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ORIGINAL PAPER

# Determinants of residential vulnerability to flood hazards in Metro Vancouver, Canada

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**Abstract** What influences residents' vulnerability to flood hazards in a Canadian coastal city? This study addresses the question 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: (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. Survey findings offer insights into 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 correlations with variables that define the other determinants. Institutional arrangements, 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 of the study have implications for our understanding of how vulnerability is produced and how, or whether, local policy can address these factors to equitably reduce risk.

**Keywords** Hazards · Flood · Vulnerability · Determinants · Metro Vancouver

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## 1 Introduction

Metro Vancouver is the site of a dynamic human–environment relationship, characterized 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 region 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 (City of Vancouver 2012; City of Surrey 2013). 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, urban 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 paper 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 (2008a, b, 2009), one determinant was examined in other recent flood risk studies (Terpstra and Gutteling 2008; Kellens et al. 2013), and another determinant was unexpectedly found to exist in this study and 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 into how these determinants produce unequal vulnerability to flood hazards.

## 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 (e.g. Burton et al. 1978). Influenced by the call to recognize that political economic structural forces create unequal risk (Hewitt 1983; Wisner et al. 2004) 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. Understanding 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"—is critical to reducing risk (Wisner et al. 2004, 11). People have unequal vulnerability based on these characteristics, which are influenced by factors both internal and external to a

household. It is, therefore, necessary for researchers to look across scales and across actors to investigate how factors related to political economic structural forces, human agency, and place interact to produce vulnerability to hazards. Extending earlier hazards research in this vein, amenity value conflicts and institutional incentives were identified as factors that also affect 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 (2008a, b, 2009) adds ecological knowledge, social vulnerability, place dependency, housing factors, and self-protection as other potential determinants of vulnerability, some of which may apply to flood vulnerability in a Canadian city. Factors identified in other studies that also apply include attribution of responsibility (Terpstra and Gutteling 2008; Kellens et al. 2013) and 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 (Grothmann 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. People living in places exposed to flood hazards tend to value the environmental amenities that such a location provides. Whether it is a nice view of the sea or proximity to a river shore, people usually value the benefits of the location and at the same time, those benefits can increase their risk (i.e. exposure to flood hazards) (Collins 2005; 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 to residents, factors related to insurance take-up include housing tenure, income, and exposure, resulting in uneven benefits achieved by this risk transfer mechanism (Kellens et al. 2013).

Recent research points to other factors that influence vulnerability to flood hazards. Characteristics that affect social vulnerability, like 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), and 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 2006). Another factor that has been found to influence vulnerability to flood hazards is how residents attribute responsibility for flood mitigation. The public often 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 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. Flood hazards, including urban flash flood caused by heavy rainfall, riverine, and coastal, including sea level rise, have emerged as a concern for residents and municipal planning departments. Though a number of Metro Vancouver municipalities have significant exposure to flood hazards, two were chosen for this study. Vancouver and Surrey have the largest populations, have taken policy steps towards reducing flood risk, and have neighbourhoods with exposure to flood hazards and residents with a wide range of socio-economic characteristics. Two neighbourhoods exposed to flood hazards in both Vancouver and Surrey were selected for study: one neighbourhood with relatively high social vulnerability and one neighbourhood with relatively low social vulnerability in each city in order to provide a population with a wide range of socio-economic characteristics (Oulahen et al. 2015). In Vancouver, the study was conducted in the neighbourhoods known as Kits Point (low social vulnerability) and Marpole (higher social vulnerability). In Surrey, the neighbourhoods of Crescent Beach (low social vulnerability) and Bridgeview (higher social vulnerability) were selected as study sites. Both the level of exposure and social vulnerability for each neighbourhood were confirmed by the local experience of municipal planners and engineers. This sampling approach was used in order to learn more about the characteristics of residents living in neighbourhoods where exposure would intersect with high or low social vulnerability in a local flood risk assessment. Municipal representatives agreed that these were appropriate and interesting neighbourhoods for the purposes of the study.

### 3.1 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 study neighbourhoods. An eight-page, 28-item questionnaire was developed, 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. 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 February to April 2013. The neighbourhoods are fairly small, each with approximately 400 homes, and every home was included in the population to maximize the representativeness of the neighbourhood. The survey was hand-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 approximately 29.9 %. 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. Compared to population data of the neighbourhoods, the survey sample over-represents homeowners and under-represents renters, under-represents residents aged 18–30 and over-represents residents aged 65 and older, under-represents residents with a high school diploma or less education and over-represents residents with a university degree, and under-represents residents with an annual household income less than $60,000 and over-represents residents with an annual household income greater than $120,000 (Statistics Canada 2011). This participation bias may not perfectly reflect the perceptions of all residents living in the study neighbourhoods.

## 4 Results and analysis

The survey assessed independent variables representing social vulnerability, hazard perceptions, institutional arrangements, amenity values, self-protection, and attribution of responsibility. Through open-ended survey responses and conversations with residents, another 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 provides survey results of the variables by determinant and an analysis of how these factors influence vulnerability. First, in the interest of improving the operationalization and comparability of flood risk research, detailed tables are included listing the measures, metrics, and descriptive statistics of the determinants of residential flood hazard vulnerability (Kellens et al. 2013). Secondly, resident qualitative feedback, coded according to determinant, is incorporated to provide narratives about how residents perceive the factors affecting vulnerability in their neighbourhood. Thirdly, previous studies have 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 correlations between this contributor to social vulnerability and the other determinants of vulnerability, household income is tested against the independent variables representing the determinants. Statistically significant correlations are identified for each determinant ($p < 0.01$ unless otherwise noted).

### 4.1 Social vulnerability

The survey draws on earlier studies to investigate the influence of household socio-economic characteristics on vulnerability to hazards. Table 1 provides the descriptive statistics of respondent characteristics.

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 Reusswig 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, which was especially evident 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 for elevated construction in flood prone areas 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.

**Table 1** Social vulnerability

| Social vulnerability | *n* | Percentage |
|---|---|---|
| Housing tenure | 460 | |
| Own | 394 | 85.7 |
| Rent | 66 | 14.3 |
| Sex | 448 | |
| Male | 221 | 49.3 |
| Female | 227 | 50.7 |
| Age | 449 | |
| 18–30 | 17 | 3.8 |
| 31–45 | 73 | 16.3 |
| 46–64 | 203 | 45.2 |
| 65+ | 156 | 34.7 |
| Education | 448 | |
| Some grade school or high school | 16 | 3.6 |
| High school graduate | 35 | 7.8 |
| Some post-secondary | 51 | 11.4 |
| College or trade certificate or diploma | 84 | 18.8 |
| University degree | 262 | 58.5 |
| Total household income | 350 | |
| <$30,000 | 31 | 8.9 |
| $30,001–$60,000 | 84 | 24 |
| $60,001–$90,000 | 73 | 20.9 |
| $90,001–$120,000 | 55 | 15.7 |
| >$120,000 | 107 | 30.6 |

> 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 city-wide policy intended 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.

### 4.2 Hazard perceptions

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 whether they have previously experienced a flood; less than 8 % of respondents reported they have experienced a flood in their current home. The median perceptions of the hazards were quite low, with the three highest perceived hazards at just above a moderate level of concern (Table 2). Respondents' perceptions of flood hazard were fairly 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.

Respondents indicated a higher perception of climate change impacts than hazard risk (Table 3). Almost 90 % of participants agreed that they think the climate is changing. Nearly two-thirds (62 %) of the 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 whether there are more frequent and severe rainfall events now than there were 20 years ago.

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 (Grothmann and Reusswig 2006; Siegrist and Gutscher 2006; Keller et al. 2006). A Crescent Beach resident described, "We live in a sea-

**Table 2** Perception of hazards

| Perception of hazard[a] | *n* | M | Median | SD |
|---|---|---|---|---|
| Flood | 445 | 3.04 | 3 | 1.51 |
| Earthquake | 452 | 3.52 | 4 | 1.3 |
| Sea level rise | 451 | 3.20 | 3 | 1.43 |
| Wind storm | 444 | 2.71 | 3 | 1.25 |
| Landslide | 442 | 1.53 | 1 | 1.03 |
| Wildfire | 442 | 1.43 | 1 | 0.89 |
| Land subsidence | 439 | 2.43 | 2 | 1.42 |

[a] Metric: 1 = low, 5 = high; range = 4

**Table 3** Perception of climate change impacts

| Perception of climate change impacts[a] | *n* | *n* of "Don't know" | M | 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 | 1.0 |
| 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 | 1.19 |
| 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 |

[a] Metric: 1 = strongly disagree, 5 = strongly agree; range = 4

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 said rhetorically, "We know we are vulnerable. We have a dike 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 worth noting this shared perception that although their neighbourhoods are exposed to flood risk, the government will provide them protection when necessary, is held by residents who live in neighbourhoods with quite different social vulnerability.

Negative correlations were found to exist between residents' perceptions of hazards and household income. Specifically, perceptions of flood, earthquake, and subsidence risk had correlations 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 are consistent with the findings of previous studies (Lindell and Hwang 2008; Zhang et al. 2010).

### 4.3 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. A total of 93 % of respondents reported that they purchase property insurance (Table 4). When asked whether 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 whether 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

**Table 4** Institutional arrangements

| Institutional arrangements | *n* | Percentage |
|---|---|---|
| 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 |

their home from natural hazards. This statistic is revealing, and disappointing, 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.

Regarding local government institutional arrangements, only 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 policy 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 study 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.

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 $= -0.16$).

### 4.4 Amenity values

Survey participants were asked to indicate the level of importance they place on a number of residential amenities in response to the question: "Why do you choose to live in this neighbourhood?" (Table 5).

Natural environment benefits and neighbourhood safety are the two most important influences on participants' residential choices. More than two-thirds (70 %) of the

**Table 5** Amenity values

| Amenity values[a] | *n* | M | 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 | 1.5 |
| 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 |

[a] Metric: 1 = low, 5 = high; range = 4

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… 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 is of high 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 indicated 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 might 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

**Table 6** Self-protection

| Self-protection | *n* | Percentage | M | Median | SD |
|---|---|---|---|---|---|
| Knowledge about mitigation actions[a] | 449 | | 2.56 | 3 | 1.19 |
| Preventing damage is a high priority for me[b] | 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 | | | |

[a] Metric: 1 = not knowledgeable; 5 = very knowledgeable; range = 4

[b] Metric: 1 = strongly disagree; 5 = strongly agree; 23 respondents replied "Don't know" to this question; range = 4

they could not consider it affordable at its current higher resale value. These comments highlight that although a neighbourhood may be unaffordable for most people, there are some homeowners who have lived for an extended time in the neighbourhood who may not have the same level of income as many of their new neighbours. This discrepancy has implications for categorizing vulnerability of a neighbourhood as a single value, as is commonly done in social vulnerability indexes.

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).

### 4.5 Self-protection

The survey had several questions directed at assessing respondents' attitudes and actions towards protecting their homes from flood damage (Table 6).

Almost half (47 %) of the respondents indicated that they had no or little knowledge of mitigation action they could take to protect their home from flood damage. 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 the 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 the 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 the respondents indicated that they have no opinion or do not know whether preventing damage is a high priority for them, so some apathy or indifference also does exist in these neighbourhoods. Another 27 % said they disagreed that it is a high priority for them. Only one-quarter (25.5 %) of the 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.

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).

### 4.6 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). 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 1 shows 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.

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 fulfil 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.

Significant correlations were found between several variables identifying attribution of responsibility and household income. A positive correlation exists between household

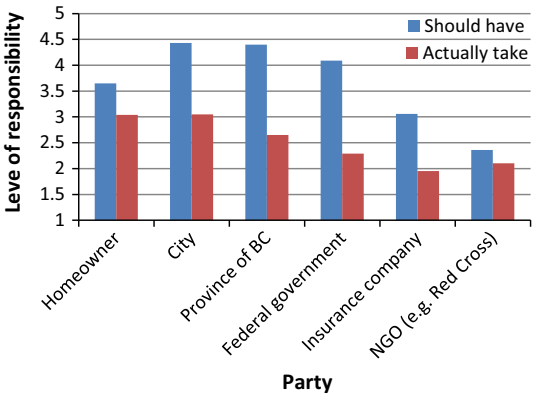


**Fig. 1** Perceived level of responsibility each party should have versus actually takes

income and the level of responsibility residents think that the homeowner should have for preventing damage from natural hazards (correlation = 0.2). 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, −0.2, −0.12, and −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).

### 4.7 Attenuation of risk due to another dominating concern

In analysing the findings of the 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. 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:

> …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 increasingly 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:

> 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 such as 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.

## 5 Conclusions

The seven determinants investigated 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 correlations 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 might appreciate. Institutional arrangements 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, appear to have uneven impacts on residents in the study neighbourhoods. The intention of both of these arrangements 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 incentives. 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' (2008b, 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 illustrate that Collins' (2008b) 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 incentive 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 (currently a popular practice) in Crescent Beach will need to abide by the regulation. Furthermore, many residents noted the perceived 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 might 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; Oulahen 2015). 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 interact to produce 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 other factors that influence the vulnerability of residents. The findings of this study offer an empirical look at what factors influence residents' vulnerability to flood hazards in a Canadian city and how unequal vulnerability is produced. A commonly held view, appealing to what are perhaps popular Canadian values, might 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 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 whether a more transformational approach is required (Collins 2009b; Pelling 2011).

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