

Wading through the Muddy Floodwaters:

Social Vulnerability to Flooding in Northfield, MN, a Case Study

Zoe Craig, Matt Jaquette, Colleen Stewart, Jia Yang

Comprehensive Project

Advised by Kimberly Smith and Tsegaye Nega

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Carleton College

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Abstract

Many researchers have studied social vulnerability in coastal cities and at large scales, yet few have conducted investigations on a smaller scale. This study characterizes the current social vulnerability to flooding of Northfield, Minnesota, a small river town using the frameworks of Blaikie et al.'s (1994) social vulnerability definition and Cutter et al.'s community resilience dimensions (2008). Our methodology combines archival and interview analysis. Archival analysis illustrates that flooding has often been a risk to the economy, infrastructure, and people of Northfield. Interview analysis, through the lens of experts, residents, and business owners, shows how the community anticipated, coped with, resisted, and recovered from recent flood events. We generated 15 factors to characterize Northfield's current social vulnerability to flooding, which generally fit into Cutter et al.'s dimensions (2008). We argue that Blaikie's et al.'s (1994) definition and Cutter et al.'s (2008) dimensions are helpful frameworks to examine social vulnerability to environmental hazards in small communities. We also make policy suggestions for Northfield based on our 15 factors. We hope this study provide insights into flood management and research for Northfield and other small towns in Minnesota.

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I. Introduction

Flooding has always been an important issue for communities along the Mississippi River. During the Great Flood of 1993, approximately 54,000 people were evacuated due to floodwaters that covered 20 million acres of land across nine states (USGS “Missouri Water Science Center”). Due to climate change, the magnitude and frequency of floods has recently increased, impacting numerous communities by making them more vulnerable to flooding (Miller 1996). Northfield, Minnesota, located along the Cannon River, is one of these communities.

As flooding has large impacts on communities, researchers have used assessments of social vulnerability to understand affected communities’ risk and resilience to flooding. Although a term with various definitions across different disciplines, we define social vulnerability as “the characteristics of an individual or group that impact their ability to anticipate, cope with, resist, and recover from a natural hazard” (Blaikie et al. 1994). Most social vulnerability assessments are done at a large scale, such as for coastal regions and cities (Cutter and Emrich 2013). Few studies have applied social vulnerability theories to smaller communities, such as that of Northfield, to see whether they hold true independent of the size of the study area. Moreover, most social vulnerability assessments use quantitative approaches. It is important to use a qualitative approach to understand how social vulnerability is actually experienced by affected individuals and communities. This qualitative study examines *what characterizes Northfield’s current social vulnerability to flooding as seen through individual residents’ and the community’s ability to anticipate, cope with, resist and recover from floods?*

We begin by reviewing scholarly literature on social vulnerability and flooding on the Mississippi River. We then summarize Northfield’s historical encounters with flooding. We analyze interview data through Blaikie et al.’s framework (1994). We then compare the 15 factors we find to Cutter et al.’s dimensions (2008). We suggest that these factors: *Flood Knowledge, Equipment, Economic Resources, Property Design, Community*, are the most important ones to characterize Northfield’s current social vulnerability. We conclude that the frameworks of Blaikie et al. (1994) and Cutter et al. (2008) are helpful tools to examining social vulnerability at small communities. We end by making policy suggestions based on the 15 factors we find.

II. Literature Review

Vulnerability

The term vulnerability has different definitions across disciplines, but broadly speaking, it is the potential for loss from environmental hazards (Cutter 1996). There are two dominant ways to conceptualize vulnerability. The first regards it as the potential exposure of a community to an environmental hazard. Researchers with this perspective study the distribution of hazardous conditions, as well as the way they affect people and society. The second perspective seeks to isolate the patterns of differential losses among affected people. Researchers with this perspective study the potential coping ability of individuals or communities, including the ability to withstand the damage of a hazard and to recover quickly from that damage. Based on these two perspectives, Cutter (1996) and Cutter et al. (2000) demonstrated a third approach--vulnerability of places--in which vulnerability is both a biophysical risk and a social response within a specific geographic area. Many researchers have used this third approach in studies that range in size from local to national contexts (Wu et al. 2002). In our study of social vulnerability, we adopt the second perspective to understand the ability of the Northfield community and

individuals to anticipate, cope with, resist, and recover from flooding.

Considering these different ways of conceptualizing vulnerability, it is not surprising to find vulnerability models that vary in explaining the root causes of vulnerability. The vulnerability models cited most often include: (1) Blaikie and Wisner et al.'s pressure and release model (Wisner et al. 2004); (2) Turner et al.'s (2003) vulnerability/sustainability framework; and (3) Cutter and Cutter et al.'s hazards-of-place model of vulnerability (Cutter 1996; Cutter et al. 2000). Blaikie and Wisner et al.'s (2004) pressure and release model goes through the progression of vulnerability from root causes to dynamic pressures to unsafe conditions, but it does not address the coupled human-environment system in relation to hazard exposure. Turner et al.'s (2003) vulnerability/sustainability framework uses a place-based approach in which local vulnerability is seen within the larger contexts that influence it, but it does not include a temporal dimension that shows when vulnerability begins and ends. Cutter's hazards-of-place model integrates biophysical exposure and social vulnerability, but it does not explain the root causes of the social vulnerability prior to the disaster or post-disaster impact and recovery (Cutter et al. 2008). Studies should aim to address the root causes of social vulnerability throughout a hazard event and contextualize it within history, policy, and the human-nature dichotomy. This study combines the frameworks of Blaikie et al. (1994) and Cutter et al. (2008) in an attempt to characterize social vulnerability at a more holistic scale. Vulnerability can be described in both biophysical and social terms, which we will describe in the following sections.

Biophysical Vulnerability

Flooding is the last stage of the hydrologic cycle and is caused by oversaturation of the land by precipitation (Hey and Philippi 1995). There are two key biophysical factors that influence floods: climate and floodplains, which have both changed over the last several hundred years. Current and future climate change influences the flood regime of large rivers. Research suggests that climate change is increasing the risk of 100-year floods (i.e. one percent chance of a flood occurring in a given year), as it leads to more intensive precipitation events, increased summer dryness, higher minimum temperatures, and an increase in mean peak discharges (Milly et al. 2002; Tockner and Stanford 2002). Groisman et al. (2004) studied changes of the hydrologic cycle over the United States and observed that precipitation, temperature, stream flow, and heavy precipitation have all increased during the twentieth century, especially within the past three decades and in the northern and eastern regions of the United States (Hubbard et al. 1997; Groisman et al. 2004). Within Minnesota, there has been a 25-30% increase in precipitation since 1970, resulting in higher base flow of streams. Warmer winters have led to a decrease in early spring flooding, and increased frequency of high intensity storms in this area has been linked to larger floods (Madigan and Kallestad 2014). See Appendix D for figures modeling this shift in precipitation and baseflow.

Floodplains mitigate flood events by acting as buffers, storing massive amounts of water during a flood and then slowly releasing it over time (Zedler 2003). In the Midwest, the construction of levees and the draining of wetlands for agricultural purposes have isolated and destroyed most floodplains (Galat et al. 1998; Hey and Philippi 1995; Tockner and Stanford 2002). In Minnesota, floodplains decreased by 40% from 1770 to 1980 (Zedler 2003). The effects of floodplain loss are manifested in erratic river levels, larger and more frequent major floods, and fewer stable low-water summers (Sparks et al. 1998).

Social Vulnerability

Definition

Although a term with various definitions, we describe social vulnerability in terms of Blaikie et al.'s definition, which is widely cited in social vulnerability literatures (1994). The definition is:

the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by a discrete and identifiable event in nature or in society (Blaikie et al. 1994; Bara 2010).

According to this definition, we identify the four-stage framework through which we examine social vulnerability as: (1) anticipate; (2) cope; (3) resist; and (4) recover. While this definition is widely cited in social vulnerability literature, these four stages are not clearly defined. Using existing literature, we created succinct definitions for each stage and constructed our interview questions and analysis around these definitions (Blaikie et al. 1994). We define (1) anticipate as occurring before a flood event. It includes one's ability to be aware of a coming flood, either through interpreting cues from the environment or through warning systems. It also incorporates one's ability to prepare for future flooding. We define (2) cope as occurring during a flood event. It includes one's ability to process what has happened, and to handle stress and disaster-related problems, such as defense mechanisms. We define (3) resist as occurring before, during, and after a flood event. It includes one's ability to minimize the damage from the current flood event and to prevent damage from future flooding. We define (4) recover as occurring after the flood event. It includes one's ability to cleanup and get back to daily lives. By using this framework, we identify social vulnerability factors that are present at each stage for Northfield.

A wide variety of factors, including: gender, age, disability, family structure and social networks, housing and built environment, income and material resources, and race and ethnicity (Wu et al. 2002), have been identified in social vulnerability assessments. In the next section we will illustrate the different methods for describing social vulnerability, which includes this system of isolating relevant factors.

Social Vulnerability Assessments

There are two main approaches to assessing social vulnerability. One is quantitative, typically involving constructing a composite index of social vulnerability, such as the Social Vulnerability Index (Cutter et al. 2003). The other approach is qualitative, and often consists of interviews and focus group discussions (e.g. Tapsell et al. 2002). In addition, there are assessments that use both of these approaches, such as the Vulnerability and Capacity Assessment developed by the International Federation of Red Cross and Red Crescent Societies, which involve methods such as statistical analysis and interviews (Bara 2010).

Among these approaches, quantitative methods are most often used. However, using a quantitative approach has several limitations. First, a composite index can lessen the importance of a single vulnerability factor, which could skew the results if that factor shows extreme vulnerability (Rygel et al. 2006). Second, vulnerability assessments often fail to acknowledge differential vulnerabilities within the unit of analysis (Bara 2010). Third, there are many complex and interrelated factors affecting vulnerability that could not be easily translated into a quantitative approach (Alwang et al. 2001). Fourth, quantitative social vulnerability assessments tend to use demographic data, which is collected at a large scale. The smallest unit available in

the United States is block group data, which consists of tens or hundreds of people. Therefore, the area of interest is usually large cities and coastal regions, and it is rare to find quantitative social vulnerability studies focusing on small towns. Due to these limitations, we decide not to use quantitative methods in our research.

Accordingly, we use a qualitative approach to examine Northfield's current social vulnerability for several reasons. First, since we summarize a factor's importance based on the knowledge gained through conducting interviews, it is unlikely that an extremely important factor would be left out. Second, since our interviews are targeted at individuals, they might reveal facets of vulnerability that a quantitative approach could not reach. These facets might characterize how individuals and the community anticipate, cope with, resist, and recover from flooding. We also choose to look at newspapers to learn about Northfield's historical encounters with flooding. Several studies (e.g. Wu et al. 2002, Kleinosky et al. 2007) have investigated social vulnerability using a similar approach.

Resilience

In addition to using Blaikie et al.'s (1994) definition of social vulnerability, we also make use of Cutter et al.'s dimensions for assessing disaster resilience at a community level when analyzing our results (2008). These dimensions are Community Competence, Social, Infrastructure, Economic, Institutional, and Ecological, as illustrated in Table 1. According to Cutter et al., Community Competence highlights those attributes of places that promote population wellness, quality of life, and emotional health. Social resilience is influenced by factors such as communications, risk awareness, preparedness, and the development and implementation of disaster plans. Infrastructure resilience includes both the physical systems themselves such as the number of pipelines, as well as their dependence and interdependence on other infrastructure. Economic resilience typically includes property loss and post-event business disruption. Institutional resilience addresses how organizations manage or respond to disasters. Ecological resilience is influenced by factors like biodiversity and management plans (2008).

Although these dimensions concern resilience, we use them to study Northfield's current social vulnerability because Cutter et al. define resilience as the ability of a social system to respond to and recover from disasters, as does our social vulnerability definition (2008). Researchers formed these dimensions based on aggregated studies and they have not been widely used as a framework; this study is one of the first case studies that does so.

Table 1. Community Resilience Dimensions (modified from Cutter et al. 2008).

Dimension	Variables
Community Competence	Local understanding of risk, counseling services, absence of psychopathologies, health and wellness, quality of life
Social	Demographics, social networks and social embeddings, community values-cohesion, faith-based organizations
Infrastructure	Lifelines and critical infrastructure, transportation network, residential housing stock and age, commercial and manufacturing establishments
Economic	Employment, values of property, wealth generation, municipal finance/revenues

Institutional	Participation in hazard reduction programs, hazard mitigation plans, emergency services, zoning and building standards, emergency response plans, interoperable communications, continuity of operations plans
Ecological	Wetlands acreage and loss, erosion rates, % impervious surface, biodiversity, # coastal defense structures

Gap in Literature

Only a few social vulnerability researchers have worked with qualitative methods or studied social vulnerability at a smaller scale. Moreover, researchers have rarely used Cutter et al.'s dimensions to study a community's social vulnerability (2008). This study uses interviews of people in Northfield to characterize its current social vulnerability. We use Blaikie et al.'s (1994) social vulnerability definition and Cutter et al.'s community resilience dimensions as our frameworks (2008). We also conduct archival newspaper research to learn about Northfield's historical encounters with flooding. We hope our research will provide insights on studying social vulnerability at the scale of small towns and will be useful to policymakers reviewing Northfield's flood management system.

History and Policy of Flooding

“The Mississippi River will always have its own way; no engineering skill can persuade it to do otherwise...” (Mark Twain 1940)

This study uses a historical perspective to understand current flood problems and policy in both the US and Northfield, Minnesota. In this section, we briefly outline the history of floods in the US. Human control of American rivers began when the first European trappers and settlers came to America. As settlement increased, there was a corresponding increase in agriculture and infrastructure surrounding rivers. Wetlands were viewed as impediments to economic development, and so, were converted to farmland. These events led both to changing floodplains and to flooding becoming a problem for those who lived near rivers because those wetlands had filled an important role in water storage. The natural reaction was for communities to move the problem of flooding downstream. This was accomplished by creating levees. For the past 200 years, levee building has been the biggest flood control policy in the US (Hey and Phillippi 1995).

The first federal policy concerning flood control occurred in 1928 as a reaction to the 1927 Mississippi River flood. Named the Lower Mississippi Flood Control Act, this policy aimed to reduce flooding through the federally funded construction of levees. Occurring around the time of the Great Depression, this act also sought to increase employment and economic development as part of Roosevelt's New Deal (Platt 1986). Between 1927 and 1978, the US government spent \$14 billion on 900 levee and flood control projects, with 6000 miles of levees and floodwalls and 8000 miles of channelization (Camillo 2013).

Meanwhile, studies beginning as early as 1852 showed that levees may cause flood problems. Debate over the issue was not fruitful, mainly because structural solutions, such as levees, were more economically feasible than natural methods of flood mitigation, such as storage ponds (Platt 1986; Hey and Phillippi 1995). In terms of economic and developmental gain, limiting river boundaries gave more room for agriculture and urban expansion. Moving entirely away from rivers was not treated as an option because economically desirable lands were

often close to water sources (Lansford and Jones 1995; Ma and Swinton 2011).

Similarly to levee building, the nationwide Flood Insurance Program encouraged increased infrastructure on floodplains (Pinter 2005). Created in 1968, and modified in 1969, 1973, and 1994, the program was created to try and stem the tide of increasing floodplain development and limit the costs of flood disasters (US Congress 1966). Citizens with buildings in the Federal Emergency Management Agency (FEMA) floodplains could choose to participate in this program by buying flood insurance. There was a debate over the usefulness of this program because while many believe it is based on a long-term plan, others argue it is incomplete and has flawed methods (Burby 2001). In 1986, Platt argued that the Flood Insurance Program was ineffective because it encouraged the settlement of land on floodplains by minimizing flood risk with a simple insurance fee (1986). Between 1970 and 2000, extensive development occurred in areas with high flood risk (Mileti 1999). Following the Great Flood of 1993, the population within inundated areas increased by more than 23% (Hipple 2005).

More recently, higher awareness has resulted in a shift in flood policy away from the engineering of “river correction” towards a model of living with rivers (Zaugg 2002; Stockum 2002). The debate over the success of canalizing and straightening rivers, which started over a hundred years ago, has recently increased. Alternatives to levees have been developed, such as action plans that focus on longer storage and slower release of water (Van Leussen et al. 2000; Werritty 2006). Since the late 1970s, organizations, such as the Association of State Floodplain Managers, have urged the US government to reduce levee building and start working with rivers. They call for a policy in which the actions of one place do not adversely affect the flood risks of another (AFSPM 2013). Related policies include the destruction of levees to flood agricultural land instead of cities, the federal purchasing of repeatedly flooded lands, and the relocation of regularly flooded towns (Frank 2011). These solutions present social and environmental problems, demonstrating that more comprehensive plans need to be developed. Social vulnerability studies may help inform policy makers creating these new solutions, which is significant due to increasing flood damage.

Increasing Flood Damage

Increasing flood damages have been associated with social, climatological, and geological factors. The most significant factor has been global climate change, which has led to changing precipitation patterns in the US (Hamburger 1997). Increased flooding has been perceived in newspapers and among the public as caused by heavy rainfall, which has led to the overtopping of riverbanks and breaching of levees (Prince 1995).

Another explanation for increased flood damages is the increase in population growth and development around rivers (Kerwin and Verrengia 1997). Many place the blame on unsuccessful federal policies, such as extensive levee building (Coyle 1993), while others think damages would be much greater without the nation’s success in its current flood policies (Labaton 1993). According to Morss, changing flood risk is caused by social factors, such as development in and near floodplains, land surface change, community response, and social vulnerability (2005).

Climate, population growth, development, and policy each play a significant role in increased flood damage. However, these factors are still poorly understood. The role of each of these has increasingly been recognized in literatures surrounding flooding in the academic community. Yet, it has not been as apparent in the media, which has led communities in the US to have a poor understanding of flooding. We hope to address this debate on increased flood damage by examining social vulnerability to flooding in Northfield, through Blaikie et al.’s (1994) and Cutter et al.’s frameworks (2008).

III. Case Selection

Northfield, Minnesota is located in Rice County on the Cannon River watershed, a subset of the Mississippi River watershed. As of 2010, US Census data shows that the town has a population of 20,007. The racial makeup of Northfield is 88.8% White, 1.3% African American, 3.5% Asian, and 0.2% American Indian and Alaska Native (US Census Bureau). Northfield is home to two colleges—St. Olaf and Carleton, and its downtown is centered around the Cannon River, which is controlled by a floodwall and hard infrastructure. The floodwall is made of porous limestone, with its western side lower than the eastern side (Interviewee D, pers. comm.). Heath Creek and Spring Creek, both small tributaries to the Cannon, flow through residential neighborhoods and are covered by FEMA floodplain maps. The Carleton College Arboretum surrounds the river, and is largely affected by flooding. It creates a space for the floodwaters to spread, which may help minimize downstream flooding (Interviewee G, pers. comm.). In the 1970s, a river walk, which is a sidewalk alongside the Cannon River, was created in the town to foster a greater involvement with the river (Interviewee K, pers. comm.). The town has experienced three large floods in the last four years: in 2010, 2012 and 2013 with discharges of 20500 cfs (cubic feet per second), 19500 cfs, and 11400 cfs, respectively (See Appendix D). The Cannon River watershed and the city of Northfield have not been studied in relation to the social impacts of flooding.

Northfield has frequently been impacted by flooding, on both large and small scales, throughout its history of growth and expansion. Northfield's current floodwall was built in the year 1900 as a reaction to flood damage ("Flood Insurance Study" April 03, 2012). This follows a national pattern; where flood mitigation plans attempt to control rivers with hard infrastructure (Platt 1986; Hey and Phillippi 1995). These walls are occasionally breached by floodwaters, causing both economic and social damage. Some of Northfield's policies reflect the idea of reconnecting with rivers, such as the creation of a river walk, and the encouragement of Northfield residents to create natural water storage areas in their own backyards (Interviewee K, pers. comm.).

We choose Northfield for the location of our case study, as it is both an important and an atypical case. Northfield is an important case because the town is currently deciding what changes to make to its flood mitigation and response policies. With the record breaking 2010 flood and flash flooding during the summer of 2013, flooding is an issue that is fresh in Northfield residents' minds. After a disaster, there is a brief window of opportunity where public interest in natural hazard mitigation increases and citizens are more likely to engage in the planning process (Godschalk et al. 2003). The Northfield City Council has responded by creating a committee to address flooding and decide the future direction of Northfield's flood management policies. Past social vulnerability research has been used to aid governmental bodies and other organizations in allocating resources for reducing vulnerability (Eaken and Luers 2006). We hope our study informs city planners and policy makers about the nature of Northfield's flooding to help them effectively allocate resources.

Northfield is atypical from a theoretical perspective. The majority of social vulnerability literature focuses on coastal cities (Wu et al. 2002; Cutter and Emrich 2013) or on the impacts of flooding on a much larger scale (Cutter et al. 2000; Tapsell et al. 2002; Fekete 2009), while our study assesses the social vulnerability of Northfield, a small town that is affected by recurrent natural disasters (US Census Bureau). Moreover, Northfield is a typical small town in southeastern Minnesota built around a river. The methods and results of our study can be used to

study social vulnerability in other small river towns in Minnesota.

IV. Methodology

Archival Analysis

Kasperson et al. (1988) and Mileti et al. (2004) explain that the presentation and communication of risks influence how they are perceived and understood. Newspapers are one of the ways in which information about disasters are communicated. They provide detailed information about these disasters in the context of time and place. Written by a range of people, they also incorporate a breadth of views (Carvalho 2008). As primary sources, newspapers are able to tell the history of a place, such as how it has experienced flooding.

From preliminary research, we identified the floods of 1965, 1993, and 2010 as having large impacts at either the local or regional scale. We then expanded our archival research to include the floods of 2012 and 2013 because our interviewees emphasized the significant effect that these recent flood events had on Northfield. We used archival analysis to learn about Northfield's historical flood events from these years. We had access to three newspapers: the local newspaper, The Northfield News, and the two college newspapers, the Carletonian and Manitou Messenger. We read and analyzed all flood-related articles using as a guide the four stages of flooding: anticipate, cope with, resist, and recover. For our analysis, all four investigators read several randomly selected articles and developed a list of factors we encountered. Equipped with this list of initial factors, a primary reader then analyzed all newspaper articles. To validate her findings, a secondary reader analyzed a portion of these articles. While completing this phase of our study, both readers also recorded facts, including who and what was impacted, how they were impacted, where they were, and why the flood event occurred. They also documented names of potential interviewees and paid attention to the cultural construction of flooding.

Semi-structured Interviews

We chose to conduct semi-structured interviews to ensure that our interviews covered the four stages of social vulnerability, but were flexible enough so that interviewees could express more tangential opinions and experiences on flooding. In conducting such interviews, an interviewer not only asked questions directly from an interview protocol, but also tailored them to the interviewee's response (Dicicco-Bloom and Crabtree 2006). We used a snowball sampling method by reaching out to the Northfield Senior Center, the Northfield Historical Society and six local places of worship. From these places, we compiled an initial list of people to contact as potential interviewees. This list then expanded as we asked interviewees for recommendations on additional people to speak with in Northfield (USGS "Snowball Sampling").

We divided our interviewees into two groups. One group was experts, including people from the Northfield Police Department, City Council, Public Works, Cannon River Watershed Partnership (CRWP), Carleton College Arboretum, Carleton College Geology Department, Carleton Athletics, and Carleton Facilities. The other group was non-experts, including residents and business owners. We structured both interview protocols through Blaikie et al.'s social vulnerability definition (1994). We asked about the floods of 1965, 1993, and 2010 as well as any additional floods interviewees recalled (See Interview Protocol in Appendix A). In expert interviews, we asked about how the community anticipates, copes with, resists, and recovers from these flood events. In non-expert interviews, we asked about how the residents went through these four flood stages. In addition to asking questions, we also asked each interviewee

to fill out a short demographic form to provide context on our sample of interviewees (See Demographic Information Form in Appendix B).

We conducted and recorded interviews on the Carleton College campus or in the interviewees' home or place of business. For the two interviews where the audio recorder malfunctioned, we wrote a summary of what the interviewee said and conducted a short follow-up interview. We transcribed interviews using an online tool called "Transcribe," which allowed us to easily slow down recordings and insert timestamps.

To analyze the transcripts, two investigators worked on expert interviews, while the remaining investigators worked on non-expert interviews. Each researcher independently read all transcripts in their section and looked for factors that appeared at the four stages of anticipate, cope with, resist, and recover. Each group of researchers then compared their results and validated that they had identified the same factors. Later, the entire research team compared factors from both expert and non-expert interviews. Originally, we collectively identified more than 20 factors. We grouped many of these into larger factors and agreed on a list of 15 factors that characterize Northfield's social vulnerability. We then categorized these final factors into Cutter et al.'s six community resilience dimensions (2008).

V. Results

Flood Narrative

Development of Cannon River and Northfield

The Cannon River watershed, 941,000 acres in size (Madigan and Kallestad 2014), was created by glacial snowmelt 14,000 years ago. Resting on bedrock, groundwater provides the base flow of the river, and as a gaining river discharge increases as it goes further downstream. Large rocks "which are probably not mobile under any reasonable present discharges" provide evidence of prehistoric flooding on the Cannon River (Interviewee B, pers. comm.). Historically, the land surrounding the river was primarily a mix of floodplain forest and wetland ecosystems (Interviewee G, pers. comm.). Since Northfield was founded as a mill town in the 1850s, much of the natural area has been converted to agricultural land and urban-suburban developments. Town development centered on the Cannon "because there were the two mills built here, a saw mill and a flour mill, and that needed the river so we had development along the river" to power the milling industry (Interviewee I, pers. comm.). In the 1850s, large tracts of land in the watershed were converted to wheat farming as part of the "boom in wheat" (Interviewee B, pers. comm.). During this time, most farms were around 160 acres in size, as organized by the Homestead Act, and differed from modern farms as the land was "not really consolidated" and "the agriculture was more varied on the landscape [...] because of the combination of crops and animals" (Interviewee B, pers. comm.).

This is a stark contrast to the modern trend of large monoculture farms, which use agricultural techniques that were not available in the 1850s, such as tiling, mechanical plows, and tractors. In the mid-1900s, agricultural production switched to dairy. In the last 50 years, there has been a shift towards corn and soybean production and an increase in tiling (Interviewee B, pers. comm.). The combination of increased row crop agriculture and a decrease in grazing has led to more bare ground that is ineffective at soaking up spring rains. In the 1850s, the Cannon River followed a meandering path that looked "like ribbon candy [...] with swags and back-ups" (Interviewee A, pers. comm.). By the 1930s the river had a straighter route and a steeper gradient associated with high water velocities. Possible factors associated with this straightening were historic logging, deforestation, and the mill system, which contributed

sediment to the water system and disrupted water flow (Interviewee B, pers. comm.).

By the 1960s, initial settlement and multiple agricultural trends had altered land use in Northfield and the Cannon River followed straighter course and a steeper gradient. In this social and biophysical context, the Northfield community had to weather several severe flood events. Below we expand on the floods of 1965, 1993, 2010, 2012, and 2013. We detail the specific characteristics of these flood events, including why the flood occurred, what its impacts were, how the event was discussed, and how Northfield responded. With these results we describe historical flooding in order to provide context for Northfield's current social vulnerability to flooding.

1965

The flood of March 1965 was caused by a combination of snowmelt, rainfall, and frozen ground. The recorded flow rate of the water was 200,000 gallons per second as water flowed downstream into the Cannon River from the Straight River. While the flood hit Northfield, the regional flood event impacted other towns along the Cannon River and Mississippi River more severely. The early spring timing of this flood meant the community had to deal with ice chunks in the river damaging downtown buildings, and thawing out sewer catch basins in order to drain street water.

According to five newspaper articles, this flood was the highest in the memory of Northfield residents. Northfield News interviewed two long time Northfield residents who had “long observed the antics of the Cannon” and both of them “[couldn't] remember seeing the water at Wednesday's stage of flood.” It acknowledged that the river has been high before, but examples given were floods from almost 80 years prior (the floods of 1888, 1860, and 1866). Downtown businesses on the West side of the river experienced flooding, and other businesses were impacted by interrupted water supplies. Residential houses near the river had flooded basements, the Carleton College athletic fields were flooded, but West Gym was saved by sandbagging efforts. Damage to public property was an issue, with estimated total cost reaching \$15,000 (varying amounts were presented). Transportation was limited because the many unpaved roads became muddy, prohibiting the movement of school buses, the postal service and other vehicles. Most strongly affected by road flooding were people from rural areas, who had trouble getting into Northfield. There was some concern that the flooding would be worse than it was, especially in regards to an ice dam upriver, that, if broken, would have resulted in the flooding of Bridge Square.

Flood response was limited in this flood compared to more recent floods. Similar to other floods, people used pumps to remove water from buildings, and many expected the city to provide these. The city, owning a limited number of pumps, stressed that it was “not in the pumping business”, and charged people the commercial rate for the use of pumps, unless they demonstrated plans to make permanent corrections to their buildings to prevent future flooding. After the flood subsided, flood damage was measured, and little time was spent in discussing flood recovery, how future flooding could be prevented, or the cause of the current flood (Northfield News March 1965; The Carletonian March 1965; Manitou Messenger March 1965).

1965-1993

Between 1965 and 1993, few floods occurred in Northfield. A small flood event occurred in 1969, during which St. Olaf and Carleton helped with sandbagging the river. Newspapers mentioned a debate that happened downtown over whether Northfield should use a hard or soft point flood prevention system, demonstrating awareness of different methods of flood control

(Manitou Messenger 1969).

1993

In 1993, there was flooding across the entire Mississippi River watershed, but this was only a relatively small flood event in Northfield. Newspapers imply that the cause of the flooding in town was large amounts of rain and the floodwaters from the regional flood. Due to lightning, part of Northfield experienced a loss of electricity in the morning hours. Even with the diminutive size of the event, we found similar themes in newspaper articles about flooding.

Flood damage was mostly limited to flooding of Carleton athletic fields, the flooding of several residential basements, and problems with water on the roads. Several trucks and cars were sent into the creek and had to be rescued by the Northfield rescue squad. Farmers also experienced flooding of their fields. Because of limited flood damages, flood response and recovery was small, mainly limited to barricading flooded roads and pumping water out of basements. Northfield received much less damage than other river towns in both the Cannon River watershed and Mississippi River watershed. This flood led to an expanded awareness that Northfield was unprepared to deal with larger flooding. Little mention was given to how to decrease flooding in the future, though one article mentioned the possibility of extending the floodwall one foot higher and plugging drainage holes along the wall (Northfield News July 1993).

2010

The September 2010 flood was a regional flood caused by intense rainfall in the area over the relatively short time period of “36 hours.” The Cannon River rose to a never-seen-before height of 25.2 feet, compared to its usual height of less than 15 feet, and the previous record of 22.2 feet. The extent of damage caused by this flood was larger than ever before, with flooding occurring in 17 southern Minnesota counties. Newspaper articles focused on the damage caused by the flood and ways in which people affected were helped and could get future help. The role of community was emphasized in this flood, as was the need for a better flood mitigation plan, within both short and long term flooding. Newspapers printed a timeline of the rising of the Cannon River and peoples’ reactions to it during the flood event.

Numerous people and places were affected by this flooding, but newspapers mostly focused on downtown business damage. One Northfield resident said that 16 businesses were affected by flooding, some of which had never been impacted by flooding before. Damages ranged from lost business, while the power was shut down, to thousands of dollars of damage to buildings. Several homeowners were mentioned as having flooded basements, because of both river flooding and large amounts of rain. Flood damage was exacerbated by wastewater treatment problems dirtying river water (mainly in the 1965 and 1993 floods) and energy shutdowns caused by power lines underwater. Carleton College suffered \$5.5 million worth of damage to athletic facilities and student housing. Estimates of total flood damage to retaining walls, parks, and other city owned infrastructure was estimated at over \$1 million with the brunt of the damage affecting electrical lines along the riverfront.

Flood response was much larger in this flood than previous floods. Economic resources and losses came up in the descriptions of the loan and flood aid opportunities, coming from different government levels and organizations. Newspapers mentioned Northfield’s Emergency Response plan to protect public infrastructure and safety, but the near flooding of the Safety Center impeded government flood response as many city resources went to saving the building. Thirty-six National Guards were brought to Northfield for law enforcement and flood control.

While an article after the flood event explained, “recovery has just begun,” newspaper articles trailed off within two weeks after the flood event.

Newspapers described how Northfield came “together as a community,” as evidenced by the large number of people who volunteered to sandbag during the flood. The role of the government was also emphasized, especially in relation to resisting future flooding. As a result of the flood, Northfield updated its stormwater regulations to limit runoff from development. FEMA gave a grant to Northfield to reduce their long-term risk to natural disasters, and there was a general sense that people wanted to learn from the flood. The Northfield City Council made recommendations for emergency management training for each department in the city. Problems with response to flooding during the flood event included: a lack of early warning systems, poor water data, and a general sense of being unprepared, partly because water came up higher than predicted by FEMA floodplains (Northfield News September 2010; The Carletonian September 2010).

2012

The flood of June 2012 was a flash flood, with the river rising up 3 feet after 5.88 inches of rain and hail. This flood was not as severe as the flood of 2010 because rainfall was more localized and the Cannon River did not fill with water from other counties. The water level of the Cannon was not high enough to affect downtown businesses, but rain and local topography led certain farmers and homeowners to be flooded. Newspapers did not mention the cause and severity of the flood, which had much less coverage than the 2010 flood.

For the first time there was an emphasis on farm damage, and newspapers conducted interviews with three impacted farmers. These articles stressed the issue of farmers’ livelihoods, as well as the powerlessness they faced in such an event. Homeowners suffered both flooded yards and basements. Ninety people’s basements were waterlogged due to sump pump failures and saturated soil. Similar to past floods, the floodwaters temporarily affected the Carleton College arboretum, the golf course and roads, resulting in stranded motorists due to dangerous road conditions, until water levels subsided after a couple of days. Newspapers emphasized community response and how people helped one another. A flash flood warning was put up in Northfield in case of more rain, and firefighters helped with sandbagging and cleaning up flood damage. Newspaper coverage revealed an awareness of causes to flooding, as seen in references to changing rainfall patterns and lack of natural sponges due to development and farming (Northfield News June 2012).

2013

The flood of July 2013 was very localized, but still caused significant damage because there was a large amount of rain in a short period of time. The Cannon River rose seven feet as a result of the storm. Newspapers often contrasted this flood to the 2010 event. Twenty people were displaced from their homes in this flood, which demonstrates a greater impact on homeowners compared to 2010. Seven of these people were given lodging for three days by the Red Cross, because they did not have anywhere else to go. Roads suffered the brunt of the flood damages with five streets closed for repair or because of dangerous conditions. An article mentioned that terrain changes because of development led to citizens having their yards and basements flooded.

In response to the flood, newspapers posted warnings for closed and dangerous roads. They emphasized the community in helping people cope with the flood, as epitomized in the 150 volunteers that stacked “thousands of sandbags” for four hours along the west side of the river.

Similar to newspapers' coverage of past flooding, floods were portrayed as powerful events. The floodwater was described as "fierce" as it "rips" through trees and "continues to rage." There was flooding in places that had rarely flooded before, and newspapers quoted a resident saying "I have never seen anything like this" and "it has not ever, ever flooded here" (Northfield News June-July 2013).

Current Northfield Flooding

Northfield, which was at a population of 8,600 during the 1970s (Interviewee I), has since grown to 20,007 people (US Census Bureau 2010). This population growth has led to an increase in infrastructure and impervious surfaces along the river, as well as an increase in the number of residents present that may be impacted by flooding. Northfield's changing landscape can currently be described as about 70% agricultural and 3% urban (Madigan and Kallestad 2014). Across both types of land, the city controls runoff with a Stormwater Management plan that is governed by Minnesota's MS4 Municipal Separated Storm Sewer Permit. The Public Works manages stormwater and flooding through structural measures, best management practices, and public education. In 2013, the city of Northfield began a contractual relationship with the CRWP to manage the city's public education and public awareness efforts relating to the local watershed (Interviewee I, pers. comm.).

In January, the National Oceanographic and Atmospheric Administration updated the definition for the amount of rain that causes a 100-year flood from 6.1 inches of rain to 7.37 inches. This means that existing retention ponds are undersized to accommodate water from a 100-year flood, and many ponds cannot be expanded because they are surrounded by developments (Interviewee I, pers. comm.). This is an important limitation of existing infrastructure, as there have been five "mega-rain" events, or events with at least 4 to 6 inches of water, in the last 12 years (Madigan and Kallestad 2014). In an effort to capture stormwater the city of Northfield encourages "slow the flow" practices, such as rain barrels, rain gardens, and planting native prairie (Interviewee K, pers. comm.; Interviewee A, pers. comm.). Also, there are 128 wetlands, ponds, and waterways in the city that are designed to address stormwater through natural means (Madigan and Kallestad 2014). The city recently purchased a 42-acre plot of land upriver to create a new retention pond and increase the town's retention capacity, which cannot be done downtown due to bedrock geology and development (Interviewee A, pers. comm.; Interviewee F, pers. comm.). In Northfield, construction is regulated by a Smart Growth compact development plan "that pursues density and preserves green open space," in order to "put the sponge back that used to be there to collect the water" (Interviewee A, pers. comm.). Moreover, new ordinances encourage low impact development and mandate that an area's runoff rates remain the same before and after construction (Interviewee K, pers. comm.).

During a flood event the community depends on effective planning and the dispersal of relevant information. The Northfield Police Department uses "an all hazards plan, which means you don't specifically say this plan is for flood [...] and that's the beauty of an all hazards plan, it's quickly adaptable to your incident" (Interviewee D, pers. comm.). After the 2010 flood, technology like social media has become important in organizing community response and spreading awareness. The non-profit 5th Bridge has a website where citizens can request help or offer to volunteer in times of crisis (Interviewee A, pers. comm.). The Northfield Downtown Development Corporation works with the community to spread information on storms, such as predicted severity and how to fill a sandbag (Interviewee L, pers. comm.). Northfield's current flood management plan, which has to contend with population growth and increasing rain events, combines natural and structural forms of stormwater management across the entire city.

Demographics

To describe social vulnerability in Northfield, we conducted interviews that draw on residents' experiential and expert knowledge. From this research we determined what factors affect residents' ability to prepare for and respond to flooding. We interviewed a total of 11 experts and 11 non-experts, or home and business owners. We documented several demographic features in relation to the quantitative indicators of social vulnerability that Wu et al. compiled from this field (2002). Our small sample size renders many of these demographic factors irrelevant, but some are important to note due to the general lack of diversity among our interviewees. Future research should address the issue of an overly homogeneous selection of interviewees. The demographics of the non-experts are less important to look at because these people tended not to be vulnerable to flooding in Northfield, beyond a few cases of basement flooding. Our total interview sample was predominantly white and none of the participants were of Hispanic or Latino ethnicity. This reflects the predominantly white demographic of Northfield (88% based on 2010 census), but was viewed as a limitation because being of a minority race is often viewed as making one socially vulnerable (Bara 2010). While it could be that those people who are mainly affected by flooding in Northfield are white, it would require further investigation and the inclusion of, for example, Latino interviewees to substantiate that claim.

Of the 11 non-experts we interviewed, only two were female. The ages of non-experts ranged from 25 to 78. The elderly can be more vulnerable to flooding due to lack of mobility and strength, while younger people may be vulnerable because they have fewer resources to help them in case of a flood event. Seven of the eleven non-experts were married with one or two children. Only two were single with no children and one was married with seven children. There was a wide range in the number of relatives in town for the non-experts, with seven interviewees having 0 to 2 local relatives, and three having between 10 and 50. The presence of family and relatives in town represents a support system that can help one cope with, resist, and recover from a flood, both emotionally and physically. Few interviewees supplied us with their annual income, but with those whom did we found a spread from \$20,000 to \$100,000, representing a variety of income levels. For those of low income, coping with a flood event can be more difficult, due to lack of resources. In future studies, researchers should try to gather data from a larger sample size, which includes a wider range of diversity.

Factors

After conducting interviews with Northfield residents and experts and collecting flood-related articles from historical newspapers, we analyzed these data sources for recurring factors. With this research we determine what factors characterize Northfield's social vulnerability to flooding. We used as a framework Blaikie et al.'s (1994) definition of social vulnerability, which delineates the four stages of disasters as anticipate, cope with, resist, and recover, and Cutter et al.'s six dimensions of flood vulnerability (2008).

Below are the definitions and descriptions of the 15 factors we identified in our analysis. These factors are characteristic of Northfield's social vulnerability to flooding. They were found in our 22 interviews and in our archival newspaper analysis. The factors are organized under the subheadings of Cutter et al.'s six dimensions and listed in order from greatest to least significance (2008). The dimensions framing social vulnerability are: Community Competence, Social, Infrastructure, Economic, Institutional, and Ecological (See Table 1 for descriptions of these dimensions; see Appendix C for a table of our factors).

I. Community Competence

(a) Equipment (This factor also applies to Dimension III. Infrastructure)

“Our basement was flooded, where we do all of our production. So all of our equipment, most of our equipment was impacted by the floods. So our embroidery machines, our screen printing machines, a lot of product was damaged by water.” (Interviewee M, pers. comm.)

This factor is most significant to the resist stage of a flood and encompasses concrete objects, such as sandbags, sump pumps (which help to pump water out of basements), and generators. Using equipment is often the first strategy people employ to prevent damage to property.

In expert interviews, this factor came up for cope, resist, and recover. In the past, Carleton staff has used sandbags to protect the West Gym and the Stadium. More recently, such as for the 2010 flood, the Facilities department built makeshift sand dikes from tarps covered with sand as a faster and less labor intensive barrier to floodwaters. Equipment also helped residents and business owners resist and anticipate flood damage. Several interviewees mentioned that their sump pumps became useless when electricity was shut off during the 2010 flood unless they had generators or gas powered pumps. One major downtown business had a back-up gas powered pump in case electricity was lost during the 2010 flood. Most of the downtown business owners that we spoke with said that after the 2010 flood they bought sandbags to store and use in the event of future flooding.

Sandbags and water pumps were used as methods for protecting homes and businesses from floodwaters for all flood events described in newspaper articles. There has not been much historical change or adaptation of these methods.

(b) Flood Knowledge and Awareness

“We’ve lived here all our life, [in] the rolling hills we know what the water’s going to do [...] We’ve been around and we know where it’s going to go, we know what it’s going to do.” (Interviewee Q, pers. comm.)

This factor is connected to the anticipate and resist stages of a flood and people’s ability to recognize precursors to flooding. In one case, this frequently mentioned factor was associated with coping. Northfield residents’ and experts’ knowledge and awareness of flood-related issues and flood dynamics included the causes, the effects, and the nature of flood events. Flood knowledge could be based on past flood experiences or formally taught, as was the case of some experts. After the flood in 2010, Northfield residents gained experiential flood knowledge and became more sensitive to the risk of flooding due to the destructive effects and unprecedented magnitude of the flood.

In non-expert interviews, experiential flood knowledge was demonstrated through awareness of the weather. Many interviewees for the 2010, 2012, and 2013 floods noted that the heavy rains, which preceded these flood events, helped them anticipate imminent flooding. Other non-experts monitored river levels or were aware how flooding affects their building or land. One farmer found that he was better able to cope with the 2010 flood because past experience taught him that his land is at risk of flooding. Experts tended to have flood knowledge that viewed Cannon River flooding within the watershed context. They mentioned that direct actions like increasing stormwater storage and infiltration upstream could help to minimize flooding downstream. Effectively capturing and filtering stormwater could also improve water quality in rivers and lakes downstream. Experts noted that if Northfield residents see flooding at a

watershed level, they would be better at anticipating and resisting flood events, because this perspective supports implementing comprehensive flood mitigation strategies upriver and at the watershed level.

Flood knowledge and awareness is not mentioned as a concrete phenomenon in newspapers, but there is, in general, increasing awareness about flooding in Northfield, especially after 2010. Yet, flood awareness did not seem to change after the flood of 1965, possibly because there was less damage in this year than in 2010. Often, newspaper articles compare current floods with historic flood events. For all the years we investigated in Northfield newspapers, there was hardly any discussion on what caused flooding or if there had been an increase in flooding. Although newspapers probably intended to promote awareness, there were no concrete recommendations for action or awareness of flooding.

(c) Individual Responsibility

“I can provide you with information on how to build a sandbag wall, but unfortunately I can't provide the resources for it. Some people refer to it as the Hurricane Katrina Syndrome. I've been down in New Orleans, it's, ‘the government will save me,’ and the fact is that you can't rely on that.” (Interviewee D, pers. comm.)

Individual responsibility refers to the implied responsibility of business and homeowners to protect their own private property. In general, the government seeks to raise awareness of property owners of their own responsibilities in planning for, preparing for, and cleaning up after a flood. Experts mentioned that it is the obligation of citizens to take care of their property, and not the government's role. If people are more prepared, they will be less reliant on outside sources and thus they will have fewer damages.

One expert described how, when people lack a sense of individual responsibility they suffer from the “Hurricane Katrina syndrome,” and expect that the government will take care of them in the case of a disaster. Many non-experts were aware of their own responsibility to protect themselves and mentioned how they were self-reliant in handling flooding on their properties. These property owners had detailed plans for how to deal with floods without the help of the government or outside services. However, some non-experts mentioned that in past flood events, there were home and business owners who expected more assistance from the government.

This factor also includes underlying assumptions of what experts refer to as “American culture.” This describes a lack of a sense of responsibility, both to take care of oneself, and others. Rather than thinking about the possibility of a flood, Americans are more focused on personal desires. Although we did not see this within community response to flooding—as many people help business owners during floods, it could be seen in the fact that many homeowners were not aware of how their property affects flooding on other people's properties. It could be difficult to motivate people to make changes to their properties, such as the creation of rain gardens, to reduce runoff.

Individual responsibility is not emphasized in newspapers. We see this concept most clearly in an article during the 1965 flood, which talked about how it was the home or business owner's responsibility to flood-proof their buildings and pay for pumps.

II. Social

(a) Community

“People just showed up to help. I don’t know who. Part of them I’ve never seen. Part of them I’ve never seen them again [...] The community is great. When they have a disaster or something going on, they are here to help.” (Interviewee S, pers. comm.)

Community is most significant to the resist stage and encompasses volunteers, friends, family, strangers, and students. It also includes social media used to organize volunteers, such as 5th Bridge. Interviewees tended to receive different levels of help from various community circles. Help with sandbagging is often from everyone, whereas help with one’s house generally only comes from family and friends. Interviewees tend to agree that Northfield residents have a strong sense of community. Some experts mentioned the significance of communal impact, meaning that when all citizens make small contributions, such as building a rain garden, there are decreased flood impacts across the whole community. Some business owners told us how grateful they were to strangers who came to help. In newspapers community was strongly emphasized, as seen in coverage of the 2010 flood when newspapers documented the community action and urged people to help with cleanup.

III. Infrastructure

(a) Infrastructure

“they should raise [the floodwall], if they are gonna have a wall [...] Because what they do is that they restrict the flow of water, and make it worse for some place else.” (Interviewee S, pers. comm.)

This factor is most significant in the resist stage, but was also associated with anticipation and recovery. Infrastructure includes hard structures that are city owned and maintained, such as bridges, roads, and floodwalls. The floodwall is lower on the west bank of the river. Therefore the floodwaters breach this side of the wall first and cause significant flood damage. Some experts argued that raising the floodwall could cause additional damage downstream by speeding up water flow. Moreover, as Northfield’s wall is made of porous material it is not an effective solution to flooding. A higher floodwall negatively impacts community members and tourism by blocking the scenic view of the Cannon River. Yet, some non-experts proposed raising the floodwall because at its current height they are not protected from large flood events. For example, during the 2010 flood the floodwall directed more floodwater toward the businesses on the west side of the river.

Newspapers also proposed raising the floodwall to protect the downtown from flood damages.

(b) Land Use (This factor also applies to Dimension IV. Economic and Dimension VI. Ecological)

“...the dominant effects on flooding has to do with tiling and in the conversion of wetlands into agriculture, so it’s not so much the particulars of the crops as the conversion [...] into cropped areas.” (Interviewee B, pers. comm.)

Land use is mentioned in relation to the anticipate and resist stages and is only discussed in expert interviews. This factor describes how Northfield’s social vulnerability to flooding was affected by agriculture and development, including residences and impervious surfaces like roads and driveways. Native vegetation and wetlands have the most water storage capacity, while developed land has increased runoff rates due to the clearing of native plants, agricultural tiling,

and a higher percentage of impervious surfaces. Discussions of flood damage often focus on the downtown because this area is hit hard by the floodwaters and sustains very visible damage. This attention fuels storm water management plans for regulating businesses' runoff rates. However, equal attention should be placed on residential plots, which tend to have higher runoff than commercial ones because there is currently less regulation in these areas.

According to the expert interviewees, increased ability to anticipate flooding is tied to awareness that developing natural land decreases the area's water storage capacity and causes a corresponding increase in flood risk. For example, the CRWP works with farmers to teach them how to minimize runoff through agricultural buffers and how to capture precipitation by creating terraces. The connection between the resist stage and land use can be seen downtown where there is currently no way to capture water and mitigate flooding because the area is almost entirely impervious surfaces.

The factor of land use was not very developed in newspaper archives. In all studied years articles mentioned, but did not focus on, how floods affected farmed land differently than developed land. Interestingly, there was little mention of agricultural damage in more historical floods, possibly because of the nature of past floods. In more recent years, specific damage to farmers came up more frequently in articles. Newspapers did not mention how development and increasing impervious surfaces affect flooding until recent years.

(c) Property Design

“we raised the floor, raised the windows, get a new type of barricade. We put in more permanent sumps [...] Now, we have seven sumps. And, they are all wired individually. We have a control panel in here, where they automatically switch to a generator outside, so [...] everything is totally different now.” (Interviewee S, pers. comm.)

This factor is connected with the anticipate, resist, and recover stages of flooding and describes features of houses, businesses, and private properties that affect how a building is impacted by a flood. These features are often built in anticipation of future flooding, but also include historical designs of buildings and how they affect flood impact. This factor includes raising possessions off of the ground, remodeling parts of a property, and adding renovations to a building.

This factor was mentioned in expert interviews in relation to Carleton buildings and individual homes. For example, after the 2010 flood, Carleton installed flood doors in the West Gym to prevent water from entering the building. In general, property owners are encouraged to make structural changes to their property to resist impacts of future flood events. In non-expert interviews property design tended to be mentioned more by businesses than households. After the 2010 flood, one business owner replaced plate glass windows with glass blocks, installed a floodgate, and moved the boiler, air conditioning, and electrical utilities out of the basement. Farmers also talked about changes they made to help their fields resist flooding, such as installing pipes to drain water off their land faster and building small berms or terraces on sloping land to slow water down, reduce erosion, and increase infiltration.

Property design was not mentioned in newspapers, though there was a story of how people living in a tent experienced major flood damage.

IV. Economic

(a) Economic Resources

“[[flood insurance has] always very specific rule or covers. It’s very limited. It’s very expensive. I figured that even if I spend a couple of hundred thousand dollars on here, I probably save another two hundred thousand dollars by not having flood insurance.” (Interviewee S, pers. comm.)

This factor is most significant to the recovery stage and describes the economic resources of the city, homeowners, and business owners. It encompasses flood insurance, crop insurance, loans, grants, relief funding, and paid employees.

Experts mostly mentioned this factor as a way to recover from damage their home or business properties sustained during flood events. For example, the Northfield Downtown Development Corporation is currently writing grant proposals to receive funding for research on the local watershed and citywide changes related to flooding. Economic resources also helped residents and business owners recover from flooding by paying for the costs of cleaning up and replacing equipment. However, grants often take a long time to arrive. Generally, there was confusion among non-experts as to who could purchase flood insurance and what it covers. There was an impression that is not affordable and has limited coverage. A downtown business owner decided *not* to purchase flood insurance, because its cost would be greater than the costs of cleaning up. After the 2010 flood, several business owners have bought flood insurance.

Economic resources, mostly used to handle damage, were also relevant to newspaper coverage, especially the floods of 1965 and 2010. In 1965, there was no mention of city, state or federal aid for affected people. In 2010, newspapers placed more emphasis on money coming in the forms of aid and grants. Additionally in recent years, the issue of farmer’s livelihoods has started to be recognized.

V. Institution

(a) Flood Mitigation Plan

“We had people, so we had resources, we had planning and I think that allowed us to execute against that plan with those resources and that ultimately led to [...] an outcome that was probably as good as you’re gonna get with that type of an event.” (Interviewee R, pers. comm.)

This factor is associated with the anticipate and resist stages of flooding and includes how businesses, homeowners, and the city as a whole make plans for dealing with flood events. It encompasses plans at all scales: for individuals, businesses, Carleton, and the city. Flood mitigation plans are designed in anticipation of future flooding and incorporate a system for monitoring the Cannon’s river levels both in Northfield and upstream. Flood mitigation plans also help people resist flooding by prompting citizens to have necessary resources at the ready, to form plans on how to use their resources, and knowing where and how to access any additional resources. The 2010 flood acted as an impetus for people to either create or make changes to their flood mitigation plans.

Expert interviewees discussed how the city and some businesses had plans prior to 2010, but because of the exceptional size of the 2010 flood these plans were not designed to handle a flood of that magnitude. After the flood the city reexamined its all-hazards plan, which includes methods for response, recovery and mitigation of disasters. After 2010, Carleton’s monitoring plan was put into writing, and the Carleton Facilities department created a new plan that corresponded specific stages of flood response with rising river levels.

In non-expert interviews, flood mitigation plans focus on resisting the effects a flood

event may have on an individual, and place less emphasis on the community wide impact of a flood. Businesses are more likely than homeowners and farmers to have flood mitigation plans. One business by the river had, and implemented, a plan for their property which helped them respond to the flood with the resources they had and minimize the damage sustained by their property. Their plan is designed to be executed in 24 hours, and includes river monitoring, sandbagging, using pumps to evacuate water, isolating where they can get another pump if necessary, and shifting employee manpower to where it is most needed. Newspaper archives mentioned flood mitigation plans of the city briefly, but without details in 2010 and 2013.

(b) Flood Warning System

“Now the problem is, I can't tell them what to do, and I also can't provide them resources, I can notify them. But that's half the battle - notification.” (Interviewee C, pers. comm.)

Flood warning systems, on both an individual and systematic level, were most important within the anticipate stage of a flood, but were also relevant to the resist and cope stages. This factor deals with how individuals or the city anticipate if and when a flood is coming and communicate this to the rest of the community. Within resisting and coping, a flood warning system gives home and business owners as well as the government more time to prepare for a flood and hopefully decrease the severity of flood damages. This factor includes technological devices, such as gauges that monitor river levels.

In general, flood warning systems have become more systematic since the flood of 2010. As a direct result of the 2010 flood, two gauges were put on the Cannon River. Before 2010, the river was monitored indirectly by watching the water levels, being in contact with people upstream, and relying on the experience of a hydrologist. The National Weather Service is also instrumental in flood warnings, as they post flood watches and warnings. The notification system to communicate flood warnings has also improved. Before 2010, the police department used business lists to get in contact with at-risk businesses by calling or going door to door. A new system, called Everbridge, has since been put in place, which uses phone-calls, texts, and emails. The police department can stipulate which areas of Northfield receive the notification, which is valuable in responding to localized flooding. The texting system does have some limitations though, as it only works through certain phone services.

Individual property owners often have their own ways of predicting floods, as does Carleton College. Often these are not highly regimented systems and simply include watching the weather and water levels of the river, as well as keeping track of flooding upstream. Other non-experts in Northfield learned about the flood via news reports, radio, or calling the police department.

This factor was rarely mentioned in newspapers other than a call in 2010 for the city of Northfield to create a better warning system.

(c) Government Services and Jurisdiction

“Water knows no political boundaries.” (Interviewee I, pers. comm.)

“it was good having the National Guard outside of our door. They were [...] very responsive to the needs of the business people, doing what they could to help.” (Interviewee M, pers. comm.)

This factor is prominent in both expert and non-expert interviews, and applies to the

anticipate, cope, resist, and recover stages of flooding. It encompasses the services that the government provides and which governmental body the services come from. Many home and business owners accept that it is not the government's responsibility to protect their property from flooding, yet those who suffered more flood damage expressed a desire for more government services and support (See *Individual Responsibility* in Dimension I).

Within non-expert interviews, this factor addresses what the government can do and has done to help them. In 2010, the National Guard helped business owners with flood resistance by filling sandbags and helped one owner cope by keeping his building secure, while he aired the moisture out of his business. The city crew assisted one owner with the recovery process by taking sandbags and other recyclable material away from his business after the 2010 flood. In talking to different government employees, we found a complicated flood mitigation system that one expert described as “an inter-jurisdictional nightmare” (Interviewee A, pers. comm.). They expressed a desire for increased communication through an intergovernmental committee at the watershed level. Within the government a lack of both power and resources can limit their response to property owners' concerns. For example, the city's building codes can only effectively minimize stormwater runoff if they are followed properly. Also, citizens may look to the police department for postings on flood warnings, but in actuality this is the responsibility of the National Weather Service. It is the police's responsibility to provide security to the community and the government's to protect public property.

Government services include: helping with sandbagging downtown, protecting public buildings, ensuring public safety by closing roads and reacting to emergency calls, and creating opportunities for discussion through community meetings. In the past the police helped to warn the community about an oncoming flood by knocking on doors and calling at-risk businesses, but after the flood of 2010 they switched to an automated warning system (See (b) *Flood Warning System*). Flood mitigation also occurs through both state and city mandated regulations on developers and the creation of natural and non-natural systems of stormwater management (See (f) *Stormwater Management*). As part of the national government, this factor is also dependent on the actions of FEMA and the National Guard.

Government services were mentioned in newspaper archives for all the years we investigated, although the frequency and significance of this factor increased in more recent years compared to 1965. In 1965 the governmental role was small, while in 2010 the government played a large part in flood anticipation, coping, resistance and recovery. Newspapers presented an increasing awareness to organize government roles and jurisdiction in flood management, because different sectors have specialized responsibilities.

(d) Location

“We found out in 2010 we had to worry about other locations as well. If that river kept on coming, or if we got another rainstorm [...] Greg and I went and looked at elevation charts and the next building that would have gotten water would have been the lower level of Goodhue. So people could have been out sandbagging buildings while water was coming another location [...] Anyway that's what that flood taught us, is we couldn't just worry about the spray along the banks of the river; we had to start working upstream.” (Interviewee H, pers. comm.)

This factor is connected with the anticipate, cope, and resist flood stages, and describes how the physical location of a place impacts if and how it is flooded. The factor location is related to both topography and proximity to the Cannon River. Since flooding from the Cannon has severe and highly visible effects on the properties adjacent to the river, people living at those

locations are often better able to anticipate future flooding. Homes on lower ground may also be impacted by stormwater runoff from neighboring property on higher ground.

In expert interviews location affected people's ability to anticipate and resist flood impacts. An insurance agent we interviewed noted that, in 2010, the majority of the claims filed with their firm were from residential homes, demonstrating that flooding is prevalent outside of the areas immediately adjacent to the Cannon. Residents can be flooded due to their proximity to lakes and retention ponds, from heavy rain events that oversaturate the ground, or from poor landscaping that leads to runoff and water accumulation on their property. In non-expert interviews we found that businesses next to the river were generally aware that their location makes them vulnerable during flood events. One downtown business owner has prepared for flooding through property design, equipment, and planning because he is aware of his vulnerability to flooding. Two interviewees have homes that are not near the Cannon River, but they both experienced disastrous flooding during large rain events because water ran onto their property due to the surrounding topography.

In archived newspapers, location was emphasized in how buildings close to the river are more often damaged by floods. Starting in 2010, and to a higher degree in 2012 and 2013, there was an acknowledgement that flood damage also occurs in locations not near the Cannon River. In all years, newspapers mentioned how a property on top of a hill will experience less flood damage compared to downhill properties.

(e) Politics

“So here we are, 50 years later and the river's flooding because [...] our solution was to dump the rainwater, stormwater, into the river as quickly as possible, but I think, maybe there's a new paradigm of how do you handle stormwater [...] Trying to handle the stormwater where it falls [...] and trying to, you know, retrofit our existing system bit by bit to more appropriately handle the stormwater is the solution” (Interviewee L, pers. comm.).

Politics is connected to the anticipate, cope, and resist stages of flooding. This factor is only mentioned in expert interviews, and not to any great extent. Politics impacts Northfield's social vulnerability because power dynamics in the community affect how flood mitigation plans are created. In the City Council these plans are determined by elected officials' votes, and the current paradigm for how the council attempts to decrease flood damages.

Around 50 years ago, the template for the town's stormwater task force was to move water off the land and into the river as quickly as possible. Now, the task force is trying to retrofit the town to capture the water where it falls. The consensus among conservative and liberal leaders is that flooding has changed and become a significant problem for the city to contend with. This was expressed by a member of Northfield's Downtown Development Corporation, who said, “Over the last five years we have (...) to my knowledge” experienced “three 100-year floods” (Interviewee M, pers. comm.). A City Council member believes that reform in flood mitigation can only happen when a majority of the council believes that effective mitigation combines natural and man-made forms of stormwater management. The council holds open town meetings, which allows their constituents to express opinions and concerns relating to flood mitigation plans.

This factor may be fairly opaque because while City Council meeting minutes are accessible to the public, flooding is usually discussed as an act of nature rather than an issue that can be regulated by policies. Politics are associated with anticipation because city organized

education programs shape the community's awareness of flooding. They are related to resistance because the city dictates which forms of structural flood mitigation are used. They are related to cope because city preparation and education affects how citizens make decisions to limit damage to their property during a flood event. Political processes were not discussed in newspaper archives, except in brief mentions of City Council meetings and their recommendations for future action.

(f) Stormwater Management

"I am very excited about the regional park. I'm most excited about natural features as an element of integrated development and stormwater mitigation. So that it's not incumbent on the downtown businesses to take care of something that should be taken care of upriver."

(Interviewee A, pers. comm.)

Stormwater management relates to the anticipate and resist stages of flooding and is only discussed in expert interviews. This factor includes both natural and structural flood mitigation techniques that aim to capture and slow the movement of stormwater, which comes from both precipitation and snowmelt. Flooding does not only occur along riverbanks, so this factor also involves understanding the hydrology of local watersheds. Flood events are an indicator that precipitation in the watershed has pushed the area beyond its collective water storage capacity.

Experts described how the community's ability to anticipate flooding depends on their understanding of the area's hydrology. Northfield has developed an understanding of how much water the area can hold and how floodwaters require a place to spread once they breach riverbanks or exceed groundwater levels. Natural flood mitigation techniques include buying property and taking it out of development to create regional and local parks, storage ponds, natural and restored wetlands, and natural berms. At an individual scale the CRWP promotes the creation of rain gardens and catching stormwater in rain barrels (See *Individual Responsibility in Dimension I*).

This factor was briefly mentioned in newspapers often separate from flood events, such as an article before the 1965 flood about how conservation practices of farmland could reduce flooding. We see city stormwater management explored in brief detail in 2010, but it was not until 2013 that flooding was mentioned as a watershed problem that should be addressed on a larger scale.

VI. Ecological

(a) Changing flood regimes / Character of flood event

"I think that the increase in total precipitation, but more especially the increase in the frequency of high intensity storms [is the main reason flood intensity has increased]."

(Interviewee B, pers. comm.)

This factor is related to all four stages of flooding: anticipate, cope, resist and recover, and is key in determining who is vulnerable to flooding and to what degree. Flood impacts are determined by water quality, time of the year, whether a flood is localized or regional, speed of onset of a flood, location in watershed (Cannon River versus Spring Creek), size of the flood, and the cause of the flood: storm, upstream rain, or ice melt. This factor also includes the current changing regimes of flooding in Minnesota, which is attributed mostly to climate change.

Since 2010, there has been increased awareness of changing flood regimes among both expert and non-expert interviewees. There has been an increase in rainfall in the spring and fall

and a decrease of rainfall in the summer. These shifts contribute to flood events occurring at atypical times of the year. As winters have become milder, snowmelt has become less of a contributing factor. Meanwhile, the quantity and intensity of large rain events has increased by an estimated 25 to 30% since 1970, leading to a larger number of floods with an often unexpected level of intensity. Especially during 2010, the unprecedented size of the flood event left people unprepared for the resultant flood damages. At Carleton College the floodwaters hit previously unaffected areas of campus. Moreover, the timing on the flood in the fall made cleanup after the flood more difficult because of oncoming winter weather. Farmers are more vulnerable to flooding because fall is harvesting time. Fall flooding events are often faster because farms are entering their dormant period, and so vegetation cannot store or impede the movement of floodwaters. The speed of a flood alters citizens' ability to prepare, meaning with additional time it is easier to resist and cope with a flood.

The area's storage capacity for precipitation has an impact on the size and duration of a flood event. In the event of a thunderstorm floods can cause more damage because the associated loss of electricity hinders response and recovery. Recovery can also be altered by the frequency of floods and the cleanliness of the floodwater. Interviewed business owners stressed the difficulties of cleanup after a flood event because dirty water leads to contamination and possibly additional damages. As climate change impacts flood regimes and the character of floods existing flood knowledge needs to be expanded to account for new flooding characteristics.

Newspapers addressed the character of each flood event and how this affected Northfield residents. The degree and location of damage in Northfield varied between different historical floods. The character of the flood event was mainly discussed in terms of size, although season and location (localized or regional) of the flood event are also mentioned. Changing flood regimes was only discussed when increasing rainfall was regarded as the cause of a recent flood.

VI. Discussion

In the first section, *Characterization of Social Vulnerability In Northfield*, we discuss the five factors we identified in interviews as the main characteristics of Northfield's social vulnerability to flooding. In the second section, *Relevance to Surrounding Literature*, we compare our factors to Cutter et al.'s community resilience dimensions (2008) demonstrating that the social vulnerability theory applies to smaller communities. However, we acknowledge that these dimensions and Blaikie et al.'s (1994) four stages are interconnected and do not have distinct boundaries. We discuss the importance of incorporating biophysical and historical contexts into social vulnerability studies. In the third section, *Application*, we use the five main characteristics of Northfield's social vulnerability to make policy suggestions in relation to local flood management.

Characterization of Social Vulnerability in Northfield

Our research aims to identify the characterizing features of Northfield's social vulnerability to flooding. By asking experts and non-experts about Northfield's and their own abilities to anticipate, cope with, resist, and recover from floods, we identify 15 factors that describe different aspects of Northfield's current social vulnerability to flooding. Among these factors, *Flood Knowledge*, *Equipment*, *Economic Resources*, *Property Design* and *Community* are found to be particularly characteristic of Northfield's social vulnerability (See Appendix C for a table of our factors). Our interviewees emphasized these factors as being the most important in describing how Northfield has anticipated, coped with, resisted, and recovered from flood

events. These factors were also mentioned in the largest number of interviews, reflecting their importance towards describing Northfield's social vulnerability. Their importance is briefly described below:

As a factor, *Flood Knowledge*'s importance stems from how it informs early flood warnings, characterizes information about disasters, and is widely accessible as a means to decrease one's social vulnerability. *Flood Knowledge* was the primary way that many residents and business owners were able to anticipate incoming flood events, as well as the nature of these events. Prior experiences of flooding inform *Flood Knowledge* and provide Northfield with information about the characteristics of flood events. This helps individuals and the city know where to focus their efforts and resources so that they will be most effective in minimizing flood damages.

Equipment is a characterizing factor because of its widespread use and ability to effectively reduce damages. Sandbags are utilized by businesses and the city, and almost all at-risk buildings use sump pumps to resist flooding. In cases where equipment fails, damages tend to be more severe.

The factor *Economic Resources* was emphasized by interviewees when discussing recovery from monetary damages caused by flooding, such as impacts to buildings and equipment. Northfield business owners and residents navigated the array of resources available to them in different ways to try and ease recovery.

Property Design was emphasized by interviewees as a way to resist flooding, though only in response to previous experiences of flooding. Both experts and non-experts discussed the renovations that they performed after a flood so that their properties would be better protected against future floods.

Interviewees frequently mentioned *Community* as an important factor for helping people resist and recover from the physical damages of flooding. Nearly all businesses and households that were affected by flooding received help from the community at some level, either with resisting a flood event or cleaning up after it. *Community* is one of the factors that we identified as being most characteristic of social vulnerability in Northfield because of its widespread accessibility to these citizens and the emphasis placed on it by interviewees. We are surprised, then, to find it mentioned in only 11 of 22 interviews.

Relevance to Surrounding Literature

Our study adds to social vulnerability literature by applying the field's theory to an atypical case. Social vulnerability research tends to focus on large cities as well as large isolated disasters (Cutter et al. 2000; Tapsell et al. 2002; Wu et al. 2002; Fekete 2009; Cutter and Emrich 2013). By analyzing flooding in Northfield, Minnesota, we bring social vulnerability theory to a smaller scale, as Northfield is a small town and flooding affects small portions of the population. Additionally, Northfield experiences some degree of flooding annually, though not always at disaster levels. Our study concludes that, despite these differences, social vulnerability theory can be applied to smaller communities like Northfield.

Out of the existing literature on social vulnerability we chose to compare our results with Cutter et al.'s dimensions (2008) because they were identified from multiple studies on community resilience to environmental hazards. We find that the majority of our factors correspond with the broader dimensions identified by Cutter et al. (2008). This demonstrates that social vulnerability theory can still function when applied to smaller communities and more localized disasters than are traditionally studied.

Table 2. Factors we identified grouped into Cutter et al.'s dimensions (2008).

Dimension	Factors
Community Competence	Equipment, Flood Knowledge and Awareness, Individual Responsibility
Social	Community
Infrastructure	Equipment, Infrastructure, Land Use, Property Design
Economic	Land Use, Economic Resources
Institution	Flood Mitigation Plan, Flood Warning System, Government Services and Jurisdiction, Location, Politics, Stormwater Management
Ecological	Changing Flood Regimes, Land Use

By looking at a small case, we find that localized disasters have community impacts that tend to be overlooked by social vulnerability studies conducted at a larger scale. Quantitative social vulnerability assessments are limited by the resolution of available data. This data is often only accessible at the scale of thousands of individuals when using census groups or block groups. At this scale the vulnerability of the individuals being affected by scattered flood events is blurred with the vulnerability of the rest of the community, especially if the data being used to describe flooding does not include these localized flood events (for example, FEMA flood zones). Additionally, social vulnerability research needs to be conducted at the scale at which management occurs in order to be useful for making policy suggestions (Eakins and Luers 2006). If small communities, such as Northfield, are to address social vulnerability they need results that are appropriately scaled to be incorporated into policy changes. We suggest that it is important for social vulnerability studies to be conducted at small community levels to address disasters, and individuals suffering from them, that have been previously overlooked.

We found an example of an overlooked flood type in our study of Northfield. In addition to the more recognized downtown river flooding, many people encounter another type of flooding that is not restricted to the areas near the Cannon River or within the FEMA flood zones. The recent floods of 2012 and 2013 are examples of this type of flood. These floods are isolated events that are difficult to predict and affect disparate areas and individuals. Despite the impact they had on Northfield residents, the city is less aware of these localized flood events and they have not been the focus of the flood conversation. We found that individuals responded to both kinds of flooding in very similar ways. These smaller floods are an example of a serious disaster, which affects a relatively small area and therefore is generally missed by social vulnerability research, which focuses on large events.

A central question of social vulnerability research is how to identify and evaluate the diversity of stressors most relevant to a social vulnerability assessment (Cutter 2003). In our research, we became aware that features important in characterizing Northfield's social vulnerability can best be understood at a larger theoretical scale, and not within factors or stages of social vulnerability (e.g. Blaikie et al. 1994, Cutter et al. 2008). Dividing social vulnerability

into distinct categories oversimplifies the reality of the situation.

This can be most clearly seen in how the factors *Equipment* and *Land Use* did not fit into the divided dimensions of Cutter et al.'s theory (2008). *Equipment*, as understood in relation to its importance to Northfield's social vulnerability, applies to both Infrastructure and Community Competence as described by Cutter et al. (2008). *Land Use* applies to Ecological, Economic, and Infrastructure, but cannot be fully described by any one of these dimensions. While these dimensions are helpful for understanding this complex theory, it is important to remember that the factors influencing social vulnerability are highly interrelated and may be relevant to multiple dimensions. This can be also seen in how the four stages of anticipate, cope with, resist, and recover (Blaikie et al. 1994) often merge with each other and thus these stages of flood response are not always distinct.

According to Adger (2006), in a review of social vulnerability literature, a challenge researchers face is how to develop robust and credible measures of social vulnerability that incorporate diverse methods and include perceptions of risk and vulnerability. We were limited in our study by the challenge of how to describe social vulnerability holistically. When isolating factors related to the four stages of social vulnerability (Blaikie et al. 1994), some biophysical and historical facts had to be omitted and instead included in our flood narrative. To include perceptions of risk and vulnerability, which often came up in interviews, we had to expand the stage anticipate to also include awareness. We argue that these frameworks need to be comprehensive and incorporate additional disciplines that relate to social vulnerability, such as historical and biophysical research.

Biophysical processes have a large effect on the social characteristics of a community. How these interact impacts how much and in what way a population is socially vulnerable. Many researchers have recognized this connection. Resilient ecosystems and resilient societies can better cope with external stresses, such as natural disasters (Blaikie et al. 1994; Stabinski et al. 2003; Turner et al. 2003). In our research we see this most strongly reflected in our *Changing flood regimes / Character of flood event* factor; yet it was difficult to fit this factor into any of Blaikie et al.'s stages (1994). An example of a model that could be better equipped to incorporate biophysical research into the conversation surrounding social vulnerability is Blaikie and Wisner et al.'s pressure and release model, because their model explicitly locates social vulnerability at the intersection of biophysical and social pressures (Wisner et al. 2004).

Social vulnerability definitions also need to incorporate historical context because the past has shaped communities' current interactions with environmental hazards. In our research we found that the 2010 flood was a catalyst for flood conversations, yet this result did not fit within our framework of Blaikie et al.'s definition (1994) or Cutter et al.'s dimensions (2004). Therefore, we had to create a flood narrative in order to include historical information in our study.

The importance of historical analysis has previously been recognized in vulnerability assessments. Bohle et al. (1994) as well as Blaikie et al. (1994) recognize that ability to cope with future disasters and environmental change is rooted in a full understanding of the complex structures and causes of present vulnerability. This recognition did not translate into a clear emphasis on history within the frameworks of Cutter et al. (2008) or Blaikie et al. (1994).

Historical context is significant, especially in understanding how the existing flood management paradigm informs Northfield's social vulnerability. We found that flood management in Northfield is shaped by the historical human-nature dichotomy. In the past, Northfield's system of stormwater management and desire for economic stability led the

community to control the Cannon River by constraining its banks and waters. Yet, this has led to increased flood problems along the river and disrupted natural spaces and ecosystems (Interviewee B, pers. comm.). An increased understanding and awareness of how biophysical factors have historically affected social vulnerability might help to lessen the classic human-nature dichotomy found in the history of flood mitigation in the US. Thus, we suggest that social vulnerability assessments need to incorporate historical context.

Social vulnerability should be applied to smaller communities, such as Northfield. The problems we encountered with social vulnerability methodology were not dependent on the size of our case study, but rather are representative of larger issues within the field of social vulnerability. We suggest that these limitations could be addressed by incorporating historical and biophysical contexts into the theoretical framework. Once social vulnerability research expands to include these contexts it will be better suited to inform policy.

Application

The findings of our study have implications for Northfield as well as other cities. In the face of climate change and the increasing frequency of severe floods, it is vital to conduct research on how flooding impacts small towns. Considering Northfield's recent revision of flood plans, it is our hope that city planners and policy makers will incorporate our findings into the ongoing conversation about how Northfield is to thrive as a river town in the midst of disastrous flooding. The 15 factors we found characterize how Northfield residents and businesses experience social vulnerability during floods and should be included in the flood conversation, particularly the factors of *Flood Knowledge, Equipment, Economic Resources, Property Design* and *Community*.

Based on these factors, we present several recommendations for policy makers in Northfield. First, we have two proposals related to community programming through the CRWP and 5th Bridge. We recommend expanding the recent partnership made between the city of Northfield and CRWP regarding educational programs. These expansions would include covering flood insurance education, how individual citizens can hold runoff on their property and thereby decrease flood impacts to the watershed, and recommendations for vulnerable citizens and business owners to create their own flood mitigation plans. Flood mitigation planning can be done with the help of citywide workshops that teach citizens how to create a communication system that they could use to reach a network of community members and volunteers. Another valuable lesson could cover budgeting and instruct people on how much money they should try and save before each flood season.

5th Bridge is the new online hub for organizing and recruiting community members to help out during a flood. This website could be expanded to include an equipment share program, to urge volunteers to assist during flood cleanup, and to develop a list of vulnerable Northfield citizens that currently lack a community support system (such as the elderly). Community members have demonstrated their dedication to helping people during a flood event; yet vulnerable homeowners often receive little support because the flooding that impacts them occurs outside of central areas, such as downtown. Volunteer support lessens dramatically during the time of flood cleanup after the initial fervor of community flood resistance and sandbagging has passed. It would be useful to have a system that facilitates people's access to equipment. In our study we found that equipment is an important factor to resisting and recovering from a flood. Often the companies that currently provide equipment are not able to handle demand during a flood event.

Second, we have four recommendations regarding government organization and city

infrastructure. The city of Northfield has been considering creating a watershed-wide inter-jurisdictional committee to deal with flooding. We would strongly recommend this collaboration because we perceived a lack of communication between different government sectors and organizations in town. An inter-jurisdictional committee could help to increase and improve the conversation surrounding flooding. Fostering communication between different towns in the Cannon River watershed is key in addressing flood mitigation holistically because flooding occurs at the scale of the watershed, not just the town. Moreover, this committee can provide some oversight and make sure the actions of one town do not adversely affect another. Moving the city's transformer to higher ground farther from the river would limit the risk of a power outage during a flood. However, we do not know how feasible this shift would be. Power outages have resulted in large damages for property owners and a loss of the ability to resist flooding on their own. Research should be done to see if there is a connection between power outages and larger amounts of damage or a more vulnerable population overall. Although we would like to make a recommendation specific to the Northfield floodwall, more information would be needed concerning how this might impact downtown Northfield as well as areas further downstream. If the city chose to raise the floodwall, then we would advise the government to stress that the wall is a temporary solution and it is not a comprehensive flood mitigation technique compared to stormwater management. The floodwall is a structure that speeds water flow creating downstream consequences and ignores the reality that floodwaters operate at the watershed level.

Third, we would advocate for stricter development mandates for building new houses and neighborhoods. Developers should not only build flood proof homes if they are in vulnerable locations, but also pay attention to how landscaping might lead to the collection of water or runoff in a certain area. Older buildings that are commonly flooded could also benefit from renovations to reduce basement flooding and runoff. More research needs to be done on how this might be incentivized and whether or not a mandate for this would be fruitful.

We will be giving the audio recordings and transcriptions of our interviews to the Carleton College library to be archived. The library has been compiling a digital collection of photos, flood data, and oral histories relating to the 2010 flood ("Northfield Flood 2010"). Recordings of our interviews could be used by other research groups or by government and community members to further the understanding of flooding and social vulnerability in Northfield.

While this study is very specific to Northfield, our results and policy suggestions are likely applicable to other small river towns in the region. Towns or centers of population that are located adjacent to or around a river that periodically floods may also experience many of the factors we identify. However, because each case is unique these factors may be manifested in different ways or degrees of relative importance.

VII. Future Research

Our study provides a preliminary exploration of social vulnerability to flooding in Northfield, Minnesota. However, it is limited in its scope and could be expanded with further research. Future studies could conduct more interviews that successfully capture the diversity of the study area's population. Our snowball sampling method produced an extensive list of people to interview, but due to time restraints we did not interview all of them. To get a fuller picture of the Northfield community it would have been advantageous to contact other types of community hubs to find people that could speak about historic flooding, such as the Veterans of Foreign

Wars (VFW). Additionally, our interviewee sample was relatively homogeneous. Given that quantitative studies have shown how race, age, and income significantly influence social vulnerability the diversity among our interviewees should be improved upon in future studies. The demographics of our interviewees are not representative of young people or of Northfield's Hispanic population. We assumed that the owners of businesses along the river would be best at speaking about how their businesses were affected. Therefore, we did not interview any of the employees of these businesses whose livelihoods may have been disrupted by floods. By interviewing a homogenous group of individuals, our findings may miss important variations in characterizing Northfield's social vulnerability.

In our archival analysis we encountered problems with the accessibility of newspaper archives. Articles between 1988 and 2011 for the St. Olaf newspaper, Manitou Messenger, were inaccessible because they had not yet been archived by the college. Also due to time limitations, we were unable to conduct an analysis that included all articles that discuss historical floods in Northfield; instead we selected five specific flood events. Future studies could analyze all flood events to create a more comprehensive image of historical flooding in the town, rather than shaping the study around a select set of floods.

Other methods for studying social vulnerability to flooding in Northfield might include increasing the sample size of the study by sending out surveys instead of conducting interviews. This study provides an initial assessment of what characterizes Northfield's social vulnerability. Future studies could use the 15 factors we identify to create a community survey and provide a quantitative assessment of the relative importance of these factors. Sending a survey to a large sample size would also be an efficient way to capture the variance in social vulnerability of Northfield.

When determining if the results of this study can be extrapolated to other communities, we found that expanding the number of cases would increase the comparative value of our study. Investigating other small towns in the Mississippi River watershed might help to verify that the factors we identified in Northfield are applicable to other cases. Expanding the geographic extent of the study would also yield interesting insights. By confining our research to the Northfield area, we were able to focus on a singular community, but failed to address the watershed scale at which flooding occurs. Investigating social vulnerability at a watershed level and the directional nature of river systems could show important spatial relationships regarding social vulnerability to flooding.

While our study is limited in its variance and its scope, it does provide a preliminary exploration of the factors influencing Northfield's social vulnerability. The 15 factors we identified are valuable to conversations regarding flooding in Northfield. Our study establishes the basis for using Cutter et al.'s (2008) community resilience dimensions in future research and demonstrates its relevance in studying social vulnerability in small towns.

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IX. Appendix

Appendix A: Interview Protocol

Typical Community Members

1. Which of these 3 floods did you experience: 1965, 1993, 2010?
 - Are there any other floods that come to mind?
 - What do you remember most about these floods and why?
2. What are your memories of these floods?
 - How were you affected by the flood?
 - Did you anticipate the flood?
 - How did you cope with the flood? (psychological - personally deal with the effects)
 - What did you actively do to minimize the impacts of the flood? (Resist)
 - How did you recover from the flood?
 - How long did these flood events impact your daily life?
 - Why?
 - Do you feel connected to the downtown area of Northfield which is often hit hardest by these floods?
3. Can you tell us about how your home (or apartment / rooms) are at risk of flooding?
 - During one of these floods?
 - Compared to different parts of town?
4. Can you tell us about how your neighbors, family, or friends were impacted by these floods?
 - What about your experience do you think was different from that of your neighbors or other citizens of Northfield?
 - Are you involved in a community that could provide help during a crisis?
5. Do you think the floods have changed, and if so, how?
6. Is there anything else you would like to mention that we did not cover?

Expert

1. Which of these 3 floods did you experience: 1965, 1993, 2010?
 - Are there any other floods that come to mind?
 - What do you remember most about these floods and why?
2. What are your memories of these floods?
 - How were you affected by the flood?
 - Did you anticipate the flood?
 - How did you cope with the flood? (psychological - personally deal with the effects)
 - What did you actively do to minimize the impacts of the flood? (Resist)
 - How did you recover from the flood?
 - How long did these flood events impact your daily life?
 - Why?

- Do you feel connected to the downtown area of Northfield which is often hit hardest by these floods?
3. Can you tell us about how your home (or apartment / rooms) are at risk of flooding?
 - During one of these floods?
 - Compared to different parts of town?
 4. Can you tell us about how your neighbors, family, or friends were impacted by these floods?
 - What about your experience do you think was different from that of your neighbors or other citizens of Northfield?
 5. Do you think the floods have changed, and if so, how?
 - Have flood's intensity, extent, or frequency changed?
 - Why do you think this change has occurred?
 - Can you discuss how the impact on Northfield has varied (if at all) with each of these floods?
 6. What areas of town do you think are most vulnerable to flooding?
 - Can you describe how the community was affected?
 - What was the response of the community to each of these floods?
 7. Can you tell me about what institutions Northfield has in place for flood mitigation?
 - Is there something else that should be incorporated into Northfield's flood management?
 8. Is there anything else you would like to mention that we did not cover?

Appendix B: Demographic Information FormDemographic Information Form

Senior Comprehensive Project - Carleton College
 Zoe Craig, Matt Jaquette, Colleen Stewart, Jia Yang

We are collecting basic demographic information to help provide context for this interview. If you don't feel comfortable filling in any of these questions, feel free to leave them blank.

Name: _____

Business Address: _____

Home Address: _____

Gender: M/F Age: _____

Marital Status: (single, married, divorced) _____ Number of Children: _____

Do you have relatives in the town? Y/N. If yes, how many: _____

Is your house in the FEMA flood zone: Y/N/don't know

Do you have flood insurance?: Y/N/don't know

Annual Income: _____

Ethnicity:

- Hispanic or Latino
- Not Hispanic or Latino

Race (check all that apply):

- White
- Black or African American
- American Indian or Alaskan Native
- Asian
- Native Hawaiian or Pacific Islander
- Other

Do you have a disability?: Y/N. If yes, what is your disability:

Appendix C: Table of Factors from Interviews and Newspapers

Dimensions	Factors	Years Mentioned in Newspaper	# Non-expert Interviews	# Expert Interviews	Level of Significance
Community Competence	Individual Responsibility	1965	3	4	Low
	Flood Knowledge and Awareness	2010; implied in all other years	7	11	High
	Equipment	All years	9	6	High
Social	Community	All years; especially 2010, '12, '13	6	6	High
Infrastructure	Infrastructure	1993	5	3	Medium
	Property Design	N/A	9	6	High
	Land Use	2010, 2012, 2013	0	5	Medium
Econ.	Economic Resources	All years; especially 2010	4	10	High
Institutional	Location	All years	4	7	Medium
	Political Process	All years; very briefly	0	2	Low
	Stormwater Management	2010	0	10	Medium
	Flood Mitigation Plan	2013	3	6	Medium
	Flood Warning System	2010	3	6	Medium
	Government Services and Jurisdiction	All years	3	6	Medium
Ecological	Character of Flood Event / Changing Flood Regimes	2010	3	8	Medium

Table 3. The 15 factors we identified and their relative significance organized by their relation to Cutter et al.'s community resilience dimensions (2008). This table shows the years these factors were found in archival analysis and the number of expert and non-expert interviews they were mentioned in.

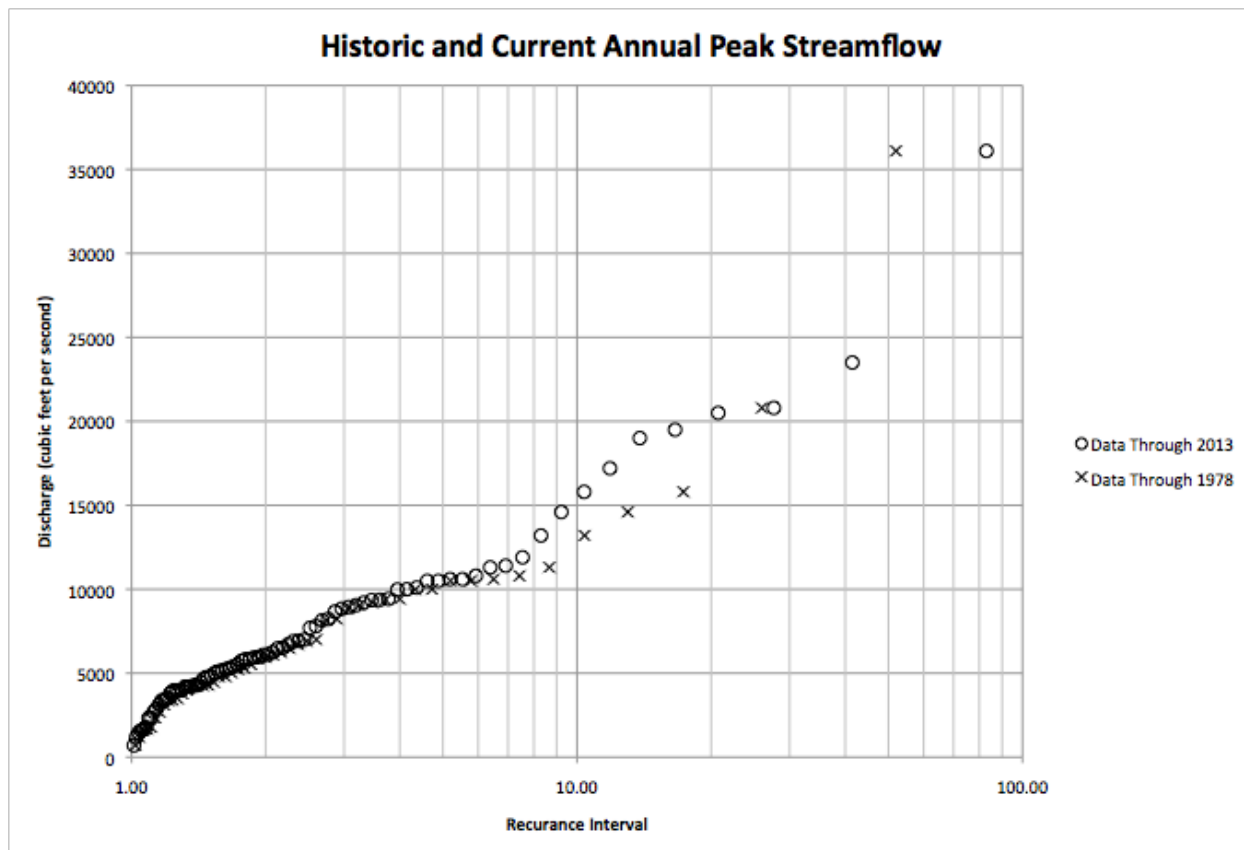


Figure 2: This graph illustrates how the magnitude of flooding has changed in recent history. The recurrence interval describes the average number of years between flood events of similar magnitude and is calculated as $r = (n+1) / m$, where r is the recurrence interval, m is the relative rank of an event in the dataset (the largest flood is ranked 1, the second largest flood is ranked 2, etc.), and n is the number of events in the dataset. For example, a flood event with a recurrence interval of 10 would be expected to occur an average of once every 10 years. This graph shows that while floods with a high recurrence interval have not changed significantly over the last 35 years, floods with a low occurrence interval have increased in severity.

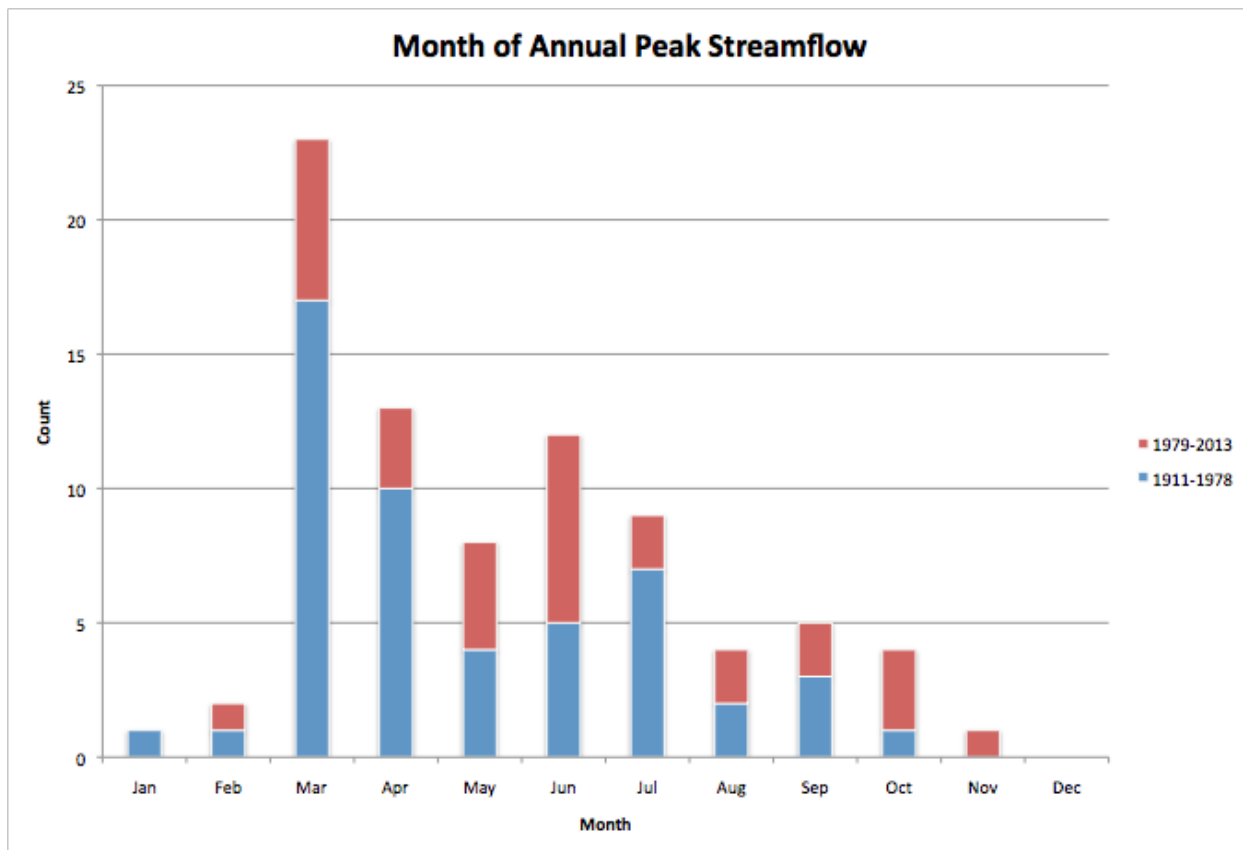


Figure 3: This chart displays the months of when flood events occurred. Historically, flooding was most common in the spring, as shown by the large number of flood events from March to June. While spring floods are still the most common when looking at the entire dataset, more recent flooding has tended to occur in later months. This shows a shift in the seasonality of flooding on the Cannon River.