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The Production of Unequal Vulnerability to Flood Hazards in Metro Vancouver, Canada

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A thesis submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in Geography

THE PRODUCTION OF UNEQUAL VULNERABILITY TO FLOOD HAZARDS IN METRO VANCOUVER, CANADA

(Thesis format: Integrated Article)

by

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Abstract

Flood risk is a growing concern in Canada's cities. Residents of these cities have differential risk according to their unique vulnerability and exposure to flood hazards. Factors related to societal structural forces, human agency, and place interact to produce vulnerability to hazards. Analysis of the factors that influence vulnerability will lead to a better understanding of how unequal vulnerability to hazards is produced among residents of a city. This dissertation investigates the factors that influence vulnerability to flood hazards in a Canadian coastal urban region, Metro Vancouver. It develops and applies a conceptual framework for looking across scales and across actors to identify and situate the factors that influence vulnerability. The study uses multiple research methods to investigate these factors, including statistical analysis of population data, focus groups with municipal practitioners, a practitioner survey, a residential survey, and informal interviews with residents. The investigation centres on what I refer to as indicators and determinants of vulnerability, and how they interact to produce vulnerability. Social vulnerability is identified as an important determinant of vulnerability, and indicators of social vulnerability are tested with an index of population data at the neighbourhood scale. A participatory process illustrates that the input of municipal flood managers can be used to make a quantitative assessment of social vulnerability more meaningful to those working in local policy and reveals findings about how practitioners view vulnerability in their community. Institutional arrangements such as development regulations and property insurance are found to be another key determinant that influences vulnerability. The availability of overland flood insurance, as an institutional arrangement were it to be introduced in Canada, would have implications

for residential vulnerability and the current regime of public flood management. Institutional arrangements appear to interact with social vulnerability and other determinants to allow some groups of people to live in hazardous places without taking on the full associated risk. The findings of the study offer insights to what produces vulnerability and how, or whether, policy measures can address these factors to equitably reduce risk.

Key words: vulnerability, hazard, flood, determinant, indicator, Metro Vancouver

Co-Authorship Statement

This dissertation is written in the integrated article format. Three chapters are written as independent manuscripts with the purpose of publishing them in academic journals. While I am the single or principal author of all chapters in the dissertation, other individuals made contributions to some aspects of the research process. Co-authorship of two chapters recognizes these contributions.

Chapter 2, entitled "Unequal vulnerability to flood hazards: "Ground truthing" a social vulnerability index of five municipalities in Metro Vancouver, Canada", is co-authored with Linda Mortsch, Kathy Tang, and Deborah Harford. The manuscript has been accepted for publication in the *Annals of the Association of American Geographers*.

Chapter 3, entitled "Determinants of residential vulnerability to flood hazards in Metro Vancouver", is co-authored with Dan Shrubsole and Gordon McBean. The manuscript is under review in *Natural Hazards*.

I am the single author of Chapter 4, entitled "Flood insurance in Canada: implications for flood management and residential vulnerability to flood hazards". The manuscript has been accepted for publication in *Environmental Management*.

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1. Introduction

1.1 Introduction to the study

Canada's most common hazard is flood. There have been more disasters in Canada's history caused by flood than by any other hazard, and flood disasters have affected more people and caused more property damage than any other kind of disaster (PSC 2014). Over the last decade alone, damage caused by flooding totals more than $10 billion (MMM 2014). The 2013 floods in southern Alberta and the Greater Toronto Area, and 2014 floods across the prairies illustrate both the magnitude of the hazard and the cross-country exposure to it. While people in many parts of the country might have an uneasy familiarity with flooding, it is flood risk in cities that is especially cause for growing concern. Localized flood events caused by extreme rainfall are occurring often enough in urban areas across the country that one gets the impression, aided by mainstream media coverage, that this is something of a "new normal" (e.g. Davison 2013). The research supports that observation: flood risk is expected to increase as a result of more frequent and severe precipitation events caused by climate change, an increase in population living in exposed areas, and more valuable property at risk (IPCC 2012).

So it is becoming clear that Canadians face a new level of flood risk. But are we all in this together? Do Canadians have the same level of risk as their neighbours or other residents of their city? The answer, hypothetically, is no. People have differential risk based on their unique exposure and vulnerability to a hazard (Wisner et al. 2004). A focus, therefore, on peoples' vulnerability to hazards, and how it is produced, is crucial to

understanding how to reduce risk. A substantial literature has for years described the political ecology of hazard vulnerability in a developing country context (e.g. Watts 1983; Blaikie and Brookfield 1987; Wisner 1993; Blaikie et al. 1994; Pelling 2003). After Hurricane Katrina devastated New Orleans in 2005, critical scholars and journalists famously described race and class issues that created differential vulnerability to that disaster, and demonstrated that a multi-scalar structural approach that examines state and market mechanisms is also valuable for hazards research in a developed country urban context (e.g. Burby 2006; Cutter et al. 2006; Dyson 2006). These authors showed that factors including state and city land use decisions, a failing public flood insurance program, levee infrastructure construction, and private residential development worked in concert to make powerful groups less vulnerable to hazards than others. Such an approach has not been systematically applied in a study to understand the factors that produce unequal vulnerability to hazards in a Canadian city. This dissertation seeks to address this research gap.

1.2 Vulnerability to hazards

Vulnerability is a central concept in hazards research. The human relationship with a sometimes hazardous environment is a long-standing theme at the heart of geographic study. Recently, a focus on human vulnerability to hazards – "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" – has yielded new insights to the human-environment relationship (Wisner et al. 2004, 11). Researchers have found that people have differential vulnerability based on these characteristics, which are influenced by factors that can be considered both internal and

external to a household. Understanding what makes people vulnerable, and why people have different levels of vulnerability, is seen to be critically important in knowing how to reduce risk. In other words, analysis of the factors that influence peoples' vulnerability to hazards, and thereby produce unequal vulnerability among populations, can advance knowledge to ultimately contribute to more equitable and sustainable risk reduction. Such an objective is informed by a long line of hazards research that has taken various epistemological approaches in diverse contextual settings. A study that seeks to understand the production of vulnerability to hazards in a Canadian city should draw upon two related bodies of literature: the vulnerability approach to hazards research in geography and the application of political ecology in the so-called "First World". The theoretical orientation of this study is shaped primarily by these research foundations[1].

1.2.1 Hazards research and the vulnerability approach

Early hazards research drew upon the human ecology tradition in geography to investigate human interaction with environmental hazards. Pioneered by Gilbert White, the objective of this research program was to provide practical solutions for reducing disaster losses that did not rely on engineering measures, which were found to be ineffective despite unprecedented investments (White 1945; White 1974; White and Haas 1975; Burton et al. 1978). Research conducted under the human ecology paradigm sought to understand how an individual perceives risk, and then generalized that perception to attempt to predict group behaviour. The approach essentially placed the initiative of a

[1] As such, the terminology used in the dissertation reflects the hazards literature. Since readers may have experience based in other fields that have different understandings of common terms (e.g., climate change research), a glossary of key terms is included in Appendix A.

disaster on the hazardous environment and left human, individual choice to adjust to, or modify, the hazard in order to reduce losses. Informed by the psychometric paradigm of risk analysis, studies concluded that people's perceived and acceptable risk appeared to be systematic, quantifiable and predictable (Slovic 1992). While remarkably productive in forging an area of geographic study, those early behavioural studies were critiqued for not accounting for the influence of local context and wider structural mechanisms on individual interaction with environmental hazards (Bunting and Guelke 1979; Torry 1979; Hewitt 1983).

The limitations of the human ecology approach in explaining how broader social, political and economic organization affected the hazardous human-environment relationship created the need to better understand the dynamics of the political economy. Critical geographers argued that questions of access to and control over resources could be traced through "chains of explanation" to uncover why some people are affected by, and in turn impact, the environment differently than others (Blaikie and Brookfield 1987). Marxist political economy was built upon to argue that inequality, poverty and environmental degradation are inevitably produced by capitalism and that the study of the human-environment relationship must be understood as dialectical rather than as interactions between two distinct things (Peet 1975; Watts 1983). Hewitt (1983, 25) advanced three arguments in his influential critique of the previously "dominant" paradigm of hazards research: disasters are characteristic rather than accidental features of the places where they occur; the risks and uncertainties come from ordinary life rather than from the rareness of "extremes"; and, natural extremes are actually more expected and knowable than many of the other events that happen in everyday life.

Blaikie et al. (1994) and Wisner et al. (2004) build from many of the arguments put forward by Hewitt (1983) to advance what they refer to as the vulnerability approach to understanding disasters. This approach refines the argument that biophysical and social factors cannot be separated from each other and that "treating disasters as something peculiar … is to risk separating them from the social frameworks that influence how hazards affect people" (Wisner et al. 2004, 4). The authors stress that disasters should not be considered as separate from everyday life, and that disasters are the result of vulnerabilities that exist in people's normal existence. Hazards researchers must focus on these vulnerabilities, the reasons they exist, and how they interact with "triggers" in the natural environment. This distinction between hazards causing disaster versus merely triggering an interaction between the environment and an already vulnerable population is made clearly, and has been widely accepted in current hazards scholarship and United Nations-led efforts in disaster risk reduction. Their vulnerability approach can be considered a refined political ecology that attempts to "reintroduce human agency with greater precision, while avoiding the dangers of an equally deterministic approach rooted in the political economy alone" (Wisner et al. 2004, 11).

The authors state that this approach arose from situations in less developed countries where normal, daily life was itself difficult to distinguish from disaster. Wisner (1993) notes though that vulnerability is not simply equivalent to poverty, and attempts to deconstruct poverty by looking at social characteristics such as class, gender, ethnicity, age and disability, which affect unequal access to resources. He agrees with Hewitt (1983) that "modernization of administration, planning and communication" is not necessarily the cure for social vulnerability, and may actually be the cause of it (Wisner

1993, 128). Such technocratic measures are featured as solutions presented by some hazards research approaches, starting with the behavioural paradigm and found in Mileti's (1999) revised version of it, which he calls "sustainable hazards mitigation". Wisner (1993) explains that human agency to reduce risk is not just constrained by bounded rationality, as proposed in the behavioural paradigm, but is limited by the relationship between agency and societal structures. Wisner et al. (2004, 50) interrogate the chain of explanation to understand that vulnerability "is rooted in social processes and underlying causes which may ultimately be quite remote from the disaster event itself".

This understanding of vulnerability to hazards is based on a materialist view of marginalization, whereby vulnerable people are forced to interact with the environment in ways that degrades it and therefore increases their risk (Susman et al. 1983). Collins (2008; 2010) extends this critical hazards construct of marginalization to include what he calls its mutually constitutive antithesis, facilitation. He argues that powerful geographical groups of people (i.e. neighbourhoods) are often provided security by state and market institutions to exploit environmental benefits (e.g. a nice view) associated with hazardous places for private gain while externalizing the full cost and risk of living there, with uneven social and environmental consequences (Collins 2008; 2010). Public and private institutions provide security to these groups of people through mechanisms like land use planning, residential development and property insurance. In hazards theory, marginalization is based on the assumption that hazardous environments present risks rather than rewards, which is why the least powerful groups of people often live in hazard-prone locations (Collins 2010). But in many developed countries, like in Canada, powerful groups are able to minimize risks (by externalizing them) so that rewards

outweigh the risks, which makes living in some hazardous environments appealing and possible. This nuanced view of Collins' marginalization/facilitation construct can profitably be used in a First World political ecology approach to understanding the factors that produce vulnerability to hazards.

The vulnerability approach has also been advanced by a different focus on social vulnerability to environmental hazards. Cutter (1996) refined our understanding of vulnerability and produced what she called the hazards-of-place model of vulnerability, based in part on Hewitt and Burton's (1971) "hazardousness of place" concept. Important to this model is the notion of *hazardscape*, wherein "the interplay of social, political, and economic factors – interacting separately, in combination with one another, and with the physical environment – creates a mosaic of risks and hazards that affect people and the places they inhabit" (Cutter et al. 2000, 716). Cutter's model was operationalised by overlaying mapped locations of social vulnerability with locations of biophysical exposure. A social vulnerability index (SoVI) was created by carefully selecting socio-economic variables that indicate vulnerability and then normalizing the statistical data by defined geographic area (Cutter et al. 2000). The statistical methodology for creating the index was later made more sophisticated in a SoVI for the United States at the county level (Cutter et al. 2003). SoVI is a purely quantitative methodology for assessing hazard risk that can significantly help practitioners make more informed decisions but its limitations in understanding causal factors of vulnerability across scales are well recognized (Andrey and Jones 2008). Such indexes can be especially useful for risk reduction planning purposes before a disaster event occurs. Cutter's conceptualization of risk is similar to that of Wisner et al. (2004) in that a hazard poses no risk when people

are not vulnerable. Likewise, if hazard exposure is the same but vulnerability is different in two places, then there is a different level of risk in these places.

The vulnerability approach to hazards research began as a hard reaction against White's earlier work and as such carries with it the risk of discounting individual perception and human agency in its focus on political-economic structural mechanisms. Many of those who espouse the vulnerability approach, however, warn readers to be careful to avoid such determinism in their research. Cutter's contribution has been to tie hazard vulnerability to place, through a "statistical portrait" of the people living in a given area, but lacks the ability to investigate causal factors or disaggregate the findings. Mileti's (1999) more recent concept of sustainable hazards mitigation draws heavily upon the human ecology tradition and is useful in some developed country contexts given that it can provide clear policy oriented solutions, but it is subject to many of the same critiques faced by the behavioural approach. There is room within hazards research to further refine our understanding of how human agency, structural mechanisms and place interact to produce hazard vulnerability. Applying research methods traditional to each approach in a case study of a Canadian urban region may be an appropriate way of achieving a well-rounded understanding of vulnerability. The application of political ecology in the so-called First World, another body of literature that influences this study, makes some progress towards this goal.

1.2.2 First World political ecology

Political ecology has had a significant impact on the study of human-environment relations in recent decades, due, in part, to contributions by hazards researchers. Political

ecology "combines the concerns of ecology and a broadly defined political economy. Together this encompasses the constantly shifting dialectic between society and land-based resources, and also within classes and groups within society itself" (Blaikie and Brookfield 1987, 17). Some scholars have made the case that political ecology can be used to better understand the human-environment relationship in the First World as it has in the Third World[2], where the approach was developed. Bryant and Bailey (1997) reject such a global political ecology and declare that the true home and rightful place of political ecology is in the Third World because the issues there deserve a unique and devoted epistemological approach. Those issues, they argue, need an academic "project" that is built specifically to address them. McCarthy (2002), however, submits that using political ecology in a First World context would help a researcher examine environmental issues as well as make political ecology more theoretically robust. He argues that "many of the themes, insights, and methods of political ecology are directly applicable to First World cases" (McCarthy 2002, 1284). His examination of the Wise Use movement in the rural American West adopts a political ecology approach because, he says, that populist movement shared all the things that would have made it an attractive political ecology case study if it took place in a Third World location. Why should Western researchers ignore issues that are happening in their own "backyards"?

[2] I use the labels Third World and First World as sketched out by Bryant and Bailey (1997) rather than "less developed countries" and "more developed countries" as used by Blaikie et al. (1994). The First/Third World terminology has been more widely adopted in recent political ecology literature (see, for example, the 2005 themed issue of *Environment and Planning A, 37* and 2006 special issue of *Geoforum, 37*). This language is somewhat uncomfortable given that my academic training has largely discouraged it, but its use pays a crucial homage to the structuralist roots of political ecology and serves to further the point.

McCarthy's argument is based on the premise that political ecology, rather than being based on a single theoretical or methodological approach, is actually based on the presence of most or all of a set of themes in a case study. These major themes, the identification of which is an important contribution in itself, include: "access to and control over resources; marginality [and facilitation]; integration of scales of analysis; the effects of integration into international markets; the centrality of livelihood issues; ambiguities in property rights and the importance of informal claims to resource use and access; the importance of local histories, meanings, culture, and micropolitics in resource use; the disenfranchisement of legitimate local users and uses; the effects of limited state capacity; and the imbrications of all these with colonial and postcolonial legacies and dynamics" (McCarthy 2002, 1283). These themes are often just as present in First World contexts as they are in the Third World, so it would seem that the transportation is not only possible but appropriate. Robbins (2002, 1510, his emphasis) agrees with McCarthy: "there is, it would seem, *nothing* about the epistemology, methodology, philosophy, or politics of Third World political ecology that bars its deployment in other contexts". Robbins rightly observes that plenty of good critical human-environment research is already happening in developed countries, but he says that using a political ecology approach to examining these issues can help flesh out underemphasized questions and themes. Robbins (2002, 1510) warns though that such efforts "would profitably benefit from a careful reading of the existing [political ecology] literature and, if [they are] to be successful, should work towards some symmetry of practice with that of Third World studies".

It is important to consider critically this proposed application of political ecology in the global North because of the very different contexts between it and the global South, where it has been almost exclusively applied. The Third World is a different place than the First World, is it not? Does it not have different sets of power relations, economic structures, environmental issues, and livelihoods? If we use the same political ecology in both places does this risk making light of the differences between them? Robbins (2002) addresses these concerns by laying out the argument that a political ecology that looks "inward" and "near" rather than "outward" and "far" (from the perspective of a Western researcher) must also look "up" instead of "down". By this wordplay, he means that traditional political ecology research investigates "down" to the land managers and local communities in the Third World, but a First World political ecology must investigate symmetrically "up" to central institutions of power. This is not to say that citizens in the First World are not relevant to a political ecology approach, as they are in the Third World context, or that looking up towards powerful organizations is not important anymore in the traditional home of political ecology. Rather, examining the practices and discourses of central institutions, which are so pervasive to daily life and by which citizens are so affected, can reveal how their knowledge and power is perpetuated. An oversimplification of looking "up" in the First World and looking "down" in the Third World is not what is being prescribed here; instead Robbins (2002, 1510) admonishes us to "invert the preoccupation with 'indigenous movements and NGOs rather than government ministries' and the obsession with 'local organizations of resistance rather than central organizations of oppression'" (after Dove 1999, 240).

An investigation of the roles of human agency and place are within the scope of the First World political ecology approach promoted by McCarthy and Robbins but are not always seen as research priorities. When Robbins tells us to look "up", a researcher might take that to mean that a resident's individual experience in a given area of a city is not important. Concentration solely on "scaling up" and outside causal mechanisms may prevent a researcher from investigating how human agency and place, along with those outside mechanisms, co-produce an uneven human-environment relationship. These structuralist tendencies remain strong in some political ecology research. The approach has matured, however, to be able to incorporate methods and findings more common to other hazards research traditions; those that seek to understand the role of agency and place in peoples' interaction with environmental hazards.

1.2.3 Research on vulnerability to hazards in the First World

Based on the theoretical progression of the hazards and political ecology literatures, a current challenge for researchers is to bring together these three elements – structural forces, human agency, and place – to identify and situate the factors that influence vulnerability to hazards. Researchers must look across scales and across actors in order to investigate how such factors work together to produce vulnerability. Properly situating the factors that influence vulnerability must draw upon a recognition that the environment is not only hazardous, but that it provides both risks and rewards. Human interaction with these risks and rewards are not neutral processes. Groups of people have different abilities to minimize risks and maximize rewards, with profound effects on their vulnerability. Making more explicit the factors that influence vulnerability to hazards, and articulating how they relate to one another, is a needed contribution to hazards

research. This study builds on the existing literature in an attempt to make some progress towards this objective.

1.3 Problem statement

The main problem confronted by this dissertation is unequal vulnerability to hazards among residents in a Canadian city. This problem is couched within a broader interest in the human relationship with an environment that offers both risks and rewards. Specifically, this dissertation investigates the factors that influence residential vulnerability, and thereby produce unequal vulnerability, to flood hazards in a Canadian coastal urban region. In so doing, it takes several municipalities in Metro Vancouver as case studies.

The study is conducted under the pragmatic premise that flood risk reduction in a Canadian city is a responsibility shared among three major parties: government, the private sector, and residents. Each of these parties is multi-faceted, and as such, the responsibility for flood risk reduction must be analysed across actors and across scales. Critically, the study proceeds with the view that the imperfect tension in sharing this responsibility is what creates unequal vulnerability to flood hazards among a population. In other words, public policy decisions, private market mechanisms, and residents' own agency interact dialectically to produce differential vulnerability. Furthermore, the dissertation interrogates the concept that these factors facilitate powerful groups in their pursuit of environmental benefits without having to assume the full associated risk, with negative socio-economic consequences (Collins 2008).

1.4 Research questions

The study addresses the problem statement by posing three main sets of research questions. Each of these questions is addressed, in turn, in chapters 2, 3, and 4.

(1) Who is vulnerable to flood hazards in Metro Vancouver? How do local flood managers perceive indicators of vulnerability to flood hazards?

(2) What influences residents' vulnerability to flood hazards? How do these determinants produce unequal vulnerability?

(3) As one aspect of the institutional arrangements determinant of vulnerability, what would be the implications of private flood insurance for flood management in Canada and residential vulnerability to flood hazards?

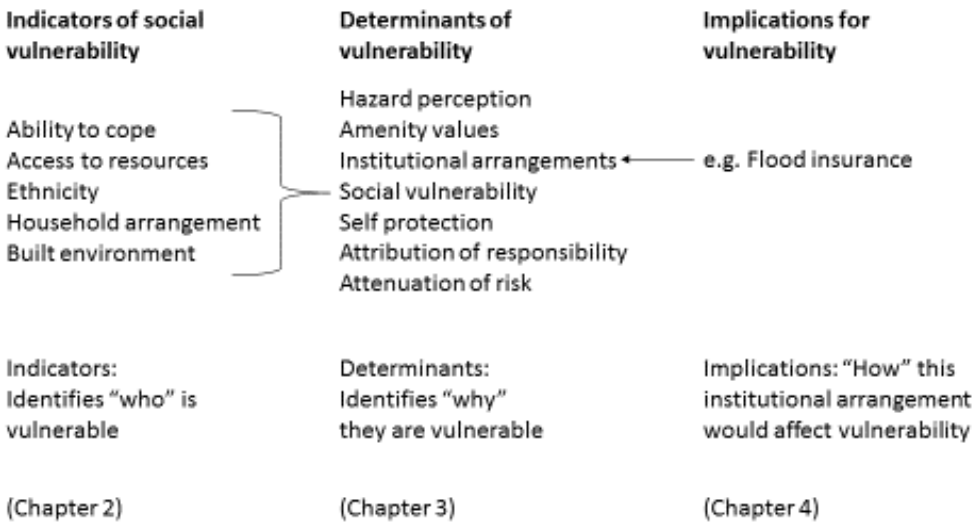
1.5 Conceptual framework

In order to better understand the production of vulnerability, this study investigates what I refer to as *indicators* of vulnerability and *determinants* of vulnerability. Indicators of vulnerability are characteristics of a population that identify *who* is vulnerable. Indicators consist of groups of variables that when analysed together can describe the level of vulnerability of a household or group of households. In this study, indicators of social vulnerability include: (1) ability to cope, (2) access to resources, (3) ethnicity, (4) household arrangement, and (5) the built environment (see chapter 2). Determinants of vulnerability, on the other hand, are factors that identify *why* people are vulnerable. These factors can be examined to learn what influences peoples' vulnerability. They are specific to a household and work dialectically to co-produce

vulnerability. This study identifies and tests seven hypothetical determinants of vulnerability to flood hazards: (1) hazard perception, (2) amenity value conflicts, (3) institutional arrangements, (4) social vulnerability, (5) self-protection, (6) attribution of responsibility, and (7) attenuation of risk due to another dominating concern (see chapter 3).

A framework that conceptualizes how such determinants and indicators interact would be useful in looking across actors and across scales at the factors that influence vulnerability. Such a framework is proposed here (Figure 1.1), and is used as a way of structuring the investigation of the production of vulnerability in the dissertation.

Figure 1.1: The production of unequal vulnerability to hazards in a Canadian city



Drawing on the hazards literature and study findings, social vulnerability is identified as a key determinant of vulnerability to flood hazards. In order to better

understand this determinant, the study investigates the indicators of social vulnerability and how they are viewed by municipal flood managers. Institutional arrangements, such as public policy or private market mechanisms, are found to be another important determinant of vulnerability. One institutional arrangement, property insurance, and specifically flood insurance were it to be available, would have implications for residential vulnerability. The framework provides a lens through which to view the interaction of this institutional arrangement with the factors that influence vulnerability. The other determinants could similarly be investigated using this conceptualization.

1.6 Metro Vancouver as study site

Metro Vancouver, an urban agglomeration of 2.3 million people living in 21 member municipalities, one electoral area, and one treaty First Nation in lower mainland British Columbia, was selected as the site of the study. While Metro Vancouver is the regional study site, case studies were conducted in only five selected municipalities. Chapter 2 investigates vulnerability in Vancouver, Surrey, Richmond, District of North Vancouver, and Delta. Chapters 3 and 4 further concentrate the study on neighbourhoods in Vancouver and Surrey. Metro Vancouver is an appropriate case study site for a number of important reasons.

First, the region is exposed to several flood hazards. This heavily urbanized area is located on and around the delta of the Fraser River at the Strait of Georgia, exposing residents to urban, riverine, and coastal flood hazards. Municipalities rely on a suite of engineering and non-structural measures to mitigate damage from these three types of flood hazards. With an increase in impervious surfaces that comes with development and

aging infrastructure in urban areas, overland "flash" flooding from increasing extreme rainfall events is a problem faced in Metro Vancouver, as in many other Canadian cities (Murdock et al. 2007). The Fraser River has had two major floods of record, in 1894 and 1948, both of which caused significant damage. There is an estimated one-in-three chance that a similar magnitude flood will occur in the next 50 years, which would cause billions of dollars in damage (Fraser Basin Council 2014). Metro Vancouver communities have experienced a number of coastal flood events that exceeded the protection of sea walls and dikes, many of which were caused by a combination of high tides and storm surges (Forseth 2012). Rising sea levels as a result of climate change are anticipated to affect coastal areas and the hydrology of the Fraser River (BC Flood Safety Section 2014). The provincial government has recently released a policy mandating local planning to account for 1.2 m of sea level rise by 2100 (BC Ministry of Environment 2011). Exposure to flood hazards has caused municipalities in the region to implement a range of adjustments to mitigate flood risk.

Second, Metro Vancouver is home to populations with a wide range of socio-economic characteristics. Vancouver has the dubious distinction of being the least affordable city in North America in which to live while being home to what is known, at least colloquially, as Canada's poorest postal code, the Downtown Eastside (Cox and Pavletich 2014). Consequently, the real estate market and ongoing neighbourhood gentrification are popular issues in local media (Quastel 2009). Vancouver recently spent nearly a decade atop *The Economist's* (2011) annual ranking of the world's most livable cities but this city is not equally liveable in all places; its socio-economic challenges are geographically based (Ley and Dobson 2008). The unaffordability of so many parts of

municipalities in the region has resulted in the concentration of lower-income populations in select neighbourhoods. This disparity makes communities in Metro Vancouver appropriate sites for investigating how people with diverse socio-economic characteristics interact with flood hazards.

Third, a better understanding of how vulnerability is produced in a Canadian, urban context is a needed contribution to hazards research, and Metro Vancouver municipalities are places befitting such an investigation. These municipalities are of significant interest as Canadian cities because of the competing issues at play: large and growing populations, intense development pressures, some progressive local governments who are working towards sustainability and climate change adaptation, and a provincial government providing policy guidance on reducing flood risk to local decision makers after having downloaded many of the responsibilities that would help achieve it. Such provincial policy actions have real and far-reaching implications for local government decision making. There are a significant amount of assets exposed to flood hazards in the region; in fact, Vancouver has been identified as one of the top cities globally for assets at risk (Hallegatte et al. 2013). Over the course of the research for this dissertation, the City of Vancouver and City of Surrey both released climate change adaptation strategies, being among the first Canadian cities to have taken this policy step (City of Vancouver 2012; City of Surrey 2013). Studying the problem of unequal vulnerability to flood hazards in such a dynamic place, where a large-scale flood event has not recently occurred, offers the opportunity to investigate the roots of vulnerability as they are – under the surface – and contribute to theory based on a pre-disaster analysis.

Finally, though not least importantly, five municipalities in Metro Vancouver agreed to participate in some parts of the study.

1.7 Overview of research methods

This dissertation uses a number of different research methods to investigate the production of residential vulnerability to flood hazards in Metro Vancouver. Employing multiple research methods together in a single study can be considered a "mixed methods" or "multi-method" approach. Such an approach is used by researchers as a pragmatic way of asking a broad range of questions on a topic, grasping at different aspects of reality, and enriching the data collected (Baxter and Eyles 1997; Hesse-Biber and Leavy 2004; Rank 2004; Onwuegbuzie and Leech 2005). A multi-method research design can be used to effectively apply a political ecology approach to understanding vulnerability to hazards in a developed country, urban context. This design is useful in looking across scales and actors at what influences residents' vulnerability to flood hazards in a Canadian city.

This study uses both quantitative and qualitative research methods to investigate indicators and determinants of vulnerability, including: statistical analysis of population data; focus groups with local practitioners in five municipalities using a semi-structured interview guide; a survey questionnaire of those municipal practitioners; visualizing the analysis with a geographic information system (GIS); a structured survey of residents in four neighbourhoods with closed- and open-ended questions; informal interviews and follow-up conversations with residents, and; a focus group with representatives of a neighbourhood residents association. These methods were used in a manner that Tolman

and Szalacha (2004) call “sequential integration”, whereby the research is conducted in phases and the knowledge gained through the research is incorporated in the methods used later in the study. For instance, the findings of the municipal practitioner focus groups informed the residential survey phase of the study. Quantitative methods were used to test the influence of indicators and determinants on vulnerability, while qualitative methods enabled a nuanced understanding of local processes that produce vulnerability.

The research was conducted over a period of two years, from March 2012 to February 2014. During that time, I spent approximately six weeks in Metro Vancouver conducting field research. This time was spent meeting with municipal respondents, holding focus groups, and conducting the residential survey. Doing the field research in separate phases provided the opportunity to take what was learned at each stage of the study and incorporate it in later stages. Preliminary results of some parts of the study were shared with participants in February 2014: practitioner survey results and the weighted social vulnerability index were presented to municipal practitioners, and the Crescent Beach neighbourhood results of the residential survey were shared with executive members of the Crescent Beach Property Owners’ Association during a focus group. This manner of “member checking” revealed that research participants generally believed the findings were credible and were interested in learning more about the results of the study.

1.7.1 Residential survey methodology

Residential surveys are a common tool used in hazards research to investigate public perceptions, attitudes, and actions towards hazards (Bird 2009). A survey can inform both human ecology and political ecology epistemological approaches. This study conducted a residential survey during February and March 2013. Since the survey methodology is not fully described in the manuscripts that draw upon survey findings (Chapters 3 and 4), it is elaborated upon here. A self-administered structured survey methodology based on Dillman's Tailored Design Method (TDM) was followed to conduct the survey simultaneously in four neighbourhoods (Dillman et al. 2009). The modified TDM consisted of four unique contacts with each home in the population over the course of the survey. First, I hand-delivered letters that notified residents the survey was being conducted in their neighbourhood. One week later, I hand-delivered the survey package to all homes in the population. The package contained a cover letter, the questionnaire, and a postage-paid, self-addressed return envelope. Two weeks after the survey package was delivered, a thank you/reminder post-card was mailed to each home in the population. The postcard was mailed because I now had an accurate and trustworthy address list of homes. Three weeks after the postcard was sent a second survey package was mailed to each home in the population to entice those who had not yet completed the survey. This survey package included a new cover letter, an identical questionnaire, and a postage-paid, self-addressed return envelope. The package was mailed to each home in order to comply with Western's Research Ethics Board instructions to not collect mailing address information from residents on the questionnaire.

Delivering door-to-door the pre-notice letters and survey packages was an important part of the research process for several reasons. First of all, it ensured that surveys were delivered to every home in the defined study area. In some neighbourhoods, there were significant discrepancies between the address list obtained from the municipality and the home addresses in reality. The most common error was the omission of other addresses that shared the property, such as a basement or upstairs apartment unit that had its own marked address. I wanted to make sure these homes were included in the sample. The geographic boundary of each neighbourhood was also set during the delivery of pre-notice letters. In three of the neighbourhoods, I had to make a decision to exclude some homes that would have been included in the Statistics Canada dissemination area because I had a maximum of 400 surveys for each neighbourhood. In these cases, I excluded addresses on streets that were furthest away from the flood hazard exposure. For these reasons, delivering the surveys by hand was important in ensuring that a proper population was contacted.

Another important reason for hand delivering the surveys was for me to gain first-hand knowledge about each neighbourhood. Each of the four neighbourhoods is quite different, and the time spent walking the streets and talking to residents was useful in learning about the neighbourhoods and the people that live in them. The letters and surveys were delivered at various times of the day and evening, during weekdays and weekends, in order to capture as much of the neighbourhood context as possible. A social vulnerability index of the municipalities has the effect of making a neighbourhood appear homogenous, with a single score for each neighbourhood created by combining various socio-economic measures of the people that live there (Chapter 2). Although this score

may be a good indication of the "average" vulnerability that exists in the neighbourhood, the field work made it quite apparent that, in reality, there is unequal vulnerability among the people that live in the neighbourhood. Experiencing this diversity on multiple times through each neighbourhood helped me to understand that it is not always appropriate to characterize a neighbourhood as a single unit.

1.8 Overview of contents

This dissertation is written in what has become known as the integrated article style, rather than in the traditional monograph format. The integrated article style is a collection of manuscripts focusing on different parts of the same study, written with the intention of submitting them independently for publication in academic journals. In this dissertation, the three manuscripts are chapters 2, 3, and 4. The manuscripts are written to stand alone but when read together in a dissertation are meant to investigate different parts of a single problem statement. The remaining chapters fill out the dissertation. Chapter 1 introduces the study and sets the context of the research. Chapter 5 concludes the dissertation by summarizing the main findings, identifying the limitations of the research, discussing the contributions of the study, and offering a comment on areas for future research.

In order to address the operating premise that flood risk reduction is a responsibility shared among government, the private sector, and residents, each of the three manuscripts focuses on one of these actors. Chapter 2 investigates municipal government practitioner perspectives on indicators of residential vulnerability to flood hazards. Chapter 3 examines residents' perceptions, attitudes, and behaviours towards

flood hazard risk and responsibility, and in so doing identifies and tests determinants of vulnerability. Chapter 4 considers a role of the private sector in flood risk reduction – providing property insurance and, specifically, the hypothetical introduction of private flood insurance in Canada – and how this institutional arrangement would affect flood management and the vulnerability of residents.

Chapter 2 describes the process of "ground truthing" a social vulnerability index with practitioners working in five municipalities in Metro Vancouver and how the index was then revised to reflect their input on indicators of vulnerability. Indexes that create a quantitative measure of social vulnerability to hazards by place have gained acceptance as a research tool that can inform local policy making. Many indexes, however, are created remotely by researchers without using the input of those working in local policy. I argue that if practitioners are involved in creating an index that they find accurate and useful, it is more likely they will incorporate the findings of the index in local policy decisions. The ground truthing process involved presenting an index to focus groups of municipal practitioners for their feedback and conducting a survey of participants that was then used to assign weights to the vulnerability indicators. The study finds that practitioners are generally accepting of the research approach to quantifying social vulnerability by place, though they often had specific concerns regarding the methodology and offered suggestions to make the index more reflective of the local context. The process of revising the index illustrates that local practitioner input can be used to create a measure of social vulnerability to hazards that is meaningful to those working in the community.

Chapter 3 poses the question, "What influences residents' vulnerability to flood hazards?" and addresses it by identifying and testing hypothetical determinants of residential vulnerability to flood hazards in Metro Vancouver. A household survey is conducted in four neighbourhoods in Vancouver and Surrey to test seven determinants of vulnerability: (1) hazard perception, (2) amenity value conflicts, (3) institutional arrangements, (4) social vulnerability, (5) self-protection, (6) attribution of responsibility, and (7) attenuation of risk due to another dominating concern. Survey findings offer insights as to how these determinants interact to produce unequal vulnerability to flood hazards among residents in a Canadian city. The study finds that social vulnerability is an important factor in determining overall vulnerability to flood hazards. Household income, as a key contributor to social vulnerability, is found to have significant relationships with variables that define the other determinants. Institutional incentives, including property insurance and development regulations, appear to interact with social vulnerability and the other determinants to allow powerful groups of people to live in hazardous places without taking on the full associated risk. The findings have implications for our understanding of how vulnerability is produced and how, or whether, local policy can address these factors to equitably reduce risk.

In chapter 4, the potential introduction of private flood insurance in Canada is considered. Currently, insurance coverage of damage caused by overland flooding is not available to Canadian homeowners. As flood disaster losses and water damage claims both trend upwards, insurers in Canada are exploring whether to offer residential flood coverage in order to properly underwrite the risk and extend their business. If private flood insurance is introduced in Canada, it will have implications for the current regime

of public flood management and for residential vulnerability to flood hazards. The chapter engages many of the competing issues surrounding the privatization of flood risk by addressing questions about whether flood insurance can be an effective tool in limiting exposure to the hazard and how it would exacerbate already unequal vulnerability. It investigates willingness to pay for flood insurance among residents in Metro Vancouver and how attitudes about insurance relate to other factors that determine residential vulnerability to flood hazards. Findings indicate that demand for flood insurance is part of a complex, dialectical set of determinants of vulnerability.

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2. Unequal vulnerability to flood hazards: "Ground truthing" a social vulnerability index of five municipalities in Metro Vancouver, Canada

2.1 Introduction

The concept of vulnerability has enriched hazards research in geography for more than three decades but the contribution of vulnerability analysis to public policy during that time has been peripheral (Mustafa et al. 2011). One of the ways in which the concept of vulnerability has been operationalized is through the "hazards-of-place" model (Cutter 1996) wherein social, economic and political characteristics that determine people's vulnerability are assessed in an index for populations living in a defined geographic location. This article addresses the disconnect between social vulnerability index construction by hazards researchers and making such an assessment relevant and usable to those who are responsible for creating local policy.

One of the main purposes for creating an index to measure social vulnerability to hazards is so that it can provide policy relevant information (Fekete 2012). It is well recognized that much of the nuance and details that describe social vulnerability can only be uncovered through qualitative research and descriptive narratives, but that these findings are often not influential in the policy realm (Adger 2006; Jones and Andrey 2007; Barnett, Lambert, and Fry 2008; Cutter et al. 2008; Mustafa et al. 2011; Rufat 2013). Thus an index is created from quantitative data because it is a form that policy

makers are comfortable using to make decisions. If the objective then is policy relevance, incorporating input from local practitioners in the creation of the index will enable it to better reflect the local context and gain legitimacy. Barnett, Lambert, and Fry (2008, 102) argue that "because vulnerability is about values at risk, there should be more input from a broader array of people when indexes are being developed and tested". Most social vulnerability index studies are primarily concerned with the creation of the index and not with external validation or bringing it to the local users (Fekete 2009). The intention of this study is to create a technically sound index but to focus on interacting with local practitioners about developing an index that they find useful and what was learned from that exercise. This article describes the process of constructing a social vulnerability index, "ground truthing" this index in five municipalities in Metro Vancouver, and then using local practitioner input to create a second version of the index. The study uses mixed research methods, including focus groups and a survey questionnaire, to incorporate local practitioner knowledge in the revised index and learn from practitioners about how they view vulnerability.

A region renowned for its attractive physical setting between British Columbia's North Shore Mountains and the Strait of Georgia, temperate climate and multicultural population, Metro Vancouver is also known for its great socio-economic inequalities. Vancouver has the dubious distinction of being the least affordable city in North America in which to live while being home to what is known, at least colloquially, as Canada's poorest postal code, the Downtown Eastside (Cox and Pavletich 2014). Vancouver recently spent nearly a decade atop *The Economist's* (2011) annual ranking of the world's most livable cities but this city is not equally liveable in all places; its socio-economic

challenges are geographically based (Ley and Dobson 2008; Quastel 2009). Other municipalities within Metro Vancouver, including Surrey, Richmond, Delta, and North Vancouver, share the problems of inequality, with large residential areas accessible only to the wealthy while other areas are home to concentrated populations of lower income. Located at the mouth of the Fraser River, the municipalities of Metro Vancouver rely on a suite of engineering and non-structural measures to mitigate riverine, coastal, and urban flood damage. Metro Vancouver has been affected by a number of flood events (Forseth 2012) but the reason it was chosen for this study is to examine vulnerable locations in order to reduce future flood risk, which is anticipated to be higher due, in part, to sea level rise and other climate change impacts (BC Ministry of Environment 2011; Hallegatte et al. 2013).

2.2 Social vulnerability to hazards

The study of social vulnerability to environmental hazards has advanced significantly as a sub-discipline of critical hazards geography in recent years. This progress has been due to advancements made by both critical geography social theorists and technical geographers specializing in spatial statistics and geographic information systems. The vulnerability approach to hazards research was borne out of a materialist critique of the behavioural approach pioneered by White (1945) and which led to seminal work by Burton, Kates, and White (1978). Hewitt (1983) argued that this "dominant paradigm" considered hazards as outside the normal spectrum of human-environment relations, which required technocratic, managerial expertise to deal with rather than addressing the normal, everyday conditions that cause people to be vulnerable. The critical realist approach of Blaikie et al. (1994) and Wisner et al. (2004) builds on this

argument and stresses that hazards researchers should focus on understanding these conditions, the reasons they exist, and how they interact with "triggers" in the natural environment. Wisner et al. (2004, 11) define vulnerability as "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard". Wisner (1993) notes though that vulnerability is not simply equivalent to poverty, and attempts to deconstruct poverty by looking at social characteristics such as class, gender, ethnicity, age and disability, which affect unequal access to resources. This critical realist approach to hazards geography was an important part of the development of political ecology as an insight into the human-environment relationship.

As important as the "chain of explanation" (Blaikie and Brookfield 1987; Wisner et al. 2004) is to understanding the causal factors of vulnerability, another approach pays more explicit attention to the role of place. Since both the exposure to hazard and a vulnerable population are necessarily place-based, this approach submits that risk should be assessed in specific locations. Cutter (1996) developed what she called the "hazards-of-place" model of vulnerability, built in part on Hewitt and Burton's (1971) "hazardousness of place" concept, which proposed to mitigate all of the hazards that may affect a given place with the same human adjustments. The hazards-of-place model adds to the analysis the idea that the people living in this place will have unequal vulnerability to the hazards based on their social, economic, and political characteristics. This model ties hazard vulnerability to place through a "statistical portrait" of the people living in a given location that may be exposed to hazard. The model is operationalized through an index to measure social vulnerability to hazards, which is a quantitative tool created from

data representing socio-economic variables of the people living in a defined geographic area. The index is often presented by overlaying that spatial data to determine locations of social vulnerability with exposure to biophysical hazard in a GIS-based risk assessment.

The hazards-of-place model of vulnerability was used in this study in order to identify exposed locations with populations at varying levels of vulnerability that could then be further investigated. The hazards-of-place model can effectively represent many factors of vulnerability through socio-economic, land use, and hazard data, but cannot describe external structural factors that may explain why people are vulnerable or human agency factors that may serve to reduce one's vulnerability. Cutter and her colleagues have, however, advanced the hazards-of-place model by applying a statistical methodology to create an index to measure social vulnerability, and using geographic information systems (GIS) to map both the physical hazard and social vulnerability, improving the spatial analysis of vulnerability. The statistical methodology for creating the index and definitions of the indicators of vulnerability were made more sophisticated in a social vulnerability index (SoVI) for the United States at the county level (Cutter, Boruff, and Shirley 2003). Since that study, indexes that measure social vulnerability and exposure to hazards have become more popular, with academics, public agencies and research organizations producing them for regions throughout the world. Academic researchers have tested different statistical methods of creating an index (Clark et al. 1998; Rygel, O'Sullivan, and Yarnal 2006; Rufat 2013), applied it to hazards induced or exacerbated by climate change in the interest of adaptation (Wu, Yarnal, and Fisher 2002; Romieu et al. 2010; Bjarnadottir, Li, and Stewart 2011), and used dissagregated indices

rather than a single index (Adger et al., 2004; Balica, Wright, and van der Meulen 2012). Most authors have argued to make the index as context-specific as possible (Chakraborty, Tobin, and Montz 2005; Barnett, Lambert, and Fry 2008).

This paper builds specifically on the work of two studies, both of which applied the "hazards-of-place" model to create vulnerability indexes for hazards in Canadian cities, including Vancouver. Jones (2004) examines the concept of social disadvantage and how it translates to hazard vulnerability in Greater Vancouver (now called Metro Vancouver). The author evaluates social vulnerability at the census tract scale and identifies whether the census tracts are located in areas exposed to hazards. Social vulnerability is evaluated using a statistical methodology that relies on a principal components analysis and builds, in large part, from the social vulnerability index created by Cutter, Mitchell, and Scott (2000). Jones selects 22 socio-economic variables that indicate social vulnerability from 1996 Statistics Canada census data for the analysis of 272 census tracts within Greater Vancouver. Jones and Andrey (2007) examine the methodological decisions involved in vulnerability index construction and find that variable selection is the most critical issue in the identification of vulnerable neighbourhoods, followed by the weighting of variables. A study of vulnerability to climate change related hazards in the Upper Thames Watershed in London, Ontario broke new ground by combining flood hazard projections under a changing climate with social vulnerability in a Canadian city (Hebb and Mortsch 2007). Based on the "hazards-of-place" model and Füssel's (2007) vulnerability framework, and following climate change studies by Clark et al. (1998) and Wu, Yarnal, and Fisher (2002), this vulnerability assessment uses global climate model (GCM) simulations to create event-based

hydrologic modelling for different climate change scenarios. The projected flood maps are then overlaid with infrastructure and the built environment and a social vulnerability index to reveal "hotspots" of exposed and vulnerable locations. The study finds that vulnerability to flooding under the different climate scenarios is not evenly distributed. Hebb and Mortsch (2007) conclude that while the GIS mapping is a useful tool to operationalize the vulnerability concept, feedback is required from the stakeholder community on the usefulness of the vulnerability indicators and maps.

2.2.1 Issues in indices: limitations and the weighting of variables

Indexes that measure vulnerability to hazards have become increasingly popular despite several important limitations of the approach. Quantitative analysis cannot fully capture the nature of human vulnerability to natural hazards (Jones and Andrey 2007). Reducing vulnerability to a quantitative metric for a geographic area is problematic. A single number oversimplifies and can hide the complexity of vulnerability and the interconnectedness of factors that cause it (Adger 2006; Barnett, Lambert, and Fry 2008; Rufat 2013). Moreover, any metric to represent vulnerability is a static snapshot of what is in fact a dynamic process (Cutter et al. 2008; Mustafa et al. 2011). The selection of the variables used to construct the index is arguably the most important step in index construction but the variables chosen will undoubtedly be subject to debate among different stakeholders (Jones and Andrey 2007). The construction of any index is likely to exclude variables considered significant by some stakeholders. For example, Chakraborty, Tobin, and Montz (2005) demonstrate that the selection of different variables in an index greatly changes the number of people identified as vulnerable. Furthermore, since vulnerability is context-specific, not generic, an index is less

meaningful at a large scale (Barnett, Lambert, and Fry 2008). Perhaps most importantly, an index does not explain any of the factors behind the value of each socio-economic variable. For example, an index can identify where low income populations are concentrated, but it cannot indicate why those populations have low income or how much that influences other factors in their lives.

An important and somewhat contentious issue in creating an index is how to weight the individual variables contributing to the total vulnerability score. Most studies choose to create an "unweighted" index (Tate 2012), meaning that the variables have equal weighting when aggregated. This choice is made for a few main reasons: the perception that this creates the most "objective" index, a lack of understanding of the relationships between indicators (Tate 2012), and because there is not a single accepted method of assigning weights to the variables (Collins, Grineski, and Romo 2009). It is widely recognized that indicators are not of equal importance (Fekete 2012; Tate 2012), but the difficulty is in finding an acceptable weighting scheme. An "unweighted" index is still subjective rather than objective, since it treats all variables as weighted equally. If an index is going to be subjective, one argument is that it should be subjective according to local practitioners. Barnett, Lambert, and Fry (2008, 115) submit:

> Input from those most knowledgeable about – or who have the greatest stake in – the exposure unit could at least come in the form of their involvement in the weighting of various subcomponents of an index. This is a minimal way to ensure some inclusion of the knowledge and values of those people who otherwise implicitly populate indexes, and to increase the legitimacy of the index to the people who are responsible for and bear the consequences of environmental management.

Following this argument and the feedback received from local practitioners, the second version of the index was constructed with weighted variables based on their input. Other studies have chosen to weight the variables based on researcher judgement (Greiving, Fleischhauer, and Lückenkötter 2006) or using a statistical methodology (Eakin and Bojorquez-Tapia 2008). Emrich (2005) used a Delphi survey method to assign variables weights based on the opinions of 39 disaster researchers and practitioners working throughout the United States. These professionals were asked to assign weights to the variables to indicate social vulnerability generally, not within the context of the city in which they work. By using the input of local practitioners to weight the variables, the objective is to create an index that will be reflective of the local context and trusted by those involved in municipal policy making.

2.3 Creating a social vulnerability index for five municipalities in Metro Vancouver

In order to assess differential vulnerability to flood hazards in Metro Vancouver, a social vulnerability index was created for five municipalities: Vancouver, Surrey, Richmond, Delta, and District of North Vancouver. Figure 2.1 locates Metro Vancouver within the Pacific Northwest and identifies the study municipalities in Metro Vancouver. The criteria for choosing the study municipalities was that they are all exposed to flood hazards, are large population centres important in the economic and social fabric of Metro Vancouver, and, importantly, the authors had existing professional contacts in each that would later make possible the opportunity for a productive meeting with municipal representatives. The preliminary social vulnerability indexes were created remotely, away from Metro Vancouver, after a one-week preliminary field trip to meet with several municipal contacts and informally visit some areas of the communities. There are a large

number of decisions to be made in constructing a social vulnerability index, the methodology of which Tate (2013) describes in detail. The steps taken in creating the preliminary index used in this study included selection of variables, data collection and normalization, principal components analysis, aggregation, and GIS mapping. An "inductive approach" was used (Tate 2012, 328), whereby a large number of variables are selected and then reduced using principal components analysis, and then the components are aggregated to create the index. This approach was made prominent by Cutter, Boruff, and Shirley (2003) and influences the design of the majority of the recent vulnerability indices produced in the literature (Tate 2012).

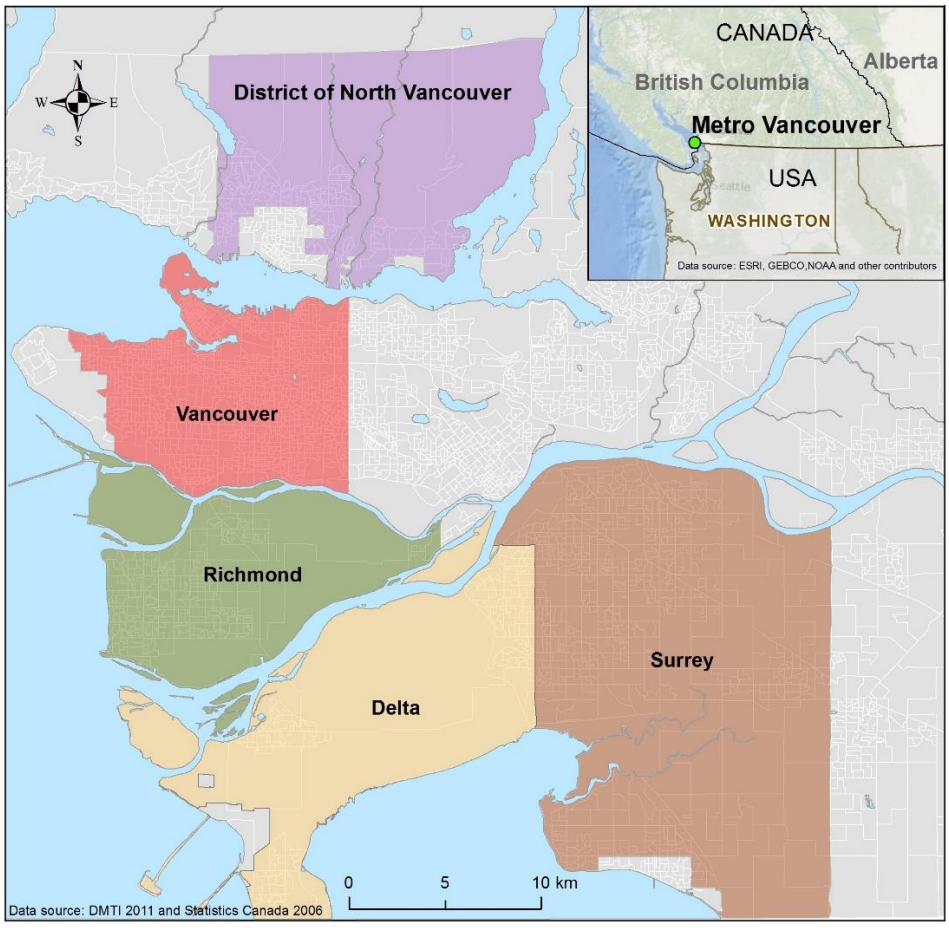

Figure 2.1: Study area map

The index used Statistics Canada 2006 Census data to assess social vulnerability at the dissemination area (DA) scale. A DA is a geographic area with an approximate population of 400-700 people, which, in a large Canadian city, is roughly the size of a small neighbourhood or sub-neighbourhood. This is a smaller scale than Jones' (2004) index of vulnerability in Greater Vancouver, which was at the census tract level. The DA scale was chosen because, based in part on preliminary field observation, neighbourhoods in Metro Vancouver have differential vulnerability at a fairly granular level (i.e., at a smaller scale than the census tract). Variables were selected to indicate social vulnerability to flood hazards (including riverine, coastal, and urban) based on a growing body of hazards literature on social vulnerability assessment. Much of this literature is based on work by Cutter, Mitchell, and Scott (2000) and Cutter, Boruff, and Shirley (2003), which identifies factors that influence many of the fundamental causes of vulnerability include: lack of access to resources, including information, knowledge, and technology; limited access to political power and representation; social capital, including social networks and connections; certain beliefs and customs; weak buildings; frail and physically limited individuals, and; type and density of infrastructure and lifelines. Twenty variables were selected, grouped around five conceptual indicators of vulnerability: ability to cope, ethnicity, access to resources, household arrangement, and built environment. The indicators of vulnerability and associated variables are listed in Table 2.1, including a rationale for their selection and their relationship (positive or negative) with vulnerability. Since vulnerability is context-specific, variables should be hazard- (e.g., flooding, earthquake) and issue-specific (e.g., evacuation response, infrastructure management) (Jones and Andrey 2007 after Buckle, Mars, and Smale 2000

and King and MacGregor 2000). The variables were selected to indicate vulnerability to flood hazards in a large Canadian city (hazard-specific) for the purposes of comprehensive municipal planning (issue-specific).

Table 2.1: Social vulnerability indicators and selected variables

Indicator	**Variable definition**	**Rationale**	**+ or – relation-ship**
Ability to cope	Age 19 and under	Dependents under law until 18; less mobile; 19 is age of majority in BC (Cutter, Boruff, and Shirley 2003; Collins, Grineski, and Romo 2009; Andrey and Jones 2008; Wu, Yarnal, and Fisher 2002; Hebb and Mortsch 2007; Greiving, Fleischhauer, and Lückenkötter 2006)	+
	Age 65 and over	Decreased mobility; even when healthy often have a limited fixed income (Cutter, Boruff, and Shirley 2003; Collins, Grineski, and Romo 2009; Andrey and Jones 2008; Bjarnadottir, Li, and Stewart 2011; Khan 2012; Hebb and Mortsch 2007; Greiving, Fleischhauer, and Lückenkötter 2006; Tate 2013)	+
	Female	On average women receive lower wages; have greater family care responsibilities (Cutter, Boruff, and Shirley 2003; Collins, Grineski, and Romo 2009; Andrey and Jones 2008; Wu, Yarnal, and Fisher 2002; Bjarnadottir, Li, and Stewart 2011; Khan 2012; Hebb and Mortsch 2007; Greiving, Fleischhauer, and Lückenkötter 2006)	+
Ethnicity	No knowledge of official languages	Communication difficulties due to language barrier (Hebb and Mortsch 2007; Khan 2012; Tate 2013)	+
	Recently immigrated (2001-2006)	Limited opportunity to receive financial aid after a disaster; limited employment opportunities (Andrey and Jones 2008)	+
Access to resources	Average (mean) dwelling value	Serves as a surrogate for wealth and, thus, resilience, rather than to infer that higher priced homes are less structurally sound (Cutter, Mitchell, and Scott 2000; Andrey and Jones 2008; Wu, Yarnal, and Fisher 2002; Tate 2013)	-
	Average household income	Wealth enables recovery from losses due to institutional resilience such as insurance,	-

		social safety nets and entitlements (Cutter, Boruff, and Shirley 2003; Collins, Grineski, and Romo 2009; Andrey and Jones 2008; Greiving, Fleischhauer, and Lückenkötter 2006)	
	Prevalence of low income (spend 20% more of after-tax income than average on necessities.	Limited financial resources (Andrey and Jones 2008; Chakraborty, Tobin, and Montz 2005; Odeh 2002; Bjarnadottir, Li, and Stewart 2011; Hebb and Mortsch 2007)	+
	Rent dwelling	Renters have less ability and/or incentive to take mitigation action because they do not own the property. Renters are usually either transient or do not financial resources for ownership. May not have adequate insurance. No equity in property (Cutter, Boruff, and Shirley 2003; Collins, Grineski, and Romo 2009; Andrey and Jones 2008; Wu, Yarnal, and Fisher 2002; Odeh 2002; Bjarnadottir, Li, and Stewart 2011; Khan 2012; Hebb and Mortsch 2007; Tate 2013).	+
	Income received from government transfers	Dependence on social safety net; economically and socially marginalized (Cutter, Boruff, and Shirley 2003; Andrey and Jones 2008; Odeh 2002; Khan 2012)	+
	Unemployed	Strain on resources and assistance programs; dependence on social safety net (Andrey and Jones 2008; Bjarnadottir, Li, and Stewart 2011; Khan 2012)	+
	High school education or less	Closely related to SES; lower lifetime earning potential (Andrey and Jones 2008)	+
	University education	Closely related to SES; higher lifetime earning potential (Cutter, Boruff, and Shirley 2003; Andrey and Jones 2008)	-
Household arrangement	Single-parent families	Financial and support constraints; child care responsibilities (Cutter, Boruff, and Shirley 2003; Andrey and Jones 2008; Khan 2012; Hebb and Mortsch 2007)	+
	Households with one person	Isolated individuals; assume all financial responsibilities (Andrey and Jones 2008)	+
	Main mode of transportation is public transit	Lack of mobility (Odeh 2002; Khan 2012; Hebb and Mortsch 2007)	+
Built environment	Population density	Higher population density presents evacuation difficulties (Cutter, Mitchell, and Scott 2000; Jones and Andrey 2007; Odeh 2002; Khan 2012)	+

	Dwelling is in apartment 5+ stories built before 1980	May not meet current construction standards due to building code changes (Hebb and Mortsch 2007)	+
	Period of home construction is before 1970	Changes in building code and zoning; ageing infrastructure (Hebb and Mortsch 2007)	+
	Housing in need of major repair	More likely to suffer flood damage (Jones and Andrey 2007)	+

Census data for each variable were then joined to unique DA boundary files (CANSIM 2012). Before undertaking further statistical analysis, the accuracy of the dataset was verified using descriptive statistics (i.e. min/max, mean, standard deviation). Missing values and DAs with population values of zero were removed from the analysis. Parks and recreational land use areas were masked out from the analysis in order to concentrate on areas in which people live (DMTI 2011). All variables were normalized using z-scores, which allows for the comparison of data across variables that may have different scales. This generates variables with a mean of 0 and standard deviation of 1. Next, a principal components analysis (PCA) was performed on the normalized data. PCA is a mathematical procedure used to reduce the number of variables used in data analysis by identifying the variables that account for the majority of data variance. The PCA was performed using a varimax rotation and Kaiser criterion for component selection. Eigenvalues greater than 1.0 were considered significant in explaining data variation. The result of Kaiser-Meyer-Olkin Measurement (0.754) indicated that patterns of correlations were relatively compact and PCA should yield distinct and reliable components. Bartlett's test was highly significant ($p<0.001$), suggesting that PCA was appropriate for the data. The PCA identified six components with eigenvalues of greater

than 1.0, which explained 67.45% of the variance in the data. Eighteen of the original twenty variables were significant in a component. The closer the coefficient between a z-score variable and the rotated component is to either -1 or 1 means it has a stronger correlation to that component. Table 2.2 displays the results of the PCA. The PCA found that two variables do not have a significant relationship with any component: "unemployed" and "main mode of transportation is public transit".

Table 2.2: Components and variable loading

Component	% of variance	Variables	Correlation	Sign adjustment
1	23.908	Population density	.670	+
		Age 19 and under	-.761	
		Rent dwelling	.627	
		Dwelling is in apartment 5+ stories built before 1980	.780	
		Households with one person	.800	
		Period of home construction is before 1970	.644	
2	14.423	No knowledge of official languages	.748	+
		Recently immigrated (2001-2006)	.750	
		Prevalence of low income	.675	
3	9.934	Average household income	.698	-
		Average dwelling value	.873	
4	7.521	Income received from government transfers	.770	+
		University education	-.645	
5	5.884	Age 65 and over	.677	+
		Female	.846	
		High school education or less	-.598	
6	5.785	Single-parent families	.604	+
		Housing in need of major repair	.734	

The component scores were then placed in an additive model and summed to generate a total social vulnerability index score for each DA, following the methodology of Cutter, Boruff, and Shirley (2003). The sign adjustment column in Table 2.2 shows whether the component increases or decreases social vulnerability. If a component has a positive relationship with vulnerability, it increases vulnerability, and if it has a negative relationship it decreases vulnerability. To use Component 1 as an example, although one variable (age 19 and under) displayed a negative factor loading, since all variables have tendency to increase vulnerability, a positive (+) sign was assigned to this component and an absolute value to Component 1 was applied to dissolve the negative sign on the variables that increase vulnerability. As another example, Component 3 displayed significant positive factor loadings on variables (average household income and average dwelling value) that theoretically decrease vulnerability. In order to adjust the sign of this component so that those variables appropriately represent their tendency to decrease vulnerability, the factor was multiplied by -1 to apply a negative sign. Weights were not applied to any components in the additive model when generating the index total score, so each component was viewed as equally important in contributing to the vulnerability of the DA.

2.3.1 Social vulnerability index maps

An index that describes the spatial distribution of social vulnerability is useful when presented in a visual manner, so GIS was used to create total score and component maps for the index. Total and component scores for each DA in five municipalities were joined to the DA boundary file and mapped to display standard deviation (SD) from the mean. The vulnerability scores were classified into five categories (quintiles): high (>1.5

SD), medium-high (0.5 – 1.5 SD), medium (-0.5 – 0.5 SD), medium-low (-1.5 – -0.5 SD) and low (<-1.5 SD). The maps presented in Figures 2.2-2.6 show the results of the total vulnerability score for the five study municipalities in Metro Vancouver. The components maps for each municipality are not included here as the number of maps would be overwhelming.

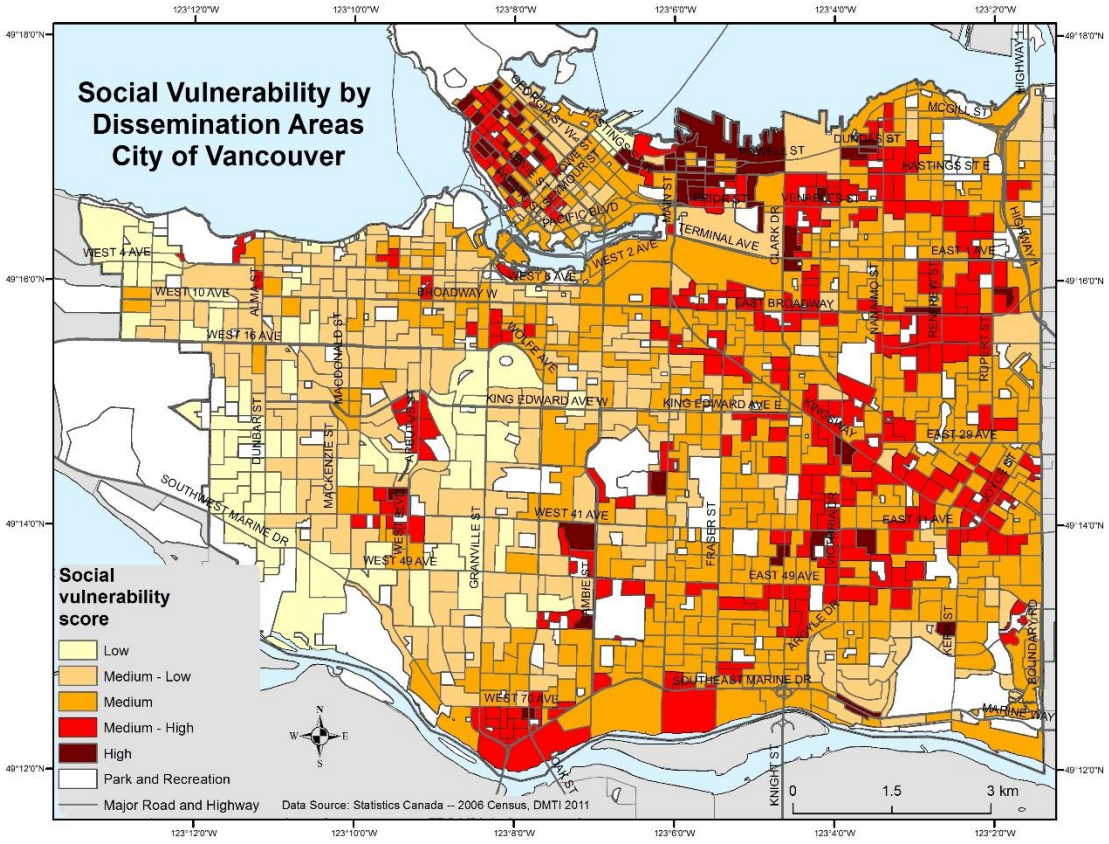

Figure 2.2: City of Vancouver social vulnerability total score map

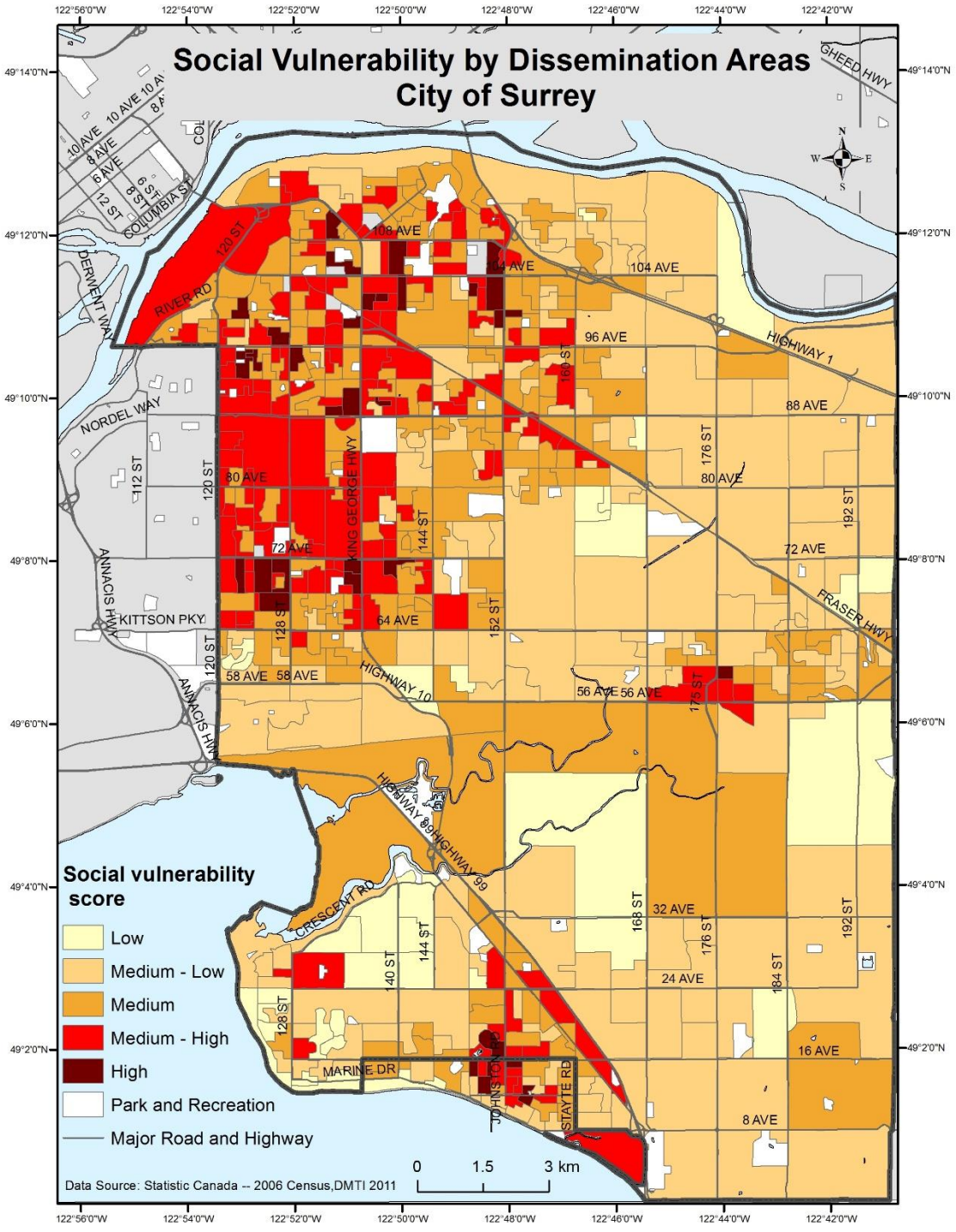

Figure 2.3: City of Surrey social vulnerability total score map

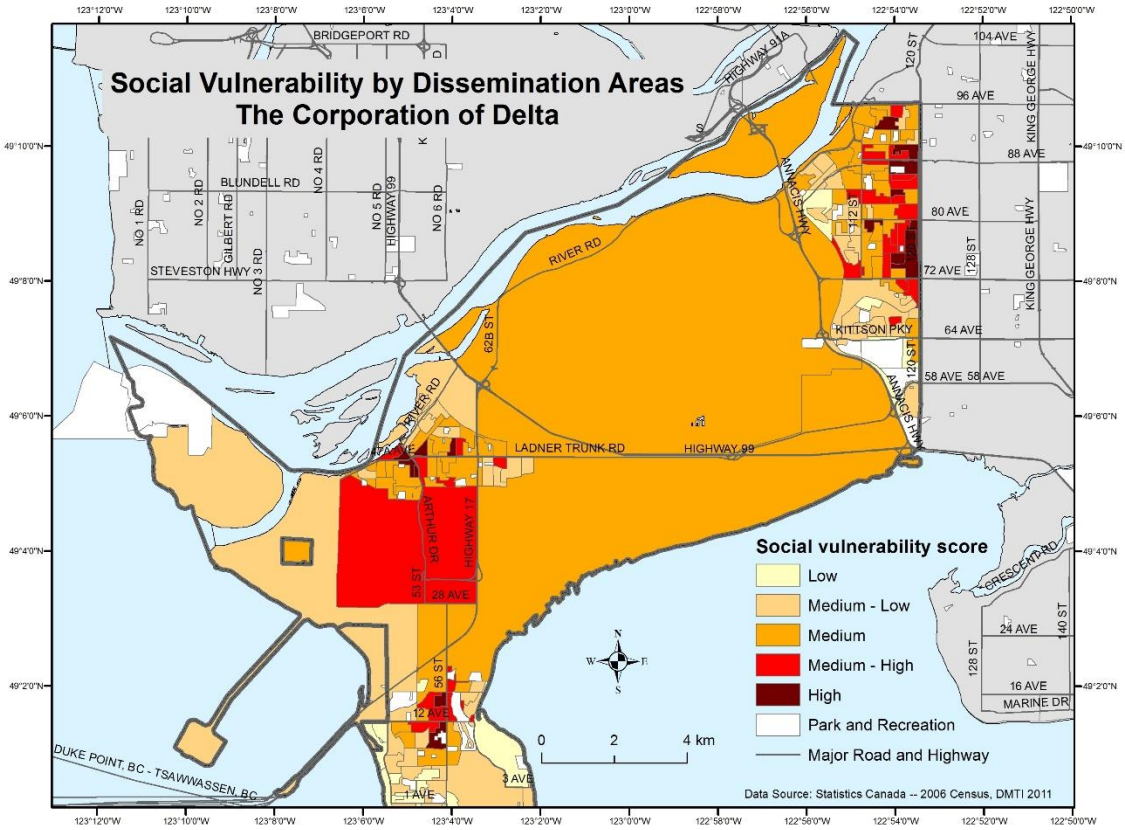

Figure 2.4: Corporation of Delta social vulnerability total score map

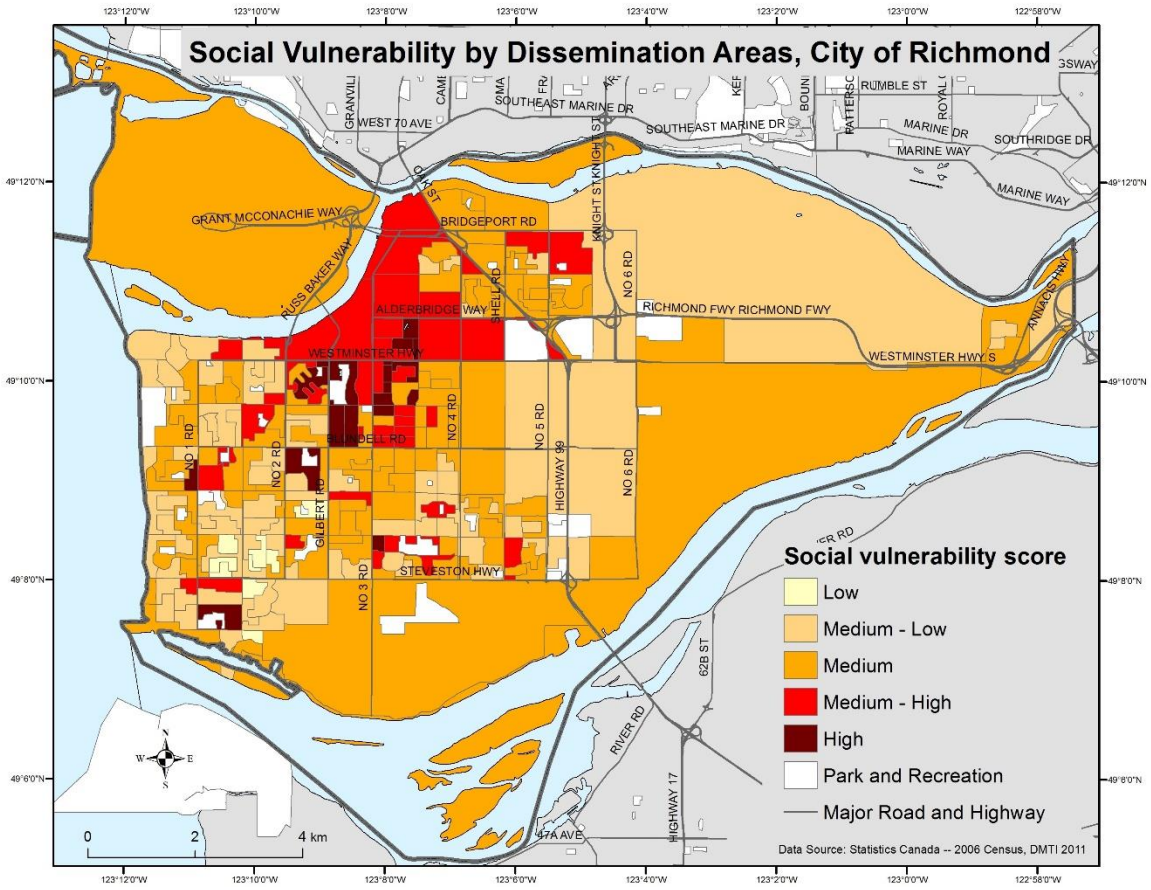

Figure 2.5: City of Richmond social vulnerability total score map

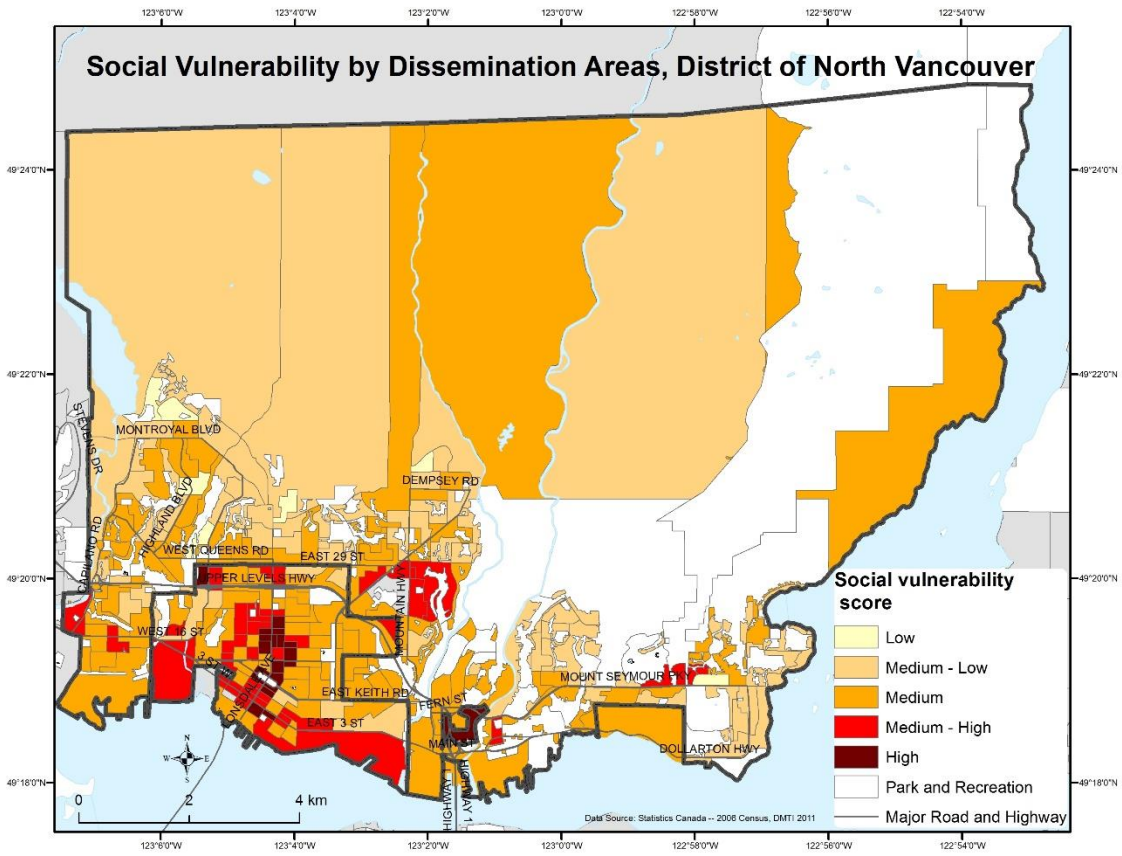

Figure 2.6: District of North Vancouver social vulnerability total score map

2.4 "Ground truthing" the social vulnerability index with municipal practitioners

Studies that create an index to measure social vulnerability to hazards often conclude that the index should undergo some type of review or validation to ensure that it "makes sense". Some studies actually take this next step and make an effort to validate the index. Most often this entails using other statistical methods to determine if a similar result is achieved (Eakin and Bojorquez-Tapia 2008; Tate 2012). Fewer studies use the opinions of other expert researchers in how to calculate the index (Emrich 2005; Greiving, Fleischhauer, and Lückenkötter 2006). Lacking are studies that create an index

and then present it to local practitioners for validation and incorporation of their feedback. If an index that measures social vulnerability to environmental hazards is meant to inform local planning and policy decisions to reduce risk, the practitioners that are involved in creating plans should be consulted in the creation of the index. Their opinions on what goes into the index are important, given their local knowledge and experience from working (and often also living) in the city. Municipal practitioners, including planners, engineers and emergency managers, hold a wealth of local knowledge and have a practical-oriented attitude. "Ground truthing", or verifying with local practitioner knowledge, a social vulnerability index can serve to ensure that it reflects the local context and is meaningful to those working in the community. In this study, local practitioners were asked for their input and variable weights were assigned based on their normative judgements in order to make the social vulnerability index useful to Metro Vancouver municipalities and learn from how practitioners view social vulnerability.

After the initial version of the social vulnerability indexes were created for the five municipalities they were presented in-person to practitioners in each of the municipalities. On consecutive days during June 11-15, 2012, the authors visited the five municipalities to meet with staff members. One day was spent in each of Vancouver, Surrey, Richmond, District of North Vancouver, and Delta. Each municipal visit followed a similar agenda: half the day was spent touring the city with municipal staff to visit exposed locations and vulnerable areas; the other half of the day included a focus group with practitioners at their municipal offices. The length of the focus group in each municipality varied from 1.5 hours to over 3 hours. The focus group consisted of a formal presentation by the authors, outlining the literature informing the research, the study

objectives, and preliminary findings, followed by structured feedback from the practitioners and then more informal feedback and sharing of experiences. Each focus group centred on the index and mapping created for that municipality. Care was taken to explain the operation of the PCA to the participants as it was considered important that their feedback be based on an understanding of how the index was constructed. A range of municipal staff participated in the focus groups. All practitioners had an interest or professional responsibility for hazard mitigation or climate change adaptation, and ranged from early career planners, engineers and emergency managers, up through increasing levels of management, to a mayor of one municipality who participated in the full length of the focus group. Practitioner feedback was solicited in two main ways: through a formal survey instrument and through more informal conversation and sharing of experiences, which was guided by a semi-structured question guide. The thoughts and opinions of local practitioners on a variety of issues related to social vulnerability were asked, including: the applicability of a social vulnerability index to their city; how the information conveyed in such an index is or is not presently used in their decision making; the variables selected to indicate social vulnerability to flood hazards; whether the total score map and components maps reflect the local contextual reality in their city (i.e. whether the maps "make sense" to them), and; if there are important variables that we may be missing.

2.4.1 Practitioner focus group feedback

Representatives of the five municipalities were found to have varying levels of acceptance of the idea of unequal social vulnerability to flood hazards within their city. The feedback received from presenting the social vulnerability index to municipal

practitioners was largely positive, affirming and constructive. The overriding feedback in four of the municipalities was that the research presented was important and potentially useful to them, though it contained minor flaws that could be fixed, in part, with local input. Practitioners from one municipality were critical of the research approach and felt that it was not applicable in their community. Many practitioners were excited to have an outside group of researchers address a topic that they felt was under-recognized in their community. One participant responded that "with all we've talked about with hazards and climate change adaptation, we haven't talked about the people who are in the places we think are exposed" (City of Vancouver staff). Overall, there was a fairly high level of agreement with the variables selected to indicate social vulnerability to flood hazards. Some practitioners suggested other variables that had not been included in the index. When presented with the total score map, the most common critique received was similar to "these variables weighted the same doesn't make sense" (District of North Vancouver staff). The idea that a variable like low income, for example, was weighted equally to a variable like having a university education was problematic for many practitioners. They suggested that the variables that are more indicative of social vulnerability should be weighted more heavily in the index than other, less important variables.

Practitioners were much more critical of the results of the principal components analysis. Often they could not validate the results of the PCA based on their own local knowledge. Sometimes they outright disagreed with the findings presented in the mapping of the statistically combined components. A common response of the practitioners to the PCA was that they would find it more useful to look at mapped individual variables or what could be called "customized combinations" of variables.

Maps of selected individual variables or custom combinations, they argued, would provide a more accurate picture of the local context and better represent what is causing differential social vulnerability. The ability to look at spatial representations of individual variables like income level, or combinations like elderly population and those living alone, for example, based on whatever may be deemed important while making planning and policy decisions, would ultimately be more useful for a municipality.

My belief that a better understanding of the local context is necessary to improve the quality of the social vulnerability index maps was reinforced during the focus groups with practitioners. Knowledge of local land use was missing during index mapping, and was perhaps the first error that stood out to practitioners. Their input on major land use omissions was useful and more efficient than browsing a publicly available internet mapping service. Land uses that practitioners thought would be most important to represent on the maps were agricultural and industrial land. These land uses are often large parcels that served to misrepresent or skew social vulnerability, as usually a very low population lives in these zones. Many practitioners suggested we visually "screen out" these land uses if the maps are intended to represent urban social vulnerability. Several municipalities offered to share with us municipal land use data to help improve the index mapping. Practitioners made several specific suggestions on built environment data that should be incorporated to better define the local context, including differentiating between areas serviced by a combined storm and sanitary sewer system and those with a separated sewer system, identifying areas serviced by pumped vs. non-pumped (gravity fed) drainage systems, and identifying transportation (highway and railway) corridors located in the floodplain.

Practitioners had a high level of agreement with the variables selected to indicate social vulnerability to flood hazards, though they offered a number of suggestions to modify or add variables to the index. Several practitioners made comments about the age that should define an elderly population. In the hazards literature, it is most common to define elderly as age sixty-five and older. There may be a need to increase this age threshold as an indicator of vulnerability to hazards in a Canadian city. Many participants echoed the comment that "Sixty-five isn't what it used to be" (City of Surrey staff). These practitioners felt that at age sixty-five many people are still healthy, highly mobile and independent; the lack of these characteristics being the reason that those above this age are often considered more vulnerable. Hazards research that investigates the stratification of this age cohort might usefully be applied in Metro Vancouver (see for example Wang and Yarnal 2012). The objection was also raised that those seniors living in condos or strata, though they may be physically frailer, might actually be less vulnerable because they often belong to resident associations. These organizations provide a social network that would be helpful to draw upon in the event of a disaster. Some residents associations may have an emergency plan wherein it has formalized its accountability to its members.

Several practitioners were concerned that a variable representing the disabled population was not included, as they argued disabled persons would be more vulnerable. The same concern was raised for a variable for homeless people and those living in informal settlements. The District of North Vancouver, for example, is aware that there are individuals living in the forests in the community but accounting for these individuals is difficult. A few of the municipalities have a large amount of intensive agriculture that

relies on migrant farm workers and some practitioners were concerned that these people were not represented in the index. Several practitioners suggested that First Nations communities should be identified on the maps. A few practitioners mentioned their concern that people living in secondary units in backyards, also known as laneway houses and granny flats, would not have been adequately accounted for in the Census data. Also, in many places in Metro Vancouver, there is a significant difference between very high property values and the value of the house on the property. There are many cases of a family of limited means living in a modest house that is on a property that has recently become very valuable due to an overheated real estate market. Some practitioners suggested that looking at property value alone may give an inaccurate representation of socio-economic status of the people living at that address.

2.4.2 Practitioner survey feedback

During the focus groups with practitioners in four of the municipalities, participants were asked to complete a short survey about the variables included in the social vulnerability index. This exercise took place during the formal presentation, after the total score map of the municipality was presented but before the components maps were shown. This timing was important so that the practitioners understood how the index worked but were not influenced by the results of the PCA. The practitioners were given at least ten quiet, uninterrupted minutes to fill in the survey. The survey included a Likert-scale to indicate their agreement with the inclusion of each variable as well as a chance to rank the variables they think are most important and add any variables they felt were missing. Participants were asked: “Based on your experience please indicate whether this variable is influential to defining social vulnerability to flood hazards in

your community by checking the appropriate box (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree) for each variable in the list". The Likert-style agreement question was completed nearly fully; the rank and add variables questions had varying levels of quality of response, so are not used in this quantitative analysis. A total of twenty-six practitioners (n=26) from four municipalities completed the survey, out of forty practitioners (N=40) from five municipalities who participated in the focus groups.

Although fourteen staff participated in the focus group at a fifth municipality, they were not asked to complete the survey because their oral feedback indicated that they generally were not accepting of the research approach. In this focus group, many of the participants rejected the idea of what they viewed as "ranking" places within their community and argued that populations in all areas of the city were of equal concern to the municipality. There was resistance to labelling populations as vulnerable, and some participants suggested that identifying "resilience" would be a more appropriate strategy. Though several strong leading voices may have affected the general view of the focus group and overpowered other opinions, the negative feedback received was significant enough to prohibit asking the participants to complete the survey.

2.5 Creating a weighted social vulnerability index

A key finding of the focus groups with municipal practitioners was that there was a high level of disagreement with the results of the PCA. While they may have found the presentation of the results to be an interesting exercise, the practitioners generally did not agree with the findings of what they saw as a statistical analysis technique performed remotely without any practical or local knowledge input. They most often could not

validate the results based on their own experience working (and often living) in the community. They questioned why certain variables were put together in some components and argued that the components were often not relevant in their community or representative of their concerns. Most practitioners expressed that they would find it more accurate and useful if the index were created based on their opinions on the weights and combinations of variables.

In response, based on the results of the practitioner survey, weights were determined for the variables in the index in order to produce a second version of the social vulnerability index. The response scores that participants gave for each variable were aggregated to determine the rank and then proportional weight of the variable (after Bell et al. 2007). In typical Likert-scale fashion, scores were assigned as follows: Strongly disagree = 1; Disagree = 2; Neither agree nor disagree = 3; Agree = 4; Strongly agree = 5. In the small number of instances where a response was not provided (7 out of a total of 520 answers [26 participants x 20 questions]), a neutral score of 3 for "neither agree nor disagree" was assigned in order to have a full data set. After the participant scores were aggregated to come up with the total score for each variable, the variables were ranked from one to twenty. The variable with the highest aggregate sum was ranked first down to the variable with the lowest aggregate sum ranked twentieth. Several variables had equal aggregated sums; the variables in these instances were given a tie ranking. The findings of the practitioner survey, and resulting rank and weight of variables is presented in Table 2.3. Rather than only counting the positive responses to each variable (agree and strongly agree) as in Bell et al. (2007), the negative (strongly disagree and agree) and neutral (neither agree nor disagree) responses were included in

the aggregated sum as well. The purpose for doing this is to incorporate the entire range of opinion on the variables, placing an integral value on those responses that are not in agreement because they are just as important and informative. The intention is to capture the level of disagreement with the variable as well as the level of agreement.

The proportional weights of each variable were calculated by

$$w_i = \frac{n - r_j + 1}{\sum(n - r_j + 1)}$$

where w_i is the standardized proportional weight for the selected variable

n is the total number of variables in the index

r_j is the ranked position of the variable

Kappa and weighted Kappa tests were performed on the practitioner survey data to determine the level of agreement between respondents, and found that the responses are appropriate for calculating weights of the variables in the index.

Table 2.3: Variable weights according to practitioner survey results

Variable	Number of responses					Sum	Rank	Weight (%)
	SD	D	NAD	A	SA			
Age 65 and over	0	0	0	9	17	121	1	0.0952
No knowledge of official languages	0	0	1	11	14	117	2	0.0905
Prevalence of low income	0	0	2	14	10	112	3	0.0857
Recently immigrated (2001-2006)	0	1	2	16	7	107	4	0.081
Single-parent families	0	1	3	18	4	103	5	0.0762
Income received from government transfers	0	2	7	10	7	100	6.5	0.069
Main mode of transportation is public transit	0	2	4	16	4	100	6.5	0.069
Age 19 and under	1	2	3	15	5	99	8	0.0619
Unemployed	0	3	8	7	8	98	9.5	0.0548
Housing in need of major repair	0	4	6	8	8	98	9.5	0.0548
Average household income	0	3	6	12	5	97	11	0.0476
Households with one person	1	3	6	12	4	93	13	0.0381
Population density	0	2	12	7	5	93	13	0.0381
Period of home construction is before 1970	0	2	12	7	5	93	13	0.0381
Dwelling is in apt 5+ stories built before 1980	0	2	12	9	3	91	15	0.0286
High school education or less	0	4	11	7	4	89	16	0.0238
Average dwelling value	0	7	8	7	4	86	17.5	0.0167
Rent dwelling	0	4	12	8	2	86	17.5	0.0167
University education	1	6	10	6	3	82	19	0.0095
Female	1	6	14	4	1	76	20	0.0048

SD=Strongly Disagree; D=Disagree; NAD=Neither Agree nor Disagree; A=Agree; SA=Strongly Agree

The resulting proportional weight was then applied to each variable in order to create a second version of the index. This new index was mapped for four of the municipalities and the second version of the maps also incorporates practitioner feedback about screening out land uses. The weighted social vulnerability index maps for Vancouver and Surrey are presented in Figures 2.7 and 2.8, respectively. These municipalities were chosen as examples because they have expressed the greatest interest in continuing to collaborate with this study. The total vulnerability scores are mapped by quintile to classify low ($\leq 20^{th}$ percentile), medium-low (21^{st}-40^{th} percentile), medium (41^{st}-60^{th} percentile), medium-high (61^{st}-80^{th} percentile) and high (81^{st}-100^{th} percentile) vulnerability for the DA. The results of the practitioner survey and weighted vulnerability maps were later presented to many of the focus group participants at a separate follow-up meeting.

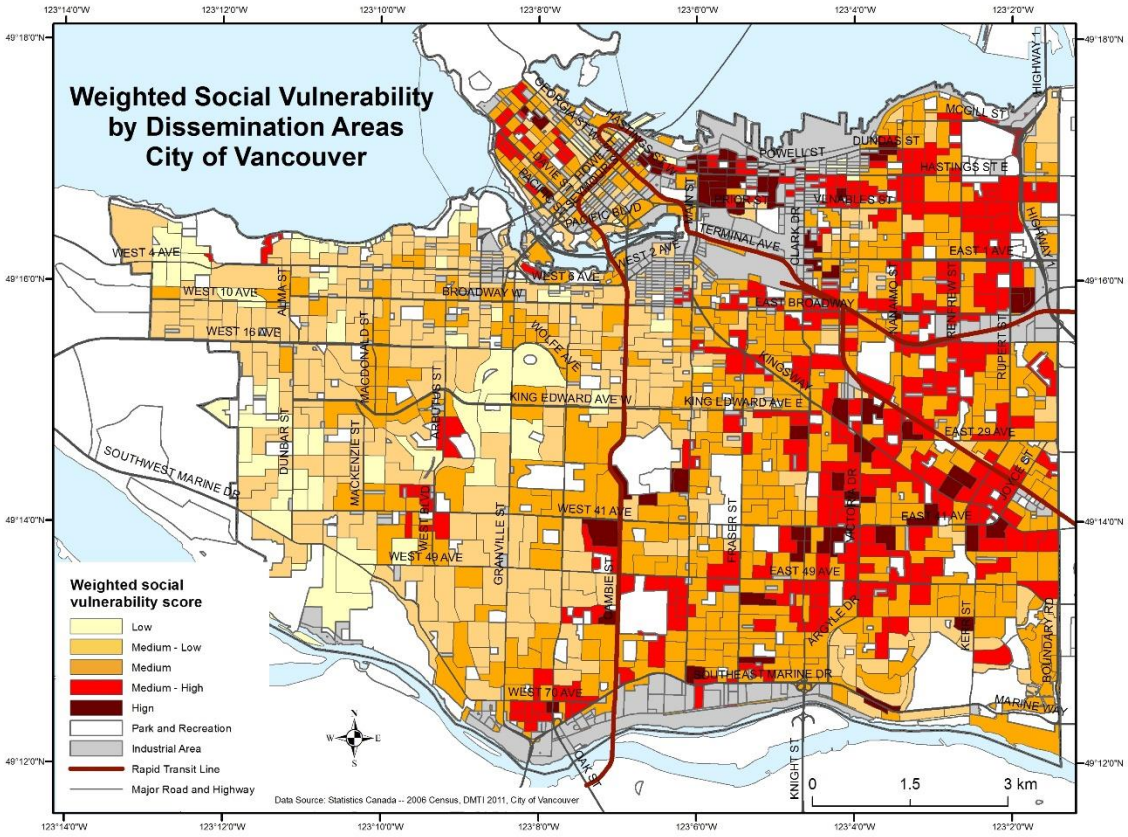

Figure 2.7: Weighted social vulnerability index map for City of Vancouver

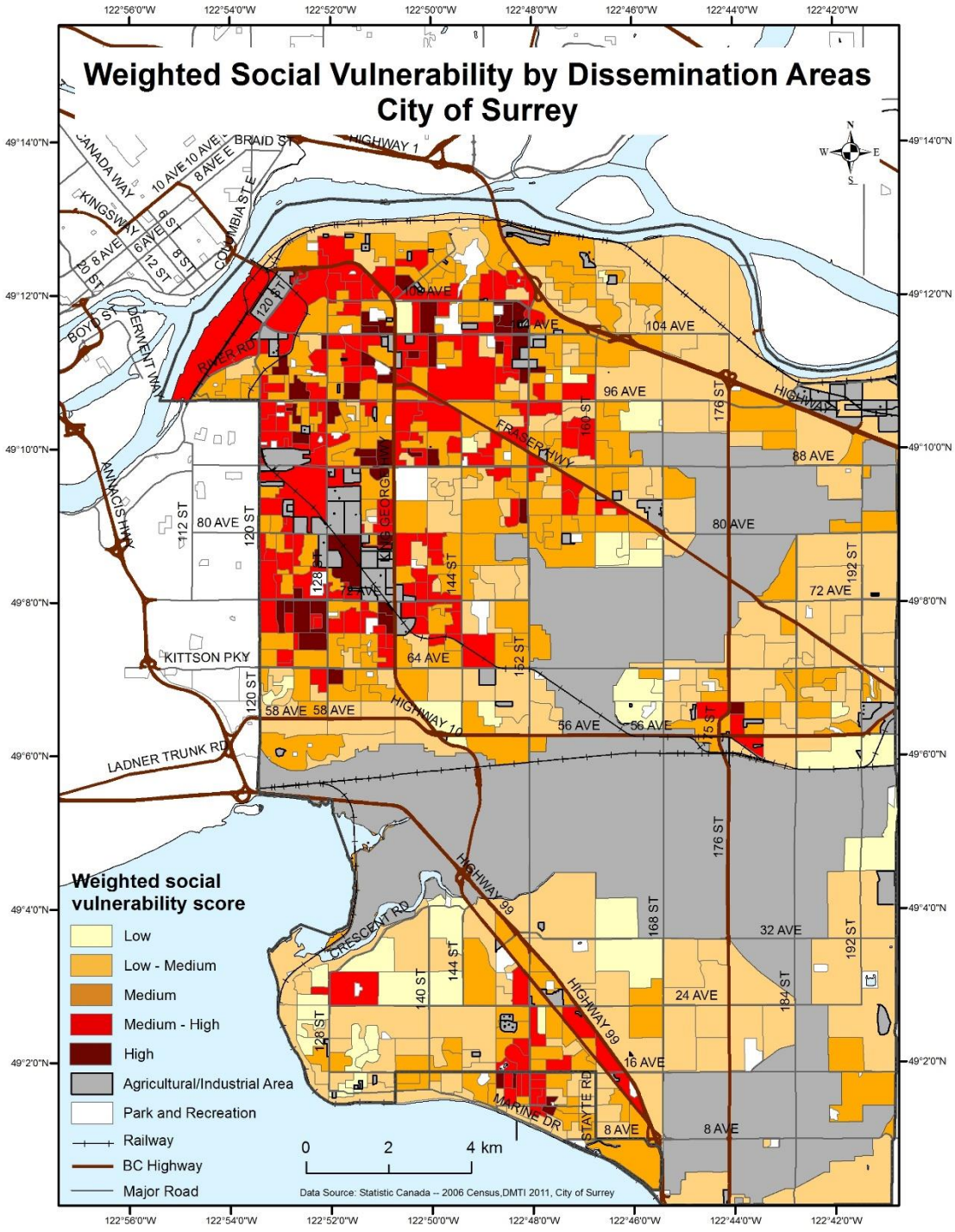

Figure 2.8: Weighted social vulnerability index map for City of Surrey

2.6 Discussion

The exercise of ground truthing a social vulnerability index in five municipalities advances an understanding of vulnerability by testing a researcher-led, statistical methodology against the local knowledge of practitioners working in the study area. If hazards researchers expect the findings of a vulnerability index to be considered in public policy decisions, the index should be meaningful to those working in the community. The process of describing to practitioners the construction of a standard social vulnerability index, verifying the local results with them, and then incorporating their input in a revised version is one way of making the index meaningful, and it revealed several findings about how practitioners view social vulnerability to hazards. Creating an initial version of the index using the standard methodology was an important part of the process because it provided a concrete, visual example with which to engage local practitioners, rather than asking for their abstract comments about vulnerability. Through this interaction, it was found that practitioners generally agree that the concept of unequal social vulnerability to hazards applies in their community and that an index to measure vulnerability can be useful but is not a perfect tool.

The social vulnerability index maps created in this study can be used by the municipalities to gain a better understanding of the spatial distribution of populations with higher vulnerability to flood hazards. The municipalities could combine the index with flood hazard information to identify place-based risk. At the time of the focus groups, participants from each municipality reported that they were at some stage of working towards updated flood hazard maps. The fact that municipalities have prioritized updating their flood hazard mapping is further evidence that flood risk is a pressing local

concern. When municipalities have completed updating their flood maps they will be able to overlay those maps with the social vulnerability index mapping in order to identify "hotspots", that is, places that are both exposed to flood hazard risk and have high social vulnerability. Information about these hotspots will give municipal governments the ability to make choices in the interest of protecting these locations and reducing the vulnerability of the people that live there.

Municipal practitioners who participated in the focus groups were critical of the results of the PCA in the first version of the index. Often they could not validate the components with their own local knowledge. Many participants expressed that they would find mapped individual variables or "customized combinations" of variables more useful. For example, a map showing where low-income populations are concentrated, or the neighbourhoods where those who are elderly, living alone and without knowledge of official languages are more prevalent, would be more helpful in municipal decision making. While practitioners understood that such a map would not be able to show exactly where such populations live, which would be useful in emergency response, they felt that information at the neighbourhood level is at an appropriate scale for comprehensive community planning. The ability to analyze customized combinations of variables would give municipalities a tool that can be flexible as priorities change. This idea of a custom combination of variables is similar to Adger et al.'s (2004) notion of a "disaggregated index", who argue that a composite index of all variables can be misleading and that disaggregated indices for different elements of vulnerability can provide information on the structure of vulnerability.

The PCA determined that two of the originally selected variables, "unemployed" and "main mode of transportation is public transit", do not have a significant relationship with any component of vulnerability. As a result, these two variables were not included in the first version of the vulnerability index and mapping presented to the municipal practitioners. When asked to indicate their level of agreement with all twenty variables in the survey, however, the practitioners had a relatively high level of agreement that the two variables were important in indicating vulnerability to flood hazards. Collectively, the practitioners ranked "main mode of transportation is public transit" tied at 6.5 and "unemployed" tied at the 9.5 position, putting both variables in the top half of twenty variables in terms of importance. The variable "main mode of transportation is public transit" is not a perfect representation of vulnerability due to lack of mobility but is an attempt to capture the portion of the population that relies on public transit because they do not own a private vehicle. These individuals may be more vulnerable in a flood event because they do not necessarily have the same ability to escape from an area as those who own a vehicle. Unfortunately, the 2006 Canadian Census did not collect this data so the variable is used as a proxy.

The similarity in the findings of the practitioner survey and the oral feedback received during the focus groups gives reason to support the mixed research methods used in the study. The rankings of the variables according to the survey results are generally in keeping with what was learned from talking with the practitioners. Specifically, the four highest ranked variables and the lowest ranked variable are all validated by repeated comments from the practitioners. The survey found "age 65 and over" to be the highest ranking variable, and this was supported by focus group

discussions. Practitioners identified that there may be reason to revisit the age of sixty-five as the threshold to define the elderly population, and a future study could examine the stratification of this variable for social vulnerability to hazards in a Canadian city. The high ranking of variables "no knowledge of official languages" and "recently immigrated", ranked second and fourth respectively, was also validated by focus group feedback. Municipalities in Metro Vancouver are home to a large population of recent immigrants, many of whom are from Asian countries. These populations are regularly taken into consideration in municipal decision making, and communication strategies to bridge language barriers are top of mind according to many participants in the focus groups. That the variable "prevalence of low income" was ranked third according to the practitioners is further evidence that the survey method was useful in accurately quantifying the oral feedback of focus group participants. This high ranking is consistent with the amount of attention given to low income earners by the practitioners, as well as in the hazards literature. The three highest ranked variables were the only variables which had no indication of disagreement from any of the practitioners in the survey results.

There are a few variables that received a notable amount of disagreement from focus group participants. This disagreement may arise from a disconnect between the findings of a broad hazards literature, including the spatial variation and regional applicability of these findings, and the practitioner community. Variables that may be considered important indicators of vulnerability in one place may not necessarily be as important in another place, and furthermore, at a different scale. The variable "female" ranked the lowest according to the practitioner survey results. Intuitively, it does not seem that a female living in a Canadian city should be any more vulnerable to flood

hazards than a male. The variable was included in the index because females on average have greater family care responsibilities and earn lower wages, which increases their vulnerability (Cutter, Boruff, and Shirley 2003; Collins, Grineski, and Romo 2009; Andrey and Jones 2008; Wu, Yarnal, and Fisher 2002; Bjarnadottir, Li, and Stewart 2011; Khan 2012; Hebb and Mortsch 2007; Greiving, Fleischhauer, and Lückenkötter 2006). Such characteristics, however, may be regionally defined and poorly understood by many practitioners. Participants in the focus groups had a high level of disagreement with the variable as an indicator of vulnerability in Metro Vancouver. It was the only variable that had more disagree responses than agree responses in the survey. It also had the highest number of "neither agree nor disagree" responses, indicating that participants were sceptical or unsure about the variable. Ranked nineteenth, the variable "university education" had a highly balanced response with almost as many "disagree" responses as "agree". Other than income earning potential (Cutter, Boruff, and Shirley 2003; Andrey and Jones 2008), there is seemingly nothing about having a university education that would make someone less vulnerable to flood hazards than a college or trades diploma. The coarseness of the variables may be the problem here; perhaps variables for other levels of education should be included. The regional variation of this variable is another consideration, as the value of different levels of education is not necessarily consistent across countries. The variable "average dwelling value", tied at rank 17.5, had a large number of "disagree" responses. This is reflective of the feedback we received during the focus groups about the overheated real estate market in Metro Vancouver: that just because a homeowner's property value has skyrocketed does not necessarily equate to them having low vulnerability to flood hazards. The other variable ranked at 17.5 is "rent

dwelling". The low ranking of this variable does not reflect the findings of recent hazards literature, which identifies renters as being a more vulnerable population (Cutter, Boruff, and Shirley 2003; Collins, Grineski, and Romo 2009; Andrey and Jones 2008; Wu, Yarnal, and Fisher 2002; Odeh 2002; Bjarnadottir, Li, and Stewart 2011; Khan 2012; Hebb and Mortsch 2007; Tate 2013). With generally lower income, increased transience, and fewer social networks in a high renter neighbourhood, renters also have little control over hazard mitigation in their home as they do not own the property. This research may not have yet reached the practitioner community, who might generally view a renter as the same able bodied individual as a homeowner. The high number of "neither agree nor disagree" responses to this variable would indicate that focus group participants were unsure of the contribution of the variable to vulnerability.

When comparing the maps produced from the first and second versions of the index, three general observations emerge. First, the maps have similar patterns of vulnerability. The aggregated components maps and the weighted variables maps have only minor differences in the vulnerability score category they display for each DA. If a DA has a different level of vulnerability in the two maps, it is most often different by only one category (e.g. changes from medium-low to medium or from high to medium-high). This closeness in scores is due to the fact that both indexes are constructed from largely the same variables, albeit with a different method of aggregation and weighting. It was important to use the same variables in both versions of the index, rather than introduce new variables suggested by some of the practitioners or remove the "female" variable, in order to be able to directly compare the outcomes to see the role played by the practitioner-generated weightings. Second, the weighted version of the index divided

into quintiles presents vulnerability as more "extreme". Many DAs that scored in the medium-low and medium-high categories in the first version score in the low and high categories, respectively, in the second version. Also, there are fewer DAs that score in the medium category in the second version. They are instead pushed to either medium-low or medium high. This is likely a result of using different methods to categorize vulnerability: based on standard deviations in the first version versus quintiles in the second version. Since local knowledge is incorporated in the construction of the second version of the index, it is appropriate to divide vulnerability scores into quintiles. Having more DAs with scores in the lower and higher categories has implications for policy making, in that a neighbourhood with a low score will receive more attention than one with a medium-low score. The third observation is that the identification of industrial and agricultural land uses in the second version of the index results in a visually clearer map. "Screening out" these land uses was suggested by many practitioners who argued that presenting a social vulnerability score for them was misleading and created general scepticism about the map from people who are familiar with the community. Identifying these areas in a separate category allows one to concentrate on residential areas of the city and is more representative of the local context.

2.7 Conclusion

Vulnerability is an important though complex concept in hazards research. The "hazards-of-place" model has made significant contributions to the field and, when operationalized in an index to measure social vulnerability to hazards, has the potential to inform public policy decisions. This article has argued that rather than researchers working remotely to create a social vulnerability index based solely on statistical

methodologies, the input of municipal practitioners should be incorporated in the construction of the index to ensure that it is accurate and meaningful in the local context. The article demonstrates one process of using this input and describes what was learned about how practitioners view vulnerability. Integrating qualitative and quantitative research methods in soliciting practitioner input proved relatively successful given the consistency in both types of feedback and should be an objective of an interactive process. Collaboration in this manner between hazards researchers and local practitioners on a vulnerability assessment can facilitate knowledge sharing while improving the applicability of vulnerability concepts in what is most often a pragmatic policy environment. Modifications could be made to the methodology of weighting the variables, and a larger sample size of practitioners would better represent the opinions of those working in local policy, but this study serves to illustrate that local input can and should be incorporated in a tool that is meant, in part, to contribute to local policy decisions.

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3. Determinants of residential vulnerability to flood hazards in Metro Vancouver

3.1 Introduction

Metro Vancouver is the site of a dynamic human-environment relationship, characterised by a complex interaction between a geophysical setting offering rewards and risks and a growing population featuring wide socio-economic gaps. Traditionally, attention to hazards in this urban area has focused on earthquake risk, but lately a combination of damaging events, urban development pressures, and concern about climate change impacts has expanded the popular focus to include flood hazards. The municipal governments of Vancouver and Surrey have responded to this increased public awareness, in part, by introducing climate change adaptation plans that address flood risk at a local policy level, being the first two cities in Metro Vancouver to take this policy action. In both of these cities, residents will experience these plans differently based on their unique risk. The hazards literature documents that unequal vulnerability leads to differential risk among populations exposed to hazards (Wisner et al. 2004). Earlier findings on vulnerability in the developing world have been theorized and investigated in a developed country context. It has been found that a number of factors, unique to households, interact to determine peoples' vulnerability to hazards. Some of these "determinants" have been identified and tested through studies of different hazards in various international contexts. Determinants of residential vulnerability have not been examined, however, for flood hazards in a Canadian urban context.

This chapter addresses this research gap by identifying and testing seven determinants of residential vulnerability to flood hazards in Metro Vancouver. Each of the determinants has been examined in previous hazard studies but they have not been applied collectively to investigate urban flood risk in Canada. Five of the determinants were brought together in a foundational study of wildfire risk in the American West by Collins (2008; 2009), one determinant was examined in other recent flood risk studies (Terpstra and Gutteling 2008; Kellens et al. 2013), and one determinant found to exist in this study is theorized in earlier risk analysis research (Kasperson et al. 2003). The study employs a household survey to test the determinants in four neighbourhoods in Vancouver and Surrey. The determinants identified are (1) social vulnerability, (2) hazard perception, (3) institutional arrangements, (4) amenity value conflicts, (5) self-protection, (6) attribution of responsibility, and (7) attenuation of risk due to another dominating concern. The findings of the survey offer insights as to how these determinants produce unequal vulnerability to flood hazards.

3.2 Determinants of residential vulnerability to flood hazards

Early hazards research sought to understand how perception of risk affects human interaction with a hazardous environment (White and Haas 1975; Burton et al. 1978). Influenced by the call to understand how political-economic structural forces create unequal risk (Hewitt 1983; Blaikie et al. 1994) and a body of literature on the social determinants of human health (Marmot and Wilkinson 2006), hazards researchers have more recently looked beyond perception to identify other determinants of vulnerability to hazards. Amenity value conflicts and institutional incentives were identified as factors that influence the vulnerability of residents to hazards (Collins 2005). In examining

peoples' interactions with wildfire hazards at the wildland-urban interface in the American West, Collins (2008; 2009) adds ecological knowledge, social vulnerability, place dependency, housing factors, and self protection as other potential determinants of vulnerability. Of these, this dissertation postulates that hypothetical determinants of vulnerability to flood risk in a Canadian urban context include: (1) hazard perception, (2) amenity value conflicts, (3) institutional incentives, (4) social vulnerability, and (5) self protection. Determinants identified in other studies that apply to flood vulnerability in a Canadian city are: (6) attribution of responsibility (Terpstra and Gutteling 2008; Kellens et al. 2013) and (7) attenuation of risk due to another dominating concern (Kasperson et al. 2003).

Flood hazard research has long found that risk perception influences how one responds to the hazard (Slovic 1992). Research has shown that residents exposed to flood hazards often underestimate their risk. Canadian studies have found that significant portions of residents who live in defined flood plains perceive themselves at no or low risk of flooding (Kreutzwiser et al. 1994; Shrubsole et al. 1997). Often, previous experience of a disaster increases one's perception of risk (Grothman and Reusswig 2006; Siegrist and Gutscher 2006; Keller et al. 2006; Kellens et al. 2011; Terpstra 2011). Amenity value conflicts can also be a determinant of vulnerability (Collins 2005). People living in places exposed to flood hazards tend to value the environmental benefits, or amenities, that such a location provides. Whether it is a nice view of the sea or proximity to a river shore, people tend to value the benefits of the location at the same time those benefits can increase their risk (i.e. exposure to flood hazards) (Terpstra et al. 2006; Zhang et al. 2010). The influence of societal institutions on the daily life of a resident in a

Canadian city is far reaching. Institutional arrangements, such as insurance and development regulations, can act as another determinant of vulnerability, since access to them is often uneven among populations. For example, those who buy property insurance have been shown to have slightly greater risk awareness and are more likely to adopt mitigation strategies (Thieken et al. 2006). In countries where overland flood insurance is available, factors related to insurance take-up are housing tenure (Takao et al. 2004), income (McEwen et al. 2002), and exposure (Figueiredo et al. 2009), resulting in uneven benefits achieved by this risk transfer mechanism (after Kellens et al. 2013).

Recent research points to other factors that influence vulnerability to flood hazards. Characteristics that affect social vulnerability, such as age, gender, education, income and housing tenure, have been found to have significant relationships with flood risk perception (Kellens et al. 2013). Household income has been shown to be negatively correlated with risk perception (Lindell and Hwang 2008; Zhang et al. 2010). Those households with higher incomes have been found to be more willing to pay for flood mitigation measures (Zhai et al. 2006). Housing tenure has also been identified as an important factor, with homeowners found to perceive relatively higher risk than renters (Grothmann and Reusswig, 2006). Knowledge about self-protection from hazards affects the measures a resident may take and their ability to perform those actions (Thieken et al. 2007). Studies have found that perception of high risk is necessary for motivating protective actions (Grothmann and Reusswig 2006; Siegrist and Gutscher 2008). Another factor that has been identified as a determinant of vulnerability to flood is how residents attribute responsibility for flood mitigation. Also called the “locus of responsibility”, studies have investigated the degree to which residents think protection from flood is a

homeowner or government responsibility. Studies have found that the public perceives flood protection as a primarily public rather than private responsibility (Burby 2006; Terpstra and Gutteling 2008; Kreibich et al. 2009; Lara et al. 2010). Similar findings have also come out of hazards research on wildfire (Martin et al. 2009), earthquake (Lindell and Perry 2000), and coastal erosion (Friesinger and Bernatchez 2010). In cases where people do perceive flood hazard protection as their personal responsibility it has been found that mitigation actions are more likely (Kellens et al. 2013). Finally, when a community is faced with multiple hazards, a focus on one hazard can attenuate the perceived risk of another hazard (Kasperson et al. 2003). That is, when people are focused on a hazard that receives a large amount of popular attention, that dominating "selected" hazard can serve to distract them from taking action to reduce their risk from other hazards. Testing these determinants of vulnerability for flood hazards in a Canadian city will contribute to a body of literature on the factors that influence hazard vulnerability and reveal findings about how these factors interact to produce unequal vulnerability to flood hazards among residents.

3.3 Residential flood hazard risk in Vancouver and Surrey neighbourhoods

Metro Vancouver is an urban agglomeration of municipalities located on and around the Fraser River delta at the Strait of Georgia in British Columbia, Canada. With a growing population of 2.3 million, Metro Vancouver is the site of complex competing human-environment relations. Population growth and urban development pressures have contributed to an expensive real estate market relative to other Canadian cities while an attractive geophysical location also presents a number of hazards. Earthquake risk receives a large amount of attention from governments and residents, but flood hazards

are increasingly the subject of local attention due to the damage they have caused and are expected to cause (Forseth 2012). Flood hazards, including urban flash flood caused by heavy rainfall, riverine, and coastal, including sea level rise, have emerged as a particular concern for residents and municipal planning departments. Though a number of Metro Vancouver municipalities have significant exposure to flood hazards, two were selected for this study. Vancouver and Surrey are the two largest and fastest growing cities (Stats Can 2011) and both have neighbourhoods with varying exposure to flood and residents with a wide range of socio-economic characteristics. These characteristics contribute to determining the vulnerability of the neighbourhood to flood risk. Unequal vulnerability of neighbourhoods exposed to flood hazards results in differential flood risk (Blaikie et al. 1994). Vancouver and Surrey have recently released climate change adaptation strategies that address flood hazards. Similarly exposed neighbourhoods in other municipalities were not included in this study due to logistical barriers caused, in part, by local political and development pressures.

Two neighbourhoods in both Vancouver and Surrey were selected for this study. Each neighbourhood has exposure to flood hazards. The level of exposure was determined by municipal flood maps and confirmed by municipal planners and engineers. One neighbourhood with relatively high vulnerability and one neighbourhood with relatively low vulnerability were selected in both cities, in order to provide a population with a wide range of socio-economic characteristics. The overall vulnerability of these neighbourhoods was determined by creating a social vulnerability index for Vancouver and Surrey (Chapter 2). The index used the dissemination area scale, which divides a city into areas of approximately 400-700 people, or roughly the size of a small

neighbourhood. Both the level of exposure and vulnerability for each neighbourhood were confirmed by the experience of municipal planners and engineers, who agreed that these were appropriate and interesting neighbourhoods for the purposes of the study.

In Vancouver, the study was conducted in the neighbourhoods known as Kits Point and Marpole. Figure 3.1 locates the study neighbourhoods within Vancouver and indicates their level of social vulnerability. Kits Point has relatively low social vulnerability for Vancouver and is surrounded on three sides by English Bay and False Creek. With this proximity to the bay and coastal environment amenities, and a location near Vancouver's downtown core, Kits Point has long been a highly sought after residential neighbourhood. Expensive detached homes, townhouses and condominiums line the streets, though the neighbourhood is also home to a significant population of renters, who often live in basement apartments. The southern part of Marpole is the other focus of the study in Vancouver. The neighbourhood has higher social vulnerability than Kits Point and is located near the northern banks of the Fraser River. Historically settled largely by Chinese and other Asian immigrants to Vancouver, Marpole remains home to a large population of recent immigrants and non-English language speakers. Duplexes and apartments are the most common homes in the neighbourhood, though in the northern part of the neighbourhood single detached homes are more common. The elevation of Marpole increases in a northward direction, with the south part of the neighbourhood having greater exposure to flood. The value of the homes likewise increases in a roughly northward direction.

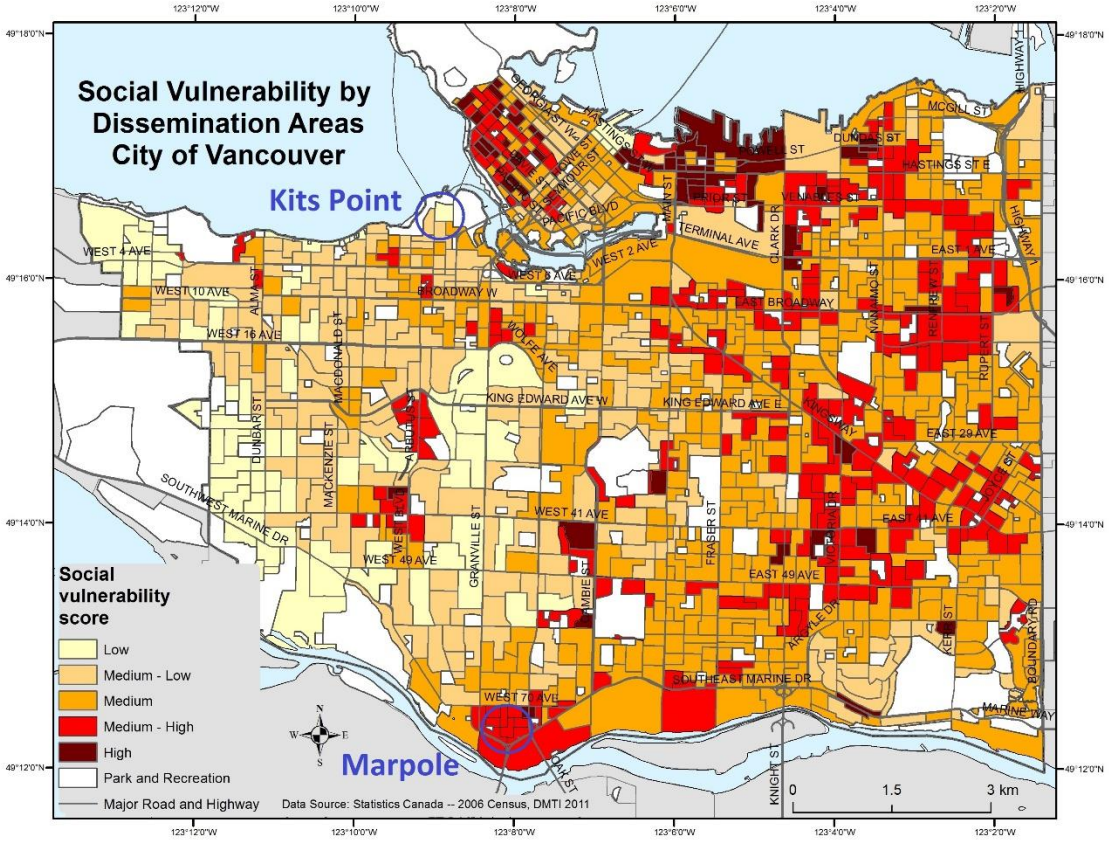

Figure 3.1: Study neighbourhoods in Vancouver

In Surrey, the neighbourhoods known as Crescent Beach and Bridgeview were selected for study. Figure 3.2 locates the study neighbourhoods within Surrey and indicates their level of social vulnerability. Crescent Beach has low social vulnerability relative to other neighbourhoods in Surrey and is located on a spit of land that reaches out into Boundary Bay at the mouth of the Nicomekl River. Originally settled as a cottage community, the village neighbourhood has a long beach, walking paths on the shore, and trees and vegetation that provide an aesthetic environment. The village is a popular destination for those living outside the neighbourhood to visit for a walk or a meal at one

of the small restaurants. Some of the original cottages remain but many of them have been torn down or substantially renovated, so modern and expensive detached homes are the new norm in the neighbourhood. Bridgeview has relatively higher social vulnerability for the city and is located in North Surrey on the banks of the Fraser River in the "shadow" of the Pattullo Bridge. Bridgeview was historically home to the families of the inmates of the prison across the river, and its reputation as an undesirable neighbourhood continues to the present. Most homes are detached on lots with large ditches due to the lack of storm sewers, which gives the neighbourhood something of a rural feeling in the city. A growing South Asian immigrant population is fueling some redevelopment of homes in the neighbourhood.

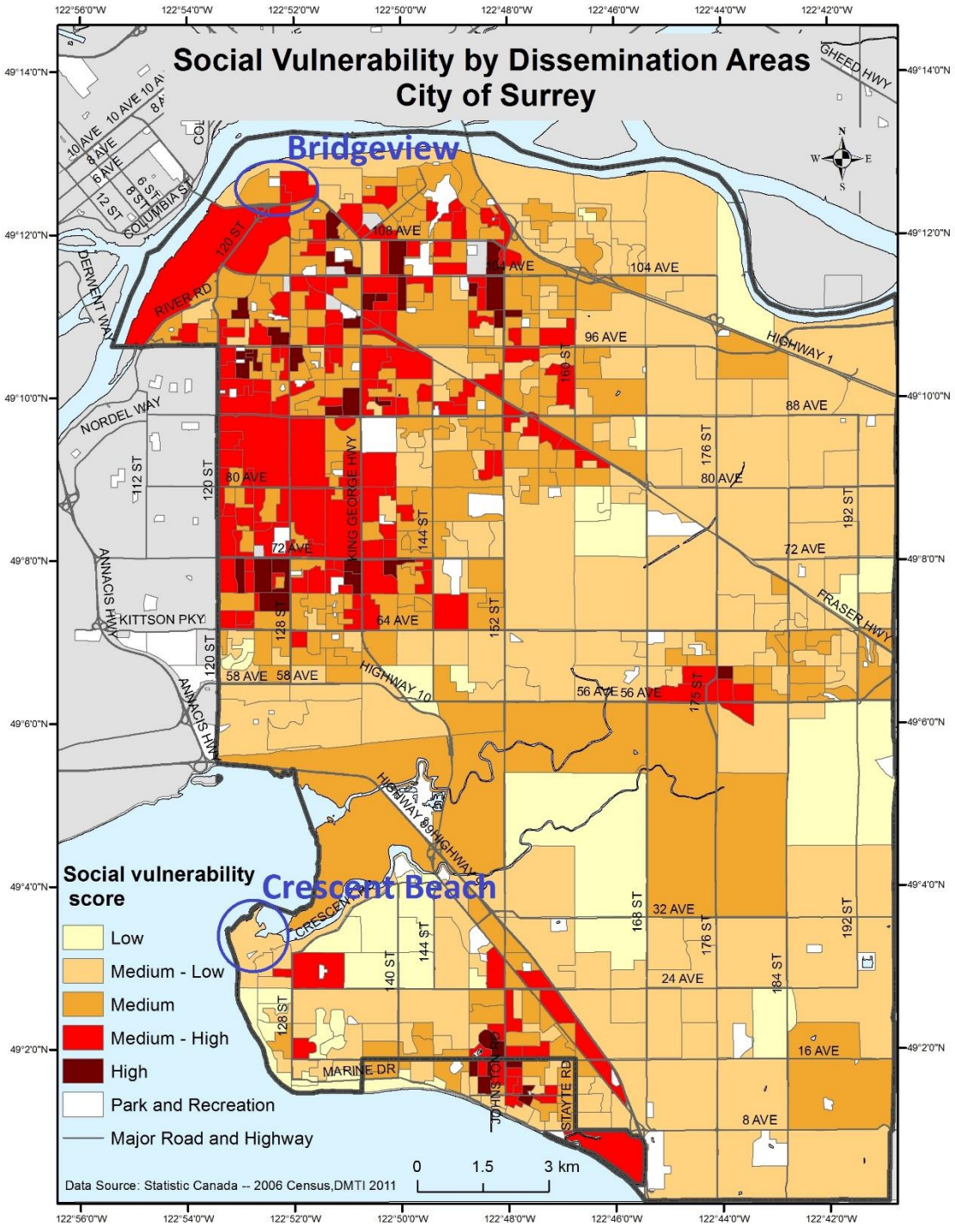

Figure 3.2: Study neighbourhoods in Surrey

3.4 Residential survey

In order to test resident perceptions and attitudes against the seven determinants of vulnerability to hazards, a residential survey was conducted in the four case study neighbourhoods. An 8-page, 28-item questionnaire was developed by the author, informed by previous hazards studies and then vetted by 12 other hazards researchers and piloted with officials from both municipalities to check for applicability. The survey contained both closed- and open-ended questions. The closed-ended questions included yes/no, categorical, and Likert-type scale answers. Answers to open-ended survey questions, as well as face-to-face conversations and follow-up phone calls with residents served to enrich the data and provide narratives. A self-administered structured survey methodology based on Dillman's Tailored Design Method (TDM) (Dillman et al. 2009) was followed to implement the survey simultaneously in the four neighbourhoods during late February to April 2013. The TDM was used as a methodological guide in order to obtain as high a response rate as possible given existing budgetary constraints. The modified method consisted of four unique contacts with each home in the population over the course of the survey, including separate hand-delivery of a pre-notice letter and the first copy of the survey package, and mailing a thank you/reminder postcard and a second copy of the survey package. Hand-delivery of the first two contacts ensured that the survey reached each home in the study area and allowed the author a chance to gain first-hand knowledge of each neighbourhood. The survey population included every home within a defined area that included the majority or all of each neighbourhood. The neighbourhoods are fairly small with approximately 400 homes and every home was included in the population to maximize the representativeness of the neighbourhood. The

survey was delivered to a total population of 1540 homes (N=1540). This population included 388 homes in Kits Point, 398 homes in Marpole, 355 homes in Crescent Beach, and 399 homes in Bridgeview. A total of 461 completed surveys were received from all neighbourhoods (n=461), for a response rate of 29.9% of surveys returned. This sample size compares favourably with that of other flood risk perception studies (Kellens et al. 2013). With this number of completed surveys from the survey population, the margin of error is less than ±4%, 19 times out of 20.

3.5 Results and analysis

The survey assessed independent variables representing hazard perceptions, amenity values, institutional incentives, social vulnerability, self-protection, and attribution of responsibility. Through open-ended survey responses and conversations with residents, an additional determinant was discovered: attenuation of risk due to another dominating concern. While this determinant was not tested in the survey, it is included here as the seventh determinant because it was found to be an important factor in two of the four neighbourhoods. This section presents survey results of the variables by determinant, starting with social vulnerability. In the interest of improving the operationalization and theoretical progression of flood risk research, as argued by Kellens et al. (2013), detailed tables are included listing the measures, metrics, and descriptive statistics of these determinants of residential flood hazard vulnerability. Resident qualitative feedback, coded according to determinant, is incorporated to provide a narrative about factors affecting vulnerability in the neighbourhoods.

Study results support earlier findings that social vulnerability is an important determinant of vulnerability to hazards. The overall social vulnerability of each of the four survey neighbourhoods was assessed in Chapter 2, and a better understanding of how social vulnerability interacts with other determinants of vulnerability at the household level will add analytical depth to that assessment. Previous research has identified household income as an important factor in resident interactions with flood hazards (Zhai et al. 2006; Lindell and Hwang 2008; Zhang et al. 2010), and, hypothetically, this factor is a key contributor to social vulnerability in a Canadian city. In order to explore relationships between this contributor to social vulnerability and the other determinants of vulnerability, household income was tested against the independent variables representing the determinants. Statistically significant bivariate relationships ($p < 0.01$ unless otherwise noted) were found. Spearman's rho test was applied because the variables are measured with ordinal or ranked data. The analysis is included in this section.

3.5.1 Social vulnerability

Respondents were asked to indicate their housing tenure, sex, age category, education level, total household income, the number of people in their home, and the number of years they have lived in their home in order to enable an analysis of social vulnerability to flood hazards (Table 3.1).

Table 3.1: Social vulnerability

Social vulnerability variables (metric)	n	Percent	Mean	Median	SD	Range
Housing tenure	460					
Own (1)	394	85.7				
Rent (2)	66	14.3				
Sex	448					
Male (1)	221	49.3				
Female (2)	227	50.7				
Age	449					
18-30 (1)	17	3.8				
31-45 (2)	73	16.3				
46-64 (3)	203	45.2				
65+ (4)	156	34.7				
Education	448					
Some grade school or high school (1)	16	3.6				
High school graduate (2)	35	7.8				
Some post-secondary (3)	51	11.4				
College or trade certificate or diploma (4)	84	18.8				
University degree (5)	262	58.5				
Total household income	350					
Less than $30,000 (1)	31	8.9				
$30,001 to $60,000 (2)	84	24				
$60,001 to $90,000 (3)	73	20.9				
$90,001 to $120,000 (4)	55	15.7				
More than $120,000 (5)	107	30.6				
Number of people in home	426		2.43	2	1.242	7
Number of years in home	454		15.8	12	13	66.75

Most respondents (86%) reported that they own their home. Homeowners and renters have previously been found to have different attitudes towards flood hazards and abilities to take action to mitigate their risk. Owners usually feel they have more to lose in a flood and renters are often prohibited from undertaking mitigation action on the property (Grothmann and Reuswigg 2006). One renter in Kits Point articulated this difference by saying: “Because I'm a renter I don't feel that sea level rise will affect me in terms of net worth but I do worry about how the city will cope with more and more

floods in general". It was apparent that other characteristics that create higher social vulnerability influenced residents' interactions with flood hazards, especially in Bridgeview. One Bridgeview resident complained about what he views as the plight of those living in his neighbourhood: a lack of representation in municipal decision making. "When you live down here for long enough you start to get really pissed off at the City. We spend all this money on taxes and what do they do for us?" Another resident in the neighbourhood echoed this view: "I believe they [municipal government] have a responsibility to inform us what they have done, the risk of flooding, and the plan they will do in the future [sic]. The government doesn't care, because this is a poor neighbourhood." One Bridgeview homeowner talked specifically about how Surrey's regulation requiring new construction in flood prone areas to be elevated affects him (City of Surrey 1993 [2014]; City of Surrey 1996 [2014]):

> I think it's dumb they are making these new houses have to go up one storey. How is someone like me [using a wheelchair] supposed to get up there? I'd need an elevator. You know how much that would cost? This bungalow here [pointing across the street] is perfectly fine, well-constructed. So is mine. I couldn't afford to build a new one like this.

This statement illustrates that a municipal building regulation intending to reduce flood risk is perceived to have unequal impacts on residents based on their ability to pay for the cost of adhering to the policy.

3.5.2 Hazard perception

Hazard perceptions were measured with survey questions that asked residents to indicate their level of concern for various types of local hazards and their level of

agreement with statements about climate change impacts. Participants were also asked if they have previously experienced a flood. Less than 8% of respondents reported they have experienced a flood in their current home. Their answers to this question, however, indicate that there exists some confusion about what constitutes a flood hazard. Many respondents indicated that a burst pipe or leaking appliance in their home caused a flood. This type of water damage was not the subject of the survey. Since the survey asked them to describe the flood event and damage it caused, it is possible to separate the water damage replies from the flood damage events. The respondent confusion to the question, however, gives cause for some lack of confidence in the reliability of reported flood experience.

The median perceptions of all hazards were quite low, with the three highest perceived hazards at just above a moderate level of concern (Table 3.2). Respondents' perceptions of flood hazard were quite evenly distributed from low to high, with the median response very close to a moderate level of concern. Earthquake was perceived as the greatest hazard risk. One resident went so far as to say, "Earthquake is the only natural disaster that concerns me." The high level of concern for earthquake is not surprising given the amount of attention given to the hazard in Metro Vancouver and on the west coast of North America generally. Sea level rise was perceived as the second highest risk, and greater than traditional flood hazards, which were perceived as the third highest risk. Landslide and wildfire were perceived as the lowest risks, which is likely an accurate relative perception given that the neighbourhoods are located in an urban area.

Table 3.2: Perception of hazards

Perception of hazards*	n	Mean	Median	SD
Flood	445	3.04	3	1.506
Earthquake	452	3.52	4	1.299
Sea level rise	451	3.20	3	1.425
Wind storm	444	2.71	3	1.253
Landslide	442	1.53	1	1.030
Wildfire	442	1.43	1	0.888
Land subsidence	439	2.43	2	1.419

*Metric: 1 = low, 5 = high; Range = 4

Respondents indicated a higher perception of climate change impacts than hazard risk (Table 3.3). Almost 90% of participants agreed that they think the climate is changing. Nearly two-thirds (62%) of participants reported that they have noticed the impacts of climate change in their city, and the same percentage are concerned about the impacts of climate change in their neighbourhood. Half (50%) of all respondents perceive that the risk of flooding that would affect their property is increasing. Three-quarters (76%) of respondents perceive that climate change is causing more extreme weather events. About one-in-six respondents (17%) replied that they do not know if there are more frequent and severe rainfall events now than there were twenty years ago.

Table 3.3: Perception of climate change impacts

Perception of climate change impacts*	n	n of "Don't know"	Mean	Median	SD
I think the climate is changing.	458	5	4.33	4	0.84
I have noticed the impact of a changing climate in my city.	450	25	3.72	4	1.04
I am concerned about the impacts of climate change in my neighbourhood.	456	16	3.68	4	1.05
I am concerned about the impacts of climate change in my city.	453	12	3.74	4	1.00
I am concerned about the impacts of climate change in BC.	454	13	3.95	4	0.95
I am concerned about sea level rise affecting my neighbourhood.	454	16	3.72	4	1.19
I think there are more frequent and severe rainfall events now than there were 20 years ago.	457	80	3.40	4	1.12
I think the risk of flooding that would affect my property is increasing.	454	33	3.42	4	1.16
I think climate change is causing more extreme weather events.	456	30	4.05	4	0.98

*Metric: 1 = strongly disagree, 5 = strongly agree; Range = 4

Within the range of perceptions of hazards and climate change, residents articulated both high and low concern that hazard impacts would negatively affect them. Some residents perceive a high level of risk due to their experience with hazards, which meets with the findings of previous studies (Grothman and Reusswig 2006; Siegrist and Gutscher 2006; Keller et al. 2006). A Crescent Beach resident described, “We live in a sea-level community that has seen the action of high tides in winter coupled with wind. It resulted in breaking down the raised walkway, flooding some waterfront homes”. Another Crescent Beach resident told me rhetorically, “We know we are vulnerable. We have a dyke but not a very good one. We do live right on the water.” A third Crescent Beach resident declared “I think in 200 years we’ll all be under water anyway”, and went on to explain that the neighbourhood was under water at one time, which is evidenced when “people find all kinds of interesting things while digging in their yards”. A Bridgeview resident explained, “The sewer system is very bad in my neighbourhood. Heavy rain can easily cause flooding in the neighbourhood.” Two residents reported that

they are taking the substantial proactive measure of selling their home and moving to another location due to flooding and climate change concerns.

Other residents also perceive a high level of risk but feel that they are safe from hazards because they believe local authorities will take actions to protect their neighbourhood. A Kits Point resident stated:

> I do think sea level rise may affect my property but not in my lifetime or my children's lifetime. I believe that considering the importance of the park area where I live, the city would go to lengths to protect the area.

In Bridgeview, a resident had a similar belief:

> If the Fraser floods, I don't think they'll let it affect this area – there is too much important infrastructure near here with the rail lines and dock yards. That would cost a lot of money if those went down. So we'd be okay because of that.

It is interesting that these residents, from neighbourhoods with quite different overall social vulnerability, both have the view that even though their neighbourhoods are exposed to flood hazards, some level of government will provide them with protection when necessary. Some residents reported a low perception of hazard risk but their feedback was often couched. As a Crescent Beach resident explained:

> The city would have to deal with rising sea levels in 50 years and as such it has 50 years to work on the sea wall and dikes. Apart from that the city is well situated that no huge natural hazards can be anticipated. However, if the climate becomes more tropical then the storm water drainage should be looked at and necessary changes made.

Negative correlations were found to exist between residents' perceptions of hazards and household income. Specifically, perceptions of flood, earthquake and subsidence risk had correlations with household income of -0.16, -0.14, and -0.29, respectively. Those with higher household incomes are found to generally have lower perceptions of risk from these hazards. Negative correlations also existed between household income and types of flood hazard to which all neighbourhoods are exposed, specifically flooding caused by heavy rain, sewer backup, and ground water rising (correlations = -0.18, -0.21, and -0.17, respectively). For perception of climate change impacts, negative correlations exist between household income and whether residents have noticed the impact of a changing climate in their city (correlation = -0.11) and whether they think there are more frequent and severe rainfall events now than there were 20 years ago (correlation = -0.19). The negative correlations found between hazard perception and household income is consistent with the findings of previous studies (Lindell and Hwang 2008; Zhang et al. 2010).

3.5.3 Institutional arrangements

The survey included a number of questions intended to assess the influence of institutional arrangements on how residents interact with flood hazards. These questions focused on the role of municipal government and private insurance. 93% of respondents reported that they purchase property insurance (Table 3.4). When asked if they have received any advice from their insurance company about how to prevent flood damage to their home, approximately 4% of respondents replied in the affirmative. Asked if they had received any such advice from the City, the percentage of respondents who said yes was almost exactly the same at approximately 4%. Only 6% of participants reported that

they had received a reduction in their insurance premium after taking action to protect their home from natural hazards. This statistic is revealing considering that incentivizing risk reduction is a role the insurance industry can play in hazard mitigation. One Kits Point resident suggested that "Insurance companies should use some of their profits for hazard mitigation!", which offers a recognition of such a role for the industry.

Table 3.4: Institutional arrangements

Institutional arrangements	n	Percent
Have home insurance	461	
Yes	430	93.3
No	28	6.1
Not sure	3	0.7
Received advice from insurer	454	
Yes	20	4.4
No	400	88.1
Not sure	34	7.5
Received advice from city	461	
Yes	16	3.5
No	365	79.2
Not sure	80	17.4
Receive a reduction for mitigation action	443	
Yes	28	6.3
No	354	79.9
Not sure	61	13.8
Aware of city plans	460	
Yes	121	26.3
No	339	73.7

Regarding local government institutional arrangements, 26% of participants indicated that they are aware of any City policies or plans that directly address natural hazards or climate change. Both Vancouver and Surrey have policies that address one or both of these topics, so again, evident is a lack of awareness of some existing institutional measures to reduce risk. On the other hand, a specific institutional measure intended to

reduce hazard risk is the City of Surrey's regulation that requires new construction on homes in flood prone areas to be built at a raised elevation (City of Surrey 1993 [2014]; City of Surrey 1996 [2014]). This policy applies to both neighbourhoods in Surrey, and residents there appear to have a good level of awareness about the policy. Though its intention is to reduce exposure to flood hazards in the city's housing stock, the policy is perceived by many residents to have negative implications for neighbouring properties. Several residents were quick to point out what they see as problems with the policy. One resident argued:

> Making new builders raise their property ground levels way up only pushes the water problem to neighbours. We have mostly no storm sewer. Low properties rot and sell. The owners have to build up the land as directed by the city and run off watersheds to the road then into neighbours, we're just moving the problem around. It's time to fix it and stop demanding new homes build up at times to 8 or 9 ft higher than the neighbours.

Another resident had a similar view of the implications of the policy:

> The change to codes requiring new structures to be built on raised lots has resulted in the need for changes to storm drainage in the area which the city has responded to with a new pump station. However, various lots have been affected by having new developments built next to them causing problems with lot drainage for the lot owner and the city.

A weak positive correlation was found to exist between household income and residents purchasing home insurance ($p < 0.05$, correlation of 0.11). There was a negative correlation between whether residents reported having received any advice from the City about how to prevent flood damage to their homes and household income (correlation = -0.16).

3.5.4 Amenity value conflicts

The survey measured amenity values by asking respondents about their residential preferences (Table 3.5). Participants were asked to indicate the level of importance they place on a number of factors in response to the question: "Why do you choose to live in this neighbourhood?"

Table 3.5: Amenity values

Amenity values*	n	Mean	Median	SD
Location: near work or school	419	3.10	3	1.61
Location: near family or friends	430	3.07	3	1.49
Location: natural environment benefits	443	4.01	5	1.36
Affordability	424	3.26	3	1.50
Enjoy local shops, restaurants, services	426	3.64	4	1.32
Proximity to public transit	434	3.38	3	1.37
Access to transportation, e.g. highways	429	3.06	3	1.29
Safe neighbourhood	438	4.02	4	1.05
Family history in neighbourhood	420	2.10	1	1.51

*Metric: 1 = low, 5 = high; Range = 4

Natural environment benefits and neighbourhood safety are the two most important influences on participants' residential choices. More than two-thirds (70%) of participants indicated that natural environment benefits are of high or somewhat high importance to them. It is similarly clear from conversations and long answer responses that many residents place a high value on the coastal or riparian environment proximate to their neighbourhoods. For some residents, the enjoyment they receive from these environmental benefits supersedes other concerns facing their neighbourhood. One beachfront homeowner in Crescent Beach argued that "If anything the City has over reacted to the potential of rising seas and has destroyed our beach in front". Another Crescent Beach resident voiced a similar sentiment:

> I would be concerned about over involvement by government in areas that function well as is. For example, sea wall protection leading to creating artificial berms, ruining beach views, creating no access areas, more "gentrification" of wilderness areas, more signs, more projects in trendy ideas like natural plants and elimination of blackberry bushes, and more areas that minor officials can create as their own projects. All of the above reduces livability for current residents. The only hazard I have noticed in past years is increased traffic, limited parking and visibility, spreading in beach areas.

Almost three-quarters (74%) of participants indicated that a safe neighbourhood has a high level of importance to them. Only 8.5% indicated that neighbourhood safety was of low importance. Though the questionnaire did not explicitly state it, safety from crime may be the common interpretation of safety, which was confirmed by a few respondent comments. A future questionnaire could be clearer on this question, because safety from crime and safety from hazards are two different issues that are likely not associated by most people. A neighbourhood could have a generally high level of safety from crime but a low level of safety from hazards. Hazard exposure may not resonate as a safety issue for many people.

The responses for the importance placed on affordability were fairly evenly distributed, with a slightly higher number indicating high importance. A number of respondents commented that they considered their home affordable at the time they bought it, but that they could not consider it affordable at its current higher value. These comments highlight that though a neighbourhood may be unaffordable for most people, there are some homeowners who have lived for an extended time in the neighbourhood and may not have the same level of income as many of their new neighbours. This discrepancy has implications for categorizing the vulnerability of a neighbourhood as a

single value. For amenity values, a relatively strong positive correlation was found to exist between the value residents place on natural environment benefits and household income (correlation = 0.31). A strong negative correlation exists between importance of affordability and household income (correlation = -0.43).

3.5.5 Self-protection

The survey had several questions directed at assessing respondents' attitudes and actions towards protecting their homes from flood damage. Questions asked participants about their knowledge of mitigation actions they can take to protect their homes, if they have taken any such actions and what they were, whether they would like to receive more information on actions they can take, whether preventing damage from hazards is a high priority for them, and if they have installed a backwater valve in their home (Table 3.6).

Table 3.6: Self-protection

Self-protection	N	Percent	Mean	Median	SD
Knowledge about mitigation actions*	449		2.56	3	1.19
Preventing damage is a high priority for me^	446		3.26	3	1.08
Taken any mitigation action on home	455				
Yes	116	25.5			
No	339	74.5			
Like to receive more information	455				
Yes	300	65.9			
No	155	34.1			
Backwater valve installed	454				
Yes	62	13.7			
No	148	32.6			
Not sure	244	53.7			

* Metric: 1 = not knowledgeable; 5 = very knowledgeable; Range = 4
^ Metric: 1 = strongly disagree; 5 = strongly agree; 23 respondents replied "Don't know" to this question; Range = 4

Almost half (47%) of respondents indicated that they had no or low knowledge of mitigation action they could take to protect their home from flood damage. On the other hand, less than 7% answered that they were very knowledgeable about mitigation action. This finding points to a clear need for increased education about the actions that residents can take to reduce flood risk. Nearly two-thirds (66%) of respondents said that they would like to receive more information about actions they can take to protect their home from flooding. Nearly half (46%) of respondents agreed that preventing damage from natural hazards is a high priority for them. Considering these results, it appears that along with a need for increased education, the desire for learning more about risk reduction actions exists for many residents. Approximately one-quarter (27%) of respondents indicated that they have no opinion or don't know if preventing damage is a high priority for them, so some apathy or indifference also does exist in these neighbourhoods. Another 27% disagreed that it is a high priority for them.

Only one quarter (25.5%) of participants indicated that they have taken any action to protect their home from flooding. The survey asked those residents to describe the actions they have taken. A range of actions were self-reported; common actions included landscaping or grading property to direct water away from the home and improve drainage, adding weeping tiles or foundation drainage pipes, installing a sump pump, clearing downspouts and ensuring they drain away from the house, raising the height of new or renovation construction, purchasing sewer backup insurance, and not storing valuable items in the basement or crawl space. It is encouraging to see residents report that they have taken these measures, as they are consistent with recommended actions for homeowners to reduce flood damage (Sandink 2009). The survey also asked a specific

question about whether residents have a backwater valve installed in their home. A backwater valve is installed in the main sewer lateral to the home and closes when there is a surcharge from the municipal system. The device has been shown to be effective in preventing water from entering a home during heavy rainfall events when the system is overwhelmed by water volume (Sandink 2013). Approximately 14% of respondents indicated that they have a backwater valve installed in their home. More revealing perhaps, is that more than half of respondents (54%) said that they are not sure if their home has a backwater valve. This lack of knowledge about a single effective and relatively simple measure that can be taken to reduce the risk of water entering the home is a signal for increased awareness building. A number of residents commented that they appreciated learning about backwater valves from the survey and would investigate the feasibility of using this risk reduction measure in their home.

Weak significant correlations ($p < 0.05$) exist between household income and variables representing self-protection. How knowledgeable residents felt about actions they can take on their home and property to protect their home from flood damage had a positive correlation with household income (0.13). Residents' agreement with the statement: "Preventing damage from natural hazards is a high priority for me in terms of spending my own money and time" is negatively correlated with household income (-0.12).

3.5.6 Attribution of responsibility

The survey included questions to assess how residents attribute responsibility for hazard mitigation, what is sometimes referred to as the "locus of responsibility" (Martin

et al. 2009) (Table 3.7). First, a question asked residents what they think the level of responsibility for preventing damage the following parties *should have*: homeowner, city, province of BC, federal government, insurance company, and non-government organizations. Respondents indicated that they think the City should have the greatest responsibility, followed closely by the provincial government and then the federal government. Responsibility of the homeowner was rated fourth. A separate question then asked residents what they think is the level of responsibility the same parties *actually take* now. The median scores for the City and homeowner were virtually tied for most responsibility, with the City having slightly more responsibility. The order of responsibility for the three levels of government remained the same as in the responses to the previous question. The responsibility that NGOs actually take was rated as higher than that of insurance companies, which is the reverse order that respondents' thought the two parties should have. There were a high number of "don't know" answers to the level of responsibility that the parties actually take, especially for the federal government, insurance companies, and non-government organizations. Figure 3.1 compares the level of responsibility that respondents think each party should have and what respondents think they actually take. The level of responsibility that each party actually takes is perceived to be less than the perceived responsibility that they should have for hazard mitigation.

Table 3.7: Attribution of responsibility

Attribution of responsibility*	n	n of "Don't know"	Mean	Median	SD
Level of responsibility parties should have					
Homeowner	453	9	3.65	4	1.16
City	455	11	4.43	5	0.81
Province of BC	455	12	4.40	5	0.87
Federal government	446	18	4.09	5	1.14
Insurance company	445	43	3.06	3	1.41
NGOs (e.g. Red Cross)	443	43	2.36	2	1.34
Level of responsibility parties actually take					
Homeowner	452	38	3.04	3	1.40
City	451	63	3.05	3	1.10
Province of BC	449	77	2.65	3	1.15
Federal government	449	96	2.29	2	1.19
Insurance company	449	100	1.95	2	1.10
NGOs (e.g. Red Cross)	442	113	2.10	2	1.25
Expect to rely on for support in event of disaster					
Yourself	455	3	4.54	5	0.90
Friends and family	453	8	3.90	4	1.12
Government	451	14	3.56	4	1.33
Insurance company	447	20	3.25	3	1.42
NGOs (e.g. Red Cross)	448	32	3.42	4	1.26
Media	358	39	2.85	3	1.51

*Metric: 1 = low, 5 = high; Range = 4

When asked about whom they expect to rely upon for support in the event of a disaster, respondents indicated they expect to rely most on themselves, followed by the support of family and friends. Expectations of relying on support from government ranked third, followed by non-government organizations, which was higher than the support expected from one's insurer. This is an interesting finding because 93% of respondents reported having property insurance, which they are paying for so that they will be supported in the event of a disaster.

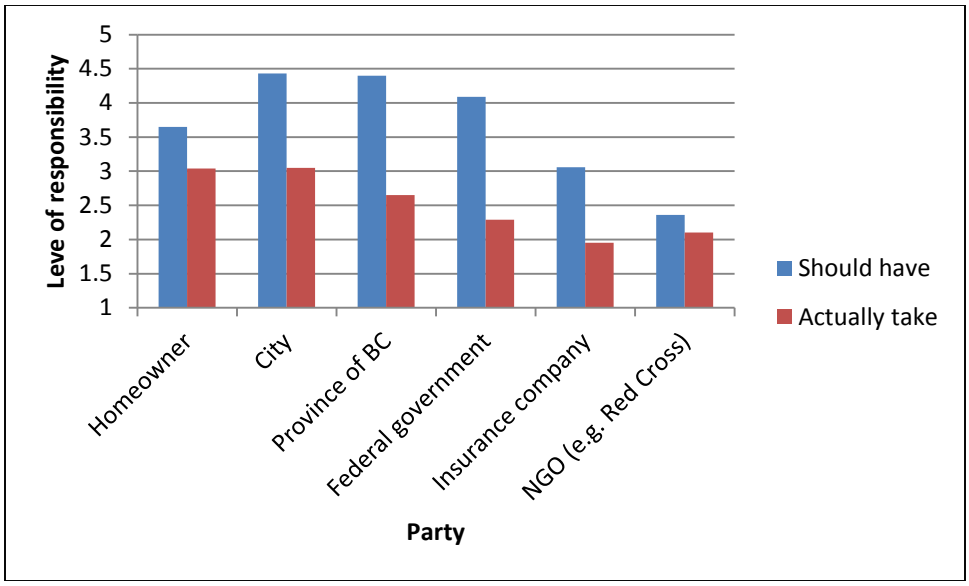

Figure 3.3: Level of responsibility each party should have vs. actually takes

The responsibility of government for hazard mitigation is a topic that garnered a lot of interest and strong reactions from respondents. The mean perception of responsibility that all three levels of government *should have* was significantly higher than the perception of responsibility that each level *actually takes*. Resident feedback articulated the dominant feeling that governments should be doing more to fulfill their responsibility. A Kits Point resident argued:

> Natural hazards, especially related to climate change, are long term risks. Most people these days don't own property over the long term, but move around. It is therefore increasingly important that the city and province legislate minimum standards so that everyone is protected.

Another resident stated:

> As an individual, I can do very little to avoid natural hazards, it is an infrastructure issue. If a flood really hits us, and as such, it is the government's responsibility to reduce any

> possible natural hazards. That's where our tax dollars should be used.

Some residents recognized the challenges involved in dividing responsibility between levels of government. A Crescent Beach resident, seemingly with some practical knowledge of multi-level governance, argued:

> Climate change needs to be taken seriously. The City only receives 8% of tax dollars so the federal and provincial governments need to make infrastructure capital available to cities to do their job well. Currently cities have little taxation room. Residents feel they are paying enough to address these basic responsibilities.

A Crescent Beach resident, when describing his concern about a perceived lack of maintenance on a dyke that protects the neighbourhood, described it as a jurisdictional problem:

> Departments keep blaming each other, saying it's not their responsibility or that someone else is stopping them from doing something. Which levels of government are at fault? It doesn't matter to me who is responsible for doing it as long as they do it.

It was apparent from resident feedback, however, that a different (minority) opinion also exists among residents: that hazard mitigation is primarily the homeowner's responsibility and that government should not be over-involved. This view was articulated in a resident's comment: "When you choose to buy a home in a certain area you accept the inherent conditions in that neighbourhood". Another resident stated: "I'd encourage self-responsibility of citizens... Knowledge about hazards is the responsibility of the individual dweller..." Another resident reasoned:

> This is quite a safe place to live relative to many others in the world, especially with respect to natural hazards. I do not want any level of government to spend a lot of money protecting me from risks that are not easily apparent. If I felt at high risk I would move to somewhere I felt safer.

Significant correlations were found between several variables identifying attribution of responsibility and household income. A positive correlation exists between household income and the level of responsibility residents think that the homeowner should have for preventing damage from natural hazards (correlation = 0.20). Negative correlations exist between household income and the level of responsibility residents think should be had by the city, province, federal government, insurance company and non-government organizations (correlations = -0.13, -0.18, -0.20, -0.12, -0.14, respectively). A negative correlation exists between household income and the level of responsibility that residents think insurance companies actually take (correlation = -0.17). There is a weak ($p < 0.05$) positive correlation between household income and the level of support residents expect to receive from themselves in the event of a disaster (correlation = 0.13). Negative correlations exist between household income and the level of how much residents expect to rely on non-government organizations and the media in the event of a disaster (correlations = -0.15 and -0.25, respectively).

3.5.7 Attenuation of risk due to another dominating concern

In analysing the findings of the residential survey, it was discovered that another potential determinant of residential flood hazard vulnerability is present in at least two of the neighbourhoods. Survey questions did not directly address this determinant but respondent oral and written feedback made it clear that another local issue is a major

concern for residents in the Surrey neighbourhoods of Bridgeview and Crescent Beach. Residents in these neighbourhoods cited a lack of access to their neighbourhood due to insufficient transportation infrastructure as a major concern. A popular, dominating local concern can be considered a determinant of vulnerability because focusing attention on that issue can distract residents from other hazards that may also be present (Kasperson et al. 2003). In this case, a focus on the issue of neighbourhood access affected by a possible rail accident takes resident attention and energy away from local flood hazard mitigation efforts. The devastating impacts of rail accidents in communities across Canada have been well covered by national media (e.g. Canadian Press 2014). It can be expected that this risk would be a high concern of residents for whom rail transportation infrastructure affects their daily lives at home. It is noteworthy that a similar dominating concern is present in Bridgeview, a neighbourhood with higher social vulnerability, and Crescent Beach, which has lower social vulnerability.

Bridgeview has seen recent expansion of road and rail transportation infrastructure adjacent to the neighbourhood. Many residents are concerned about the impact of this infrastructure on their health and safety, and complain that this development has occurred while the basic drainage and storm sewer infrastructure that they need and which has been promised by the City has not yet been installed. A resident of the neighbourhood expressed:

> The city, provincial and federal governments continue to reduce and eliminate access to the Bridgeview area. Since I have lived here, exits have been eliminated. We presently can only exit on Bridgeview way and south on [highway] 124 under the Patullo Bridge. If we need to exit our homes due to an emergency there would be a backlog and traffic would not get through.

Another resident touches on a similar issue:

> ...Then we have trains that are carrying hazardous things right next to these roads. We never know what is going through our community. With an increase of cars avoiding the Port Mann fee's our roads are now impassable and we only have one way in or out of our area. God help us if we need to evacuate.

In Crescent Beach, many residents are concerned about the impact of the rail line that crosses the single road that provides access in and out of the neighbourhood. It is a busy track, and cars and pedestrians must wait while trains are crossing the road. Residents are vocal that this is a major safety issue, and complain that there are more and longer trains using the track. They are also concerned that the materials transported by the trains are hazardous. One resident neatly sums up the reason this can be considered a distracting concern: "We are more concerned with the number of trains (especially coal trains) passing through our community than natural hazards". Another resident expands on the same sentiment:

> I'm not so concerned about natural hazards. The big concern of residents of Crescent Beach is the railway crossing on Beecher Rd. If there was a derailment anywhere near that railway crossing (and trains do carry chemicals, fuel, etc.) the exit to leave Crescent Beach would be blocked. No way in, no way out! The City of Surrey, province of BC, and the federal government need to do something to enable residents, visitors, etc. to have an exit in case of this man-made hazard.

Another resident paints the picture:

> A serious hazard we are all aware of is the risk of a derailment of a train carrying hazardous materials through our community. There are a couple trains per hour, many

> carry hazardous materials. The rail line runs along the coastline, right next to the ocean. Due to heavy rains and storms surges, the railway tracks are vulnerable to wash outs. The banks above the tracks experience frequent subsidence. There is only one access road - no way to escape or for emergency vehicles to enter. Increased number of coal trains using tracks. We are up in arms!

Transportation infrastructure appears to be a dominant issue in these two neighbourhoods, which may be taking residents' attention away from other local concerns like natural hazards. Such a distraction can serve to attenuate other risks (Kasperson et al. 2003). Alternatively, if neighbourhood residents are able to connect the two concerns, like some respondents do when they consider the implications of a train-blocked road during a flood or earthquake disaster, their awareness of both risks will increase. If this raised awareness can result in action towards flood hazard mitigation, then the dominating concern can have the effect of reducing other risks.

3.6 Conclusions

The seven determinants identified in this study were found to produce unequal vulnerability to flood hazards among residents in the survey neighbourhoods. Residents have unique vulnerabilities due to their household characteristics, perceptions and attitudes, and how these factors interact with one another. Survey findings suggest that social vulnerability is an important factor in determining vulnerability to flood hazards and has significant relationships with other factors. Household income, as a key contributor to social vulnerability, was found to have significant relationships with characteristics that define the other determinants. The survey finding that people with higher incomes tend to have a lower perception of hazard risk is consistent with the

findings of previous studies (Lindell and Hwang 2008; Zhang et al. 2010). Residents with higher income reported that they felt more knowledgeable about how they could reduce their own flood risk but tended to feel that hazard mitigation was not a high priority for them in terms of spending money and time. This seems to contradict the finding by Zhai et al. (2006) that those with higher income are more willing to pay for flood mitigation measures. The study found that higher income residents did, however, feel that the homeowner should have a high level of responsibility for preventing damage from natural hazards. The findings that those with higher household incomes expect less responsibility for hazard mitigation from governments and insurers than those with lower incomes point to a dissonance of understanding how existing institutional arrangements help minimize their vulnerability. These institutions are, in reality, taking a much greater responsibility for reducing the risk of high income earners than they appreciate. Institutional incentives help facilitate these residents in their pursuit of the natural environment amenities that they so highly value.

Institutional arrangements were indeed found to be an important determinant of vulnerability. The two institutional factors examined in the study, property insurance and development regulation, both appear to have uneven impacts on residents in the study neighbourhoods. The intention of both of these measures is to reduce risk but in reality they are not equally accessible to all people. Only those who can afford to be fully covered by insurance and build a home that meets the municipal bylaw will benefit from these institutional arrangements. In this way, some residents are facilitated in their desire to live in an attractive but hazardous place. By drawing on these institutional arrangements, higher income homeowners can externalize their risk. They can reap

environmental rewards without taking on the full cost of living in a hazardous place. Collins' (2008, 22) concept of facilitation "denotes how powerful groups are provided security to exploit environmental opportunities associated with hazardous places for private gain, with deleterious social and ecological consequences". When risk is minimized by these institutional incentives, the environmental rewards outweigh the risk, which makes living in these places appealing to those who can afford it. The survey found that residents with higher household income place a greater value on living near natural environment benefits, and it would appear that institutional incentives are facilitating these groups in their pursuit of those environmental amenities. These findings show that Collins' (2008) argument that public and private institutions can play a dual role in producing unequal wildfire risk in the US wildland-urban interface also applies to flood risk in a Canadian city.

A development regulation in Surrey is an institutional arrangement intended to reduce flood risk but serves to facilitate powerful groups in their pursuit of environmental benefits. The City of Surrey's bylaw that homes being rebuilt in the floodplain must elevate the ground floor means that not everyone can afford this extra construction cost, so only some (wealthier) residents can afford to live or rebuild in floodplain areas. People already living in the neighbourhoods who cannot afford to rebuild are marginalized: they must remain in their house in its current state or be forced to sell and move. For example, those who would like to buy a home and rebuild it (which is currently a popular practice) in Crescent Beach will need to abide by the regulation. Furthermore, many residents noted the negative impacts that increased building elevations can have on neighbouring properties, by changing drainage patterns that can result in water damage to adjacent

buildings. It is not the free residential choice of these neighbours that they must then live beside someone who may be putting them at greater risk. The impact of this bylaw is at the street scale rather than the individual home scale. Thus, the intention of such a bylaw may be to reduce exposure but it has the effect of increasing vulnerability. On the other hand, most homeowner self-protection actions, other than landscaping or grading, only affect the homeowner, and do not result in negative impacts to the neighbours.

Property insurance also serves to facilitate residents in living in an attractive but hazardous location. By purchasing private insurance, homeowners can externalize the risk of living in a hazardous place. They can enjoy the rewards without taking on the full cost because they are subsidized by other policy holders when their premiums are pooled by their insurer, a risk transfer mechanism. Though overland flood insurance is not available to Canadian homeowners, the nebulous nature of water damage claim payouts results in some homeowners who have suffered a flood loss receiving a payout from their insurer (Sandink et al. 2010). In practice, insurers may make a pragmatic business decision to pay out a flood claim if the source of the flood damage is uncertain, in order to show good faith and dependability to its customers. Survey findings indicate that residents with higher household incomes are more likely to purchase property insurance.

Social vulnerability, institutional arrangements, hazard perception, amenity value conflicts, and self-protection were found to be determinants of vulnerability that apply to creating unequal flood risk in a Canadian city. In addition, attribution of responsibility and the attenuation of risk caused by another dominating concern were revealed as factors that influence the vulnerability of residents. The findings of this study offer an empirical view of how residential vulnerability is produced, and why residents in a

Canadian city have unequal vulnerability to flood hazards. A commonly held view, appealing to what are perhaps popular Canadian values, may be that Canadian cities are places in which residents have equal opportunity and support to reduce their own risk but this study demonstrates that this is not necessarily the case. As municipalities work to manage flood hazards and many begin to create climate change adaptation plans, they would be well served to consider the factors that produce unequal vulnerability among their citizens and how local policy can address it. An understanding of the determinants identified in this study can help policymakers transition towards more equitable and sustainable vulnerability reduction. The question remains, however, whether technocratic measures can meet the needs of the most vulnerable without being co-opted by more powerful groups to extend unequal vulnerability, or if a more transformational approach is required (Collins 2009; Pelling 2011).

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4. Flood insurance in Canada: implications for flood management and residential vulnerability to flood hazards

4.1 Introduction

Flood risk poses a unique and complex challenge in Canada. Floods are by far Canada's most frequent natural disaster; over the last decade alone they have caused billions of dollars in damage and directly affected tens of thousands of people (MMM 2014; PSC 2014). Municipal and provincial governments have long traditions of managing land use in flood-prone areas and building infrastructure to reduce flood risk. Provincial and federal governments have responded to flood disasters with financial assistance for communities and citizens affected by flood losses. The Canadian property and casualty (P&C) insurance industry finds itself in a complicated role in this challenge; it is, in essence, neither here nor there. Insurers do not provide coverage against overland flood damage to homeowners in Canada. Despite this exclusion, water damage has become the principal source of claims for insurers, surpassing fire and theft combined (KPMG 2014). This profound shift in claims is causing the industry to re-evaluate its role in managing flood risk in Canada.

The industry is, and has been for some time now, exploring the viability of offering overland flood insurance to homeowners in Canada. Most other developed countries, including the United States, United Kingdom, Germany, and France, have some type of arrangement in which insurance coverage of flood damage is available to residents. Recent flood events in Canada, including the 2013 disasters in southern Alberta and the Greater Toronto Area, have served to cast public attention on what has largely

been an internal discussion. The media have given voice to frustrated homeowners who have learned that their insurance policy does not cover damage caused by flooding or that their rates have increased following a flood. Such media coverage contributes to a reputational risk for insurers. At the same time, gaps in insurance coverage are seen as a missed business opportunity in what is a mature, competitive industry. If insurers decide to offer coverage of residential flood damage in Canada, it will not, of course, be for an altruistic vision of reducing risk for all Canadians; it will be to minimize their own risk and maximize profits.

As such, the introduction of private flood insurance in Canada will have implications for flood management and the vulnerability of Canadians to flood hazards. It raises questions around how it will exacerbate already unequal vulnerability to flood hazards and whether it can be an effective tool in limiting development in areas exposed to the hazard. Flood insurance "privatizes" flood risk and creates losers and winners as part of a suite of institutional arrangements that influence peoples' vulnerability to hazards. There is a lack of research that investigates the implications and issues surrounding the introduction of residential overland flood insurance in Canada. Two recent reports commissioned by members of the insurance industry have assessed the viability of flood insurance in Canada but do not critically engage many of the complex, competing issues surrounding the topic (Sandink et al. 2010; Thistlethwaite and Feltmate 2013). This chapter seeks to address this research gap by examining how the introduction of such an insurance product will affect residential vulnerability and interact with other determinants of vulnerability.

The chapter begins by describing the role of the insurance industry within the current arrangement of flood risk management in Canada and then outlines what are seen as the requirements for insurability and some international models of flood insurance. It then reviews previous research on the willingness of residents to pay for flood insurance and how demand for insurance relates to other factors that contribute to vulnerability to flood hazards. A case study on flood insurance in a Canadian city is undertaken in Metro Vancouver, and a residential survey investigates attitudes towards flood insurance and how they relate to other determinants of residential vulnerability to flood hazards. The findings of the study contribute to an understanding of how the introduction of flood insurance will affect the vulnerability of Canadians.

4.2 Flood risk and the Canadian insurance industry

Flood risk is currently an important topic on the minds and in the boardrooms of members of the P&C insurance industry in Canada. Recent flood events, such as the 2013 disasters in southern Alberta and Greater Toronto Area, reminded Canadians of the consequences of their exposure to flood hazards. These disasters also brought to the public's attention the fact that home insurance policies in Canada do not cover damage caused by overland flooding. Homeowner damage claims from these and other floods have been met with a range of responses from Canadian insurers, ranging from full payment to no payment and withdrawal of coverage. Many Canadians falsely believe that their home insurance policy covers damage caused by flooding. A 2004 survey of 2100 homeowners across Canada found that nearly 70% believed their insurance policy covers flood damage (Sandink et al. 2010). This proportion may be lower now due to recent discussion of the exclusion in the media but it indicates that a large number of people do

not fully understand their home insurance policy. The reaction of this Hamilton, Ontario homeowner has been echoed frequently by flood victims across the country (Kernaghan 2009):

> I don't have insurance for flooding. I thought I did. It was a big shock to me. I was with the same insurance company for 40 years. I paid all that money and now, nothing.

This gap in coverage is problematic for the insurance industry too, being at once a reputational risk and a missed opportunity for potential growth. Denying claims detracts from an insurer's reputation among existing and potential customers. Even if denying a claim is the correct response according to the policy contract, such an action hurts the chance of a customer renewing their business with the insurer. At the same time, including overland flood coverage in a policy is seen as a potential new line of business for insurers in what is an otherwise highly competitive and mature industry in Canada. As long as the risk is priced accurately and customers are willing to pay the premium, an insurer would be motivated to offer the coverage.

The nature of flood risk in Canada appears to have changed in recent years, prompting consternation from insurers, but the hazard is not new. Floods have long been Canada's most frequent natural disaster (PSC 2014). A major reason the insurance industry is paying closer attention to flood risk is that water damage has recently become the principal source of claims. Water damage has now surpassed fire and theft, the two foundational perils of the industry, in claims made and paid out (KPMG 2014). For example, Aviva Canada, one of the largest providers of home insurance in the country,

reported that 51% of all property claims in 2013 were for water damage. Even with the Alberta and GTA disasters removed, water damage still would have accounted for more than 40% of all claims for the company (Aviva 2014).

This shift in the source of claims is having a profound effect on insurers because they have not been underwriting the risk accordingly. Water damage covered by a homeowner's policy, such as that caused by indoor plumbing problems, malfunction of appliances, or water entering the home through an opening caused by extreme wind, is underwritten and the risk is applied in the premium. Some home insurance policies include coverage of water damage caused by sewer backup. If it is not included, most homeowners can add sewer backup coverage to their existing policy as an optional endorsement. Damage caused by sewer backup is at least partly the source of increasing water damage claims. Water damage that is caused by overland flooding, however, is excluded from home insurance policies and not underwritten directly into the premium. Overland flooding can be the result of severe rainfall or riverine or coastal flooding and cause property damage by entering a home through doors or window wells, for example. Where a problem arises is in the ambiguity on the claims side of the business. An insurer may decide to pay out a water damage claim despite it not being covered as stipulated in the policy contract. When the source of the water damage is difficult to determine, or there is some kind of external pressure, an insurer may make a business decision that paying out the claim is in the best interest of the company. The nebulous nature of paying water damage claims has contributed to this shift in the industry.

Insurers are considering offering overland flood insurance in order to properly underwrite flood risk and "firm up" their book of business. Flood insurance is a risk

transfer mechanism that spreads the cost of flood losses over time and space. If flood insurance is bundled with coverage of other hazards, such as fire, wind, hail, and lightening, it also spreads the risk across perils. Insurers pool premiums paid by policy holders across these scales so they can pay out claims related to losses distinct in location and time. Primary insurers most often purchase reinsurance from international reinsurers to cover their losses beyond a predefined limit. Insurers and reinsurers invest revenues in the markets, where investment returns can overcome underwriting losses. As such, the insurance industry operates at both local and global scales (Sturm and Oh 2010). It is this ability to move capital across scales that allows the industry to manage risk.

4.3 Flood management in Canada

Flood hazard management in Canada is a complex arrangement of efforts by municipal, provincial, and federal governments, as well as some special purpose agencies (e.g. conservation authorities in Ontario) (de Loe 2000; Shrubsole 2000; Shrubsole 2007; Sandink et al. 2010). Governments and these agencies use a combination of structural and non-structural measures to mitigate flood risk. Flood control structures like dams, dykes, and levees were primarily relied upon until approximately the late 1960s when an increased emphasis was placed on non-structural measures such as land use planning to limit development in the floodplain. Generally, provinces set policy guidance and minimum standards for municipalities and other local agencies to carry out flood management in their jurisdiction. Currently, the main role of the federal government is to provide affected residents with Disaster Financial Assistance Arrangements (DFAA) in cooperation with provincial governments following a disaster. The federal government formerly played a role in non-structural flood mitigation with the Flood Damage

Reduction Program (FDRP) and is currently advocating a fledgling National Disaster Mitigation Strategy (NDMS). If private flood insurance is to be made available to homeowners in Canada it will occupy a role within the current suite of public flood management efforts and will have an impact on the functioning of these other measures.

4.3.1 Flood Damage Reduction Program and flood hazard mapping

The FDRP was launched by the federal government in 1975 to support joint federal-provincial initiatives to limit development in flood-prone areas (Bruce 1976; Watt 1995). A major contribution of the program was to support flood hazard mapping and identification of floodplains. The development of flood hazard maps under the FDRP laid the foundation for flood risk identification throughout much of the country. Though some provinces had existing policy and procedures for floodplain management (e.g. conservation authorities in Ontario), the FDRP made national a high standard of flood risk identification and a commitment to non-structural flood mitigation measures. The federal government entered into individual agreements with the provinces on identifying the regulatory flood standard, based on local situation. For example, in British Columbia the regulatory flood is 1:200, many provinces use the 1:100 standard, while in Ontario three different regulatory flood magnitudes are applied by region. After the FDRP was wound down during the 1990s, provinces have been individually responsible for maintaining and updating their flood hazard maps. Provinces have made uneven efforts towards this end, and furthermore, within each province, municipalities have shown different levels of willingness and ability to manage floodplain development. In some cases, the original FDRP maps remain as the most current flood hazard maps.

The state of existing flood maps in Canada presents some challenges for the introduction of flood insurance. Mapping created under the FDRP and other government programs for the purposes of floodplain management are considered flood hazard maps. These maps are useful for land use planning and other management decisions but are not ideally suited as flood risk maps for the purpose of insurance underwriting. Risk maps would identify degrees of probability, using information about frequency and severity of flooding, that an insurer could use to set differential rates based on location (Sanders et al. 2005). Hazard maps are commonly used by insurers to underwrite flood insurance in Europe, however, where true risk maps are often not available (van Alphen et al. 2009). The provincial and regional differences in flood hazard mapping create an additional challenge for insurers in assessing risk-based rates as they would have to work through the inconsistency in flood return periods. Access to the maps is another challenge as they are housed in so many different agencies. Perhaps most problematic is the age of many maps. Outdated maps do not accurately identify current hazards, let alone projected flood risk due to climate change impacts, and thus cannot be relied upon for underwriting. As land use and the built environment change with urbanization, so too does flood risk, which is not reflected in outdated maps (Nirupama and Simonovic 2007). Insurers that write commercial flood insurance in Canada have, however, demonstrated that it is possible to work with less than ideal flood maps to deliver an insurance product (Sandink et al. 2010).

The current state of flood maps in Canada is identified by insurance executives as a major impediment to offering flood insurance to homeowners (Thistlethwaite and Feltmate 2013). If the UK model is any indication though, poor quality flood maps are

not necessarily a barrier to offering flood insurance, as premiums there do not always correlate well to risk. Those living outside the floodplain are oftentimes paying the same amount for flood insurance as those at high risk (Penning-Rowsell and Pardoe 2012). In this case, cross-subsidization makes up for poor risk identification. Canadian insurers may decide to individually or collectively create new flood risk maps, rather than rely on governments to update existing maps. Insurers could justify such an expense as an investment to protect their risk. This approach would allow insurers to map flood risk according to their needs and keep the information confidential, as insurers in the UK have done (Crichton 2002).

4.3.2 Disaster Financial Assistance Arrangements

After a disaster in which uninsurable losses exceed the ability of the municipal government to cover, the provincial and federal governments have established a way to work together to provide financial assistance to the affected community. DFAA is a discretionary agreement designed to help provinces with the costs of post-disaster response and repairing infrastructure and personal property to pre-disaster condition. Initiated in 1970, this arrangement follows a per-capita cost-sharing formula between the federal and provincial government. In this formula, the first dollar of damage per person in the province is the responsibility of the provincial government's disaster assistance program. As damage increases beyond this threshold, the federal contribution increases proportionately. Table 4.1 describes the DFAA cost-sharing formula. The allocation of disaster financial assistance is the responsibility of the province. Provincial financial assistance programs set their own standards of what damage costs will be covered. For example, in British Columbia, uninsurable losses are covered at 80% of the amount of

total eligible damage, to a maximum of $300,000, and the deductible to receive assistance is $1000 (EMBC 2012).

Table 4.1: DFAA cost-sharing formula

Eligible disaster costs (per capita)	Federal share	Provincial share
First $1	0%	100%
Next $2	50%	50%
Next $2	75%	25%
Remainder	90%	10%

Source: PSC 2011

Between 1970 and 2011, the federal government paid out approximately $2 billion in financial assistance to the provinces. The number of events requesting federal assistance and amount paid out per event both increased over this time (PSC 2011). These trends call into question the long-term sustainability of the arrangement but it would appear that the federal government values its role in helping Canadians through their "time of need" (PSC 2011, ii). The availability of overland flood insurance would affect provincial and federal post-disaster financial assistance. Since residential flood damage would be an insurable peril it would not be eligible for government assistance. While this change would reduce the burden on Canadian taxpayers who contribute to DFAA, governments would lose an important role in post-disaster recovery. Government financial assistance is designed to help a community and its residents return to a pre-disaster state by compensating them for close to the pre-disaster value of only essential items. This is significantly different than the payout of an insurance claim, which would cover the full new cost of replacing all items.

The classification of flood as an insurable peril would raise the question of what happens when a homeowner who does not have flood insurance suffers flood damage.

Under the intentions of DFAA, provincial and federal governments would not provide financial assistance to a homeowner in this situation. Given the public attention this would create, governments may find it difficult to resist assisting such citizens. Indeed, it may call into question whether this is consistent with Canadian values. Such a situation will be encountered if flood insurance is made available to residents, regardless of how it is delivered. If it is an optional product, many residents will choose not to purchase flood insurance. If it becomes a mandatory part of home insurance policies, it will increase premiums, and more people will not insure their homes because the cost is prohibitive. If insurers offer flood insurance but refuse to cover residents in locations deemed too high of a risk, governments will retain the responsibility for assisting them. Thus it is clear that flood insurance will not totally relieve governments of their current responsibility for providing financial assistance to flood victims.

4.3.3 National Disaster Mitigation Strategy

After the 1996 Saguenay River flood, the 1997 Red River flood, and the 1998 eastern Canada ice storm together affected 20% of the Canadian population and drew heavily on DFAA, the federal government initiated a consultation process to develop a National Disaster Mitigation Strategy (NDMS) (OCIPEP 2002; Hwacha 2005; PSC 2008). The purpose of the NDMS is to prioritize improvements in hazard mitigation as a cost-effective part of disaster management, and to encourage the integration of mitigation in decision making at all three levels of government. Adopted as a strategy document in 2008, an important objective of NDMS is to link with a revised DFAA wherein 15% of the funding is provided for mitigation purposes (e.g. building new infrastructure with greater capacity) (PSC 2008; PSC 2011). Rather than continuing to simply repair a

community to its pre-disaster state, this provision allows for improvements to be made towards hazard mitigation that will reduce future risk. The idea is that spending part of the money on mitigation measures will offer an improved return on investment by rebuilding the community in a safer way.

4.4 Flood insurance: international models and requirements for insurability

Canada is unique among G8 countries in that insurance coverage against overland flood damage is not available to homeowners (IBC 2014). Other countries have different models of flood insurance, which include four general arrangements of public or private delivery with optional or bundled coverage (Crichton 2008). In a public model, insurance coverage is provided or backed by government, whereas in a private model, insurance is provided by private insurers. With optional coverage, people can choose whether to purchase coverage of flood damage, whereas with bundled coverage, flood insurance is included with coverage against other perils. For example, the United States has a public and optional model, France has a public and bundled model, Germany has a private and optional model, and the United Kingdom has a private and bundled model. In both of these public models, private insurers play a large role.

In the United States, the federal government financially backs the National Flood Insurance Program (NFIP), sets premium rates and identifies flood risk areas. State and local governments regulate land use and development in floodplains. Private insurers sell policies to homeowners in eligible communities on behalf of the government but do not bear any of the risk. Public subsidization of flood insurance premiums has caused a number of widely noted problems, including a failure to discourage development in the

floodplain (e.g. Burby 2001; Michel-Kerjan 2010). In France, private insurers purchase reinsurance from the government-run reinsurer at reduced rates, which enables them to include catastrophe insurance in standard home insurance policies (Michel-Kerjan 2001). In Germany, natural hazards insurance, which covers flood damage, is offered by private insurers as an optional supplement to home insurance policies but the take-up rate is only about 10% of households (Thieken et al. 2006). British insurers have an informal agreement with the government wherein they will insure flood loss in all but the highest risk areas if the government provides adequate flood infrastructure, hazard mapping, and land use management (Crichton 2008). In a review of international models of flood insurance, Sandink et al. (2010) propose that a private and bundled model similar to that used in the UK is best suited for Canada because insurers would be able to set their own risk-based rates and governments would maintain responsibility for reducing risk.

Proponents of insurance as a tool to reduce risk identify three major functions of insurance: to reimburse damage costs; enable the spread of risk over time, space and perils, and; encourage actions to reduce exposure and vulnerability (Treby et al. 2006 after Arnell 2000). For a peril to be considered insurable, a number of conditions must be met. Crichton (2002) uses the mnemonic BASIC MUD to identify these conditions:

B: Big enough "book" of business

A: Adverse selection minimized

S: Sustainable so that risks can be spread over time

I: Information available about hazard, vulnerability, and exposure

C: Consistent with existing insurance practices, systems, and laws

M: Moral hazard low

U: Uncertainty about potential loss

D: Demand exists for insurance

4.4.1 Challenges for flood insurance: adverse selection and moral hazard

Adverse selection is perhaps the most difficult challenge to overcome in the insurability of flood damage (Hausmann 1998). Adverse selection occurs when only those living at high risk are interested in purchasing flood insurance, and when insurers are interested in selling insurance to only those living at low risk. In this way, insurers and policy holders select against each other (Crichton 2008). The problem is inherent when flood insurance is an optional product, and results in premiums being prohibitively high in order for insurers to cover the risk assumed and therefore low market penetration. Adverse selection can be overcome by bundling flood coverage into home insurance policies but this requires cross-subsidization of risk, wherein those at low risk are paying for some of the risk of those living in higher risk areas.

Moral hazard is another challenge of insurability, in which those who have flood insurance do not take any actions to reduce their risk. This is especially a problem when premiums are kept artificially low by subsidization. When rates reflect risk they can incentive mitigation behaviour, and thus reduce moral hazard. In managing moral hazard and adverse selection, an insurer is not so much interested in reducing losses as making sure that losses are not greater than expected (Bennett 1999 after Heimer 1985).

4.5 Willingness to pay for flood insurance and determinants of vulnerability

If flood insurance is available and one can afford to purchase it, the coverage theoretically serves to reduce household vulnerability to flood hazards by covering (most of) the cost of flood damage. But not everyone will be able to pay for flood insurance, and some of those who can afford it will choose not to purchase the coverage (Priest et al. 2005). Thus having or not having flood insurance is a factor that contributes towards differential vulnerability to flood hazards among a population. Flood insurance is one of a number of institutional arrangements that together are a determinant of vulnerability to flood hazards. Other determinants of vulnerability, like hazard perception, amenity values, self-protection, attribution of responsibility, and social vulnerability, factor together to make individuals more or less vulnerable to flood hazards than others (Collins 2008; Chapter 3). Examining the relationships between willingness to pay (WTP) for flood insurance and other determinants of vulnerability can provide an understanding of what contributes to unequal vulnerability.

Previous studies outside of Canada have used residential surveys to investigate factors related to demand for flood insurance (Kousky 2011). These studies found that perception of risk, assessment of potential damage costs, previous experience with the hazard, the price of insurance, income level, and education level are among the factors that are significantly associated, at least in some cases, with an individual's decision to purchase hazard insurance (e.g. Baumann and Sims 1978; Kunreuther 1979; Palm and Hodgson 1992; Pynn and Ljung 1999; Blanchard-Boehm et al. 2001). Though studies have mixed findings, the dominant finding is that there is a positive relationship between perceived flood risk and willingness to purchase flood insurance (Kunreuther 1996;

Kunreuther 2006; Botzen and van den Bergh 2012). Botzen and van den Bergh (2012) find that perception of flood risk is more important than actual risk in the demand for flood insurance. Laska (1990), however, does not find a significant relationship between risk perception and flood insurance purchase. Hung (2009), on the other hand, finds a negative relationship between these variables. However, many people perceive their risk to be lower than their actual risk, so choose to not purchase insurance (Slovic et al. 2000). Social norms, like when people hear that their neighbours are doing it, are an important influence on the decision to purchase flood insurance. Lo (2013) finds that WTP is associated with perceived social norms, but not perceived flood risk.

Thieken et al. (2006) find that insured households undertook more mitigation during a flood than uninsured ones and speculate that this is because they are more aware of the risk. Studies have found that demand for flood insurance is positively related to previous experience with flooding (Krantz and Kunreuther 2007; Michel-Kerjan and Kousky 2010). Lo (2013), however, finds that previous experience is not predictive. Studies have found that willingness to purchase flood insurance declines slightly as price of the premium increases (Browne and Hoyt 2000; Kriesel and Landry 2004). Blanchard-Boehm et al. (2001) find that income and education level do not have a significant influence on insurance purchase. The authors find that the most significant factor in the purchase of flood insurance is the requirement to do so by mortgage lenders. However, the experience in the US has been that enforcing insurance purchase has little incentive for banks as there have been few consequences for not doing so (Blanchard-Boehm et al. 2001). Botzen and van den Bergh (2012) find a large proportion of homeowners in a river delta area of the Netherlands do not want to purchase flood insurance. The authors find

that risk-averse individuals have a greater WTP for flood insurance, age and WTP have a negative relationship, household income positively influences WTP for flood insurance, and property value has a negative relationship with WTP for flood insurance.

A small number of American studies have used existing NFIP policy data in the analysis and have found that those living in high risk areas, such as coastal areas, floodplains, and behind structural protection, as well as those with higher incomes and previous experience with flooding, are more likely to purchase flood insurance (Kousky 2011). Kousky (2011) adds to this empirical literature with a study of policy data from St. Louis County, Missouri, and finds that income, age, and education have no significant effect on flood insurance take up. When higher-income individuals do insure, however, they tend to purchase more coverage. In higher risk areas, more households are insured but previous experience of a flood did not predict insurance purchase. The findings of these studies, drawing on both residential surveys and insurance policy data, show that demand for flood insurance is related to other factors that influence peoples' vulnerability to flood hazards.

4.6 Case study: Metro Vancouver residents' attitudes towards flood insurance

Metro Vancouver can provide a case study to examine associations between individual attitudes towards flood insurance and other characteristics that determine vulnerability to flood hazards. Since flood insurance does not exist for Canadian homeowners, a residential survey must be used to collect this information from potential purchasers. Located on the Fraser River delta at the Strait of Georgia, Metro Vancouver municipalities are exposed to a number of flood hazards, including riverine, coastal and

urban flash flood caused by heavy precipitation (Forseth 2012). Though earthquake has long been a primary concern in this urban region, public attention on hazards has recently expanded to include flood risk, likely due to a combination of recent damaging events, urban development pressures, and increased awareness about climate change impacts. The municipal governments in Metro Vancouver have responded in varying ways to this growing concern. The City of Vancouver and the City of Surrey have introduced climate change adaptation plans that address flood risk at the local policy level. Many municipalities in Metro Vancouver have made a more long-standing effort to reduce earthquake risk and the provincial government has improved building codes and other regulations to increase earthquake resilience. Additionally, earthquake insurance is available to residents in British Columbia as an optional rider on home insurance policies. In Metro Vancouver, 55% of the total value of residential property is covered by earthquake insurance (AIR 2013). For these reasons, earthquake insurance resembles something of a precedent for Metro Vancouver residents and their insurance choices related to hazards.

The expensive real estate market in Metro Vancouver relative to other Canadian cities is well known across the country, with Vancouver considered Canada's most expensive city in which to live (Cox and Pavletich 2014). The high current market value of homes in the region adds an additional consideration related to flood insurance. In the event of flood damage, there is a significant gap between what homeowners can expect to receive in disaster financial assistance and the current market value of their homes. The Disaster Financial Assistance program in British Columbia covers uninsurable losses to 80% of the amount of total eligible damage that exceeds $1000 to a maximum of

$300,000 (EMBC 2012). With such a large proportion of private properties worth significantly more than that, this gap is problematic. Compared to insurance policies that promise to replace the full value of the loss, disaster financial assistance may not come close enough to meeting the needs of many residents in Metro Vancouver. Knowing this, residents might be more willing to choose to privately insure their risk.

Further complicating matters, the funding structure of DFAA provides little incentive for municipalities to dedicate their limited resources to hazard mitigation. In the event of a disaster, the municipality is required to pay the first ten percent of the cost and the provincial and federal governments are responsible for the balance. This limited responsibility acts to dissuade municipalities from taking action because they know upper levels of government ultimately hold most of the liability. This municipal attitude is evidenced in the reluctance of some municipalities in BC to update how they define the floodplain. In 2003, the province mandated that municipalities whose floodplain by-law is not up to provincial standards will not qualify for DFAA in the event of a flood disaster. Some municipalities have reacted to this by not adopting a floodplain by-law rather than introducing one that is realistic for their community but deemed inadequate by the province (Stevens and Hanschka 2014). The BC Real Estate Association has taken a leadership role in lobbying the provincial government to update flood hazard maps across the province, without success to date.

4.6.1 Residential survey

A survey was conducted in four neighbourhoods in Vancouver and Surrey to investigate resident perceptions, attitudes, and behaviours regarding flood hazard issues,

including flood insurance. The neighbourhoods were selected to represent a range of social vulnerability. In Vancouver, the survey was conducted in the neighbourhoods known as Kits Point and Marpole, and in Surrey, in the Crescent Beach and Bridgeview neighbourhoods. Kits Point and Crescent Beach have relatively low social vulnerability while Marpole and Bridgeview have higher social vulnerability (Chapter 3). A self-administered survey was delivered to all of the slightly fewer than 400 homes in each neighbourhood for a total population of 1540 homes (N=1540). A total of 461 completed surveys were received from all neighbourhoods (n=461) for a response rate of approximately 29.9% of surveys returned. This sample size compares favourably to that of other flood risk perception studies (Kellens et al. 2013). With this number of completed surveys from the survey population, the margin of error is less than ±4%, 19 times out of 20. The survey asked residents questions around six determinants of vulnerability to flood hazards: perception of hazards and climate change, amenity values, institutional arrangements, social vulnerability, self-protection, and attribution of responsibility. Questions on institutional arrangements included several about insurance, the results of which are displayed in Table 4.2.

Table 4.2: Residents' experience with insurance and attitudes towards flood insurance

Insurance variables	N	Percent
Have home insurance	461	
Yes	430	93.3
No	28	6.1
Not sure	3	0.7
Received advice from insurer	454	
Yes	20	4.4
No	400	88.1
Not sure	34	7.5
Receive a reduction for mitigation action	443	
Yes	28	6.3
No	354	79.9
Not sure	61	13.8
Sewer backup insurance	450	
Yes	106	23.6
No	153	34
Not sure	191	42.4
Earthquake insurance	449	
Yes	267	59.5
No	132	29.4
Not sure	50	11.1
WTP for flood insurance	454	
Yes	238	52.4
No	216	47.6
Yes, WTP ($/year)	233	
<$100	158	67.8
<$200	53	22.7
<$300	12	5.2
<$400	4	1.7
>$400	6	2.6

Most respondents (93%) indicated that they have home insurance. A small minority of respondents reported that their insurance company actively encourages them to take actions to mitigate risks from hazards. Four percent have received advice from their insurer on how to reduce their risk. Six percent receive a reduction in their insurance

rate for mitigation action they have taken on their property, like installing a backwater valve or disconnecting their downspouts from the foundation drain. Take up on two optional riders that residents can add to their premium for additional coverage was quite different. Coverage for damage from earthquakes is offered to residents in British Columbia by most insurers and coverage for damage caused by sewer backup is available across Canada. Sixty percent of respondents reported that they purchase earthquake insurance. Comparatively, 55% of the total value of residential property in Metro Vancouver is covered by earthquake insurance (AIR 2013). Slightly less than one-quarter (24%) of respondents indicated that they have sewer backup insurance. More revealing, perhaps, is that 42% were not sure if they have sewer backup insurance, indicating that the availability of this extra coverage is not well known to residents. When asked if they would be willing to pay for additional coverage on top of their current policy to cover damage caused by overland flooding, results were close to evenly split. Slightly more than half (52%) of respondents indicated that they would be WTP for flood insurance. The remaining 48% reported that they would not be WTP for flood insurance. Of those who are WTP, more than two-thirds (68%) said they would only be WTP up to $100 per year for flood coverage. About 10% of respondents said they would be WTP more than $200 per year. Survey findings indicate associations between attitudes about flood insurance and variables representing the other determinants, which are reported in Table 4.3.

Table 4.3: Associations between WTP for flood insurance and other determinants of vulnerability

Variable	T-test[a]	Chi-square[b]
Experienced a flood in current home		2.764
Perception of hazards		
Flood hazards (all)	7.07***	
Sea level rise	5.6***	
Flooding caused by heavy rain	5.34***	
Sewer backup	2.09*	
Perception of climate change		
The climate is changing	2.74**	
There are more frequent and severe rainfall events now than there were 20 years ago	2.74**	
The risk of flooding that would affect property is increasing	5.19***	
Climate change is causing more extreme weather events	1.52	
Protective actions		
Knowledge about protective actions	1.22	
Would like to receive more information on how to reduce risk		34.117***
Have taken action to protect home from flooding		8.3**
Preventing damage is a high priority for their money and time	4.47***	
Backwater valve installed		0.757
Institutional incentives		
Purchase earthquake insurance		16.318***
Purchase sewer backup insurance		0.974
Attribution of responsibility for preventing damage from natural hazards		
Homeowner	0.97	
City	3.6***	
Insurance company	1.7	
In event of disaster, support expected to receive from:		
Myself	1.55	
Insurance company	1.68	
Amenity values		
Natural environment benefits	2.76**	
Affordability	-0.44	
Social vulnerability		
Sex		0.987
Age	-1.07	
Education	-0.28	
Household income	1.18	

[a] Independent samples t-test

[b] Chi-square test for independence (using Yates' Correction for Continuity)

*p< .05; **p< .01; ***p< .001

Independent samples t-tests and chi-square tests were used to identify how other determinants of vulnerability might statistically differentiate those who are WTP for flood insurance from those who are not WTP for flood insurance. Independent samples t-tests were used to compare means between the groups – those WTP and those not WTP – in relation to other determinants when data for the dependent variable is ordinal, and chi-square tests were used when the dependent variable is categorical data (Zumbo and Zimmerman 1993). The tests found statistically significant differences between the groups on a number of variables representing the determinants. There was not a significant association between WTP for flood insurance and previous experience of a flood. For perception of hazards, those who are WTP for flood insurance have a higher perception of both flood risk and sea level rise. They also have a higher perception of flooding specifically caused by heavy rain as well as by sewer backup. Those WTP for flood insurance have a higher perception that the climate is changing, that there are more frequent and severe rainfall events now than there were 20 years ago, and that the risk of flooding that would affect their property is increasing. There is not, however, a significant difference between the groups on their perception that climate change is causing more extreme weather events.

For protective actions, there is not a significant difference between the groups in their self-reported knowledge about actions they can take on their property to protect their home from flood damage. There are, however, significant associations between those who are WTP and those who have taken action to protect their home from flood damage, as well as those who would like to receive more information about such actions. Those WTP for flood insurance have a greater level of agreement that hazard mitigation

is a high priority for spending their money and time. In terms of a specific protective action, installing a backwater valve in the main sanitary line to their home, there is not a significant association between WTP for flood insurance and having a backwater valve.

Questions on institutional incentives included two about optional coverage that homeowners can add to their insurance policy. It was found that there is a significant association between WTP for flood insurance and purchasing earthquake insurance but not between WTP for flood insurance and sewer backup insurance. In terms of attributing responsibility for preventing damage from natural hazards, those who are WTP for flood insurance felt that the City should have a higher level of responsibility than those not WTP. There was not a significant difference between the groups, however, in the level of responsibility that they feel a homeowner should have, as well as an insurer should have, in preventing damage from hazards. When asked on whom they would expect to rely for support in the event of a disaster, there were no significant differences between the groups for support they expect to receive from themselves or from their insurance company. In terms of the value that residents place on neighbourhood amenities, those who are WTP for flood insurance place a higher value on natural environment benefits than those who are not WTP. There is not a significant difference between the groups on the value they place on the affordability of living in their neighbourhood. Results on socio-economic characteristics that contribute to social vulnerability revealed no significant associations between WTP for flood insurance and a person's age, sex, education, or household income.

4.7 Discussion

Flood risk management in Canada is presently a public responsibility. Provincial and municipal governments, sometimes along with other local agencies, use non-structural and structural measures to attempt to keep people out of hazardous areas and flood hazards from where people live. If flood damages do occur, an arrangement exists for all three levels of government to work together to provide financial assistance to affected communities and citizens. Since overland flood insurance is not available to homeowners in Canada, insurers do not play an active role in flood risk management, but often play an ad hoc role in paying out claims to policy holders for water damage and in cases where the source of flood losses are unclear. It appears there are two main reasons the arrangement exists in this way: because Canadians generally value the role of government in mitigating flood risk, and because insurers to date have not viewed coverage against overland flood loss as a profitable line of business.

After recent flood disasters have contributed to a public perception that flood risk in Canada is increasing, there may be pressure on the reasons for this arrangement. First, flood disasters show that public agencies cannot always meet their responsibilities to mitigate flood risk. Second, if flood risk is rising, flood insurance may be seen as a profitable venture for insurers. For insurers, it is not so much whether the overall risk is low; it is whether or not people are willing to pay for coverage against it. An insurer's primary interest is in maximizing premiums and minimizing claims, which reduces their risk, as opposed to reducing overall risk inherent in the system. Insurers do not need to alter the nature of the risk because risk generates business: "there is no such thing as a bad risk, there are only mispriced risks" (The Economist 1994, 10 in Bennett 1999, 199).

Therefore, insurers should not be counted on for keeping people from living in flood-prone areas because it is not their first priority. If they can price risk accurately and policy holders will pay the full or cross-subsidized rate, insurers will offer the product.

An important question then, if insurers move to provide the coverage, is how will flood insurance create losers and winners? And how will these losers and winners be different from those created by the current system of flood risk management? The introduction of flood insurance can be expected to create two sets of losers: those who cannot afford to purchase the coverage and those living at low risk subsidizing those at high risk with their premiums (Penning-Rowsell and Pardoe 2012). Those who cannot afford to buy insurance are of greatest concern because in the event of a loss they will not be covered and government will be supposed to not provide financial aid to these people since the risk is insurable. Whether to assist these people or not will be reduced to a political decision. Winners created by the product will be those living at high risk who can afford to pay the premium. The premium may indeed be affordable because it is subsidized by other policy holders living in lower risk areas. Those living at high risk are thus facilitated in their search for environmental benefits by not having to pay the full cost of the associated risks (Collins 2008). The current public arrangement may attempt to be fair to all members of society, but in practice there are uneven benefits which contribute to unequal vulnerability to flood hazards. Powerful groups of people are already facilitated in their desire to achieve environmental benefits without paying the full cost by tax-payer funded infrastructure and disaster financial assistance, among other benefits (Chapter 3). Will a private flood insurance scheme amplify the unequal vulnerability found in the current arrangement? Understanding how individual demand

for flood insurance is associated with other determinants of vulnerability to flood hazards can provide insight into how such a scheme will affect Canadian households.

This study was the first to ask Canadian homeowners and renters about their attitudes towards flood insurance along with their perceptions of hazard risks, how they attribute responsibility for hazard mitigation, their behaviours to reduce risk, and personal socio-economic characteristics. Collecting this information enables an understanding of relationships between willingness to purchase flood insurance and other determinants of vulnerability to flood hazards among residents of a Canadian city. Survey findings reveal both expected and unexpected results. With most residents indicating that they have home insurance policies, it is evident that a culture of insurance and the administrative infrastructure required to deliver an insurance product already exist in Canada. Flood insurance could readily be added to a market with high insurance penetration if the demand or requirement for the coverage exists. Advocates of insurance as a tool for risk reduction argue that the insurance industry can play an active role in encouraging governments and homeowners to adopt measures to reduce risk (Crichton 2008). Evidence of the industry presently filling this role by promoting hazard mitigation behaviour among policy holders, however, is not found in the survey results. With only four percent of respondents reporting that they have received advice from their insurer on how they can reduce their risk, and six percent indicating they receive a reduction in their premium for mitigation actions they have taken on their property, the influence of such a role appears to be limited in practice. Claiming this role without filling it leaves the insurance industry open to criticism that it is not interested in actually reducing risk.

Results on residents' take up of earthquake and sewer backup insurance provide comparative examples of optional coverage that homeowners can add to their policy. Sixty percent of respondents indicated that they have earthquake coverage, which is reflective of 55% of the total value of residential property in Metro Vancouver covered by earthquake insurance (AIR 2012). Earthquake risk is well known among the public in British Columbia, and the same survey found that earthquake risk is perceived to be higher than flood risk (Chapter 3). Coverage at less than two-thirds of the population on a well-known risk indicates that (optional) insurance is not a universally accepted measure for risk reduction. Residents may not purchase additional earthquake coverage for a variety of reasons, including: they cannot afford it, they feel the cost of insurance is poor value based on the risk, they believe that in the event of an earthquake disaster the government will provide assistance, they object to the coverage on principle, or they simply have not bothered to add it to their policy (Priest et al. 2005). The same reasons would apply to the decision to purchase optional flood insurance. Just over half (52%) of respondents said that they would be WTP for flood insurance. This proportion may reflect the slightly lower perceived flood risk as compared to perceived earthquake risk and resultant earthquake insurance take up. The survey also found that those who purchase earthquake insurance are more WTP for flood insurance. This finding may indicate that risk aversion of individuals is an important factor in the decision to purchase flood insurance (Botzen and van den Bergh 2012). Sewer backup insurance take up is lower at 24% but 42% of respondents indicated they were not sure if they had the coverage. A significant association was not found between sewer backup insurance and WTP for flood insurance. Compared with 11% of respondents who were not sure if they

had earthquake coverage, it is clear that sewer backup insurance is not well understood by policy holders. This points to a need that insurers should address. It is not surprising, given the choice of how much they would be WTP for flood insurance, that most people (68%) selected up to $100 per year and a minority (10%) said they would be WTP more than $200 per year. Studies on NFIP policies have found that demand for flood insurance declines slightly with an increase in price (Kousky 2011), so it could be expected that the number of those WTP for flood insurance would be lower than the survey indicates if premiums are high.

The survey finding that there is not a significant association between WTP for flood insurance and previous experience of a flood is not consistent with other studies that found those who have experienced flooding are more likely to purchase flood insurance (Krantz and Kunreuther 2007; Michel-Kerjan and Kousky 2010). Lo (2013), however, also finds that previous flood experience does not determine demand for flood insurance. Given the low number of survey respondents who had experienced a flood (8%), this result may be statistically questionable. The positive association found between WTP for flood insurance and perception of risk from flood hazards is consistent with the dominant findings of previous studies (Kunreuther 1996; Kunreuther 2006; Botzen and van den Bergh 2012). Though other studies have found no relationship (Laska 1990) or a negative relationship (Hung 2009), this relationship had not previously been tested for Canadian residents. The finding of significant positive associations between concerns about climate change impacts and WTP for flood insurance reinforces that those with higher perception of flood risk have greater demand for flood insurance.

These associations have implications for the introduction of flood insurance in Canada. The insurance industry can be expected to respond in a few ways if only those who perceive their risk to be high are willing to purchase flood insurance, which presents the problem of adverse selection. An optional product will have to be priced at a high rate such that it would be prohibitively expensive for some people at high risk. Many will view their risk to be lower than it actually is (Slovic et al. 2000) so will choose not to purchase the coverage. Insurers may bundle flood coverage with other risks as a "catastrophe insurance" product or as part of a standard home insurance product, allowing cross-subsidization to reduce rates. Botzen and van den Bergh (2012) find that residents living in a more flood prone area do not necessarily have higher demand for flood insurance, leading the authors to believe that concerns about adverse selection may be unfounded. It could be, perhaps, that perception of risk is more important in the decision to purchase insurance than actual risk.

The findings that WTP for flood insurance is not significantly associated with the level of responsibility that respondents feel homeowners or insurers should have in preventing and responding to disasters suggest that flood insurance would appeal to those with a variety of views on attribution of responsibility. Significant positive associations could be expected between WTP for flood insurance and the level of responsibility that residents think an insurer should have in preventing damage from hazards, as well as the level of support they expect to receive from their insurer in the event of a disaster, but were not found. One might presume that an individual who is willing to involve their insurance company in their personal risk management by purchasing flood insurance would view an insurer as having a high level of responsibility for preventing damage

from hazards. Perhaps, though, their view is that they are taking more personal responsibility by fully insuring themselves. Those who are WTP for flood insurance feel that the City should have a high level of responsibility for preventing damage from hazards, which suggests that if flood insurance exists, citizens will still expect governments to be actively involved in hazard mitigation. This would support the position of insurers that governments must remain involved in reducing risk.

Variables that indicate homeowners taking a personal initiative to reduce their risk have significant positive associations with WTP for flood insurance. Undertaking mitigation measures, wanting to receive more information about what they can do to reduce their risk, and prioritizing hazard mitigation as a personal expense were traits of those willing to purchase flood insurance. It stands to reason that buying flood insurance would be one of the measures that someone with a personal sense of responsibility would take to reduce their risk. The finding by Thieken et al. (2006) that those who have flood insurance take more action during a flood seems to support this observation. Social vulnerability was found to be a determinant that did not predict WTP for flood insurance. The findings of previous studies are mixed on whether factors like age, income, or education level influence the decision to purchase flood insurance, but two US studies found that they did not in an existing program (Blanchard-Boehm et al. 2001; Kousky 2011). It seems intuitive that those with higher incomes would be more willing to purchase flood insurance but the case study does not bear that out. In the United Kingdom, where home insurance coverage is not mandatory but includes flood coverage, there is uneven uptake along income levels. Crichton (2002) finds that 30% of poor households have insurance compared to uptake at 95% of the overall population. The

survey also found that those who value living in what they consider an affordable neighbourhood are not significantly more or less likely to purchase flood insurance. WTP for flood insurance is found to be significantly associated with highly valuing natural environment benefits as a neighbourhood amenity. This finding indicates that those seeking environmental rewards – rewards that may come with risks – are willing to pay a cost for living near them.

4.8 Conclusion

Insurers are considering offering flood insurance as a new product to Canadian homeowners. If private insurance is available to cover losses caused by overland flooding, it will have implications for the vulnerability of residents to flood hazards and how flood risk is managed in Canada. The introduction of private flood insurance raises questions around how it will exacerbate already unequal vulnerability to flood hazards and whether it can be an effective tool in limiting exposure to the hazard. How would the availability of flood insurance benefit some people more than others? How are the winners and losers created by the privatization of flood risk different from those in the current system of flood management? Would the introduction of flood insurance weaken public management efforts to keep people from living in flood-prone areas?

This chapter attempts to address these questions by contributing some understanding of how demand for flood insurance relates to other determinants of vulnerability to flood hazards. Case study findings reveal some expected results, such as WTP for flood insurance is positively associated with risk perception, but other results are not hypothesized, like socio-economic characteristics that contribute to social

vulnerability do not predict WTP for flood insurance. These findings indicate that demand for flood insurance is part of a complex, dialectical set of determinants of vulnerability. Since the study is the first to examine how demand for flood insurance relates to other determinants of residential vulnerability in Canada, future studies could build upon the findings with comparative empirical evidence. Findings could then be analysed against experiences with flood insurance in other countries. If private flood insurance enters the Canadian flood risk management landscape, an understanding of the implications for flood management and residential vulnerability to flood hazards will allow policy makers to make related decisions in the best interest of all Canadians.

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5. Conclusion

This chapter concludes the dissertation by summarizing the main findings of the study, identifying the limitations of the research, discussing the contributions of the study, and offering a comment on future research directions.

5.1 Summary of findings

The dissertation makes a number of findings that, without being repeated here, can be summarized according to how they address the main research questions set out in the introductory chapter.

Question 1: Who is vulnerable to flood hazards in Metro Vancouver? How do local practitioners view indicators of vulnerability to flood hazards?

The study addresses a gap in the literature on place-based assessment of social vulnerability to hazards. Over the past approximately fifteen years, researchers have created social vulnerability indexes for many cities around the world. These studies use a variety of statistical methods for constructing and/or verifying the index but none have systematically incorporated the input of local practitioners in creating such an index. Based on the argument that an index that is meaningful to those working in local policy will be more useful in decision making, this study uses an interactive, participatory process to inform the creation of an index that provides a measure of social vulnerability to flood hazards by place. The "ground truthing" process provides insights as to how local flood managers view indicators of vulnerability – indicators that identify *who* is vulnerable to flood hazards – in their community.

The study creates two versions of an index that provide quantitative measures of social vulnerability to flood hazards at the neighbourhood scale in five municipalities in Metro Vancouver. Both versions use the same indicators of vulnerability, including (1) ability to cope, (2) access to resources, (3) ethnicity, (4) household arrangement, and (5) the built environment, and the same population data. The method of constructing the two versions of the index, however, is different. The original version uses the traditional social vulnerability index methodology of Cutter et al. (2003). The second version applies what was learned from ground truthing the original version with municipal practitioners, and assigns weights to the variables based on their local knowledge. The result is that social vulnerability maps of both versions of the index show similar patterns of vulnerability with some minor differences in the level of vulnerability calculated for some neighbourhoods.

Local practitioners were found to be widely accepting of the idea of quantifying social vulnerability to flood hazards by place. For many of them, this approach was a novel way of analysing the human dimensions of flood risk at a time when their municipal government was most focused on the physical hazard and how to mitigate risk through engineering and land use measures. A visual representation of social vulnerability to flood hazards in their community was usually welcomed by them as a new and potentially useful tool. Participants in the municipal focus groups had a high level of agreement that the indicators widely used in vulnerability assessments apply in their communities, and with the selected socio-economic variables that constitute these indicators. They had opinions about which variables were more and less important, and offered ideas on other variables that should be included in the analysis.

While the practitioners found the approach to assessing vulnerability to be useful, they were most often critical of the method of analysis. They often could not validate, and many times outright disagreed with, the results of the principal components analysis. The statistically combined components may have been viewed as an interesting exercise but most practitioners felt that mapping individual variables or custom combinations of variables would enable a more useful analysis. Furthermore, practitioners felt that incorporating local land use information in the social vulnerability maps would make the index more meaningful. The ground truthing process revealed findings about how practitioners view social vulnerability to hazards and illustrates that their input can be used to create a more meaningful local assessment.

Question 2: What influences residents' vulnerability to flood hazards? How do these determinants produce unequal vulnerability?

Factors that influence residents' vulnerability to flood hazards have not previously been collectively studied in a Canadian urban context. This study identifies, situates, and tests seven hypothetical determinants of vulnerability in order to better understand how they influence, and interact to produce, vulnerability to flood hazards. The determinants are investigated through a residential survey in four neighbourhoods with a wide range of social vulnerability in Vancouver and Surrey. Based on a foundational study of wildfire risk in the American West by Collins (2008; 2009) and other hazards and risk analysis research, the determinants of residential vulnerability to flood hazards investigated in this case are: (1) hazard perception, (2) amenity value conflicts, (3) institutional arrangements, (4) social vulnerability, (5) self-protection, (6) attribution of responsibility, and (7) attenuation of risk due to another dominating concern. Survey findings offer

insights as to how these determinants interact to produce unequal vulnerability to flood hazards among residents in a Canadian city.

Study findings support earlier hazards research that identifies social vulnerability as an important factor in determining overall vulnerability to flood hazards. Survey results find that household income, as a key contributor to social vulnerability, has significant correlations with variables that define the other determinants. Institutional arrangements are found to be another important determinant of vulnerability. Property insurance and development regulations have uneven impacts on residents in the study neighbourhoods. Powerful groups are found to be better able to use an institutional arrangement like property insurance to externalize the risk associated with their desire to live in an attractive but hazardous place. A development regulation in Surrey that requires homes built in the floodplain to have an elevated construction level may have the intention of reducing household exposure but is found to have the effect of increasing neighbourhood vulnerability.

Question 3: *As one aspect of the institutional arrangement determinant of vulnerability, what would be the implications of private flood insurance for flood management in Canada and residential vulnerability to flood hazards?*

Insurance coverage of damage caused by overland flooding is currently not available to Canadian homeowners. With water damage claims and overall flood losses rising, insurers are considering offering coverage of overland flood damage to homeowners in order to properly underwrite a problematic peril, limit reputational risk,

and extend their business. Research on the topic is limited. While two recent reports commissioned by members of the industry assess the viability of flood insurance in Canada (Sandink et al. 2010; Thistlethwaite and Feltmate 2013), they do not critically engage many of the complex, competing issues that come with making such coverage available. In chapter 4, I argue that the introduction of private flood insurance in Canada would have implications for the current regime of public flood management and for residential vulnerability to flood hazards.

Private flood insurance would necessarily affect the current state of flood management in Canada. Insurers would expect governments to continue to play an active role in mitigating risk through structural and non-structural measures, including maintaining and improving infrastructure, limiting development in flood prone areas, compensating uninsurable homeowners for flood damage, and potentially providing updated flood hazard maps. Governments would be expected to continue to manage flood risk in these ways while losing control of disaster relief, an important element of disaster management, for all but those deemed too risky to insure and those who do not buy coverage. The result is that the government would still take on the worst risks. While losing the responsibility of compensating flood victims for their losses may seem like a victory for tax payers concerned about the public purse, providing disaster relief is an opportunity for government to play an important role in rebuilding a community in a safer way, which is an objective of the NDMS and DFAA. Since federal money flows to communities through the province, and provinces are responsible for land use planning and building regulations, disaster relief can be a way for governments to reduce overall risk by being involved in all stages of the disaster management cycle.

Flood insurance would also influence peoples' vulnerability to flood hazards. The household survey of four neighbourhoods in Vancouver and Surrey found that just over half (52%) of residents would be willing to pay for flood insurance. Demand for flood insurance is found to have significant associations with other determinants of vulnerability. Notably, demand for flood insurance is positively associated with risk perception, taking action to protect one's home, and value placed on natural environment amenities in one's neighbourhood. Socio-economic characteristics that contribute to social vulnerability, however, do not predict willingness to pay for flood insurance. These findings indicate that demand for flood insurance is part of a complex, dialectical set of factors that determine vulnerability.

5.2 Limitations of the study

While the dissertation investigates institutional arrangements that influence vulnerability, like public policy and private market mechanisms, it does not thoroughly analyse the discourse surrounding them to learn more about the role it plays in producing vulnerability. The study finds that policies at the municipal, provincial and federal levels of government, for example, affect residential vulnerability, but an analysis to discover whether these policies constitute the sort of hegemonic technocratic discourse that produces unequal vulnerability, as theorized by Mustafa (2005) and Collins (2009), may better make the case that powerful geographic groups of people are facilitated in their pursuit of environmental amenities. The study stops short of providing a full articulation of how such discourse produces, and perpetuates, unequal vulnerability to hazards, and doing so would serve to make clearer the link between policy, the policy process, and how it differentially affects residential vulnerability to hazards in a Canadian city.

The study would have greater comparative capabilities if the residential survey had been conducted in more than two municipalities. The original intention of the study was to conduct the survey in four municipalities, including Vancouver and Surrey. Practitioners in two other municipalities were not supportive of the survey being delivered in their communities. They did not want issues surrounding flood risk raised directly to residents during what they viewed as a sensitive time due to acute political and development pressures. While I could have ignored their requests and proceeded with the survey, my objective in doing the research is to contribute to the work of hazards researchers and practitioners, not to exacerbate an already challenging issue for municipalities. Their opposition to the survey, however, highlights the relevant and timely nature of the topic in Metro Vancouver communities. Comparing neighbourhoods with high vulnerability to neighbourhoods with low vulnerability across four cities would have allowed for a fairly robust comparative analysis. Survey findings from neighbourhoods in two cities does not lend itself to the same opportunities for comparison and generalization, though analysis of the existing findings could be extended to explore this possibility.

This dissertation adds a Canadian case to a growing First World urban political ecology of hazards literature. Studies in the US and other developed countries have begun to build a theoretical and empirical foundation on the topic but this study does not explicitly compare findings to that literature. Indicators and determinants of vulnerability may be similar for Canadian cities and cities in other countries but examining the differences more closely could lead to discovery of whether there is a uniquely Canadian production of vulnerability. Differences between Canada and the US, for example, in

private property rights, property insurance coverage, citizen participation in the planning process, and exposure to hazards are all worth investigating to see how they affect vulnerability.

The study could be extended in at least two other ways to increase the research findings with existing results. For example, the dissertation includes a limited comparative spatial analysis of the two methods of social vulnerability index construction. Further insights could be gained about the two methods of construction and the importance of the indicators if the mapped results of the indexes are more closely compared. With the residential survey results, the dissertation provides a bivariate analysis of household income and factors that represent the other determinants, but greater insights might be made by performing a multiple regression analysis. Creating such a model would allow for a more sophisticated exploration of the relationships among the determinants, and relative contribution of each determinant, in producing differential vulnerability.

5.3 Contributions of the study

The dissertation makes several modest contributions to the theoretical knowledge base of hazards research as well as to practical efforts towards flood risk reduction.

5.3.1 Theoretical contributions

To hazards theory, the dissertation contributes a conceptual framework for understanding what influences residential vulnerability to hazards in a Canadian city. Vulnerability is produced through actions by government, the private sector, and

households, and viewing these through the lens of factors that determine vulnerability provides a way of analysing across actors and across scales. The framework proposes indicators that identify who is vulnerable and determinants that identify what influences their vulnerability, and conceptualizes how these factors work together to produce unequal vulnerability. Unpacking one determinant, social vulnerability, into indicators and then learning how local government representatives view the relevance of those indicators in their community is one application of the framework. Deconstructing how one institutional arrangement, private flood insurance, would affect flood management and residents' vulnerability were it to be introduced in Canada, demonstrates that the framework provides a useful lens for analysing determinants of vulnerability. The framework could likewise be used to better understand how the other determinants influence vulnerability.

Utilizing this conceptual framework, the study applies a political ecology of hazards approach to understanding vulnerability to flood hazards in a Canadian city. This approach addresses gaps in the literature on hazard vulnerability and First World political ecology. It does so by taking Canadian cities as case studies and examining how public policy, private mechanisms, and households factor together to create differential vulnerability to flood hazards. Such an approach has not been explicitly taken in studying vulnerability to floods in Canada, and this study is guided by it to look across actors and across scales at the factors that influence vulnerability. I use "guided by it" purposefully: urban political ecology studies, especially those conducted in the so-called First World, do not purport to follow a standardized approach (McCarthy 2002). This study is lacking in some elements that would satisfy a purely political ecology research agenda, a few of

which are addressed as limitations in the previous section. Instead, this study, driven by a desire to uncover the factors that produce unequal vulnerability by looking across multi-faceted actors and scales, uses approaches from across the spectrum of research in hazards geography. Methodologically, the study is drawn as much from a pragmatic collection of hazards research tools as it is from political ecology. Combining methods that draw upon population census data, local practitioner input on indicators of vulnerability in their municipality, household survey data, and long answer, interview, and focus group feedback of residents illustrates that hazards research tools can be used instructively to pursue some of the objectives of a political ecology approach. As such, this study can inform theory on the political ecology of hazards with both its epistemological contributions and limitations.

The study makes other theoretical contributions that are more specifically focused. While studies that create an index to assess social vulnerability are plentiful in the hazards literature, there is a striking research gap on incorporating local practitioner knowledge in constructing such an index. In chapter 2, I argue that if a social vulnerability index is meant to be relevant to local decision making, then it should be meaningful to those working in local policy. One way of ensuring an index is meaningful is to involve local practitioners in the construction of it. This study contributes what was learned from one exercise in bringing an index to practitioners in five municipalities and incorporating their input in a revised version. There surely are other ways of using local knowledge in the construction of an index and other methods of assigning weights to the variables but the study serves to illustrate that an interactive process can inform the measure of social vulnerability by place.

The finding that social vulnerability and institutional incentives are important, and related, determinants of vulnerability to flood hazards contributes to a theoretical understanding of how powerful groups are facilitated in their pursuit of environmental benefits. Institutional arrangements in a Canadian city appear to allow higher income homeowners to reap environmental rewards, like living near the sea, without taking on the full associated risk. This finding supports Collins (2008) conceptualization of facilitation by showing that public and private institutions play a dual role in producing differential vulnerability to flood hazards. Furthermore, the study finding that a development regulation may increase neighbourhood vulnerability, when its intention it to reduce household exposure, challenges the popular notion that such technocratic measures reduce risk. Powerful groups may, in practice, be able to co-opt this type of measure to perpetuate or extend unequal vulnerability to hazards in their community.

The dissertation situates a private risk transfer mechanism, overland flood insurance, within a set of factors that influence vulnerability. The implications of insurers introducing this product for residential vulnerability are put into the context of how it would create losers and winners by interacting with other determinants of vulnerability. Given that many Western, developed countries have some type of flood insurance arrangement, and studies have investigated various aspects of these models, analysing the implications of flood insurance where it does not already exist allows an unique opportunity to apply and build theory. Asking residents about their attitudes towards flood insurance when it is not available to purchase contributes to a base of knowledge on a widely used cost-sharing measure. The implications of other institutional arrangements,

both existing and proposed, could also be investigated in this way to learn how they interact with determinants of vulnerability.

5.3.2 Practical contributions

The purpose of this dissertation is not to make prescriptive policy recommendations but it does make some practical contributions to reducing flood risk. First, the study creates an actual assessment of social vulnerability to flood hazards in five municipalities in Metro Vancouver. It creates two versions of a social vulnerability index: the first based on a purely statistical methodology and the second based on local practitioner input on the importance of the variables. Both versions could be used by the municipalities. In fact, the City of Vancouver is currently conducting a project on climate change impacts that includes creating a social vulnerability index, the impetus of which may well have come from this study's focus group with Vancouver staff.

Survey results contribute an empirical set of data on residents' perceptions, attitudes, and behaviours towards flood hazard risk and responsibility. This information, viewed according to the descriptive statistics, could be useful for municipal policy makers to gain a better understanding of the views and actions of residents living in their community. For example, perception of hazard risk and climate change impacts, awareness of municipal actions, and how residents attribute responsibility for risk reduction are potentially useful making local policy decisions. My intention to conduct a residential survey was described during the municipal focus groups and the survey was later piloted with some participants to ensure accuracy and applicability. Participating practitioners offered their encouragement to conduct the survey in order to gain

knowledge about residents in their community and conveyed their enthusiasm to learn the results.

The act of conducting a household survey on the topic of natural hazards could itself be considered a practical contribution of the study. By bringing issues surrounding flood risk and climate change impacts to the attention of residents living in exposed locations, the survey served as something of a public education tool. Many respondents remarked that they did not know about some of the flood issues or mitigation measures described in the survey, and some thanked me for the learning opportunity or for bringing the issue to the attention of their neighbours. At the very least, the survey caused residents in the study neighbourhoods to briefly consider local hazard issues.

The data on residents' willingness to pay for overland flood insurance is, to my knowledge, the first of its kind collected in Canada. Demand for flood insurance has been tested in other countries where the coverage is and is not available, so the results could be compared directly to those findings. While perhaps crude by actuarial standards, the information could also be of interest to insurers as they weigh introducing a flood insurance product, though they will surely use their own methods of testing the market.

5.4 Future research

Further research on the factors that influence vulnerability to hazards is needed to learn more about how unequal vulnerability is produced. Discerning the role and relationships of the determinants of vulnerability will help researchers progress from understanding vulnerability to knowing how to reduce it. Equitable and sustainable vulnerability reduction should be an objective of hazards researchers, and pursuing this

agenda does not preclude them from helping policy makers achieve it. At the end of chapter 3, I draw on Collins (2009) to raise the question of whether technocratic measures can meet the needs of the most vulnerable without being co-opted by more powerful groups to extend unequal vulnerability. This study finds that some technocratic measures used in Metro Vancouver may not fulfill this aim but further research could identify if there are other such measures that may be able to do so. As more and more municipalities move to adopt climate change adaptation plans, this policy window may provide an opportunity to integrate hazard vulnerability reduction strategies in broader initiatives. If a more transformational approach than technocratic measures allow is indeed required to reduce vulnerability, an understanding of how structural forces, human agency, and place interact to produce unequal vulnerability is a needed contribution to scholarship and practice on climate change adaptation and community resilience building (Peet et al. 2011; Pelling 2011). With interest in adaptation and resilience currently driving (and funding) much of hazards research, this is a role primed for researchers with a grounded understanding of vulnerability to contribute knowledge and alternative ideas to popular topics that are clearly not neutral processes.

5.5 References

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Appendix A: Glossary of key terms

Glossary of key terms

Determinant	Factors that influence, and interact to produce, a person's vulnerability to a hazard.
Exposure	The presence of people, infrastructure, or other assets in places that could be adversely affected by a hazard (IPCC 2012, 559).
Hazard	A natural or human-induced physical event that may have adverse impacts on life or property.
Indicator	Characteristics of a person or group that identify who is vulnerable to hazards. Indicators consist of variables that when analysed together can describe the level of vulnerability of a person or group.
Mitigation	The lessening of the potential adverse impacts of a hazard.
Risk	The interaction between a person's exposure to a hazard and their vulnerability to the hazard.
Vulnerability	The characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (Wisner et al. 2004, 11).

Appendix B: Municipal practitioner survey instrument

Coastal Cities at Risk

Practitioner survey on social vulnerability indicators

Name: _____ Municipality: _____

Position: _____ Years of experience: _____

Number of years professionally involved in climate change issues: _____

1. The following table contains variables that we have used to develop a preliminary Social Vulnerability Index. Based on your experience please indicate whether "this variable is influential to defining social vulnerability to climate hazards in my community" by checking (√) the appropriate box (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree) for each variable in the list.

Indicator	Variable	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Age	% Population age 19 and under					
	% Population age 65 and over					
Gender	% Female population					
Ethnicity	% With no knowledge of official languages					
	% Population recently immigrated (2001-2006)					
Social status	Average dwelling value					
	Average household income					
	Prevalence of low income (those spending 20% more than average on necessities)					
	% Population who rent their dwelling					
	% of income received from government transfers					
	% Labour force (>age 15) unemployed					
	% Population with high school education or less					
	% Population with university education					
Household arrangement	% Single-parent families					
	% Households with one person					
	% Main mode of transportation is public transit					
Built environment	Population density					
	% House type is apt 5+ stories built before 1980					
	% Period of home construction is before 1970					
	% Housing in need of major repair					

Coastal Cities at Risk

Practitioner survey on social vulnerability indicators

Indicator	Variable	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
What about?	First Nations population					
	Ethnic origin					
	Population change					

2. Based on your experience, what other variables are important but not included here?

_____

_____

_____

_____

_____

3. From the list above, please identify the five key variables that you think are most influential to social vulnerability to climate hazards and rank in order from most important to least important.

1) _____

2) _____

3) _____

4) _____

5) _____

Thank you!

Appendix C: Residential survey instrument

You, Your Home, and Natural Hazards

Your participation in this survey will contribute to a better understanding of what people think about the risks of natural hazards like flooding, sea level rise, and earthquake.

Kits Point Resident

Part A: Please tell us about your home

1 How long have you lived in your current home? _____ years

2 Do you own your home? ☐ Yes ☐ No

If NO, do you rent your home? ☐ Yes ☐ No

3 What type of dwelling is your home?

☐ Detached ☐ Semi-detached ☐ Townhouse ☐ Apartment/Condominium

☐ Other _____

4 Why do you choose to live in this neighbourhood?
Please check the box that corresponds to the importance you place on each reason.

	LEVEL OF IMPORTANCE				
	Low 1	2	3	4	High 5
Location – near work or school					
Location – near family or friends					
Location – natural environment benefits					
Affordability					
Enjoy neighbourhood amenities – for example: shops, restaurants					
Proximity to public transit					
Access to transportation – for example: highways					
Safe neighbourhood					
Family roots in neighbourhood					
Other – please describe:					

Part B: Natural hazards risk

5 We are interested in what you think about the risk of various types of natural hazards. Please indicate your level of concern for the following natural hazards affecting your home (with 1 representing low concern and 5 representing high concern).

	LEVEL OF CONCERN				
	Low 1	2	3	4	High 5
Flood					
Earthquake					
Sea level rise					
Wind storm					
Landslide					
Wildfire					
Land subsidence (sinking)					
Other (please describe):					

6 Flooding has been identified as a frequent cause of property damage in British Columbia. Have you ever experienced flooding in your current home? ☐ Yes ☐ No

If YES:

When was the most recent flood event? _____

Do you know how the water entered your home? (If so, please describe)

_____

Did you report the flood to the City? ☐ Yes ☐ No

Did you make an insurance claim? ☐ Yes ☐ No

Did you receive an insurance payout? ☐ Yes ☐ No

7 In your opinion, on a scale of 1 to 5, what is the level of probability that your home will be impacted by the following types of flooding?

	LEVEL OF PROBABILITY					
	Low 1	2	3	4	High 5	Don't know
Flooding caused by heavy rain						
River flooding						
Sea level rise						
Sewer backup						
Coastal storm surge						
Ground water rising						
Tidal flooding						
Other (please describe):						

8 Please indicate your level of agreement with the following statements related to climate change.

	LEVEL OF AGREEMENT					
	Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree	Don't Know
I think the climate is changing.						
I have noticed the impact of a changing climate in my city.						
I am concerned about the impacts of climate change in my neighbourhood.						
I am concerned about the impacts of climate change in my city.						
I am concerned about the impacts of climate change in British Columbia.						
I am concerned about sea level rise affecting my neighbourhood.						
I think there are more frequent and severe rainfall events now than there were 20 years ago.						
I think the risk of flooding that would affect my property is increasing.						
I think climate change is causing more extreme weather events.						

Part C: Protecting homes from natural hazards

9 On a scale of 1 to 5, how knowledgeable are you about actions that you can take on your home and property to protect your home from flood damage?

KNOWLEDGE ABOUT ACTIONS				
Not knowledgeable 1	2	3	4	Very knowledgeable 5

10 Would you like to receive more information about actions you can take to protect your home from flooding?

☐ Yes ☐ No

If YES, from whom would you like to receive this information?

☐ City ☐ Insurance company

☐ Other _____

11 Have you taken any actions on your home or property to protect your home from flooding?

☐ Yes ☐ No

If YES, please describe these actions:

_____

_____

_____

12 The next set of questions asks about your actions to protect your home from natural hazards.

	Yes	No	Not sure
Do you have home/property insurance?			
Have you received any advice from your insurance company about how to prevent flood damage to your home?			
If YES, have you acted on any of that advice?			
Do you receive a reduction in your home/property insurance premium because of any action you have taken to protect your home from natural hazards?			
A backwater valve can prevent storm and waste water from backing up into your home. Do you have a backwater valve installed?			
Sewer backup insurance is extra coverage you can add to your home/property insurance policy. Do you have sewer backup insurance on your policy?			
Earthquake insurance is extra coverage you can add to your home/property insurance policy. Do you have earthquake insurance on your policy?			

13 Home insurance coverage for damage caused by overland flooding (for example, from severe rain) is currently not available anywhere in Canada. Would you be willing to pay a premium to receive this coverage?

☐ Yes ☐ No

If YES, what would you be willing to pay in addition to your current premium?

☐ Less than $100 per year ☐ Up to $200 per year ☐ Up to $300 per year

☐ Up to $400 per year ☐ More than $400 per year

14 Have you received any advice from the City about how to prevent flood damage to your home?

☐ Yes ☐ No ☐ Not sure

If YES, have you acted on any of that advice?

☐ Yes ☐ No

15 Are you aware of any City policies or plans that directly address natural hazards or climate change?

☐ Yes ☐ No

If YES, do you think these plans are adequate?

☐ Yes ☐ No ☐ Not sure

16 Please indicate your level of agreement with the following statements:

	LEVEL OF AGREEMENT					
	Strongly Disagree 1	Disagree 2	No Opinion 3	Agree 4	Strongly Agree 5	Don't Know
The City is acting to address the risks posed by natural hazards.						
Municipal infrastructure (e.g. stormwater drainage, sewage system, sea wall, dikes) in my neighbourhood is satisfactory right now to handle the risk of flooding.						
Further financial investment needs to be made in infrastructure to protect the city from natural hazards.						
People have been allowed to live in areas of the city that are prone to natural hazards.						

17 What else do you think the City could do to reduce the risk of damage caused by natural hazards? Please describe.

Part D: Managing the risk of natural hazards

18 In your opinion, on a scale of 1 to 5, what level of responsibility for preventing damage from natural hazards **should** the following parties have?

	LEVEL OF RESPONSIBILITY					
	Low 1	2	3	4	High 5	Don't know
Homeowner						
City						
Province of British Columbia						
Federal government						
Insurance company						
Non-government organizations (for example, Red Cross)						
Other (please describe):						

19 What amount of responsibility do you think the following parties **actually take** now?

	AMOUNT OF RESPONSIBILITY					
	Very low 1	2	3	4	Very high 5	Don't know
Homeowner						
City						
Province of British Columbia						
Federal government						
Insurance company						
Non-government organizations (for example, Red Cross)						
Other (please describe):						

20 In the event of a natural disaster, who would you expect to rely on for any support you might need? Please identify the level of support you would expect to receive from each of the following parties.

	LEVEL OF SUPPORT					
	Very low 1	2	3	4	Very high 5	Don't know
Yourself						
Social networks (friends and family)						
Government						
Insurance company						
Non-government organizations (for example, Red Cross)						
Media						

21 Was information about potential local hazards provided to you when choosing to live in your home?

☐ Yes ☐ No ☐ Do not remember

22 We are interested in your level of agreement with the following statements about topics that are sometimes raised by residents.

	LEVEL OF AGREEMENT					
	Strongly Disagree 1	Disagree 2	No Opinion 3	Agree 4	Strongly Agree 5	Don't Know
I am worried about the risk of flooding or sea level rise negatively affecting the resale value of my home.						
If the City performs disaster risk reduction work that affects my neighbourhood (e.g. improving infrastructure), it would affect the resale value of my home.						
If AGREE, it would increase the value.						
OR, it would decrease the value.						
The local important issues in my part of the city receive adequate attention from the municipal government.						
Preventing damage from natural hazards is a high priority for me in terms of spending my own money and time.						

Part E: Please tell us a bit about yourself (optional)

Finally, we would like to ask a few questions about you to help determine if there are connections between peoples' characteristics and their opinions. This information will be kept strictly confidential. If there is a question that you do not want to answer please leave it blank and move to the next question.

23 What is your gender? ☐ Male ☐ Female

24 What is your age?

☐ 18 or under ☐ 19 to 30 ☐ 31 to 45 ☐ 46 to 64 ☐ 65 or over

25 What is your highest level of education?

☐ Some grade school or high school education ☐ High school graduate
☐ Some post-secondary education ☐ College or trades certificate or diploma
☐ University degree

26 Which category best describes your total household income before tax in 2012?

☐ Less than $30,000 ☐ $30,001 to $60,000 ☐ $60,001 to $90,000
☐ $90,001 to $120,000 ☐ More than $120,000 ☐ Choose not to answer

27 How many people live full-time in your home? _____

Part F: Additional feedback

28 Would you like to share anything else with us about your thoughts on natural hazards in your city?

If you are interested in having a conversation with a researcher about these topics or would like to learn the results of this study, please contact Greg Oulahen at [redacted]

Thank you for participating in this survey.

Please fold and return your completed survey in the postage-paid reply envelope provided.

Appendix D: Western Research Ethics approval notice

Western Research

Research Ethics

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Dr. Gordon McBean
File Number:103320
Review Level: Full Board
Approved Local Adult Participants: 0
Approved Local Minor Participants: 0
Protocol Title: The production of unequal vulnerability to climate hazards in Metro Vancouver, Canada
Department & Institution: Social Science\Geography,Western University
Sponsor:
Ethics Approval Date: February 06, 2013 **Expiry Date:** February 28, 2014

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Letter of Information	Survey second drop cover letter	2012/12/11
Letter of Information	Survey reminder/thank you postcard	2012/12/11
Letter of Information	Survey first drop cover letter	2012/12/11
Letter of Information & Consent	Residential questionnaire	2012/12/11
Western University Protocol		2012/12/13
Recruitment Items	Recruitment script	2013/01/25
Recruitment Items	Debriefing script	2013/01/25
Recruitment Items	Reminder postcard revised	2013/01/25
Recruitment Items	Prenotice letter revised	2013/01/25
Letter of Information	Letter of information	2013/01/25
Recommendations Form	REB recommendations form (with my responses)	2013/01/25
Instruments	Revised questionnaire	2013/01/25

This is to notify you that The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the applicable laws and regulations of Ontario has granted approval to the above named research study on the approval date noted above.

This approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the NMREB's periodic requests for surveillance and monitoring information.

Members of the NMREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the NMREB.

The Chair of the NMREB is Dr. Riley Hinson. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

[redacted]

Ethics Officer to Contact for Further Information

Grace Kelly [redacted]	Janice Sutherland [redacted]

This is an official document. Please retain the original in your files.

Western University, Research [redacted]

Appendix E: Curriculum Vitae

Greg Oulahen – Curriculum Vitae

EDUCATION

Doctor of Philosophy (PhD), Geography
The University of Western Ontario, 2010-2014
Dissertation title: *The production of unequal vulnerability to flood hazards in Metro Vancouver, Canada*

Master of Environmental Studies (MES), Geography
University of Waterloo, 2006-2008
Thesis title: *Citizen participation in post-disaster flood hazard mitigation planning: Exploring strategic choices in Peterborough, Ontario*

Bachelor of Environmental Studies (BES), Honours Planning
University of Waterloo, 2001-2006
Specialization in Environmental Planning and Management
Diploma in Environmental Assessment

EXPERIENCE: Research Management

Institute for Catastrophic Loss Reduction (ICLR), Toronto and London
Research Associate/Coordinator
May 2008 to present

Coastal Cities at Risk (CCaR) project
Network Manager
August 2011 to August 2013

EXPERIENCE: Teaching

The University of Western Ontario, Department of Geography
Guest Lecture
Geography of Hazards undergraduate class, March 2012
Teaching Assistant
September 2010 to April 2011
- GEOG 2152F: Geography of Hazards
- GEOG 2010B: Geography of Canada

University of Waterloo, Department of Geography and Environmental Management
Teaching Assistant
September 2006 to April 2008
- GEOG 101: Introduction to Human Geography
- GEOG 206: Human Dimensions of Natural Hazards (2x)

RESEARCH FUNDING AND AWARDS

SSHRC Doctoral Fellowship, 2013-2014
The University of Western Ontario Graduate Research Scholarship, 2010-2014
James and Nora Nelson Award in Environmental Planning, Univ. of Waterloo, 2007
Master's Thesis research funding, Institute for Catastrophic Loss Reduction, 2007

RESEARCH CONTRIBUTIONS

Peer reviewed

Oulahen, G. (Accepted). Flood insurance in Canada: implications for flood management and residential vulnerability to flood hazards. *Environmental Management.*

Oulahen, G., Mortsch, L., Tang, K., and Harford, D. (Accepted). Unequal vulnerability to flood hazards: "Ground truthing" a social vulnerability index of five municipalities in Metro Vancouver, Canada. *The Annals of the Association of American Geographers.*

[Oulahen, G. – Contributing author] Romero-Lankao, P., J.B. Smith, D.J. Davidson, N.S. Diffenbaugh, P.L. Kinney, P. Kirshen, P. Kovacs, and L. Villers-Ruiz. (2014). North America. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Oulahen, G. and Doberstein, B. (2012). Citizen participation in post-disaster flood hazard mitigation planning in Peterborough, Ontario, Canada. *Risk, Hazards & Crisis in Public Policy, 3*(1), Article 4.

Currently in review

Oulahen, G., Shrubsole, D., and McBean, G. (In Review). Determinants of residential vulnerability to flood hazards in Metro Vancouver. *Natural Hazards.*

Joakim, E., Mortsch, L., and Oulahen, G. (In Review). Using vulnerability and resilience concepts to advance climate change adaptation. *Environmental Hazards.*

Sandink, D., Kovacs, P., Oulahen, G., and Shrubsole, D. (In Review). Flood management in Canada: Review and commentary on cost sharing and risk transfer for flood losses. *Canadian Water Resources Journal.*

Commissioned research papers

Oulahen, G. and Doberstein, B. (2010). *Citizen participation in flood reduction planning: Strategic choices in Peterborough, Ontario.* ICLR Research Paper Series, #47. Toronto: Institute for Catastrophic Loss Reduction. 45 pgs.

Sandink, D., Kovacs, P., Oulahen, G. and McGillivray, G. (2010). *Making flood insurable for Canadian homeowners: A discussion paper.* Armonk, NY: Swiss Reinsurance Company Ltd. 82 pgs.

Presentations

Oulahen, G. (2014). Flood issues in Canada. Presentation to the Ontario Mutual Insurance Association annual meeting. November 18, 2014. Simcoe, Ontario.

Oulahen, G. (2014). Social vulnerability to flood hazards in Metro Vancouver, Canada. Integrated Disaster Risk Management (IDRiM) Society Conference. November 1, 2014. Western University, London, Ontario, Canada.

Oulahen, G., Mortsch, L., Tang, K., and Harford, D. (2014). Unequal vulnerability to flood hazards: "Ground truthing" a social vulnerability index of five municipalities in Metro Vancouver, Canada. Canadian Risk and Hazards Network (CRHNet) Symposium. October 23, 2014. Toronto, Ontario.

Oulahen, G., Mortsch, L., Tang, K., and Harford, D. (2014). Unequal vulnerability to flood hazards: "Ground truthing" a social vulnerability index of five municipalities in Metro Vancouver, Canada. Canadian Association of Geographers conference. May 27, 2014. Brock University, St. Catharines, Ontario.

Oulahen, G. and Joakim, E. (2014). Integrating social vulnerability and resilience: Challenges and applications in Metro Vancouver. Presentation to Coastal Cities at Risk meetings of local public and private practitioners. February 6-7, 2014. Simon Fraser University, Vancouver, British Columbia.

Mortsch, L., Oulahen, G., and Joakim, E. (2013). Social vulnerability to climate hazards in Metro Vancouver, Canada. Presentation to IDRC Coastal Cities at Risk conference. February 8, 2013. Manila, Philippines.

Oulahen, G. (2012). Global changes and catastrophic loss. Presentation to annual meeting of Engineers Canada. September 15, 2012. Quebec City, Quebec.

Oulahen, G. (2008). Engaging citizens in flood reduction planning in Peterborough, Ontario. Presentation to the Insurance Institute of Ontario. March 26, 2008. Barrie, Ontario.