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UNIVERSITY OF CALGARY

Exploring Flood Risk Perceptions and Risk Management Preferences in the Aftermath of the Calgary Flood of 2013

by

Alexa Tanner

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

GRADUATE PROGRAM IN GEOGRAPHY

CALGARY, ALBERTA

August, 2016

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Abstract

Many studies have examined the general public's flood risk perceptions; however, discussion continues around clarifying the variables that drive perceptions and management preferences. This thesis examines flood risk perceptions and management preferences of the general public within the City of Calgary in the aftermath of the 2013 Alberta flood. The findings reveal that short-term flood risk is influenced by direct experience with flooding, while long-term risk perceptions are not. Using perceptions of distance, direct experience was found to influence perceptions of distance, and by proxy, risk perceptions. Further, participants' views towards climate change were found to be more influential in shaping risk perceptions than being evacuated due to the risk of flooding. In addition, it was found that response-efficacy and flood mitigation preferences were influenced by direct experience during the flood. These results are significant in understanding the role evacuation experience plays in risk perception formation and shaping mitigation preferences.

Acknowledgements

Over the past two years I have met many wonderful people who have inspired and pushed me. First, I would like to thank my co-supervisors Dr. Joe Arvai and Dr. Dianne Draper. Thank you, Joe, for guiding me through the research process and for your honesty, generosity, and kindness. My thinking has developed from your advice and mentorship. Dianne, thank you for your flexibility in taking me in part way through my degree and the feedback that you have offered over the past year. Thanks also goes to Dr. Yvonne Martin and Dr. Cathy Ryan for being part of my thesis examination committee.

This research would not have been possible without funding from Dr. Joe Arvai, the Joseph-Armand Bombardier Graduate Scholarship through the Social Science and Humanities Research Council and the Queen Elizabeth II Graduate Scholarship. I am very appreciative of this support and the opportunities it provided.

I would also like to thank those who have been part of the Geography Department over the past two years. Paulina, thank you for answering all my emails and being the 'go to' person for all things related to U of C regulations. A special thanks also goes to my fellow graduate students in Geography; my time at U of C would not have been the same without you.

Dr. Victoria Campbell-Arvai and Sara Goto, thank you for taking the time to help me with stats and making me feel welcome to ask questions. I admire you both, particularly your love for research. I'm happy to say that stats don't scare me as much anymore and I'm excited to learn more in the future.

The past year would not have been the same without being a member of The Graduate College. The inaugural year of the College has strengthened my enthusiasm for

education, research, and community engagement. Thank you, College community; without you, I would not have had the opportunity or confidence to participate in many of the events we did.

Outside of the university, I would like to thank Calgary Synchronized Skating Club and, in particular, the women on Black Gold Open for reminding me that a world exists outside of academia and rekindling my love of figure skating. Thank you for welcoming me on to the team.

And finally, I would like to thank my parents for their unconditional love and support. I most certainly would not be here today if it were not for them.

Dedication

I dedicate my thesis to Cathy Charles. Her never-ending encouragement, support and enthusiasm over even the smallest accomplishments will remain with me forever.

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Chapter 1: Introduction

Over the past decade, we have witnessed an increase in the frequency and severity of extreme weather events and related damages (Winsemius et al. 2016). In many urban areas, the risk of flooding is a growing concern, with increasing populations living in flood risk regions. Additionally, there is uncertainty about how climate change is impacting flood and drought regimes (Jongman et al. 2012, Buttle et al. 2016). Globally, damages due to flooding are projected to increase at a faster rate than economic wealth is gained (Winsemius et al. 2016) with flood losses in Europe potentially doubling by 2050 (Jongman et al. 2014).

Canada has not been exempt from this trend, with the risk of severe flooding emerging as one of the country's most prevalent natural hazards (Milrad et al. 2015, Buttle et al. 2016). Historically, flooding has represented 40% of all natural hazards recorded in Canada and response to flooding has received 78% of the funding from Canada's Disaster Financial Assistance Arrangements Program since its establishment in 1970 (Insurance Bureau of Canada 2015, Public Safety Canada 2015, Buttle et al. 2016, Story 2016). The prevalence of flood events and financial costs shows the significance of hydrologic events for Canadian society.

Canada's costliest natural disaster prior to 2016[1], and the world's eighth costliest flood by insured losses between 1980 and 2015, occurred in Alberta during June and July 2013 (Chief Financial Officer's Department 2014, Expert Management Panel 2014, Pomeroy et al. 2015, Munich RE 2016). The estimated financial costs due to the 2013

[1] At the time of writing the Fort McMurray wildfires are ongoing. It is anticipated that the financial costs from this wildfire will exceed $6 billion CAN, becoming Canada's most costly natural disaster.

flood vary, although estimates in the range of $5 and $6 billion CAN have been suggested by government agencies (Chief Financial Officer's Department 2014, Expert Management Panel 2014, Pomeroy et al. 2015). In total, the historic flood led to a State of Local Emergency being declared in the province of Alberta, as coordinated response and recovery efforts were required (Alberta Government 2014a, Expert Management Panel 2014).

The City of Calgary is one region that experienced major overland flooding as a result of the 2013 Alberta floods. High flow rates in the Elbow and Bow Rivers, both which flow through the city, caused the rivers to overflow their banks. Within the City of Calgary, 29 communities experienced a mandatory evacuation order and it has been estimated that 100 000 residents' lives were disrupted due to the flood, as shown in the maps in appendix A (Expert Management Panel 2014).

Due to Calgary's geographic location along the Bow and Elbow Rivers—and because of the city's proximity to the Rocky Mountains—floods have been common throughout Calgary's history, with the 2013 floods being the largest since the 1900s (Expert Management Panel 2014, Pomeroy et al. 2015, City of Calgary n.d.-c). Major flood[2] events that have occurred previously on the Bow River occurred in 1879, 1897, 1902, 1915, 1929, 1932, 1995, and 2005; in contrast the Elbow River experienced significant floods in 1915, 1923, 1929, 1932, 1995 and 2005 (Golder Associates Ltd. 2012, IBI Group 2015b). The Bow River floods in 1879, 1897 and 1932 are considered to

[2] Major flooding has not been defined by the consulting firms hired to write the reports on flood risk assessments in the Province of Alberta and City of Calgary, although it can be gathered through flood frequency charts provided by the City of Calgary that 'major' has been defined approximately by floods which were greater than 1 in 20 years (City of Calgary n.d.-b)

be of a similar magnitude as the 2013 flood; however, financial and infrastructure losses were minimal in comparison to the 2013 flood as development was limited at the time (Expert Management Panel 2014). With the extensive history of flooding in Calgary, the risk of major flooding has been known for much of the city's development, though large-scale action and appropriate zoning has not been implemented. The omission of large, historic flood data in regional flood risk analyses and flood risk management has been seen as a flaw in the city's development and flood management.

The recent 2005 and 2013 high-profile flood events have drawn attention to the frequency and severity of flooding in the City of Calgary. These two recent, large floods have helped shape the flood risk perceptions of emergency and risk managers, as well as the general public. Further, the prevalence of flooding has pushed the region to make flood mitigation a priority in the City of Calgary and the Province of Alberta (Public Safety Canada 2014).

By examining the general public's risk perceptions, researchers are able to study the thoughts and beliefs that people hold towards flood risk; this, in turn, may lead to insights about people's flood risk management preferences. Within the academic literature, risk perceptions are seen as individuals' subjective beliefs and understandings of risk, shaped through their worldviews. An individual's worldview and values influence how messages surrounding risk are interpreted, with direct and indirect experiences with the risk playing a significant role (Slovic et al. 1980, Wachinger et al. 2013).

Given the City of Calgary's location along the Elbow and Bow Rivers, and historic flood records, the City is very likely to experience flooding in the future. With the growing influence of climate change on river processes and increasing uncertainty

surrounding extreme weather, it is important to understand how the public perceives the risk of flooding and their flood risk management preferences. This information can help risk and emergency managers to better understand the varying perceptions and management preferences the general public holds towards flood risk. Appropriate risk communication can then be taken to encourage the general public to take protective action, improve knowledge and understanding of flood processes, and understand preferences and support for flood management actions that fit communities' beliefs and values.

With the continued risk of flooding within the City of Calgary and the need to understand the public's flood risk perceptions and mitigation preferences, this thesis examines how experience with the Calgary flood of 2013 has shaped perceptions of flood risk. Specifically, the research furthers understandings around short- (5 year) and long- (100 year) term flood risk perceptions and incorporates how perceptions of distance change based on evacuation experience. Flood evacuation experience, views towards climate change and an individual's coping appraisal are assessed to see how these variables influence flood risk perceptions. Finally, management preferences are looked at in relationship to evacuation experience.

To put this research on flood risk perception into perspective, this thesis begins with a brief review of the 2013 Calgary flood and provides an overview of the flood risk management options being discussed. A review of the scholarly literature on risk perceptions, both generally and as related to flood risk, is then provided. Chapter 1 concludes with the research questions motivating this thesis and the significance of the work. Chapter 2 describes my research in the structure of a journal article for submission

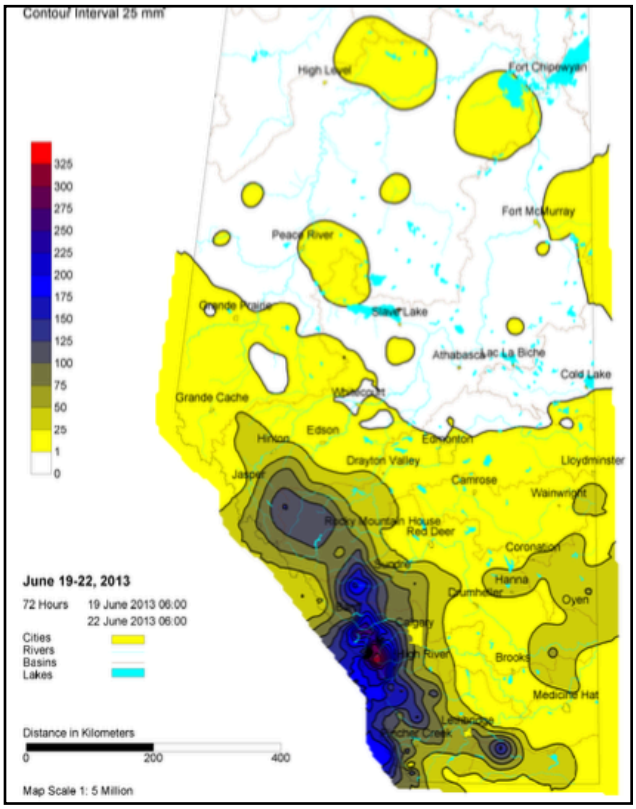
to a refereed journal. The research entailed using an internet based survey to assess flood risk perceptions of Calgary residents. The thesis concludes with a final chapter that focuses on the benefits and limitations of this research and future opportunities for flood risk perception research based on the findings of this research.

The Calgary Flood of 2013

In the winter of 2013, Southern Alberta experienced higher than normal precipitation and a snowpack that was slower to melt than average. By late spring (May-June), the ground at lower elevations in the Rocky Mountains and foothills region was heavily saturated, with significant snow accumulation remaining in higher elevations. These conditions were due to several precipitation events in late May and early June that increased snow accumulation in higher elevations and rainfall totals in lower regions. These events lead to the soil being heavily saturated and unable to absorb any additional amounts of precipitation (Milrad et al. 2015, Pomeroy et al. 2015).

On June 19th, a three-day period of extreme precipitation began. In total, between June 19th and June 21st, 2013, approximately 76 mm of rain fell over Calgary, 91 mm of rain over the Rocky Mountain foothills, and between 200 mm and 350 mm of rain over the Front Range, illustrated in the map created by the Alberta Environment and Sustainable Resource Development in Figure 1 below. The region already had high groundwater saturation and snow accumulation in higher elevations and as the storm system progressed the snowmelt was accelerated, increasing the run-off (Milrad et al. 2015, Pomeroy et al. 2015). The overall stream flow was also intensified as the soil in the region was frozen or partially frozen, preventing the water from being absorbed,

increasing the run-off rate of the water that proceeded to flow through the City of Calgary.



© Alberta Queen's Printer, 2013.

Figure 1- Precipitation Map of Alberta, June 19-22, 2013

Government of Alberta, Alberta Environment and Sustainable Resource Development

The storm system was particularly damaging as the air mass producing the precipitation had undergone evapotranspiration in the northern US plains, increasing moisture accumulation and creating a strong, slow-moving system with circulation between the upper and lower air masses. A large high-pressure ridge to the North of the Rocky Mountains blocked the system from moving east and pushed the system against the Rocky Mountains creating an upslope flow. This trapped the system over southern

Alberta releasing great quantities of precipitation over a short period of time (Milrad et al. 2015, Pomeroy et al. 2015).

This substantial three-day rainfall event led to widespread flooding. Within the City of Calgary, a State of Local Emergency was called on June 20th, 2013 in advance of anticipated high river flows and widespread flooding (City of Calgary 2013b). The extensive floodwaters and record-breaking discharge rates caused erosion of the river channels and destroyed infrastructure in its path, such as bridges and roadways. Upstream of Calgary, two hydroelectric dams, Cascade Dam and Barrier Dam, had their spillways opened for the first time since they were constructed in the 1940s (see Figure 2). Opening the spillways ensured that the dams were not overtopped and severely damaged but this action allowed the water to flow rapidly downstream. The high flow rates caused erosion to the river channels, as they were not intended to handle the extreme flow rates (Milrad et al. 2015, Pomeroy et al. 2015).

Extensive flooding and related damages were experienced in Calgary and elsewhere in Southern Alberta. In Calgary, it was estimated that 100 000 residents' lives were disrupted, with 28 neighbourhoods being evacuated including the downtown core and twelve communities being evacuated for three or more days (City of Calgary 2013a, c). Once the water levels subsided and an initial flood response had occurred, the State of Local Emergency in the City of Calgary was lifted on July 4 2013, 15 days after being initiated (City of Calgary, 2013d). Across Alberta, damages were estimated to be between $5 and $6 billion CAN, with future flood mitigation efforts still being a topic of ongoing discussion (Chief Financial Officer's Department 2014, Expert Management Panel 2014, Pomeroy et al. 2015).

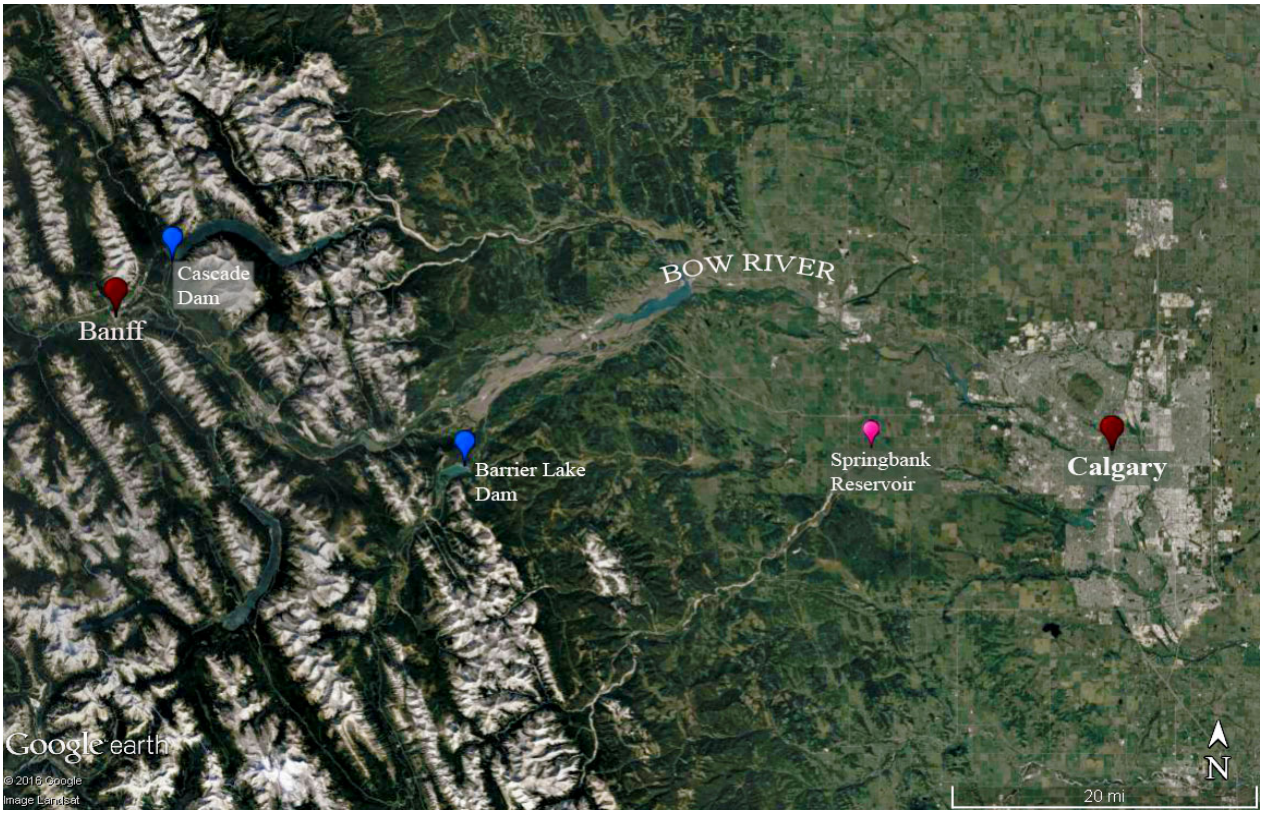


Figure 2- Map of the Rocky Mountain Foothills, Banff to Calgary Corridor
Google Earth Pro (2013)

Flood Risk Management in Calgary

In response to the 2005 Calgary flood, where a State of Local Emergency was called and 80 000 citizens were evacuated (Vroegop 2014), the Alberta Flood Mitigation Committee was created and a Provincial Flood Mitigation Report was drafted based on findings from a 2002 flood report. The 2005 report recommended updating flood risk resources such as maps and notification systems, regulating development in riparian zones, providing province-wide support to municipalities for regulations, and programming and access to experts in flood-prone regions (Groeneveld 2006). Some of

this work has been completed, such as building partnerships across governments and publishing updated hydraulic models for inundation zones, including new 1:100-year flood maps (Golder Associates Ltd. 2012). However, both the 2002 and 2005 reports have been criticized, as neither led to implementation of widespread action to lower flood risk (Groeneveld 2006, Wingrove 2013). Unlike previous floods and flood reports, in the three years since the July 2013 flood, action has begun to be taken to prevent future flood damage (Expert Management Panel 2014).

In July of 2013, an expert flood mitigation and management panel was appointed to provide arms-length recommendations to mitigate future flood risk in Calgary (Expert Management Panel 2014). The panel recommended focusing mitigation efforts in three main areas; "(1) social impacts; (2) impacts to the environment; and (3) impacts to the local economy" (City of Calgary n.d.-e). From these broad areas, six themes of actions were created to group the 27 specific recommendations. The six themes included; climate change, watershed management, event forecasting, infrastructure and property resilience, managing flood risk, and storage, diversion and protection concerns (Expert Management Panel, 2014). The recommendations ranged from smaller scale municipal projects, such as riverbank stabilizations, to large-scale engineering projects supported by the Province of Alberta such as the Springbank Off-stream Reservoir in the Elbow River Basin. The recommendations also varied in their timeframes, type of action to be taken, and their locus of responsibility (Expert Management Panel 2014).

Since 2013, progress has been made on the smaller scale projects; for example, an automated outfall gate was installed in Sunnyside, a community on the Bow River immediately north of Calgary's downtown core; river monitoring equipment has been

upgraded or replaced along the Bow and Elbow Rivers; and 26 tonnes of silt and 24 tonnes of debris was removed from the Elbow River and the Bow River respectively (City of Calgary n.d.-a). There was also work done to re-map, digitize and update river models and inundation zones as the river system has changed since the 2013 flood. Response plans were updated, and discussion of policy changes related to development in the floodplain has occurred (City of Calgary n.d.-a, c). The Expert Panel also recommended that the City consider three large-scale mitigation projects: The Springbank Off-stream Reservoir, the McLean Creek Flood Storage, and the Glenmore Reservoir Diversion Tunnel.

The Springbank Off-stream Reservoir was approved in late October, 2016, as the large-scale engineering project that would move forward in the construction process. This reservoir will be located to the west of Calgary, upstream of the Glenmore Reservoir, sitting adjacent to the Elbow River. The dry reservoir will be built with gates that would remain closed during normal flow rates, and opened during high flow events. When the gates are opened it will allow the water to flow through a channel leading into the reservoir, to be held until normal flow conditions return in the Elbow River. When the river flow subsides, the water will be allowed to flow, through a second channel, back into the Elbow River to continue downstream (Alberta Environment and Sustainable Resource Development 2015, Alberta Government 2015b). Currently, the project is undergoing a four season Environmental Impact Assessment (EIA) to meet provincial and federal requirements. Once completed, the EIA will be one component of the application for construction that will be submitted to Alberta's Natural Resources Conservation Board. The EIA began collecting field data in March 2016 and an estimated

construction and completion date has yet to be provided (Alberta Government March 2016).

The McLean Creek Flood Storage and the Glenmore Reservoir Diversion Tunnel are two other mitigation projects that were considered, and are currently on hold as financial and environmental costs were significantly greater than those associated with the Springbank Off-stream Reservoir (Alberta Government 2015c, a). The McLean Creek Flood Storage project involves creating a dry dam by installing an earth filled dam across the Elbow River using a concrete outlet and service spillway; gates would remain open during normal flow and be closed to slow the flow rate during flood events (Alberta Government 2014b, IBI Group 2015a). The final major flood mitigation project originally proposed by the Expert Management Panel is the Glenmore Reservoir Diversion Tunnel. This project has three options, all of which involve using deep underground tunnels that divert high flow waters from the Glenmore Reservoir to the Bow River with minimal impact to the water quality. The route proposed, based on a feasibility assessment, recommended the diversion tunnel be built beneath Heritage Drive to the Bow River; Figure 2 provide a reference to the location of the mitigation options (Hatch Mott MacDonald Ltd. 2014, Alberta Government 2015a). Both of these projects are on hold, while the Springbank Off-stream Reservoir continues with the review and construction process.

A series of mid-scale mitigation projects have also been proposed, such as using hydroelectric dams for flood mitigation, increasing the availability of overland flood insurance, and government purchase of homes in the floodplain. For example, TransAlta Utilities operates eleven hydroelectric dams in the Bow River watershed near Calgary.

These dams were designed and built for hydroelectric generation but can provide minimal flood protection, such as longer evacuation periods and slightly reduced stream flows, as was seen in 2013 (City of Calgary 2015b, n.d.-d). As of April 2016, the Province of Alberta and TransAlta have entered a five-year agreement to allow the province to set the water level in the Ghost River hydroelectric facility between May 16th and July 7th each year. Determining the water levels allows the province to begin adapting to a changing climate by mitigating against the risk of flooding and drought (Alberta Government 2016, Fletcher 2016).

Before 2013, overland flood insurance was not available within Canada due to a lack of flood risk assessment tools, such as detailed and accurate flood hazard mapping, which prevented adequate pricing of insurance premiums. There was also concern that the high estimated premiums for those in high risk regions, would lower demand for overland flood insurance (Insurance Bureau of Canada 2015). Between 2013 and 2016, insurance companies and the Insurance Board of Canada have worked to re-evaluate overland flood insurance, with up to five options now being available in Alberta. The primary providers are Aviva Canada, the Co-operators and Intact Insurance (Office of the Superintendent of Insurance March 2016). Additional annual premiums are in the range of $5,000 for eligible homes in the floodplain (5% flood risk), with $150,000 coverage for content and building damages from overland flooding (McClure June 2015).

Since 2013, the Province of Alberta has bought 17 homes that had been built within Calgary's floodplain. Complete demolition of these homes is expected by the end of July 2016, but questions remain about the long-term use of the lands. The Government of Alberta anticipates putting the lots back on the private market once the flood

mitigation projects have been completed and the risk of flooding lowered. In the meantime, Alberta Infrastructure is responsible for the safety and maintenance of the land (Alberta Government and Municipal Affairs 2016).

In addition to the work by the City of Calgary, Alberta WaterSMART, an environmental consulting firm, provided direction for the Province's flood mitigation plans. The Alberta WaterSMART project focuses on policy recommendations that use proactive actions and science to plan for extreme weather events and is based on a similar program in the Netherlands (Alberta WaterSMART and Water Management Solutions 2013). The recommendations and management strategies by WaterSMART are supported by vocal community members; however, they are not being pursued by the City of Calgary.

Whichever flood mitigation projects are implemented, there remains a continued risk of flooding in Calgary; the mitigation projects being completed are not a solution and should not provide a false sense of security. Fundamental watershed health, development in floodplains and personal preparedness must always be undertaken, in addition to large scale mitigation (Expert Management Panel 2014). As has been stated, the engineering mitigation projects, such as Springbank Off-stream Reservoir, will provide a structural defense against flooding; however, this is only one form of mitigation that should be considered. Despite the work that has been completed over the last three years, flood mitigation is still an ongoing discussion topic within the City of Calgary.

With the ongoing risk of flooding and growing uncertainty of historic flood models, it is important to understand the general literature on risk and risk perception. This literature provides a theoretical component to the practice of risk management by

looking at risk managers' assessments of the risk and the general public's risk perceptions. Combined, these help explain why people behave and act as they do in flood risk scenarios and how this shapes risk management preferences.

Risk Literature

The term 'risk' is used to describe the potential for a negative event to occur while incorporating the complexity and uncertainty of outcomes (Renn 1992). Risk can be studied from two broad perspectives: the statistical risk associated with an event, as well as non-statistical risk perceptions. Statistical risk assessments are typically used by experts in risk analysis and management who study statistical probabilities, known as 'real' risks. Risk (r) is analyzed by looking at the probability (p) of the event occurring and the consequences (c) that would be felt if the risk were to occur; thus $r = p \times c$. By contrast, risk perceptions focus on how various beliefs about risk are formed, and held by experts and the general public. The following section discusses the risk literature, first by examining the statistical and descriptive flood risk in Calgary, followed by an examination of the broader risk perception literature.

Characterizing the Statistical Flood Risk in Calgary

The City of Calgary is located in Alberta, Canada (approximately 51°6 N, 114°1 W) to the east of the Rocky Mountains in the foothills region, within the Bow and Elbow River watershed and downstream from the Rocky Mountains (see Figure 3). Calgary is the province's largest city with a population of approximately 1,439,800 in 2015 (Statistics Canada and CANSIM 2016). When snowmelt and rainfall occur in the Bow

and Elbow River watershed, the runoff quickly flows downhill into the Bow and Elbow Rivers, and into the urban area of Calgary (Milrad et al. 2015). The short downstream distance from the headwaters to the City of Calgary allows runoff to reach the city rapidly, leaving limited time for flood warnings or flood preparation (City of Calgary 2015a).

Figure 3- Map of Alberta, Western Canada (Google Maps 2016)

Meteorologically, high rainfall events occur in the foothills of the Rocky Mountains where the mountainous topography brings warm, moist air from the Pacific Ocean and the Gulf of Mexico, in some cases, trapping low-pressure systems over the front ranges of the Rocky Mountains. This can lead to large-scale rainfall events in the headwaters of the Bow and Elbow Rivers and subsequent high flow rates. Yearly, expected high runoff flow rates, and increased risk of flooding, occur in May and June,

during seasonal snowmelt and spring precipitation (Pennelly et al. 2014, Harder et al. 2015, Pomeroy et al. 2015, Buttle et al. 2016). It is these conditions that lead to potential flooding in Calgary.

Particularly in the spring, slow moving, heavy rainfall events are known to occur on frozen or already saturated ground, creating peak flows and overland flooding (Expert Management Panel 2014, Harder et al. 2015). When a rainfall event occurs on ground that has snow cover or that remains frozen, a rain-on-snow event is experienced. The rain-on-snow event increases the amount and speed of water running into the drainage basin as the ground may be unable to absorb the precipitation and the snowmelt increases the quantity of water. These events are infrequent in the region, but can occur at higher elevations, in particular during Chinook winds when warm westerly air quickly moves into the region raising the temperature abruptly. As the temperature increases, snowmelt can occur and precipitation falls as rain rather than snow, inducing a rain-on-snow event (Burn and Whitfield 2015, Pomeroy et al. 2015, Buttle et al. 2016).

It is also common for rainfall events in the area to result in higher peak flow rates in Calgary than in the Front Ranges of the Rocky Mountains, such as in the town of Banff, located approximately 130 km to the west of Calgary. This is important as it shows that water runoff in the Foothills is influenced by land use and watershed management and highlights the importance of ecosystem services for flood management (Wijesekara et al. 2014, Pomeroy et al. 2015).

As climate change progresses, specific projections of regional changes related to flood risk are uncertain. Within Alberta, it is anticipated that seasonal flow magnitudes related to snowmelt will have a decreasing trend (Burn and Whitfield 2015, Harder et al.

2015) and annual base flow rates on the Elbow River will be lower than historic observations (Cunderlik and Ouarda 2009). However, it is projected that the Elbow River will have a higher risk of flooding due to increased peak flow rates (Valeo et al. 2007). Conversely, the Bow River watershed may experience an annual increase in precipitation (Rood et al. 2008).

As the snowmelt runoff is anticipated to occur earlier in the season compared to historic records, precipitation events are expected to increase soil moisture and change traditional seasonal flood regimes, affecting the accuracy of historic flood risk models in predicting future flooding (Valeo et al. 2007, Rood et al. 2008, Harder et al. 2015). With the changing climate, the foothills of the Rocky Mountains are predicted to experience shifting wind and precipitation patterns as an increase in warm atmospheric moisture moves from the Gulf of Mexico (Pennelly et al. 2014, Harder et al. 2015, Buttle et al. 2016). The result is that climate change is shifting the probability and timing of flooding in Alberta.

Within the Rocky Mountain Front Ranges, changes in land use are expected to increase peak flows, as there is more urban development and less vegetation, which increases runoff times (Wijesekara et al. 2014, Pomeroy et al. 2015). As well, there has been an increase in the number of people living and building in high flood risk regions (such as the flood fringe, the area immediately outside the mainstream and overbank) that has increased the exposure to flood damages and the amount of infrastructure that is in the path of the flood hazard. This increases the consequences and expected damages from high flow events (Rood et al. 2008, Burn and Whitfield 2015). Combined, these changes have increased the probability of flooding and heightened the potential consequences

when a flood does occur, influencing the overall risk of flooding and indicating the need for flood management to be undertaken.

Risk Perception Literature

The subjective nature of risk has been studied from different disciplines, using various models and theories (Sjoberg 2000). This thesis uses a psychological approach to study risk perceptions. To understand how the field of risk perception has developed, an overview of the literature is provided. This includes discussion of the use of heuristics and biases, the psychometric paradigm, and details on the subjective nature of risk perceptions. Cultural theory, originating from Anthropology, is briefly examined to address the concept of worldviews.

The study of risk perception originated in the 1960s when Sowby (1965) examined risk comparisons, and Starr (1969) studied revealed and expressed preferences to understand the subjective nature of risk, as well as the differences between voluntary and involuntary risks (Slovic 1987, Sjoberg 2000). When using revealed preferences, examined through studying behaviour, it was found that the general public uses trial and error before determining what they feel is an acceptable level of risk to assume. In contrast, when using expressed preferences, examined through surveys and interviews, it was found that a greater level of risk is accepted for voluntary activities than for involuntary ones (Slovic 1987, 1992).

Research by Tversky and Kahneman (1974) on heuristics and biases was used by the field of risk perception to help understand how individuals form their risk perceptions; they examined how uncertainty surrounding risks was comprehended by the

public (Slovic 1987, 2000). The literature on risk evaluation identifies six important heuristics and biases in shaping perceptions: the affect heuristic, availability heuristic, representativeness heuristic, overconfidence, desire for certainty, and the role of anchoring and adjustments. These are described in more detail below. Heuristics and biases have been used across a variety of risk and decision-making settings and are used by both the general public and risk experts to quickly comprehend and process the complexity of the world by using mental short cuts (Slovic et al. 1980, Fischhoff et al. 1993). However, using heuristics leads to predictable biases and inaccuracies in how we process information, such as the probability of a risk.

The *affect heuristic* is a mental shortcut used by people to make quick judgements based on an emotional response to a stimuli. Individuals react differently to stimuli based on their past experiences; these experiences have placed an affective (positive or negative) tag on the memory creating an 'affect pool'. This affective tag allows for quick judgment, while minimalizing the influence of analytic thought processes; however this can lead to biases in how the risk is perceived (Zajonc 1980, Slovic et al. 2002, Slovic et al. 2004, Slovic et al. 2007).

The *availability heuristic* is a shortcut used to comprehend the probability of an event occurring based on the ease with which the event can be recalled from memory. Using the availability heuristic, events which are more memorable are easier to recall, influencing the perceived probability and frequency of the event occurring. This creates biases as some events are easier to retrieve (Tversky and Kahneman 1973, 1974). For instance, when the media reports on shocking events, they are easier to remember and recall later, increasing the perceived risk. The opposite occurs with events that receive

little attention or are seen as common; they are not memorable and may be perceived as having lower risk estimates than the statistical nature of the risk (Lichtenstein et al. 1978). Affect is a component in the availability of memories due to the emotional tags attributed to certain memories, increasing their ease of recall, however affect is just one component of the availability heuristic (Finucane et al. 2000, Slovic et al. 2004, Slovic et al. 2007).

The *representativeness heuristic* is used when an individual relies on their pre-existing knowledge to form a perceived probability of an event occurring based on similarities from previous experiences. The probability that is assigned is based on the whole population and how the sample fits within it, creating subjective probabilities that overlook the statistical realities of the current event (Kahneman and Tversky 1972, Tversky and Kahneman 1974).

The *overconfidence bias* is used unconsciously by individuals, both experts and the general public, who overestimate their confidence in accurately estimating risks and overlook the assumptions they are making. Overconfidence is found most prevalently with tasks that are complex, with high levels of uncertainty, leading to underestimation of the true risk (Slovic et al. 1980, Plous 1993).

People also have a *desire for certainty*, the certainty effect, which suggests a tendency for people to make judgments that lead to sure gains (risk aversion) or sure losses (risk seeking). When uncertainty is present, the certainty of the event is overestimated, with a focus on the possibility that an event could occur and not the probability of its occurrence. Prospect theory builds on the desire for certainty to explain the inconsistency and preference reversals found in judgments depending on if the risk

leads to gains (risk aversion) or losses (risk seeking). In Prospect theory, losses are seen as worse than the equivalent positive gains when assessed against a neutral reference point. As well, small probabilities are over- or under- estimated to achieve certainty (Kahneman and Tversky 1979, Tversky and Kahneman 1981, Loewenstein et al. 2001).

Finally, the role of *anchoring and adjustments* is used in risk perception formation; this refers to situations where individuals use a reference point and adjust perceptions, up or down, to form their perceptions. Based on the anchor given, the reference point, beliefs can vary with inadequate adjustments being made before arriving at the final judgment (Tversky and Kahneman 1974).

To further understand how risks are perceived, Fischhoff et al. (1978) studied risk using the psychometric paradigm. A factor analysis using a three-factor matrix was used to chart risks based on new- old, sense of dread, and number of people exposed. This method accounted for 60-70% of the variance found in risk perceptions. It was during this time that researchers reported that 'dread' was influenced by a range of variables such as voluntariness, fairness and fear of catastrophe (Slovic et al. 1980, Sjoberg 2000, Slovic et al. 2004).

From the judgement and decision making literature, the rational choice model can be applied to research on risk perception. This model suggests that people rationally assess the outcomes of each decision option before choosing the best option available to them. The rational choice model was critiqued by Zajonc (1980) and a dual process model was proposed (Zajonc 1980, Kahneman 2003, Leiserowitz 2006). The dual process model, also from the judgment and decision-making literature, suggests that cognitive (analytic) and affective (experiential) responses are combined to influence decision-

making. The dual process model suggests that the affective process alone is susceptible to biases and errors for both the general public and risk experts, and it is balanced with the use of slower analytic thought processes. The concept is brought into the risk literature by showing that peoples' perceptions of risk are influenced by both the cognitive and affective components of the risk (Slovic et al. 1980, Bouyer et al. 2001, Kahneman 2003, Slovic et al. 2004, Leiserowitz 2006).

Construal level theory (CLT), also from the judgement and decision making literature, as well as social psychology, examines psychological distance to a concept using the individual's current place as the reference point. As the sense of distance to a stimuli increases, the stimuli is seen as further away, abstract and having a higher-level of construal, such as items that are difficult to imagine, or in a distant time or place. The higher the level of construal, the more abstract the stimuli is and details in the peripheral components are lost. Items that are closer have a lower construal, and are seen as concrete, more salient, and, as such, easier to recall. CLT assesses distance in four dimensions: temporally, spatially, socially and hypothetically (Liberman et al. 2002, Liberman and Trope 2008, Spence et al. 2012).

Temporal discounting is related to construal level theory and is used to explain how the timespan being assessed influences the value of the reward or risk. The subjective value of a reward is discounted as time to receiving the reward or probability increases, for instance, a longer delay or smaller probability has a lower subjective value. When there is a decision between a smaller reward in the present or a larger reward in the future, the future reward is reduced making the present reward seem more desirable. This may lead to preference reversals when the smaller reward in the present is more desirable

than waiting for the larger reward in the future. When looking at risk, large risks in the future are seen as smaller than equal risks in the present (Green et al. 1994, Green and Myerson 2004). Within flood risk, large future risks are minimized in peoples' minds.

Risks are perceived differently by different people including, for example, important variances between risk managers, who see and determine risk in terms of annual fatalities, and the general public, who perceive risk using a range of characteristics influenced by values (Slovic 1987, Fischhoff et al. 1993, Slovic 2000). Gregory and Mendelsohn (1993) have debated the importance of voluntariness[3] and newness[4] in risk perception formation by using different statistical analyses to assess each variable. They proposed the variable 'voluntariness' which shows perceived benefits are found to be present when activities are voluntary, leading to a decrease in risk perceptions for these risks.

All expert risk assessments contain a combination of facts, values and uncertainties, suggesting that all risk assessments contain subjective elements and are influenced by risk perceptions (Freudenburg 1996). This can be illustrated when representing the number of fatalities from an event. Depending on the time frame used and the specific measures reported (such as deaths per days worked vs. deaths per accident), researchers can change the objective number of fatalities, influencing how the risk is reported and its role in shaping the formation of perceptions (Slovic 1999).

When there is distrust in expert risk assessment, the public typically has stronger and more negative views towards the risk, with the risk being seen as uncertain. This

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[3] Voluntariness can be defined as the level of control one has to being exposed to the risk
[4] Newness can be defined as how recent the activity has been discovered

creates demand for regulations to lower the risk, regardless of what the risk assessment indicates (Slovic 1993). High risk activities are seen as having lower perceived benefits, while low risk activities are seen as having higher perceived benefit. It was also found that an individual's attitude toward the risk is influenced by their affective views of the risk, with positive feelings leading to higher perceived benefit and lower perceived risk. The opposite is also found, negative feelings lead to lower perception of the benefits and higher perception of the risks. This shows an inverse relationship between perceived benefits and perceived risks (Fischhoff et al. 1978, Alhakami and Slovic 1994, Slovic 2000).

The general increase in public concern over risks comes at the same time that the probability of some risks is decreasing, while others, such as those related to climate change, are increasing. The disconnect between technical risk assessment and risk perceptions has created conflict and misunderstanding between experts and the general public (Slovic 1993). Most activities in life have risks; it is the qualitative aspects that shape risk perception, such as dread and worldviews that create differences between what experts believe and how differing groups within the public react. People's belief systems, values and personal experiences lead to different responses towards the risk. Events that have strong negative imagery and are seen as personally relevant are given greater attention by the public regardless of the quantitative risk. This helps explain why some very low probability risk events, such as the risks associated with nuclear power generation, are seen by the public as having a much higher risk of occurring than other higher risk events such as driving a car (Slovic 1986, Renn 2004, Leiserowitz 2006).

Over time, the differences in assessments of risk between experts and the general public has led to conflict, distrust and misunderstanding (Slovic 1993, 1999, Sjoberg 2000).

Personal beliefs are established partly on the basis of the reputation of experts. This is important in risk communication as establishing trust between experts and the general public can influence which risk messages are transmitted and how the risk is perceived. By understanding the general public's risk perceptions, and what shapes these, risk communication can overcome gaps in knowledge and clarify misinformation (Wildavsky and Dake 1990). Fischhoff and Quadrel (1993) found that many risk communicators assume that they know what the general public's beliefs and risk preferences are; however, experts make assumptions, and details can be overlooked (Fischhoff et al. 1993). In order for risk communication to be successful, there should be a two-way communication between experts and the public that respects values and knowledge areas. This can help develop trust and communication so that future potential conflicts can be addressed before irreparable damage has been done, thus helping to establish and maintain trust (Fischhoff 1995, Arvai 2014).

Building and maintaining trust is critical as it can be lost easier than it can be maintained or gained (Slovic 1993, Freudenburg 1996, Slovic 1999). As technology has become more specialized, responsibility for managing risk has spread to multiple groups, increasing the importance of establishing trust between experts and the general public (Freudenburg 1996). Understanding risk must include the general public's and experts' views on conflicts and misunderstandings, which, if not addressed, can further decrease trust (Renn 2004).

Cultural theory provides another perspective on risk perception. This perspective focuses on how culture and worldviews shape and influence how risk is perceived and accepted. According to cultural theory, risk is seen as actively created and shaped by institutions and society (Douglas and Wildavsky 1982, Rayner 1992). The worldview that an individual holds influences their culture and associated ideologies and values. This creates cultural biases favouring the individual's values and related beliefs, creating the potential for conflict when beliefs differ (Wildavsky and Dake 1990). Based on an individual's worldviews and political alignment, their acceptance of technology and level of risk deemed as acceptable can be predicted; individuals make decisions that are in line with their personal beliefs (Douglas and Wildavsky 1982, Wildavsky and Dake 1990, Bouyer et al. 2001).

As the study of risk perception has evolved, researchers have developed a more sophisticated understanding of why certain beliefs and perceptions are held. Risk communication has been used to encourage conversation between experts and the general public, to help understand an individual's risk perception and help align the probabilities of risk occurring with their perceptions. The research on risk perception, our understanding of how and why individuals react to specific risks, is progressing.

Flood Risk Perception Literature

Based on the general study of risk perceptions, researchers have applied the results to specific hazards, such as flood risk. Factors that shape an individual's flood risk perception and their management preferences are the focus of this thesis.

Direct experience with flooding has been shown to increase an individual's perception of future flood risk (Botzen et al. 2009, Zaalberg et al. 2009, Bubeck et al. 2012a, Lawrence et al. 2014), and increase their motivation to take action (Zaalberg et al. 2009, Bubeck et al. 2013, Lawrence et al. 2014). In accordance with the availability heuristic, direct experience can create strong and instinctive negative impressions, increasing the salience of the risk, and heightening sensitivity to the frequency, severity and uncertainty of future floods (Tversky and Kahneman 1973, Keller et al. 2006, Botzen et al. 2009, Kunreuther et al. 2014). Direct experience with a hazard can also facilitate a sense of vulnerability, and decrease perceptions of response costs (Siegrist and Gutscher 2008, Zaalberg et al. 2009, Lawrence et al. 2014, Boer et al. 2015).

When relying on experiences to understand the risk of flooding, underestimation occurs with an overreliance on external factors such as trust and time in the property. Views such as 'it won't happen to us' are common, as is a lack of clarity on flood risks due to inconsistent expert reports. If a minor event has occurred, it lowers estimates that a worse flood could occur and, if the resident is aware of the risk, there is a lack of concern regarding potential damages (Burningham et al. 2008).

Perceptions of risk may be dampened when an individual has had no direct experience with a hazard, such as severe overland flooding, and overestimated when they have had these experiences (Kunreuther et al. 2014); however, *how* an individual interprets their experience is critical in the formation of risk perceptions. Indirect experience with flooding, such as through media exposure, has been shown to have only a small effect on risk perceptions (Siegrist and Gutscher 2006, 2008). It has been shown

that an individual tags memories with affect[5], influencing the ease of recall and availability of the memory. Without a negative tag on memories, such as through indirect flood experience, memories are less salient and are more difficult to recall (Slovic et al. 2004, Slovic et al. 2007, Siegrist and Gutscher 2008).

Residents must be explicitly told of flood risks, the preparedness actions available, and given reminders in order for protective behaviours to be undertaken. If structural mitigation is present, such as dams, residents tend to have a false sense of security and are unaware of residual flood risks, regardless of education and income (White 1945, Bradford et al. 2012, Ludy and Kondolf 2012). Those who have experienced flooding may be in denial that flooding could occur again, lack concern over future flood risks or be overly optimistic that future floods will be less severe (Bradford et al. 2012).

As time between elicitations of risk perception and exposure to hazardous experiences increases, risk perceptions tend to return to levels seen before the hazard. In line with the availability heuristic and construal level theory, the passage of time and distant events have been shown to minimize risk perceptions, with individuals becoming less motivated to take protective behaviour as the flood event becomes less salient, more abstract and difficult to recall (Siegrist and Gutscher 2006, Trumbo et al. 2014, Maidl and Buchecker 2015). In support of this, the literature review by Bubeck et al. (2012a) found

[5] Affect is an immediate and automatic feeling that is evoked in a person by a stimuli, leading to an immediate judgment to be made without engaging the cognitive thought process (Slovic et al. 2004, Slovic et al. 2007). It is measured using valence, the 'goodness' or 'badness' of a stimuli, and arousal, the 'alertness' that the stimuli elicits (Slovic et al. 2004, Wilson and Arvai 2006).

that direct experience with flooding, specifically the severity of the floods and how recent the flood event was, significantly influenced protective behaviours taken.

That said, it has also been found that past experience does not insure that mitigation actions and personal preparedness will be taken (Miceli et al. 2008, Wachinger et al. 2013). Wachinger et al. (2013) provided three explanations for this: people may accept the risk because the benefits are greater than the potential costs, the sense of responsibility for taking action is transferred to others, or the risks may be understood but the individual lacks access to the necessary resources to take action.

Flood risk perceptions can also be studied by looking at how perception of distance to a flood risk area interacts with the formation of flood risk perceptions. O'Neill et al. (2016) found that living close to a flood zone increased flood risk perceptions and that perceptions decreased as distance from the flood zone increased. Further, perception of distance from the flood zone was greater than actual physical distance. Earlier work by O'Neill et al. (2015), using cognitive mapping[6], found large differences between the expert assessment of risk and the general public's spatial perception of flood risk. These results further Botzen et al. (2009) findings, which show that objective distance to a high flood risk region aligns with respondents' perceptions. It was also found that evacuation experience increases perceptions of future flooding and lowers expectations of damages. However, those without experience with flooding had lower flood risk perceptions than the actual objective risk, although expected damages from flooding were accurate.

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[6] The term 'cognitive maps' is used in this study as flood risk maps that participants have drawn from memory, based on a template provided of the region. Respondents maps' are compared to a flood extent map to see how participants' understanding of the spatial extent of flood risk, and related perceptions, relate to the 'objective' expert flood risk.

Conversely, work by Siegrist and Gutscher (2006) separated participants into four categories of perceived flood risk based on expert maps and home location, and showed that expert assessment of the objective flood risk in a region aligned with the general public's flood risk perceptions. This indicates that physical distance from a flood hazard relates to flood risk perceptions. However, when looking at estimates of risk, people in some regions overestimated the risk of flooding, taking greater protective action than expert recommendations, while, in other areas, risk estimates and protective action were lower than recommended.

Outside of flood risk research, Trumbo et al. (2011) found that hurricane outlook was related to physical distance to past hurricane paths, while optimistic bias was not. However, risk perceptions were found to be associated with the distance an individual was to the landfall of Hurricanes Katrina and Rita, rather than the objective risk of living on the coast. This is an indication that perceptions of distance influence the public's behaviour around risk mitigation.

As the effects of climate change are felt, it is imperative that individuals' views towards the changing climate are examined in relation to flood risk perceptions. Recent work by Bruine de Bruin et al. (2014) found that those who linked flooding to climate change were more likely to report that the risk of flooding was increasing over time. Contradictory results surrounding the role of direct experience with flooding, and its influence on increasing climate change concern, have been reported; Spence et al. (2011) saw an increased concern with climate change, while Whitmarsh (2008) found the opposite, direct experience with flooding did not increase concerns surrounding climate change. In these studies, climate change was seen as a distant concern, in line with

construal level theory (Whitmarsh 2008, Spence et al. 2011, Jones et al. 2016). As discussed by Taylor et al. (2014b), the differences in reported results between Whitmarsh (2008), Spence et al. (2011) and more recent work may be attributed to the wider acceptance of climate change and the media's efforts to mention changing climatic systems and the frequency of extreme weather events.

Looking at the relationship between risk perception and affect, when an extreme weather event occurs, an individual may begin to see a connection between the event and climate change (Reser et al. 2014). Once this connection has been made, subsequent extreme weather events may be attributed to the effects of climate change, increasing risk perceptions (van der Linden 2014). In support of this, Shao and Goidel (2016) found that weather patterns, such as extreme weather events, can influence perceptions towards climate change.

As Taylor et al. (2014b) suggest in their literature review, the media can be used to create connections between flood events and the implications of climate change, connecting the two processes. This aids in the public's understanding of the local implications of climate change. Further, Taylor et al. (2014a) found that wet-weather events increased climate change beliefs, more so than hot-weather events. Wet-weather creates negative emotions that are more salient and can be more easily connected to the negative influences of climate change (Taylor et al. 2014a).

Another element that can be examined in relation to flood risk perceptions is coping appraisal. The term coping appraisal has been used to assess an individual's belief that they have the skills, resources and motivation to take action that will lead to effective reduction in risk exposure. Coping appraisal originates from the health literature using

Protection Motivation Theory (PMT) to understand what beliefs are required for an individual to take protective behaviours with the goal of lowering risk. Coping appraisal research has shown that it is a combination of high-risk perception, knowledge of the risk and appropriate risk reduction behaviours, as well as the belief that an individual can take action and has the means to lower risk that results in protective action being taken (Zaalberg et al. 2009, Bubeck et al. 2013, Boer et al. 2015). When risk perceptions are low or response costs are perceived to be too high, action will not be taken (Koerth et al. 2013). Specifically within flood risk research, coping appraisal has used a combination of "response efficacy, self-efficacy and response costs". Self-efficacy is as a person's value orientation and belief that they have the capability to overcome challenges in life, whereas response-efficacy is focused on a person's view that they have the ability and resources to meaningfully lower the risk that is being faced (Rogers 1975, Grothmann and Reusswig 2006, Bubeck et al. 2012a).

Coping appraisal is an important element in understanding the motivation and action behind taking flood mitigation and risk lowering activities (Bubeck et al. 2013). When motivating an individual to take action, the socio-psychological model proposed by Grothmann and Reusswig (2006) showed the importance of communicating the effectiveness and cost of taking action, as well as the risks and potential consequences. More recent work by Bubeck et al. (2013), focused on the importance of response-efficacy and self-efficacy, with risk communication needing to emphasize which actions should be taken and the effectiveness of such actions. Further work has shown that encouraging dialogue and building trust between risk managers and the general public, as well as using multiple forms of communication, is necessary to encourage protective

action and support for large-scale mitigation projects (O'Sullivan et al. 2012, Arvai 2014).

Direct experience with flooding has been largely shown to temporarily increase risk perceptions; however, the relationship between higher levels of flood risk perception and, the intention to take, or taking, protective action is unclear (Bubeck et al. 2012a, Wachinger et al. 2013). Some studies have found that having a higher risk perception does not indicate that protective action has been taken (Siegrist and Gutscher 2006, Bubeck et al. 2012a), or increases intentions to take action (Terpstra 2011). Others have found the opposite, direct experience increases intentions to take protective behaviour (Kievik and Gutteling 2011), and increases preparedness behaviour focused on preventing damages from flooding (Boer et al. 2015).

Bubeck et al. (2012a) proposed that the relationship between risk perceptions and taking protective actions is not found because both risk perceptions and coping appraisals must be elevated for action to be taken. This suggests that the belief that protective action is needed, through elevated risk perceptions, and the sense that the individual has the ability to lower the risk, is critical in leading to protective action being taken. Conversely, it has been shown that those with elevated risk perceptions may have already taken action to lower their perceived risk, therefore altering their risk perception. In support of the claim that high risk perceptions increase protective actions being taken, Kievik and Gutteling (2011) found that living in a region with increased flood risk led to increased information seeking and intentions to take self-protective behaviours.

At a community level, Lawrence et al. (2014) found that a community's perception of flood risk was important in motivating an individual to take action to lower

their personal risk. The individual's risk perception helps in the decision-making process of taking action, but, on its own, does not lead to action being taken (Lawrence et al. 2014).

Flood experience has been shown to increase intention and motivation to take protective behaviours because it increases a sense of vulnerability, salience of past memories and negative affect, as well as decreases the perceptions of response costs (Siegrist and Gutscher 2008, Zaalberg et al. 2009, Koerth et al. 2013, Kunreuther et al. 2014, Lawrence et al. 2014, Boer et al. 2015). Those without direct flood experience have lower coping appraisals, and those with minimal flood risk knowledge see higher barriers in taking protective action (Harvatta et al. 2011).

Post-exposure wakeup and letdowns are another way to view responses after a low probability event. Post-exposure wakeup is when people have elevated risk perceptions and a stronger desire to take protective behaviour after a negative event has occurred; in contrast, post-exposure letdown is when people lower their risk perceptions, feel safer, and fail to take protective action, post-event, with the notion that another low probability event will not occur again (Arvai et al. 2006). Within wildfire research, Arvai et al. (2006) have used post-exposure wakeup and letdowns to examine responses in the aftermath of a wildfire. It was reported that individuals who were directly affected by a wildfire, experienced post-exposure letdowns, where affective emotions lead to no further preparedness behaviour being taken as the risk was seen as low. However, those who were indirectly affected by the wildfire had higher risk perceptions post-event and used this to take protective action to mitigate future wildfire risk, creating a post-exposure wakeup (Arvai et al. 2006, Arvai et al. 2010).

In order to motivate an individual to take protective action, both risk perception and coping appraisal needs to be aligned, and there needs to be a sense of personal responsibility towards taking action (Soane et al. 2010, Bubeck et al. 2012a). However, by increasing risk awareness and knowledge exclusively, risk managers can inadvertently reinforce the general public's apathy towards protective action by encouraging views of denial or wishful thinking. This may be the case when coping appraisal is low but the person has a high risk perception. Combined, these results indicate the need to study coping appraisal, risk perceptions and risk management preferences concurrently (Grothmann and Reusswig 2006, Soane et al. 2010, Kievik and Gutteling 2011, Bubeck et al. 2012a).

The options available for flood risk management, and how the projects are selected, is unique to each region and should be comprised of structural mitigation and personal preparedness actions (White 1945). Within the Netherlands and the UK, a shift away from structural mitigation towards integrated land use planning and behavioural adaptation has been used in current mitigation practices (Butler and Pidgeon 2011, Bubeck et al. 2012a). This shift opens up new ways to address flood risk that includes the general public as key contributors to flood mitigation.

As discussed in the risk perception literature, affect plays an important role in risk perception formation (Leiserowitz 2006, van der Linden 2014) and establishing an acceptable level of risk varies by person based, partially, on the perceived benefits and voluntariness of the risk (Gregory and Mendelsohn 1993, Slovic et al. 2004). As risk perceptions are subjective, and different segments of the population view risk differently, what is seen as acceptable for flood mitigation varies. For example, risk and emergency

managers view risk differently from the general public, and within each broad group, values differ (Slovic 1987). Furthermore, individuals need to connect personal values to perceptions and preparedness actions; the disconnect between these can help to explain why certain risks may be acknowledged but no risk mitigation actions taken (McCaffrey 2010).

The role of trust towards officials and the effectiveness of flood protection measures has also been shown to be an important component in encouraging preparedness actions. Generally, those who have higher levels of trust in officials perceive lower risks of future floods (Siegrist and Cvetkovich 2000) and experience less dread of the risk, lowering intentions to take preparedness actions (Terpstra 2011). However, Wachinger et al. (2013) found contradictory evidence. If participants had higher levels of trust in officials, they were more likely to take recommended mitigation and preparedness actions, and to listen to warnings and expert recommendations (Lin et al. 2007, Wachinger et al. 2013). By using public participation in setting mitigation and awareness activities, trust can be built and a higher uptake of preparedness actions at the household level can occur (Wachinger et al. 2013). Further, Lin et al. (2007) found that it was the sense of control, as well as trust, that predicted if personal mitigation and preparedness efforts would be undertaken.

When the public is brought into the discussion of flood risk mitigation options, dialogue between the general public and risk managers is recommended. The mitigation options proposed should clearly communicate the probability of the risk, and the suggested mitigation options should align with the community's values and preferences. This is needed to encourage protective action being taken and to encourage support for

large-scale mitigation projects (O'Sullivan et al. 2012, Arvai 2014, Hartmann and Spit 2016). As Bradford et al. (2012) show, risk managers should look to the general public to understand how risk is viewed and what their management preferences are.

Relying on structural flood mitigation does not provide certainty in preventing damage from future flood events; structural flood mitigation may lead to a false sense of security that flood risks are being adequately managed (White 1945, Neale and Weir 2015). As climate change progresses, past models may not accurately calculate future flood risk, nor are engineering solutions certain to prevent flood damages (Bradford et al. 2012). There should be multiple flood risk measures to be taken by both risk managers and the general public (White 1945, Burton and Kates 2008).

Research Questions

Given the severity of the 2013 flood, and the ongoing risk of flooding within the City of Calgary, the aim of this research is to deepen our understanding of how people perceive flood risks and their management preferences. In addressing this, this research will question:

1. How are perceptions of flood risk in the short- (5 year) and long- (100 year) term influenced by flood evacuation experience, views towards climate change and an individual's coping appraisal?
2. Does flood evacuation experience moderate flood risk perceptions in relation to physical and perceived distance?
3. How does flood evacuation experience influence response-efficacy and self-efficacy?
4. How are individuals' flood risk management preferences influenced by experiences with the 2013 flood?

Together, these research questions will help to improve our understanding of flood risk perceptions and mitigation preferences, generalized to the public, within the City of Calgary in the aftermath of a major flood. These are important questions to examine when looking at what components shape risk perceptions and trying to understand management preferences. For example, it is important to understand if the general public connects climate change to flood risk as this connection may help understand how risk perceptions may evolve into the future.

Further, the differences in risk perceptions in the short- and long- term, as well as the role flood experience plays in shaping flood risk perceptions and perceptions of distance, is important in understanding the temporal and spatial differences of flood risk. If significant differences are found between individuals with different flood experiences, then there could be tension when risk management is discussed within communities. This can be used to understand how risk perceptions change over different time periods and efforts can be made to ensure that management plans align with the public's risk perceptions and management preferences.

This research is also significant in furthering our understanding of how differences in experience influence coping appraisal, specifically related to self-efficacy and response-efficacy. In terms of flood mitigation within the City of Calgary, this research is important to help understand the mitigation preferences of the general public. The results will give risk managers an idea of which mitigation projects will have the greatest levels of support. These results could be applied to other regions, facing similar flood risk management decisions.

Research Approach

This thesis brings together multiple research areas surrounding flood risk perceptions as they pertain to the 2013 Calgary flood. The research furthers our understanding of how the general public's views towards flood risk have been influenced by personal experience. Addressing these research areas is expected to have broad social and scientific significance as the results may help inform risk communication processes designed to facilitate high-quality risk management decisions about natural disasters at the public and policy levels (Arvai 2014). Furthermore, with the impending effects of climate change on watersheds and flood risks in Canada, these findings will offer insights that will help set policy into the future (Public Safety Canada 2014).

As a researcher, my interpretive framework and philosophical assumptions have been developed on the basis of my past experiences with emergency management and business continuity and by completing an undergraduate degree in Geography and Environmental Management. The reflexivity is furthered by being a young adult who did not live in Calgary during the 2013 floods. The survey used was comprised primarily of pre-established scales that were adapted to meet this project's needs, limiting the role of my personal interpretations.

My research fits within the discipline of Geography as it incorporates residents' geographic locations relevant to the flood zone, focusing on differences between those who were evacuated during the 2013 flood and those who were not. The geographic context is evaluated to see how it may drive risk perception formation and examines the importance of past experiences in shaping these views. My research project touches on the various aspects of resource management as it relates to flood risk, from the objective

nature of the flood to perceptions around flood risk that influence mitigation preferences and ultimately policy recommendations. The research uses multiple temporal and spatial scales to fully address the research areas covered. More broadly, all 'natural disasters' are created at the intersection of human behaviour and natural processes, a key element in the discipline (White 1945).

The remainder of this thesis is structured first by providing an article for submission to a refereed journal that includes details on the data collection, analysis, results and discussion of the presented research. Chapter 3 provides a conclusion to this thesis; it also discusses the strengths and limitations of my research, and provides suggestions for what might be done to further this work.

Chapter 2: Risk Perceptions and Management Preferences

Introduction

Over the past decade, we have witnessed an increase in the frequency and severity of extreme weather events, such as floods, and the associated damages of these events (Winsemius et al. 2016). In many urban areas, overland flooding is a growing concern because of the increased human presence—in terms of population, property, and infrastructure—in regions susceptible to flood-related risks. These concerns are exacerbated by climate change, which is expected to influence flood and drought regimes (Jongman et al. 2012, Buttle et al. 2016).

Canada has not been exempt from this trend, with the risk of severe overland flooding being one of the country's most prevalent natural hazards (Milrad et al. 2015, Buttle et al. 2016). One such event occurred in the summer of 2013, leading, at the time[7], to Canada's costliest natural disaster (Chief Financial Officer's Department 2014, Expert Management Panel 2014, Pomeroy et al. 2015).

Several studies have been conducted on flood risk perceptions and protective behaviours (Bubeck et al. 2012a, Bubeck et al. 2013, Kellens et al. 2013, Bruine de Bruin et al. 2014, Boer et al. 2015, Maidl and Buchecker 2015). However, few of these studies sought to understand the risk perceptions of people directly and indirectly exposed to flood risks, nor focused on an event as significant as the Calgary flood of 2013. To this end, the research reported here measured public perceptions of flood risk, as well as

[7] At the time of writing, the 2016 wildfires in Fort McMurray, Alberta are ongoing, and will likely become Canada's costliest natural disaster in history. Prior to 2016, the 2013 Alberta floods were Canada's costliest natural disaster.

public preferences for flood risk management options, *in the aftermath of a major flood*. At the same time, with increased uncertainty due to climate change, this research also sought to deepen our understanding of how attitudes toward climate change might influence flood risk perceptions.

Flood Risk Perceptions

Research has shown that there are many factors that shape individuals' flood risk perceptions and their flood risk management preferences (Slovic 2000). Two of these — direct experience with flooding and views towards climate change — are the focus of this chapter.

Direct experience with flooding has been shown to increase an individual's perception of future flood risk (Botzen et al. 2009, Zaalberg et al. 2009, Bubeck et al. 2012a, Lawrence et al. 2014) and increase motivation to take action (Zaalberg et al. 2009, Bubeck et al. 2013, Lawrence et al. 2014). In accordance with the availability heuristic[8], direct experience can create strong and instinctive negative impressions, increasing the salience of the risk, and heightening sensitivity to the frequency, severity and uncertainty of future floods (Tversky and Kahneman 1973, Keller et al. 2006, Botzen et al. 2009, Kunreuther et al. 2014). Direct experience with a hazard can also facilitate a sense of

[8] The availability heuristic is a mental shortcut people use to comprehend the probability of an event occurring based on the ease the event can be recalled. Using the availability heuristic leads to biases in how we process the probability of a risk (Tversky and Kahneman 1973, 1974). For instance, events which receive media attention and are shocking are easier to remember and recall later, increasing the perceived risk. The opposite occurs with events that receive little media attention or are seen as common; they may be perceived as having lower risk estimates than the statistical nature of the risk as they are harder to recall instantly (Lichtenstein et al. 1978).

vulnerability, and decrease perceptions of response costs (Siegrist and Gutscher 2008, Zaalberg et al. 2009, Lawrence et al. 2014, Boer et al. 2015).

Perceptions of risk may be dampened when an individual has had no direct experience with a hazard, such as severe overland flooding, and overestimated when they have had these experiences (Kunreuther et al. 2014); however, *how* an individual interprets their experience is critical in the formation of risk perceptions. Indirect experience with flooding, such as through media exposure, has been found to have only a small effect on risk perceptions (Siegrist and Gutscher 2006, 2008). It has been shown that an individual tags memories with affect[5], influencing the ease of recall. Without a negative tag on memories, such as through indirect flood experience, memories are less salient and are more difficult to recall (Slovic et al. 2004, Slovic et al. 2007, Siegrist and Gutscher 2008).

As time from exposure to hazardous experiences increases, risk perceptions tend to return to levels seen before the hazard. Associated with the availability heuristic[8] and construal level theory[9], indirect experience and distant events have been shown to minimize risk perceptions and lessen motivation to take protective behaviour; this is seen as the hazardous event is less salient, more abstract and difficult to recall (Siegrist and Gutscher 2006, Trumbo et al. 2014, Maidl and Buchecker 2015). In support of this, the literature review by Bubeck et al. (2012a) found that direct experience with flooding,

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[9] Construal level theory (CLT) examines psychological distance to a concept using the individual's current place as the reference point. As the sense of distance to a stimuli increases, the stimuli is seen as further away, abstract and having a higher-level of construal, such as items that are difficult to imagine, or in a distant time or place. The higher the level of construal, the more abstract the stimuli is and details in the peripheral components are lost. Items that are closer have a lower construal, and are seen as concrete, more salient, and, as such, easier to recall. CLT assesses distance in four dimensions: temporally, spatially, socially and hypothetically (Liberman et al. 2002, Liberman and Trope 2008, Spence et al. 2012).

specifically the severity of the flood and how recent the flood event was, significantly influenced protective behaviours taken.

That said, it has also been found that past experience does not ensure that mitigation actions and personal preparedness will be taken (Miceli et al. 2008, Wachinger et al. 2013). Three explanations for this have been provided: people may accept the risk because the benefits are greater than the potential costs, the sense of responsibility for taking action is transferred to others, or the risks may be understood but the individual lacks access to the necessary resources to take action (Wachinger et al. 2013). To further this, flood risk perceptions are important to understand to see how they fit within these explanations and to see if other factors influence beliefs towards taking protective behaviour.

For instance, flood risk perceptions have also been examined in relation to individuals' views towards climate change. Recent work by Bruine de Bruin et al. (2014) found that those who linked flood events to climate change were more likely to report that the risk of flooding was increasing over time. Contradictory results surrounding the role of direct experience with flooding, and its influence on increasing climate change concern, have also been reported; Spence et al. (2011) found an increased concern about climate change in those who had direct flood experience, while Whitmarsh (2008) found the opposite, direct experience did not increase climate change concerns. In these studies, climate change was seen as a distant concern, in line with construal level theory[9] (Whitmarsh 2008, Spence et al. 2011, Spence et al. 2012, Jones et al. 2016).

When an extreme weather event occurs, an individual may begin to see a connection between the event and climate change (Reser et al. 2014). Once this

connection has been made, subsequent extreme weather events may be attributed to the effects of climate change, increasing risk perceptions (van der Linden 2014). In support of this, Shao and Goidel (2016) found that weather patterns, such as extreme weather events, can influence perceptions towards climate change.

Flood risk perception can also be studied by looking at its interaction with perceptions of distance to a flood risk area. O'Neill et al. (2016) found that living close to a flood zone increased flood risk perceptions and that perceptions decreased as distance from the flood zone increased. Further, perception of distance from the flood zone was greater than actual physical distance. Earlier work by O'Neill et al. (2015), using cognitive mapping[6], found large differences between the expert assessment of risk and the general public's spatial perception of flood risk. These results further Botzen et al. (2009) findings, which show that objective distance to a high flood risk region aligns with respondents perceptions. It was also found that evacuation experience increases perceptions of future flooding and lowers expectations of damages. However, those without experience with flooding had lower flood risk perceptions than the objective risk, though expected damages from flooding were accurate.

Conversely, work by Siegrist and Gutscher (2006) separated participants into four categories of flood risk based on expert maps and home location, and showed that expert assessment of the objective flood risk in a region aligned with the general public's flood risk perceptions. This suggests that physical distance from a flood hazard relates to flood risk perceptions. However, when looking at estimates of risk, people in some regions overestimated the risk of flooding, taking greater protective action than expert

recommendations, while in other areas, risk estimates and protective action were lower than recommended (Siegrist and Gutscher 2006).

Protective Action

Direct experience with flooding has been largely shown to temporarily increase risk perceptions; however, the relationship between higher levels of flood risk perception and the intention to take, or taking, protective action is unclear (Bubeck et al. 2012a, Wachinger et al. 2013). Some studies have found that having a higher risk perception does not indicate that protective actions have been taken (Siegrist and Gutscher 2006, Bubeck et al. 2012a) or increases intentions to take action (Terpstra 2011). Others have found the opposite, direct experience increases intentions to take protective behaviour (Kievik and Gutteling 2011) and increases preparedness behaviour focused on preventing flood damages (Boer et al. 2015).

Bubeck et al. (2012a) proposed that the relationship between risk perceptions and taking protective actions was not found because both risk perceptions and coping appraisals must be elevated in order for protective action to be taken. This suggests that the belief that protective action is needed, through elevated risk perceptions, and the sense that the individual has the ability to lower personal risk, is critical in leading to protective action being taken. Alternatively, it has been shown that those with elevated risk perceptions may have already taken action to lower their perceived risk, therefore altering their risk perception. In support of the claim that high risk perceptions increase protective actions being taken, Kievik and Gutteling (2011) found that living in a region

with increased flood risk led to increased information seeking and intentions to take self-protective behaviours.

The term coping appraisal has been used to assess an individual's belief that they have the skills, resources and motivation to take action that will lead to effective reduction in risk exposure. It is seen as an important element in understanding an individual's motivation to take flood mitigation actions (Bubeck et al. 2013). Within coping appraisal, three elements have been reported: response-efficacy, self-efficacy and response costs (Rogers 1975, Grothmann and Reusswig 2006, Bubeck et al. 2013). When motivating an individual to take action, Grothmann and Reusswig (2006) showed the importance of communicating the effectiveness and cost of taking action, as well as the risks and potential consequences. Bubeck et al. (2013) focused on the importance of response-efficacy and self-efficacy, with risk communication needing to emphasize which actions should be taken and the effectiveness of such actions.

In order to motivate an individual to take protective action, both risk perception and coping appraisal need to be aligned, and there needs to be a sense of personal responsibility towards taking action (Soane et al. 2010, Bubeck et al. 2012a). However, by increasing risk awareness and knowledge exclusively, risk managers can inadvertently reinforce the general public's apathy towards protective action by encouraging views of denial or 'wishful thinking' (Norman et al. 2005, Grothmann and Reusswig 2006). Conditions to create this may be found when coping appraisal is low but the individual has a high risk perception. Combined, these results indicate the need to study coping appraisal, risk perceptions and risk management preferences concurrently (Norman et al.

2005, Grothmann and Reusswig 2006, Soane et al. 2010, Kievik and Gutteling 2011, Bubeck et al. 2012a).

When the public is included in the discussion of flood risk mitigation options, dialogue between the general public and risk managers is recommended. The mitigation options proposed should clearly communicate the probability of the risk, and the suggested mitigation options should align with the community's values and preferences. This is needed to encourage protective action being taken and to encourage support for mitigation projects (O'Sullivan et al. 2012, Arvai 2014, Hartmann and Spit 2016). Risk managers should look to the general public to understand how risk is viewed and what their management preferences are (Bradford et al. 2012).

The Present Study

This chapter examines how people perceive flood risk, as well as their management preferences, in the aftermath of a major flood. The research reported here focuses on short- (5 year) and long- (100 year) term flood risk perceptions and incorporates a novel measure of risk perception, specifically focused on how perceptions of distance from at-risk areas are influenced by prior experience with flood evacuation. Flood evacuation experience, views towards climate change, and individual coping appraisal were assessed as variables that may influence flood risk perceptions. Finally, response-efficacy, self-efficacy, and management preferences were examined in relationship to evacuation experience.

In 2013, the City of Calgary experienced a major flood, leading to Canada's costliest natural disaster due to flooding. Much of the city during this time was directly or

indirectly impacted by flooding and discussion continues around appropriate flood risk mitigation (Expert Management Panel 2014, Pomeroy et al. 2015). The extensive 2013 flood event makes the City of Calgary an excellent location to study flood risk perceptions.

The mitigation projects being discussed in the City of Calgary and Province of Alberta range in size and focus, from building an off-stream reservoir to constructing additional permanent flood barriers, and at the most local scale, providing further information and resources to home and business owners to inform them about actions that can be taken. Recent flood mitigation efforts have led to the local government purchasing homes in high- flood risk regions, and entering an agreement with a local hydroelectric power generation company to use a dam for flood and drought mitigation during the region's eight weeks of high flood risk. Lastly, some local insurance companies are offering overland flood insurance that can be added to a homeowner's existing insurance; prior to current mitigation efforts, overland flood insurance was unavailable in the region. Preferences towards these flood mitigation options are examined in relation to respondents' experiences during the 2013 flood.

Based on past research, it was anticipated that flood experience would shape risk perceptions and coping appraisals and that beliefs towards climate change would influence flood risk perceptions. As little work has been completed on how risk perceptions may shift when elicitation assesses short- (5 year) and long- (100 year) term flood risk perceptions, this will be explored. A novel measure of studying risk perception is provided by examining how experience with flood evacuation influences perceptions of distance from a high flood risk region. As well, views towards climate change are

assessed in relation to flood risk perceptions. Finally, this research deepens our understanding of the influence flood experience has on coping-appraisal and support for mitigation.

Methods

Sample

An Internet based survey was conducted in Calgary, Alberta, Canada during September and October, 2015. The survey was fielded by Insightrix Research, using a pre-recruited panel and probability sampling. Participants were members of Insightrix's diverse network, who had previously agreed to complete a set number of surveys in exchange for incentives. Using this method allowed for the research to achieve a balanced response between respondents who lived in communities that were evacuated during the extensive floods of 2013 and those who were not. Ethics approval was received from the University of Calgary's Conjoint Facilities Research Ethics Board (Ethics ID: REP15-1538).

A representative sample was used to match the demographic characteristics of Calgary residents. In total, the sample consisted of 806 residents living in Calgary. Following standard practice, 43 respondents were removed having spent below the half median time to complete the survey[10] (taking less than 7.23 minutes for those living in an evacuated community and 7.02 minutes for those who were not). This was done to remove respondents who had not taken sufficient time to read and complete the survey.

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[10] In this study, a total of 22 respondents in the flood evacuated communities and 21 respondents in the non-evacuated communities were removed.

The neighbourhood respondents lived in was used to determine if they were at-risk for flooding, with respondents self-identifying as being evacuated during the flood. In total, 763 respondents were included in the final sample; 379 (49.7%) lived in communities that had high flood risk areas evacuated and 384 (50.3%) lived in communities that had no evacuation order. Results indicated that 198 respondents (26%) were evacuated, of whom 73 (9.6%) experienced water damage to their home. For those who had experienced water damage, it took longer than a year for 16 respondents to repair the damages, with a further 9 respondents indicating their homes were still not repaired, two years after the event. Two respondents had still not returned home at the time of survey completion. It was indicated by 24 respondents that they had relocated permanently due to the risk of flooding, with 19 respondents planning on doing so in the future.

The sample consisted of a close-to-even gender balance; 50.7% self-identified as female, 48.5% identified as male and 0.8% declined to answer. The average age range was between 40 and 49; 55% had a university degree and 91.7% had some post-secondary education. In terms of income, 28.1% reported earning more than CAN$150,000 with 78.7% earning at least CAN$60,000.

Survey Instrument

Prior to the survey instrument being provided to Insightrix Research for data collection, I created the survey questions. Previous research was drawn upon to understand techniques and variables used to study risk perceptions. Based on these findings, a survey instrument was created, by myself with the guidance of Dr. Joe Arvai,

that consisted of a series of questions on perceptions of flood risk, views towards climate change, coping appraisal, and mitigation preferences. Unless otherwise specified, questions were asked using a seven-point Likert scale, ranging from strongly disagree (1) to strongly agree (7). A version of the survey instrument, with the relevant questions to this thesis, is found in appendix C.

Following a series of questions surrounding personal experience with flooding, I assessed risk perception using the question, "How would you characterize the risk of a major flood in Calgary, like the one experienced by the city in 2013, over the next 5 years?"; I obtained responses using a Likert scale, which ranged from 1 (very low risk) to 5 (very high risk). A similar question was asked to assess views towards long- (100 year) term flood risk. Short-term flood risk perceptions were assessed over the next 5-years as this is a psychologically proximal time period, in line with construal level theory. In contrast, long-term flood risk perceptions were assessed at the 100-year time period as this is a psychologically distant time period, the time period frequently used in flood risk analysis and aligns with past research (Keller et al. 2006, Bell and Tobin 2007, Kellens et al. 2013).

I assessed risk perception using a proxy; perception of safe distance from a high risk flood area. This was completed by geocoding respondents' addresses in ArcGIS, and calculating straight-line distances from the respondents' homes to the 100-year flood inundation zone which surrounds the Bow and Elbow Rivers, as indicated by the City of Calgary. The distances, in meters, became the variable used for physical distance to a high-risk flood zone.

I then assessed views towards climate change using a four-item scale adapted from Tobler et al. (2012) with an additional question added to assess flood risk: "Climate change will increase the probability of severe flooding in the future." A composite variable, 'climate change views', was created with strong inter-item reliability, Cronbach's α=.947[11] (full details in appendix B).

I measured coping appraisal by using a 12-item scale divided into six questions assessing self-efficacy, adapted from Schwarzer and Jerusalem (1995), and six questions assessing response-efficacy. There was strong inter-item reliability for both scales, with self-efficacy having a Cronbach's α= .916 and response-efficacy with a Cronbach's α= .848 (full details in appendix B). Self-efficacy[12] and response-efficacy[13] were used together to assess coping appraisal.

I measured respondents' preferences about flood mitigation options using six different risk mitigation strategies that were established in consultation with a regional flood risk manager. These projects were selected from a list of actual strategies that were under consideration in the study area, and ranged in resource intensity from increasing education to building an off-stream flood reservoir.

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[11] Cronbach's α is a reliability analysis to test if a set of items can be combined to create a single composite variable. The closer to 1 the Cronbach's α is the more similar the variables are, indicating that the grouped variables go well together and can be combined and used as if they were one variable.

[12] Self-efficacy assesses a respondent's value orientation towards a sense of their capability in overcoming challenges in daily life. For example "I am resourceful when it comes to handling unforeseen situations".

[13] Response-efficacy assesses a respondent's views towards their ability and resources in taking action to lower flood risk. For example "It is worth the effort to take personal action aimed at lowering my risk of future flood damage".

Analysis

Once the survey reached the targeted sample size, Insightrix Research provided me with a raw data file that I used for my statistical analysis. I opted to use multivariate statistical tests, as they are the most appropriate tools to analyze the data, while making comparison of the different evacuation groups.

I used analysis of variance (ANOVA)[14] and multivariate analysis of variance (MANOVA)[14] to test for differences between flood risk perceptions, and mitigation preferences, from the perspective of three distinct groups: those living in flood evacuated communities but not evacuated, those not living in flood evacuated communities and not evacuated, and those evacuated. I analyzed the results were using Tukey's *post-hoc* test[15]; with a Bonferroni correction[16] being used when assessing mitigation preferences.

I used hierarchical multiple regression[17] to assess the influence of being evacuated on perception of distance to a high-risk flood area. This was done to determine if

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[14] The ANOVA and MANOVA tests were selected to assess differences between the mean responses between flood experience and the independent or dependent variable. If mean scores between the variables were significantly different, they were reported and an explanation provided. The primary difference between the ANOVA and MANOVA test is the number of dependent variables included; as well, the MANOVA test uses a linear composite value of means that combines the mean values of the dependent variables included in the test.

[15] Alone, ANOVA and MANOVA tests do not give the direction of the differences in means that were found. *Post-hoc* tests were completed to see where the differences were occurring, and in which direction. As the data in this sample met the homogeneity of variances criteria, Tukey's HSD *post-hoc* test was chosen.

[16] A Bonferroni correction was applied when assessing the mitigation preferences to avoid making a Type 1 error, as multiple mitigation options were assessed within one statistical test. The p-value that significance is accepted becomes smaller to avoid accepting a significant value due to chance.

[17] Hierarchical multiple regression was selected to see if the dependent variable could be predicted by entering multiple independent variables in the specified order. This allows for moderating factors to be assessed.

evacuation status was a moderating factor and if perceived distances changed based on evacuation experience.

To examine how views towards climate change and coping appraisal influenced flood risk perceptions, I used multiple linear regression[18]. The tests were designed to determine if there were general trends, rather than specific differences, between evacuation statuses, as was seen in the ANOVA and MANOVA tests.

Results

Flood risk perceptions

Respondents' views towards the risk of a major flood in the next 5 and 100 years indicated a mean rating of 2.75 (*SD*= 1.07), and 4.15 (*SD*= 1.00), respectively. A multivariate analysis of variance (MANOVA) showed these responses to be significantly different ($F(4, 1384)=2.71$, $p=0.03$); Table 1. Subsequent tests of between-subject effects revealed differences between evacuation experience for the next 5 years ($F= 5.01$, $p=0.007$), but not for the next 100 years ($F= 2.52$, $p>0.05$). Tukey's HSD *post hoc* test revealed that those not in the flood zone and not evacuated had significantly lower 5-year flood risk perceptions ($\bar{x}=2.62$, $SD=1.05$) than those in the flood zone and not evacuated ($\bar{x}=2.90$, $SD=1.02$, $p=0.012$).

[18] Linear multiple regression was selected to see if the independent variable could predict the dependent variable. This test creates a model that fits a regression line to the data; the lower the variance, the better the model is at predicting the dependent variable.

Table 1. Mean ratings, ANOVA and MANOVA of 5 year and 100 year flood risk perceptions based on flood experience

	Not Flood zone, not evacuated		Flood zone, not evacuated		Evacuated				
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	*F*	*df*	*P*
Views of Risk of a Major Flood				*F*= 2.71, *df*= 4, 1384, *p*=.03					
5 year	2.62	1.05	2.90	1.02	2.83	1.11	5.01	2	0.007
100 year	4.07	1.02	4.25	0.99	4.24	0.97	2.52	2	>0.05

A second way to assess flood risk perceptions was completed by comparing physical and perceived distance to a high flood risk area. To examine how evacuation experience influences perceived distance in relation to physical distance, a hierarchical multiple regression was used, see Table 2. This regression assessed the statistical significance of the interaction term between distance to the 100-year inundation line (meters) and evacuation status. There was a statistically significant moderator effect of evacuation status, as evidenced by the addition of the interaction term which explained an additional 12.5% of the total variance; p<0.001.

Table 2. Hierarchical multiple regression analysis predicting the influence of experience on perceived distance

	Model 1			Model 2		
	B	*SE*	*β*	*B*	*SE*	*β*
Meters to 100 year inundation	0 .001	0.00	0.88***	0.001	0.27	0.80***
Evacuation experience[a]	1.88	0.32	0.31***	0.17	0.00	0.03
Interaction (Distance x Evacuation Experience)				0.004	0.32	0.42***
R^2	0.46			0.59		
$F(df_1,df_2)$	205.36***(2, 477)			225.83*** (3, 476)		
$\Delta F(df_1,df_2)$	N.A.			143.81*** (1, 476)		

[a] Dummy variable for evacuation status was used (0=not evacuated, 1=evacuated)
*p ≤ .05, **p ≤ .01, ***p≤ .001

Because climate change may be linked to public concern about future flood events, participants' views of climate change were assessed in relation to flood risk perceptions. The composite variable for climate change had a mean score of 4.66, *SD*= 1.71 and was used in a stepwise linear regression. The regression model indicated that an individual's evacuation experience during the 2013 flood accounted for only 1.4% of explained variability surrounding perceptions of flood risk in the short- (5 year) term (F(2, 707)=5.03, p=0.007). This increased to 12.4% when views towards climate change were added to the regression model (F(3, 706)=33.42, p<0.001 see Table 3). This result suggests that views towards climate change have a more significant influence on flood risk perceptions in the short-term than evacuation experience, and the more concerned one is about climate change, the higher the short-term flood risk perception.

Table 3. Linear regression analysis predicting short-term flood risk perceptions

	Model 1			Model 2		
	B	*SE*	*β*	*B*	*SE*	*β*
Not Evacuated, Flood zone	0.28	0.10	0.12**	0.24	0.09	0.1**
Evacuated	0.21	0.10	0.09*	0.14	0.09	0.06*
Climate Change views				0.21	0.02	0.33***
R^2		0.01			0.12	
$F(df_1,df_2)$		5.03**(2, 707)			33.42***(3, 706)	
$\Delta F(df_1,df_2)$		N.A.			88.96*** (1, 706)	

*p ≤ .05, **p ≤ .01, ***p≤ .001

When assessing flood risk perceptions in the long- (100 year) term, the regression model revealed that evacuation experience during the 2013 flood explained only 0.5% of

the variability (F(2,720)=1.95, p>0.05). When views towards climate change were added, this increased to 9.9% of explained variation (F(3,719)=26.36, p>0.05, see Table 4). This shows that including the climate change variable increases the explained variability substantially, indicating views towards climate change are an important influence in flood risk perceptions, in both the short- and long- term.

Table 4. Linear regression analysis predicting long-term flood risk perceptions

	Model 1			Model 2		
	B	*SE*	*β*	*B*	*SE*	*β*
Not Evacuated, Flood zone	0.15	0.09	0.06*	0.11	0.09	0.05*
Evacuated	0.15	0.09	0.06*	0.08	0.09	0.04*
Climate Change views				0.18	0.02	0.04***
R^2		0.01			0.1	
$F(df_1,df_2)$		1.95 (2, 720)			26.36 (3, 719)***	
$\Delta F(df_1,df_2)$		N.A.			74.79 (1, 719)***	

*p ≤ .05, **p ≤ .01, ***p ≤ .001

Coping appraisal was measured to understand its role in shaping flood risk perceptions over the short- and long- term; however, it was found not to be influential. For those who lived in a flood evacuated community, a linear regression analysis established that an individual's evacuation experience during the 2013 flood provided limited predictive explanation for perceptions of short- (5 year) term flood risk; F(1, 358)=0.41, p>0.05 and accounted for 0.2% of explained variability. When coping appraisal was added to the regression model, it increased to 0.5% of explained variation (F(2, 356)=0.43, p>0.05). Taking a long- (100 year) term perspective of flood risk

perceptions, the regression model revealed that experience during the 2013 flood explained 0.3% variation in the model (F(1, 369)=.001, p>0.05); when coping appraisal was added, this increased to 0.8% of explained variation (F(2, 367)=1.96, p>0.05).

To examine coping appraisal further, response-efficacy was examined in isolation. The ANOVA for response-efficacy revealed that mean responses differed significantly by experience in the 2013 flood (*F*=3.85, p=0.022, as shown in Table 5). A Tukey HSD *post-hoc* test found the response-efficacy was greater for those not in the flood zone and not evacuated ($\bar{x}$=4.37, SD=1.14) than for those who were evacuated ($\bar{x}$=4.10, SD=1.28, p=0.024). This indicates that evacuation experience lowers response-efficacy and increases views that individual action will not meaningfully lower flood risk. Evacuation experience did not influence respondents' views of self-efficacy, indicating that respondents' overall beliefs in their ability to handle life stresses is isolated to flood risk.

Table 5. Mean ratings and MANOVA revealing the influence of evacuation experience on response-efficacy and self-efficacy

	Not Flood zone, not evacuated		Flood zone, not evacuated		Evacuated				
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	*F*	*df*	*P*
				F= 2.261, *df*= 4, 1520, *p*>0.05					
Response-efficacy	4.37	1.41	4.37	1.22	4.10	1.28	3.850	2	0.022
Self-efficacy	4.99	1.01	5.08	1.00	4.90	1.00	1.480	2	>0.05

Mitigation preferences

A series of six questions were asked about participants' support for different mitigation actions currently being considered in the City of Calgary. They range in project scale from providing further information about flood risk to building an off-stream reservoir; see Table 6. A MANOVA showed a significant multivariate effect ($F(12,1512) = 4.75$, $p<0.001$) based on flood experience and support for mitigation, indicating that experience during the 2013 flood had a significant impact on some mitigation preferences.

Table 6. MANOVA Mean ratings for support towards mitigation options

	Not flood zone, not evacuated		Flood zone, not evacuated		Evacuated				
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*F*	*df*	*P*
				F= 4.75, df= 12, 1512, p<.001					
Government purchase of homes and businesses in the flood prone areas with the intent of removing them and converting the empty lots into parks	4.09	1.90	4.56	1.85	4.31	2.00	3.80	2	0.023
Require insurance companies to provide mandatory overland flood insurance to homes and businesses in flood-prone areas	4.41	1.87	4.60	1.95	4.92	1.93	4.59	2	0.010
Provide information and resources to home and business owners so that they may take action themselves aimed at reducing their personal risks	5.49	1.35	5.59	1.27	5.32	1.43	2.08	2	>0.05
Build an off-stream reservoir	4.82	1.57	5.19	1.54	5.35	1.54	8.77	2	<0.001
Construct additional permanent flood barriers within Calgary city limits in order to protect vulnerable infrastructure and communities	4.83	1.47	5.27	1.37	5.42	1.39	13.22	2	<0.001
Modify the operation of hydroelectric dams upstream of Calgary to increase control over flooding	5.16	1.26	5.39	1.27	5.57	1.28	7.19	2	0.001

Specifically, evacuation experience significantly influenced the level of support for building the Springbank off-stream reservoir (F(2,760)=8.77, p<0.001). Tukey's HSD

post hoc test with a Bonferroni correction revealed those not in the flood zone and not evacuated indicated less support ($\bar{x}$=4.82, SD=1.57) than those in the flood zone and not evacuated ($\bar{x}$=5.19, SD=1.54, p=0.020) and those who were evacuated ($\bar{x}$=5.35, SD=1.54, p<0.001).

Views towards constructing additional permanent flood barriers were also influenced by evacuation experience (F(2,760)=13.22, p<0.001). Tukey's HSD *post hoc* test with a Bonferroni correction revealed those not in the flood zone and not evacuated indicated less support ($\bar{x}$=4.83, SD=1.47) than those in the flood zone and not evacuated ($\bar{x}$=5.27, SD=1.37, p=0.002) and those evacuated ($\bar{x}$=5.42, SD=1.39, p<0.001).

As well, support for modifying the hydroelectric dams along the Bow River for the purpose of flood control was significantly influenced by evacuation experience (F(2,760)=7.19, p=0.001). Tukey's HSD *post hoc* test with a Bonferroni correction revealed respondents who were not in the flood zone and were not evacuated ($\bar{x}$=5.16, SD=1.26) revealed significantly less support than those who were evacuated ($\bar{x}$= 5.57, SD=1.28, p=0.001).

Using a Bonferroni correction, the test of between-subject effects for the remaining mitigation options did not significantly differ based on flood experience in the 2013 flood; views towards government purchase of homes and businesses in flood prone areas (F(2,760)=3.8, p=0.023), support towards requiring insurance companies to provide overland flood insurance (F(2,760)=4.59, p=0.01), and support for providing further information and resources to home and business owners (F(2,760)=2.08, p>.05).

Discussion

The purpose of this research was to deepen our understanding of how people perceive flood risk, as well as their management preferences in the aftermath of a major flood. Results demonstrate that direct flood evacuation experience does not consistently raise risk perceptions, although experience does influence response-efficacy and management preferences.

Results indicate that evacuation experience increases short- (5 year) term flood risk perceptions. Respondents who lived in a flood evacuated community, but were not personally evacuated, had elevated perceptions of flood risk in the next five years when compared to those who did not live in a flood evacuated community. In contrast, results for long- (100 year) term flood risk perceptions did not indicate that evacuation experience influenced perceptions of flood risk. This is contrary to past research that typically finds direct experience increases risk perceptions, in line with the availability heuristic[8] (Keller et al. 2006, Siegrist and Gutscher 2006, 2008, Botzen et al. 2009, Zaalberg et al. 2009, Bubeck et al. 2012a, Lawrence et al. 2014).

Construal level theory[9] may be used to explain why long-term flood risk perceptions were not influenced by flood experience, while short-term flood risk perceptions were. Flood risk in the long-term is constructed abstractly, with prior experience being heavily discounted[19] and no longer influencing perceptions of flood

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[19] Temporal discounting is used to explain how the timespan being assessed influences the value of the reward or risk. The subjective value of a reward is discounted as time to receiving the reward or probability increases, for instance, a longer delay or smaller probability has a lower subjective value. When there is a decision between a smaller reward in the present or a larger reward in the future, the future reward is reduced making the present reward seem more desirable. This may lead to preference reversals when the smaller reward in the present is more desirable than waiting for the larger reward in the future. When

risk. Further, the risk of flooding is seen as distant, with the peripheral details being lost. Flood risk perceptions in the near-term are more proximal and concrete, with experiences in 2013 remaining salient and the details of the flood event still represented in the risk perception. This is important when understanding the nuances in the framing of risk perception and the implications it may have for communicating flood risk and planning for short- and long- term flood mitigation.

Flood risk perception was also assessed using linear regression and in a novel approach that incorporated perceptions of distance. From the regression analysis, evacuation experience was not found to be an explanatory variable for either short- or long- term risk perceptions. Due to the magnitude of flood damages, and the continued media coverage of flood risk and mitigation, it is likely that the whole community has been influenced by flooding, in some degree, raising risk perceptions of all citizens regardless of personal, direct experience with the flood. This provides an explanation for why differences in risk perception were not found by direct flood evacuation experience, as would be expected (Wachinger et al. 2013).

When perception of distance to a high flood risk area was used as a proxy for flood risk perceptions, evacuation experience was found to have a moderate, 12.5%, influence in shaping perceptions. This is in line with previous research that finds perceived distance relates to flood risk perception (O'Neill et al. 2016). Accordingly, by examining perceptions of distance, an alternative view of flood risk perceptions is

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looking at risk, large risks in the future are seen as smaller than equal risks in the present (Green et al. 1994, Green and Myerson 2004).

provided; indicating perceptions of distance may be influenced by personal, direct experience.

The differing results between using linear regression to examine flood risk perceptions and those found when incorporating perceptions of distance shows that perceived distance and risk perceptions are similar, but distinct concepts. Using perceptions of distance to examine risk perceptions may provide a more refined perception of flood risk that removes the influence of external factors, such as the media and communities' responses. Assessing flood risk perception using a survey question may be incorporating external factors that increase risk perception but do not influence desire to take protective action. For example, the entire City of Calgary was impacted by flooding, increasing risk perceptions for the majority of residents. The heightened flood risk perception may conceal the influence that direct, personal flood experience had. By incorporating perceptions of distance, the influence of direct experience of flooding to the home may be isolated; this may be influential in understanding and encouraging protective behaviours and support for mitigation.

To further understand factors that drive flood risk perceptions, views towards climate change were assessed, and were found to be significant in influencing perceptions. Results indicate that climate change views are more important in explaining flood risk perceptions than evacuation experience, with higher perceptions of flood risk found amongst those more concerned about climate change. This suggests that for some, views towards climate change are connected to flood risks (Bruine de Bruin et al. 2014, Reser et al. 2014, van der Linden 2014, Shao and Goidel 2016). Further, this indicates that direct experience is not needed to raise perceptions of flood risk as increasing

knowledge of climate change (Shi et al. 2015) may subsequently increase perceptions of flood risk. These results also suggest that since climate change views are more influential in shaping flood risk perceptions than experience, flood risk perceptions may remain stable over a longer period of time as memories of extreme events fade.

In line with previous research (Bubeck et al. 2012a), the role of coping appraisal was not found to be significant in shaping short- or long- term flood risk perceptions. When response-efficacy and self-efficacy were examined individually, being evacuated was found to diminish views of response-efficacy, while self-efficacy remained stable. Those who were evacuated do not feel they have the resources and ability to take action to lower personal flood risk, thus, individuals' beliefs about themselves remain stable despite evacuation experience. This suggests that response-efficacy is more adaptive than self-efficacy, therefore risk communication should target building an individual's sense of capability in taking protective action.

When looking at specific mitigation preferences, those who were evacuated consistently were the most supportive of mitigation options, while those not living in a flood evacuated community were the least supportive. There were two, non-significant, exceptions where evacuation experience did not raise preferences as expected; the government purchase of homes in high flood risk regions and providing further information and resources. This result shows that for some mitigation options, other variables beyond evacuation experience may be influential in shaping preferences, such as the influence of response-efficacy and desire to maintain a community in a high flood risk region.

Significant differences based on evacuation experience were found for three mitigation options; building an off-stream reservoir, constructing additional flood barriers, and supporting modifying dams for flood control purposes. These results are expected, as those who were directly impacted by flooding are personally invested in lowering flood risk by using large-scale mitigation.

Without future flood events, it is anticipated that support for all types of mitigation will decrease. Construal level theory, the availability bias, and results found for long-term flood risk perception support this prediction. As time passes from the flood event, it is anticipated that risk perceptions will be reduced and priorities shift to new pressing concerns. Ongoing efforts will be needed to sustain flood risk perceptions for all, particularly if large-scale, structural flood mitigation is implemented as residents may feel more protected from future flood damages.

This study furthers our understanding of flood risk perceptions and the influence direct experience with flooding has on mitigation preferences. A few limitations of this research are noted, with further details provided in Chapter 3. The 2013 Alberta flood was a significant flood in Canada and generalizability to other communities should not be done without caution. Data was also collected two years post-event in a city where most residents felt the effects of the flood. As with most research on flooding, a cross-sectional design was used, accordingly results represent one temporal perspective. Future research could include other variables, such as the role of trust in risk managers to see how these influence perceptions of flood risk and mitigation preferences.

The presented research demonstrates that direct flood experience influences flood risk perception in the short-term and when perceptions of distance are evaluated.

However, flood experience was not found to influence long-term risk perceptions. This was explained using construal level theory and as a result of the entire city having elevated flood risk perceptions. Future research is needed to deepen our understanding of the nuances in flood risk perceptions and the role perceptions of distance have in forming risk perceptions and management preferences. Furthermore, attitudes towards climate change were shown to be more influential than flood experience in raising risk perceptions; this is significant for future work examining the role of values and belief systems in influencing risk perceptions and mitigation efforts. Finally, results surrounding flood mitigation showed the role direct experience has on influencing support for proposed mitigation projects, with those directly impacted favouring large-scale mitigation projects and showing lower levels of response-efficacy. This is important information for local flood risk managers when creating mitigation plans that support communities' preferences and beliefs.

Chapter 3: Conclusion

Conclusion

This thesis examined how experience during the Calgary 2013 flood may have influenced risk perceptions, coping appraisal and mitigation preferences. As well, given the increasing influence of climate change, views towards climate change were examined for their role in shaping flood risk perceptions. Together these results deepen our understanding of flood risk perception in the aftermath of a major flood.

A discussion of the results is provided in chapter 2; however, several points merit further explanation. The influence that climate change views have on flood risk perception shows that climate change beliefs are significant in shaping perceptions and suggest that direct experience may not be necessary to raise perceptions of extreme weather. Additionally, direct experience with flood evacuation did not influence coping-appraisal or self-efficacy, but did influence response-efficacy. This is significant as these three elements are related to protective behaviours being taken at the individual level, an important aspect of flood mitigation. As well, the results show that mitigation preferences are influenced by flood experience, particularly for large-scale projects.

Direct experience with flood evacuation does not necessarily increase perceptions of flood risk. Due to the severity of the 2013 Calgary flood, it is likely that all residents have been influenced, in some degree, by flooding and have been exposed to the ongoing media coverage of flood risks in the city and discussions surrounding mitigation. This has likely made concerns of flooding universal for all citizens. The 2013 flood is unlike smaller floods that are more common, where only those with direct, personal experience tend to be invested in understanding flood risk and the media quickly moves on to other

topics soon after the initial flood reports. These smaller, though still significant, floods are typically what is examined in flood risk perception research, and explain why direct experience is significant in raising flood risk perceptions.

When evaluating flood risk perception using a survey question, and assessing perceptions based on 2013 flood evacuation experience, differences in perceptions based on flood evacuation experience were found for 100-year flood risk perceptions but not for the 5-year risk perceptions. As well, the regression analysis for flood risk perceptions did not find evacuation experience to explain a significant component of the model. The difference between results can be explained using construal level theory, as described in earlier sections of this thesis. In general, as a long-term perspective is taken, the risk is seen as abstract and experience in 2013 is heavily discounted, playing only a minor role in shaping risk perceptions. However, when a short-term perspective of flood risk is taken, the risk is seen as concrete and experience in 2013 is considered, accounting for the differences in perceptions.

To further understand why evacuation experience does not consistently increase risk perceptions, as would be expected based on previous research, perceptions of distance were evaluated. By using perceptions of distance, risk perceptions based on evacuation experience could be assessed without the influence of the general elevation in risk perception that was seen throughout the region. The results show that evacuation experience influences perceptions of distance and, by proxy, risk perception and sense of vulnerability to future flooding. Using perceptions of distance may provide a technique to examine an individual's sense of flood vulnerability and risk perception that separates out the media and community's influence on raising perceptions.

Limitations

As with all research, some limitations are worthy of discussion. The first major limitation, and one that is commonly found in research involving humans, relates to generalizing the results to the whole population or other cities experiencing natural hazard risks. The 2013 flood was a significant event and the sample used was exclusively Calgary residents. While the research presented in this thesis focuses exclusively on the sample, future generalizations beyond the city of Calgary, and the sample group used, may not be representative of others' experiences. However, past research into flood risk perception has been completed in a variety of communities and different cultures with similar results being found (Bubeck et al. 2012b). Aspects of risk perception may be similar in other cities, but every disaster and every community is unique in their perception of risk and should be researched accordingly.

This is important as the research presented here is unique to the City of Calgary and the foothills of the Rocky Mountains. The magnitude of the 2013 flood and the risk perceptions that were found two years post-event will be hard to generalize to other communities, due to the size of the flood and the widespread damage that was experienced. An interesting future study may be a comparison of this research to other disasters, such as experiences with the 2016 wildfires in northern Alberta, an even larger natural disaster that involved an entire city being displaced. The 2016 wildfires would provide an interesting comparison to the 2013 floods as both major disasters occurred within the same Province, within a few years of each other; this provides a unique situation where wildfires and flood risk perceptions could be compared directly. Further

understanding of climate change beliefs could be examined to see how these views have been influenced by these 'natural' events. As well, construal level theory could be examined to see how the two events contrast with each other, as the wildfires have occurred more recently.

The participants included in this study were recruited through Insightrix's network of respondents. Though efforts were made by Insightrix to have a representative sample that matches the local (i.e., Calgary) demographics reported in the census, the sample is slightly wealthier and older than the average Calgarian. This is to be expected, as it is this group of individuals who have the time, energy and desire to complete online surveys. The sample likely excluded vulnerable groups, such as low-income families and the elderly, and those not comfortable with the English language. Future work could use interview techniques to target vulnerable groups to gain a wider representation of voices. Though vulnerable groups are not the average person, they do play a critical role in risk management and may need different forms of communication and aid in preparing for, and responding to, flood risks.

Another limitation of this research is the research design used. The survey relied on a cross-sectional, closed-ended survey with Likert style questions. This was done intentionally due to the scale and focus of the project but this meant participants were unable to have an open dialogue or verbally express their opinions and concerns about flooding. An assumption was made that the right questions were being asked to understand the public's flood risk perceptions. This was partially overcome by consulting with the City of Calgary on the mitigation options being assessed and by using established scales to evaluate the various components of flood risk perceptions. Previous

research looking at flood risk perceptions was drawn upon to understand how the components of flood risk perceptions have been studied and assessed.

To overcome this limitation, future research could incorporate qualitative interviews that allow for an open dialogue with participants that would help to understand the public's opinions and concerns in detail. Doing so, it is anticipated that the results would provide a wider range of mitigation preferences with a more diverse range of needs being expressed. Alternatively, there are opportunities for Calgarians to get involved and informed about flooding within the City of Calgary and with related watershed based organizations. Using these established community groups, data could be collected through sitting in on meetings and noting the concerns that are raised.

Further, this research relied on a cross-sectional survey, a common approach in the field of flood risk perception. As stated by Siegrist (2013), future work should take a longitudinal approach to see how risk perceptions change over time. A follow-up research project could be completed to look at how flood risk perceptions change over time within the City of Calgary. It would be interesting to see how perceptions of flood risk, climate change and support for flood mitigation shift based on recent weather patterns and extreme climate events, such as drought, wildfires and floods.

Significance

This study demonstrated that perceptions of physical distance to a high-risk flood region varied based on experience of flood evacuation. The research presented here, and the research completed by O'Neill et al. (2016) and Botzen et al. (2009), begins to understand how perceptions of distance relate to the objective risk of flooding and how

experience with flood influences flood risk perceptions. Further studies could examine how distance and place-based connections change in response to a natural hazard. This is important to understand as it provides a way to assess sense of vulnerability without the influence of external factors, such as the media. Changes in perceptions of distance can also be used to study sense of place, to see how the characteristics and priorities of a community change after a natural disaster and how different members of the community may have different perspectives. It is anticipated that community members' priorities will differ based on perceptions of distance and evacuation experience; some members may prefer to retain the sense of place that was experienced prior to the flood, through the use of mitigation or denial of the risk, while others would like the community to evolve and move away from (re)building in high-flood risk regions.

Using perceptions of distance to understand risk perceptions, it is anticipated that further nuances in flood risk perceptions will be uncovered. This is important, as most research on risk perception asks direct questions, which may not be providing results that are consistent with underlying beliefs and sense of flood vulnerability. By focusing on perceptions of distance, future work could see how these perceptions influence coping appraisal and the desire to take protective behaviours.

Further, this research finds differences in short- and long- term flood risk perceptions. This difference indicates the need to further understand the role of construal level theory, temporal discounting and how the framing effect influences risk perception formation. For example, the use of temporal and spatial distance can be examined to see how construals (abstract verses concrete thinking) are formed and change over time. Further understanding of the significance of short- versus long- term risk perceptions may

help understand the role framing plays in risk perceptions and management options. Further work using longitudinal studies would allow for construals to be examined over time, to see how perceptions shift as psychological and temporal distance from the risk event increases.

The research also shows that views towards climate change are more significant in increasing flood risk perceptions than direct experience with flooding. Based on this result, it would be interesting to see if specifically raising views towards climate change, through priming participants, would also raise flood risk perceptions, and potentially perceptions towards other extreme weather events. By doing so, research could see if participants' risk perceptions and coping-appraisals could be elevated without direct experience. This would be significant, as much research shows the need for direct experience to motivate action being taken; however, experience with a natural disaster is not a desirable motivator. For example, future research could first try to get participants to consistently connect extreme weather with climate change, then see if increasing climate change beliefs would also increase risk perceptions of flooding and how this would influence coping appraisal.

Examining coping-appraisal shows that evacuation experience significantly influences response-efficacy, with those who were evacuated having the lowest sense of personal ability in lowering flood risk. This shows the need to encourage confidence in personal action for those who were evacuated and fully understanding the difficulties and barriers that those who were evacuated face. Differences in views of coping-appraisal may also help explain variances in support towards mitigation options. Using coping appraisal, future work could examine the differences in response- and self- efficacy,

outside the construct of Protection Motivation Theory, to see if an individual's value system can be attuned towards taking protective action and building support for protective behaviour. In part, this is important as the implications of climate change progress and extreme weather is experienced more frequently.

As the scope of this research was to examine the general public's perceptions of flood risk, experts were not explicitly included in the survey. Future work could combine the research presented here with surveys or interviews with experts to understand the interplay between what the general public believes and experts' understandings. This would provide a more complete view of how flood risk is assessed and managed. By studying both experts and the general public, differences in understandings of flood risk and areas of priority could be compared. It is anticipated that experts would examine flood risk by probability calculations and focus on general risks to the City, while the general public would prioritize local implications of flooding and externalities of mitigation projects. This is important when understanding how to effectively communicate flood risks and management practices.

With 806 respondents and nearly an equal split between those who lived in a flood evacuated community and those who did not, as well as a balance in the demographics of respondents, a largely representative sample was achieved. This indicates that the results presented here represent the opinions of Calgarians, and can be used to support future flood risk mitigation planning.

In particular, this is important when examining mitigation preferences as the City of Calgary is currently working to understand citizens' flood risk mitigation preferences. With many flood mitigation projects being large-scale and resource and time intensive, it

is important that any flood risk mitigation action that is taken has public support and that the public feels included in the decision-making process. Eliciting the public's opinion, and including them in discussions around flood mitigation, could aid in lowering conflict and building support for proposed projects. This also would assist in building trust towards the government agencies responsible for flood mitigation.

Final Thoughts

The research presented in this thesis contributes to understanding flood risk perceptions and mitigation preferences in the aftermath of a major flood. In the course of the two years this research has taken, efforts have been made by the City of Calgary and the Province of Alberta to mitigate the risk of flooding and related damages. As well, flooding seems to be a part of the community's culture and dialogue and I am hopeful that this will be sustained into the future.

Due to the scope of this thesis, other variables were included in the survey instrument, but not presented in my data analysis. This includes variables around sense of trust, responsibility for future mitigation, and worldviews; these are areas of potential future analysis that may provide further understanding about beliefs of flood risk and mitigation.

The research completed fits within the broader landscape of natural disasters. The focus has been on flood risk due to the recentness and size of the 2013 flood; however, future research can expand on the ideas and findings related to other natural hazards, such as wildfires and droughts. As climate change continues to progress, and the frequency and severity of extreme weather is experienced, understanding individuals' responses to 'natural' hazards will, unfortunately, become increasingly important.

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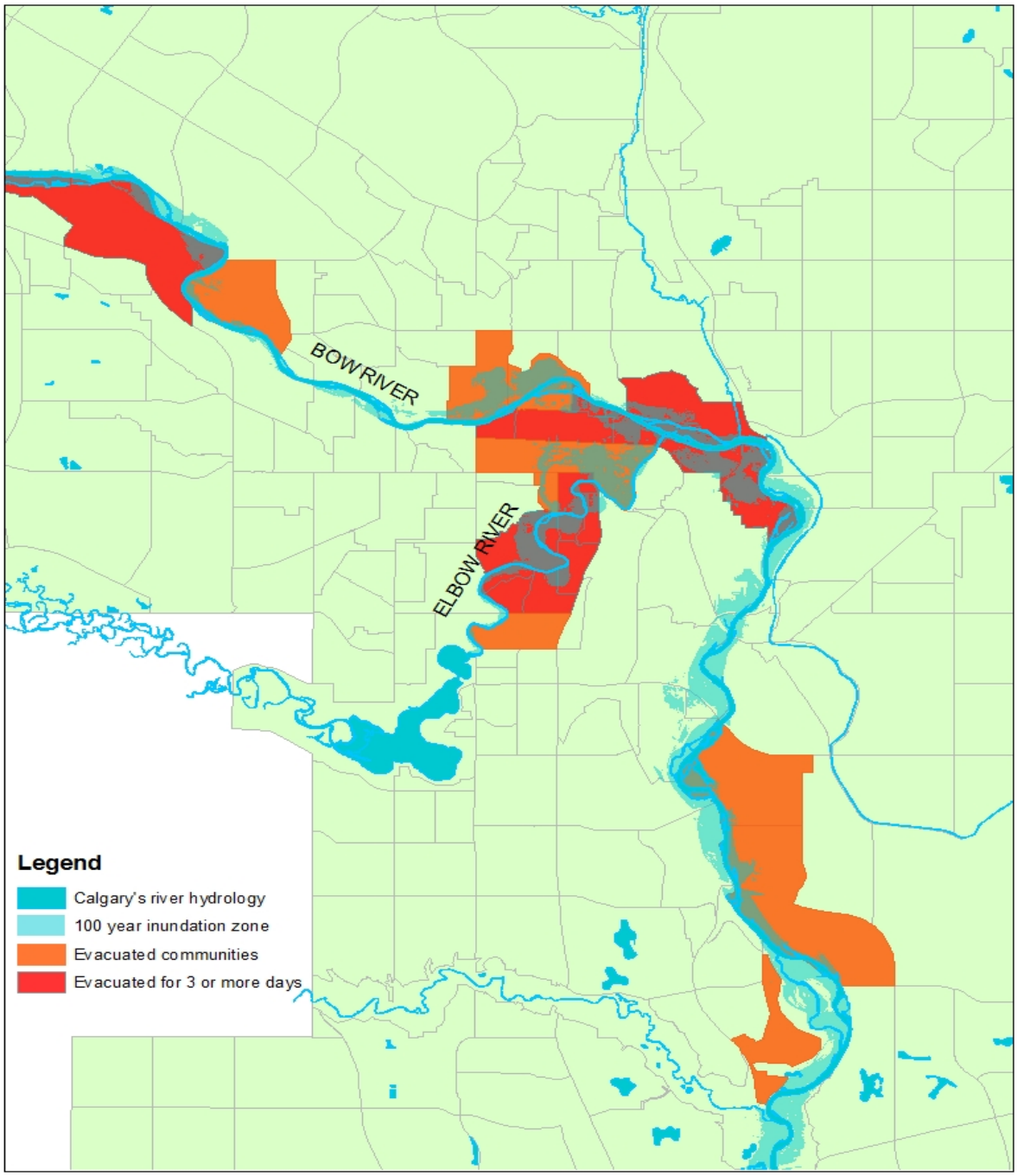
Appendix A- Map Of Evacuated Communities In The Calgary Region



Sources: City of Calgary, Infrastructure and Information Services 2012, Bylaw flood hazard (100 year); City of Calgary, Infrastructure and Information Services 2013, Hydrology; City of Calgary, Infrastructure and Information Services 2015, Community boundaries
Cartography: A.Tanner, 2016

Appendix B- Composite Variables

(self-efficacy, response-efficacy and views towards climate change); items, means, standard deviations and the internal reliabilities cronbachs α, means and standard deviations

Items per scale	$\bar{x}$	*SD*
Self-Efficacy (Cronbach's α= .916, $\bar{x}$=5.39, SD= .19)		
1. I can solve difficult problems if I try hard enough	5.69	1.02
2. It is relatively easy for me to accomplish the goals I set for myself	5.12	1.10
3. I am confident that I can deal efficiently with unexpected events	5.32	1.16
4. I am resourceful when it comes to handling unforeseen situations	5.41	1.15
5. I am able to remain calm when facing challenges or difficulties	5.35	1.20
6. When I am confronted with a challenge or problem, I can usually find more than one solution to it	5.43	1.12
Response-efficacy (Cronbach's α= .848, $\bar{x}$=4.69, SD= .46)		
1. I am capable of taking personal action that will lower my risk of future flood damage	4.99	1.46
2. It is worth the effort to take personal action aimed at lowering my risk of future flood damage	5.32	1.33
3. I am knowledgeable about the range of personal actions I could take in order to lower my risk of future flood damage	4.63	1.54
4. I have the time that would be required for me to take personal action to lower my risk of future flood damage	4.72	1.50
5. I have the money that would be required for me to take personal action to lower my risk of future flood damage	3.94	1.79
6. I am motivated to take action in order to lower my risk of future flood damage	4.57	1.50
View towards Climate Change (Cronbach's α= .947, $\bar{x}$=4.96, SD= .28)		
1. I worry that the state of the climate is changing.	4.58	1.88
2. Climate change will have severe consequences for humans and for nature.	5.14	1.77
3. Taking steps to protect our climate is important for our future.	5.19	1.79
4. Climate change will increase the probability of severe flooding in the future.	4.93	1.73

Appendix C- Survey Instrument

Available upon request.