awareness by providing insights into the FRM strategies and policy instruments. The results will be discussed in chapter 5. In particular, the interviews and flood maps indicate that a risk-based

approach is being practiced only partially in New Hamburg. While some strategies, such as preparedness and recovery via insurance, exhibit a risk-based approach, other strategies rely on hazard-based approaches. This lag in the adoption of FRM across a wide range of flood management strategies reflects poor coordination between federal, provincial and local governments, in addition to the insurance industry and the local community. This is unfortunate for the local government and property owners, as the upper tier governments' shift to a risk-based approach without supporting policy change at the local scale has led to flood management uncertainty.

Chapter 2: Flood Risk Management

The general focus of flood management policy is to reduce vulnerability and increase resilience to flooding (Vinet, 2017). To understand the importance of flood management and investigate if current strategies are effective, this chapter aims to compare flood hazard and risk management approaches and define the flood management strategies of prevention and preparedness, mitigation, response and recovery. This section reviews the application of FRM in England, Germany and United States. In addition, these strategies are further analyzed using flood management policy instruments of flood maps, land use planning, structural defences, disaster assistance aid and flood insurance.

2.1 Flood Hazard Management vs. Flood Risk Management

2.1.1 Flood Hazard Management

Flood hazard management is an approach that designates a flood of a particular magnitude as the foundation for the design of public infrastructure and flood protection (Jakob and Church, 2011). Its policy emphasis is segregating people and assets from the hazard using 1 in 100-year flood statistics, which includes development in a floodplain. The equation to calculate flood hazard is as follows (Wallingford et al., 2006):

$$HR = d * (v + 0.5) + DF \quad (1)$$

Where;

HR = (flood) hazard rating;

d = depth of flooding (m);

v = velocity of floodwaters (m/sec); and

DF = debris factor (dependent on land-use: pasture/arable, woodland or urban)

Flood hazard management includes the use of structural defences such as dams and levees to reduce risk. If the flooding exceeds the structural protection, then government disaster-assistance aid provides compensation to communities as a source of recovery (Henstra & Thistlethwaite, 2017). There are several documented weaknesses of this approach, and the following are identified by Henstra and Thistlethwaite (2017):

1. High cost of structural flood controls, which includes building and maintenance
2. Communities upstream and downstream face problems related to water diversion and agricultural drainage due to a lack of basin-scale coordination
3. Hazard based approach promotes an image of safe settlement in flood-prone areas due to structural protection, which leads to increased settlement on floodplains
4. Compensation for loss is part of the disaster relief programs for flood victims, which can be seen as an effective way of encouraging risk-taking behaviour
5. During the post-disaster period, an emphasis on restoring communities to the pre-flood state sets the stage for failure because it does not involve any additional measures to mitigate future flood risk.

In response to these weaknesses, scholars and policymakers are shifting towards a risk-based flood management approach, known as flood risk management (FRM).

2.1.2 Flood Risk Management

FRM is an evolving paradigm that engages the stakeholders in government and the insurance sectors using risk management practices for flood risk reduction (Henstra and Thistlethwaite, 2017). Flood risk is the product of exposure, frequency of occurrence and vulnerability, which are the most critical sources of risk that can be controlled by this management approach. FRM is considered a different approach from flood hazard management for two reasons. First, risk information which includes measurements of exposure and vulnerability are included in risk assessments and used to design flood policy. Second, rather than relying primarily on government to support risk reduction, a diversity of strategies and stakeholders are involved in supporting and implementing flood policy.

The level of flood risk for an area can be calculated using the following equation (Wallingford et al., 2006; Thistlethwaite et al., 2018):

(2)

*Flood Risk = Exposure (assets affected by flooding) * Frequency of Occurrence (how often flooding impacts an area) * Vulnerability (susceptibility to damage)*

FRM includes a diversity of strategies that can be adopted to reduce flood risk. These methods include risk-sharing techniques and risk-based flood management strategies.

2.1.2.1 Risk Sharing Techniques

Once risk is determined, various stakeholders and policies are assigned responsibility for this risk. For example, Henstra and Thistlethwaite, 2017 developed a framework that classified different risk-sharing approaches. The first way is to share the burden of loss through flood coverage from insurance companies for policyholders (Henstra and Thistlethwaite, 2017; Kovacs and Sandink, 2013). The second way is to share responsibility for risk reduction, which spreads accountability among non-governmental parties that are affected by flood risks. This technique involves stakeholder engagement, community contribution to Geographic Information Systems (GIS), flood warning systems, flood hazard disclosure, subsidies, flood mapping, by-laws and integrated stormwater management (Henstra and Thistlethwaite, 2017; Seher and Löschner, 2015). The third way is to share the cost of risk reduction through public funding distribution (Henstra and Thistlethwaite, 2017; Mori and Perrings, 2012). The use of these techniques can assist in creating a resilient FRM plan to reduce flood risk.

2.1.2.2 Risk-based FRM Strategies

More often, however, FRM strategies are divided into key objectives that support risk reduction. The goal is to allow individuals and communities to anticipate the severity of disasters and emphasize multiple techniques to reduce flood impact (IP Access, 2018; Lindsay, 2012). FRM strategies that are successfully practiced internationally and embrace a diverse set of objectives are preparedness, mitigation, response and recovery. These strategies are used to inform FRM decisions before, during and after flood events (Figure 1) (Alexander, 2002; Drissen et al., 2018; Matczak et al., 2015).

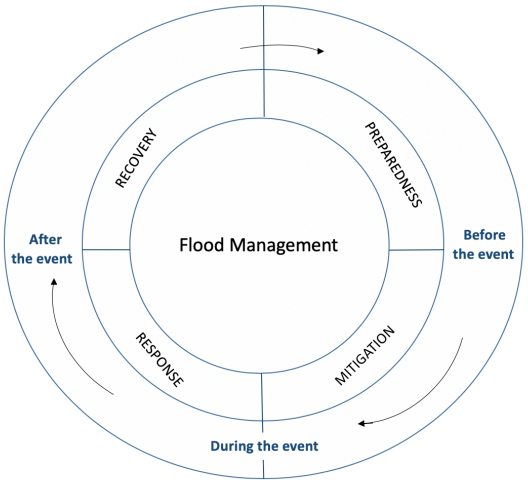

Figure 1: Flood management strategies that are used before, during and after a flood event (Alexander, 2002)

First, the goal of preparedness strategy is to create procedures to help the community with risk reduction before flooding occurs. This strategy includes the use of flood forecasting and flood warning system to reduce risk (FEMA, 2018a; Raadgever & Hegger, 2018). Second, mitigation strategy promotes the use of flood risk reduction through structural and non-structural methods before a flood event (Public Safety Canada, 2017a). Structural flood mitigation includes the construction of infrastructure such as dams, levees, bridges, culverts or dykes (National Research Council, 1991; National Research Council, 2013). Non-structural measures include (Public Safety Canada, 2017a):

1. Risk-based land use planning, which enforces strict building and development codes;
2. Detailed property surveys to increase flood mapping accuracy;
3. Updated flood models to understand the impact of urbanization on flood risk;
4. Promoting property-level-flood-protection and incentives to encourage its adoption by property-owners, and;
5. Increasing flood risk awareness

Third, response strategy focuses on protecting lives and preventing property damage during a flood event (Ontario, 2017). This includes actions such as road closures, warning people by using alert systems, evacuation plans, sandbagging, and door knocking to reduce risk. Fourth, the goal of recovery strategy is to return to a safe situation post-emergency through financial assistance after flooding (Benjamin, Brown & Carlin, 2017). This strategy promotes a "build back better" approach using private flood insurance (Alexander et al., 2016).

Although FRM is tackled differently in all countries and provinces, the main emphasis is to incorporate risk-information into the design of policy and embrace a diversity of policies implemented by a range of stakeholders. The following section will explore some examples of FRM in practice.

2.2 Strategies Adopted by England, Germany and United States

2.2.1 England

According to a 2012 research study, 6 million people are at high risk of flooding in England (Ramsbottom et al., 2012). In 2013 and 2014, flooding caused over £2 billion of damage to 5000

homes and 17 deaths (Raadgever & Hegger, 2018). The country is highly vulnerable to fluvial, pluvial and coastal flooding due to the proximity of settlements to water. The risk is also high in England due to urbanization, population growth, aging drainage infrastructure, and erosion (Alexander et al., 2016). Literature has also identified flooding as a continuous issue for England due to an increase in the frequency of floods because of climate change (Kundzewicz et al., 2014).

While England has been following diversified flood management strategies for 65 years, these strategies have been focused on hazard-based approaches such as reliance on structural defences and government financial aid against flooding (Alexander et al., 2016; Matczak et al., 2015). However, after the 1998 and 2000 floods, several strategies embracing FRM were initiated by the government of England (Alexander et al., 2016) (Table 1). These efforts were further motivated by the EU Flood Directive that embraced FRM (Dieperink et al., 2014).

Table 1: Flood risk management strategies adopted by England and recommended by the EU Flood Directive (Brussels, 2004; Raadgever & Hegger, 2018; Matczak et al., 2015; Girgin and Krausmann, 2019; Priest et al., 2016)

Flood Events	FRM Strategies	Action
Before the event	Preparedness	Use of flood forecast and warning system, conduct flood risk assessment using past data and increase awareness
	Mitigation	Prohibit development in high risk areas, through strict land-use planning. Reduce flood impacts through structural (infrastructure and government aid) and non-structural measures (flood risk mapping and property-level-flood-protection)
During the flood	Response	Develop emergency response guidelines in case of flooding such as, evacuation plans and road closures
After the flood	Recovery	Gain recovery through the purchase of private flood insurance or state-funded compensation

2.2.2 Germany

Another country that has adopted the FRM strategies successfully is Germany. The damage costs of the 2013 Germany flooding were estimated between €6 to 8 billion, which led to a re-evaluation of the flood hazard management approach (Engel, 2004). The hazard-based flood control policy of 2002 heavily relied on embankments (Thieken et al., 2016; Engel, 2004). However, structural defences were found to be limited in their efficacy. Therefore, to achieve the goal of reducing flood damage, the FRM strategies including mitigation, preparedness, and recovery were implemented as an alternative approach (Kreibich et al., 2005; Thieken et al., 2016; Kienzler et al., 2015).

First, mitigation and preparedness strategies were combined in efforts to update land-use planning. Land-use planning policy is a key component of mitigation strategy that was used for urban planning to limit development and densification in flood-prone areas (Thieken et al., 2016; Kienzler et al., 2015). The updated planning information was then used to create a flood forecasting capacity as part of the preparedness strategy (Thieken et al., 2016; DKKV, 2004). Furthermore, to promote these strategies, risk maps were made digitally available to the public in all German states (Petrow we al., 2006).

Second, to assist with recovery, a risk transfer method involving both government and insurance industry to distribute and share risk was used to balance the financial burden within the society (Thieken et al., 2016). Due to this approach, financial equity was created, which allowed flood insurance to become available for home and commercial owners (Schwarze and Wagner, 2004). Finally, in addition to the use of flood insurance, financial assistance such as grants and credits were also offered to encourage mitigation practices, which discouraged risk taking behaviour compared to the hazard-based approach (Kreibich et al., 2011).

2.2.3 United States

The third country to have successfully adopted the FRM strategies and policies is the United States. Flood risk in the United States has significantly increased due to climate change and sea-level rise, while development continues near rivers and coastlines (Konrad, 2003). The flood events that occurred since 2004 have exceeded the cost of $200 billion, and the recorded cost of 2012 insured flood losses in the United States was $58 billion (Knowles and Kunreuther, 2014). Historically,

the United States government had dealt with the flood hazard by building flood control structures (FEMA & NRC, 2009). However, the repetitive results of disaster events and failure of costly infrastructure led to the formation of three phases of emergency management, also known as the FRM strategies: mitigation, response and recovery (Morrissey, 2006). The goal of these strategies is similar to those of England and Germany, with more emphasis on standardizing and updating flood maps to assist with flood insurance availability.

Flood insurance was not always available in the U.S. because only people who were highly prone to flooding were interested in buying insurance. As a result, companies offering insurance could not afford to provide coverage, given the risk of damage (Chastain, 2005; Knowles and Kunreuther, 2014). The escalating financial flood loss due to several hurricanes in the 1950s and 1960s led to the establishment of the National Flood Insurance Program (NFIP) in 1968 (Chastain, 2005; FEMA & NRC, 2009). This program is administered by the Federal Emergency Management Agency (FEMA). The program's objective is to identify and map flood-prone areas to make insurance available for communities that adopt a risk-based mitigation strategy.

To promote flood risk reduction, FEMA created Flood Insurance Rate Maps (FIRMs) for insurance. These maps were also used for floodplain management and land use planning by the federal government (FEMA & NRC, 2009; NRC, 2011). The use of consistent flood maps among government and insurance sectors led to map standardization, which reduced uncertainty for flood prone areas. Furthermore, FEMA also converted manually produced maps to digital FIRMs (DFIRMs), which allowed for a smoother transition to updating flood maps (Aycock and Wang, 2004; Maune, 2007) (Figure 2).

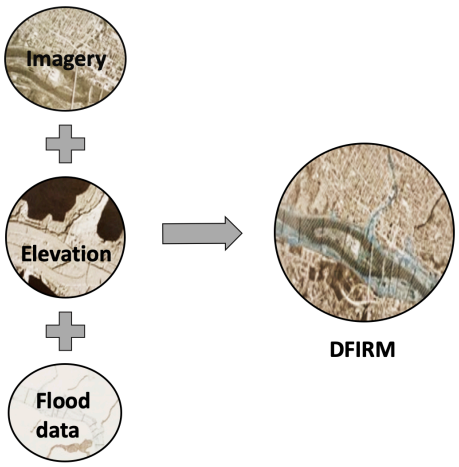

Figure 2: Map layers needed to create DFIRM, layers obtained using photogrammetry, remote sensing and GIS (FEMA & NRC, 2009; Maune, 2007)

Despite the use of these strategies, FEMA has struggled to update the flood maps regularly due to funding constraints. However, with the recent introduction of the Risk Mapping, Assessment and Planning (Risk MAP) program, the focus is to work with major stakeholders to identify flood risk and promote planning and development practices (FEMA, 2019a).

2.3 Hazard vs. Risk Maps

Flood risk mapping is the common policy approach used in each of these countries to support FRM. It is important to distinguish flood risk maps from hazard maps since these tools are used to inform the design of other policies, such as land-use planning, structural defences, disaster assistance and insurance. To demonstrate how risk information is used in practice, it is important first to review the difference in the role of mapping.

Hazard maps portray flood event probability for a specific area and use flood depth and flow velocity data to define the floodplain (Merz et al., 2007). However, hazard maps are limited because they only focus on a single flood period and do not provide information on other risk factors, such as climate change, population growth and urbanization (Jakob and Church, 2011). These maps, however, can be improved by combining risk information, which will allow the authorities to better mitigate and prepare for a flood event (Wallingford et al., 2006).

Flood risk maps show risk parameters that include risk to people and assets, multiple flood return periods, and some even incorporate climate change data (Stevens and Hanschka, 2014). A risk map dissects the floodplain into low, medium and high-risk zones (Wallingford et al., 2006) (Table 2). This information can be used by government at all levels, insurance industry and the general public to inform FRM decisions and reduce the probability of damage (MMM Group, 2014). Furthermore, accurate flood maps can encourage property owners to invest in FRM policies, such as property-level flood protection. Investment in risk-based mitigation reduces housing/commercial premiums for owners interested in purchasing insurance (Kunreuther, 2016). Lastly, risk maps also show legal and economic priorities for flood control and land-use planning (Palom et al., 2017).

Table 2: Example of information portrayed by a risk map that accounts for hazard, exposure and vulnerability (Wallingford et al., 2006)

Parameter	1- Low Risk Area	2- Medium Risk Area	3-High Risk Area
Speed of Onset	Onset of flooding is very gradual (many hours)	Onset of flooding is gradual (one hour or so)	Rapid flooding
Nature of Area	Multi-storied apartments	Residential areas; commercial and industrial properties	Bungalows, mobile homes, busy roads, parks, single storied schools, campsites
Flood Warning	Score for flood warning= 3- {P1x (P2+P3)} Where, P1=% of Warning Coverage Target Met P2= % of Warning Time Target Met P3=% of Effective Action Target Met		

2.4 Flood Management Policy Instruments

Flood maps have been used to inform several other important policy instruments such as land-use planning, structural defences, disaster assistance and flood insurance.

2.4.1 Hazard-based Policy Instruments: Land-use Planning

Land use planning is an integral part of the flood mitigation strategy that has been used to regulate zoning by-laws to reduce the impact of flooding (Palom et al., 2017). Some of the planning includes environmental protection, identifying boundaries for urban development, providing a vision for future development and exercising safe use of floodplains (OECD, 2017). However, this policy remains informed by hazard management because the structural engineering solutions and design standards for communities use historical flood statistics to determine land-use requirements for development (Henstra and Thistlethwaite, 2017).

Furthermore, hazard-based land-use planning uses flood hazard maps to assign building codes and regulate zoning by-laws. This is problematic because these maps do not account for exposure and vulnerability, which means that the regulations are limited to the information provided by hazard maps (Palom et al., 2017).

2.4.2 Hazard-based Policy Instruments: Structural Defences

Structural defences are a crucial part of a hazard-based preparedness and mitigation strategy because they are the first line of defence during a flood. This infrastructure is built using the information on the historical frequency of a flood and hazard map. For example, flood walls are designed to protect against the worst flood recorded in the last 100 years. However, structural defences are expensive to maintain and raise a concern of deterioration over time (Wynn, 2002). Additionally, due to structural defences, the level of flood protection has become negotiable because it encourages a perception of safety that supports development in high-risk areas (Palom et al., 2017; Vinet, 2017; Henstra and Thistlethwaite, 2017). Some examples of cities that practice this approach include Paris, Amsterdam, Lisbon, and Barcelona (Palom et al., 2017). However, due to climate change, the geographical extent of the 100-year zone is likely to increase, which might reduce the effectiveness of structural flood protection (Aerts and Botzen, 2011).

2.4.3 Hazard-based Policy Instruments: Disaster Assistance

Disaster assistance plays a vital role as part of the recovery strategy after a flood event. If a flood overflows the structural defence system, then disaster assistance aid can be provided by the provincial/state or federal government to compensate the victims (Thistlethwaite et al., 2018). The purpose of disaster aid is to return the property to its basic functions, and it cannot be used to make improvements (Ministry of Municipal Affairs and Housing, 2018). Disaster assistance often helps to cover emergency expenses and repairs (Ministry of Municipal Affairs and Housing, 2018). However, government aid has been criticized for creating a moral hazard that encourages people to re-develop in high-risk areas without taking additional action to reduce risk (Thistlethwaite, 2017).

2.4.2 Risk-based Policy Instruments: Land-use Planning

In response to increased development in high-risk areas, policymakers are looking for a risk-based approach to land-use planning that will restrict growth in floodplains. FRM policies for land-use are different from the hazard-based approach in the following ways.

First, risk-based land use planning uses flood risk maps, which include detailed geospatial analysis on flood exposure, and divides the floodplain into various levels of risk (Wallingford et al., 2006;

Kron, 2007). This facilitates the agreement of land-use change that decreases habitation in flood prone areas despite the potential drop in economic value (Palom et al., 2017). This risk-based approach incorporates information on exposure and vulnerability, which can significantly change existing and previous land-use designations (Tingsanchali, 2012). Such policy focuses on using knowledge from past and current flood events to reduce risk to the economy by restricting development in the floodplain (Cœur and Lang, 2008; Dodds and Whiles, 2012).

Second, risk-based land use planning focuses on (1) extending land along the waterbodies for flood waters, (2) regulating the type of development allowed for areas at risk of flooding, (3) limiting building density to decrease risk to assets and people (Kron, 2007; Henstra and Thistlethwaite, 2017), and (4) re-evaluating natural and agriculture lands that were converted into urban areas, based on the new zoning laws that account for climate change (Tingsanchali, 2012).

The above approaches can create a better understanding of a risk-based land use planning policy amongst the provincial government, insurance industry and the general public (Chang, Lee and Huang, 2017). An example of adopting this policy is found in the United States, where the government has constructed land development management principles, some of which include (Burby et al., 2000):

1. Linking historical and current flood data to design risk-based guidelines for maps;
2. Ensuring hazard-free land is available for development;
3. Offering incentives to encourage developers to locate projects outside of hazard areas and/or to adopt mitigation measures that exceed those required by law, and;
4. Using the post-disaster window of opportunity to encourage owners to retrofit or relocate.

2.4.2 Risk-based Policy Instruments: Structural Defences

The goal of a risk-based structural defence policy instrument is to provide flood control without singularly using the 1 in 100-year flood statistics by combining flood control and land use policy. Through this, a risk-based development criterion can be formed for delineating strict zoning by-laws, which inhibit growth in high risk areas (Watson and Adams, 2011). Risk-based defences use risk maps to define regulatory zones within which development standards apply to both residential

and commercial properties (Barredo et al., 2007). Some examples of risk-based structural measures include (Government of Ireland, 2009; Dilley and NetLibrary, 2005):

1. Building and extending permeable urban structure,
2. Identifying and protecting land using conveyance routes, flood storage and protection areas, and
3. Proper drainage and maintenance stormwater management system to decrease vulnerability

2.4.2 Risk-based Policy Instruments: Flood Insurance

Disaster assistance from the federal government has played an active role in supporting economic recovery. Nevertheless, this method remains informed by hazard-based flood management because government aid is not a substitute for risk management. Disaster aid is not intended to restore the impacted areas to pre-disaster condition but rather to a state that is safe and livable (Henstra and Thistlethwaite, 2017).

Due to the increasing cost of recovery, governments are stepping away from providing financial assistance in favour of insurance. This means that the responsibility of flood protection has never been greater for a property owner (Gollom, 2017). Due to the shift in level of responsibility, financial aid is only available through flood insurance. Insurance is a risk-based approach because it prices risk using premiums as a market-signal that can discourage development in high risk areas, and lower the financial burden on government aid, which will increase both social and economic recovery time (Raadgever & Hegger, 2018).

This policy is successfully practiced in England, United States and Germany (Priest et al., 2016). England's Gentleman's Agreement authorizes homeowners to purchase flood insurance as part of standard home coverage (Surminski and Thieken, 2017). More recently, England's government initiated a Flood Re program, which is funded through a levy on insurers and premium collection that allows owners to file flood claims. This levy raises €180 million every year that is used towards home insurance policies to cover flood risks (Flood Re, 2019). Once the claim is filed and paid by insurers, then the insurance company gets reimbursed by Flood Re-fund (Flood Re, 2019).

Flood insurance in England and the U.S. is supported by forms of government subsidy, which has allowed for an even distribution of risk equity among the public. The U.S. government is working with insurance companies to make coverage affordable. In addition, the government mandates residents in high-risk areas to purchase flood coverage through the public National Flood Insurance Program (NFIP) (FEMA, 2019).

Lastly, the German government is actively promoting and encouraging homeowners to purchase flood insurance, while working with insurers to create standardized flood risk maps that homeowners can use to understand the influencers of their premiums (Schwarze and Wagner, 2004; Thieken et al., 2016). Flood insurance is a crucial part of the FRM recovery strategy (Browne and Hoyt, 2000), which is visible in countries practicing FRM to reduce risk.

Chapter 3: Flood Risk Management in Canada

This chapter highlights the evolution of flood management in Canada. It focuses on the current flood management practiced in Ontario. This section emphasizes the roles of the Government of Ontario, Conservation Authorities (CAs) and local governments in managing flooding.

3.1 History of flooding in Canada

According to the Canadian Disaster Database, between 1900 and 2005, 241 flood disasters occurred in Canada. This is five times more than the next common disaster, wildfire (Figure 3) (Sandink et al., 2010). Major Canadian cities and small communities are prone to flood damage due to population increase, urbanization, building density, and valuable infrastructure networks (Henstra & Thistlethwaite, 2017; Sandink et al., 2010; Moghal & Peddle, 2016).

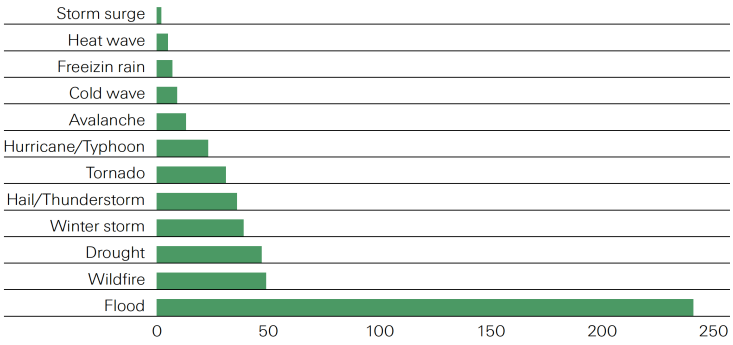

Figure 3: Climatological and Hydrological Incidences in Canada,1900-2005 (Sandink et al., 2010)

One of the most disastrous flooding events in Canada was Hurricane Hazel in 1954. This event generated flash flooding throughout Ontario. It remains the most destructive flood in Ontario's history when indexed for inflation (Sandink et al., 2010a). During Hazel, within 48 hours, recorded rainfall of 285mm (28.5cm) left Toronto with estimated damage of $760 million in 1989 dollars and killed 81 Canadians (Sandink et al., 2010a; Robinson & Cruikshank, 2006; Belore, 2000).

More recently, in 2013, a severe flash flood event in Toronto resulted in a major power failure, affecting approximately 300,000 people. According to the Insurance Bureau of Canada, the damage to insured properties exceeded $940 million, and cost the municipal government $65 million for response and recovery (Henstra & Thistlethwaite, 2017; Nelson, 2013). During the same year, Calgary was also hit with flooding that killed 5 people and resulted in a $6 billion

financial loss (Calgary, 2018). According to the Insurance Bureau of Canada, the historical flood records has revealed that 1.8 million Canadian households are at an extremely high risk to flood damage (Henstra & Thistlethwaite, 2017; Meckbach, 2015).

In Canada, flood events have historically been managed using the flood hazard management approach, which has been the dominant technique used to reduce the impacts of flooding (Kumar et al., 2001). This approach was supported by the Canada Water Conservation Assistance Act that approved a 75% grant for the capital cost of structural flood defences (Shrubsole, 2000, Quinn, 1985). These defences, however, are over 50 years old and require maintenance and upgrades to account for the increasing frequency of flooding (Shrubsole, 2000). Moreover, the increasing cost of flood damage has heightened the demand for disaster relief, which is evidence for the failure of exclusive investment in structural defences (Government of Canada, 2013c). This led to the development of the Flood Damage Reduction Program (FDRP) that supported both structural and non-structural methods to reduce flood risk (Watt, 1995).

3.2 Flood Damage Reduction Program (FDRP)

The FDRP was initiated in 1975 to discourage future development in high risk areas and promote the use of non-structural methods to reduce flood damage (Page, 1980; De Loë and Wojtanowski, 2001; Government of Canada, 2013a). The program's general policies followed a basic approach where all flood reduction measures were considered and selection was made based on effectiveness, cost and benefits, and environmental impacts (Government of Canada, 2013a). To enforce these policies, flood maps were used to designate flood risk areas to prohibit development (Page, 1980). The program also stated that any new development in high risk area would not qualify for disaster assistance in the occurrence of a flood (De Loë and Wojtanowski, 2001). However, the program relied heavily on constructing infrastructure for damage control and lacked in overall cost-effectiveness. In 1996, the FDRP was cancelled due to budget cuts and lack of enforcement towards risk-based methods (McClearn, 2019).

After the FDRP phased out, major flood events like the Calgary and Toronto flooding of 2013 heightened the demand for disaster relief (Sandink et al., 2010). As a result, the Canadian

government is looking for a risk-based mitigation approach, which led to the initiation of the National Disaster Mitigation Program (NDMP) (Government of Canada, 2013b).

3.3 National Disaster Mitigation Program (NDMP)

The NDMP was established in 2015 by the federal government as an effort to support risk-based mitigation methods (Canada, 2016). There are four funding streams under this program: risk assessments, flood mapping, mitigation planning and investment in non-structural and small-scale structural mitigation projects. The goal of this program is to focus investments on mitigation to improve eligibility of property owners to buy flood insurance (Public Safety Canada, 2018).

Both provincial and territorial governments are eligible for funding and can regulate the redistribution of funds to municipal and other local governments. British Columbia is the first province to receive over $10 million for flood mitigation from the program. This funding will alleviate pressure from the federal disaster assistance program, which has paid up to 80% of flood damage costs over the past two decades (Staff, 2018).

Furthermore, CA's in Ontario have submitted a proposal for this funding to create flood event database, update flood maps to redefine flood lines and increase risk awareness. The funding will be also used for land-use planning, which will include a city-wide flood risk profile, update zoning policy and maintaining structural defences (Conservation Ontario, 2018). However, this is a short-term program with a budget of $200 million from 2015 to 2020 (Public Safety Canada, 2019). So, future federal government support to implement risk-based solutions is uncertain.

3.4 Flood Management in Ontario

Between the period of 1900 and 2005, more flood disasters (49 flood events) have occurred in Ontario compared to any other province in Canada (Sandink et al., 2010a). In Ontario, flooding is managed by the federal and provincial governments, Conservation Authorities (CA's) and municipalities/townships (Moghal & Peddle, 2016; GRCA, 2015) (Figure 4).

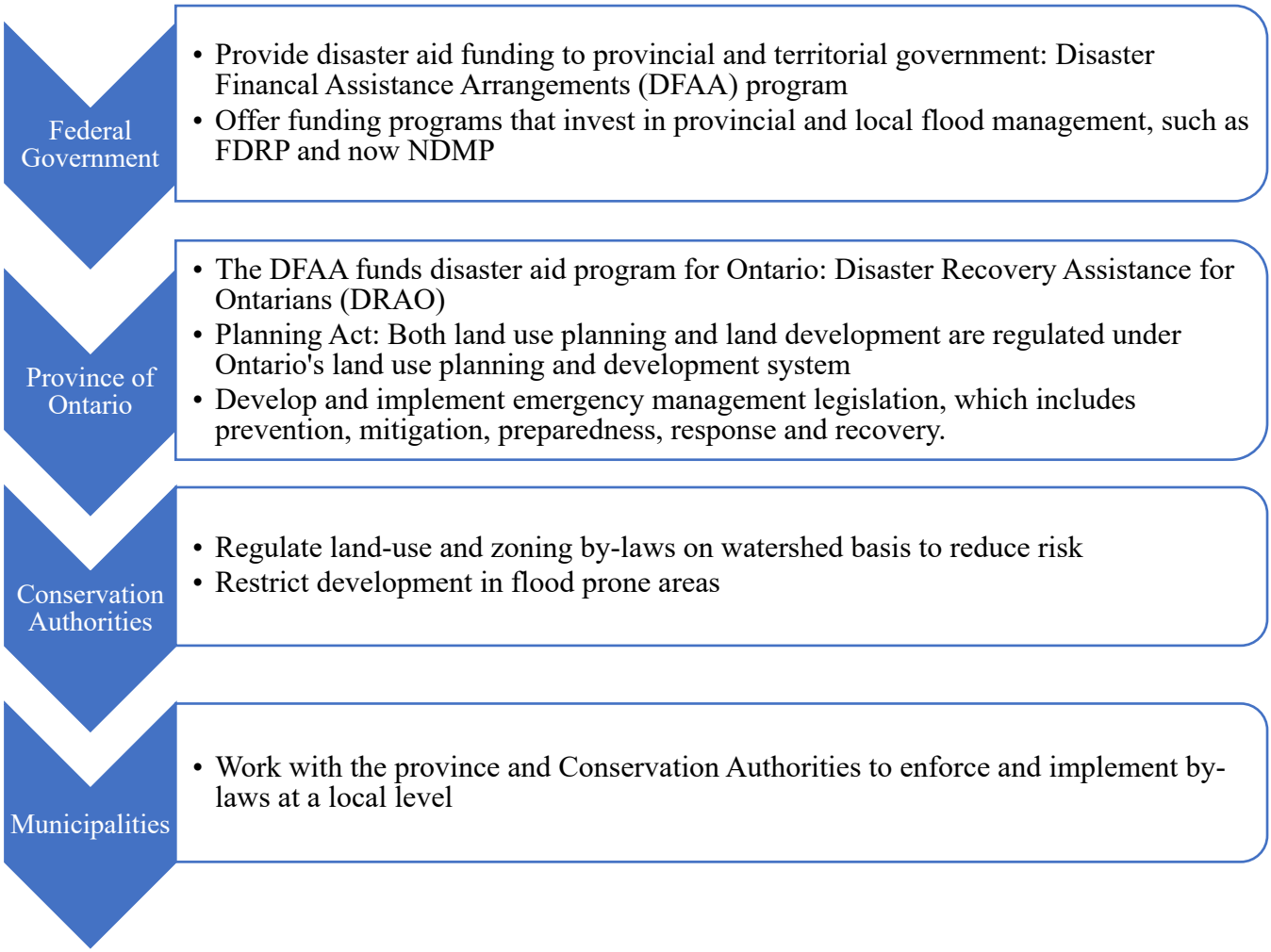

Figure 4: Schematic showing the distribution of responsibility to aid Ontarians with flood management (Ministry of Heritage, 2019; Conservation Ontario, 2019)

The federal government provides financial assistance through the Disaster Financial Assistance Arrangements (DFAA) program, which is administered by Public Safety Canada (Zeuli, Nijhuis and Gerson-Nieder, 2018). The DFAA was created in 1970 to assist provincial and territorial governments when response and recovery costs exceeds expected loss (PBO, 2016).

3.4.1 Role of Government of Ontario in Flood Management

The Government of Ontario plays two significant roles in flood management by (1) providing funding for disaster assistance aid, and (2) by regulating land-use policy under the Planning Act and implementing emergency management legislation and guidance.

First, the disaster assistance program for Ontario is the Disaster Recovery Assistance for Ontarians (DRAO), which is administered by the Ministry of Municipal Affairs and Housing. The program is designed to help homeowners, tenants, small owner-operated businesses and farms, and non-profit organizations to restore essential structures, furnishings and property to pre-disaster condition (Zeuli, Nijhuis and Gerson-Nieder, 2018). The DRAO provides financial assistance for flood damage that is sudden or unexpected and does not provide assistance for costs that can be claimed through insurance (Ministry of Municipal Affairs and Housing, 2019).

Like the federal DFAA program, however, the DRAO has been criticized for weakening individuals' incentive to implement risk-reduction measures. Another concern regarding DRAO is the delay in dispensing funds between the time a community submits a claim and when it receives it (Henstra and Thistlethwaite, 2017). This was the case after the Toronto's December 2013 ice storm, when aid was approved in February 2015, more than one year after the storm (Zeuli, Nijhuis and Gerson-Nieder, 2018).

Second, the Government of Ontario has the power to regulate and set out ground rules for land-use planning and land development under the Planning Act. This Act is administered by the Ministry of Municipal Affairs and Housing, and it defines the provincial and municipal roles for planning administration. The provincial government is responsible for encouraging local municipalities to adopt the planning policies and zoning by-laws for flood prone areas (Ministry of Heritage, 2019).

These zoning by-laws are used to divide communities located in the floodplain into two-zones. The first zone is known as the floodway, and all development is restricted in this area. In the floodway zone, the following policies are in effect (Sandink et al., 2010a):

1. Federal or provincial infrastructure that is vulnerable to flood damage will not be built in this zone;
2. New buildings placed in flood risk area are not eligible for government funds such as, Canada Mortgage and Housing Corporation, and;
3. Any development built after the designation of the flood zone will not be eligible for government disaster aid.

The second zone is known as the flood fringe and development is allowed in this area provided that it is adequately protected from flood damage (Sandink et a., 2010a; Government of Canada, 2013b). This two-zone concept is used to differentiate between high and low risk areas in the floodplain to determine better suited land for development (Sandink et a., 2010a).

In addition, since these zoning by-laws were assigned in the 1990s, the areas that were already developed before the floodplain were allotted the title of Special Policy Areas (SPAs) (McMullen, 2015; Sandink et a., 2010a). These areas may include central business districts within the cities. SPAs allow for some development provided that infrastructure has been flood-proofed to a minimum 100-year flood level (Sandink et a., 2010a).

The third role for the province involves setting out and implementing emergency management policy. This role is defined by the Emergency Management Plan, which include prevention, mitigation, preparedness, response and recovery strategy (Figure 5) (Fortin, 2009; McNeil, 2019). This approach indicates that Ontario has embraced the policy diversification aspect of FRM. However, these management strategies were created using a hazard-based approach and the reliance on government disaster aid and structural defences, suggests that Ontario remains informed by hazard management. This is unfortunate as demand for flood risk reduction is significant in high-risk areas.

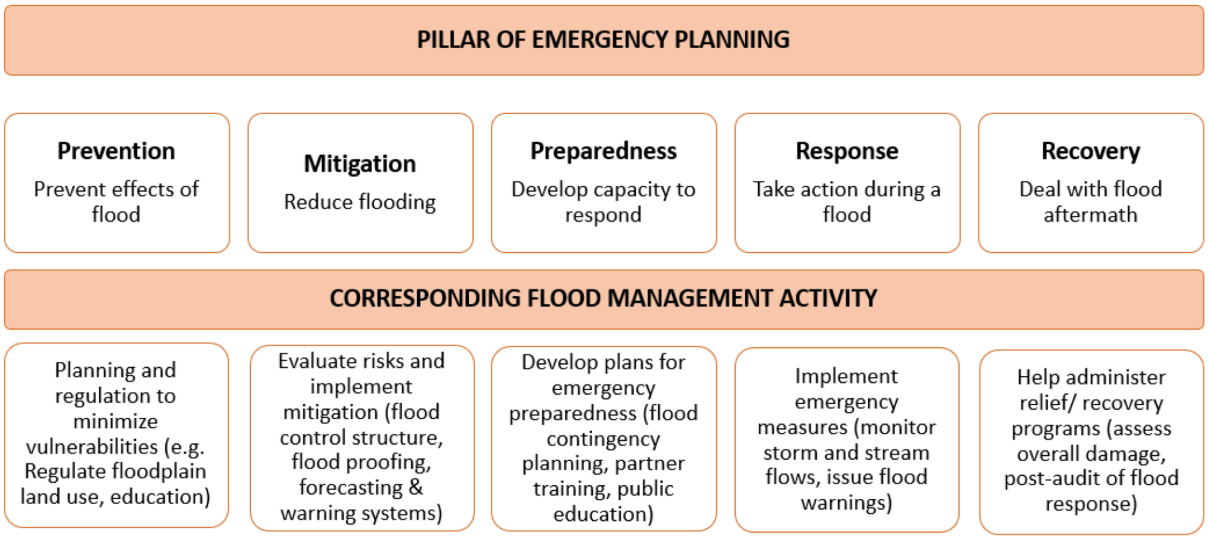

Figure 5: Ontario's emergency management strategies (Fortin, 2009)

Furthermore, to enforce the land-use planning and zoning by-laws in communities, the Ontario regulation 97/04 was initiated by the Government of Ontario in 2004, which allowed the Conservation Authorities (CAs) to prohibit or regulate development in river or stream valleys to control and prevent flood damage (Government of Ontario, 2011).

3.4.2 Role of Conservation Authorities in Flood Management

Ontario has 36 Conservation Authorities (CAs) that protect Ontarians and infrastructure from flooding. These authorities are local watershed management organizations that are authorized through provincial legislation to protect and manage water and other natural resources. They work in partnership with municipal governments and other organizations to reduce risk (Henstra and Thistlethwaite, 2017). The first CA was established in 1946 by the provincial government (Conservation Authority, 2019; Moghal & Peddle, 2016). The CAs have five flood management responsibilities (Moghal & Peddle, 2016; Sandink et al., 2010a):

1. Maintain and monitor the watershed assigned to each CA;
2. Govern land-use planning decisions on a watershed basis;
3. Provide technical advice on flood mitigation to municipalities;
4. Use flood forecasting and warning system to prepare community for flooding, and;
5. Operate dams and flood control structures to decrease flood risk during a flood event

Furthermore, the CAs are empowered by the Government of Ontario to develop flood maps and restrict development in high-risk areas by enforcing the zoning by-laws (two-zone concept and SPAs). While the enforcement of land-use planning is important, it lacks effective mapping data and the CAs have failed to update the flood maps due to lack of funding (Fortin, 2009).

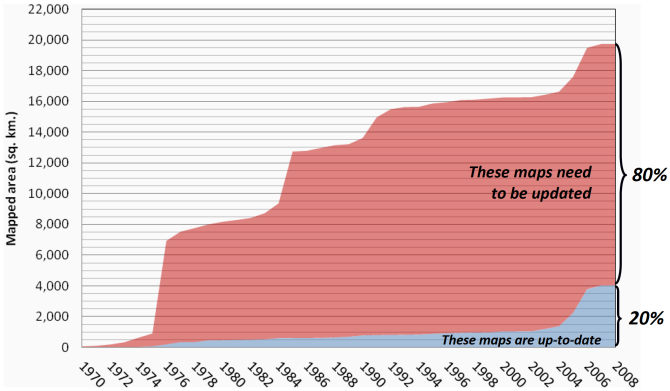

Figure 6: Comparison between flood maps required for Ontario and the one that are up to date (Fortin, 2009)

For example, in a report by Conservation Ontario, it was identified that 80% of the

existing maps need to be updated because the current flood maps are approximately 22 years old and 39% of these are over 30 years old (Figure 6). Funding constraints, however, have delayed any initiatives (Fortin, 2009).

3.4.3 Role of Municipalities in Flood Management

Municipalities are empowered by the Government of Ontario to govern local decision-making, which consists of land-use planning and zoning by-laws (Sandink et al., 2010a). They use information from CA's to define the regulatory requirements for development in the floodplain (ECO, 2011). Municipal governments also have the responsibility to protect infrastructure and property owners for their respective municipality, primarily through non-structural measures (Moghal & Peddle, 2016).

To manage flooding during a flood event, cities and townships have the authority to declare flood emergency and activate the emergency management plan, based on dialogue with CA flood coordinators (Moghal & Peddle, 2016). Upon receiving a flood watch or warning from a CA, municipalities act as mediators to communicate that information to the public and other officials (e.g. fire department and local police), while deciding the suitable response action. Lastly, the municipalities also have the authority to appeal for disaster assistance from the provincial government (Government of Ontario, 1990).

3.5 Knowledge Gap

There is evidence that governments in Canada support the use of FRM. In particular, the NDMP has funded a variety of different risk assessment, mapping and mitigation projects for provincial and local governments. The federal government is also promoting insurance as source of recovery, rather than government disaster assistance. Furthermore, there is also demand among provinces and municipalities for FRM. The recent report on the "independent review of 2019 flood events in Ontario", for example, advocates for the adoption of FRM (McNeil, 2019). However, very little is known about how this shift in policy is influencing the existing flood management, particularly in high risk areas. The next section will introduce the study's methodology for addressing this gap.

Chapter 4: Methodology

To better understand whether and how FRM is influencing flood management in high risk areas, a case study on flood risk was conducted in the town of New Hamburg, which is located along the banks of the Nith River in the Region of Waterloo, Ontario. Since the implementation of FRM remains largely unexplored in Canada, a case study method was adopted to identify assumptions and hypothesis that can be tested in future studies. The case study had ethics approval as a part of a broader project on Municipal Policy Capacity in Canada (#30891) (Appendix 1). The purpose of this case study was to analyze the current flood management strategies being used in a high-risk area. The research explored the use of sources of risk information to understand how these policy instruments are being designed in New Hamburg, and the various instruments adopted to support flood risk reduction.

4.1 Study Site

The study site is a growing urban area of New Hamburg located in the Township of Wilmot, which is in the Region of Waterloo, Ontario, Canada (Figure 7). New Hamburg was chosen as a case study because the majority of New Hamburg is located near the Nith River (Township of Wilmot, 2013) (Figure 7). This is because early settlement in the 1800's occurred along the Nith River because of the flour mill (Township of Wilmot, 2013). As a result, the river has caused multiple flood events in the local community (CBC News, 2017; CBC News, 2018). So, due to the town's high exposure to flood risk and changes in recovery policy by the upper tier governments, New Hamburg represents an ideal location for evaluating the adoption of FRM.

Figure 7: Study site with Nith River passing through the town of New Hamburg

New Hamburg is a mixture of residential and business properties that continues to grow in population and employment size based on the 2016 census (Township of Wilmot, 2017). The town's population in 2011 was 11,709 and in 2016 was 13,595, which is a 16.1% growth rate compared to the nearby towns in the Township of Wilmot, which indicated a population percentage change of only 6.9% (Statistics Canada, 2018a; Statistics Canada, 2018b). This increase in development and population is contributing to the increase in exposure and vulnerability to flooding for the local community.

In addition, flood risk is even higher during spring because of extreme rainfall, ice jams and melting snowpacks (GRCA, 2017). Major floods have occurred in New Hamburg in 1954, 1961, 1975, 2008, 2017, and more recently in 2018 and 2019 (Sandink et al., 2010; GRCA, 2009; Fortin, 2009; New Hamburg Independent, 2013; New Hamburg Independent, 2018). Flooding in New Hamburg has resulted in residential and commercial damage that include business closures, basement flooding, building exterior damage, and sewage back-up (Thomson, 2018; Mercer, 2018). For example, during the February 2018 flood, 270 homes in New Hamburg near the Nith River were estimated to be affected by flooding (Flanagan, 2018).

4.2 Flood Management in New Hamburg

To manage flooding, the primary focus of flood protection is provided through structural flood control, flood forecasting and a warning system. However, research and news articles have identified the Town of New Hamburg as a high-risk area due to annual flooding and lack of flood control measures (New Hamburg Independent, 2013; New Hamburg Independent, 2018; Thomson, 2018; Mercer, 2018). For example, the technical report of 1983 by Frigon & Committee on the Grand River basin identified that the Nith River dam, which was supposed to reduce flood damage, had no effect on average annual damages in the Grand River basin. The report concluded that despite this structural flood control, the area is prone to frequent flooding in residential areas with potential for large commercial damage at less frequent flood flows (Frigon & Committee, 1983).

The two main governing bodies that manage flooding in New Hamburg are the Township of Wilmot and the Grand River Conservation Authority (GRCA). The township plays an important

role during a flood event by providing sandbags to the community, declaring road closures and by acting as a moderator between the residents and the GRCA to communicate flood warning information (GRCA, 2009). After a flood event, the township restores the community's infrastructure that was damaged by applying for funding through the Municipal Disaster Recovery Assistance program (McNeil, 2019).

4.2.1 Role of GRCA

The GRCA plays an important role in flood risk reduction for the Region of Waterloo by using both structural and non-structural methods. The structural protection for New Hamburg is provided through berms, whereas, non-structural methods include flood forecasting and flood warning systems. Additionally, GRCA is also responsible for land-use planning, maintaining and building structural defences, and proactively deploying preparedness and response strategies (Cooke, 2014; Frigon, 1983; GRCA, 2014; Fortin, 2009).

The zoning by-law for New Hamburg was appointed using the flooding standard flood limit based on Hurricane Hazel (McMullen, 2015). Similar to the zoning by-law defined by the Government of Ontario (see section 3.4.1), the GRCA has separated the communities under its jurisdiction into one-zone and two-zone policies, and SPAs (GRCA, 2015) (Figure 8):

1. *One-Zone Policy Area*: the entire regulatory floodplain is considered the floodway. Development is not permitted in the flooding hazard limit or regulatory floodplain (Figure 8a)
2. *Two-Zone Policy Area:* the floodplain is divided into the floodway and flood fringe (Figure 8b)

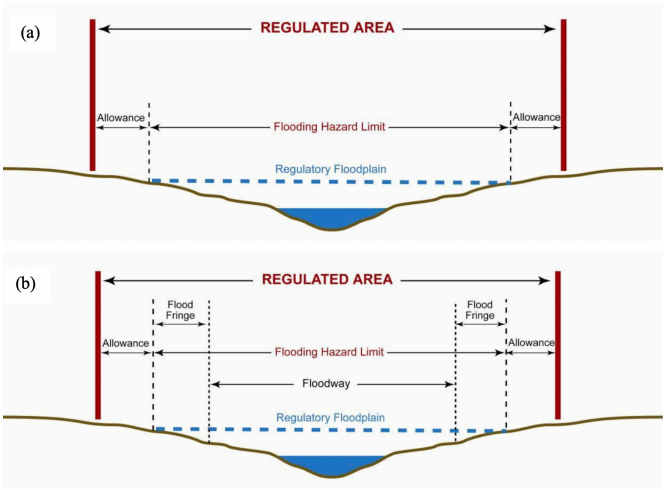

Figure 8: (a) Regulated area for zone-one policy, which shows the riverine flooding hazard limit and allowance (b) GRCA's two-zone policy, which shows floodway where construction is restricted and flood fringe that allows limited development (GRCA, 2015)

a. *Floodway:* area of floodplain required for river flow and flood water. Development is not permitted in this zone.
b. *Flood fringe:* area located between the floodway and the edge of the floodplain. Limited development is permitted in this zone.

3. *Special Policy Areas (SPAs):* Area within a community that has historically existed in the floodplain. Development in SPAs is only permitted if a community does not have feasible opportunities for growth outside the floodplain. The municipality, GRCA and the Government of Ontario have floodproofing and technical standards and have accepted a higher level of risk for this area. Additionally, SPA regulations have been in place since 1990, limiting new development in the floodplain without GRCA's approval.

Most regulated areas in the Grand River watershed are One-Zone Policy Areas but there is a lack of information on which zoning policy applies to New Hamburg.

The town, however, is also divided into four flood risk zones by the GRCA based on the amount of water flow during a flood event and proximity to the river. These zones were also defined using the 100-year regulatory flood limit based on the Hurricane Hazel flood statistics. The flood risk zones are divided into level 1 to level 4, where level 1 represents the highest risk and level 4 the least amount of risk (GRCA, 2009) (Figure 14). To further understand flood management in New Hamburg and how risk information is being used to design flood policy, interviews and geospatial analysis was conducted for the town.

4.3 Semi-Structured Interviews

To understand how flood management is being used to reduce risk in New Hamburg, semi-structured interviews were conducted. These interviews included an informal verbal interchange initiated by the interviewer to prompt interviewees for information by asking a list of predetermined open-ended questions (Ayres, 2008). As the interviews unfolded, the conversation offered the participants a chance to explore issues they deem important (Longhurst, 2003; Ayres, 2008). This qualitative approach was used to assist in identifying the key local stakeholders

involved in the decision-making process. Through open-ended and elicit questioning, the interviewees had the chance to bring forward flood risk concerns.

The interview focused on three key areas:

- Identify the effects of transitioning towards the adoption of FRM in New Hamburg;
- Study the impacts of flood insurance and how it is changing perceptions towards key non-structural strategies of preparedness, mitigation, prevention and recovery; and
- Identify the level of responsibility each stakeholder should have before, during and after flood events.

A total of 14 interviews were conducted over a 4-month period at the beginning of 2019 (Appendix 3). The participants included representatives from the GRCA, Township of Wilmot and a local insurance company. Additionally, a local news journalist, a non-profit committee member and a topic expert from the University of Waterloo were also interviewed. Interviewees were anonymous and identified as "Interview #, 2019" throughout the text.

Due to limited local expertise in New Hamburg, a small sample size was gathered. The interviewees were selected based on newspapers and academic journal articles that highlighted the need for changes to the current flood management policy. Overall, the goal was to use semi-structured interviews to identify the current flood management in New Hamburg, identify the importance of flood insurance and flood mapping as sources of risk information used to information policy, and what role these policies could play to reduce flood risk.

4.3.1 Thematic Analysis and Atlas.ti Software

All interviews were audio recorded and transcribed verbatim. The data were analyzed using thematic analysis through the Atlas.ti software. Thematic analysis allowed the use of an interpretative and narrative approach that identified common issues/themes and priorities described by the interviewees (Braun and Clarke, 2006; Aronson, 1995). This approach permitted an open-ended questioning with the experts, while teasing out individual perspectives of organizational relations (Soin & Scheytt, 2006; Gliszczinski, 2018). This approach generates codes and themes from the data (Braun and Clarke, 2006; Boyatzis, 1998).

Codes are an effective way to collect and organize desirable data relevant to the research question. When multiple similar codes are identified, common themes can be detected to draw insight on policy decision-making in the case study. (Clarke & Braun, 2017). This methodology was most suitable for the analysis of semi-structured interviews because thematic analysis focuses on producing rigorous and high-quality analysis (Clarke & Braun, 2017; Braun and Clarke, 2006).
To assist with analysis, the interview data was uploaded to Atlas.ti 8.4.2 software program, which is used for data management and script analysis. This program is a computer-assisted qualitative data analysis software that facilitates the examination of unstructured and semi-structured data allowing the identification of themes, patterns and meanings (Smit, 2002).

Based on the research questions, sections from each interview were highlighted as quotations that identified the current flood management strategies, policies and challenges faced by the community. More specifically, the research questions were used to inform the coding analysis by looking for commonly repeated themes that align with the principles of FRM. Policies and perspectives that are consistent with hazard-based approaches were identified in addition to those consistent with risk-based approaches.

Using thematic analysis, 5 themes and 15 codes corresponding to these themes were identified from 14 interviews. For example, "*property owners are responsible for their property*" (Interview 2, 2019) was assigned the theme "level of responsibility" and was coded under property owners. Furthermore, quotations were also assigned multiple codes to showcase the interconnectivity between different themes, for example, "*government aid is important, but property owners need to adopt mitigation measures like property-level-flood-protection"* (Interview 1, 2019) was coded as disaster assistance, mitigation and property-level-flood-protection. This was done by using a hybrid coding strategy that combines open coding with codes from documents of interviews (Hwang, 2008).

After all codes and themes were assigned, the data were further analyzed with a "network" tool that conceptualized the data by connecting sets of similar elements in a visual representation (Friese, 2013). This tool was used for analysis because it gathered all codes and themes to show

repetition or frequency, which represents the significance of a strategy, policy or challenge in New Hamburg.

4.4 Flood Risk Mapping

To understand how flood risk information is being used to inform policy decisions, geospatial analysis was also conducted because it is the first critical component in policy design. This analysis involved exploring differences between flood maps used by CA's/provincial government and insurance sector to inform decision-making in New Hamburg. For the government sector, a flood map was generated using the open source GRCA database known as Grand River Information Network (GRIN). The flood map was developed to show the SPA's, regulated floodplain, regulation limit, New Hamburg dam, and the proximity of the properties to the Nith River. The regulated floodplain for this map was based on the 100-year standard flood statistics.

For the insurance sector, the flood maps were created using the 100-year floodplain data that was acquired from JBA Risk Management, which is a company with global expertise in natural hazard modelling (JBA Risk Management, 2019). The firm assists the insurance industry, governments and financial institutions with flood risk management by providing access to data outputs produced by its exclusive 2D hydrodynamic flood model (JBA Risk Management, 2019). Both Insurance Bureau of Canada and the Government of Canada have used this model to assess the number of properties vulnerable to flooding. JBA's datasets have also assisted insurers in pricing premiums for single properties (Thistlethwaite et al., 2018; Lyle and Hund, 2017; Nadarajah, 2016). Additionally, these models are used to map flood-prone areas in Canada, which includes federal government data on the location of major and minor rivers, historical streamflow, water levels, and topographical and environmental inputs (Thistlethwaite et al., 2018).

Using the JBA database, flood insurance maps were generated in ESRI ArcGIS software. These maps were created for the quantification and visual representation of residential and commercial properties at risk of flooding. However, the geospatial analysis did not include data on property-level-protections or structural infrastructure. Additionally, to avoid mapping inconsistencies, both GRCA and insurance maps were generated using the 100-year floodplain. Lastly, property information for mapping was acquired from the KitchenerGeoHub (City of Kitchener, 2018).

To furthermore understand how risk information is used to inform decision-making, insurance premium information for a small sample of properties was acquired from a local New Hamburg insurance company. To conduct this analysis houses were selected at random to obtain premium rate information. The goal of this inquiry was to understand if GRCA's use of hazard data aligns with risk-models created by insurers. Finally, this information was also used to highlight concerns regarding insurance affordability and availability in New Hamburg.

Chapter 5: Results and Discussion

This chapter presents the results while analyzing the data based on the research questions. The first section illustrates the results obtained from semi-structured interviews. This analysis was performed to determine the use of FRM strategies and policies for reducing flood risk in New Hamburg. The second part of this chapter provides analyses on the use of flood mapping in New Hamburg. Maps were created to explore differences between existing maps and those being used by insurers to support risk-based recovery through flood insurance. This section also shows information on insurance premium rates to highlight similarities and dissimilarities for the four flood zones used to identify hazard extent by the GRCA. Flood mapping and insurance results are used to understand how risk information is being used to design flood policy.

5.1 Interview Results and Analysis

In total, 14 interviews were included in the sample. After they were transcribed, Atlas.ti was used to organize and identify recurring themes and codes. Fifteen codes emerged, representing recurring concepts and phrases relevant to flood risk reduction. These codes were organized into five broader themes including flood hazard management, flood risk management, flood management strategies, level of responsibility, and challenges (Table 3). Furthermore, the themes and codes were analyzed for significance using a frequency count (Table 3). To further assist with analysis, the data was also depicted using a graphical representation of all themes and some quotations (Figure 9). The following analysis will describe each of the broader themes and the related codes that emerged from the interviews.

Table 3: Frequency count for themes and codes created using Atlas.ti for thematic analysis

Core Themes	Codes	Frequency Count / Code	Total Frequency Count
Flood Hazard Management	Structural defence	99	169
	Disaster assistance aid	52	
	Build to pre-flood conditions	18	
Flood Risk Management	Insurance uncertainty	104	203
	Property-level-flood-protection	54	
	Flood map	45	
Flood Management Strategies	Preparedness	34	108
	Mitigation	48	
	Response	10	
	Recovery	16	
Level of Responsibility	Property owners	75	137
	Government	50	
	Real Estate	12	
Challenges	Lack of funding	85	122
	Lack of awareness	37	

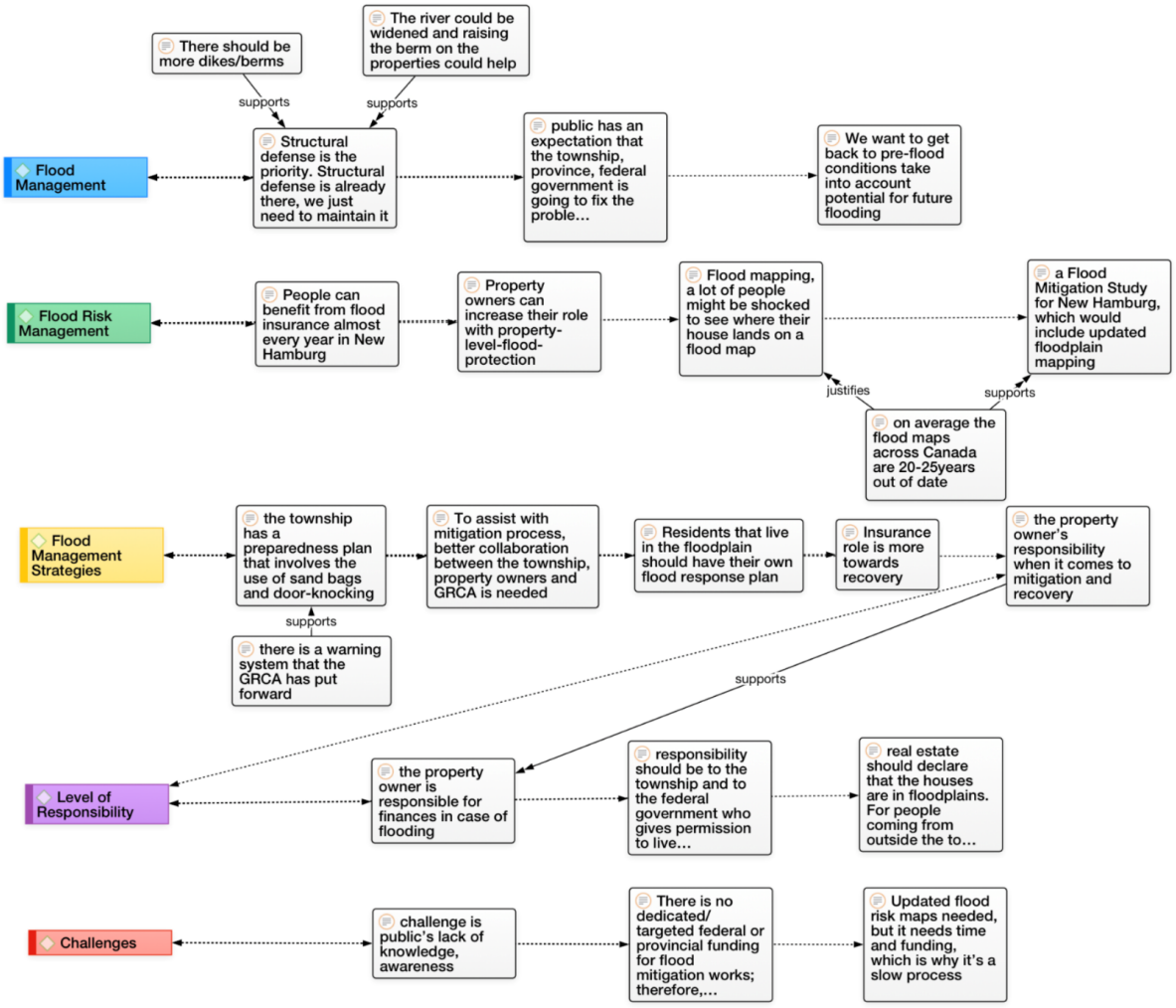

Figure 9: Graphic representation of themes created using Atlas.ti to show interconnectivity between themes and quotations. These quotes were used to create specific codes.

5.1.1 Flood Hazard Management

Participants discussed flood hazard management 169 times by referring to policies that are consistent with this approach. These policies include structural defence, disaster assistance, recovery designed to build-back to pre-flood conditions.

5.1.1.1 Structural Defences

Participants described structural defence in several ways. Some were quite supportive: "*structural defence is the priority",* and that "*defence is already there, we just need to maintain it. Because it's not as effective as when it was first put in back in the 70s".* Others emphasized the need for

structural defences but more aligned with risk-based approaches that embrace a diversity of strategies: *"structural defences are very important and defending your property by making it as flood proof as you can. If the structural defences fail, non-structural methods of flood risk reduction need to be combined together with good communication and collaboration"*.

Many respondents prioritized structural defences above other policies, signalling support for the hazard-based approach. The high frequency count (99) relative to other policies and strategies suggests that structural defences remain an active part of the local discussion on solutions. Flood control provided by the structural defence, however, has led to development in floodplains, which provides a false sense of security (Henstra and Thistlethwaite, 2017; Meckbach, 2015). For New Hamburg, the GRCA is responsible for structural flood protection. There is no structural defence system installed in New Hamburg other than a berm that provides partial flood protection. The berm has a standard design that was built to protect the town from the 100-year flood (Cooke, 2014; GRCA, 2009).

Since the 1970s, there has been limited maintenance in New Hamburg with only an effort to remove invasive vegetation for a more efficient passage for flood water (Thomson, 2017). Some respondents noted this gap in maintenance as an area of concern: *"the dykes definitely need to be maintained. The river could also be widened and raising the berm on the properties could also help. Increase structural defences, dredge the rivers. It's the most economically effective way too. It's not hard to dig a hole"*.

November 2017 was the first time that the GRCA conducted a significant maintenance for the infrastructure with the cost of $50,000, which was divided between the CA and the Ontario government (Thomson, 2017). The 2014 Grand River Watershed report stated that it was not realistic to build additional flood defences because of physical constraints (e.g. existing development) (Cooke, 2014). However, an interviewee's response questioned that analysis arguing that "*for people living at the river who are at risk of flooding, they care more about mitigating flood risk than the view of the river"* (Interview 9, 2019).

Support for the use of structural defences aligns with flood hazard management. These defences limit the incentive for municipalities to promote the use of other measures such as land-use planning, building codes and risk communication instruments to inform people of flood risk. Since the floodplain is protected, municipalities benefit from the tax revenue from development in these areas (Zimonjic, Roman & Simpson, 2017). However, properties that are located by the water are not an asset but rather a financial risk (Schaefer, 1990). Nevertheless, floodplain regulations that control development are viewed as being restrictive to future development and economic growth (Schaefer, 1990), which could be a factor limiting the motivation for New Hamburg to reduce the emphasis on structural defences.

5.1.1.2 Government Disaster Assistance Aid

The second code used to analyze the first theme was government disaster assistance aid, and it had the second highest frequency count of 52 among the three codes. Disaster assistance was often described as critical to flood management because the *"public has an expectation that the township, province, federal government is going to fix the problem"* (Interview 12, 2019) and "*I think that we should offer disaster relief*" (Interview 13, 2019). The participants also vocalized that *"from a community standpoint, finances for people or any kind of aid should be provided to raise morale"* and *"what definitely will help the people the most is any kind of the financial assistance available to satisfy them, the most and perhaps make the whole town a little less upset".*

Others discussed the shift in responsibility of disaster aid from government to property owners by stating that "*for areas with no disaster assistance, the property owners need to put in place measures to lower the probability of flood occurrence because not adapting is not an option".* Some interviewees also stressed that *"the role of property owners and businesses is to educate themselves, make sure they are prepared and understand the consequences because financial assistance is not a long-term solution, the owners have to learn to become self-sufficient".*

The recognition that disaster assistance is not a long-term solution aligns with proponents of a risk-based approach. The main reason disaster assistance is problematic is that it supports recovery in high risk areas, thus ignoring risk and exposure. This contributes to a moral hazard, which limits incentives for property owners or communities to change policy that reduces risk. Conversely, no

access to government disaster aid compels the homeowners of existing development to take more responsibility to reduce their risk to flooding (Henstra & Thistlethwaite, 2017). While limiting disaster assistance is recommended by the research, respondents did reveal some hesitation about moving towards a risk-based approach with less availability arguing that: "*people were upset that the government aid wasn't given out to the people who were affected but, the thing is aid wasn't available"*.

5.1.1.3 Building-back to pre-flood conditions

The third code used to analyze the theme of flood hazard management was building back to pre-flood conditions, which had the frequency count of 18. This emerged as a consistent response among participants who were concerned about flood recovery and future flooding. The count for this code is not as high as other codes, but it shows that some stakeholders are not moving towards "building back better" methods because they *"want to get back to pre-flood conditions"*. They often described flood recovery *as "getting back to pre-flood conditions"*.

The code on building-back to pre-flood condition aligns with a hazard-based recovery plan that focuses on providing compensation to victims and rebuilding to pre-disaster conditions (Thistlethwaite et al., 2018). Support for building-back to pre-flood conditions fails to reduce exposure and vulnerability because it does not promote flood risk reduction methods. This limitation was identified by a minority of the respondents as a concern that flood policy should "*focus on not building back to the conditions that led to flooding"*.

Once a disaster has occurred the goal should be to create post-disaster recovery plan that integrates risk reduction measures to restore infrastructure and societal systems (UNISDR, 2017). Building back to pre-flood conditions will result in similar consequences as the past flood events. Previous flood events have demonstrated the need for preplanned preparedness, mitigation, response and recovery strategies, as a critical opportunity to "Build Back Better", which will result in communities becoming resilient to disasters (Wahlström, 2015).

The above results reveal that traditional flood management remains a significant part of policy considerations in New Hamburg. It appears there is a lot of ambiguity about shifting away from

the hazard-based approach mainly due to the uncertainty about the alternatives. The next section on the theme of FRM reveals some of this uncertainty.

5.1.2 Flood Risk Management

The second core theme identified in the interviews was FRM, which had a total frequency count of 203. The codes that aligned with the principles of FRM include insurance uncertainty, property-level-flood-protection, and flood maps.

5.1.2.1 Insurance Uncertainty

The influence and role of flood insurance regarding flood management in New Hamburg was described by several participants as uncertain, which had a frequency count of 104. This result was expected because flood insurance was only recently introduced in 2017 (IBC, 2019). Some participants stated that they are "*not sure what flood insurance looks like for New Hamburg when comes to managing flood*" and that they are "*not aware of how much of an impact flood insurance has made, no change*".

Flood insurance is currently the only external financial assistance available for recovery, but less than 30% of Canadians have taken the action to purchase flood insurance to protect their property (Thistlethwaite et al., 2017). In 2017, due to institutional pressure and stakeholder expectation, flood insurance was expanded to adopt a stronger role in managing flood risk by providing coverage for flood damage (IBC, 2019; Thistlethwaite, 2017). However, flood damage is still part of an uninsured peril when it is an expected event. This means that homes built in floodplains are not covered by insurance if flooded (IBC, 2017a; IBC, 2017b). While flood insurance for high-risk areas is unavailable, there are some insurers that do offer an optional coverage plan that provides policyholders protection from riverine flooding and sewer backup/water damage (IBC, 2017b). Most Canadians, however, are unaware that flood insurance coverage is an additional policy that needs to be added to their existing house insurance (Thistlethwaite et al., 2017a). This inconsistency in availability emerged throughout the interviews.

Others described a concern regarding property owners being unaware of flood insurance being a separate part of the standard home insurance policy. An interviewee said that *"I am unsure if*

property owners are aware that standard home insurance only covers sewage and not riverine flooding" (Interview 3, 2019). These perspectives align with research on flood insurance in Canada conducted in 2013 by the Co-operators showing that 70% of Canadian homeowners believed that their standard household insurance policy covered them for flooding, but it did not (Nadarajah, 2016).

In addition to the coverage concern, other participants questioned the affordability and availability of flood insurance for property owners in high-risk areas by stating that *"they (property owners) may think they are buying it (flood insurance) but don't have it, especially the ones that need it, so it's not accessible or available and if it was available it would not be affordable* "and *"I live on Asmus St., near Nith River and insurance was denied to me for any price"* (Interview 9, 2019).

For properties located within a high-risk zone, owners will face challenges related to availability and affordability of insurance (Dransch et al., 2010; Nones, 2016). High-risk areas are problematic to insure due to immense risk and if coverage is available then, the premiums are expensive, which questions its affordability (Hodgson, 2018). This creates confusion regarding insurance availability and affordability, which is why insurance uncertainty had the highest frequency count compared to all other codes.

Insurance coverage, however, is essential for property owners because failure to protect assets without coverage will leave owners to pay for their own damage expenses, which can increase the risk of mortgage defaults. With provincial government not willing to pay for flood damage, property owners are responsible for purchasing flood insurance (Thistlethwaite et al., 2017; Gollom, 2017). So, it is essential for property owners to understand that affordability of flood insurance is dependent on the amount of risk to a property, which was mentioned during an interview: "*the premiums are not inexpensive because the premiums are linked to the risk and if the risk is high then the premium is also high*" (Interview 2, 2019).

Another factor contributing to insurance uncertainty is the unpredictable damages that could occur during a flood event, which depends on the type of flooding: overland/urban flooding and riverine flooding. This variable has made it difficult for insurance companies to determine accurate

premium rates, while keeping the profit margins (Horn & Webel, 2019). Due to the different types of flooding, some interviewees questioned the coverage itself by saying that "*often it is assumed that overland flood insurance refers to urban overland flooding, but it is unclear if riverine flooding is covered and/or included in this terminology*" and that *"there is a miscommunication between the terms riverine and overland flooding*". The difference between overland/urban and riverine flooding was identified to be part of the confusion surrounding insurance uncertainty as it was argued by an interviewee that "*techniques to reduce the impacts of flooding need to be clear on the types of flooding being referred to"* (Interview 5, 2019).

The current insurance policy that protects from flood damage is known as overland flood insurance (IBC, 2017a). Insurance defines overland flooding as overflow of a waterbody like a river causing water damage by entering property at or above ground level (Intact Insurance, 2019). However, government bodies like the GRCA describe overland or urban flooding as a result of water on landscape from excess runoff, which is not from a waterbody and causes sewer backups (Cooke, 2019). Due to the interchangeable use of terminology the interviewee expressed concern by saying that "*riverine flooding is very different than urban drainage flooding resulting from urban drainage or sewer backup. Lumping all types of flooding together is not helpful and confuses the general public*" (Interview 5, 2019). The inconsistent use of terminology creates insurance uncertainty for areas like New Hamburg that are prone to flood damage from both riverine and overland/urban flooding.

5.1.2.2 Property-level flood protection

Another policy instrument that aligns with the principles of FRM is property-level-flood protection, which had a frequency count of 54. This indicated that the policy is being considered as an important part of FRM. The policy was identified by the stakeholders as an important risk reduction method: "*property owners can increase their role with property-level-flood-protection. This is a layered responsibility and the role of a property owner in the floodplain is to plan for flood emergencies"*. Some discussed this measure in depth, such as one interview stated "*property-level-flood protection measures should be adopted such as, disconnecting downspout from the eavestrough system," and "ground-level windows are watertight"* (Interview 2, 2019).

To promote flood risk reduction measures, it is important to adopt policy instruments that align with FRM like property-level-flood protection. Examples include contouring around the house to direct water away from the foundation, storing extra sump pump and batteries, installing a backwater valve to let water flow out of the basement and purchasing flood alarms for the basements (HFPP, 2019; Kumar et al, 2001; Evans & Feltmate, 2019). The deployment of these measures can also increase the availability and affordability of insurance by lowering risk to the property (Evans & Feltmate, 2019).

Furthermore, municipalities often support the adoption of property-level-flood-protection through subsidies or awareness programs, but none of the interviewees discussed this approach in the case of New Hamburg. It was however identified by some interviews as an important example of flood mitigation in other communities:

> *Municipalities in large cities offer subsidies for downspout disconnect, sump pump installation and back water valve installation but the uptake in cities across Canada for people who are eligible for these subsidies is only about 6%-7%, which is very low*

Other participants were supportive of the need for CA's and provincial government involvement through "*incentives being given for promotion of property-level-flood-protection*" while arguing that "*more awareness and education is needed"*. This education gap in the use of property-level-flood protection is unfortunate because even those who have such measures fail to maintain them (Evans & Feltmate, 2019). Moreover, since, government disaster assistance is not available anymore for areas with reoccurring floods, the property owners need to use property-level-flood-protection measures to decrease flood risk (Moudrak and Feltmate, 2017).

5.1.2.3 Flood Map

Another code used to determine if FRM policies are being practiced in New Hamburg was flood mapping, which had a frequency count of 45. This implied that flood maps are considered as an important policy in flood risk reduction. Respondents noted a few key problems with flood maps including concerns that they are outdated, there is little engagement with existing maps limiting awareness among property owners, and maps are insufficient to addressing this lack of awareness.

Flood risk mapping is a critical first step in FRM. These maps can be used to provide information needed to quantify flood risk and include an inventory of buildings in floodplain, number of people affected and the probability of economic damage to assets (MMM Group, 2014; Kjellgren, 2013). However, literature revealed that the cities that are dependent on hazard maps, which are created using the 1-100-year flood statistics, base the flood management techniques on the extent and depth of inundation related with historic flood scenarios (Kjellgren, 2013).

To reduce flood risk, flood maps need to become accessible and updated for stakeholders at all levels such as, government, insurance and the general public (De Moel et al., 2009). Several participants addressed the issue of inadequate flood mapping by stating that "*on average the flood maps across Canada are 20-25years out of date*" and asked openly "*when was the last time those were updated*".

A province-wide inventory of flood mapping was conducted in 2015 by CAs and the Ministry of Natural Resources and Forestry (MNRF) and the results indicated that in Ontario floodplain maps are 25 years old on average (Moghal & Peddle, 2016). The survey outcomes showed that 67% of maps are from mid 1980's to early 1990's, with some dating back to 1970's (Moghal & Peddle, 2016). Upon further investigation, it was found that to update these maps assistance is needed from federal and provincial governments with financial resources, policy direction and technical expertise (Moghal & Peddle, 2016). Some participants did note that the GRCA is trying to resolve this problem by pursuing funding from the NDMP to update the current flood maps: "*using National Disaster Mitigation Program (NDMP) a Flood Mitigation Study for New Hamburg, would include updated floodplain mapping".*

Updated flood maps and policy changes will improve urban flood predictions, flood modelling, and Intensity Duration Frequency (IDF) curves. Accurate flood maps can be used as the initial step towards encouraging property owners to invest in cost-effective property-level-flood-protection measures, which would result in reduced housing/commercial premiums (Kunreuther, 2016).

However, even once they are updated, interviewees expressed a concern that *"a lot of people might be shocked to see where their house lands on a flood map"*. This is a legitimate problem since

existing maps show that more than 75% of development on floodplains predate land-use regulations of 1990 (Kumar, Burton and Etkin, 2001). This concern was raised by an interviewee stating that "*many of the homes that are in the flood zones predate that by-law*". This suggests that updating flood maps can be controversial and face opposition. This backlash is associated with perceived property values, which was revealed by an interviewee that *"flooding is a suppressing problem in New Hamburg, property value/real estate has been affected"* (Interview 11, 2019).

In addition to political opposition, interviews also stressed confusion over flood mapping. For example, insurance flood maps are not available to the general public. This was confirmed by interviewees who discussed the unavailability of insurance flood maps: *"the general public doesn't have access to insurance maps"* and *"the GRCA and insurance have their own flood maps and it is unknown if they are working together towards map standardization"*.

This quotation aligns with existing research that argues that inconsistent and outdated flood maps lead to flood zone uncertainty for property owners (De Moel et al., 2009). The difference between government and insurance maps can make it difficult for property owners to determine if the property is in a high or a low risk zone. This can create uncertainty for homeowners in terms of assessing exposure to risk and deciding if flood insurance is needed. However, accurate risk maps can be used by all levels of government to invest in flood mitigation and by property owners to install property-level flood protection methods and purchase of flood insurance (Meyer, Scheuer and Haase, 2009; NRC and Public Safety Canada, 2017).

Based on the above results it was found that insurance, property-level-flood-protection and flood mapping policies that align with FRM are being discussed among the stakeholders, but it is not clear if these policies are currently being used to inform flood risk in New Hamburg. This is unfortunate as some interviewees supported FRM policies, reflecting broader Canadian public opinion. For example, in the case of flood mapping, a survey of Canadians residing in high-risk areas found that 92% of property owners want updated flood maps that are available to the general public (Thistlethwaite et al., 2017).

5.1.3 Flood Management Strategies

In addition to a range of specific policy instruments, four broad strategies emerged in the interview analysis. This is consistent with some of the GRCA's approach which includes a diversity of approaches including flood forecasting, flood warning and researching mitigation techniques, to reduce flood damage. The GRCA proposed six methods of flood control, which include (1) continuation of assessing and maintaining berms and dams, (2) restricting development in floodplains, (3) preparing and maintaining emergency plans, (4) implementing of flood mapping for areas and (5) investigating options to increase infiltration rates to increase resiliency for variable climate and increasing severe storms frequency (Heyming, 2014; Cooke, 2014). Additionally, in May 2019 GRCA received $90,000 in funding from the NDMP, which is approximately half of the total project cost ($180,000) to start a flood mitigation study in New Hamburg (Hicks, 2019; Ivey, 2019).

The theme of flood management strategies was identified 108 times based on four codes preparedness, mitigation, response and recovery.

5.1.3.1 Preparedness

Preparedness for the New Hamburg is monitored by the GRCA and the Township of Wilmot. During the interviews some discussed the various methods used to prepare the community for flooding: *"the township has a preparedness plan that involves the use of sandbags and door knocking, preparing people who will be impacted"* and "*the GRCA releases a flood condition statement and Alert Waterloo Region is a massive notification system, that's text, email, phone, all at once"*.

A risk-based preparedness strategy includes flood forecasting and monitoring in conjunction with structural defences, which overlaps with response strategy that includes evacuation plans and road closures (Driessen et al., 2016; Suykens et al., 2016). This overlap was visible through some interviews that referred to the use of sandbags, door knocking and use of alert system as part of preparedness, which was why this strategy has the second highest frequency count of 34 among other strategies.

Furthermore, in New Hamburg and other parts of Canada, a preparedness strategy has been practiced over decades in form of structural defence control built using the 100-year standard flood statistics (Schanze, Zeman & Marsalek, 2007). The GRCA plays a major role in risk management by providing support through the distribution of a flood preparedness brochure, flood forecasting and flood warning system (Cooke, 2017). The introduction of flood forecasting and flood warning systems as preparedness has initiated the first steps towards the adoption of FRM in New Hamburg (GRCA, 2009). Since these preparedness measures increase the ability of the local government and property owners to respond to flooding, it reduces exposure and vulnerability of people and assets to flooding.

In addition to the discussion on ongoing protocols surrounding preparedness, some participants verbalized the issues with the current preparedness measures being used for the town and how it fails to provide the necessary tools to reduce flood risk. Participants argued that *"the flood preparedness 2009 protocol should be updated because the risk has increased, and sand bagging is not the greatest option"* (Interview 9, 2019) and "*preparing municipal emergency response plans are practical adaptive actions that can be taken to improve preparedness and adaptation for climate change and climate variability*" (Interview 6, 2019).

These quotations align with the reasons why risk-based strategies are needed for flood risk reduction. Due to climate change, weather predictability has decreased and there is an increase in the frequency of severe storms and temperature fluctuations (Heyming, 2014; Birkholz et al., 2014). This change requires preparedness strategies to account for climate variability and the frequency count for this strategy supports the discussion surrounding the adoption of a risk-based approach.

5.1.3.2 Mitigation

The mitigation strategy was mainly discussed as "*homeowners have to assume much greater responsibility for their properties in terms of flood mitigation*". Currently in New Hamburg, the property owners bear the most responsibility to reduce risk, and with outdated flood maps and land-use planning based on hazard policies, there is no presence of an FRM mitigation strategy

(Dransch, Rotzoll and Poser, 2010). However, the emphasis on the need for a mitigation plan was evident throughout the interviews, which led to this strategy's high frequency count of 48.

Mitigation strategy is a strong tool that can be used for flood risk reduction by creating a resilient risk-based land-use planning policy (Burby et al., 2000; Barredo et al., 2007; Drissen et al., 2018). This was confirmed when a stakeholder was asked to discuss the policies that need to be prioritized: *"improving building codes"* (Interview 10, 2019). Such policy is needed because hazard-based solutions are difficult to manage without costly infrastructure (Van Alphen et al., 2009).

The current land-use planning policy in New Hamburg functions as a hydraulic floodway, which is the minimum requirement for a regulatory flood to pass through (GRCA, 2015). The policy states that any obstruction in the floodway could lead to an increase in flood levels and velocities, which is why no new construction is permitted (Moudrak and Feltmate, 2017). Plus, any commercial development and redevelopment located in a SPA will be required to dry floodproof the property and the minimum flood level for these developments need to meet the 1-100-year flood elevation requirements. The acceptable residential building codes are determined by the GRCA, and the existing facilities are not permitted to expand without the approval from the Township and the GRCA. Furthermore, the building permits will not be issued by the Township of Wilmot until the GRCA has approved (Township of Wilmot, 2017). These are GRCA's land-use policies, but majority of the town pre-dates the zoning laws of 1990 (GRCA, 2015), which is why New Hamburg is known as a high-risk community for flooding.

Others, however, expressed concern with the current mitigation strategy by stating that *"there are no simple flood mitigation solutions for New Hamburg. Previous studies have not shown sufficient cost benefit to justify public investment in flood mitigation works"*. The need for risk-based mitigation was supported by some interviewees: "*measures that are feasible and cost effective need to be looked into for risk mitigation"* and "*research in assessing the benefits of flood mitigation to provide a factual account of their effectiveness*".

In addition to the FRM policies of property-level-flood protection and flood risk maps, a risk reduction mitigation policy also includes risk-based land-use planning, which is defined as the assessment of existing land use to identify infrastructure built in high and low risk areas. There are two potential solutions for properties in high risk areas, redevelopment in new low risk zones or purchase of insurance with high premium (Struik et al., 2015).

A risk-based land use policy also entails buying out homes that were damaged in a flood event and moving homeowners to a low risk area (Thistlethwaite et al., 2018; Calamai & Minano, 2017). This policy prohibits development in not only 20-year floodplain but, also 50 to 100-year floodplain to is protect homeowners from future flooding (Thistlethwaite et al., 2018). This change will result in enforcing firm land use planning policies restricting any ongoing infrastructure investments, new private and public assets from building in high-risk zones. The discussion surrounding risk-based mitigation was evident through the frequency count, which was the highest for this code amongst other strategies. However, there was concern regarding the deployment of these methods: *"we need to effectively move quicker to deploy the risk mitigation practices. Challenge is the deployment of practices not the identification of what needs to be done"* (Interview 2, 2019).

To enforce and monitor this regulation, both provincial and municipal governments need to create strict land use planning, zoning and development criteria (Calamai & Minano, 2017). Overall, a risk-based land-use planning policy calls for collaboration between government stakeholders to regulate development practices, ban construction in floodplains, update zoning laws that account for climate change and allot land that allows "safe flooding", which accounts for overflow (Van Alphen et al., 2009).

5.1.3.3 Response

The response strategy for New Hamburg is regulated by the GRCA using the flood warning system and the township acts as a mediator of delivering that information to the community. Several participants mentioned that the "*fire department go door-to-door, delivering the sandbags and warning people when the flood is expected*" and that the "*township is working with the GRCA to take directions from them when there is an issue for flood warning*".

The strategy of response received the lowest frequency count of 10 amongst the 4 strategies because other than initiating evacuation plans, road closures and door knocking to inform the public, not much can be done to stop water from entering the town. This approach relies on risk-based preparedness, mitigation and recovery strategies. The goal is to initiate preparedness during a flood using warning system to inform the community, reduce potential damage by deploying mitigation strategy, and use of flood insurance to recover from flooding. However, the current response strategy fails as there is a lack of implementation of risk-based mitigation and recovery to decrease flood risk (Schanze, Zeman & Marsalek, 2007).

5.1.3.4 Recovery

For recovery, property owners are liable because there is no disaster assistance aid from the government (Butler et al., 2018). However, the frequency of 16 represented that there was a lack of support from some interviewees for this statement because they identified various stakeholders to be responsible for flood recovery in New Hamburg: "*flood recovery is managed by the municipality, the province (Disaster Recovery Assistance Program) and non-government organizations*".

However, since 2011, the liabilities for Disaster Financial Assistance Arrangements (DFAA) program have considerably increased due to numerous weather-related events that led to damage (Fréchette, 2016). DFAA had transferred $280 million to the provinces during 2012-2013 but, the amount increased to $1.02 billion for 2013 – 2014, which was the year of Calgary and Toronto floods (Fréchette, 2016). Due to this increase, the federal government has stepped back from providing financial aid for reoccurring flood events (Butler et al., 2018).

Due to the lack of aid, some respondents vented concern towards the lack of flood recovery: "*flood recovery? There isn't one. There's none. Quite frankly, after the flood happens, the township has no support for the people, the citizens in these areas. We're left to our own devices*". This is unfortunate because the focus of a risk-based recovery policy is to shift away from disaster aid, and move towards (1) reconstructing to build better than pre-flood conditions, (2) relocate to a low-risk zone, (3) encourage property buyouts with government assistance and (4) purchase of

flood insurance (Driessen et al., 2016). But this approach is not practiced in New Hamburg and the low frequency count for this strategy can be explained by the mixed views on liability.

Furthermore, literature recommends that recovery for high-risk areas is first the responsibility of property owners (Butler et al., 2018). This was supported by some respondents: "*flood recovery has been much more individual"* and *"the responsibility is all property owners for finances in case of flooding"*. To accept this responsibility, property owners need to purchase flood insurance and exercise flood risk reduction measures to assist with insurance affordability and availability (Forani, 2019).

However, the market penetration of insurance is limited. This is not only an issue for New Hamburg, but also for rest of Canada, which was emphasized by a stakeholder during the interview: *"having insurance means having money to recover from flooding. However, the current uptake of insurance is approximately 25-30% by homeowners in Canada"* (Interview 2, 2019). The successful use of insurance to reduce risk is practiced in countries like England, Germany and United States to reduce flood risk, which was discussed in chapter 2. The level of responsibility of a property owner to mitigate and recover from flooding is higher than ever before, which leads to the next theme.

5.1.4 Level of Responsibility

The theme of responsibility was evident throughout discussions with stakeholders, which had a total frequency count of 137. The codes that emerged from this theme were property owners, government and real estate.

5.1.4.1 Property Owners

To contextualize property owner responsibility, participants were asked to discuss the roles performed by homeowners, government and insurance towards financial assistance in case of flooding. The majority of participants emphasized that the first step towards managing flood risk is for property owners to accept their responsibility: *"Homeowners have to assume much greater responsibility for their properties in terms of flood mitigation"* and *"the owners have to learn to*

become self-sufficient". This was also evident among the codes, where property owners had the highest frequency count of 75.

Since almost 80% of Canada's disaster assistance costs have been spent on flood recovery (Oulahen, 2014), the federal government will now play a smaller role in providing financial support to Canadians by suggesting the purchase of private flood insurance (Gollom, 2017). In Canada, disaster recovery has now become a shared responsibility between property owners and insurance companies, with more liability on homeowners (Butler et al., 2018). This was supported by some interviewees: *"it's not insurers responsibility to communicate information on flood risk rather it is the property owner's responsibility to ask for that information"* and *"they (property owners) live in a floodplain and should investigate their options for insurance coverage"*.

The current flood management in New Hamburg is provided through berms, flood forecasting, alert system, road closures, door knocking and sandbagging (GRCA, 2009). However, property owners are responsible for signing up for the alert system and being proactive to acquire information on ways to reduce flood risk using the policies that underline mitigation and recovery strategies (Evans & Feltmate, 2019; Forani, 2019; Thistlethwaite et al., 2017; Gollom, 2017).

5.1.4.2 Government

Government's responsibility towards risk reduction was emphasized as a secondary step by the participants, after property owners had implemented the policies of mitigation and recovery. This code had the frequency count of 50, which suggests that multiple stakeholders want the local government to take responsibility for risk reduction: *"primarily the responsibility is all property owners for finances in case of flooding"* but, *"there is a part that municipality plays because they allowed this place to be built, the municipal government needs to work with homeowners on the mitigation strategies"*, which is why *"the government needs to step in"*.

Despite the role local government should play, as suggested by some participants, the change in disaster assistance policy is focused on reducing financial exposure of government funding by transferring responsibility to property owners (Henstra & Thistlethwaite, 2017a). These changes include higher expense thresholds for federal disaster assistance, tightened guidelines for

provincial disaster assistance, renewed public education efforts, and funding for flood maps, risk assessments and small structural protection projects to mitigate flood damages (PBO, 2016; Henstra & Thistlethwaite, 2017a). Additionally, the availability of disaster assistance through federal government lacks legitimacy because the primary goal of the NDMP established by the Government of Canada is to fund efforts that will promote mitigation strategies, which will increase the accessibility to private insurance for flooding (Henstra & Thistlethwaite, 2017a; Public safety Canada, 2017).

However, the residential flood insurance has become a method to avoid some expense of disaster assistance and means to mitigate the rising pressure on DFAA (Henstra & Thistlethwaite, 2017a). Furthermore, disaster aid is only available if the owner's existing insurance policy does not cover damage from a disaster (Government of Ontario, 2018; Suykens et al., 2016). Even then, government will only assist with unpredictable and irregular flood events (Ministry of Municipal Affairs and Housing, 2018). However, the flood events in New Hamburg are not irregular, some stakeholders stated that *"part of the eligibility for this funding was that it has to be an unusual flooding occasion or occurrence but, flooding from Nith River is not unusual"*. This further confirmed that pay outs from the government are only a hazard-based solution, whereas, risk-based solutions like property-level-flood protection or flood insurance are needed.

5.1.4.3 Real Estate

Real estate, which was also identified by some respondents, plays a key role in reducing flood risk, but had a low count of 12 in this study. The frequency count for this code is lower than other codes, but it shows that some interviewees expect real estate brokers to take the responsibility of informing buyers of latent risk. Some participants argued that "*real estate should declare that the houses are in floodplains. For people coming from outside the town they might not know when they're going to get flooded. It's the real estate's responsibilities. Let people know there is risk"*.

Although there is an obligation to disclose flood information by the seller, it is not mandatory for property owners to legally disclose information regarding flood risk to the potential buyers (Henstra & Thistlethwaite, 2018; Kyriazis and Zizzo, 2015). The reason is not ignorance, but lack of awareness (Henstra & Thistlethwaite, 2018). However, flood risk reduction is a shared

responsibility that requires collaboration between all levels of stakeholders, which includes real estate brokers.

5.1.5 Challenges

During the interviews multiple challenges were mentioned that are causing hinderance towards the adoption of FRM strategies and policies. The main challenges that were mentioned during the interviews had a total frequency count of 122. The codes that represented this theme were lack of funding and lack of awareness.

5.1.5.1 Lack of funding

Multiple research articles have emphasized lack of funding as a deterring factor for local governments that want to adopt risk-reduction methods (Waylen et al., 2018; Ouikotan et al., 2017; Thaler et al., 2019). This code had a frequency count of 85, which shows that several stakeholders expressed concern surrounding the lack of funding for mitigating flood risk: "*there is no dedicated/targeted federal or provincial funding for flood mitigation works; therefore, flood mitigation funding has to compete with other township projects"* and *"currently, there is no dedicated funding for flood mitigation works"* but, *"there is a need for dedicated provincial /federal funding to map flooding, complete flood damage assessments and provide directed funding for flood mitigation"*. Furthermore, these funding challenges can prolong the efforts of updating flood maps and also lead to limited or deferred maintenance and/or upgrades to structural defences (Ouikotan et al., 2017), which has been the case for New Hamburg (Thomson, 2017).

Furthermore, some respondents stressed the need for research funding because *"research assessing the benefits of flood mitigation is needed"*. Funding cutbacks on research and risk reduction programs can contribute to an increase in flood risk, which was unfortunately issued for multiple CA's in Ontario, where flood management funding was cut in half in 2019 (CBC News, 2019; TheReview, 2019). Furthermore, the recent report on the "independent review of the 2019 flood events in Ontario" recommended that the province should maintain, at a minimum, the current level of funding in departmental budgets and programs related to everything flood (McNeil, 2019). However, flood risk reduction measures such as updating flood maps and promoting mitigation strategies all require funding to commence. Lack of funding, however, can

be addressed through the increase in awareness towards flood risk reduction measures that can be practiced using FRM strategies and policies.

5.1.5.2 Lack of awareness

Lack of awareness regarding flood risk reduction methods poses a great threat for the town of New Hamburg, which was indicated by the frequency count of 37. This gap was highlighted by several stakeholders: "*the first challenge is public's lack of knowledge, awareness and their expectations"* and *"there is an overall lack in awareness about prevention, mitigation and even recovery methods"*.

Lack of awareness is a major contributor to increasing flood risk not just for New Hamburg but also Canada more broadly (Bosanac, 2017; White, Kingston & Barber, 2010; McClearn, 2019). A national research survey polled 2300 Canadian property owners living in high-risk flood zones and found that only 6% knew they were living in high risk areas (Thistlethwaite et al., 2017a; CBC Radio, 2017). This was confirmed by a stakeholder: *"there are the new residents who don't know that they live in a flood zone"* (Interview 14, 2019).

Public awareness regarding flood risk reduction needs to be addressed through the use of social media (Amour-Gomes, Heldsinger & Peddle, 2018), which was supported by some respondents: *"due to social media the mapping has become more accessible"*. Flood maps can be used an effective tool to communicate risk to raise public awareness (Dransch et al., 2010). This includes tailoring flood maps for specific audiences, pairing flood maps with local historic flooding and community information, providing and promoting interactive online flood mapping and property-specific mapping services, supplying flood maps with information about flood impacts and tangible protection measures, and using cartographic features to simplify and support explanations (Minano & Peddle, 2018).

Furthermore, risk awareness can also be increased through the use of outreach programs, infographics and collaborative information seminars that involve CA's, provincial and local government, insurance industry, businesses, real estate agencies and property owners (Amour-Gomes, Heldsinger & Peddle, 2018). The interviews did highlight that the GRCA and the

Township of Wilmot are encouraging this approach through community outreach programs: *"the township staff and GRCA worked collaboratively to put together an open house with information for residents of New Hamburg"* but some interviewees argued that *"there's a lot of information that can be shared, but it's not being shared"*.

Lastly, another challenge that was mentioned by only one stakeholder as lack of awareness was the increase in mental health problems during and after a flood event: *"Mental health damage is overlooked because quantifying a disaster is easier than understanding the qualitative damage flooding can cause"* (Interview 1, 2019). This was supported by research of the Intact Centre on Climate Adaptation (ICCA) that, 47% of household members in Burlington, Ontario dealt with mental stress within the first 30 days of being flooded and 48% property owners were concerned of being flooded during a rain event (Decent & Feltmate, 2018). However, due to lack of research this is an ongoing concern that needs to be addressed.

Overall, all code and theme counts indicated uncertainty over the use of FRM. Stakeholders are using a diversity of strategies to deal with flood risk but are only adopting a few select FRM methods and if the approach is being used, the stakeholders remain informed by the hazard-based approach. In particular, stakeholders emphasized preparedness as one area of activity supporting risk reduction. Similar inconsistency with policies trying to enforce FRM can be found in other communities in Canada like Halifax, because, each province has its own definition of risk management and various ways to regulate policies (Sandink & ICLR, 2013; Sandink et al., 2010; Thistlethwaite et al., 2018). Such inconsistency also exists amongst local authorities and insurance companies as they deliver flood protection and disaster assistance information (Sandink & ICLR, 2013).

5.2 Flood Mapping and Analysis

Based on the above results, which revealed partial adoption of FRM strategies, it is important to understand how risk information is being used to design flood policy in New Hamburg. An evaluation of flood mapping offers an effective way to measure the use of risk information in New Hamburg's flood management strategy, which is identified in the literature review as an important indicator of the adoption of FRM. To inform this analysis, GRCA and insurance flood maps were

generated to explore the differences in the use of risk information. The GRCA map uses hazard information to inform its floodplain designations and the insurance map is designed to support flood risk management.

First, GRCA maps were created using Grand River Information Network (GRIN), which shows the Nith River flowing through the town of New Hamburg and the boundary of the regulated 100-year flood zone (Figure 10). Based on the definition of "one and two zone" policy (see section 4.2.1), which is the entire floodplain, a statistical analysis conducted in ArcGIS found that there are approximately 230 properties located in the floodplain. The map also illustrates the location of SPA's in New Hamburg. However, the mapping data on the zoning by-law that divides the floodplain into floodway and fringe was inaccessible by the public.

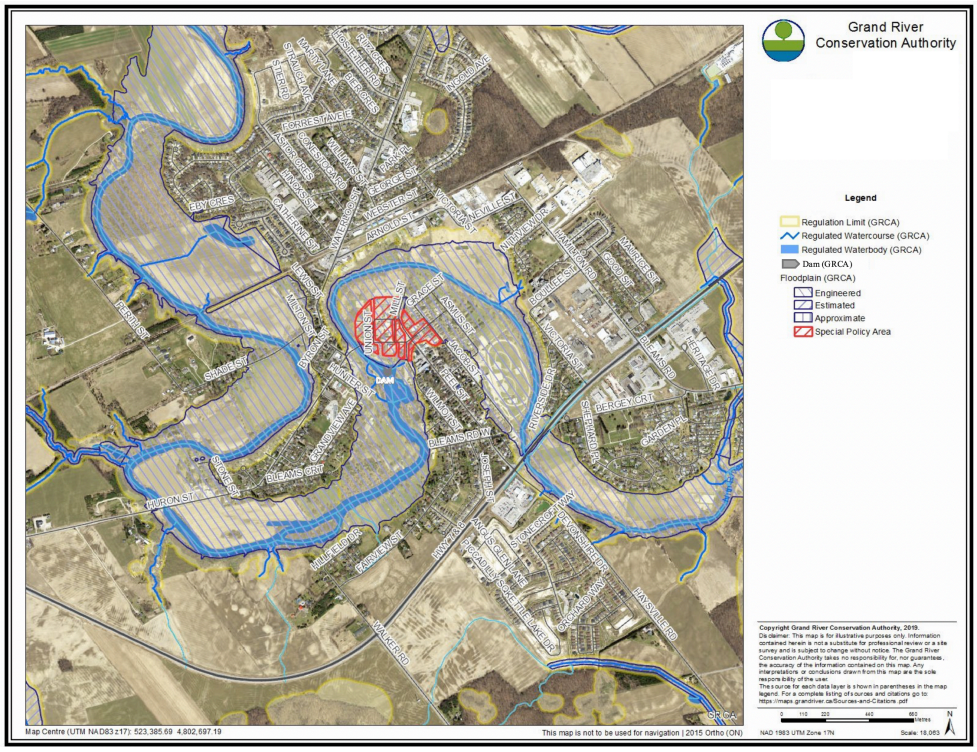

Figure 10: Nith River floodplain map generated using Grand River Information Network (GRIN) online database for 2018. The regulated area is outlined in purple by the Grand River Conservation Authority to delineate the 100-year flood zone. Special Policy Areas are in red and situated in the center of New Hamburg (GRIN, 2018)

Second, an insurance flood map for New Hamburg was created in ArcGIS using flood maps obtained from JBA Risk Management (Figure 11 A). Using the overlay toolset in ArcGIS

approximately 287 properties were identified that are located in the floodplain. In contrast to the GRCA flood map, a total of 57 properties outside the GRCA's regulated floodplain were identified at risk by the insurance map, which is approximately a 25% difference (Figure 11 B).

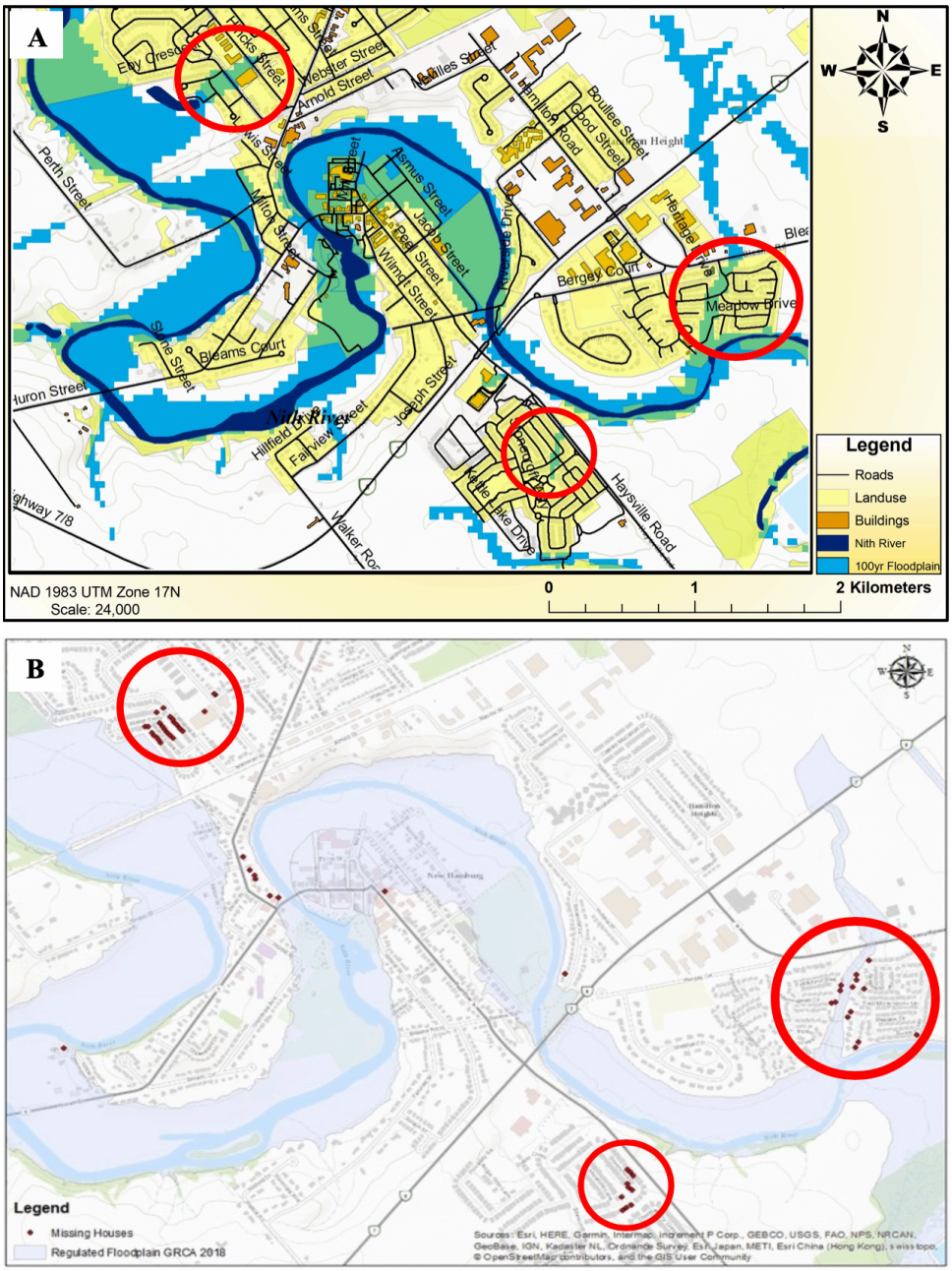

Figure 11: (A) New Hamburg insurance flood map created in ArcGIS using JBA Risk Management's Canada Flood Map, showing the extent of flooding with a return period of 100 years. The red circles show the extent of water damage to properties at risk that is not highlighted in the GRCA map. (B) Insurance map illustrating New Hamburg properties in red at risk of flooding unaccounted for in the existing GRCA map. The red circles in map A and B, show the properties at risk of flooding.

These map comparisons revealed that there was an inconsistent delivery of risk information, which is a concern because the insurance map identified some properties in the high-risk flood area, while the GRCA map did not. This gap can be explained by the base statistics used to create each map. GRCA and other CA's currently use the 100-year flood statistics, which is based on a single return period to delineate the floodplain (GRCA, 2009; McMullen, 2015). The GRCA maps can be unreliable because they are based on a historical return period, which fails to account for current flood map, which includes risk (Kharin et al. 2007; Kharin and Zwiers, 2005). However, the insurance map includes data for multiple return periods and velocities (JBA Risk Management, 2019a; Flood Resilience Portal, 2018). Due to these differences, the floodplain and flood information is viewed differently between these sectors. GRCA uses risk information to shape strategies for risk reduction and filter that information down to the community, whereas, an example of insurance use of risk information is to perform loss analysis (Kron, 2002). This inconsistency is evidence of partial adoption of FRM in New Hamburg because government flood maps do not incorporate risk information.

This reflects a broader problem in all of Canada. For example, in Halifax, Nova Scotia, research was conducted using geospatial analysis to create a flood risk map for Halifax Regional Municipality. The study found 1300 residential properties at high risk that were unaccounted for in existing hazard maps (Figure 12) (Thistlethwaite et al., 2018). However, this information was found using insurance data that is unavailable to the public, which creates flood risk uncertainty.

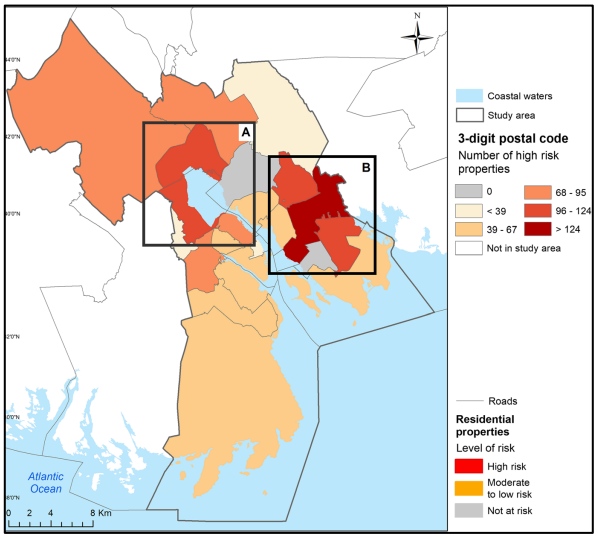

Figure 12: Spatial distribution for residential properties at risk of flooding in parts of Halifax Regional Municipality (Thistlethwaite et al., 2018)

It is unfortunate these maps are inconsistent for the following reasons (Nones, 2016; Meyer et al., 2012; McClearn, 2019):

1. Increase in uncertainty regarding exposure and vulnerability
2. Delivery of inconsistent risk communication between government and property owners
3. Unreliable information regarding the location of risk zones, which increases uncertainty for property owners interested in buying flood insurance

This is problematic because of the recent changes in Canadian disaster assistance policy limiting the availability of financial aid now that flood insurance is available. Without a map showing risk, people are unlikely to purchase insurance and may be unaware that they will not receive disaster assistance. However, their decision-making is compromised due to irregular flood mapping.

Flood maps can be used to encourage conversation amongst decision-makers and communities because there is a direct correlation between the notion of visualization and behaviour change (Broad et al., 2010). So, through visual risk communication, improvements can be made to increase risk awareness, and enhance GRCA/Township and public relationships (Charrière et al., 2012).

This inconsistency has been addressed in other countries such as England, Germany and the United States through flood map standardization, where property owners can use government websites to assess a property's susceptibility to flooding by entering a postal code (McClearn, 2019) (Fig 13).

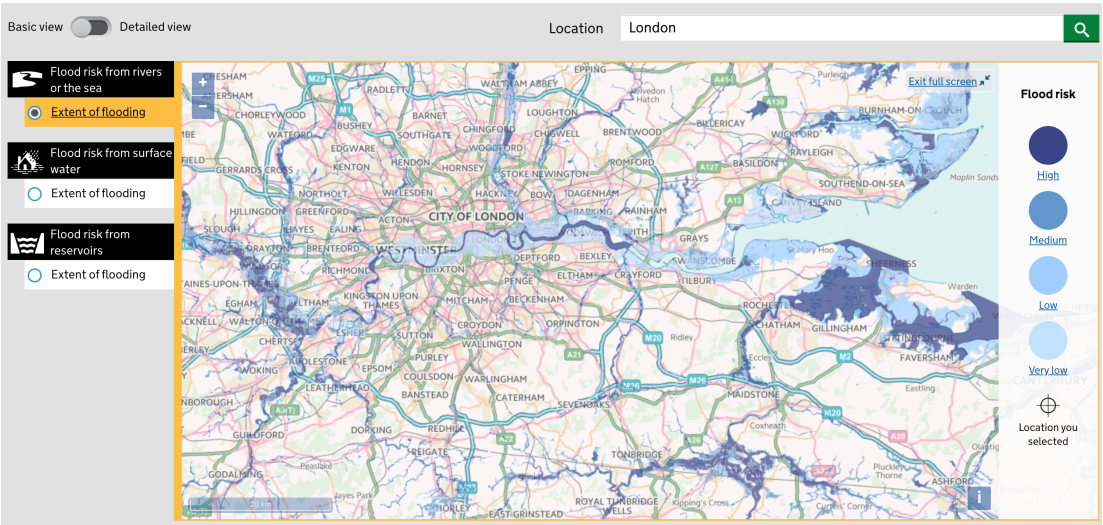

Figure 13: Screenshot of the flood warning service provided by England for the City of London, which allows the owner to identify the level of flood risk for their property (Flood Hub, 2019)

Flood maps have been proven to be of value in England and Germany, where information campaigns were organized to increase public awareness regarding flood mitigation efforts at property-level to encourage purchase of private flood insurance (Klijn et al., 2008; Minano & Peddle, 2018). Flood risk maps were used to share information with stakeholders and the general public for a better understanding of flood risk (Müller, 2013).

5.2.1 Flood Insurance Premium Analysis

To further understand how risk information is being used in New Hamburg to design flood policy, the GRCA and JBA insurance maps were used to select properties at random to obtain annual premium information. Consistency between the GRCA and JBA maps would reveal that premiums are high in the areas where the GRCA has identified significant risk, and low in areas where deemed less at risk. To conduct this analysis, premiums for properties located in the flood zone levels 1 to 4 (Figure 14) of New Hamburg were acquired from a local insurance broker (Figure 18). GRCA has defined zone 1 to represent the highest risk, whereas zone 4 represents the lowest risk (GRCA, 2009) (Figure 14).

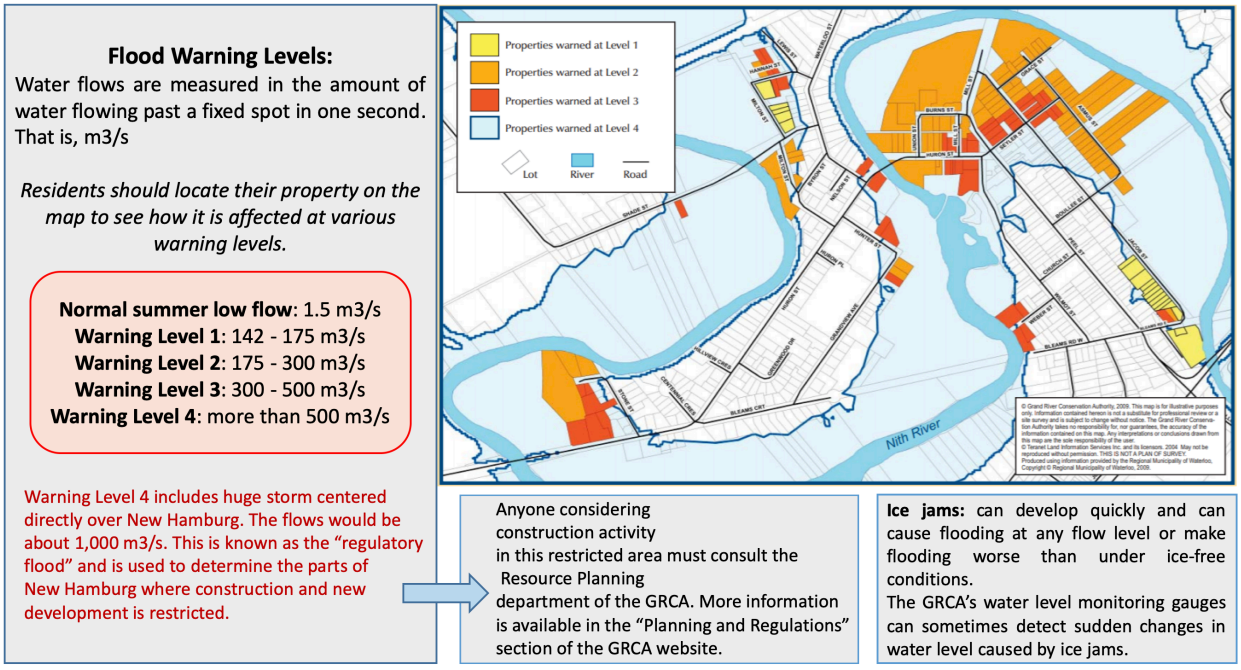

Figure 14: GRCA's flood map for New Hamburg, illustrating regulatory flood lines and warning levels. Flood zone 1 is in yellow, flood zone 2 is in orange, flood zone 3 is in red orange and flood zone 4 is in blue (GRCA, 2009).

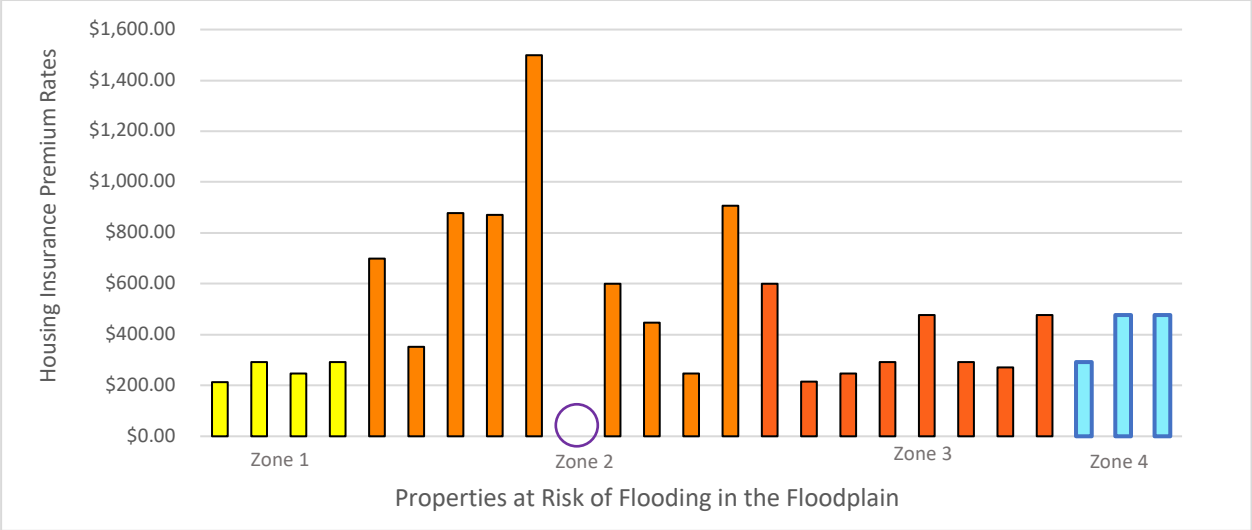

Figure 15: Premium rates acquired from a local New Hamburg insurance broker for 25 out of 230 houses located in floodplain regulated by GRCA. Yellow represents flood zone 1, orange is zone 2, red orange shows zone 3 and blue represents zone 4. Out of the 25 properties, one property was denied insurance coverage, which is marked using purple circle. *Note: Property information has been removed from the x-axis due to privacy*

First, 25 properties were selected at random out of 230 houses found in the floodplain using the GRCA map. The premium data showed the highest insurance cost for a zone 2 property ($1500) (Figure 15). This is more than twice as high as the average cost of flood insurance at $700 in United States (ValuePenguin, 2019). The lowest premium cost was found in zone 3 ($215), with one property that was fully denied any coverage (Figure 15). The results revealed an inconsistency between insurance premiums and risk predicted by the GRCA. The premium values for the 25 properties indicated a non-linear regression. Premiums were the highest in zone two and somewhat higher in zone three and four than zone one whereas they should have gone down across each risk zone creating a linear regression (Figure 15).

An external factor that could have influenced the premiums is the property value. Since the cost of insurance is based on risk, a high property value would require more coverage for recovery, making this a limitation of the research. However, some interviews and research articles highlighted that these properties have a coverage limit of $10,000, which controls for any influence of property values since the coverage is standard across each property (McNeil, 2019).

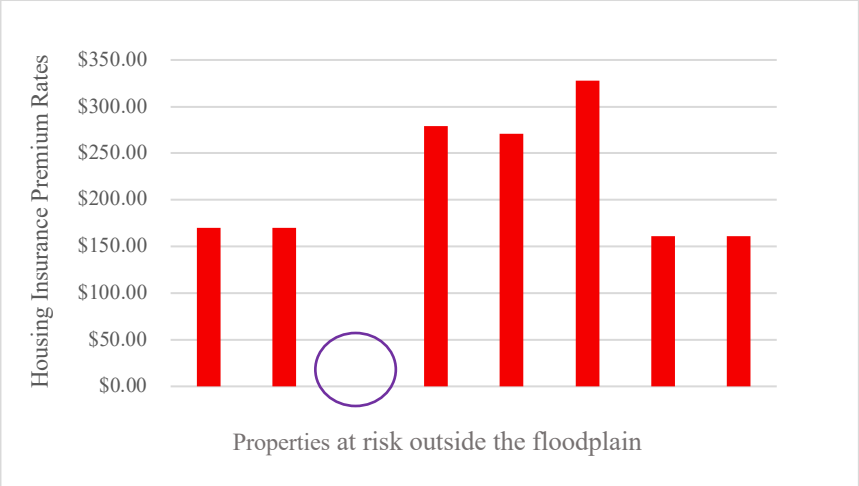

Figure 16: Premium rates acquired from a local New Hamburg insurance broker for 8 out of 57 houses located outside the floodplain regulated by GRCA. These properties were found at risk using the JBA Risk Management database. Out of the 8 properties, one property was denied insurance, which is marked using purple circle. *Note: Property information has been removed from the x-axis due to privacy*

Second, coverage rates were also obtained from the same insurance broker for 8 out of 57 properties located outside the GRCA flood zone, which were identified at risk according to insurance. The highest premium rate was $327 and the lowest was $161 (Figure 16). However, 1 out of 8 properties was fully denied any coverage because of high-risk. Although this is a very small sample, this raises a concern regarding the identification of properties at risk outside the floodplain, which might not qualify for flood insurance. This shows discrepancy of flood mapping techniques between the two stakeholders. In addition, insurance maps are unavailable to the general public, so the 57 property owners are unaware of this risk.

One of the reasons why the insurance map is not available is concerns over privately-owned risk information. The unavailability of insurance map information was explained by a respondent that "*the insurance companies have spent a lot of money on their proprietary rating services*" because sharing the data would mean that *"you've lost your competitive advantage"* (Interview 11, 2019). These concerns for proprietary data are unfortunate because the community is missing an important economic signal with consequences. The effects of CA's and insurance companies not collaborating together include: the lack of access to risk information for public, flood map inconsistencies and possible encouragement of development in areas without access to insurance.

Furthermore, instead of just providing funding for recovery, insurers have an opportunity to increase risk awareness, which in return will reduce risk for both insurers and property owners. Since the insurance premiums are based on risk, if the overall risk is reduced through the promotion of policies like risk-based land-use planning and property-level flood protection, then affordable coverage can be purchased (Insurance-Canada, 2019). Although one can argue that similar to structural defence, the ownership of flood insurance can lead to a false sense of security because of decreased level of vulnerability. But insurance is a powerful motivator for property owners to reduce FR through mitigation strategies. The tactic to this objective is a deductible, which is the amount paid by an insured to a loss after flood event and it can also assist in reducing insurance premiums (Kron, 2002).

Overall, the analysis of the use of FRM strategy and information in New Hamburg reveals the following. First, there is evidence that stakeholders support and embrace a diversity of strategies. But adoption of risk in these strategies is uneven. For example, there is an emphasis on preparedness through flood forecasting and warning rather than just relying on structural defenses. Insurance is also available as a recovery strategy, but it is not widely available, and most stakeholders consider disaster assistance the main approach to recovery. Furthermore, there is also a recognition that non-structural approaches need to be expanded and strengthened. However, stakeholders identified a lack of funding as a major challenge limiting the implementation of this strategy.

Second, insurance companies are using risk information to design flood maps, whereas government flood maps are informed by hazard-based data, which is evidence of partial adoption of FRM. The geospatial results indicated that outdated and inconsistent flood maps have been used to design the flood policy for New Hamburg. Inconsistent flood maps are a concern because it limits awareness, incentives to purchase insurance and design flood mitigation policy. This is problematic particularly for property owners because they are unable to differentiate between high and low risk zones, limiting their motivation to purchase insurance. Based on these inconsistences it can be determined that there is a lack of coordination between government and insurance, which is required to implement FRM strategies.

Chapter 6: FRM Adoption and Research Limitations

6.1 Steps to Adopting FRM and Challenges

The above results indicate that there is a partial adoption of FRM strategies in New Hamburg and risk information is only being used only by insurers to design flood insurance policies. Additional collaboration between all levels of government and the insurance industry is necessary to share information on flood risk through mapping, which will assist in designing effective flood policy (Hodgson, 2018). This strategic framework involves flood risk analysis and characteristics such as the:

1. Probability of occurrence and consequences of flood events are evaluated to develop and compare different risk controls;
2. Technological, social, economic and institutional measures are used to decrease and share flood risk responsibility;
3. Recognition that there is no absolute protection plan so, framework focuses on building resilience in all aspects of design;
4. Responsibility of risk and finance is shared amongst all levels of stakeholders;
5. Information is communicated openly between decision makers and the general public related to community's risk from flooding, which further supports risk reduction, and;
6. Restrict the rebuild of properties damaged by flooding and relocate them to a low risk zone (Henstra and Thistlethwaite, 2017a).

Furthermore, updating flood maps should be CA's the first step in designing a flood policy because it is used to inform FRM strategies and policy instruments. The cost of updating flood maps, map maintenance, and conversion to new standards do not outweigh the benefit of reduction in damage (Skinner, 2005). Accessibility to accurate risk maps for the public is crucial in order to provide a consistent flood map information (Michel-Kerjan and Kunreuther, 2011). Accurate maps and flood risk products can assist with land-use planning and development decisions by highlighting areas of high-risk in need of mitigation (FEMA, 2019a). The lack of information, however, on flood data needed to update has impeded the Government of Canada to renew the maps (Thistlethwaite et al., 2018). For example, a 2017 report by Ganaraska Region identified an absence of flood data

that is needed to update the flood maps. The report explained that the only flood data that is available for floodplain mapping is based on the 100-year flood event. There is lack of information on a flood event greater than those statistics (Ganaraska Region, 2017; McMullen, 2015).

Risk maps, however, can be used to identify flood zones with high residential property density exposed to flooding. This information can promote flood risk reduction measures, which will assist with insurance affordability. To ensure flood insurance affordability four standards can be applied: the first standard for insurer must be to accurately price the probability of a flood event and flood damage. The second standard would allow affordable premium pricing as long as it reimburses the insurer for its costs. The third standard is that premiums would be priced to ensure modest profit for the insurer for supplementary assumed risk. Lastly, the fourth standard would encourage policyholders to adopt risk-mitigation measures through premium pricing (Nadarajah, 2016).

Additionally, the residential owners who are unable to purchase or afford insurance, which accounts for approximately 5-10% of properties in Canada need to educate themselves with options that are available through the provincial government and flood mitigation plans (Thistlethwaite et al., 2018; Calamai & Minano, 2017). For example, property-level-flood protection measures can be used to reduce risk, which will assist with flood insurance availability and affordability (Amour-Gomes, Heldsinger & Peddle, 2018; Nadarajah, 2016). A full adoption of FRM, however, requires property owner engagement and willingness to commence protective behaviour. From recent policy change in Canada regarding disaster assistance, which has assigned more responsibility to homeowners, it is unclear if residents accept this obligation (Henstra et al., 2017).

The new maps, however, could cause fluctuation in real estate values by categorizing homes in floodplain that were originally omitted and potentially devaluing them (Horn and Webel, 2019a). To promote FRM risk awareness, property sellers should declare a property's flood vulnerability as part of the real estate advertisement. This will also encourage the homeowners to adopt flood mitigation measures as a means to increase the property value (Klijn, et al., 2008; Mees et al., 2016; Raadgever & Hegger, 2018). Despite the controversy that updated floodplain maps may cause, accurate flood risk maps are essential for flood risk reduction (Insurance Business, 2017).

On a positive note, the Canadian government has recommended that the most efficient flood management involves proactive prevention and mitigation measures that eliminate, reduce or adapt to risk (Public Safety Canada, 2019a). This management includes both structural measures such as, construction of floodways and berms and non-structural mitigation methods like building codes, land-use planning and insurance incentives (NDMP Guidelines, 2016; Contant, 2019). The return on these investments, while subject to the disaster type and location, would produce a savings of $6 for every $1 spent on prevention, which is why building back better strategies need to be promoted (Lightbody & Fuchs, 2018). Previously, government aid has provided compensation to the property owner to return the property to its basic functions and cannot be used to make improvements (Ministry of Municipal Affairs and Housing, 2018). To become a risk-based disaster assistance, incentives should be provided to "build-back-better". To increase awareness among homeowners about flood risk, the Canadian government is also working with real estate and insurance industries (McNeil, 2019).

A limitation, however, that needs to be recognized by the general public regarding FRM is that these strategies are ways to reduce flood risk and not eliminate flooding. To diminish flood risk, federal and provincial governments needs to step in and assist high-risk communities with property buyouts (Driessen et al., 2016). The practice of these policies is not new, but the lack of data, research and funding makes it challenging to suggest re-zoning and property buyouts. For example, governments of Alberta and Nova Scotia offered to purchase severely damaged homes and relocate the owners to low risk areas. This approach is effective and should be managed through an intergovernmental effort because local municipal governments are unable to buy out properties themselves (Thistlethwaite et al., 2018).

Chapter 7: Conclusion, Limitations and Future Recommendations

7.1 Conclusion

Flood risk in Canada continues to increase due to population growth, urbanization and climate change. The current flood management system is rooted in hazard-based policies to reduce flood damage. The reliance on structural defences fails to manage flooding because the infrastructure was built based on a single return period, which is the 100-year flood. The use of infrastructure has been used as a leeway to allow development in floodplains. Past flooding and damage caused by failure of flood control methods increased the need for government funded disaster assistance, which led to payouts that were unsustainable. In response, the Canadian government has shifted its approach to Flood Risk Management. FRM uses a risk-based approach, which accounts for exposure and vulnerability of people and assets to flooding. It uses a diversity of strategies and policies to reduce risk.

The purpose of this research was to evaluate the adoption of FRM strategies and policy instruments in efforts to reduce flood risk in Canada. To achieve this objective, the following questions were used to shape the research:

1. How is flood risk management used to reduce flooding in high risk areas?
   1c. What flood risk management strategies are used in Canada?
   1d. How is risk information being used to design flood policy?

To answer these questions, the research conducted a case study in New Hamburg, ON to analyze the adoption of a diversity of strategy and investigate the use of risk information to design flood policy.

This study conducted 14 semi-structured interviews and geospatial analysis. Upon the evaluation of results the paper concluded that New Hamburg is not currently practicing the FRM strategies with the exception of preparedness. The interview analysis showed that there is no government support for mitigation solutions, except for the promotion of property-level-flood-protection. The interviewees identified that the property owners rely on government disaster aid after a flood event

as a form of recovery, while having a goal to build back to pre-flood conditions. The analysis also showed a high amount of insurance uncertainty surrounding its affordability and availability for properties in high-risk zones. Furthermore, the flood maps available for the public to identify if they are located in a high-risk area are also based on the historic flood mapping model. These results show that most flood management practices in New Hamburg are rooted in hazard-based flood management.

To reduce flood risk, a diversity of FRM strategies should be promoted. In Canada, preparedness and recovery strategies are used to support FRM, but these strategies remain mostly informed by hazard-based approaches. Moreover, FRM requires the use of risk information to design flood policy. Insurers, however, are the only stakeholders using this approach, whereas, other policymakers are not informed with risk information.

In conclusion, based on the assessment of FRM in New Hamburg, there is a partial adoption of FRM in high-risk areas because the diverse strategies used by the Canadian government does not incorporate risk information. This lag in adoption reflects the lack of coordination between stakeholders (government, insurance and public) that is needed to organize the implementation of the diversity of FRM strategies.

7.2 Research Limitations

In terms of results, the shortcomings of using a qualitative approach is that the quality of analysis is heavily contingent on the individual skillset of the research. Qualitive research is useful for understanding problems encountered by a community, however, this method is also more prone to a researcher's personal bias compared to a quantitative approach (Anderson, 2010). For example, for the semi-structured interviews conducted in this research, the meetings were guided by a predetermined set of questionnaires. Due to this, some aspects of a participant's perspective could have been missed. Additionally, the research findings were also limited due to the small sample size, which affected the generalization of the data.

For the second part of results, that analyzed flood mapping and insurance, the study was limited in gathering flood map database from GRCA because of inaccessibility. Due to this restriction, it

was challenging to determine risk measuring factors such as age of infrastructure and categorize the four flood zones in the floodplain for the maps generated for this research. Furthermore, the data collected for 33 properties to inquire about insurance premiums was a small sample compared to the 287 properties that are located in the floodplain. This limitation occurred due to time constraint and because it was voluntary data. Additionally, since properties were chosen at random, zone 1 properties could be considered an outlier because the premium values were lower than properties zone 2. Since the flood warning zones were assigned based on level of risk, further research and premium inquiry for all properties located in zone 1 – zone 4 is required for a full analysis.

Overall, the focus of this research is a small-town community and although it floods annually, it does not fully represent the issues a larger city such as Toronto might face during a flood event. Also, GRCA is known for being proactive with watershed management and is one of the larger CA's in Ontario. However, such is not the case for other small-town communities that are managed by small CA's.

7.3 Future Research Recommendations

The analysis in this paper recommends the following projects for future research. First, a research study exploring how stakeholders collaborate to support FRM involving both insurance and government officials is needed. This research will be used to analyze flood risk governance in Ontario and assess the legitimacy of transition towards FRM strategies.

Second, Government of Ontario and the CA's need to implement FRM strategies and policies needed in other towns located in the GRCA watershed that are struggling with flood risk, such as Paris and Brantford. To assess flood management practices, similar case studies need to be conducted in other communities, cities and provinces dealing with flood risk.

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Appendix 1: Ethics Approval

Renewed application # 30891 has ethics clearance

Subject: Renewed application # 30891 has ethics clearance
From: Kuali Notifications <no-reply@kuali.co>
Date: 2019-04-23, 11:59 a.m.
To: dhenstra@uwaterloo.ca

Dear Daniel Henstra and other members of the research team:

Your application has been reviewed by Delegated Reviewers. We are pleased to inform you the **Renewed application for 30891 Municipal Policy Capacity in Canada** has been given ethics clearance.

This research must be conducted in accordance with the most recent version of the application in the research ethics system and the most recent versions of all supporting materials.

Ethics clearance for this study is valid until Monday, July 13th 2020.

The research team is responsible for obtaining any additional institutional approvals that might be required to complete this Expedited study.

University of Waterloo Research Ethics Committees operate in compliance with the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), Internalization Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), and the applicable laws and regulations of the province of Ontario. Both Committees are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (Human Research Ethics Committee) and IRB00007409 (Clinical Research Ethics Committee).

Renewal: Multi-year research must be renewed at least once every 12 months unless a more frequent review has been specified on the notification of ethics clearance. This is a requirement as outlined in Article 6.14 of the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS2, 2014). The annual renewal report/application must receive ethics clearance before Sunday, June 21st 2020. Failure to receive ethics clearance for a study renewal will result in suspension of ethics clearance and the researchers must cease conducting the study. Research Finance will be notified ethics clearance is no longer valid.

Amendment: Changes to this study are to be submitted by initiating the amendment procedure in the research ethics system and may only be implemented once the proposed changes have received ethics clearance.

Adverse event: Events that adversely affect a study participant must be reported as soon as possible, but no later than 24 hours following the event, by contacting the Director, Research Ethics. Submission of an adverse event form is to follow the next business day.

Deviation: Unanticipated deviations from the approved study protocol or approved documentation or procedures are to be reported within 7 days of the occurrence using a protocol deviation form.

Incidental finding: Anticipated or unanticipated incidental findings are to be reported as soon as possible by contacting the Director, Research Ethics. Submission of the incidental findings form is to follow within 3 days of learning of the finding. Participants may not be contacted regarding incidental findings until after clearance has been received from a Research Ethics Committee to contact participants to disclose these findings.

Study closure: Report the end of this study by submitting a study closure report through the research ethics system.

Coordinated Reviews: If your application was reviewed in conjunction with Wilfrid Laurier University, Conestoga College, Western University or the Tri-Hospital Research Ethics Board, note the following: 1) Amendments must receive prior ethics clearance through both REBs before the changes are put in place, 2) PI must submit the required annual renewal report to both REBs and failure to complete the necessary annual reporting requirements may result in Research Finance being notified at both institutions, 3) In the event that there is an unanticipated event involving a participant that adversely affects them, the PI must report this to both REBs within 24 hours of the event taking place and any unanticipated or unintentional changes which may impact the research protocol shall be reported within seven days of the deviation to both REBs.

Initial application ethics clearance notification: Your clearance notification will be added to the record within 24 hours. Go to "View Admin Attachments" in the research ethics system (right-hand side) to print a copy of the initial application ethics clearance notification.

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Best wishes for success with this study.

If you have any questions concerning this notification, please contact the Research Ethics Office or email researchethics@uwaterloo.ca.

Appendix 2: Information and Letter of Consent for Interview

Title of Study: Understanding Flood Risk Management Through the Application of Overland Flood Insurance in New Hamburg

Principal Investigator: Divya Softa, Candidate of Master of Environment Studies
School of Environment, Enterprise and Development,
University of Waterloo
Phone: (519) 505-6803
Email: dsofta03@gmail.com

To help you make an informed decision about participation, this letter will explain the study, the possible risks and benefits, and your rights as a research participant. If you do not understand something in the letter, contact the Principal Investigator before consenting to the study. You will be provided with a copy of the information and consent form if you choose to participate.

You are invited to participate in a research project that is investigating the role of government and insurance involved in managing flood risk in the town of New Hamburg, which has experienced flooding on multiple occasions. Flood risk management (FRM) involves strategies to reduce the vulnerability of people and property by strengthening resilience to flood-related stress. This requires supportive governance arrangements that coordinate responsibilities between stakeholders, increase risk awareness, and align efforts. The objectives of this project are to:

- identify the effects of transitioning towards the adoption of FRM in New Hamburg;
- study the impacts of overland flood insurance and how it has changed the perception towards key policies of preparedness, mitigation, prevention and recovery;
- use open source Grand River Conservation Authority (GRCA) flood maps and insurance flood maps derived using JBA Risk Management data to understand New Hamburg's flood risk exposure, including the impacts of riverine and pluvial flooding; and
- assess the flood insurance market to identify the alignment of risk pricing with existing publicly available flood maps; and
- engage target audiences in knowledge exchange to identify the level of responsibility each stakeholder should have before, during and after flood events.

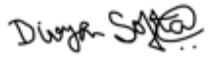
Your participation in the study will involve an interview of approximately 45 minutes, to take place by telephone or at a mutually agreed upon location. Interview questions will focus on topics such as the transition to FRM, role of overland flood insurance, standardization of flood risk maps, insurance affordability and stakeholders involved in FRM. With your permission, the interview will be audio recorded to ensure accuracy. Your participation in this study is voluntary. You may decline to answer any questions you prefer not to answer, and you may end the interview at any time. The study will benefit society by identifying the need for a new approach to flood management, and the responsibilities different stakeholders play to decrease flood vulnerability. There are no known or anticipated risks associated with participation in this study.

Your participation will be considered confidential. Your name will not be included in any paper or publication resulting from this study. With your permission, however, you may be referenced by your job title (e.g., "a municipal policy analyst") and anonymous quotations may be used. Identifying information will be removed from the data that is collected and stored separately. Study records will be retained for a minimum of 7 years on a password protected computer. You may withdraw your consent to participate and have your data destroyed by contacting the researcher within this time period. Please note that it is not possible to withdraw your data once papers are submitted for publication. Only those associated with this study will have access to these records. All records will be destroyed according to University of Waterloo policy.

This study is funded by the Marine Environmental Observation, Prediction and Response (MEOPAR) Network of Centres of Excellence and the Social Sciences and Humanities Research Council of Canada. It has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 22966). If you have questions for the Committee, contact the Chief Ethics Officer, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

If you have any questions regarding this study or would like additional information to assist you in reaching a decision about participation, please contact me by telephone at **(519) 505-6803**, or by email at **dsofta03@gmail.com**. I very much look forward to speaking with you and thank you in advance for your assistance in this project.

Sincerely,



Divya Softa
Master of Environment Studies Candidate
School of Environment, Enterprise and Development (SEED)
University of Waterloo
519-505-6803

CONSENT FORM - INTERVIEW

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by Divya Softa of the School of Environment, Enterprise and Development at the University of Waterloo. I have had the opportunity to ask any questions related to this study and have received satisfactory answers to my questions and any additional details.

I am aware that I have the option of allowing my interview to be audio recorded to ensure an accurate recording of my responses.

I am aware that excerpts from the interview may be included in the publications to come from this research, with the understanding that the quotations will be anonymous.

I was informed that I may withdraw my consent without penalty by advising the researcher.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 22966). If I have questions for the Committee, I may contact the Chief Ethics Officer, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore- ceo@uwaterloo.ca.

☐ YES ☐ NO I give permission for my interview to be audio recorded to ensure accurate transcription and analysis.

☐ YES ☐ NO I give permission to be referenced by my job title.

☐ YES ☐ NO I give permission for the use of anonymous quotations in any paper or publication that comes from this research.

I agree of my own free will to participate in the study.

Participant's name: _____ Date: _____

Participant's signature _____ Date: _____

Researcher's / Witness' signature _____ Date: _____

Appendix 3: Interview Questions

Introduction

1. Can you describe your current role at the <organization>?

Flooding in New Hamburg

We are interested in <organization's> current role in flood management in high risk areas, in particular, New Hamburg. The next set of questions will seek to clarify this role.

2. Can you describe the flood risk in New Hamburg?

3. How is flood risk currently managed in New Hamburg? What role does the <organization> play in flood management? What are some other strategies, and how are they managed?

4. What are the main challenges associated with flood management in New Hamburg? (Poor coordination, lack of resources, misaligned policy (policy working at cross-purposes)

5. How is flood recovery managed in New Hamburg?

    - Who is responsible for financial assistance in case of flooding? (property owners, insurers, government)?

Flood Risk Management

In response to the growing costs of flood damage, governments are currently shifting towards risk-based approaches to flood management. The objectives include diversifying the strategies and the stakeholders involved away from structural defences as a means of prevention, and government disaster assistance as a means of recovery. The next set of questions will seek to understand the application of flood risk management in New Hamburg by focusing on several of its key policies.

6. How has the introduction of riverine flood insurance influenced flood management in New Hamburg? Can you describe any feedback you might have heard from other stakeholders (e.g. city officials, council, insurance companies, etc.) involved in FRM?

    - Do you know if property owners are purchasing insurance and if it is affordable?

7. Now that flood insurance is available, flood damage is no longer eligible for disaster assistance. How has this change influenced decisions on local flood management?

8. What are the roles of property owners and businesses in flood management in New Hamburg? Are there any strategies to increase this role via the promotion of property-level-flood-protection?

9. How has flood mapping evolved in New Hamburg?

- How is flood risk information communicated to stakeholders, such as property owners, municipalities, insurers?

- Has the <organization> collaborated or been in contact with any insurers or risk modelling firms developing risk-based maps?

Reforming Flood Management

10. How should flood management be improved in New Hamburg? Are there any specific policies that need to be prioritized? (Structural defence, flooding mapping, flood insurance, property-level-flood-protection, property buyouts)

11. How should responsibility for flood management be allocated in the future? Should some actors be responsible for more strategies or less?

12. How can flood risk communication be improved?