PREDICTING RESPONSES TO FLASH FLOODING: A CASE STUDY OF BOULDER, COLORADO

by

Kelsey Jill Mulder

July, 2012

Director of Thesis: Burrell Montz

Major Department: Geography

Flash floods are among the deadliest weather phenomena in the world. Unfortunately, people continue to move to risky areas, resulting in high losses due to flash floods. Because of the short lead times associated with these events, it is important that those in danger understand their risk in order to respond quickly and appropriately to watches and warnings. There are, however, many factors involved in one's likelihood to respond. To assess these factors, a mail survey was conducted for a random sample of the general public in flash flood-prone Boulder, Colorado. Indices, including antecedent knowledge about flash floods, risk perception, and warning receptiveness in addition to past flash flood experience, location, and socio-demographic indicators, were included in the analysis. These variables predict both the likelihood to take protective action in a flash flood warning (REACT) and whether or not the respondent had already taken measures to prepare for flash flooding (PREPARE). Older respondents, females, and respondents with more imminent risk perceptions and higher antecedent knowledge about flash floods are more likely to react in a flash flood warning. Many respondents cited that they would not respond to a flash flood warning because they feel safe from flash flooding. PREPARE is positively correlated with length of residence, real and perceived location in the floodplain, antecedent knowledge, and warning receptiveness. The most

common form of preparation is planning an evacuation route. Results from this research can be used to target at-risk populations and provide information to help prepare them for flash flooding.

PREDICTING RESPONSES TO FLASH FLOODING: A CASE STUDY OF BOULDER, COLORADO

A Thesis

Presented To the Faculty of the Department of Geography

East Carolina University

In Partial Fulfillment of the Requirements for the Degree

M. A. Geography

by

Kelsey Jill Mulder

July, 2012

PREDICTING RESPONSES TO FLASH FLOODING: A CASE STUDY OF BOULDER, COLORADO

by

Kelsey Jill Mulder

APPROVED BY:

DIRECTOR OF THESIS: ______________________________

(Burrell Montz, PhD)

COMMITTEE MEMBER: ______________________________

(Tom Crawford, PhD)

COMMITTEE MEMBER: ______________________________

(Ron Mitchelson, PhD)

CHAIR OF THE DEPARTMENT OF GEOGRAPHY:

____

(Burrell Montz, PhD)

DEAN OF THE GRADUATE SCHOOL: ______________________________

(Paul J. Gemperline, PhD)

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Jeff Lazo, Rebecca Morss, Emily Laidlaw, Julie Demuth, and Marybeth Zarlingo for making this research possible and helping stuff all those envelopes. Also, thanks for the support and enthusiasm for this project. I would also like to thank Curtis McDonald, my undergraduate capstone partner, who helped with a lot of the survey grunt work. Special thanks goes to my committee: Dr. Tom Crawford for helping with all the software hurdles and providing the great ideas to test for a variety of functional distances, Dr. Ron Mitchelson for patience and guidance with the statistical analysis, and Dr. Eve Gruntfest for being an outside reader, supporting my interests, and getting me into geography in the first place. Of course, I could not have survived without my friends and family. Thanks especially to my mom and dad, Steve, Richard, Ali, Megan, Martha, Jessica, Mike, and Robbie. And most of all, thanks to Dr. Burrell Montz for putting up with me through weekly meetings, providing extremely helpful critiques, and helping me realize when to just let things go and have a glass of beer.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Flash floods, or floods associated with a rapid rise in water, are among the deadliest weather phenomena worldwide (Kelsch 2001). In addition, flash floods were the costliest natural disaster in terms of lives lost and property damage in the United States in the 20th century (USGS 2000). Environmental change, including global climate change, wildfires, and urbanization, is increasing the risk of flash flooding. Flash floods are of particular concern because of the hazard's quick-onset nature. Whether they are caused meteorologically from heavy rainfall or on a clear day from a dam break, the impacts are felt very soon after the causative event. This means that people at risk of flooding need to act quickly in order to be safe. To make matters worse, people continue to move into flash flood-prone areas and build structures, leading to higher levels of vulnerability (Gruntfest and Handmer 2001, Montz and Gruntfest 2002).

Because vulnerability to flash floods is increasing, it is more important than ever to focus on saving lives and property in these events. Besides managing land use, which helps save property, understanding human reactions to flash floods can help reduce deaths and injuries. Past research indicates there are many variables that encourage people to take protective action in an event. These variables include understanding the risk, trusting the source of the forecast and warning, knowing about the hazard, having past experience with the hazard, and being located in a risky area.

Some of these factors can lead to policy decisions to help foster development of effective hazard and warning communication processes in both the short and long terms. Long before a flash flood event, education and public awareness campaigns can increase public understanding of flash flooding, addressing the public's risk perceptions and knowledge about the hazard so they are more likely to respond quickly and efficiently to the event when it happens.

Additionally, at-risk groups can be targeted to increase their awareness and encourage them to take action in the event. These vulnerable populations may require special attention so education can be tailored to each group, depending on their needs. Finally, the warning dissemination process can be adapted based on these findings to get the warning message across in the most efficient way possible as the event is imminent. For example, listing the specific areas at risk, impacts expected, and timing of a flash flood in the warning can help communicate the imminence of the event and help promote quick and safe action.

Determining the specific factors that promote response to flash flooding in Boulder, Colorado, a city at risk of flash flooding, will help in two ways. First, it will add to the flash flood behavior literature by providing another case study from which researchers can draw information. Second, it will help provide specific recommendations to the City of Boulder to prepare for flash flooding. Drawing upon past literature and research opportunities, the following research questions are addressed using data from a mail survey of residents in Boulder, Colorado:

1. How do individuals' risk perceptions, antecedent knowledge, experience, warning receptiveness, location, and socio-demographic status influence their decisions to prepare for a flash flood long before the event occurs?
2. How do individuals' risk perceptions, antecedent knowledge, experience, warning receptiveness, location, and socio-demographic status influence their responses to a flash flood warning?
3. Is there any link between individuals' locations and their risk perceptions, antecedent knowledge, experience, warning receptiveness, and socio-demographic status?

4. What factors influence individuals' flash flood antecedent knowledge, risk perceptions, and warning receptiveness?

These questions are addressed in this thesis. Following a review of the relevant literature in Chapter 2, the study area and methods are described. The results from the analyses are presented in Chapters 5 and 6, with conclusions in the final chapter.

CHAPTER 2: REVIEW OF LITERATURE

Flash floods present an interesting case study in hazards research with their rapid onset and numerous causes, meteorological and otherwise. Before discussing human response to flash floods, it is important to understand the characteristics of these events. A background on flash floods is presented as well as an overview of the framework for the hazard warning system to document how the message is disseminated to the public. Research regarding risk perception and response to hazards in general, and flash floods more specifically, is also presented. A section on location with respect to flash flood risk and behaviors finishes the review of past literature.

Flash Flood Characteristics

Flash flooding is defined as:

> A flood that rises and falls quite rapidly with little or no advance warning, usually as the result of intense rainfall over a relatively small area. Some possible causes are ice jams, dam failure, and topography (American Meteorological Society 2000).

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) further defines flash flooding in terms of specific timing and special situations:

> A rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam). However, the actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters (NWS 2009b).

The key elements of flash flooding as compared to other types of flooding are geographic setting, variety of triggers, and sudden onset. Different geographic locations have unique soil types, slopes, land uses, antecedent moisture, and topography, all of which affect the probability of flash flood occurrence. In addition, different parts of the country have unique triggers that cause flash floods. Flash floods can also have worse impacts than other types of flooding. The rapid velocity associated with flash floods leads to more water flowing faster down the stream or river for a shorter period of time with greater potential for severe damage. This results in a high risk for loss of life, especially for those directly in the path of the flood (Gruntfest and Handmer 2001, Petersen 2001). The damage swath for a flash flood is typically not large (Petersen 2001), but the amount of damage in the swath is significant compared to other kinds of floods (Montz and Gruntfest 2002).

While flash floods are more likely to occur in mountainous areas, they can occur anywhere at any time. For example, a river flood can turn into a flash flood when there is a sudden influx of water from a dam break or a high precipitation thunderstorm. It is also important to note that flash floods are not always caused by meteorological events. A dam failure (either human or naturally constructed), the sudden breaking of debris, or an ice jam during spring snowmelt can cause a surge of water classified as a flash flood (NWS 2009b).

Terrain is a fundamental condition of most flash floods. Steeply sloped topography and channeling of water, often seen in canyons, help increase the rate of runoff to a centralized location (Kelsch 2001). With excess rainfall, the water will build up, quickly moving toward the outflow of the basin. If the landscape has pre-existing moisture or soil types that reduce the amount of infiltration, a greater amount of water will flow more quickly down the slope. Wildfires can also cause increased runoff because there are fewer trees and grasses to absorb the water, slow the flow, and encourage infiltration.

Meteorologically induced flash floods are often caused by sudden, short, high-intensity precipitation storms, whether convective, frontal, or orographic (Petersen 2001). Additional factors that can cause flash flooding are stationary storms and training storms. Stationary storms practically halt due to orographic lifting in mountainous areas. As noted above, these locations are particularly susceptible to flash flooding due to the terrain and channeling of water. Training storms can occur when several storms travel over the same area in a short period of time. Both stationary and training storms typically lead to extreme rainfall totals (NWS 2009b). In mountainous areas, snowpack builds up over the winter season. In the spring, the snow melts and runs off the mountains, which results in slow rises in the creek and stream levels. Also during this time of year, rain can fall on snow-covered areas, melting snow quickly resulting in rapid runoff. The combination of already high waters and rapid runoff can create a dangerous situation. Therefore, spring months are a common time to experience flash flooding. For a meteorologically created flash flood, there can be great distance between where the rainfall occurs and where the impacts are felt, depending on the where the water is channeled. In other words, there can be a difference in time and space between where the collection of water is occurring and where the actual impacts of the flooding are felt (Kelsch 2001).

The severity of a flash flood depends on the preexisting meteorological and soil features, topography, and what triggered the flash flood. At the same time, there are a variety of anthropogenic factors that exacerbate flash floods. Properties of the built environment have greatly increased the amount of runoff as well as the speed at which the water enters the stream system (Sanders 1986). Paved areas have minimal, if any, infiltration into the ground. As a result, all precipitation falling in these areas will run into streams and rivers shortly after it falls, resulting in rapid rises in water levels. Other land uses, such as agricultural land with no natural vegetation, will also lead to increased runoff totals because of less infiltration. With the application of engineering to manage water, dams became popular for preventing flooding and providing a more secure water supply year-round. Unfortunately, with the construction of dams comes the risk of a dam failure.

The nature of flash floods can make a population particularly vulnerable to the hazard. The rapid onset of flash flooding makes it difficult to warn a population in time to take appropriate action and find safety. Building in a scenic location, for example at the base of a canyon, may provide beautiful views, but it also makes that location susceptible to any fast-flowing surge of water. A stream or river running through town makes everything in and near the floodplain subject to destruction. Conversely, a population that is aware of the hazard may be able to prepare and react appropriately to the event, resulting in minimal damage and personal harm. Because the origin of flash floods may be spatially removed from where the impacts will be felt, it is important that people are able to heed warnings. Yet, warnings are only as effective as the knowledge people have about flash floods and the appropriate responses they can take (Kelsch 2001, Siudak 2001).

Warning System for Hazards

The warning system for environmental and other types of hazards includes three steps: detection of the hazard, management of the warning including deciding to warn and determining how the warning will be disseminated, and response by those who have received the warning, as shown in blue in Figure 2.1 (Mileti and Sorensen 1990). The response aspect to the warning process is composed of many steps, shown in green in Figure 2.1. First, an individual must receive the warning. This can happen either through an official source such as an outdoor siren, from an unofficial source such as a family member or friend, or from environmental cues suggesting an event is about to occur or is occurring. Second, the individual must understand what he or she has heard or seen. Third, the individual must believe the message and trust it. Fourth, a person at risk must personalize the message to understand he or she is at risk and must take action. Fifth, the individual must decide what he or she will do in response to the warning.

After all these steps, the individual must finally take protective action (Mileti and Sorensen 1990).

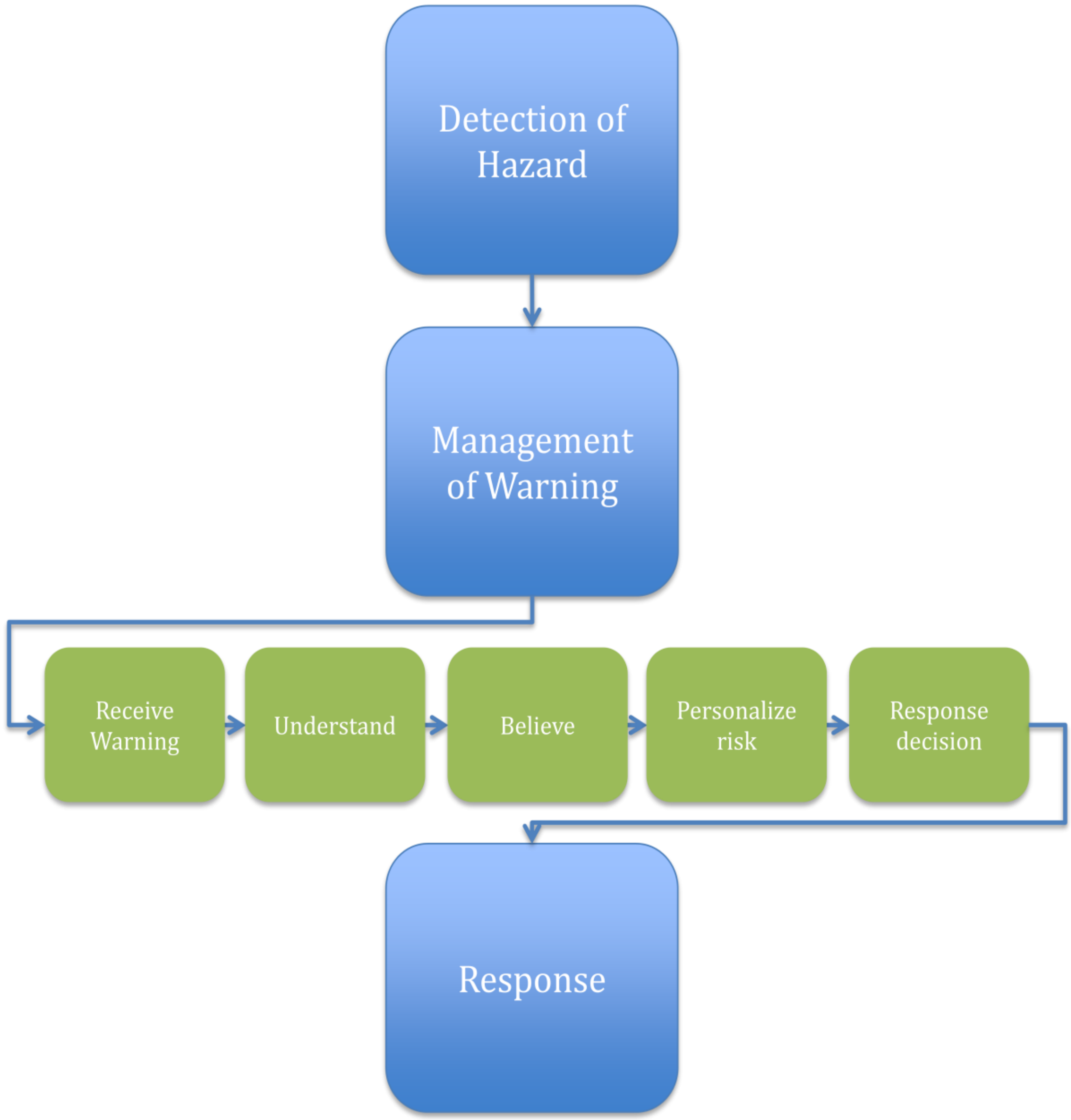

Figure 2.1: Warning System for Hazards Framework

This whole process assumes that the individual receives some sort of warning message, which is not always the case. It also assumes a person will make it through all of the steps and take protective action. Although there are many steps involved with the warning process shown in Figure 2.1, this study focuses on the final step, which is the eventual decision to take protective action. The eventual response decision depends greatly on factors such as risk perception, antecedent knowledge, trust, experience, and socio-demographic indicators, discussed below.

Risk Perception

Perception refers to the ways an individual understands or interprets an object or a situation. Therefore, risk perception is an individual's awareness, understanding, and opinion of an event that has an uncertainty of occurrence (Raaijmakers et al. 2008). Perception of a hazard includes awareness of the characteristics of the hazard (i.e. size, frequency of occurrence, time of onset, length of impact), past experience with the hazard, and personal characteristics (Kates 1971, Lin et al. 2008). Because people tend to form strong initial opinions about risks, perceptions are very hard to change, even when people are presented with accurate information (Slovic et al. 1982, Faupel et al. 1992). However, if an individual does not have a strong initial opinion, he or she is more likely to believe any information, even if it is bad information (Slovic et al. 1982). Risk perceptions can vary with time as a person experiences or does not experience the hazard (e.g. Brilly and Polic 2005), with place based on spatial and social characteristics (e.g. Thieken et al. 2007, Brommer and Senkbeil 2010, Lopez-Marrero and Yarnal 2010), and with hazard because of the varied impacts, lead times, and frequency of occurrence (e.g. Sorensen 1983, Knocke and Kolivras 2007, Lin et. al 2008).

The results of various case studies provide background on the nature of, and extent to which, various factors may influence one's perception. First, knowledge and awareness of hazards are not necessarily positively correlated with hazard risk perception. When studying storm surge, Anderson-Berry (2003) found that awareness does not always lead to understanding of storm surge from cyclones. Sorenson (1983) also found that knowledge about hazards does not impact risk perceptions. In addition, the amount of information about hazards available to a community and the accuracy of an individual's knowledge do not always lead to adequate preparation for cyclones and their associated storm surge (Anderson-Berry 2003). Similarly, when asked to map risk areas for flooded roadways, respondents tended to underestimate the risk, additionally signifying that their knowledge is not always correct (Ruin et al. 2007). Also, individuals may understand a risk, but may not think it could personally affect them (Drabek and Stephenson 1971). Therefore, knowledge and awareness do not necessarily correlate with accurate risk perceptions.

Second, experience has a significant impact on risk perception in both slow and quick onset hazards. The impact of experience on risk perception has been recognized for a long time in hazard studies, but with variable findings. Some studies have found that people who have had personal property damaged from a past slow-rise flood are more likely to have more imminent risk perceptions than those without (Miceli et al. 2008). In other words, respondents with flooding experience indicated flooding as more likely in their location than those without that experience. Similar findings came from a study on landslides (Lin et al. 2008). In another study, residents who experienced an unexpected slow-rise flooding event for the first time were more concerned about flooding than those who had not previously experienced flooding in their area (Brilly and Polic 2005). In terms of quick onset hazards, flash flood experience has been found to lead to more accurate risk perceptions (Knocke and Kolivras 2007). Individuals without flash flood experience tend to underestimate the risk while those with flood experience tend to overestimate the flood risk (Ruin et al. 2007). Before being impacted by a flash flood, few residents actually knew their residence was located in a floodplain (Bogdanska-Warmuz 2001). It was also found that exposure to traumatic events in general raises the likelihood of correct knowledge (Benight et al. 2007). Past experience with hazards greatly increases an individual's knowledge of the risk and awareness that the event could occur.

Third, confidence and trust affect how people view a hazard. Individuals with higher levels of confidence in life, in general, have lower perceived risk (Siegrist et al. 2005). In another study, respondents were presented with information that either matched or countered their current risk perceptions. If the information matched their perceptions, the individual trusted the information more. However, if the information differed from their original opinions, they did not trust it (Slovic et al. 1982). Therefore, risk perceptions can impact how much people trust the information they receive.

Fourth, length and location of residence affect risk perceptions, but the impacts are variable and conflicting. Those who lived in Cairns, Australia for a long period of time tended to believe in folklore about being protected from cyclones by the mountains and the Great Barrier Reef (Anderson-Berry 2003). Sorensen (1983) found that people who lived in their residences longer had more knowledge about the risk of tsunamis. People who resided in a location vulnerable to flash floods had more accurate perceptions of flash flood risk (Ruin et al. 2007). Knocke and Kolivras (2007) found that people who were not necessarily directly affected by flash flooding were still aware of the potential risks. Those located in high-risk areas for slow-rise flooding tended to estimate higher flood probabilities than those located in less vulnerable areas (Brilly and Polic 2005). Similarly, people in high-risk areas for slow-rise floods were found to be more likely to gather information about protective measures (Thieken et al. 2007).

Finally, socio-demographic characteristics can be responsible for individual differences in hazard risk perception. Higher educational attainment tends to indicate individuals with more accurate risk perceptions of cyclones (Anderson-Berry 2003). Older populations tend to find hazards riskier than do younger people (Siegrist et al. 2005, Knocke and Kolivras 2007), however a younger demographic thought heat was more dangerous than older generations did (Kalkstein and Sheridan 2007). Residents under 25 and older than 45 underestimated flood risk on roads (Ruin et al. 2007). Females tend to think hazards are riskier than their male counterparts (Siegrist et al. 2005, Kalkstein and Sheridan 2007). When comparing multiple hazards, females do not find flash floods as life threatening compared to other weather-related hazards (Knocke and Kolivras 2007).

Research in risk perception helps in developing emergency management plans and procedures by revealing how the public views hazards, what information (correct or otherwise) they know about the hazard, and how they might react (Slovic 1987). It is important to keep in mind that short- and long-fused events may result in different perceptions and different results. For example, Anderson-Berry (2003) determined that risk perception for cyclones in Cairns is low because the residents estimate they have plenty of time to evacuate as the cyclone makes landfall. These residents will likely prepare and react differently than those involved in a short-fused event, where it is key to take action as soon as the warning is received.

Research is needed in areas prone to but without recent flash floods. These locations may be at greater risk because residents are not aware of the threat posed by the hazard and, given its characteristics, may not have enough time to respond when one occurs. As a result, it is important to evaluate risk perceptions of residents in and out of floodplains as well as their knowledge about whether they are located in the floodplain. Such research will help to fill a serious gap in the research, especially as place and location within a community might influence their perceptions. Finally, it is important to get as much information as possible from different case studies, as their physical and social characteristics vary; context is important.

Response to Hazards

An individual's response to a hazard includes his or her reactions long before, shortly before, and during the event. People can change their behaviors depending on how they perceive the hazard (Sorensen 1983, Lindell 1994, Siegrist et al. 2005, Grothmann and Reusswig 2006, Kalkstein and Sheridan 2007, Lin et al. 2008, Lazo et al. 2010). Therefore, response is closely tied to risk perception. Previous research has also found that disaster education, trust in information sources, experience with hazards, and socio-demographic indicators have an impact on an individual's decision to respond to a hazard.

Many locales have disaster education programs in which they provide information about the vulnerability of the region to particular hazards. These programs also provide recommendations on actions to reduce the loss of lives and property. While Faupel et al. (1992) found that having prior disaster education predicted preparedness for hurricanes, Sorensen (1983) did not find that these programs had any effect. However, Sorensen (1983) did note that receiving poor information or no information at all made people less likely to form an adaptive response given hypothetical tsunami, hurricane, and earthquake scenarios.

Trust plays a significant role when it comes to an individual's decision to prepare for and react to a hazard (Siegrist et al. 2005, Lazo et al. 2010). An early study found that evacuation recommendations from authorities were taken more seriously than recommendations from the media (Drabek and Stephenson 1971). Trust in government officials and experts has more recently been found to lead to mitigative actions (Anderson-Berry 2003, Lin et al. 2008). Further, Lin et al. (2008) found that trust in the media led to mitigation intentions for flash flooding. However, there have been findings that people trust their own decision-making skills over authorities' recommendations (Anderson-Berry 2003). Receiving messages from multiple sources, regardless of trust, tends to ensure action, as does discussing the situation with neighbors and peers (Drabek and Stephenson 1971, NWS 2009a). With little or no knowledge on which to base a decision, trust becomes especially important (Siegrist et al. 2005).

Experience is the most commonly cited indicator of hazard response. Before the event is expected to occur, there are mitigative measures individuals can take, including creating emergency plans. Anderson-Berry (2003) found that after a recent tropical cyclone, people were more likely to have discussed an emergency plan than before the cyclone hit. Similarly, before a flash flood, only 3% of respondents had made an emergency plan while after the flash flood, 13% had discussed emergency plans (Drabek and Stephenson 1971). Although this was not a great increase, there was a change in emergency planning behavior. Similarly, people who had experienced slow-rise floods in Germany were more likely to gather information about mitigative measures than those who had not (Thieken et al. 2007).

When the hazard is approaching or occurring, experience is still important in response actions. Some victims make decisions based on previous actions (Kates 1971). In addition, people with more experience with the hazard are more likely to know how to respond appropriately (Sorensen 1983). Individuals who experienced Hurricanes Katrina, Andrew, and Rita were more likely to evacuate from Hurricane Gustav in 2008 (Brommer and Senkbeil 2010). People who have experienced trauma in general, or flash floods specifically, were more likely to take flash flood warnings seriously (Benight et al. 2007, Knocke and Kolivras 2007). They were also more likely to take protective action in a flash flood situation (Benight et al. 2007). Findings have also suggested that people who have experienced hazards are more likely to seek information about imminent flash flooding and landslides (Knocke and Kolivras 2007, Lin et al. 2008). However, although people in these areas may have knowledge about hazards, their situational context, such as length of residence, affects their behaviors (Tobin and Montz 1997). Further, false alarms, or instances where an event is predicted but does not come to fruition, may have a negative impact on response behaviors. False alarms have been found to create reluctance to prepare and react in a hazard (Anderson-Berry 2003). On the other hand, Dow and Cutter (1998) found that past false alarms with hurricanes did not affect future actions. Experience is often cited as impacting individual response to a hazard. Yet, there are few studies conducted in areas without recent events and how the lack of experience might affect response intentions.

Finally, socio-demographic indicators have been shown to affect decisions to take protective action. Older individuals are more likely to seek information about imminent flash flooding and to take watches and warnings more seriously (Knocke and Kolivras 2007). In hurricanes, older respondents are more likely to evacuate (Lazo et al. 2010). Finally, people with higher incomes and educational attainment are more likely to take mitigative actions for flash flood and landslide risks (Lin et al. 2008). For hurricanes, Lazo et al. (2010) found that higher educational attainment and full time employment are indicators of evacuation while higher income and longer residence result in lower likelihood of evacuation.

Location

Location is another important aspect in the decision to take action in response to a warning. In a flash flood especially, it is important that people residing in risky areas are the most likely to take protective action. While the effect of location in and out of floodplain has been documented in past literature (e.g. people located in more vulnerable areas are more likely to prepare for slow-rise floods Brilly and Polic 2005), other definitions of location have not been examined. In particular, there has been very little research focusing on location of the respondents' households and their likelihood to respond to the event.

Least cost analysis, or determining the path of least resistance of a chosen variable, and hydrologic flow distances have been used for hydrologic analyses (e.g. Ver Hoef et al. 2006). This non-Euclidian distance is accepted for hydrologic flow because water does not travel along the shortest path between two points. Instead, it meanders and follows the terrain of the area (Figure 2.2). While least cost analyses have not been used in the hazards literature, they have, for example, been conducted to measure distance to nearby wetlands in a study of livelihood mapping and poverty in Kenya (Kristjanson et al 2005).

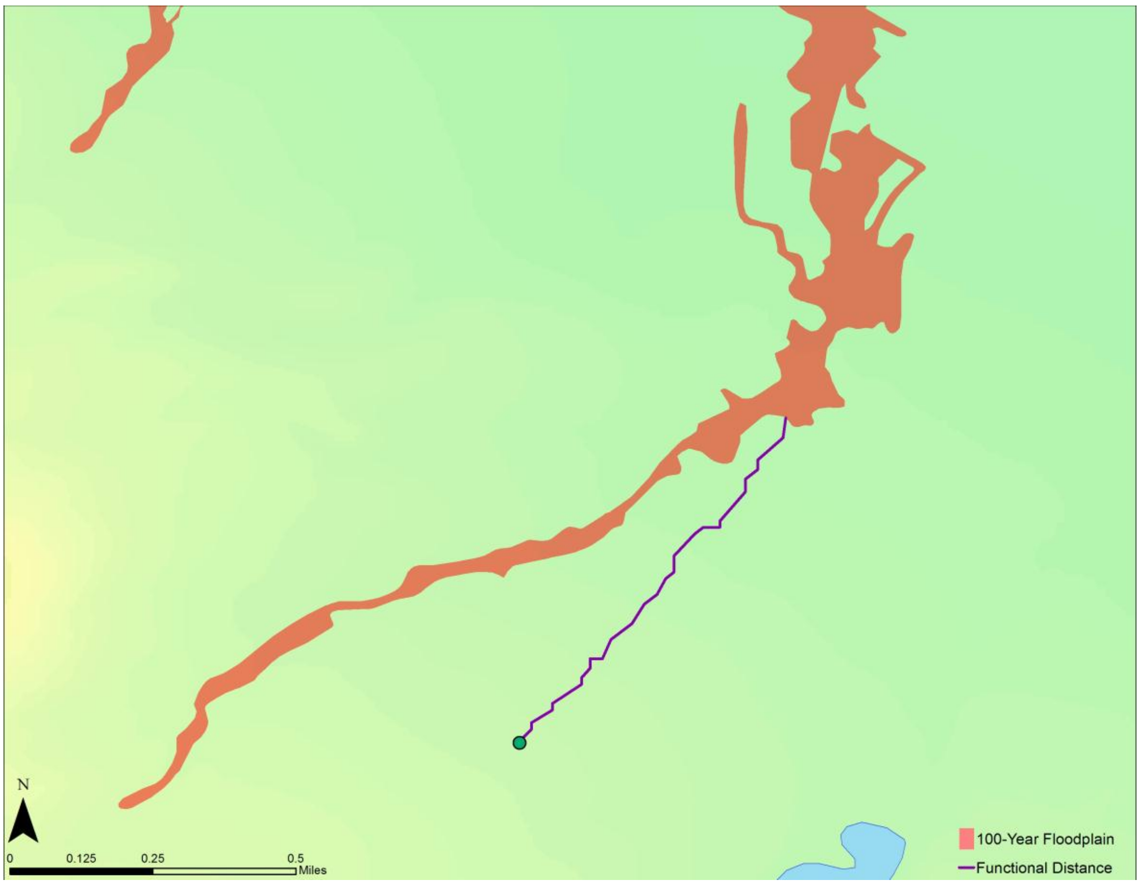

Figure 2.2: Example of Flow Distance

Humans may think of flow distance or elevation rather than a Euclidian distance (straight line between two points) when determining their distance from the floodplain or a stream. A flow distance is the distance calculation following a drop of water as it would flow into a floodplain or stream (Figure 2.2). This can be different than the Euclidian distance, or the shortest distance between two points following the surface's elevation. As seen in Figure 2.2, the shortest distance between the respondent (shown in green) and the floodplain (shown in orange) is quite different than the flow distance. The flow distance meanders with the elevation as the hypothetical drop of water travels from the point into the floodplain. Conversely, people can think of distance in terms of elevation. If an individual is located on a cliff above a stream, they are much less likely to flood than someone who is one foot in elevation above the same stream. This is just another way to think of distance.

Another gap in the hazards research pertains to spatial clusters. If there are pockets of respondents who are not very likely to respond to a flash flood warning, this spatial information could be key for public officials trying to prevent loss of life. It can also be very important to discover if those living in risky locations, either close to floodplains or within floodplains are more likely to take protective action in a flash flood warning. Clusters could also reveal if neighborhoods or social networks are at play in influencing perception and response.

Areas without a recent flash flood event are also important to study because many will not have had experience with the hazard and therefore may not know how to respond. Again, having many case studies in areas with different socio-demographic characteristics, physical traits, and hazard vulnerabilities is important in order to have a wider grasp of the factors that lead to appropriate action.

From past research, it is clear that there are many variables tied to taking action in response to a hazard including risk perception, knowledge, trust, experience, length of residence, and socio-demographic information. Yet, past research has focused very little on geographic location of the residence of the respondent. Additionally, flash floods are a special case because of their quick onset and therefore short time available to respond. All these factors converge to produce an interesting case study to research response to flash flood warnings and behaviors already taken to mitigate flash flood damage.

CHAPTER 3: STUDY AREA

Boulder, Colorado, a city of nearly 100,000 people (U.S. Census Bureau 2010), is located at the foothills of the Rocky Mountains (Figure 3.1). Included in the population estimate are some of the over 30,000 students attending the University of Colorado, which is located in the center of the city (Figure 3.1). Boulder is also home to various tourist, environmental, and technological businesses. Because of its location and job opportunities, Boulder seems to be an ideal location to live, but its location next to the mountains presents a significant risk of flash flooding. The combination of vulnerability to flash flooding, demographics of the city, and land use make Boulder an interesting case study for hazards research.

Flash Flooding in Boulder

Boulder, located at the outlet of four canyons, is at very high risk for flash flooding (Kelsch et al. 2001, City of Boulder 2009). Of the sixteen creeks in the city limits, Boulder Creek is the main stream, which runs from Boulder Canyon through downtown Boulder, shown in darker blue in Figure 3.1. The Boulder Creek Path, a major pedestrian path that runs along the creek, is a common location for commuting and recreating in Boulder. If this creek flooded, downtown Boulder could experience extreme damage, pedestrians could be exposed to the rapidly flowing waters, and the city could be cut in half. Another risk factor for Boulder is the 100-year-old Barker dam, in Boulder Canyon near Nederland, Colorado. If the dam broke, a surge of water would come down the canyon and empty into the City. Regardless of which creek in Boulder floods, people and property are at risk.

Due to its location, Boulder is subject to many climatological and meteorological factors that could create a precipitation-based flood situation. Thunderstorms build from easterly flow being forced upward due to the mountains. These types of thunderstorms develop more

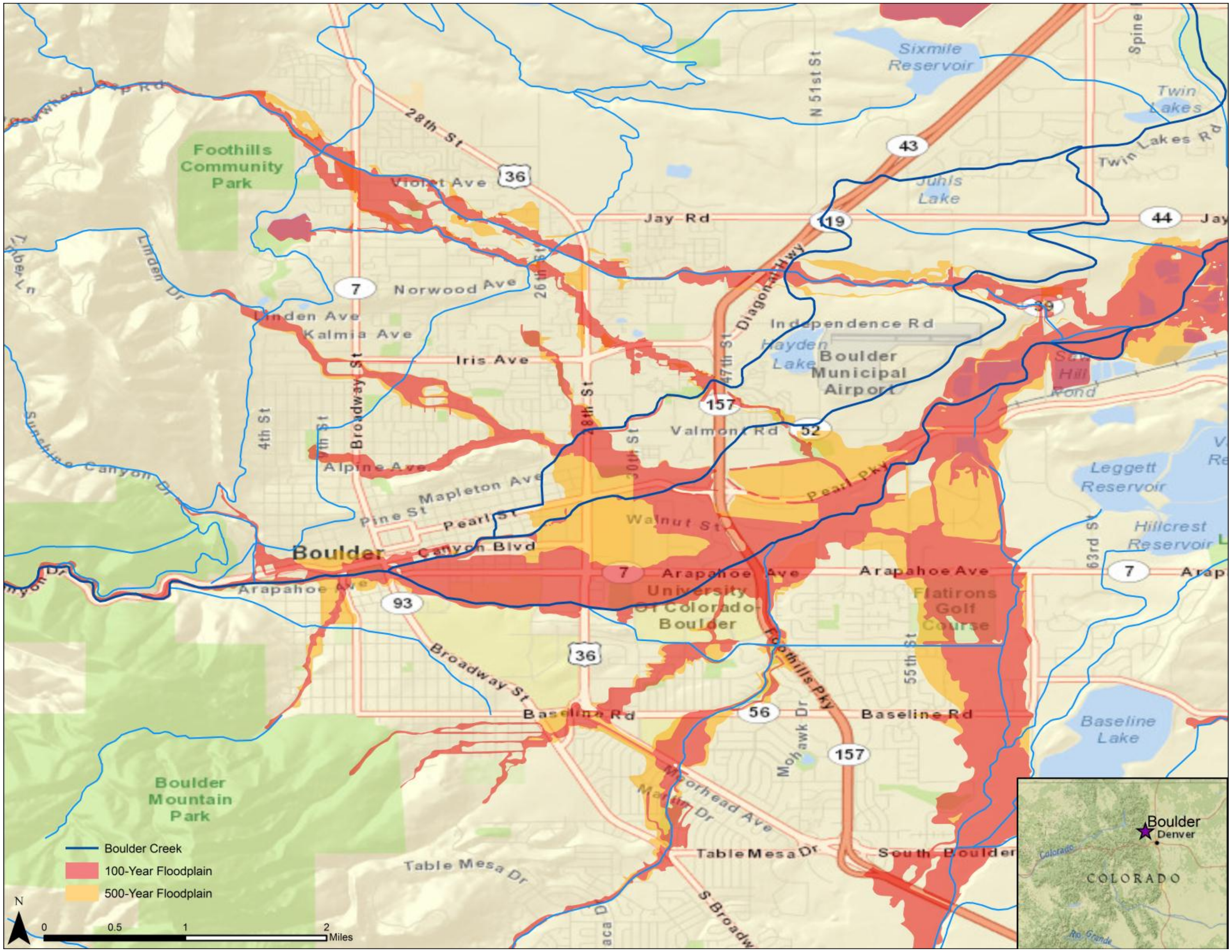

Figure 3.1: Location of Study Area

precipitation as they are forced upwards in altitude and are known for their intense rainfall (Kelsch et al. 2001). Additionally, storms tend to stall as they are being forced up the elevation and can dump all of their precipitation into one basin. If the right storm hits the right place, Boulder could experience catastrophic flooding. In addition, Boulder is located in a semi-arid climate and is therefore characterized by thin and impermeable soils, increasing the risk for flash flooding due to runoff (Kelsch 2001).

Boulder has had a long history of flash flooding, well before the first residents of Boulder settled in the area in 1858 (Mileti 1999). Past major flash floods in Boulder occurred in 1874, 1894, 1914, 1921, 1938, and 1969 (Gruntfest et al. 2002, City of Boulder 2009). These historical floods were caused by heavy snowfall, rapid snowmelt, and heavy rainfall (Mileti 1999, Gruntfest et al. 2002). The most recent flash flood scare was in early June 2010. High waters from spring snowmelt combined with an unusually wet spring, and wiped out a bridge crossing Boulder Creek to a business located in Boulder Canyon. There were fears of caught-up debris collapsing, which would have resulted in a small surge of water downstream (Aguilar 2010). In response, Boulder officials closed the bike path next to Boulder Creek all the way up to the blockage and utilized reverse 911 to inform homes and businesses near the mouth of the canyon to stay away from the creek (Aguilar 2010).

Although this situation prompted officials to respond, the threat level was relatively low. Besides the 2010 event, it has been many decades since a significant flooding event has affected Boulder. When flash flooding has not impacted an area for a long period of time, the public can forget the extent of the impacts and threats, which can lead to a false sense of security (Siudak 2001).

With the foothills so close to the city, wildfires are also a problem both for the City and upstream. The most recent fires near Boulder were the Fourmile Fire and Dome Fire, both in the fall of 2010 (Meltzer 2011). Due to increased runoff because of the fire, one report determined that a quarter inch of rain per hour could cause minor flooding while only three-quarters of an inch of rain per hour could cause significant flooding for the fire-ravaged area (Holden 2011). Another reported that an inch of rain per hour could damage 20 to 40 homes (Snider 2011). Regardless of the amounts, both the burn area and the City of Boulder have an increased flood risk in the next few years as a result of the burns (Holden 2011, Meltzer 2011, Snider 2011). Since the wildfires, there has been increased media attention about flash flooding in the area. With this in mind, the Boulder population is likely highly aware of flash flood risk.

While Boulder has not experienced significant flooding in 43 years, nearby foothills locations have. The most notable was the 1976 Big Thompson flood, just north of Boulder. This flood, caused by a stationary storm over the basin, claimed 139 lives (Grigg et al. 1999). In Fort Collins, Colorado, about 40 miles north of Boulder, there was a devastating flood in 1997. Orographic lift created intense rainfall with precipitation rates increasing toward the end of the storm, which is uncommon (Kelsch et al. 2001, Montz and Gruntfest 2002). The flood killed five and resulted in $200 million in damages, half of which was from Colorado State University, located in the city (Montz and Gruntfest 2002). While these events did not directly impact Boulder, they may have kept flash flooding in the minds of citizens. On the other hand, these events can prevent residents from personalizing the risk and realizing that flash flooding can directly impact them.

Land Use

In an effort to reduce injuries, deaths, and property loss, the City of Boulder created a flood management program. This program maps floodplains, regulates development in floodplains, mitigates flood hazards, and educates the public on floods (City of Boulder 2012). The aim of the program is to recognize that flooding will happen and work on a plan to reduce losses instead of trying to prevent flooding in the first place.

In the Boulder Creek 100-year floodplain, the largest of the floodplains in Boulder, there are only 884 total structures (City of Boulder 2010). Of the many thousands of structures in Boulder, only a small fraction of buildings are actually located in the floodplain. Figure 3.2 illustrates this point with so few streets actually located in the floodplains. There is limited development in the floodplain for a reason. One of the main uses of the 100-year floodplain is the Boulder Creek Path, a major pedestrian path that runs along the creek. When flooding does occur, the floodwaters will wash over the path and grassy areas instead of through built up property. Therefore, less damage will occur. Although the Boulder Creek Path and other greenways were created as a mitigation technique for flash flooding, people located in these areas at the time of flash flooding could be exposed to life-threatening flooding (Mileti 1999).

There are many regulations with respect to the 100-year floodplain. Buildings in the 100-year floodplain must have 1) wet floodproofing (at least two openings must be created in areas below the 100-year flood level to equalize hydrostatic pressure), 2) elevated mechanical and electrical systems above 100-year flood elevations; and 3) be anchored to minimize dangerous debris downstream. Residential structures must be elevated to two feet above 100-year flood level and new residential development cannot have a basement in the floodplain. Non-residential or mixed-use structures must elevate residential units to the 100-year floodplain level and

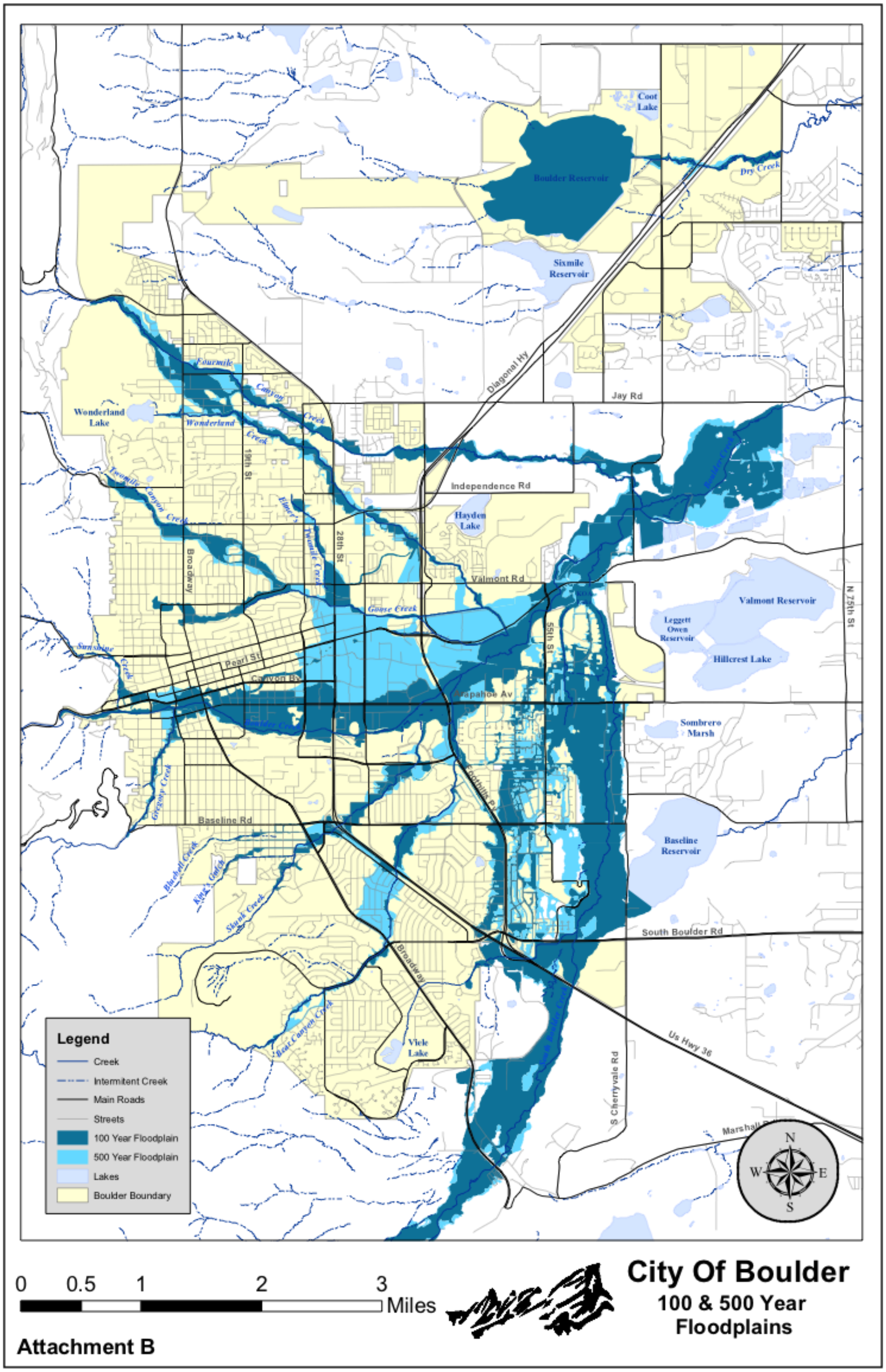

Figure 3.2: Floodplains in City Limits of Boulder, Colorado (City of Boulder 2012)

elevate or floodproof non-residential portions of the building to the elevation of the 100-year flood level. Boulder also prevents parking where flooding occurs greater than 18 inches, to prevent cars from washing downstream. All floodplain development requires a special floodplain permit. While there are currently no regulations for building in the 500-year floodplain, the City of Boulder is discussing an ordinance that all critical facilities (such as schools, hospitals, fire and police stations, and utility infrastructure) be protected to the 500-year flood level to ensure the use of these facilities in a flash flood event (City of Boulder 2012).

The City of Boulder is also aware of transient populations such as tourists or students. To help ensure their safety, the city proposes that all facilities housing these populations, such as dormitories and hotels, establish an emergency management plan and post it in the doorway of each unit as well as in large gathering areas. The purpose of this proposed ordinance is to educate and provide quick information to all transient populations in Boulder in case of flooding (City of Boulder 2012).

Demographics

Table 3.1 presents the 2010 Census data for the City of Boulder compared to national statistics. The median age of Boulder residents is lower than the national average as is the percent of homeowners, most likely because of the large student population in the city. There is also less racial and ethnic diversity in Boulder. Boulder is highly educated with 69.0% of those aged 25 and above with at least a bachelor's degree. While the median household income of Boulder residents seems on par with the national figure, it is again important to take the student population into account as they likely make a fraction of that income. Most residents of Boulder are wealthy, especially when considering the high housing costs in the city, with a median of $477,700 (City-Data 2009).

Table 3.1: City of Boulder Demographics Compared to US Population

Demographic	City of Boulder (2010 Census)	US Population (2010 Census)
Total Population	97,385 people	308,745,538 people
Median Age	28.7 years old	37.2 years old
Male	51.3%	49.2%
White	88.0%	72.4%
Black or African American	0.9%	12.6%
American Indian or Alaska Native	0.4%	0.9%
Asian	4.7%	4.8%
Other	8.9%	6.2%
Homeowners	48.8%	65.1%
Bachelor's degree or higher	69.0%*	28.1%*
Median Household Income	$51,779	$50,046

*For those aged 25 or higher

Boulder is an interesting case study for flash flood research due to its location and demographics. Although Boulder is vulnerable to flash flooding, the city has not experienced flooding for decades, which could affect perceptions and expected behaviors in a flash flood warning. Boulder also has a highly educated population, which from past research means a high percentage of the population should be expected to take protective action and to have already prepared for flooding. An added vulnerability for Boulder's population is the transient student residents, who may not necessarily have the situational awareness to know how to respond to flash flooding (Mileti 1999).

CHAPTER 4: METHODOLOGY

To address the research questions, a mixed-methods approach was utilized. The combination of responses to a mail survey and Geographic Information Systems (GIS) derived location variables are analyzed to predict both likelihood of response to a flash flood warning, or REACT, and likelihood of previous preparation for flash flooding, or PREPARE. As noted previously, Boulder is an excellent area to study behaviors related to flash flooding because of its susceptibility to flash flooding, length of time since the last flash flood, and demographics. If and when Boulder does experience flash flooding, it will be useful to have data from this research to compare to a post-flood study to see if there are changes in risk perception, response, or preparedness. Since flash flooding has not occurred in Boulder since 1969, this study also examines whether long periods of time without flooding really affects the perceptions of flash flooding and REACT or PREPARE, an instance that is sparsely reported in the literature. One of the innovative aspects of this research is its focus on the location of respondents' residences. This information can lead to policy decisions to make sure Boulder residents are prepared and ready to act in a flash flood.

Survey Development

Purpose of Survey

The survey was originally developed to ask a variety of questions about flash flooding for the public, media, forecasters, and public officials in order to compare expert responses to those of laypeople. The research reported here only focuses on the public portion of the survey. The survey contained many sections to inventory each respondent's characteristics relating to flash flooding in Boulder. These sections included risk perceptions of hazards in general and flash floods more specifically, knowledge about flash flooding, likelihood to respond in a flash flood watch and warning (REACT), trust in and perceived accuracy of flash flood forecast products, importance of improving forecast accuracy, economic valuation of flash flood forecasts and warnings, information about insurance, measures taken to prepare for flash flooding (PREPARE), and socio-demographic indicators. While there is a vast amount of survey data available for analysis, only a portion of the data is used here. Drawing from past literature, risk perception, knowledge about flash flooding, trust and perceived accuracy of forecast products, experience, and socio-demographic indicators are all cited as indicators for PREPARE and REACT. Therefore, only questions referring to these concepts have been used in the final analysis. In addition to these, location attributes derived from GIS data provide an important contribution.

Implementation

The survey was pre-tested by conducting one-on-one interviews. These interviews required the respondent to read the survey aloud, talking through his or her thought process in answering the questions, allowing for verbal feedback not only on the respondent's insights to the answers, but also his or her constructive criticisms of the questions. Such criticisms included word confusion or difficulty with interpreting the question. Five volunteers, referred by the National Center for Atmospheric Research (NCAR) employees, with no formal education in meteorology or hydrologic science completed the one-on-one interviews. The pre-test results were then used to edit the survey, ultimately creating the final survey instrument.

The survey was mailed in January 2010 to 1,000 random home addresses in Boulder, Colorado. These addresses were accessed from a survey sampling company. It is important to note that the survey instrument was implemented before the flash flood scare and multiple wildfires that occurred in the summer and fall of 2010. While there was a media surge including flash flood information after both the flash flood scare and wildfires, the survey data had already been collected.

Of the 1,000 surveys, 750 surveys were mailed following Dillman's (2000) recommendations and the other 250 were simply mailed. Dillman's survey methodology involves multiple mailings. The first was a personalized letter that notified residents they would receive the survey and emphasized the importance of completing it. One week later, the survey packet was mailed. The packet included a personalized cover letter explaining the survey, a stamped, self-addressed return envelope, incentive (see below), and the questionnaire itself. The following week, another personalized letter was mailed reminding sampled individuals to complete the survey and thanking them for their time. For those residents who did not fill out the initial survey, a second survey with a stamped return envelope and no incentive was mailed as a follow-up. The 250 surveys that did not follow Dillman's method were mailed with a non-personalized cover letter and a stamped and addressed return envelope. The non-Dillman surveys were used to test mail survey techniques.

For the surveys following Dillman's method, there were five different incentive levels. These included no incentive, a single \$1 bill, two \$1 bills, a single \$2 bill, and a single \$5 bill. These varying incentive levels were not outlined by Dillman's technique, but instead were implemented to determine the effect on response rate (Table 4.1).

Of the 1,000 total surveys distributed, 130 were bad addresses. With 408 completed surveys of 870 good addresses, there was a 46.8% response rate (Table 4.1). Looking at the range of response rates in Table 4.1, higher incentive levels, in general, led to higher response rates. Overall, the Dillman technique elicited a higher response rate than the mailings that did not use the Dillman technique. Even comparing the non-Dillman technique to the Dillman mailing without incentives, the Dillman methodology elicited higher response rates.

Table 4.1: Survey Response Rate

Mode	Incentives	Distributed	Bad Addresses	Sample Size	Completed	Response Rate
Dillman	$0	150	30	120	43	35.8%
Dillman	1 x $1	150	16	134	74	55.2%
Dillman	2 x $1	150	25	125	73	58.4%
Dillman	1 x $2	150	15	135	72	53.3%
Dillman	1 x $5	150	21	129	85	65.8%
Non-Dillman	$0	250	23	227	61	26.9%
Total		**1000**	**130**	**870**	**408**	**46.8%**

Figure 4.1 shows the hot spot analysis of respondents and non-respondents to the survey. Those who responded to the survey are spatially random (Moran's I = -0.0055). Visually, there appear to be clusters of non-respondents (shown in blue), however these clusters have many respondents to the survey (shown in pink). The only cluster of non-responses is located in northeast Boulder, in the Gunbarrel area. Besides this small area, non-response bias is not expected for this sample. This is an indication that this sample is relatively representative of the population, spatially, as there are not large pockets of residents missing from the analysis.

Survey Index Creation

The questionnaire contained over 50 items, some of which had multiple parts. Since many of the questions address a single concept, such as knowledge, indices were created to provide an overall and condensed view for each respondent for each concept. There were three indices created and used for independent variables. The first is an antecedent knowledge index, which measures how much knowledge the respondents have about flash floods. The second is a warning receptiveness index. This combines trust in NWS flash flood forecasts and warnings and perceived accuracy of these products. The third is a risk perception index. This index combines

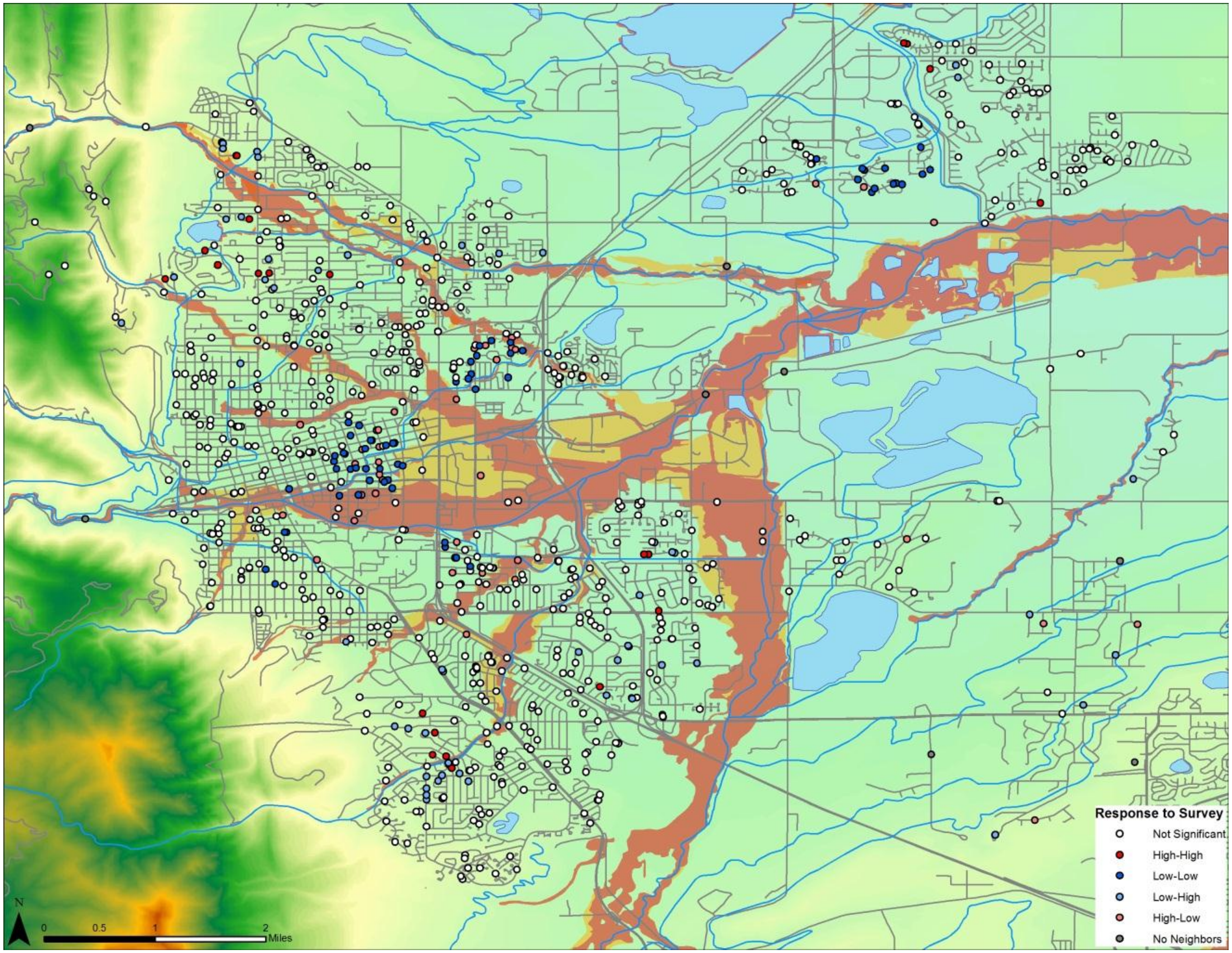

Figure 4.1: Hot Spot Analysis: Response Versus Non-Response to Survey, Half Mile Neighborhood

many questions including respondents' perceived likelihood of flash flooding occurring in Boulder, the likelihood of impacts from flooding, and if they personally feel safe from flash flooding. These indices were calculated for each respondent who answered at least two-thirds of questions making up the index. Otherwise, the index was left as missing for that respondent.

Antecedent Knowledge Index

The Antecedent Knowledge Index contains a variety of measures of an individual's knowledge of flash flood information and is comprised of questions with a correct or incorrect answer. The values for all these variables were summed to create the final Antecedent Knowledge Index value (Table 4.2). The full range of possible values for the final Antecedent Knowledge Index is 0 to 13 if all questions were answered.

The first measure of knowledge is whether or not respondents know the difference between a flash flood watch and warning. This was determined in two ways. Respondents were asked to provide a percent likelihood of flash flooding to occur in Boulder given a watch and a warning. If they gave a higher probability to the warning, they got the question correct and received one point toward the index. If the probabilities were equal or the watch probability was greater than the warning probability, a zero was recorded.

The other way to determine if respondents know the difference between a watch and a warning is with an open-ended format. A correct response was coded as one, an incorrect response as 0. Where respondents suggested that the difference was in the timings of the notifications or in imminence, but did not identify if the watch or warning was less imminent, a zero was recorded. Finally, if the respondent admitted to looking up the answer or simply stated they did not know the answer, it was considered incorrect, and coded as 0.

Table 4.2: Antecedent Knowledge Index Variables

Question	Answer coded as			
	0	1	2	3
Difference between watch and warning	Watch prob. ≥ warning prob.	Watch prob. < warning prob.	-	-
Difference between watch and warning	Incorrect	Correct	-	-
Knowledge of factors increasing likelihood of flash flooding	"Not at all important" or "Not very important"	"Somewhat important"	"Very Important"	"Extremely Important"
Only those on or near Boulder Creek are at risk from flash flooding	Agree with statement	Disagree with statement	-	-
Correct action to take in a flash flood warning if in a building	Incorrect	Correct	-	-
Correct action to take in a flash flood warning if in a car	Incorrect	Correct	-	-
Correct action to take in a flash flood warning if outside recreating	Incorrect	Correct	-	-
Maximum safe depth of rapidly flowing water to walk through	> 6 inches	≤ 6 inches	-	-
Maximum safe depth of rapidly flowing water to drive through	> 18 inches	≤ 18 inches	-	-
Definition of 100-year flood	Incorrect	Correct	-	-
Knowledge that residence is or is not in a floodplain	Incorrect	Correct	-	-

There are a variety of factors that increase the likelihood of flash flooding for a location. The survey included some of these factors: elevation compared to the stream or street level; nearness to a creek, stream, or drainage ditch; nearness to a lake, pond, or detention basin; nearness to a dam; nearness to a canyon; amount of rainfall during the last hour; amount of rainfall during the last 24 hours; and burned land from past wildfires in the area. Respondents were asked to rate the importance of these factors in determining the likelihood of flash flooding using a Likert scale. A response of either not at all or not very important was recorded as 0.

Responses of “somewhat important” were coded as 1 and “very important” as 2. If “extremely important,” it was coded as 3. The average score for the eight factors, a range of zero to three, was added to the Antecedent Knowledge Index.

Knowledge that creeks other than Boulder Creek can flood is part of this index. While Boulder Creek is central to the city, there is a possibility of flooding in many other areas in the city from different creeks and canyons. Respondents were asked whether they agree or disagree that only those on or near Boulder Creek are at risk from flash flooding in Boulder. Agreement with this statement was coded as 0, disagreement as 1.

The Antecedent Knowledge Index also included open-ended questions to see if the respondent could independently identify the correct action to take if there were a flash flood warning and he or she was in a variety of different situations. If the response involved seeking higher or safer ground, including moving upwards in the building, a 1 was coded. On the other hand, doing nothing was coded as 0 as were responses such as continuing to monitor conditions or seeking more information, because there is not enough time in a short-fused event like a flash flood to take these actions.

Other actions queried include crossing through flooded areas. In an open-ended format, the survey asked the deepest amount of fast-flowing water safe to cross by foot. Answers that were less than or equal to the NWS six inch maximum were coded as 1. Other responses were coded as 0. Similarly, if the response to the deepest amount of fast-flowing water that is safe to cross in a vehicle was 18 inches or less (as recommended by the NWS), a 1 was coded.

The final two components of the Antecedent Knowledge Index dealt with the floodplains. In an open-ended format, the respondents were asked to define the 100-year flood. Responses indicating any element of the 1% definition or those that defined it as being “the big one,” were coded as 1. Any response insinuating that the flood happens about once every 100 years or that Boulder is "due for one" was coded as incorrect.

Finally, the respondents were asked if their home is located in the 100-year floodplain, 500-year floodplain, or neither. This answer was compared to their actual location using GIS analysis. A correct identification was coded as 1 and an incorrect one as 0.

Warning Receptiveness Index

The Warning Receptiveness Index takes both perceived accuracy of and trust in flash flood warnings and forecasts into account. Warning receptiveness can be seen as a continuum ranging from people who do not think the flash flood products are accurate or trustworthy to those who find them very accurate and trustworthy. Therefore, each variable in this index was rated on a continuum. The values attributed to each variable are summed to create the index value (Table 4.3). The final Warning Receptiveness Index ranges from zero to eight.

Table 4.3: Warning Receptiveness Index Variables

Question	**Answer coded as**				
	0	1	2	3	4
Perceived accuracy of flash flood forecasts and warnings	Not at all accurate or Do not know	Not very accurate	Somewhat accurate	Very accurate	Extremely Accurate
Trust in flash flood forecasts and warnings	No trust at all or Do not know	Not very much trust	Some trust	Very much trust	Complete trust

Risk Perception Index

The Risk Perception Index represents an individual's perceptions of the risk of flash flooding in Boulder in a variety of ways. There are no right or wrong answers to these questions as they indicate how a respondent perceives the risk. As with the previous two indices, the values assigned to each variable are summed to create a final value ranging from zero to eight (Table 4.4).

Table 4.4: Risk Perception Index Variables

Question	**Answer coded as**			
	0	1	2	3
Probability of flooding in Boulder in the next year	< 30%	≥ 50%	-	-
Probability of flooding in Boulder in the next 30 years	< 30%	≥ 50%	-	-
Probability of flooding in Boulder in the next 24 hours given a warning	< 70%	≥70%	-	-
Probability of flooding in Boulder in the next 24 hours given a watch	< 50%	≥50%	-	-
Likelihood of a list of impacts occurring in a flash flooding Boulder	Not at all likely or not very likely	Somewhat likely	Very likely	Extremely likely
I believe I am safe from flash flooding	Agree	Disagree	-	-

One way to measure risk perception is to determine how likely an individual thinks flash flooding is in Boulder. This was assessed in a variety of time periods. For each of the questions, there was a continuum of percentages representing the likelihood of flash flooding in Boulder. The continuum ranged from 0% to 100% with a special line zoomed in ranging from 0% to 1% so respondents could mark very small probabilities. Each percentage was accompanied by a word definition. For example, 30% also had 30 in 100 written next to it. The respondent was asked to mark the likelihood of flash flooding in that situation on the continuum.

Respondents were asked the probability of flooding in Boulder in the next year, 30 years, 24 hours given a warning, and 24 hours given a watch. In order to create an index from these questions, a cutoff percentage was used to delineate between high (coded 1) and low (coded 0) risk perceptions. The cutoff points were determined based on the timescale given in the question and are presented in Table 4.4.

A multiple part Likert question asked about the likelihood of impacts occurring in Boulder from flash flooding. The impacts included the likelihood of damage to buildings or other property, people injured, people killed, people separated from loved ones or pets, disrupted transportation, economic losses or effects, degraded water quality, and ecological damage.

The final question associated with the Risk Perception Index asks if respondents believe they are safe from flash flooding. Those who feel safe from flash flooding were coded as 0 while those who do not feel safe were coded as 1.

Index Sensitivity

The indices were tested for sensitivity by examining their correlations with other variables. Adding questions, removing questions, and changing the weights of questions did not significantly affect behavior of the indices; the correlations were all similar. Therefore, the indices are relatively stable.

Responses to Flash Flooding

There are two dependent variables in this analysis to which all previous variables and indices are compared. The first is predicted action in a flash flood warning, or REACT. This variable is based on a 5-point Likert scale asking how likely the individual is to take protective action in a flash flood warning. The responses were collapsed into two categories: those who are not as likely to take protective action in a flash flood warning (responses of "not at all likely" through "somewhat likely") and those who are likely to take protective action (responses of very or extremely likely). Because this is a 5-point Likert scale, the middle response of "somewhat likely" was switched to the highly likely to take protective action (or REACT) category. Making this change hardly changed the results. The middle response of "somewhat likely" was therefore considered not reacting because of the hesitancy of the word "somewhat". The basis for this is that respondents to surveys may not want to look bad in front of the researcher, and can tend to sugarcoat their responses, thus opting for “somewhat” over “not” (Bertrand and Mullainathan 2001).

The second dependent variable is whether or not the respondents prepared themselves for flash flooding, or PREPARE. The possible mitigation efforts include planning an evacuation route, packing an emergency kit, making plans with family members within the residence, making plans with family or friends who do not live in the residence, and making changes to their home or property to protect it from flash flooding. If they indicated that any of these actions had already been taken, that was counted as having prepared for flash flooding. If none of these were selected, then they were considered to not have prepared.

Other Variables

Other predictive variables included in the analysis are experience, socio-demographics, and locations, which are discussed below (Table 4.5). Experience was asked in an open-ended format with those who had been personally affected by flash floods considered to have experience. Those who knew individuals in floods, saw damage, or had education on flash flooding were not counted as having past experience.

GIS Analysis

Because the survey was distributed by mail, the geographic locations of the respondents’ homes are known and were geocoded in ArcMap using the United States Census TIGER/Line road data (U.S. Census Bureau 2011, Figure 4.2). Respondents who could not be located were manually placed at their mailing addresses by looking up their address using Map Quest (www.mapquest.com). There is a potential for error involved both in geocoding and manual placement, but this should be negligible as the differences should only be a few feet. Elevation

Table 4.5: Other Variables in Analysis

Variable	Source
Age	Survey
Length of Residence	Survey
Gender	Survey
Renter or Owner	Survey
Educational Attainment	Survey
Income	Survey
Perceived Location in the 100- or 500-year floodplain	Survey
Location in the 100- or 500-year floodplain	GIS Derived
3D distance between respondent and nearest point on the 100-year floodplain	GIS Derived
Difference in elevation between respondent and nearest point on the 100-year floodplain	GIS Derived
Flow distance between respondent and nearest point on 100-year floodplain, described below	GIS Derived
Volume required to flood the respondent from 100-year floodplain, described below	GIS Derived

data used in the analysis were downloaded from the United States Geological Survey (USGS) National Elevation Dataset (NED) (USGS 2006). Boulder County has digitized its rivers and lakes, as well as the 100- and 500-year floodplains as determined by the Federal Emergency Management Agency (FEMA). These shapefiles are all located on the county's GIS website: http://www.bouldercounty.org/find/maps/pages/gisdldata.aspx and were accessed on November 17, 2011.

From Figure 4.2, it is clear there are few people residing in the floodplain because of city planning and zoning to prevent loss of property and life in a flash flood situation. Even though most respondents do not have their residences located in floodplains because of city planning, they can still be affected by flooding due to the impact on roads and infrastructure.

Determining Total Residential Buildings in Floodplains

To determine the number of residential buildings located in the 100- and 500-year floodplains, building footprints and zoning areas were downloaded from the Boulder GIS page. The Boulder zoning areas were overlain in order to pick out the buildings that were zoned for

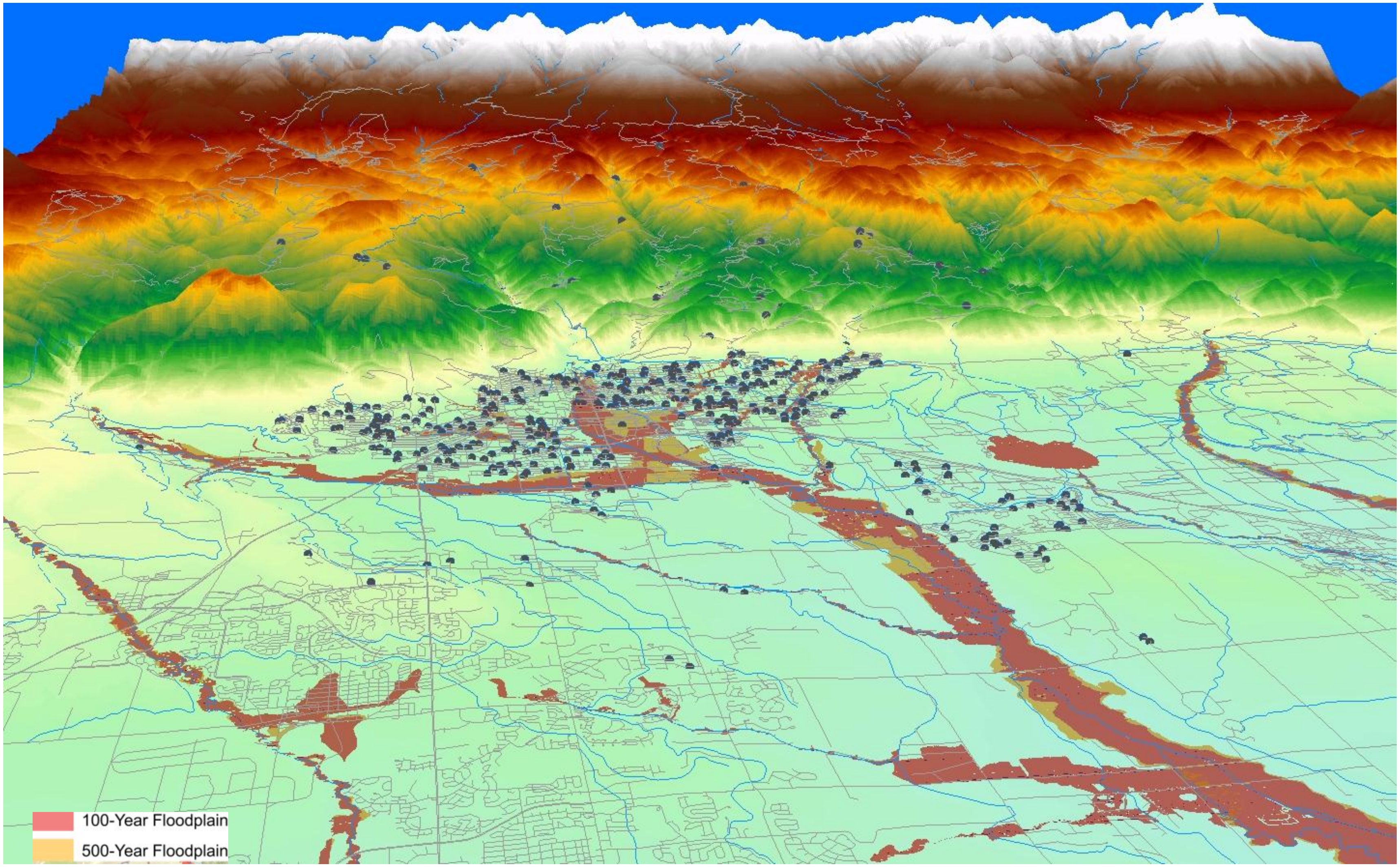

Figure 4.2: Location of Respondents, Looking West

residential purposes. Two frequencies of buildings resulted. The first was all residential zoning types, mobile homes, and mixed-use zones. There are more buildings in this estimate since mixed-use can also include some commercial buildings. The second measure did not include mixed-use zones. Once the residential buildings were extracted from the shapefile containing all buildings, buildings were selected based on their location partly or completely within the 100- or 500-year floodplain. This provided a count of the number of buildings in the floodplains including and not including mixed-use buildings.

Hot Spot Analysis

Hot spot analyses are conducted to determine if there are neighborhoods characterized by a similar attribute in a sample, as a reflection of spatial autocorrelation. Basic mapping and hotspot analyses were conducted using ArcMap version 10 and GeoDa software. Moran's I was used as a measure of spatial autocorrelation, i.e., how the attribute of one respondent is related to the same attribute of his or her neighbors. Moran's I is an index ranging from -1 to 1. Values close to 1 indicate positive autocorrelation, meaning there are similar values clustered together across areas. Values close to 0 are interpreted as portraying a random distribution, with no spatial pattern. Moran's I results near -1 suggest negative autocorrelation. This result resembles a checkerboard and is neither clustered nor random. Results from the local Moran's I can be mapped at local levels to illustrate the location of clustering. These results map the respondents classified as high-high (individuals with high level of the attribute located next to other high attribute levels), low-low (individuals with low levels of the attribute located next to other low attribute levels), high-low (individuals with high levels of the attribute located next to lower attribute levels, known as an outlier), and low-high (individuals with low attribute levels located next to higher attribute levels, also an outlier).

A weights matrix is created to define what constitutes a neighbor. The researcher defines what constitutes a neighbor in a hot spot analysis. Because points represent the respondents, not polygons, a threshold distance was used to determine the radius of a neighborhood. Four different thresholds were examined for the analyses to see if there was a difference in the results depending on various neighborhood sizes: approximately 0.5 miles, 2.5 miles, 5 miles, and 10 miles. The variables considered for hot-spot analysis included respondents versus non-respondents to the survey, REACT, PREPARE, antecedent knowledge, warning receptiveness, risk perception, and past experience. The half-mile neighborhood is used for all figures shown in the document. Using the half-mile neighborhood reduces the amount of smoothing effects.

Flow Distance Calculation

As described previously, distance can be conceptualized in many different ways: Euclidian distance (the shortest distance between two points), elevation difference, functional flow distance (Figure 2.2), or volume of water required to flood an individual. The distance between the respondent and the 100-year floodplain boundary was used for all distance measures. This distinction was chosen because there are situations where a respondent could be far away from a stream, but close to a floodplain and therefore would be likely to be flooded. Conversely, the floodplain may only extend a few feet away from the stream due to elevation. Using the distance from a floodplain standardizes the risk of flooding regardless of the distance from a stream.

To find the distance to the nearest 100-year floodplain based on flow routing, an elevation (DEM) raster was downloaded from the USGS NED database (USGS 2006). Any sinks in the raster were filled in so water did not pool in the mountains. A raster of the flow direction of the entire DEM was created with each cardinal direction, reclassified from 1 to 8. A flow path for each survey respondent was created separately because many of the flow paths eventually crossed one another, making it impossible to measure the distance. As a result, an iterator was used to automate the calculation of functional distance for each respondent, using a model from Model Builder in ArcMap 10.

The first step in the model was creating the cost path. This tool uses elevation data (that was filled) and flow direction to find the easiest path from a selected point to the edge of the elevation raster. Figure 4.3 is an example of a respondent's least cost flow path. Because this layer is output in a raster format, it is necessary to convert the layer into a polyline. This line represents the least cost distance from the respondent to the edge of the raster, not the floodplain. Therefore, the next step is to trim the line only down to the length between the respondent and the first intersection with the 100-year floodplain. Then, the intersection of the flow path line

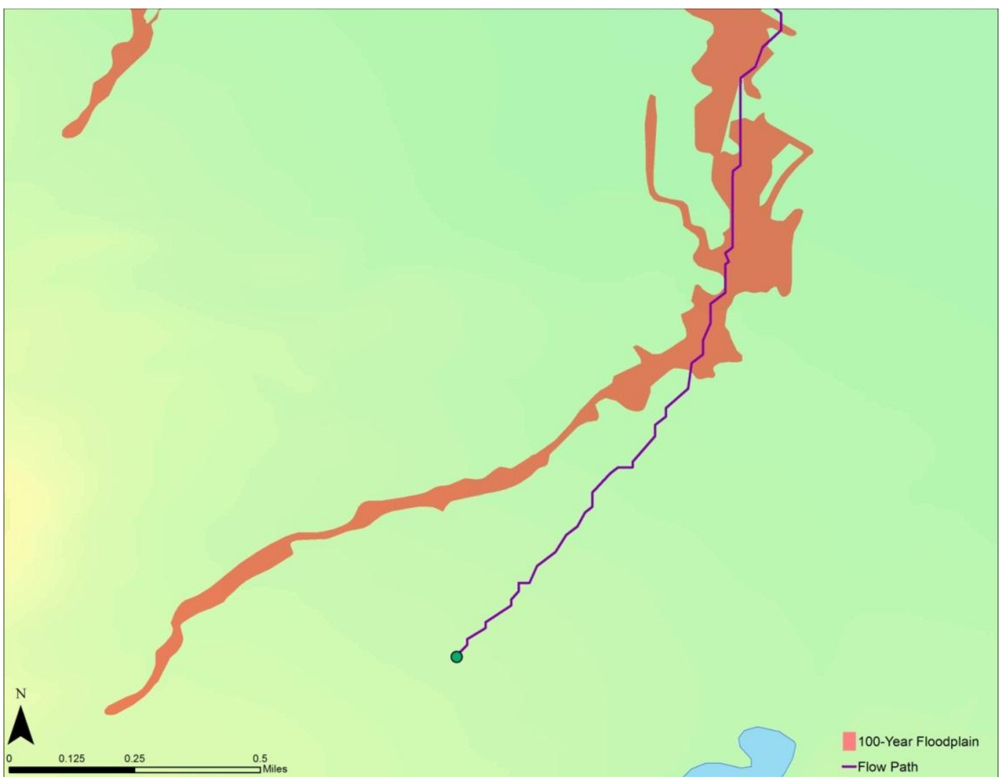

Figure 4.3: Least Cost Path for Individual Respondent

with the 100-year floodplain was used to obtain a point layer output showing every intersection between the flow path and the floodplain (Figure 4.4). This output is a multipoint layer, so the "multipart to single part" tool is needed to output individual points. Finally, the cost path line can be split into line segments using the "split line at points" tool and the intersection points. This breaks the flow line down to small segments between each intersection with the floodplain.

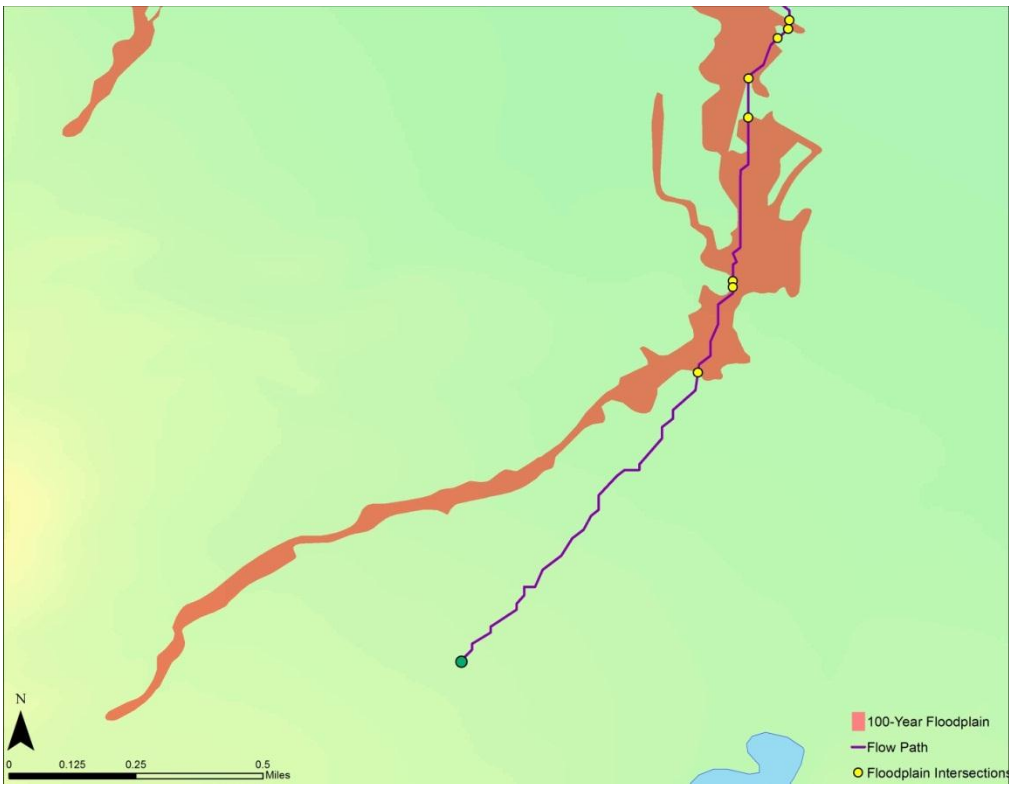

Figure 4.4: Flow Path and 100-Year Floodplain Intersections

The first line segment for each least cost line is the tiny segment representing the end flow cell at the edge of the raster. The second line segment, for each respondent's flow path is the segment between the respondent and the first intersection with the floodplain. With that information, it is possible to select the line segment where objectID is equal to 2 (segment between the respondent and the first intersection of the floodplain) and then export the layer to get the final functional distance (Figure 4.5). Because the line is based on raster data, the line may not snap exactly to the respondent and may be a few feet off, which is negligible.

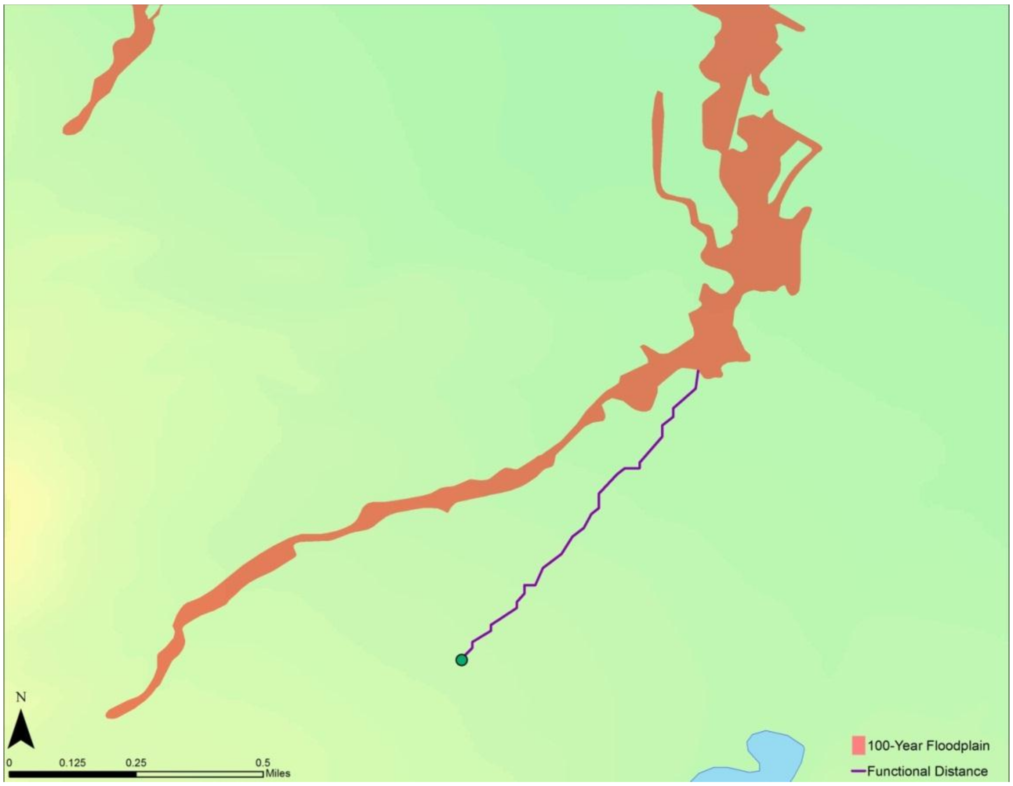

Figure 4.5: Final Flow Distance for Individual Respondent

Once the model was executed for each respondent, the segments were merged into a single polyline file (Figure 4.6). It can be seen that, as mentioned before, many of the flow paths intersect eventually. The 3-D surface distance of the line (which increases with elevation) was recorded by adding surface information from the elevation raster and converting the flows into 3D lines. For all respondents actually located in the 100-year floodplain, the flow distance was changed to zero, so it was not representing the distance to the edge of the floodplain in which they were already located.

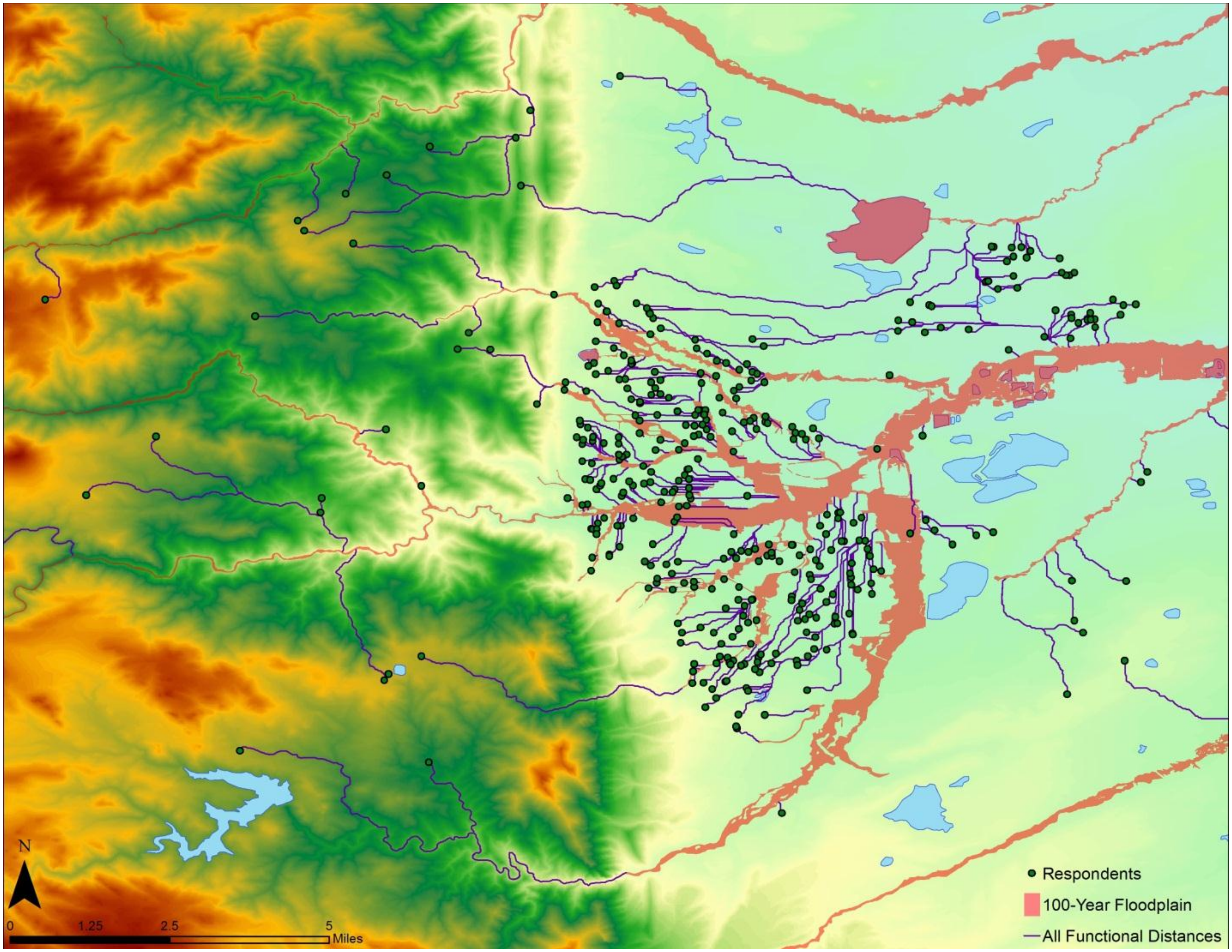

Figure 4.6: Flow Distances for All Respondents

Surface Volume Calculation

The volume of water required to flood an individual at his or her home was also calculated. Again, the 100-year floodplain was used as a starting point as it is a standardized measure of where floodwaters will go. The first step was to recreate the points where the flow path first intersects the floodplain. This was accomplished by running a model, iterating through each flow path and intersecting it with the floodplain. Since the output was in a multipoint format, the “multipart to singlepart” tool was used to make individual points. These points represented a pour point into the floodplain, or the outflow point of the respondent’s miniature watershed. Because each separate pour point was in its own shapefile, or point at which all the water in that individual’s “watershed” drains into the floodplain, it was necessary to merge all these into a single pour point feature class, making sure both the respondent’s feature class and pour points were in 3D format and had elevation information in their attribute tables.

Similar to the functional distance calculation, each volume had to be calculated separately to avoid watersheds overlapping. To do this, another model was used with an iterator to create each watershed individually. The model first snapped the pour points to the elevation raster so the pour points were located in the correct raster cell. Then, a watershed was created based on that individual pour point such that the respondent was located within the watershed. Since the elevation of the respondent is known and any area of the watershed above the resident is not needed, the raster calculator was used to create a raster showing only the elevation in the watershed that is lower than the respondent’s elevation. This output watershed was put into a surface volume calculator to determine the volume of the space in the watershed below the plane of the respondent’s elevation, representing the volume of water required to flood the individual at their home. All measurements are in feet so the final volume units are in cubic feet. For every person residing in the 100-year floodplain, the surface volume was changed to 0 as this volume is meaningless. If the volume could not be calculated for whatever reason, the volume was coded as a null value. Counting the 24 residents living in the 100-year floodplain as valid volumes, a total of 72 volumes could not be calculated. In other words, 82.4% of the respondents' volumes could be calculated.

Other Distance Measures

The other distance measures calculated are the Euclidian distance to the 100-year floodplain and elevation difference between the respondent and the nearest point on the floodplain. The 100-year floodplain had to be converted into lines and made three-dimensional using the mean elevation from the elevation DEM. The 3D near tool then calculated the three-dimensional distance, which was changed to 0 if the respondent was located in the floodplain. The tool also outputs the location of the nearest intersection (in Euclidian terms) between the respondent and the floodplain. These data were plotted using the "Make XY Event Layer" tool, with the features then exported into a new layer. From there, the elevation of the points could be determined and the difference between these points and the elevation of the respondents calculated. Some people out of the floodplain reside in lower elevations compared to the floodplain, so the respondents who were in the floodplain were changed to -25, lower than the lowest value.

Data Analysis

To conduct the statistical analysis, simple summary statistics are used. T-test is used to compare all binary variables, for example gender, location in the 100-year floodplain, and student status, with REACT and PREPARE. The ANOVA test is used for both categorical variables: income and education. For continuous variables, Pearson's correlation coefficient is used. For all analyses, a 90% confidence level is used. Finally, binary logistic regression is used to estimate prediction equations for the two dependent variables: PREPARE and REACT. A binary logistic regression makes it possible to predict variables with two possible outcomes. Since each of these variables is divided into binary categories, for example preparing or not preparing for flash flooding, this type of regression is best suited for the analysis. Binary logistic regressions are represented by the following formula:

$$p(z) = \frac{1}{1 + e^{-z}}$$

where:

$$z = B_0 + B_1X_1 + B_2X_2 + \ldots + B_nX_n$$

Each B value indicates a constant determined by the regression and each X value is a variable in the regression equation. This type of regression follows the generalized linear model, where the regression output is the equation for a line. Since there are only two possible responses in a binary variable, the regression equation must be transformed to a logistic equation. This transformation changes the probability of an outcome, for example PREPARE, into odds. The natural logarithm of the odds is considered a logit, which is used for this type of regression. In order for the logistic equation to be solved, the maximum likelihood procedure is used. This is an iterative process that uses the predictors and model criteria to create the most likely solution. Variables included in the regression are the indices, socio-demographic indicators, and all location variables.

To determine how well the equations created by the binary logistic regressions model for REACT and PREPARE, a pseudo R-squared statistic is used. The Nagelkerke R Square gives a measure of the improvement of the model. The model is compared to, for example, the assumption that all respondents will react in a flash flood warning. The greater the number, the better the model. The upper limit of the Nagelkerke R-square measure is 1.

CHAPTER 5: STATISTICAL ANALYSIS OF SURVEY RESULTS: CONTRIBUTION OF VARIABLES

Survey Population Demographics

The demographics of the survey population are shown in Table 5.1. Of the 408 respondents, the median age is 51 years. The majority of the population is white (92.0%) and male (53.9%), with the second most common cited racial or ethnic group being Asian (3.6%). Of the respondents, 73.8% own their houses and 83.6% have a bachelor's degree or higher. Finally, the median household income of the sample is between $75,000 and $99,999.

Table 5.1: Survey Demographics Compared to Census Data

Demographic	**Sample**	**City of Boulder (2010 Census)**	**Gruntfest et al. (2002) Survey**
Total Population	408 people	97,385 people	319 people
Median Age	51 years old	28.7 years old*	26 to 35 years old
Male	53.9%	51.3%	48%
White	92.0%	88.0%	-
Black or African American	0.7%	0.9%	-
American Indian or Alaska Native	0.5%	0.4%	-
Asian	3.6%	4.7%	-
Other	3.1%	8.9%	-
Homeowners	73.8%	48.8%	28%
Median Length of Residence	19 years	-	1-3 years
Bachelor's degree or higher	83.6%	69.0%**	50.0%
Median Household Income	$75,000 to $99,999	$51,779	-
CU Student	6.6%	31.2%***	51%

*The census figure includes children under the age of 18 (13.9% of Boulder's population). Under our IRB permissions, we could not survey this group. In addition, this figure includes the student population, which was hard to get a large sample of because of their transient nature.
**For those aged 25 or higher
***Census population compared to CU Boulder Enrollment (2011)

Compared to the 2010 Boulder Census data, also listed in Table 5.1, the survey sample is older, wealthier, and more highly educated than the city as a whole. Additionally, University of

Colorado (CU) at Boulder students are underrepresented (Table 5.1). These are typically younger and poorer populations. According to the Census data, 13.9% of the city's population belongs to this demographic. Thus, while the sample population is not necessarily representing Boulder in terms of age and income, the survey population represents the different racial and ethnic groups in Boulder quite well.

The survey population can also be compared to a survey conducted by Gruntfest et al. (2002) less than a decade before this survey. Their survey of the public was only for people living in the 100-year floodplain of Boulder Creek, not other creeks' floodplains and not those residing outside the floodplain. They specifically targeted the CU Student Family Housing in one part of the study and compared these results to all other occupants of the Boulder Creek 100-year floodplain. The Gruntfest et al. (2002) survey had a much younger demographic, with a very low median length of residence, few homeowners, lower educational attainment, and larger student population.

Few survey respondents (19.7%) have had direct experience with flash flooding (Table 5.2). This is a small proportion of the population, but without recent flooding in Boulder, many individuals who have lived in Boulder a long time would not have had flash flood experience unless it occurred elsewhere. A past study of Boulder residents indicated that 15% of the population had experience with flash flooding, a similar finding to the one reported here (Gruntfest et al. 2002).

Table 5.2: Past Direct Experience with Flash Flooding

Past experience with flash floods	**Frequency**	**Percent**
No past experience	284	80.3%
Past experience	72	19.7%

Location of Respondents

Of the survey population represented in this research, 5.8% of respondents live in the 100-year floodplain and 3.7% live in the 500-year floodplain (Table 5.3). This slightly under-represents the amount of residents actually located in the floodplains in Boulder (Table 5.4). As mentioned previously, there are so few people living in the 100- and 500-year floodplains because of city zoning. Although not many people live in the floodplains, the survey still under-represents the population.

Table 5.3: Location of Respondents with Respect to Floodplains

Actual Location of Respondent	Frequency	Percent of total respondents
100-year floodplain	24	5.8%
500-year floodplain	15	3.7%
No Floodplain	369	90.4%

Table 5.4: Actual Count of Residential Buildings in Boulder Floodplains

Type of Buildings	Percent of buildings in 100-year floodplain	Percent of buildings in the 500-year floodplain
Residential and mixed use	7.4%	5.0%
Just residential	7.3%	5.0%

In terms of characteristics for respondents living in the floodplain, there are no significant correlations between these characteristics and living in the 100-year floodplain (Table 5.5). Income is the only variable significantly correlated with location in the 500-year floodplain (Table 5.6). Comparing the means, the most common income range of residents living in the 500-year floodplain is $75,000 - $149,999 (Figure 5.1).

The locations of the respondents are quite variable (Table 5.7). While some are located in the 100-year floodplain, others are close to three miles away from it. The mean distance from the 100-year floodplain is 0.31 miles. While some residents are located below floodplain elevation,

Table 5.5: Characteristics of 100-Year Floodplain Residents

Location in 100-Year Floodplain	**Statistic Type**	**Correlation**	**Significance**
Age	Pearson	r = 0.012	0.814
Male	T-Test	t = 0.501	0.616
Length of residence	Pearson	r = 0.022	0.684
Student	T-Test	t = 1.295	0.196
Homeowner	T-Test	t = 0.871	0.384
Income	ANOVA	F = 1.162	0.324
Education	ANOVA	F = 2.032	0.132
Experience with flash floods	T-Test	t = 0.283	0.777

Table 5.6: Characteristics of 500-Year Floodplain Residents

Location in 500-Year Floodplain	**Statistic Type**	**Correlation**	**Significance**
Age	Pearson	r = 0.025	0.625
Male	T-Test	t = 1.435	0.152
Length of residence	Pearson	r = 0.042	0.432
Student	T-Test	t = -0.973	0.331
Homeowner	T-Test	t = 1.268	0.206
Income	ANOVA	F = 2.806*	0.040*
Education	ANOVA	F = 0.572	0.565
Experience with flash floods	T-Test	t = 0.266	0.791

*Significant at the 0.100 level

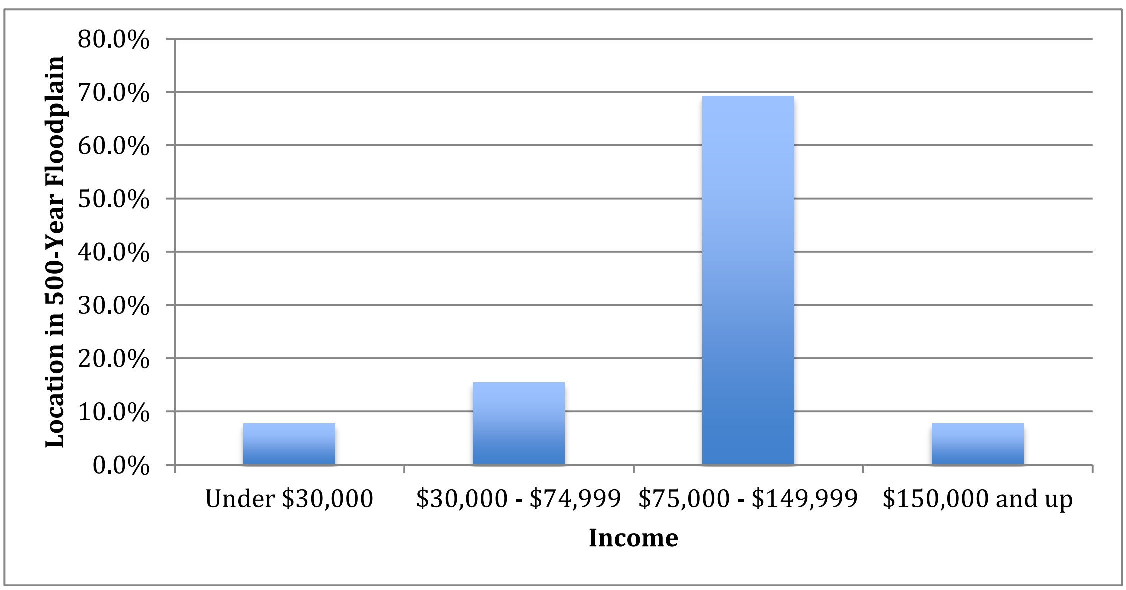

Figure 5.1: Income of 500-Year Floodplain Residents

Table 5.7: Summary of GIS-Derived Statistics

Variable	Unit	Min	Max	Mean	Median	Missing
3D distance to 100-year floodplain	Miles	0	2.93	0.31	0.21	0
Elevation difference to 100-year floodplain	Feet	-25	565.2	18.8	2.1	0
Flow distance to 100-year floodplain	Miles	0	8.55	0.99	0.51	0
Volume of water required to flood respondent	Cubic Feet	0	2.75×10^9	4.34×10^8	3.36×10^6	72

others live up to 565 feet above it. The average elevation difference between respondents' houses and the floodplain is 18.8 feet. Looking at elevation maps of Boulder (Figure 4.2), most respondents are located in the plains where elevation differences are not substantial. The mean flow distance between a respondent's home and the 100-year floodplain is approximately one mile with a maximum flow distance of 8.55 miles. Finally, the volume of water required to flood respondents at their homes is quite variable. Overall, it would not take much water to flood residents of the 100-year floodplain, but flooding is highly unlikely at most residents' homes.

To further investigate the locations of the respondents, socio-demographic indicators were mapped to determine the spatial distribution of these variables in Boulder. Older respondents tended to live in North and South Boulder with younger respondents living in the downtown area in West Central Boulder (Figure 5.2). This makes sense with the University of Colorado being located in the central part of Boulder. The income distribution corresponds to the age distribution, likely because younger respondents do not tend to make as much money (Figure 5.3). This can be related to the location the University of Colorado as well. There also seems to be a trend of lower income respondents in and near the floodplains.

Housing types and home ownership are also spatially dependent. There are many more apartments and townhomes located in and around the floodplains (Figure 5.4). Assuming the

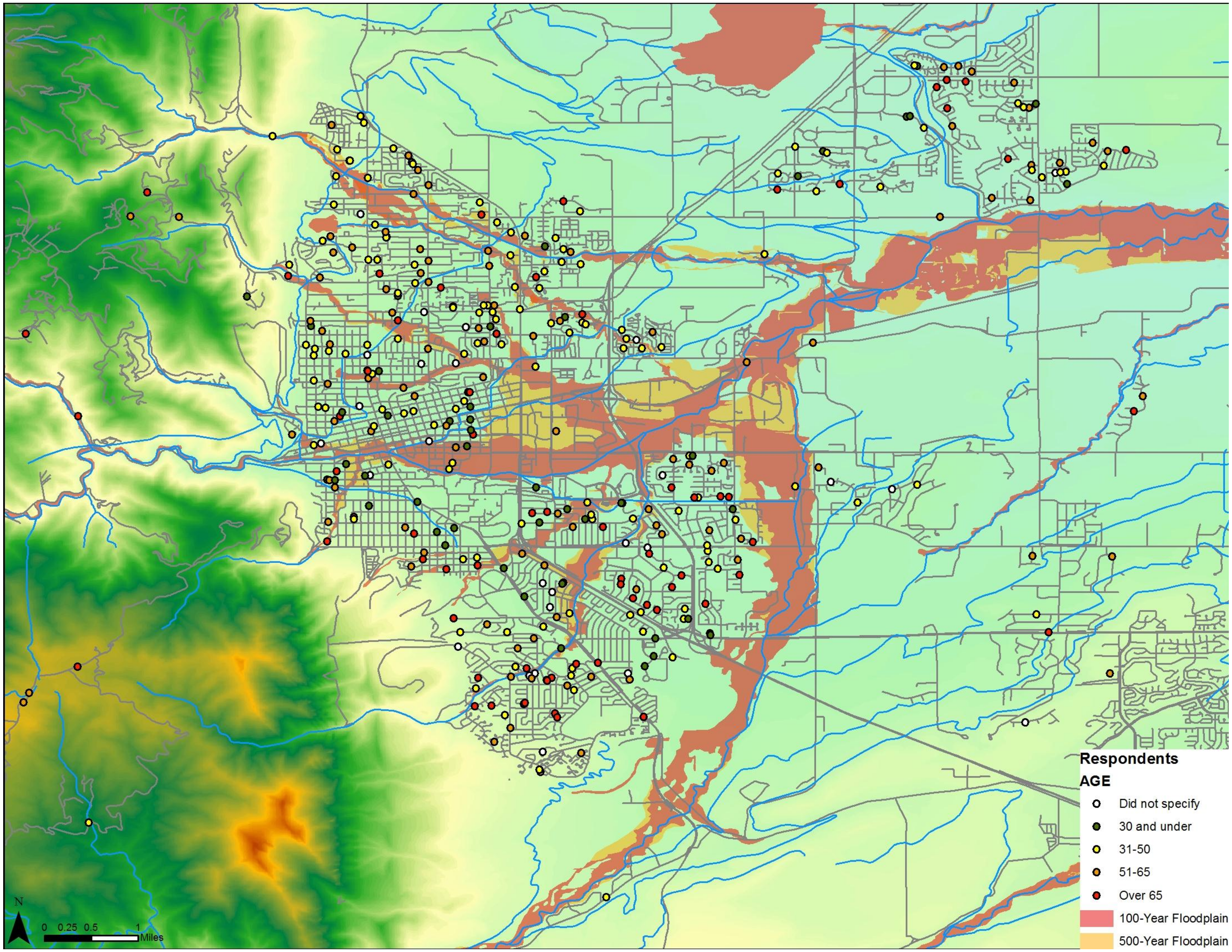

Figure 5.2: Spatial Distribution of Age

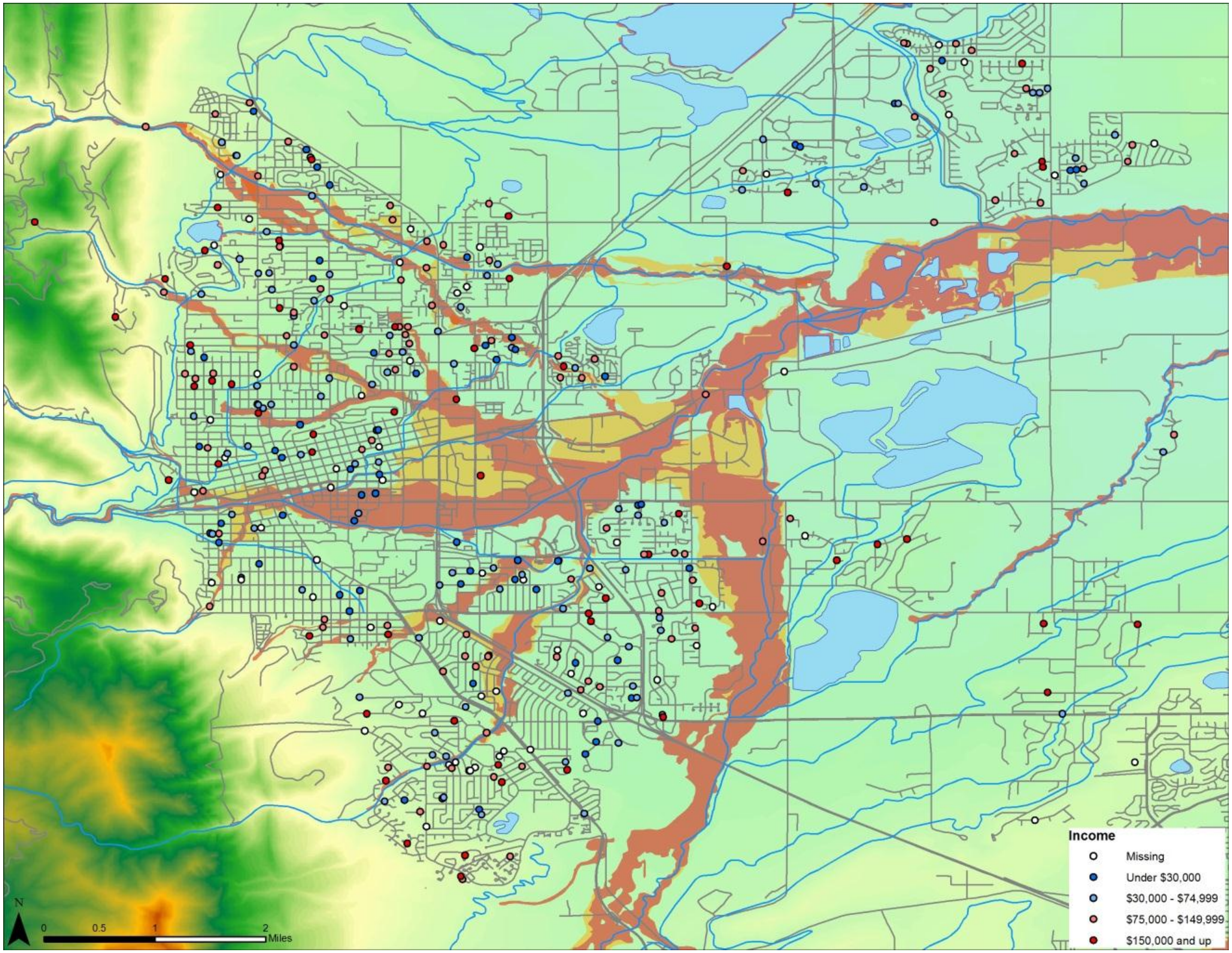

Figure 5.3: Spatial Distribution of Income

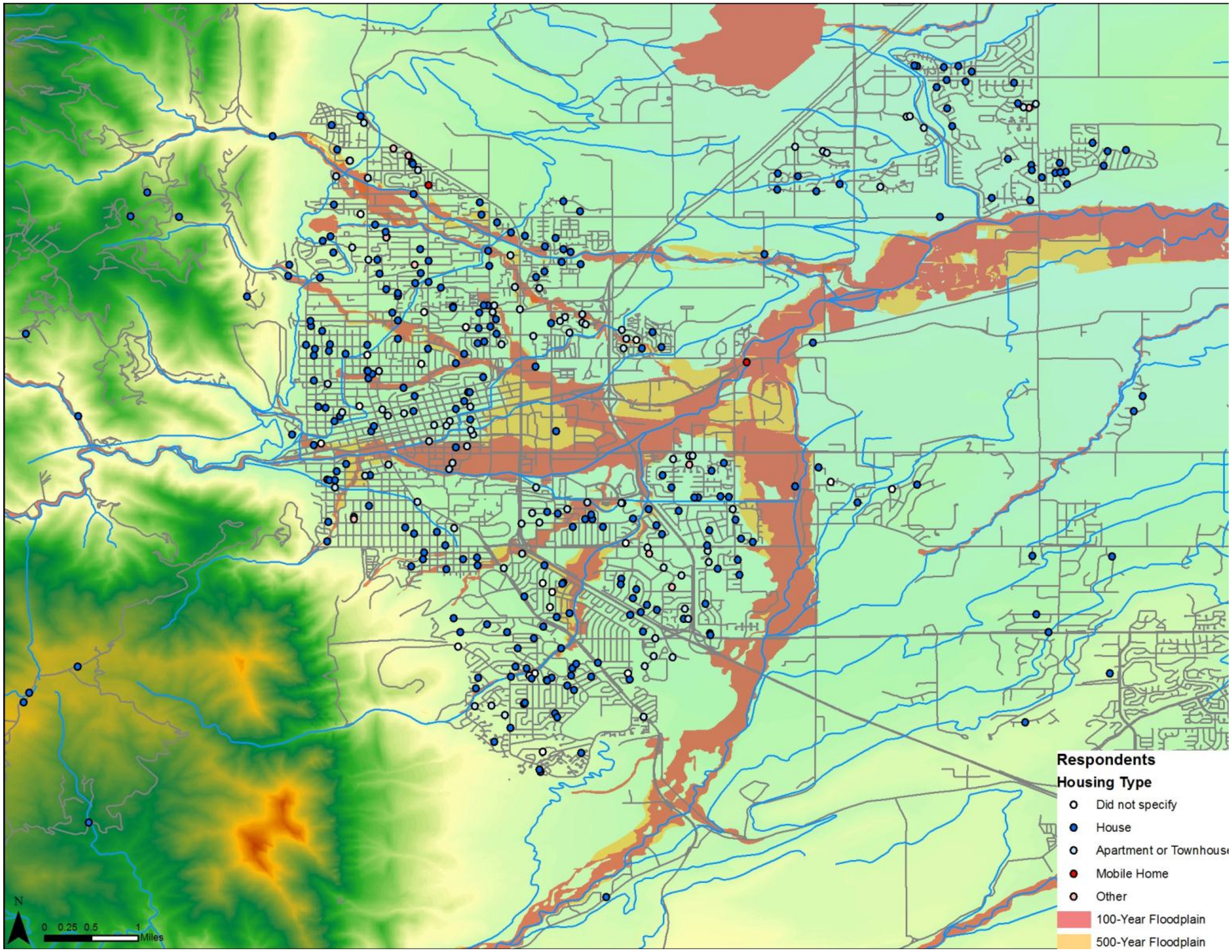

Figure 5.4: Spatial Distribution of Housing Types

construction is solid, the residents could feasibly seek higher ground in the apartment building and still be safe if they do not have enough time to evacuate out of Boulder. There are very few mobile homes in Boulder, but one of them is located directly in the 100-year floodplain, putting this individual at great risk. Finally, there are not very many renters in this sample. Of those who do rent, many live near the floodplains or streams (Figure 5.5). One of the problems with being a renter at risk of flooding is not being able to take out flood insurance. However, it is possible to obtain renters insurance to replace belongings, but many do not do so.

Hot Spot Analysis

One way to assess the spatial distribution of variables is with a hot spot analysis to determine if there are neighborhoods with high or low attributes of the same variable. The variables tested in this analysis are response versus non-response to the survey, REACT, PREPARE, Risk Perception Index, Antecedent Knowledge Index, and Warning Receptiveness Index. The Moran's I, a measure of spatial autocorrelation, for different definitions of neighborhoods for each variable tested in the analysis is shown in Table 5.8. Since all the Moran's I values are close to zero, there appears to be no significant neighborhoods of any variables, regardless of the definition of a neighborhood. In other words, the distribution of the variables is spatially random.

Sometimes, Moran's I values can be deceiving, and small areas of similar respondents may show up when the values of the tested variable are mapped. Hot spot maps of each of the variables were created for many neighborhood definitions, listed in Table 5.8, to look for areas of similar respondents. Most maps resembled Figure 5.6, with an area of low attribute respondents with random high attribute respondents located in the midst of them. This still signifies a random distribution.

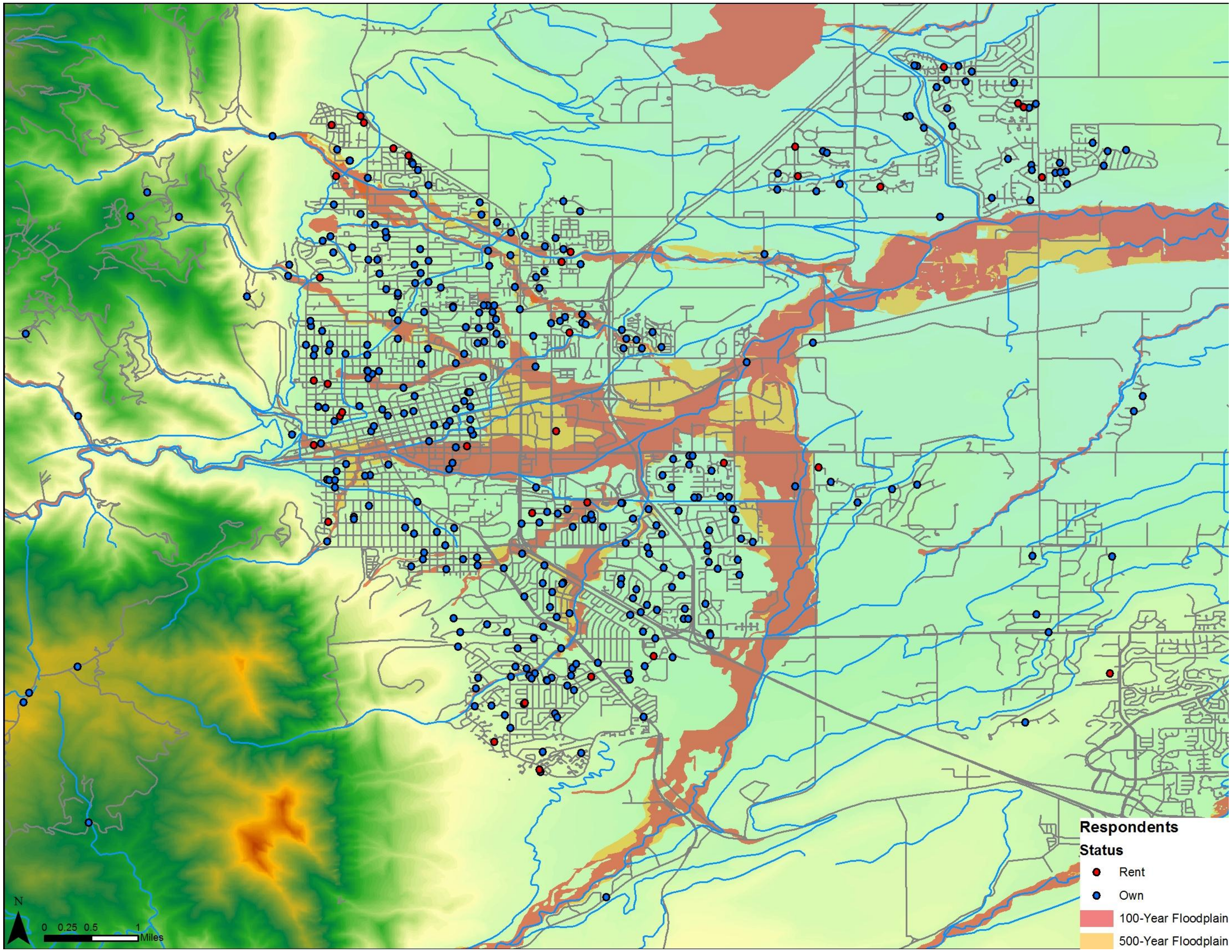

Figure 5.5: Spatial Distribution of Renters and Owners

Table 5.8: Moran's I Values for Variables using Different Neighborhoods

Variable	**Moran's I 0.5mi neighborhood**	**Moran's I 2.5mi neighborhood**	**Moran's I 5mi neighborhood**	**Moran's I 10mi neighborhood**
Response to Survey	0.0099	-0.0055	-0.0005	-0.0006
REACT	-0.0263	0.0009	-0.0078	-0.0018
PREPARE	-0.0061	-0.0009	0.0018	-0.0011
Risk Perception Index	0.0055	-0.0237	-0.0032	-0.0023
Antecedent Knowledge Index	0.0140	-0.0022	0.0008	-0.0022
Warning Receptiveness Index	-0.0299	-0.0271	-0.0053	-0.0031

Antecedent Knowledge Index

Overall, the respondents are highly knowledgeable about flash floods and warnings. About 60% of the population identifies a higher probability of flash flooding given a warning versus a watch and 73.8% of respondents can correctly identify the difference between watches and warnings in an open-ended format (Table 5.9). This is a high proportion of the population.

Table 5.9: Summary of Antecedent Knowledge Index Responses

Question	**Correct**	**Incorrect**	**Missing Responses**
Watch warning difference, probabilities	60.4%	39.6%	17
Watch warning difference, open-ended	73.8%	26.2%	34
Boulder Creek is not the only creek that floods	73.4%	26.6%	6
What to do in a flash flood warning if in a building	91.1%	8.9%	16
What to do in a flash flood warning if in a car	82.4%	17.6%	15
What to do in a flash flood warning if outside recreating	86.2%	13.8%	16
Max amount of fast-flowing water to safely walk though	59.6%	40.4%	44
Max amount of fast-flowing water to safely drive through	90.1%	9.9%	46
Knowledge of location with respect to floodplains	42.9%	57.1%	26
Definition of the 100-year flood	34.7%	65.3%	42

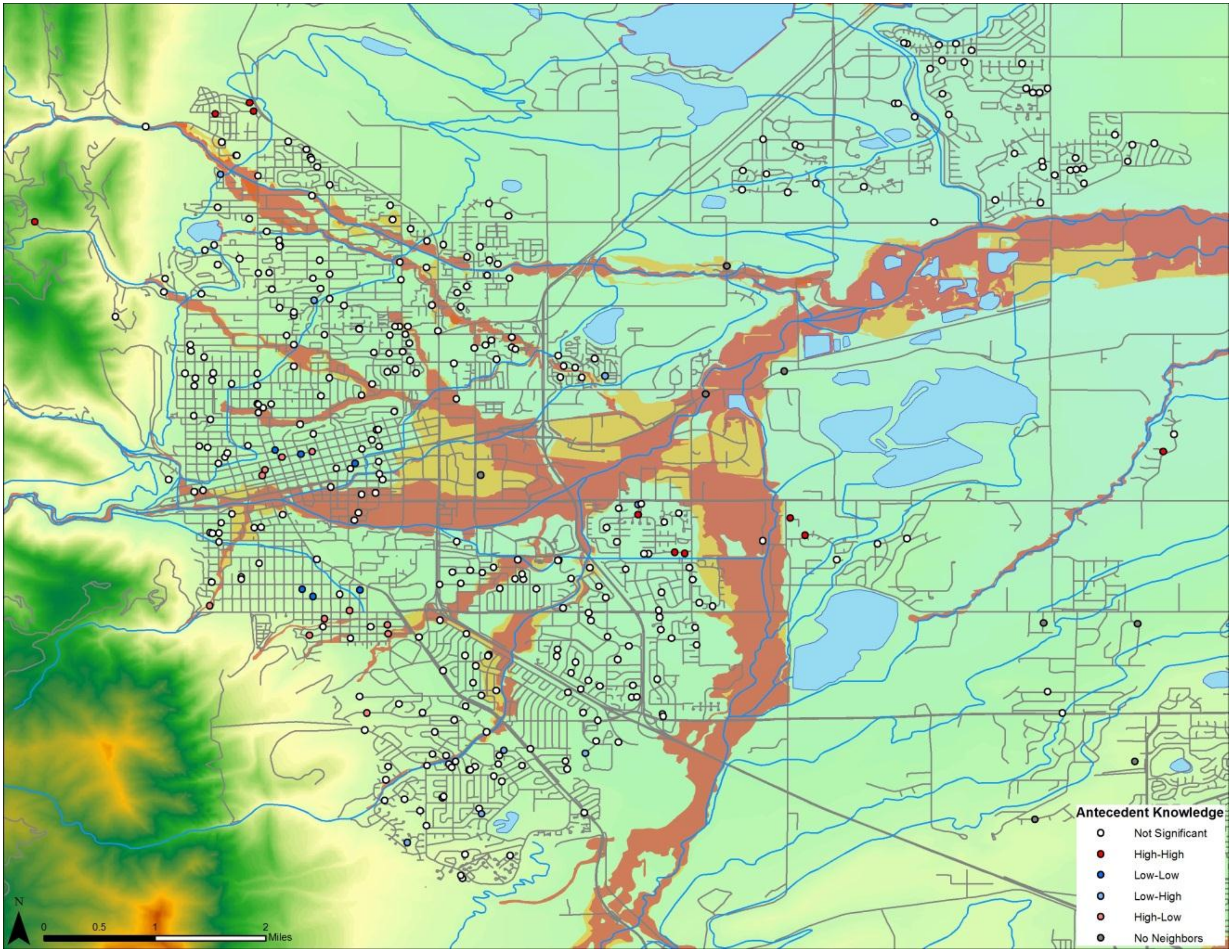

Figure 5.6: Example of Hot Spot Map, Half Mile Neighborhood

Many other studies have conducted similar tests. When asked to define hazard watches and warnings in a closed-ended format, 90% to 96% of respondents could correctly do so (Legates and Biddle 1999, Balluz et al. 2000, respectively). In the Gruntfest et al. (2002) survey of 100-year floodplain occupants, 85% of respondents could correctly identify the definition of a flash flood watch from a list and 70% correctly defined a flash flood warning. Although this was in a different format, the results are similar to the present study with a high proportion of the population understanding the definitions. Other studies have asked watch and warning differences in an open-ended format. In one, only 58% of respondents could describe the difference adequately (Powell and O'Hair 2008). Respondents in this research were more knowledgeable than those in Powell and O'Hair's (2008) survey, however, the liberal coding of this question could be part of the difference between these results and past research. Additionally, if given the possible answers in a list, people are more likely to choose the correct answer instead of having to come up with it on their own.

Fewer people understand the difference between a watch and a warning when comparing probabilities of flooding given a watch versus a warning (Table 5.9). This might provide a better sense of actual knowledge of flash flood product terminology because respondents are not directly asked the difference.

Out of a possible three points for correctly identifying the factors that cause flash floods, the average score is 2.09 (Table 5.9). This is quite high. The factors that most commonly caused incorrect answers are location with respect to a lake, pond, or detention basin, location with respect to a dam, and burned land from past wildfires. However, 73.4% do know that Boulder Creek is not the only creek that floods in Boulder.

Respondents were also asked about correct actions to take in a flash flood. The majority of respondents got all three questions right, indicating that many Boulder residents are knowledgeable about what they should do in a flash flood warning (Table 5.9). They are not, however, quite as savvy with knowing depths of fast-flowing water through which they can safely walk and drive. The NWS says the maximum amount of fast-flowing water one can safely walk through is six inches; 59.6% of respondents reported six inches or less. The mean response is 8.07 inches, greater than the recommendation, while the median is 6 inches. However, the respondents' answers ranged anywhere from zero to 42 inches (Figure 5.7). For safe driving, the NWS recommends not crossing fast-flowing water deeper than 18 inches. A total of 90.1% of respondents note this value or less than this value in the survey. The mean depth is 8.65 inches with a range from zero to 54 inches (Figure 5.7). The respondents are much more knowledgeable about safe depths to drive through than to walk though.

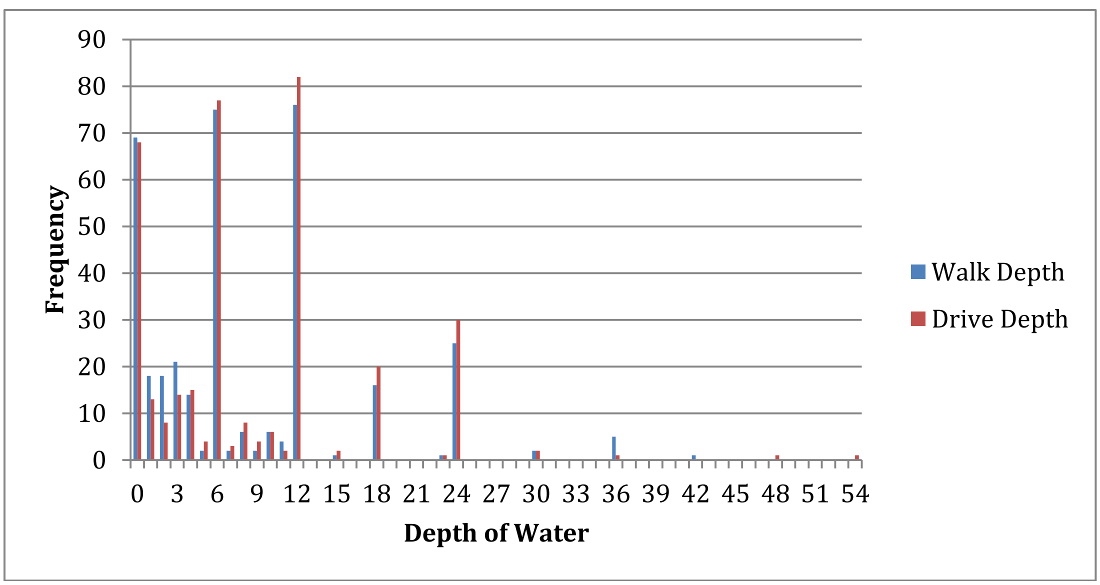

Figure 5.7: Maximum Safe Amount of Fast-Flowing Water to Walk and Drive Through

Another aspect of the Antecedent Knowledge Index is knowledge of whether or not the individual lives in the 100- or 500-year floodplains. Only 42.9% of respondents know their location with respect to the floodplains (Table 5.9). This is further broken down in Table 5.10 with correct responses bolded. In all three locations, the majority of respondents indicate that they do not know the location of their house with respect to the floodplains. Reporting the wrong floodplain is not a common problem. Additionally, respondents thinking they are not in a floodplain when they are is not as common as simply stating they do not know their location. Only 29.2% of those living in the 100-year floodplain know they are and only 20.0% of those living in the 500-year floodplain are aware of their location. This can be compared to Gruntfest et al. (2002), who found that 71% of those living in the Boulder Creek 100-year floodplain knew their location. This is quite a difference between studies. Past research has found that before a flash flood hit an area, residents were not aware that their residence was located in a floodplain (Bogdanska-Warmuz 2001). This could help explain the lack of knowledge of the location of their residence, however it cannot explain the difference between the two Boulder studies.

Table 5.10: Reported and Actual Location with Respect to Floodplains

Actual Location of Respondent	Reported Location of Respondent	Frequency	Percent (of those in that actual location)
100-Year Floodplain	**100-Year Floodplain**	**7**	**29.2%**
	500-Year Floodplain	1	4.2%
	Neither Floodplain	5	20.8%
	Do not know	11	45.8%
500-Year Floodplain	100-Year Floodplain	3	20.0%
	500-Year Floodplain	**3**	**20.0%**
	Neither Floodplain	2	13.3%
	Do not know	7	46.7%
Neither Floodplain	100-Year Floodplain	38	10.3%
	500-Year Floodplain	22	6.0%
	Neither Floodplain	**154**	**41.7%**
	Do not know	155	42.0%

Figure 5.8 shows the locations of the respondents and where they think they live. Most of the respondents who are not located within a floodplain but think they are live near floodplains, which could be a source of confusion. It is concerning, though, that although the city mails out

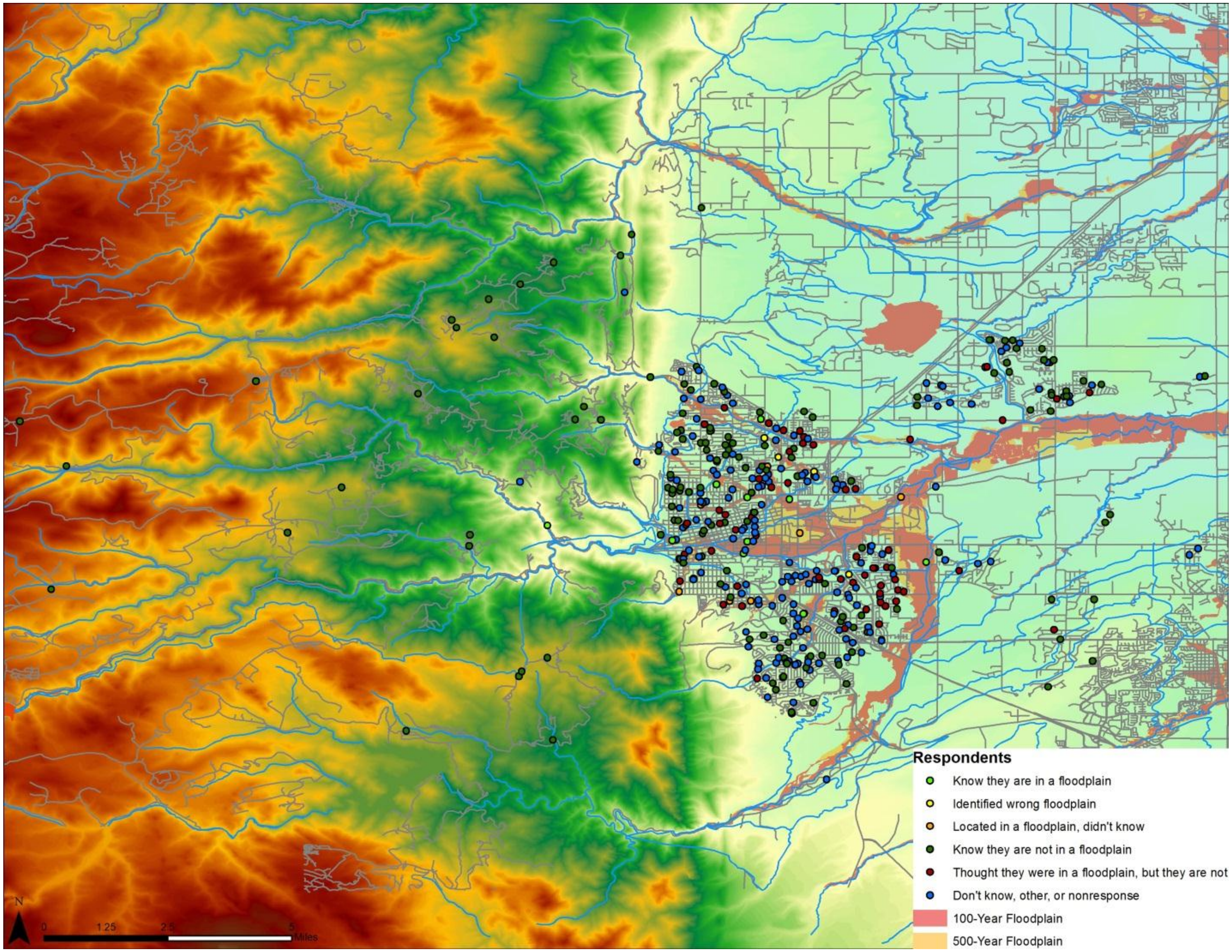

Figure 5.8: Actual Versus Perceived Locations of Respondents

information on floodplains and has resources online, most respondents do not know where their home is located.

Age, length of residence, being a homeowner, income, and experience are positively correlated with knowledge of location with respect to the floodplain (Table 5.11). With age and length of residence comes experience as well as more opportunities to check the location of the floodplains. Along with that, students are less likely to know their location with respect to the floodplain (Table 5.11). Students tend to be younger and transient and therefore may be unaware of their location. Homeowners must purchase flood insurance if they are located in the 100-year floodplain. Therefore, they are more likely to know their location. Renters, on the other hand, cannot purchase flood insurance so they may not be aware they are renting in the floodplain. Related to this notion, most people with high incomes will purchase a house instead of renting. Comparing the knowledge of being located in the floodplain with income, those with the highest incomes are most likely to know their location (Figure 5.9). Finally, those with past experience with flooding are likely to know if they are at risk in their home and are therefore more likely to accurately identify the location of their house. These demographics should be specifically targeted with information about their location.

Table 5.11: Characteristics of Respondents who Correctly Identified Location with Respect to Floodplain

Know Location	**Statistic Type**	**Correlation**	**Significance**
Age	Pearson	r = 0.141*	0.007*
Male	T-Test	t = 0.438	0.661
Length of residence	Pearson	r = 0.147*	0.007*
Student	T-Test	t = -2.043*	0.042*
Homeowner	T-Test	t = 6.387*	0.000*
Income	ANOVA	F = 5.862*	0.001*
Education	ANOVA	F = 0.847	0.429
Experience with flash floods	T-Test	t =1.958*	0.051*

*Significant at the 0.100 level

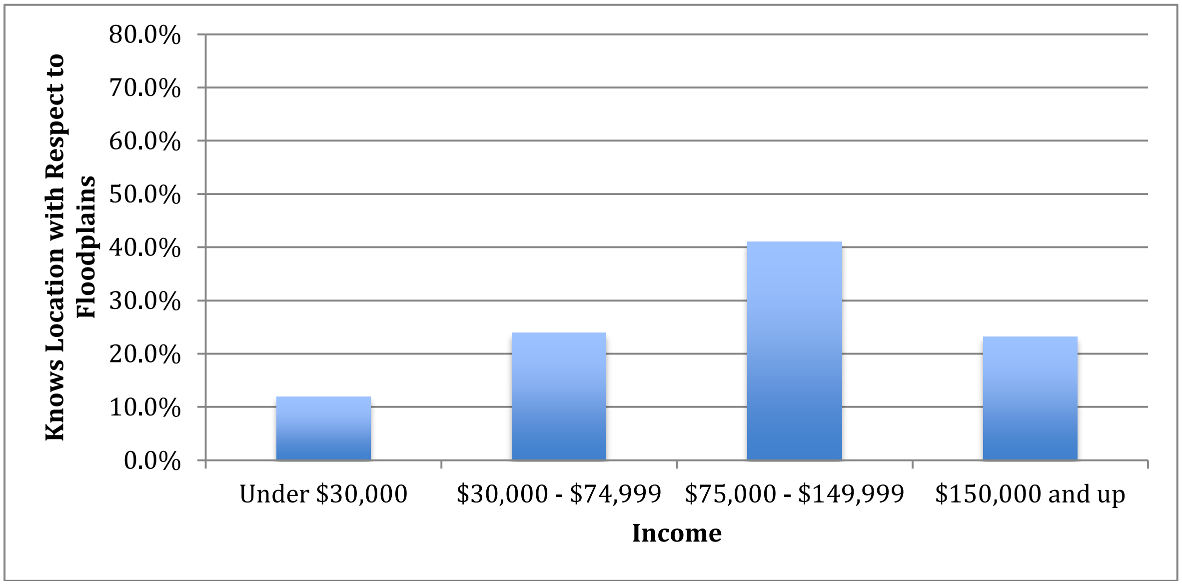

Figure 5.9: Knowledge of Location with Respect to Floodplains and Income

The final question related to flash flood antecedent knowledge is an understanding of the definition of the 100-year flood. Only 34.7% of the population can correctly define the 100-year flood (Table 5.9). This is comparable to the survey conducted by Gruntfest et al. (2002) where only 48% of respondents correctly defined the 100-year flood from a list of possible definitions. A higher proportion could be correct in their survey since it was a closed-ended format. Overall, the total antecedent knowledge of the population is quite high. Of a possible thirteen, the mean Antecedent Knowledge Index value is 8.89. No respondent scored lower than three and some earned the full thirteen. Figure 5.10 shows the distribution of knowledge of the population, which is skewed toward higher antecedent knowledge. One of the reasons the antecedent knowledge of flash flooding in Boulder is so high could be due to the effort the city has put forth in education campaigns. The city works hard to educate kindergarten through high school students about floods. Boulder also produces interactive programs and brochures for adults and includes information in monthly water bills for residents (Mileti 1999). Still, this effort has not been effective when it comes to knowing where the respondent's house is located with respect to the floodplains.

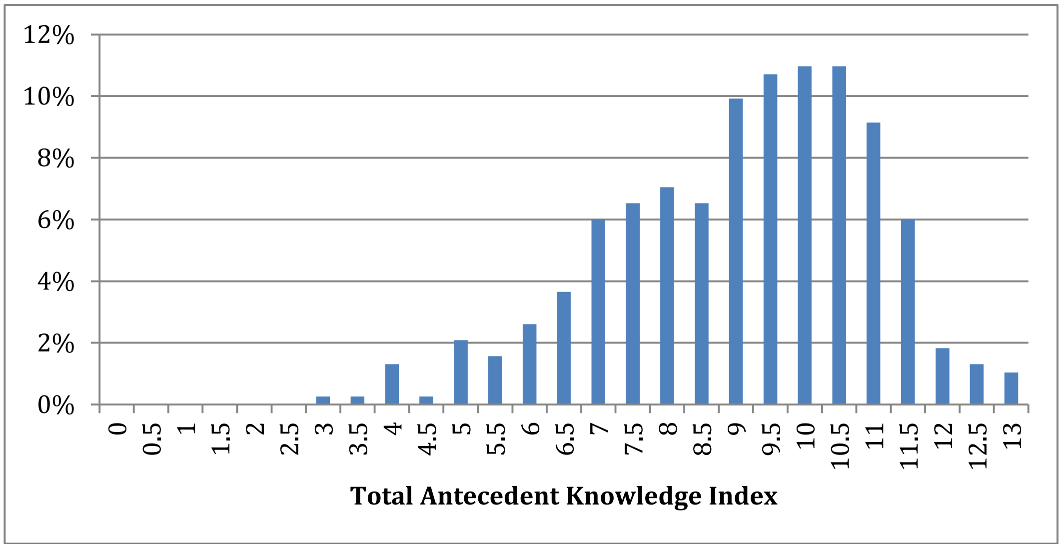

Figure 5.10: Total Antecedent Knowledge Index of Survey Population

The hot spot analysis of the Antecedent Knowledge Index is shown in Figure 5.11. As mentioned before, the Moran's I results indicate spatial randomness of the variable, which is confirmed visually. This means that there are not neighborhoods of higher or lower antecedent knowledge.

Antecedent knowledge has the highest number of significant correlations among the variables tested (Table 5.12). Knowledge is positively correlated with age (significance 0.001) and length of residence (significance 0.001). Gruntfest et al. (2002) also found that older respondents had higher knowledge scores than the younger respondents, likely from having more life experience and accumulating more information about flash flooding. Length of residence has been linked to hazard knowledge in previous research as well (Sorensen 1983, Gruntfest et al. 2002). Similarly, students are negatively correlated with antecedent knowledge (Table 5.12).

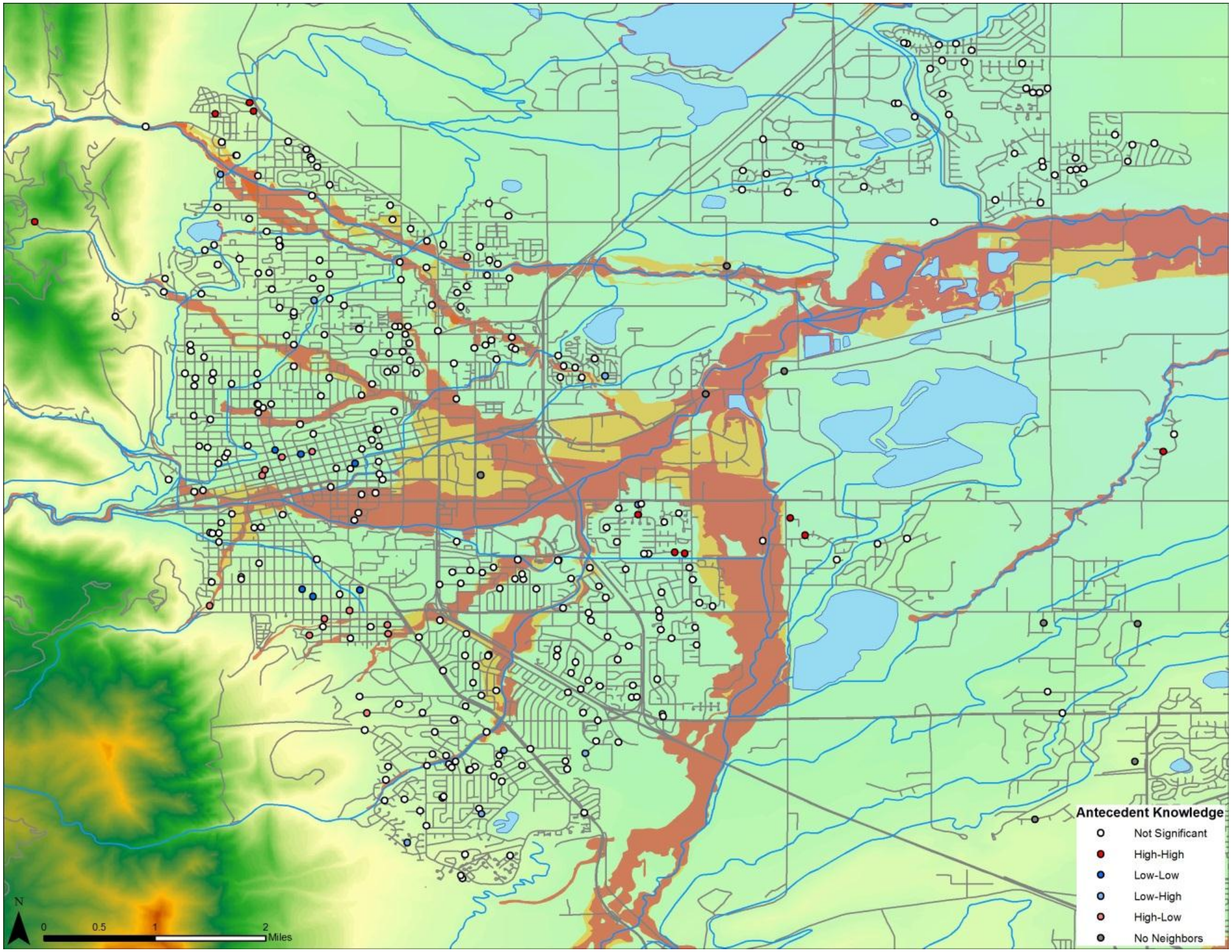

Figure 5.11: Hot Spot Analysis: Antecedent Knowledge, Half Mile Neighborhood

Table 5.12: Correlations with Antecedent Knowledge

Antecedent Knowledge	Statistic Type	Correlation	Significance
Age	Pearson	r =0.174*	0.001*
Male	T-Test	t = -1.217	0.224
Length of residence	Pearson	r = 0.181*	0.001*
Student	T-Test	t = -2.727*	0.007*
Homeowner	T-Test	t = 4.124*	0.000*
Income	ANOVA	F = 3.996*	0.008*
Education	ANOVA	F = 0.074	0.928
Experience with flash floods	T-Test	t = 1.678*	0.094*
Think they are in 100-year floodplain	T-Test	t = 0.043	0.966
Think they are in 500-year floodplain	T-Test	t = -1.382	0.168
Think they are in either floodplain	T-Test	t = 0.841	0.401
Located in 100-year floodplain	T-Test	t = -0.799	0.425
Located in 500-year floodplain	T-Test	t = -1.730*	0.084*
Elevation to floodplain	Pearson	r = 0.088*	0.085*
Distance to floodplain	Pearson	r = 0.083	0.106
Flow distance to floodplain	Pearson	r = 0.084	0.101
Volume of water to flood residence	Pearson	r = 0.024	0.669

*Significant at the 0.100 level

Homeowners, residents with past flash flood experience, and those with higher incomes are also positively correlated with antecedent knowledge (Significance of 0.008, 0.094, 0.008, respectively, Table 5.12). Specifically, those earning between $75,000 and $149,999 per year have the highest antecedent knowledge (Figure 5.12). Owning a home and making a higher income can be associated with age, which can explain the higher mean Antecedent Knowledge Index values for these groups. Experience with floods helps an individual know appropriate actions as well as how to adequately prepare for these events, which increases his or her knowledge about these events (Sorensen 1983, Benight et al. 2007). Educational attainment and gender do not have significance trends with antecedent knowledge (Table 5.12).

Location is significantly correlated with the Antecedent Knowledge Index. Respondents living in the 500-year floodplain are negatively correlated with antecedent knowledge (Table 5.12). In other words, those living in the 500-year floodplain tend to have less antecedent knowledge than respondents residing elsewhere. There is a significant (at the 0.085 level)

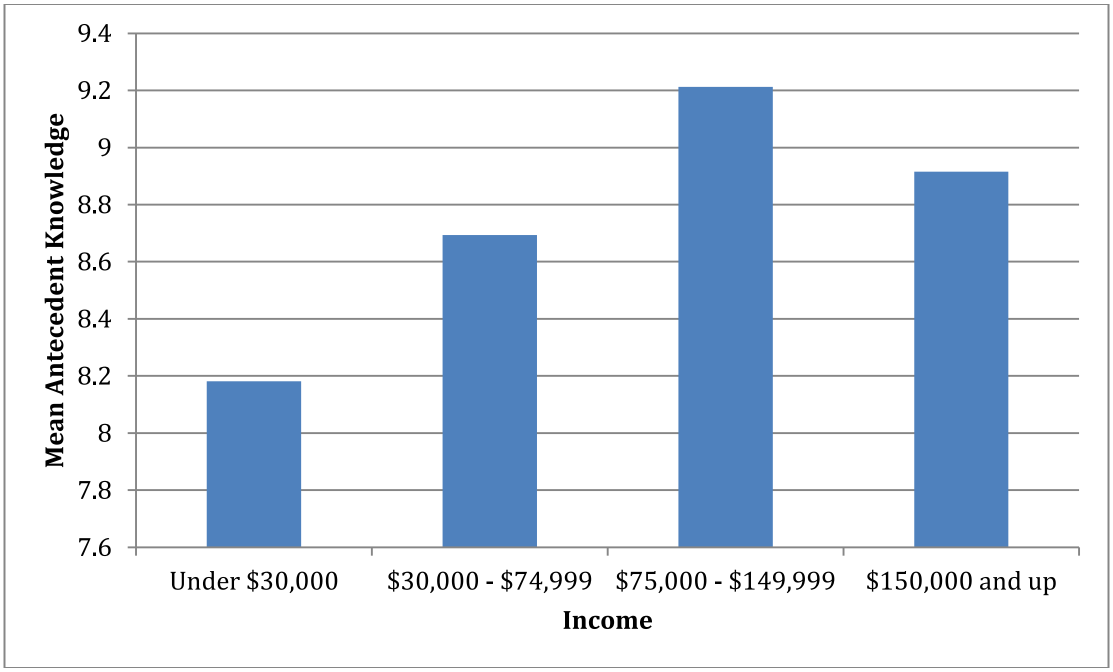

Figure 5.12: Mean Antecedent Knowledge by Income

positive correlation between elevation and antecedent knowledge (Table 5.12). Respondents living at higher elevations above the 100-year floodplain tend to have more knowledge about flash flooding. Other floodplain locations and perceived locations are not significantly correlated with` antecedent knowledge (Table 5.12)

Warning Receptiveness Index

The Warning Receptiveness Index combines trust in and perceived accuracy of flash flood forecasts and warnings. Trust in flash flood products ranges from zero, meaning no trust at all, to four, or complete trust. The mean level of trust is 2.51, with a distribution slightly skewed toward the products being trustworthy (Figure 5.13).

The respondents perceive flash flood forecasts and warnings to be less accurate, even though they indicated that they trust them. Accuracy was measured using the same Likert scale as trust. The results indicate that quite a few respondents do not find the forecasts and warnings to be at all accurate, while many believe they are somewhat accurate, and some finding them

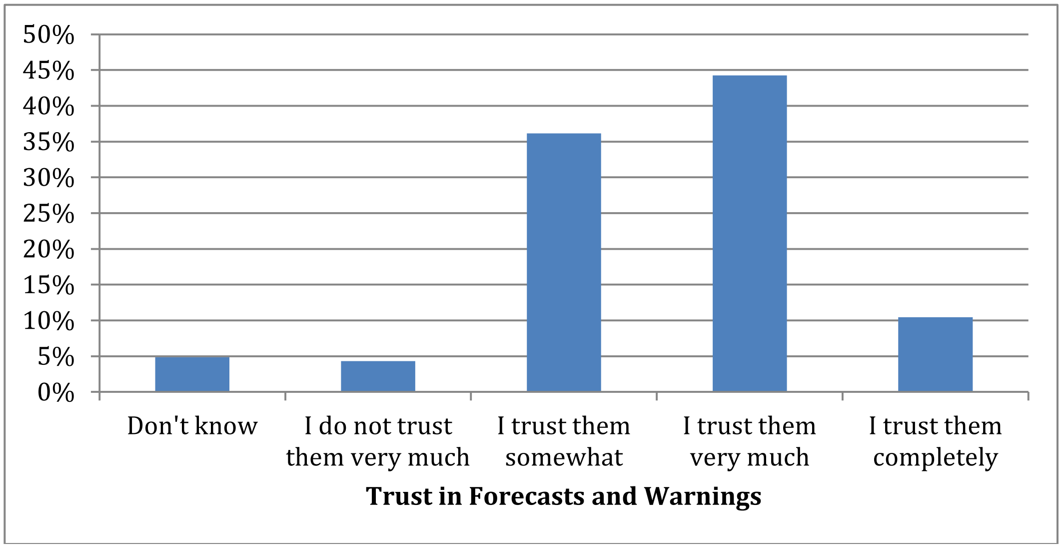

Figure 5.13: Trust in Flash Flood Forecasts and Warnings

very or extremely accurate (Figure 5.14). There is also a large proportion of respondents that are not sure. The low perceived accuracy, but high trust could be recognition that these are forecasts and there is inherent uncertainty, but the respondents still trust the decision of the authorities to warn based on the information they have.

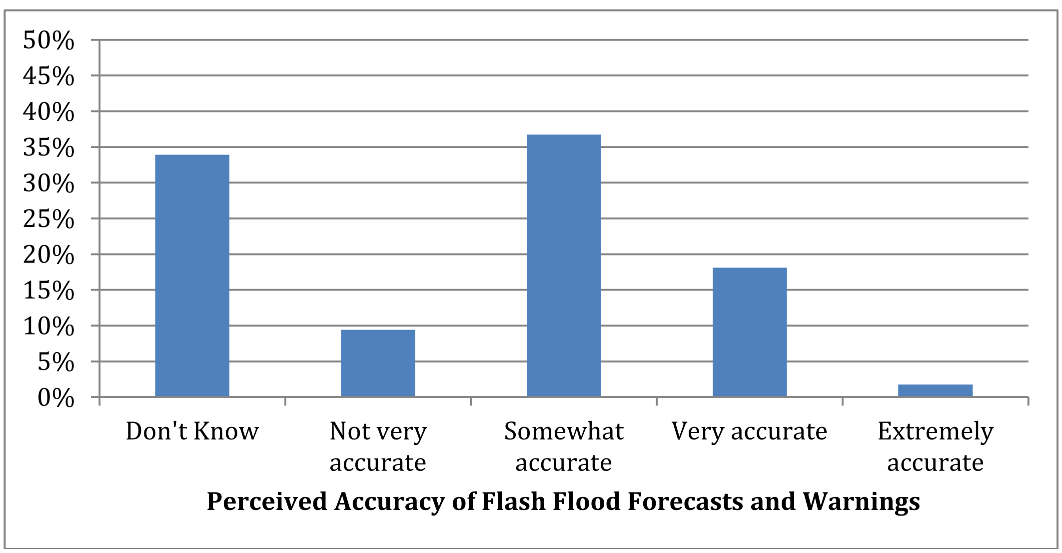

Figure 5.14: Perceived Accuracy of Flash Flood Forecasts and Warnings

Overall, the Warning Receptiveness Index ranges from zero, indicating a respondent who does not trust the flash flood forecasts and finds them inaccurate, to eight, indicating a very trusting respondent who sees the products as extremely accurate. The mean Warning Receptiveness Index is 3.95, with the distribution slightly skewed toward higher warning receptiveness (Figure 5.15). The hot spot analysis of warning receptiveness is spatially random (Figure 5.16).

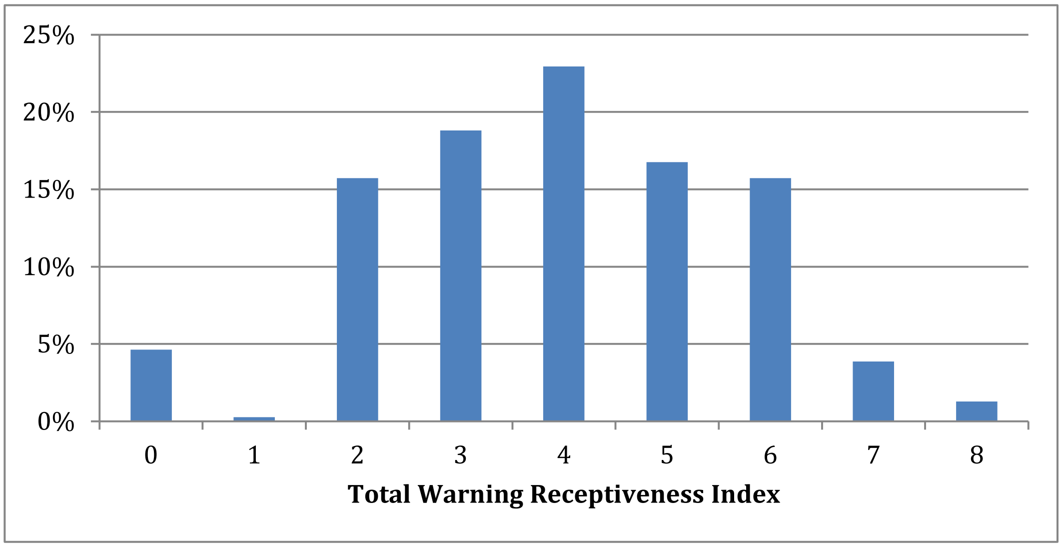

Figure 5.15: Warning Receptiveness Index Values

Warning receptiveness is positively correlated with age and length of residence, both at the 0.000 level (Table 5.13). Similarly, students are negatively correlated with warning receptiveness (Table 5.13). Older respondents and those who have resided in Boulder a long time have had flash flood forecasts and warnings, even if no flooding has actually occurred. It is interesting that although there have not been significant flash floods in many decades in Boulder (even though there have been warnings), this correlation is still present. This may indicate that false alarms do not affect this population as much as some research has found. In fact, Gruntfest et al. (2002) asked Boulder floodplain residents if they would like more or fewer flash flood warnings, even though flash flooding is hard to predict. The majority of respondents indicated they would prefer more warnings. On the other hand, having past experience with flash floods is

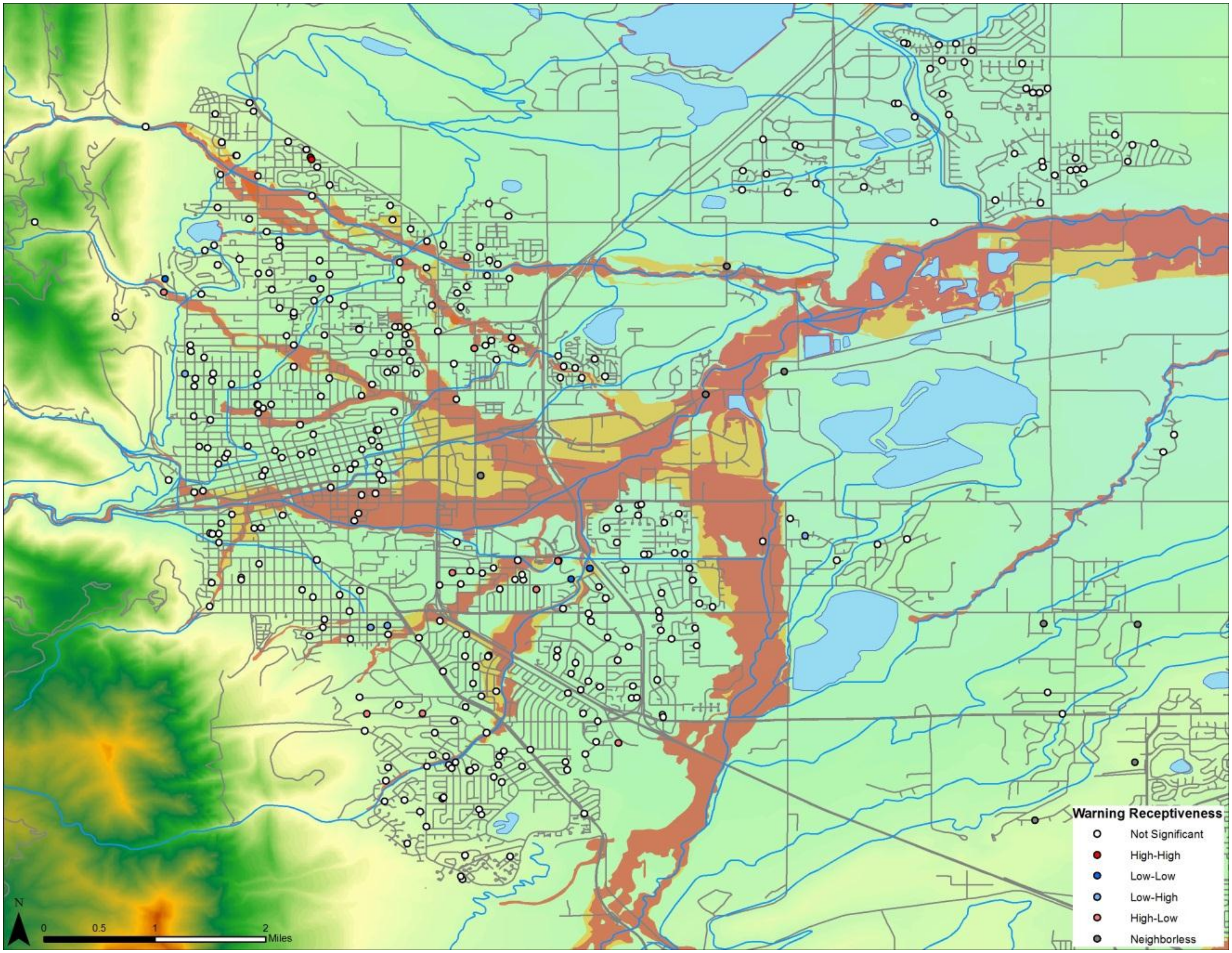

Figure 5.16: Hot Spot Analysis: Warning Receptiveness, Half Mile Neighborhood

Table 5.13: Correlations with Warning Receptiveness

Warning Receptiveness	Statistic Type	Correlation	Significance
Age	Pearson	r = 0.213*	0.000*
Male	T-Test	t = 1.095	0.274
Length of residence	Pearson	r = 0.238*	0.000*
Student	T-Test	t = -1.721*	0.086*
Homeowner	T-Test	t = 0.769	0.442
Income	ANOVA	F = 0.147	0.932
Education	ANOVA	F = 3.952*	0.020*
Experience with flash floods	T-Test	t = 1.826*	0.069*
Think they are in 100-year floodplain	T-Test	t = 0.389	0.698
Think they are in 500-year floodplain	T-Test	t = 0.870	0.385
Think they are in either floodplain	T-Test	t = 0.874	0.383
Located in 100-year floodplain	T-Test	t = -0.206	0.837
Located in 500-year floodplain	T-Test	t = -0.720	0.472
Elevation to floodplain	Pearson	r = -0.005	0.919
Distance to floodplain	Pearson	r = 0.023	0.644
Flow distance to floodplain	Pearson	r = 0.019	0.710
Volume of water to flood residence	Pearson	r = 0.038	0.501

*Significant at the 0.100 level

also positively correlated with trust in and perceived accuracy of warnings and forecasts (Table 5.13). This could be due to good experience with past warnings, or the understanding of the necessity of getting the warning message out to the public.

In terms of other demographics, those without a four-year degree and those who have an advanced degree have the highest mean warning receptiveness (Table 5.13, Figure 5.17). Neither actual location nor perceived location are significantly correlated with warning receptiveness (Table 5.13).

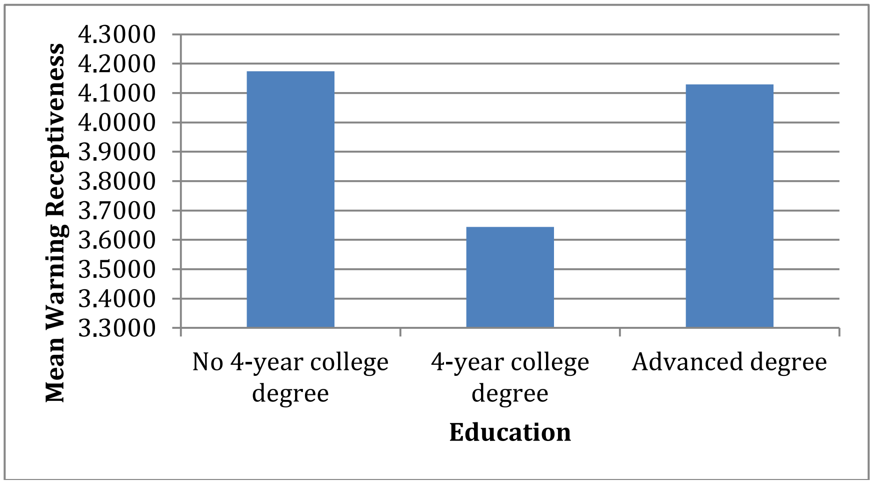

Figure 5.17: Mean Warning Receptiveness by Education

Risk Perception Index

As discussed earlier, the Risk Perception Index is comprised of survey questions relating to how likely respondents think flash flooding is in Boulder as well as how flooding will personally affect them. Respondents were first asked how likely flash flooding will be in Boulder in the next year. On a scale of 0% to 100%, the mean percent likelihood is 18% with a median of 10%. Responses range from 0% to 90%, but mostly remain less than 50% (Figure 5.18). This indicates that most respondents do not believe flooding is likely in the next year in Boulder. Some, of course, find it more likely than others.

Similarly, the respondents were asked the likelihood of flash flooding in Boulder in the next 30 years. These responses ranged anywhere from 0.0005% to 100% with a mean of 44.1%. The responses are widely variable for this question (Figure 5.18). Respondents find it more likely that flooding will occur in the next 30 years in Boulder, compared to the next year; however there are still some who barely perceive the risk of flooding in Boulder.

The next aspect of the Risk Perception Index involves the likelihood of flash flooding in the next 24 hours if there was a flash flood warning or watch issued. In the event of a warning, the responses range from 0% to 100% likelihood. The mean is 45.1% with a median of 50%. The responses are spread across this range, indicating much different impressions of how imminent flooding is after a warning is issued (Figure 5.19).

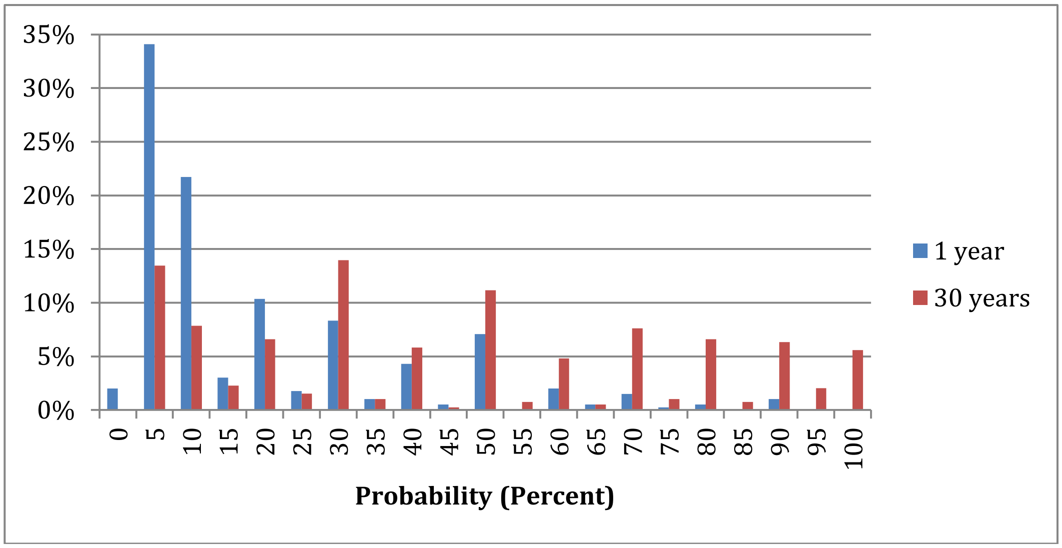

Figure 5.18: Likelihood of Flash Flooding in Boulder in the Next One and Thirty Years

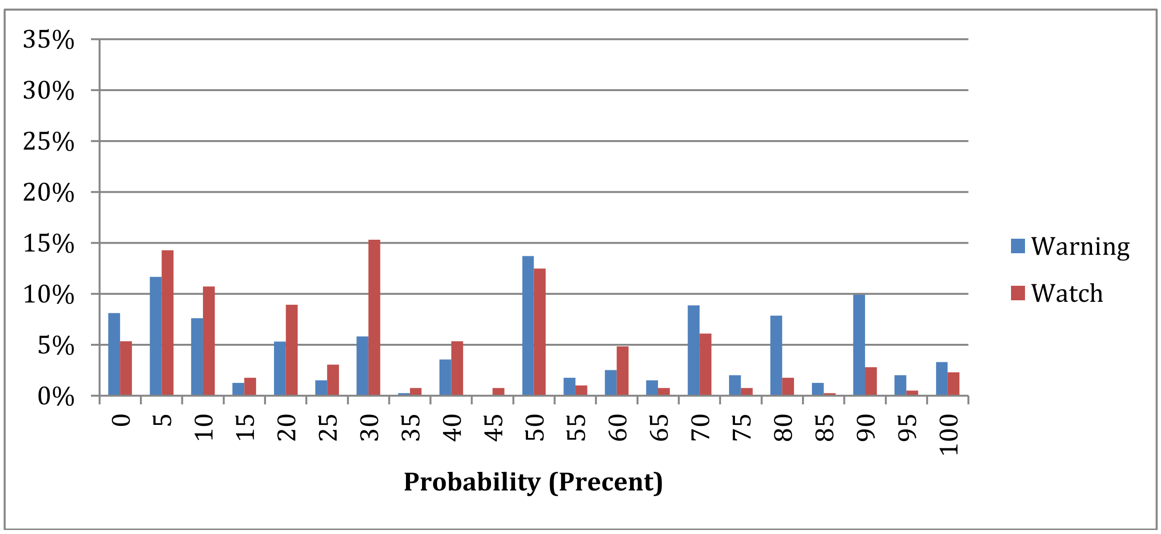

Figure 5.19: Likelihood of Flash Flooding in Boulder in the Next 24 Hours Given a Watch and Warning

Given a flash flood watch, the mean percentage likelihood of flash flooding occurring in Boulder in the next 24 hours as indicated by the respondents is 33.1%. This is lower than the average likelihood for warnings, insinuating that most know the difference between a watch and a warning. The probabilities range from 0% to 100% likelihood with highly variable results. The responses are skewed toward lower probabilities as compared to the probability of flash flooding given a warning. However, the respondents still think flash flooding is likely in Boulder after a flash flood watch, with some indicating probabilities larger than 60% (Figure 5.19).

These statistics are broken down into high and low risk perceptions (Table 5.14). Overall, there are much lower risk perceptions for the probability of flooding in the next year for Boulder than in the next 30 years in Boulder, which is expected given the longer time period. For watches and warnings, the breakdowns are almost equivalent between high and low risk perceptions.

Table 5.14: Probability of Flash Flooding in Boulder, High and Low Risk Perceptions

Probability of Flash Flood in the next…	Level of Risk Perception	Frequency	Percent
1 Year	High	107	26.2%
	Low	301	73.8%
30 years	High	181	44.4%
	Low	227	55.6%
24 hours given a warning	High	135	33.1%
	Low	273	66.9%
24 hours given a watch	High	131	32.1%
	Low	277	67.9%

Respondents were also asked to rank the likelihood of impacts occurring from flash floods in Boulder. These were presented in a Likert scale of zero, representing “not at all likely” or “not very likely”, to three, representing “extremely likely.” Overall, the average likelihood of all impacts is 1.93, with the distribution skewed toward a higher likelihood of impacts (Figure 5.20). The mean likelihood for each impact is shown in Table 5.15. The impacts ranked with the lowest likelihoods are people being killed, injured, or separated from their loved ones or pets and degraded water quality. The theme among these impacts is the effect on humans, indicating that fewer respondents believe the flood will directly affect them. The impacts with the highest mean likelihoods are economic losses or effects, disrupted transportation, and damage to buildings or

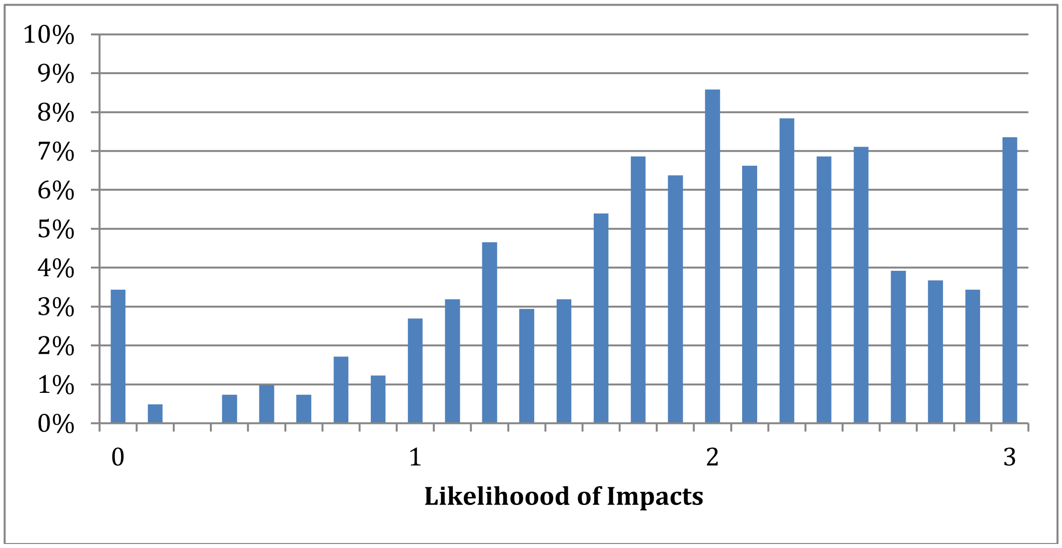

Figure 5.20: Average Likelihood of Impacts Occurring from Flash Floods in Boulder

Table 5.15: Summary of Likelihood of Impacts from Flash Flooding in Boulder

Impact	Mean Likelihood	Missing Responses
Damage to buildings or other property	2.35	12
People injured	1.71	16
People killed	1.10	16
People separated from loved ones or pets	1.82	15
Disrupted transportation	2.44	16
Economic losses or effects	2.46	13
Degraded water quality	1.94	14
Ecological damage	2.15	14

other property. For the most part, the respondents understand that there will be some form of impact from flash flooding, however they see the impact as harmful to physical property, not to people. These results compare to Gruntfest et al. (2002), who found that people were more likely to identify the risk to property than to the risk to their life.

The final attribute of the Risk Perception Index is the belief that the respondent is safe from flash flooding. Approximately 42% of respondents indicated they feel safe from flash flooding while 54.7% responded that they do not feel safe. Those who do not feel safe from flash flooding are considered to have personalized the risk. While many of those who feel safe from flash flooding may be out of the risky zones, if they have not personalized risk, according to Mileti and Sorensen (1990), they may not respond to the hazard when necessary.

The final calculated Risk Perception Index ranges between zero and eight. The mean value is 3.94, right in the middle of the distribution (Figure 5.21). The respondents vary in their risk perceptions greatly. Spatially, the distribution of risk perception is random (Figure 5.22).

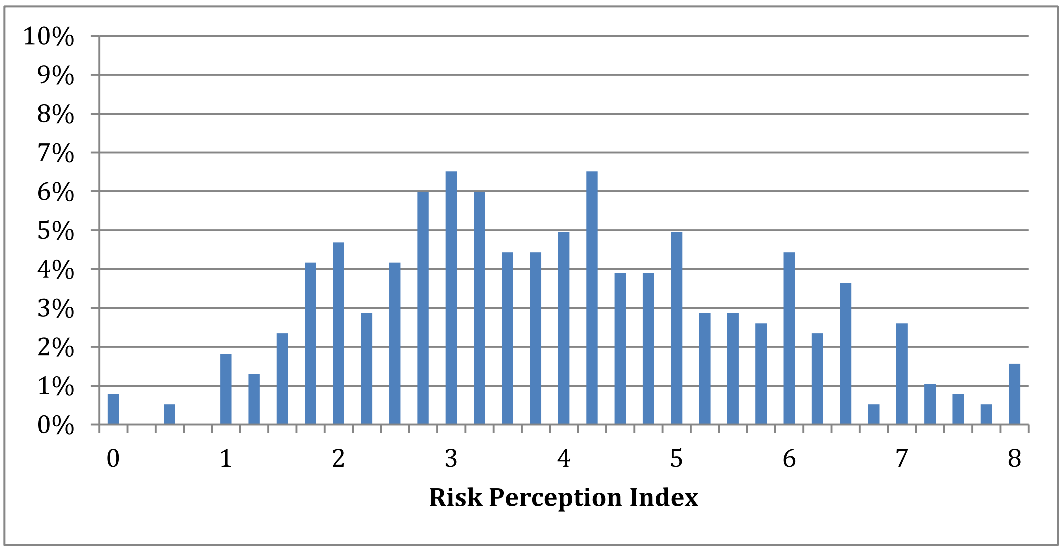

Figure 5.21: Risk Perception Index Values

Gender is the only demographic variable significantly correlated with risk perception. Males are significantly negatively correlated with risk perception, significant at the 0.001 level (Table 5.16). Females, by nature, have been found to have more imminent risk perceptions toward hazards in general (Siegrist et al. 2005, Kalkstein and Sheridan 2007), verifying this finding. Even though the correlation between risk perception and experience has been well documented in the literature, (Brilly and Polic 2005, Knocke and Kolivras 2007, Ruin et al. 2007, Lin et al. 2008, Miceli et al. 2008), experience is not significant in this analysis (Table 5.16).

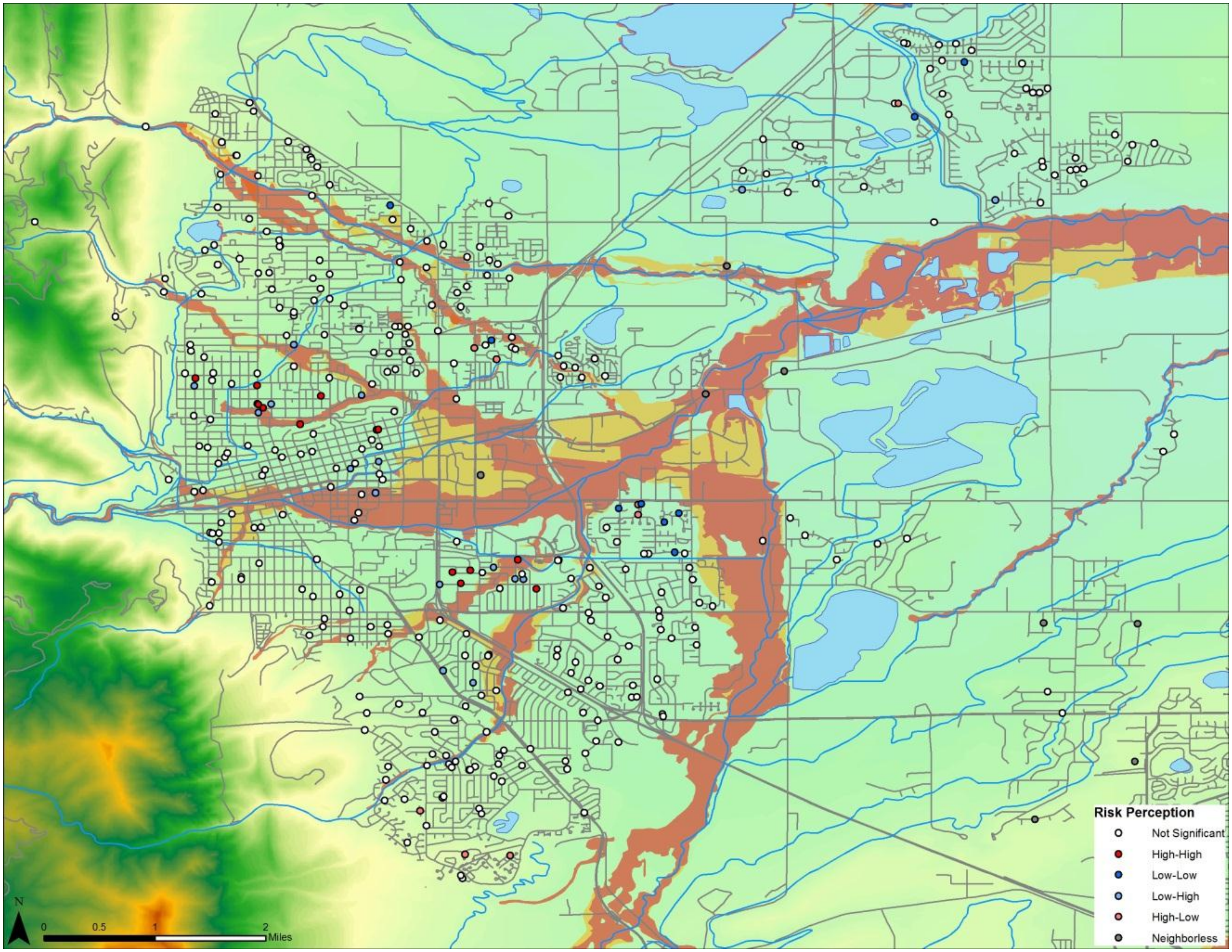

Figure 5.22: Hot Spot Analysis: Risk Perception, Half Mile Neighborhood

Table 5.16: Correlations with Risk Perception

Risk Perception	Statistic Type	Correlation	Significance
Age	Pearson	r = -0.029	0.580
Male	T-Test	t = -3.381*	0.001*
Length of residence	Pearson	r = 0.053	0.338
Student	T-Test	t = -0.164	0.870
Homeowner	T-Test	t = -0.877	0.381
Income	ANOVA	F = 0.097	0.636
Education	ANOVA	F = 0.133	0.726
Experience with flash floods	T-Test	t = 1.209	0.228
Think they are in 100-year floodplain	T-Test	t = 0.755	0.451
Think they are in 500-year floodplain	T-Test	t = 1.728*	0.085*
Think they are in either floodplain	T-Test	t = 1.708*	0.088*
Located in 100-year floodplain	T-Test	t = 0.819	0.413
Located in 500-year floodplain	T-Test	t = -1.255	0.210
Elevation to floodplain	Pearson	r = -0.023	0.657
Distance to floodplain	Pearson	r = -0.087*	0.087*
Flow distance to floodplain	Pearson	r = -0.077	0.131
Volume of water to flood residence	Pearson	r = -0.065	0.253

*Significant at the 0.100 level

The Risk Perception Index is, however, correlated with spatial variables. Specifically, those who think they live in the 500-year floodplain perceive flash floods to be more imminent (Table 5.16). The same is not true for those who think they live in the 100-year floodplain. Risk perception tends to increase closer to the floodplain, meaning those at more risk of flash flooding tend to perceive the event as riskier (Table 5.16). Past literature has also found that those who live in risky areas have more imminent perceptions of flash flood risk (Brilly and Polic 2005, Ruin et al. 2007). It is reassuring that those at the most risk view the risk as most imminent, especially as risk perception is so closely linked to actual behaviors in the hazard situation. However, it is important to keep in mind that most people do not know their location with respect to the floodplains

Likelihood to Take Protective Action in a Flash Flood Warning (REACT)

Close to three-quarters of respondents indicated they are likely to react in a flash flood warning (Table 5.17). This is a similar number to a survey conducted in the United Kingdom, which found that 77% of people surveyed would respond to a warning (Fielding et al. 2007). While this statistic is comforting, it is important to understand why some respondents are not likely to evacuate. This information can be used to target certain populations to ensure proper action in a flash flood event.

Table 5.17: Likelihood to React in a Flash Flood Warning (REACT)

REACT	Frequency	Percent
Low likelihood	102	26.4%
High likelihood	284	73.6%

Figure 5.23 shows the hot spot analysis of REACT. The results are spatially random, confirming the Moran's I results. While there are many people within and close to the floodplains who are not likely to take protective action, there are similarly minded people located far away from the floodplains. Even those in higher elevations in the foothills had variable responses, with some indicating they are likely to take protective action and some who are not. Age is positively correlated to REACT (significance 0.001, Table 5.18). The relationship between age and response to flash flooding is a finding supported by past literature (Knocke and Kolivras 2007). There is no correlation between individuals with experience with flash floods and REACT (Table 5.18). So few of the respondents have actually had personal experience with flash floods that this correlation may not be representative of the population. Finally, females are much more likely to react in a flash flood warning than males (Table 5.18). Spatially, no variables predict REACT, not even perceived locations (Table 5.18). Because REACT is based on a 5-point Likert scale, the middle response of "somewhat likely" was switched to the highly likely to react category to see if changing the cutoff for high and low likelihood of reaction made an impact on the results. Making this change, gender no longer was significant, but perception of being in the 100-year floodplain was significant. "Somewhat likely" was kept in the category

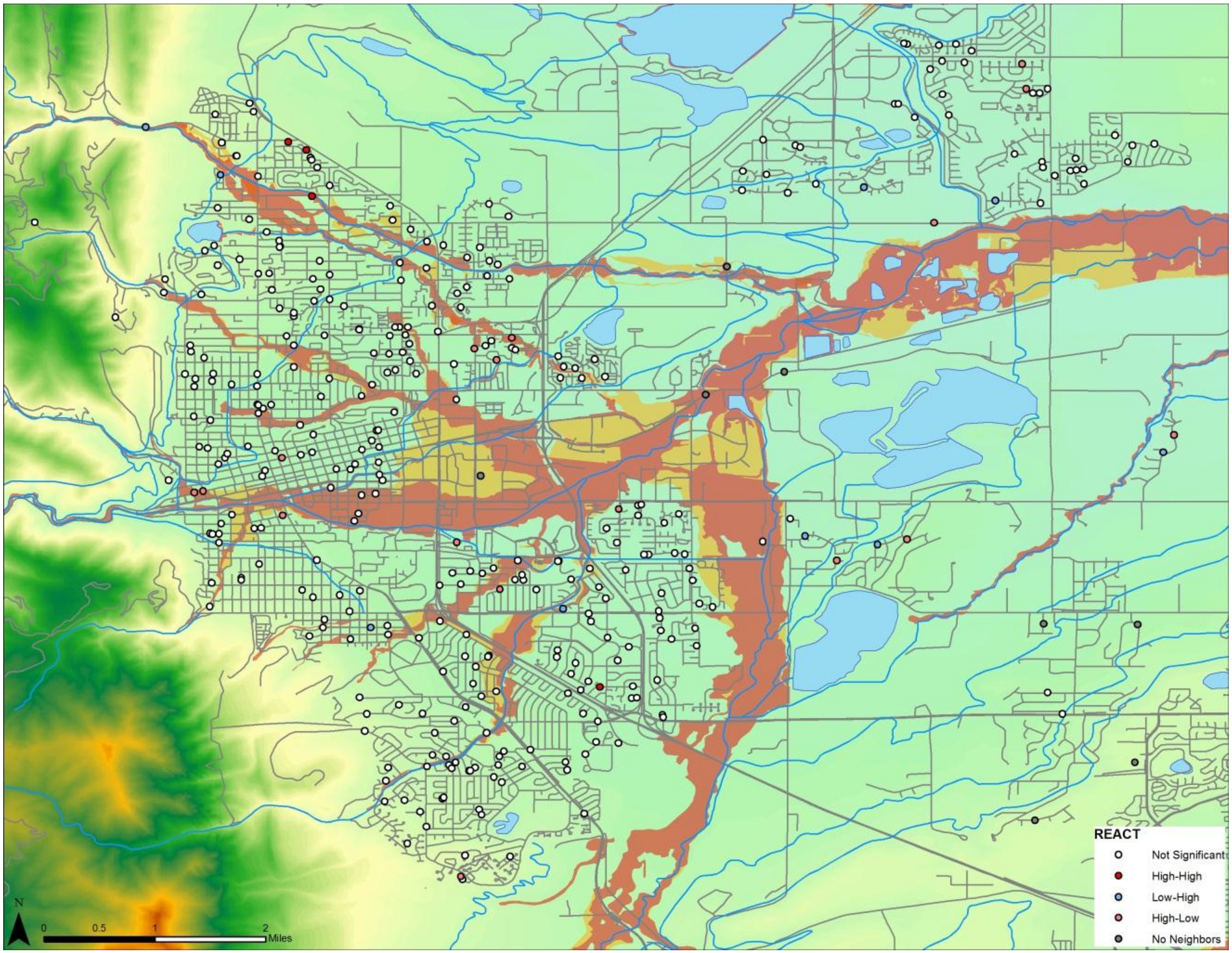

Figure 5.23: Hot Spot Analysis: REACT, Half Mile Neighborhood

signifying low likelihood of reaction because of its hesitancy to take protective action, as noted above.

Table 5.18: Correlations with REACT

REACT	**Statistic Type**	**Correlation**	**Significance**
Age	Pearson	r = 0.181*	0.001*
Male	T-Test	t = -1.651*	0.100*
Length of residence	Pearson	r = 0.069	0.211
Student	T-Test	t = -1.472	0.142
Homeowner	T-Test	t = 0.629	0.530
Income	ANOVA	F = 0.559	0.642
Education	ANOVA	F = 0.303	0.739
Experience with flash floods	T-Test	t = 0.280	0.780
Think they are in 100-year floodplain	T-Test	t = 0.938	0.349
Think they are in 500-year floodplain	T-Test	t = -0.752	0.453
Think they are in either floodplain	T-Test	t = 1.264	0.207
Located in 100-year floodplain	T-Test	t = -0.060	0.953
Located in 500-year floodplain	T-Test	t = 0.278	0.781
Elevation to floodplain	Pearson	r = -0.030	0.554
Distance to floodplain	Pearson	r = -0.054	0.288
Flow distance to floodplain	Pearson	r = -0.014	0.784
Volume of water to flood residence	Pearson	r = 0.051	0.365

*Significant at the 0.100 level

Table 5.19 summarizes the reasons respondents do not want to take protective action in a flash flood warning. The most commonly cited reason is that the respondents feel safe from flash flooding. While the respondent may not actually be at risk in his or her location, this notion could be a problem with the individual’s perception of the risk. In addition, 34.0% of respondents agree that they do not know what they are supposed to do in response to a flash flood warning (Table 5.19). While the vast majority of respondents correctly answered knowledge questions about how to respond in a flash flood, over a third of respondents lack confidence in their response. Including this information in a forecast or warning is useful, a notion to which respondents agreed (Table 5.20). Finally, not wanting to leave a home, business, or pet unprotected are also reasons that respondents said would hinder their reaction in a flash flood warning.

Table 5.19: Reasons for Not Taking Protective Action

Reasons for Not Taking Protective Action	Agree	Neither agree nor disagree	Disagree
I believe I am safe from flash flooding	42.4%	18.2%	38.1%
I do not know what I am supposed to do	34.0%	12.6%	53.1%
I have young or elderly family members that make it difficult to take action	18.1%	14.0%	66.7%
I do not trust flash flood warnings enough to be willing to take action	14.5%	13.7%	70.0%
I do not want to get wet	13.8%	14.0%	71.0%
I do not have transportation to take action	8.8%	10.6%	78.8%
I do not want to leave my home or business unprotected	23.8%	12.4%	63.2%
I am not in good enough health to take action	11.6%	6.5%	80.9%
I have a family member with a health issue or disability and that makes it difficult to take action	15.2%	10.1%	73.2%
I have a pet or pets and that makes it difficult to take action	22.6%	9.6%	66.7%

Table 5.20: Information to Include in Flash Flood Warnings and Forecasts

Information	Not Useful	Useful	Do not Know
What impacts the flooding is expected to cause	5.3%	94.2%	0.5%
Information about what to do to protect myself and others	2.3%	97.5%	0.3%

Preparing for Flash Flooding Long Before the Event Occurs (PREPARE)

Although action in a flash flood warning is key to saving lives, preparing for flash flooding long before it occurs can help people reduce their losses and evacuate quickly. Close to 35% of the respondents indicated they have already taken some form of action to prepare for flash flooding (PREPARE) (Table 5.21). The most common form of PREPARE is planning an evacuation route, followed by packing an emergency kit and discussing plans with family members living in one’s residence (Table 5.22).

Table 5.21: Taking Actions to Prepare for Flash Flooding (PREPARE)

PREPARE	Frequency	Percent
Has not prepared	266	65.2%
Has prepared	142	34.8%

Table 5.22: Specific Preparations Taken

Preparatory Action	Has done	Has not done
Planned an evacuation route	86 (22.9%)	290 (77.1%)
Packed an emergency kit	54 (14.3%)	323 (85.7%)
Made plans with family members who live within your residence	53 (14.1%)	324 (85.9%)
Made plans with friends or family members who do not live in your residence	24 (6.3%)	354 (93.7%)
Made changes to my home or property to protect it from flash floods	38 (10.1%)	340 (89.9%)

While it is comforting that the majority of the population intends to take protective action in a flash flood warning (REACT), very few have already prepared for flash flooding. This can be compared to Gruntfest et al. (2002) who found that only 17% of homeowners in the 100-year floodplain in Boulder have completed some sort of change to their property to prepare for flooding. In the same study, 14% of all respondents had created a family emergency plan and 18% of respondents said they had discussed the potential of flooding with their neighbors. These numbers are quite different than those found in this study, but they are focused on a specific floodplain in Boulder, which could yield different results. Regardless, less than a quarter of the population surveyed in both populations had made these preparations.

It is important to understand the demographics of those who have and have not already prepared for flash flooding so the importance of these actions can be emphasized to the right populations. The only demographic correlated with PREPARE is length of residence (Table 5.23). Living in Boulder longer allows time for the resident to be settled, get to know neighbors, get to know the problems with flash flooding, develop a plan, and make alterations to the property. Variables such as gender, experience, and student status are not significant in predicting PREPARE (Table 5.23).

Table 5.23: Correlations with PREPARE

PREPARE	Statistic Type	Correlation	Significance
Age	Pearson	r = 0.060	0.246
Male	T-Test	t = 0.418	0.676
Length of residence	Pearson	r = 0.089*	0.095*
Student	T-Test	t = 0.896	0.371
Homeowner	T-Test	t = 0.831	0.406
Income	ANOVA	F = 0.596	0.618
Education	ANOVA	F = 0.538	0.584
Experience with flash floods	T-Test	t = 1.540	0.124
Thinks they are in 100-year floodplain	T-Test	t = 1.710*	0.088*
Think they are in 500-year floodplain	T-Test	t = 1.683*	0.093*
Think they are in either floodplain	T-Test	t = 2.507*	0.013*
Located in 100-year floodplain	T-Test	t = 2.113*	0.035*
Located in 500-year floodplain	T-Test	t = 0.981	0.327
Elevation to floodplain	Pearson	r = 0.008	0.871
Distance to floodplain	Pearson	r = -0.038	0.449
Flow distance to floodplain	Pearson	r = -0.006	0.908
Volume of water to flood residence	Pearson	r = -0.029	0.596

*Significant at the 0.100 level

PREPARE does vary by location. Respondents who think they are located in either floodplain are positively correlated with PREPARE (Table 5.23). Additionally, those actually located in the 100-year floodplain are more likely to have prepared for flash flooding (Table 5.23). While this is a positive finding, again it is important to remember that few respondents actually know where they live with respect to the floodplains. The hot spot analysis for PREPARE indicates there are no neighborhoods of respondents more likely to prepare for flash flooding (Figure 5.24).

Similar to REACT, PREPARE is highly dependent on where individuals thinks they live. This has been verified by past studies on flooding (Brilly and Polic 2005), and is another indicator of the importance of spatial knowledge. While it is promising that more respondents

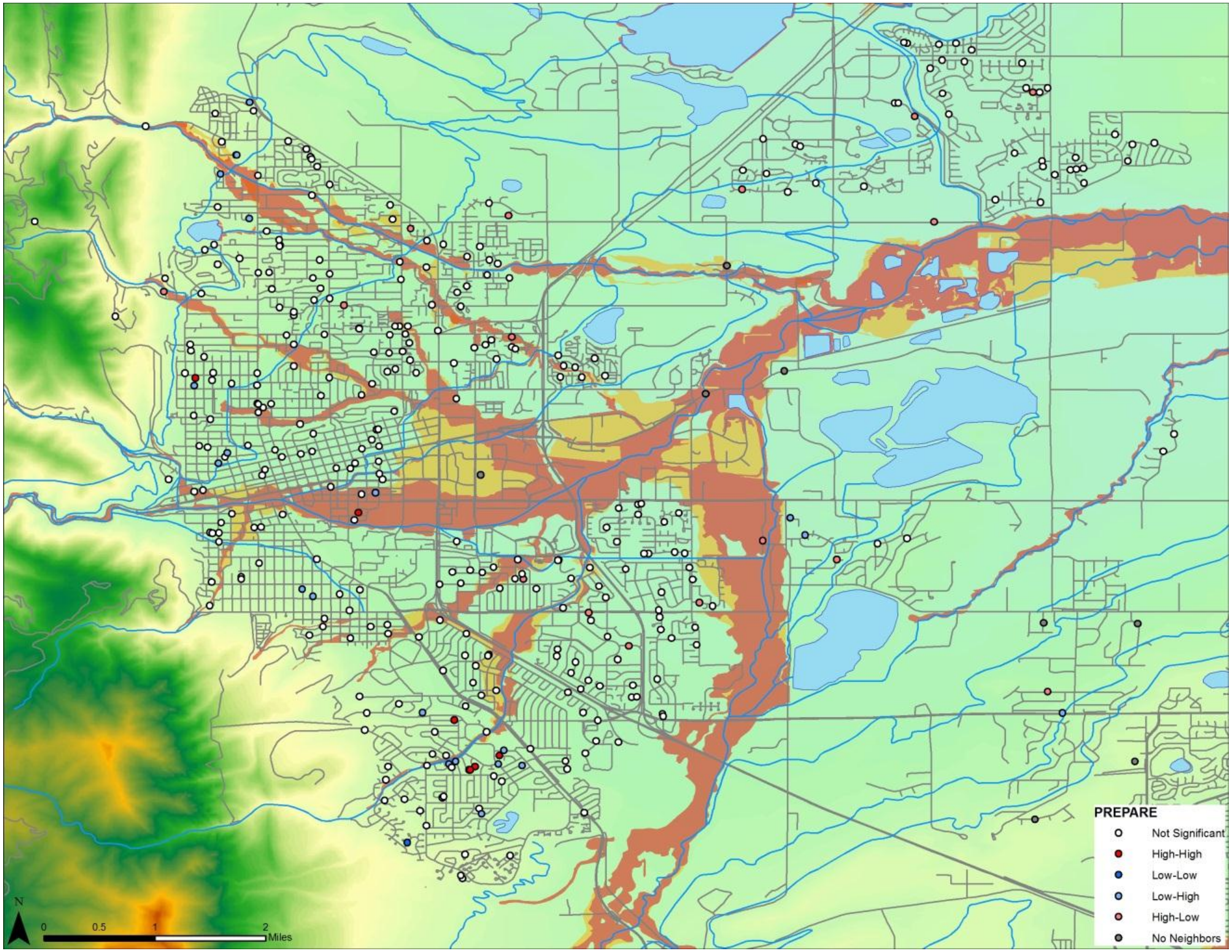

Figure 5.24: Hot Spot Analysis: PREPARE, Half Mile Neighborhood

who are at risk or think they are at risk have already prepared, this is something every resident should think about. Since such a small proportion (34.8%) of the overall population has prepared, the population needs to be informed of this important step, regardless of their location.

Summary of Correlations

Table 5.24 summarizes the correlations between the indices, REACT, and PREPARE. Location in the 100- and 500-year floodplain have significant correlations with PREPARE and the Antecedent Knowledge Index, respectively (Table 5.24). While it is good that respondents actually living in the 100-year floodplain are more likely to prepare, it is important to focus on perceived locations, as most respondents do not know their location with respect to flooding. Ensuring Boulder residents know their location with respect to floodplains may help more residents prepare before flooding impacts Boulder.

When looking across Table 5.24, the variables significant for multiple indices or behaviors are consistently correlated in the same direction. For example, being male is negatively correlated with risk perception and REACT. Length of residence is positively correlated with both the Antecedent Knowledge Index and the Warning Receptiveness Index as well as PREPARE.

Overall, the spatial variables other than location in the floodplains do not show up as significant in the analysis. Few variables are significant with respect to REACT and PREPARE. Older and female populations are cited to be more likely to react in a flash flood warning. Alternatively, neither of these variables is significantly associated with PREPARE, which is correlated with length of residence and real and perceived location. Therefore, different demographics need to be targeted for getting the population more likely to react to a flash flood warning and prepare long before flash flooding begins.

Table 5.24: Summary of Significant Correlations with Indices and Behaviors Before and During Flash Flooding

Variable	Antecedent Knowledge Index	Warning Receptiveness Index	Risk Perception Index	REACT	PREPARE
Age	+	+		+	
Male			-	-	
Length of residence	+	+			+
Student	-	-			
Homeowner	+				
Income	+				
Education		+			
Experience	+	+			
Elevation to floodplain	+				
Distance to floodplain			-		
Flow distance to floodplain					
Volume of water to flood residence					
Location in 100-year floodplain					+
Location in 500-year floodplain	+				
Think they lived in 100-year floodplain					+
Think they live in 500-year floodplain			+		+
Think they are in either floodplain			+		+

*Significant at the 0.100 level

CHAPTER 6: PREDICTIVE MODEL OF PROTECTIVE ACTION

In order to determine which variables are key in predicting PREPARE and REACT, a predictive equation for each dependent variables is developed. In predicting preparation and reaction, the indices, location variables, and socio-demographic status can be compared simultaneously to the dependent variables, allowing the unimportant variables to fall out. This leaves the most important predictors.

Likelihood to Take Protective Action in a Flash Flood Warning (REACT)

To explore variables for the predictive model for REACT, the Antecedent Knowledge Index, Warning Receptiveness Index, Risk Perception Index, socio-demographic data, and location variables were entered into the regression using a forward stepwise process. This process begins with no predictive variables in the regression and adds in the most significant variables one at a time until the model cannot be improved any further. Variables are entered into the regression at the 0.05 significance level and left out at the 0.15 significance level.

The best predictive model for REACT is:

$$p(REACT) = \frac{1}{1 + e^{-REACT}}$$

where:

REACT = -5.497 + .539 (Risk Perception) + .273 (Antecedent Knowledge) + .065 (Age) - .049 (Length of Residence) - .014 (Elevation to Floodplain)

The variables in the prediction equation include the Antecedent Knowledge Index, Risk Perception Index, and age, which are positively correlated, as well as length of residence and elevation distance to the 100-year floodplain, which are both negatively correlated (Table 6.1). The variable with the largest coefficient is risk perception, signifying it has the greatest impact on the model. As an individual perceives a more imminent risk of flash flooding, he or she is more likely to react to a flash flood warning. The second most important coefficient in predicting REACT is antecedent knowledge. Respondents who are more knowledgeable about flash flooding are more likely to react in a flash flood warning, probably because they know how to react and how powerful the flooding can be.

Age is another positive predictor of REACT, however its coefficient is not strong. This means that both risk perception and antecedent knowledge are more robust predictors of reaction to flash flood warnings. With age comes experience and wisdom about the correct actions to take in a flash flood warning, so this result is expected. Both length of residence and elevation to floodplain are negatively correlated to REACT. The longer an individual lives in Boulder, the less likely he or she is to react to a flash flood warning. Part of this discrepancy could be that it has been so long since a flash flood has happened in Boulder, therefore these respondents may not understand the imminence and importance of heeding warnings. Finally, respondents who live closer in elevation to the floodplains are more likely to take protective action in a flash flood warning. As these respondents are in the most danger of death or injury, this is an important result. While the coefficient is not strong, it is still an important finding. Past research has found risk perception (e.g. Lin et al. 2008), age (e.g. Knocke and Kolivras 2007), and length of residence (Lazo et al. 2010) as predictors of reactions to hazards, verifying the results of this analysis.

Table 6.1: Final Prediction Model for REACT: Variables and Coefficients

Variable	B	S.E.	Wald	Significance	Exp(B)
Risk Perception Index	0.539	0.140	14.855	0.000	1.715
Antecedent Knowledge Index	0.273	0.107	6.545	0.011	1.314
Age	0.065	0.021	9.688	0.002	1.068
Length of Residence	-0.049	0.023	4.484	0.034	0.952
Elevation to Floodplain	-0.014	0.006	5.852	0.016	0.986
Constant	-5.497	1.204	20.842	0.000	0.004

Table 6.2 shows how well the model classified REACT. While the model is very good at predicting high likelihood of REACT with 93.2% classified correctly, it was less accurate at predicting low and medium likelihood of REACT, only correctly classifying 51.1% of respondents. When determining the variables for the predictive model, the goal was to reduce false positives (classifying those with low and medium REACT as high REACT). For example, while age is not very influential on the predictive model, adding it into the equation helps predict those who are in the low and medium categories for REACT. This indicates that age is especially important in determining which respondents have a low likelihood of reacting.

Finally, the Nagelkerke pseudo R-square value for REACT is 0.364 (Table 6.3). This does not seem like a high number compared to the upper limit for the Nagelkerke R-square statistic, which is 1. However, combined with the statistics from Table 6.2, this model is productive at predicting REACT.

Table 6.2: Model Predictions for REACT

Observed	**Predicted**		
	Low and Medium	High	Percent Correct
Low and Medium	24	23	51.1%
High	8	110	93.2%
Overall Percent Correct			**81.2%**

Table 6.3: REACT Model Summary Statistic

Variable	**Nagelkerke R Square**
REACT	0.364

Preparing for Flash Flooding Long Before the Event Occurs (PREPARE)

The prediction model for PREPARE uses the same methods as REACT. First, all indices, demographics, and location variables are entered into the regression using the forward stepwise method. The original best model indicated that those who do not live in the 500-year floodplain, students, those who do not think they live in the 500-year floodplain, and respondents with high antecedent knowledge and warning receptiveness were more likely to prepare for flash flooding (Table 6.4). As noted previously, most respondents do not know whether or not they live in the 500-year floodplain, so variables regarding actual location in the floodplain were left out of the final prediction equation.

Table 6.4: First Prediction Model for PREPARE

Variable	B	S.E.	Wald	Significance	Exp(B)
Living in 500-year Floodplain	-2.190	1.178	3.457	0.063	0.112
Student	1.960	0.730	7.203	0.007	7.098
Think they live in 500-year floodplain	-1.547	0.705	4.814	0.028	0.213
Warning Receptiveness Index	0.257	0.111	5.330	0.021	1.293
Antecedent Knowledge Index	0.225	0.096	5.442	0.020	1.252
Constant	-0.204	1.527	0.018	0.894	0.815

After considering the results of previous models, the final prediction equation for PREPARE is:

$$p(PREPARE) = \frac{1}{1+e^{-PREPARE}}$$

where:

PREPARE = -2.186 + 1.870 (Student) – 1.593 (Perception of Living in 500-year Floodplain) + .253 (Warning Receptiveness) + 0.216 (Antecedent Knowledge)

A summary of the coefficients used in the predictive model for PREPARE are presented in Table 6.5. Beginning with the most robust variable in the prediction, being a student at the University of Colorado is positively correlated with preparing for flash flooding. These students may be extra aware of the risk because of programs and information provided by the University of Colorado. There is also a chance these students are not entirely truthful as they want to impress the survey analysts (Bertrand and Mullainathan 2001). The perception of living in the

500-year floodplain is negatively correlated with PREPARE. Residents of the 500-year floodplain may not think they are at risk for flash flooding and therefore see no need to prepare for flooding. While living in the 500-year floodplain puts an individual at less risk than someone residing in the 100-year floodplain, it is still important for residents of the 500-year floodplain to be prepared for flash flooding. If debris from a flash flood builds up near their homes, they are at great risk of flooding. Additionally, these residents could get stuck between areas of flooding and could be isolated for a time.

Table 6.5: Final Prediction Model for PREPARE: Variables and Coefficients

Variable	B	S.E.	Wald	Significance	Exp(B)
Student	1.870	0.724	6.677	0.010	6.490
Think They Live in 500-Year Floodplain	-1.593	0.686	5.394	0.020	0.203
Warning Receptiveness Index	0.253	0.109	5.366	0.021	1.288
Antecedent Knowledge Index	0.216	0.094	5.269	0.022	1.241
Constant	-2.186	1.062	4.237	0.040	0.112

Warning receptiveness and antecedent knowledge are both predictors of PREPARE in the positive direction with similar coefficients (Table 6.5). Respondents who have more trust in and higher perceived accuracy of flash flood forecasts and warnings are more likely to prepare for flash flooding. These individuals place more trust in forecasts and therefore can understand the importance of lead-time. Preparing long before flash flooding occurs reduces the amount of time it takes to react, which may be why respondents with more trust in the forecasts and warnings are more likely to prepare. Additionally, those who trust forecasts and warnings are more likely to follow measures these individuals preach, such as preparing, resulting in this group being positively correlated to PREPARE. This is verified by past work done by Lin et al. (2008), who found that trust makes an impact on preparing for flash flooding long before it occurs. Finally, individuals who are knowledgeable about flash flooding are more likely to know the types of impacts that can occur as well as the lack of lead time commonly associated with these events.

Therefore, they realize it is important to prepare for flash flooding long before it happens. In addition, they know what sort of preparations to make, such as packing an emergency kit and planning an evacuation route.

Table 6.6 shows the ability of the model to correctly predict PREPARE. The model correctly predicted 87.9% of the respondents who had not yet prepared for flash flooding, but could only predict 35.0% of those who had. While predicting respondents who had prepared for flash flooding is the goal of this model, this is the best outcome, ruling out illogical variables such as actual location in the floodplains. The results of the model predictions combined with this model's Nagelkerke R-square of 0.165 (Table 6.7) show that predictive model is ineffective at predicting PREPARE. The model is likely ineffective because so few of the respondents had actually prepared already. Figuring out how to get the population prepared for flash flooding long before the hazard strikes will be important to study further since this model is not good at predicting PREPARE.

Table 6.6: Model Predictions for PREPARE

Observed	**Predicted**		
	None taken	Some Taken	Percent Correct
None Taken	94	13	87.9%
Some taken	39	21	35.0%
Overall Percent Correct			**68.9%**

Table 6.7: PREPARE Model Summary Statistic

Variable	**Nagelkerke R Square**
PREPARE	0.165

Comparison of Results to Chapter 5

As mentioned before, the logistic regression equations present the key variables that predict both measures of action (REACT and PREPARE) with respect to flash flooding. The first prediction equation suggests a positive correlation between age and REACT in a flash flood warning. The results from Chapter 5 verify that males are less likely to react. Elevation to floodplain and length of residence are not significant in the correlation analysis in Chapter 5, but showed up as important predictor variables for REACT here. This is likely because neither variable has much variability in its distribution.

The other predictive model was created for PREPARE. The regression model's strongest predictor is student status at the University of Colorado. This does not show up as significant in the correlation results from Chapter 5. Again, this is likely because so few of the respondents are students. Also, the regression presents a negative correlation between PREPARE and perception of living in the 500-year floodplain. This finding is significant in Chapter 5, however in the opposite direction. This is a finding that requires further research.

CHAPTER 7: DISCUSSION AND CONCLUSIONS

Because people continue to live in and move to risky areas, more people are exposed to flash flooding, resulting in higher losses to these events (White et al. 2001, Montz and Gruntfest 2002). Past research has tied many variables to behavior in hazardous situations and has emphasized the need for this type of study. Besides developing policy and implementing education where necessary in hazardous areas, it is important to fully understand the social factors that make an area risky and the population vulnerable, especially since they vary from place to place (Montz and Gruntfest 2002). Knowing how residents will react, especially in a short-fused event like a flash flood, will help researchers, policy makers, and public officials prepare for the event and mitigate impacts.

Boulder presents an interesting case study with its highly educated, high-income residents, as well as its university population and exposure to flash flooding. It has been many decades since Boulder has experienced flash flooding, which may have an impact on the population's perception of these events, especially because of population changes that have taken place since the last flooding episode. Nearby flooding in recent years may also change perceptions, however it may prevent the residents from personalizing the risk and lead to the assumption that flash flooding will not directly affect them. Adding Boulder to the database of hazard-related case studies certainly increases the knowledge of behaviors prior to and during flash floods. It is important to have many case studies in every type of hazard as well as in locales with different circumstances and characteristics. With a large database of studies, researchers can begin to understand and predict behaviors in all areas and in all types of events.

Summary of Results

The survey population is very knowledgeable overall. The vast majority of respondents knows what to do in a flash flood warning and can correctly identify the difference between a watch and a warning. Some problems with respondents' antecedent knowledge include identifying the safe amount of fast-flowing water to walk and drive through, defining the 100-year flood, and knowing their location with respect to the 100- and 500-year floodplains. Knowing the location of one's residence is positively correlated with age, length of residence, not being a student, home ownership, income, and experience. Respondents with the highest Antecedent Knowledge Index tend to be older, long-time residents of Boulder, non-students, homeowners, wealthy, experienced with flash floods, live closer in elevation to the 100-year floodplain, and live in the 500-year floodplain.

The population overall has high trust and low perceived accuracy of flash flood forecasts and products. This indicates that while the respondents understand that flash floods are hard to predict, they are still confident in what the National Weather Service tells them about the flash flood threat. There is no significant change in warning receptiveness with respect to the respondents' location in and out of the floodplains. The Warning Receptiveness Index is positively correlated with age, length of residence, high and low levels of education, and experience with flash floods.

While the population has high antecedent knowledge about flash floods and trust in flash flood products, they have a wide range of risk perceptions. Overall, the respondents do not believe they have a high likelihood of injury or death in flash floods, which is unfortunate given this type of event. While the survey population does not recognize the risk of impacts to humans, they are much more likely to recognize impacts to buildings and property. Males, respondents who think they live in the 500-year floodplain, and respondents who are located close to the 100-year floodplain perceive flash floods to be most imminent.

Respondents most likely to react in a flash flood warning are older, female, live closer in elevation to the 100-year floodplain, and have higher risk perceptions and antecedent knowledge. The most commonly cited reasons for not wanting to react in a flash flood warning were perceived safety from flash flooding, confusion on correct actions to take in a warning, and the desire to protect one's home, business, or pets. Warning receptiveness is not a predictor for REACT. This adds to the conflicting research regarding the role of trust in hazard decision-making.

Predicting respondents who have prepared for flash flooding is a more difficult task in Boulder. PREPARE is positively correlated with being a student at the University of Colorado, length of residence, actual and perceived location in the 100-year floodplain, antecedent knowledge, and warning receptiveness. PREPARE has conflicting correlations with the perception of living in the 500-year floodplain. Of the respondents who have prepared for flash flooding, the most common preparation is planning an evacuation route.

Besides a small area on the map showing respondents versus non-respondents to the survey, the hot spot analysis results indicate spatial randomness in Boulder for all variables. While location in and out of the floodplains is significant in many of the analyses conducted, distance to the floodplains, elevation difference between the residence and floodplain, flow distance to the floodplain, and volume required to flood the residence are not significant in most analyses. However, those who are located higher above the 100-year floodplain tend to have more antecedent knowledge about flash floods and are less likely to react in a flash flood warning. Additionally, those closer to the 100-year floodplain perceived the risk of flash flooding as more imminent.

Implications

Based on all these findings, improved environmental education is the main recommendation as knowledge is one of the best predictors for REACT as well as PREPARE. Specifically, it is important to educate about safe depths of fast flowing water to cross. This can help save lives. It is also important to help people feel confident in what action to take in a flash flood. While many correctly identified what to do in a flash flood situation, a large portion of the population also indicated they did not know what to do in a flash flood and that would prevent them from reacting in a warning. Providing information on how to prepare long before a flash flood occurs can help the public feel confident in taking fast action when the time comes.

Additionally, residents need to know where they live with respect to the floodplains. Only 43% of respondents know this information. Respondents who believe they are located in a floodplain, regardless of where they actually live, are more likely to prepare for flash flooding. Educating the public on their location with respect to floodplains is important, however this recommendation is complicated as floodplain maps are distributed frequently by mail in Boulder, but are obviously not effective. Perhaps a clearly worded statement indicating the resident is in or out of the floodplain accompanied by the map would be more helpful. It is especially important to seek addresses of those who are at greater risk for flooding and target these populations with information including their location in the floodplain, what to do in a flash flood, and what they can do ahead of time to prepare. The City of Boulder also offers a free, quick, online search that will tell anyone if their address is located in the floodplains or not. Perhaps this needs to be advertised so people are aware of their personal risk. The best possible option is to get the information out there in as many ways as possible in hopes that residents will educate themselves about the location of the floodplain. This knowledge needs to be imparted well before the potential for flash floods exists, perhaps in the spring as the flash flood potential begins to increase. Making sure the public is knowledgeable will make sure that in the key moments before a flood strikes, the respondents act appropriately.

Another problem with the 100-year flood is that many do not understand the vocabulary. Only 35% of respondents could define the 100-year flood, with "correct" grades given liberally. If this terminology is altered to something the public understands, the flood maps will make more sense and might communicate the risk more effectively. This, in turn, will help people understand their location and be more likely to prepare for a flash flood and take action in an actual event. Wording such as "high flood risk" or "flood danger area" imparts a more imminent risk than "100-year floodplain" does.

It is imperative to target populations that are not likely to react and have not prepared for flash flooding. From the results, these groups include younger residents, males, new residents, and the population residing in the floodplains. The rapid-onset nature of flash floods means that quick and smart action is essential to reducing injuries and deaths. Preparing at-risk populations can help reduce property losses and injuries or deaths in an event.

There is always a chance that residents have not prepared for flash flooding before the event actually occurs. In a flash flood warning, including information about appropriate protective actions within the warning text will help, as will telling the public specific places to go if they had not already decided. If an individual has not prepared beforehand and is not informed, this is a good time to provide the information needed to protect his or her life.

Limitations of Research

There are, of course, limitations to the study. With respect to the spatial analysis, there is always the potential for error in geocoding. Residences that could not be geolocated had to be individually placed on the map. In addition, using the ArcGIS geolocator is not necessarily the best methodology. Using parcel data to place the respondent's residences may be more accurate and should be implemented in the future. The hot spot analysis did not show up as significant, possibly because the respondents were located too far away from each other. Future work needs to focus on smaller neighborhood definitions and more densely located survey populations.

In the sample itself, the respondents are older, wealthier, and more highly educated than Boulder's actual population, with students underrepresented. This makes it hard to generalize results across the entire population. Open-ended responses can change results greatly depending on how they were coded. Also, this study looks at expected behaviors in a flash flood warning, not actual behaviors. However, past research has shown that self-reported behavior expectations can accurately predict actual response in an event, so while this should be kept in mind, this limitation is not damaging to the research (Dow and Cutter 2000, Lindell et al. 2007).

Finally, there are limitations associated with the binary logistic regressions. When testing many variables, only respondents who have responded to all of these questions are included in the analysis. In other words, testing more variables includes fewer respondents in the results. Therefore, once the important predictor variables are determined, using only these variables in the regression uses a larger population and may not perform as well. Because of this, the results presented here are only from regressions testing all variables. Therefore, these results are biased based on the responses of individuals who answered all the questions. These results are generalized across the population. Finally, the prediction equations were not good at predicting groups with few people in them, specifically those who would not react in a flash flood warning and those who had already prepared for flash floods.

Contributions to Knowledge and Future Work

This case study is unique in that it adds many location variables to the study of behavior in hazards. While few of these variables were significant in predicting action in a flash flood warning and preparing for flash flooding, it would be interesting to continue this type of analysis with other hazards and in other locations. Conducting more hot spot analyses would also be beneficial, especially in locations with densely populated respondents to test neighborhood effects. Additionally, past literature has variable findings with respect to the role of trust. This research added to the literature on trust in forecasts and warnings with respect to action in flash flooding.

There are many options available for future work in this area. First, the student population in Boulder should be targeted to get a better grasp on students' likelihood to react in a flash flood warning and prepare for flash flooding long before it occurs. Although this study had preliminary findings on this group, they may not be accurate as so few students returned surveys. Second, work on false alarms should be conducted to see if it really matters in taking protective action in flash floods. This study found that perceived accuracy of and trust in flash flood warnings increased with age and length of residence, indicating that false alarms are not affecting how respondents view forecasts and warnings. This finding should be researched further. Third, if and when a major flash flood hits Boulder, a follow-up survey should be conducted. This will give insightful information on how residents actually respond to flash floods and if their risk perceptions, warning receptiveness, and antecedent knowledge change over time. It may also change how many people prepare for flash flooding and how many people expect to take protective action in the future. Fourth, further research should be conducted on what makes the population likely to prepare for flash flooding as the model presented in this research was not very effective. Finally, this survey instrument should be used for flash flooding in different locations to compare results to the Boulder population.

REFERENCES

Aguilar, J., 2010: Collapsed bridge removed; Boulder Creek flood risk recedes. *Daily Camera*, June 8, 2010.

American Meteorological Society (AMS), 2000: Glossary of Meteorology, Second Edition. T. S. Glickman (Ed.), American Meteorological Society, Boston.

Anderson-Berry, L. J., 2003: Community vulnerability to tropical cyclones: Cairns, 1996-2000. *Natural Hazards*, **30,** 209-232.

Balluz, L., L. Schieve, T. Holmes, S. Kiezak, and J. Malilay, 2000: Predictors for people's response to a tornado warning: Arkansas, 1 March 1997. *Disasters*, **24,** 71-77.

Benight, C., E. Gruntfest, M. Hayden, and L. Barnes, 2007: Trauma and short-fuse weather warning perceptions. *Environmental Hazards*, 7**,** 220-226.

Bertrand, M. and S. Mullainathan, 2001: Do people mean what they say? Implications for subjective survey data. *The American Economic Review,* **91,** 67-72.

Bogdanska-Warmuz, R., 2001: A study of the knowledge and behavior of Brzesko inhabitants after the flood in 1997. In: Gruntfest, E. and J. Handmer (Eds.), Coping with Flash Floods. Kluwer Academic Publishers, Dordrecht, pp. 53-60.

Boulder County: Geographic Information Systems (GIS) Downloadable Data, 2012. [Available at http://www.bouldercounty.org/find/maps/pages/gisdldata.aspx]

Brilly, M. and M. Polic, 2005: Public perception of flood risks, flood forecasting and mitigation. *Natural Hazards and Earth System Sciences,* **5,** 345-355.

Brommer, D. M. and J. C. Senkbeil, 2010: Pre-landfall evacuee perception of the meteorological hazards associated with Hurricane Gustav. *Natural Hazards*, **55,** 353-369.

City-Data, 2009: Boulder, Colorado. [Available at http://www.city-data.com/city/Boulder-Colorado.html]

City of Boulder, 2009: Flash Flood Safety Boulder, Colorado. City of Boulder Flood Safety Brochure. [Available at http://www.bouldercolorado.gov/files/Utilities/Flood%20Info/flood_brochurefn.pdf]

City of Boulder, 2010: Water Resources Advisory Board Agenda Item: Update on the Boulder Creek Floodplain Mapping Study. July 19, 2010. [Available at http://www.bouldercolorado.gov/files/Utilities/Projects/boulder_creek/BC__PMR_Update_WRAB_Memo_7_9_10.pdf]

City of Boulder, 2012: Flood Management. [Available at http://www.bouldercolorado.gov/index.php?Itemid=1253&id=3493&option=com_content&task=view]

Dillman, D. A. 2000: Mail and Internet Surveys. New York: Wiley.

Dow, K., and S. L. Cutter, 1998: Cry Wolf: Repeat response to hurricane evacuation orders. *Coastal Management*, **26,** 237-252.

Dow, K., and S. L. Cutter, 2000: Public orders and personal opinions: Household strategies for hurricane risk assessment. *Environmental Hazards*, **2,** 143-155.

Drabek, T. E. and J. S. Stephenson III, 1971: When disaster strikes. *Journal of Applied Social Psychology*, **1,** 187-203.

Faupel, C. E., S. P. Kelley, and T. Petee, 1992: The impact of disaster education on household preparedness for Hurricane Hugo. *International Journal of Mass Emergencies and Disasters*, **10,** 5-24.

Fielding, J., K. Burningham, D. Thrush, and R. Catt, 2007: Public Response to Flood Warning. R&D Technical Report SC020116.

Grigg, N. S., N. J. Doesken, D. M. Frick, M. Grimm, M. Hilmes, T. B. McKee, and K. A. Oltjenbruns, 1999: Fort Collins flood 1997: Comprehensive view of an extreme event. *Journal of Water Resources Planning and Management*, **125**, 255-262.

Grothmann, T., and F. Reusswig, 2006: People at risk of flooding: Why some residents take precautionary action while others do not. *Natural Hazards*, **38,** 101-120.

Gruntfest, E. and J. Handmer, 2001: Where we go from here: Policy and research. In: Gruntfest, E. and J. Handmer (Eds.), Coping with Flash Floods. Kluwer Academic Publishers, Dordrecht, pp. 317-322.

Gruntfest, E., K. Carsell, and T. Plush, 2002: An Evaluation of the Boulder Creek Local Flood Warning System. Report prepared for Urban Drainage and Flood Control District Boulder City/County Office of Emergency Management.

Holden, C., 2011: Weather Service training locals to record weather in Fourmile Fire burn area. *Daily Camera*, March 12, 2011.

Kalkstein, A. J. and S. C. Sheridan, 2007: The social impacts of the heat-health watch/warning system in Phoenix, Arizona: Assessing the perceived risk and response of the public. *International Journal of Biometeorology*, **52,** 43-55.

Kates, R. W., 1971: Natural hazard in human ecological perspective: Hypotheses and models. *Economic Geography*, **47,** 438-451.

Kelsch, M., 2001: Hydrometeorological characteristics of flash floods. In: Gruntfest, E. and J. Handmer (Eds.), Coping with Flash Floods. Kluwer Academic Publishers, Dordrecht, pp. 181-193.

Kelsch, M., E. Caporali, and L. G. Lanza, 2001: Hydrometeorology of flash floods. In: Gruntfest, E. and J. Handmer (Eds.), Coping with Flash Floods. Kluwer Academic Publishers, Dordrecht, pp. 19-35.

Knocke, E. and K. Kolivras, 2007: Flash flood awareness in southwest Virginia. *Risk Analysis*, **27,** 155-169.

Kristjanson, P. M. Radeny, I. Baltenweck, J. Ogutu, and A. Notenbaert, 2005: Livelihood mapping and poverty correlates at a meso-level in Kenya. *Food Policy*, **30,** 568-583.

Lazo, J. K., D. M. Waldman, B. H. Morrow, and J. A. Thacher, 2010: Household evacuation decision making and the benefits of improved hurricane forecasting: Developing a framework for assessment. *Weather and Forecasting*, **25,** 207-219.

Legates, D. R. and M. D. Biddle, 1999: Warning response and risk behavior in the Oak Grove—Birmingham, Alabama, tornado of 08 April 1998. Quick Response Report #116. Natural Hazards Research Applications and Information Center, Boulder, CO.

Lin, S., D. Shaw, and M. Ho, 2008: Why are flood and landslide victims less willing to take mitigation measures than the public? *Natural Hazards*, **44,** 305-314.

Lindell, M. K., 1994: Perceived characteristics of environmental hazards. *International Journal of Mass Emergencies and Disasters*, **12,** 303-326.

Lindell, M. K., C. S. Prater, and W. G. Peacock, 2007: Organizational communication and decision making for hurricane emergencies. *Natural Hazards Review*, ***3,*** *50-60.*

Lopez-Marrero, T. and B. Yarnal, 2010: Putting adaptive capacity into the context of people's lives: A case study of two flood-prone communities in Puerto Rico. *Natural Hazards*, **52,** 277-297.

Meltzer, E., 2011: City official: Boulder faces heightened flood risk for up to 10 years. *Daily Camera*, March 1, 2011.

Miceli, R., I. Sotgiu, and M. Settanni, 2008: Disaster preparedness and perception of flood risk: A study in an alpine valley in Italy. *Journal of Environmental Psychology*, **28,** 164-173.

Mileti, D. S., 1999: Disasters by Design. National Academies Press, Washington D.C.

Mileti, D. S., and J. Sorensen, 1990: Communication of emergency public warnings: A social science perspective and state-of-the-art assessment. Oak Ridge National Laboratory, Oak Ridge, TN.

Montz, B. and E. Gruntfest, 2002: Flash flood mitigation: Recommendations for research and applications. *Environmental Hazards*, **4,** 15-22.

National Weather Service (NWS), 2009a: Mother's Day Weekend Tornado in Oklahoma and Missouri, May 10, 2008. Service Assessment. National Weather Service, Silver Spring, Maryland. [Available at http://www.nws.noaa.gov/om/assessments/pdfs/mothers_day09.pdf]

National Weather Service (NWS), 2009b: National Weather Service Glossary. [Available at http://www.weather.gov/glossary/]

Petersen, M. S., 2001: Impacts of flash floods. In: Gruntfest, E. and J. Handmer (Eds.), Coping with Flash Floods. Kluwer Academic Publishers, Dordrecht, pp. 11-13.

Powell, S. W. and D. H. O'Hair, 2008: Communicating weather information to the public: People's reactions and understandings of weather information and terminology. *Third Symposium on Policy and Socio-economic Research*, New Orleans, LA, Amer. Meteor. Soc., Poster 1.3. [Available at http://ams.confex.com/ams/pdfpapers/132939.pdf]

Raaijmakers, R., J. Krywkow, and A. van der Veen, 2008: Flood risk perceptions and spatial multi-criteria analysis: An exploratory research for hazard mitigation. *Natural Hazards*, **46,** 307-322.

Ruin, I, J. C. Gaillard, and C. Lutoff, 2007: How to get there? Assessing motorists' flash flood risk perception on daily itineraries. *Environmental Hazards,* **7,** 235-244.

Sanders, R. A., 1986: Urban vegetation impacts on the hydrology of Dayton, Ohio. *Urban Ecology,* **9,** 361-376.

Siegrist, M., H. Gutscher, and T. C. Earle, 2005: Perception of risk: The influence of general trust, and general confidence. *Journal of Risk Research,* **8,** 145-156.

Siudak, M., 2001. Role of education in reducing flash flood effects. In: Gruntfest, E. and J. Handmer (Eds.), Coping with Flash Floods. Kluwer Academic Publishers, Dordrecht, pp. 15-18.

Slovic, P., 1987: Perception of Risk. *Science,* **236,** 280-285.

Slovic, P., B. Fischoff, and S. Lichtenstein, 1982: Why study risk perception? *Risk Analysis,* **2,** 83-93.

Snider, L., 2011: Heavy rain in Fourmile burn area could flood dozens of homes. *Daily Camera*, March 8, 2011.

Sorensen, J. H., 1983: Knowing how to behave under the threat of disaster: Can it be explained? *Environment and Behavior*, **15,** 438-457.

Thieken, A. H., H. Kreibich, M. Muller, and B. Merz, 2007: Coping with floods: Preparedness, response and recovery of flood-affected residents in Germany in 2002. *Hydrological Sciences Journal*, **52,** 1016-1037.

Tobin, G. A. and B. E. Montz, 1997: Natural Hazards: Explanation and Integration. The Guilford Press, New York.

U.S. Census Bureau, 2010: American Fact Finder: 2010 Census. [Available at http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml]

U.S. Census Bureau, 2011: TIGER Data: Topologically Integrated Geographic Encoding and Referencing System. [Available at http://www.census.gov/geo/www/tiger/

U.S. Geological Survey (USGS), 2000: Significant floods in the United States during the 20th century-USGS measures a century of floods. US Geological Survey Factsheet 4 pp. [Available at http://ks.water.usgs.gov/pubs/fact-sheets/fs.024-00.html]

U.S. Geological Survey (USGS), 2006: National Elevation Dataset. [Available at http://ned.usgs.gov/]

University of Colorado Boulder, 2011: CU – Boulder Enrollment Snapshot Fall 2010 vs. Fall 2011. [Available at http://www.colorado.edu/pba/records/snap/21172107/snappage3.htm]

Ver Hoef, J. M., E. Peterson, and D. Theobald, 2006: Spatial statistical models that use flow and stream distance. *Environmental Ecological Statistics*, **13,** 449-464.

White, G. F., R. W. Kates, and I. Burton, 2001: Knowing better and losing even more: The use of knowledge in hazards management. *Environmental Hazards*, **3,** 81-92.

APPENDIX A: IRB DOCUMENTATION

The University of Oklahoma

OFFICE FOR HUMAN RESEARCH PARTICIPANT PROTECTION

IRB Number: 12831
Approval Date: January 11, 2010

January 12, 2010

Randy Peppler
CIMMS
120 David L. Boren Blvd., NWC 2100
Norman, OK 73072

RE: Warning Decisions in Extreme Weather Events: Determining the Perception of Risks Associated with Flash Flooding in Boulder, Colorado

Dear Mr. Peppler:

On behalf of the Institutional Review Board (IRB), I have reviewed and granted expedited approval of the above-referenced research study. This study meets the criteria for expedited approval category 6, 7. It is my judgment as Chairperson of the IRB that the rights and welfare of individuals who may be asked to participate in this study will be respected; that the proposed research, including the process of obtaining informed consent, will be conducted in a manner consistent with the requirements of 45 CFR 46 as amended; and that the research involves no more than minimal risk to participants.

This letter documents approval to conduct the research as described:

Consent form - Subject Dated: December 22, 2009 Pre-Test participants
Recruitment flyer Dated: December 22, 2009 Revised - 2nd Survey without incentive
Recruitment flyer Dated: December 22, 2009 Revised - Postcard reminder
Recruitment flyer Dated: December 22, 2009 Revised - Initial Survey w/incentive
Consent form - Other Dated: December 22, 2009 Information Sheet (Revised) - $2
Consent form - Other Dated: December 22, 2009 Information Sheet (Revised) 2 - $1
Consent form - Other Dated: December 22, 2009 Information Sheet (Revised) - $1
Consent form - Other Dated: December 22, 2009 Information Sheet (Revised) - no compensation
Grant Application Dated: December 22, 2009 NSF
Survey Instrument Dated: December 17, 2009 Flash Floods and You
Recruitment flyer Dated: December 17, 2009 Letter: Pre-Survey
Protocol Dated: December 17, 2009
IRB Application Dated: December 17, 2009
Other Dated: June 08, 2009 Nat'l Ctr for Atomspheric Research - IRB apprvl

As principal investigator of this protocol, it is your responsibility to make sure that this study is conducted as approved. Any modifications to the protocol or consent form, initiated by you or by the sponsor, will require prior approval, which you may request by completing a protocol modification form. All study records, including copies of signed consent forms, must be retained for three (3) years after termination of the study.

The approval granted expires on January 10, 2011. Should you wish to maintain this protocol in an active status beyond that date, you will need to provide the IRB with an IRB Application for Continuing Review (Progress Report) summarizing study results to date. The IRB will request an IRB Application for Continuing Review from you approximately two months before the anniversary date of your current approval.

If you have questions about these procedures, or need any additional assistance from the IRB, please call the IRB office at (405) 325-8110 or send an email to irb@ou.edu.

Cordially,

Lynn Devenport, Ph.D.
Chair, Institutional Review Board

[illegible] Oval, Suite 316, Norman, Oklahoma 73019-3085 PHONE: (405) 325-8110 FAX:(405) 325-2373

701-A-1

University of Oklahoma
Institutional Review Board
Informed Consent to Participate in a Research Study

Project Title: Warning Decisions in Extreme Weather Events: Determining the Perception of Risks Associated with Flash Flooding in Boulder, Colorado
Principal Investigator: Randy Peppler
Department: Geography

You are being asked to volunteer for this research study. This study is being conducted at The National Center for Atmospheric Research in Boulder, Colorado. You were selected as a possible participant because you are resident of Boulder, Colorado.

Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study

The purpose of this study is to study how Boulder residents understand flash flooding and its associated risks.

Number of Participants

About 1000 people will take part in this study.

Procedures

If you agree to be in this study, you will be asked to complete a short survey related to flash flooding and its associated risks. We will ask you to think out loud the entire time you are completing this survey. We will then ask you some questions about your thoughts while you completed the survey.

Length of Participation

The study will take approximately 45 minutes to complete.

This study has the following risks:

There are no risks associated with this study.

Benefits of being in the study are

The benefits to participating include a greater understanding of how the public perceives and reacts to flash floods to evoke public understanding of science and risk assessment. The goal is to understand how people receive, comprehend, and react to flash flood hazards to determine better ways to provide information to these people. Their participation may influence how flash flood information is designed and communicated in the future, which subsequently may save lives.

APPROVED
JAN 1 1 2010
OU NC IRB

APPROVAL
JAN 1 0 2011
EXPIRES

Confidentiality

In published reports, there will be no information included that will make it possible to identify you without your permission. Research records will be stored securely and only approved researchers will have access to the records.

There are organizations that may inspect and/or copy your research records for quality assurance and data analysis. These organizations include the National Center for Atmospheric Research and the OU Institutional Review Board.

Compensation

You will be reimbursed for you time and participation in this study. We will pay you $50 for your time taking the survey and answering our follow-up questions. You will be compensated immediately after you have completed the survey and follow-up questions.

Voluntary Nature of the Study

Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

Audio Recording of Study Activities

To assist with accurate recording of participant responses, interviews may be recorded on an audio recording device. You have the right to refuse to allow such recording without penalty. Please select one of the following options.

I consent to audio recording. ___ Yes ___ No.

Contacts and Questions

If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at

Jeff Lazo: lazo@ucar.edu, 303-497-2857; Kelsey Mulder: Kelsey.Mulder@ou.edu, 303-875-2993; Curtis McDonald: curtism@ou.edu, 314-606-4011

Contact the researcher(s) if you have questions or if you have experienced a research-related injury.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.

APPROVED
JAN 1 1 2010
OU NC IRB

APPROVAL
JAN 1 0 2011
EXPIRES

701-A-1

Statement of Consent

I have read the above information. I have asked questions and have received satisfactory answers. I consent to participate in the study.

Signature Date

APPROVED
JAN 1 1 2010
OU NC IRB

APPROVAL
JAN 1 0 2011
EXPIRES

INFORMATION SHEET FOR CONSENT TO PARTICIPATE IN A RESEARCH STUDY

My name Randy Peppler, and I am a meteorologist in CIMMS at the University of Oklahoma. Along with School of Meteorology students Curtis McDonald and Kelsey Mulder, I am inviting you to participate in a research study titled Warning Decisions in Extreme Weather Events: Determining the Perception of Risks Associated with Flash Flooding in Boulder, Colorado. You were selected as a possible participant because you are currently a resident of Boulder, Colorado. Please read this information sheet and contact me to ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study: The purpose of this study is to study how Boulder residents understand flash flooding and its associated risks.

Procedures: If you agree to be in this study, you will be asked to complete a survey related to flash flooding and its associated risks. The survey will take approximately 45 minutes to complete.

Risks and Benefits of Being in the Study: There are no risks associated with this study. The benefits to participating include a greater understanding of how the public perceives and reacts to flash floods to evoke public understanding of science and risk assessment. The goal is to understand how people receive, comprehend, and react to flash flood hazards to determine better ways to provide information to these people. Their participation may influence how flash flood information is designed and communicated in the future, which subsequently may save lives.

Compensation: You will receive a $2 bill in the mailing with your survey regardless of your participation.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not result in penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free not to answer any question or discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Length of Participation: The survey will take approximately 45 minutes to complete.

Confidentiality: The records of this study will be kept private and your supervisor will not have access to your responses. In published reports, there will be no information included that will make it possible to identify you as a research participant. Research records will be stored securely. Standard methods to protect privacy will be maintained. Participants will be anonymous, as their name wil not be associated with the data. Data will be securely stored in a locked office or on a computer or hard disks. Hard copies of data will remain in our possession locked in my office. All data will be destroyed (i.e., shredded or erased) when data analysis is complete. Only approved researchers will have access to the records.

Contacts and Questions: If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at Randy Peppler: (405) 325-6667 or rpeppler@ou.edu; Kelsey Mulder: (303) 875-2993 or kelsey.mulder@ou.edu; Curtis McDonald: (314) 606-4011 or curtism@ou.edu. In the event of a research-related injury, contact the researcher(s). You are encouraged to contact the researcher(s) if you have any questions. If you have any questions, concerns, or complaints about the research and wish to talk to someone other than the individuals on the research team, or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at (405) 325-8110 or irb@ou.edu.

Please keep this information sheet for your records. By completing and returning this questionnaire, I am agreeing to participate in this study.

Revised 10/27/2006

APPROVED
JAN 1 1 2010
OU NC IRB

APPROVAL
JAN 1 0 2011
EXPIRES

Page 4 of 4

INFORMATION SHEET FOR CONSENT TO PARTICIPATE IN A RESEARCH STUDY

My name Randy Peppler, and I am a meteorologist in CIMMS at the University of Oklahoma. Along with School of Meteorology students Curtis McDonald and Kelsey Mulder, I am inviting you to participate in a research study titled Warning Decisions in Extreme Weather Events: Determining the Perception of Risks Associated with Flash Flooding in Boulder, Colorado. You were selected as a possible participant because you are currently a resident of Boulder, Colorado. Please read this information sheet and contact me to ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study: The purpose of this study is to study how Boulder residents understand flash flooding and its associated risks.

Procedures: If you agree to be in this study, you will be asked to complete a survey related to flash flooding and its associated risks. The survey will take approximately 45 minutes to complete.

Risks and Benefits of Being in the Study: There are no risks associated with this study. The benefits to participating include a greater understanding of how the public perceives and reacts to flash floods to evoke public understanding of science and risk assessment. The goal is to understand how people receive, comprehend, and react to flash flood hazards to determine better ways to provide information to these people. Their participation may influence how flash flood information is designed and communicated in the future, which subsequently may save lives.

Compensation: You will receive 2-$1 bills in the mailing with your survey regardless of your participation.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate ~~will not~~ result in penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free not to answer any question or discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Length of Participation: The survey will take approximately 45 minutes to complete.

Confidentiality: The records of this study will be kept private and your supervisor will not have access to your responses. In published reports, there will be no information included that will make it possible to identify you as a research participant. Research records will be stored securely. Standard methods to protect privacy will be maintained. Participants will be anonymous, as their name wil not be associated with the data. Data will be securely stored in a locked office or on a computer or hard disks. Hard copies of data will remain in our possession locked in my office. All data will be destroyed (i.e., shredded or erased) when data analysis is complete. Only approved researchers will have access to the records.

Contacts and Questions: If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at Randy Peppler: (405) 325-6667 or rpeppler@ou.edu; Kelsey Mulder: (303) 875-2993 or kelsey.mulder@ou.edu; Curtis McDonald: (314) 606-4011 or curtism@ou.edu. In the event of a research-related injury, contact the researcher(s). You are encouraged to contact the researcher(s) if you have any questions. If you have any questions, concerns, or complaints about the research and wish to talk to someone other than the individuals on the research team, or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at (405) 325-8110 or irb@ou.edu.

Please keep this information sheet for your records. By completing and returning this questionnaire, I am agreeing to participate in this study.

Revised 10/27/2006

APPROVED
JAN 1 1 2010
OU NC IRB

APPROVAL
JAN 1 0 2011
EXPIRES

INFORMATION SHEET FOR CONSENT TO PARTICIPATE IN A RESEARCH STUDY

My name Randy Peppler, and I am a meteorologist in CIMMS at the University of Oklahoma. Along with School of Meteorology students Curtis McDonald and Kelsey Mulder, I am inviting you to participate in a research study titled Warning Decisions in Extreme Weather Events: Determining the Perception of Risks Associated with Flash Flooding in Boulder, Colorado. You were selected as a possible participant because you are currently a resident of Boulder, Colorado. Please read this information sheet and contact me to ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study: The purpose of this study is to study how Boulder residents understand flash flooding and its associated risks.

Procedures: If you agree to be in this study, you will be asked to complete a survey related to flash flooding and its associated risks. The survey will take approximately 45 minutes to complete.

Risks and Benefits of Being in the Study: There are no risks associated with this study. The benefits to participating include a greater understanding of how the public perceives and reacts to flash floods to evoke public understanding of science and risk assessment. The goal is to understand how people receive, comprehend, and react to flash flood hazards to determine better ways to provide information to these people. Their participation may influence how flash flood information is designed and communicated in the future, which subsequently may save lives.

Compensation: You will receive $1 in the mailing with your survey regardless of your participation.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not result in penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free not to answer any question or discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Length of Participation: The survey will take approximately 45 minutes to complete.

Confidentiality: The records of this study will be kept private and your supervisor will not have access to your responses. In published reports, there will be no information included that will make it possible to identify you as a research participant. Research records will be stored securely. Standard methods to protect privacy will be maintained. Participants will be anonymous, as their name wil not be associated with the data. Data will be securely stored in a locked office or on a computer or hard disks. Hard copies of data will remain in our possession locked in my office. All data will be destroyed (i.e., shredded or erased) when data analysis is complete. Only approved researchers will have access to the records.

Contacts and Questions: If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at Randy Peppler: (405) 325-6667 or rpeppler@ou.edu; Kelsey Mulder: (303) 875-2993 or kelsey.mulder@ou.edu; Curtis McDonald: (314) 606-4011 or curtism@ou.edu. In the event of a research-related injury, contact the researcher(s). You are encouraged to contact the researcher(s) if you have any questions. If you have any questions, concerns, or complaints about the research and wish to talk to someone other than the individuals on the research team, or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at (405) 325-8110 or irb@ou.edu.

Please keep this information sheet for your records. By completing and returning this questionnaire, I am agreeing to participate in this study.

Revised 10/27/2006

Page 2 of 4

APPROVED
JAN 1 1 2010
OU NC IRB

APPROVAL
JAN 1 0 2011
EXPIRES

INFORMATION SHEET FOR CONSENT TO PARTICIPATE IN A RESEARCH STUDY

My name Randy Peppler, and I am a meteorologist in CIMMS at the University of Oklahoma. Along with School of Meteorology students Curtis McDonald and Kelsey Mulder, I am inviting you to participate in a research study titled Warning Decisions in Extreme Weather Events: Determining the Perception of Risks Associated with Flash Flooding in Boulder, Colorado. You were selected as a possible participant because you are currently a resident of Boulder, Colorado. Please read this information sheet and contact me to ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study: The purpose of this study is to study how Boulder residents understand flash flooding and its associated risks.

Procedures: If you agree to be in this study, you will be asked to complete a survey related to flash flooding and its associated risks. The survey will take approximately 45 minutes to complete.

Risks and Benefits of Being in the Study: There are no risks associated with this study. The benefits to participating include a greater understanding of how the public perceives and reacts to flash floods to evoke public understanding of science and risk assessment. The goal is to understand how people receive, comprehend, and react to flash flood hazards to determine better ways to provide information to these people. Their participation may influence how flash flood information is designed and communicated in the future, which subsequently may save lives.

Compensation: You will not be compensated for your participation.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not result in penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free not to answer any question or discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Length of Participation: The survey will take approximately 45 minutes to complete.

Confidentiality: The records of this study will be kept private and your supervisor will not have access to your responses. In published reports, there will be no information included that will make it possible to identify you as a research participant. Research records will be stored securely. Standard methods to protect privacy will be maintained. Participants will be anonymous, as their name wil not be associated with the data. Data will be securely stored in a locked office or on a computer or hard disks. Hard copies of data will remain in our possession locked in my office. All data will be destroyed (i.e., shredded or erased) when data analysis is complete. Only approved researchers will have access to the records.

Contacts and Questions: If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at Randy Peppler: (405) 325-6667 or rpeppler@ou.edu; Kelsey Mulder: (303) 875-2993 or kelsey.mulder@ou.edu; Curtis McDonald: (314) 606-4011 or curtism@ou.edu. In the event of a research-related injury, contact the researcher(s). You are encouraged to contact the researcher(s) if you have any questions. If you have any questions, concerns, or complaints about the research and wish to talk to someone other than the individuals on the research team, or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at (405) 325-8110 or irb@ou.edu.

Please keep this information sheet for your records. By completing and returning this questionnaire, I am agreeing to participate in this study.

Revised 3/5/2007

APPROVED
JAN 1 1 2010
OU NC IRB

APPROVAL
JAN 1 0 2011
EXPIRES

APPENDIX B: SURVEY RESULTS

1) For some hazards, the impact is minor (for example, minor injuries or illnesses). For other hazards, the most serious consequences are those that result in deaths. For each of the following hazards, if they occurred in the United States, how serious are the consequences? *Check the box of your answer for each hazard.*

Sub-question	Minor injuries or illnesses (1)	(2)	(3)	(4)	(5)	(6)	Mostly deaths (7)	n	Mean	Std Dev
Air pollution	34 (8.3%)	99 (24.8%)	97 (23.8%)	88 (22.0%)	58 (14.5%)	21 (5.3%)	3 (0.8%)	400	3.28	1.381
Global climate change	66 (16.8%)	78 (19.9%)	70 (17.9%)	67 (16.4%)	47 (12.0)	45 (11.5%)	19 (4.8%)	392	3.41	1.780
Earthquakes	3 (0.8%)	20 (5.1%)	44 (11.1%)	70 (17.7%)	105 (26.6%)	102 (25.8%)	51 (12.9%)	395	4.93	1.405
Lead paint	46 (11.8%)	78 (19.9%)	94 (24.0%)	72 (18.4%)	47 (12.0%)	40 (10.2%)	14 (3.6%)	391	3.44	1.625
Hurricanes	5 (1.3%)	18 (4.6%)	53 (13.6%)	86 (22.1%)	108 (27.7%)	88 (22.6%)	32 (8.2%)	390	4.71	1.363
Influenza	25 (6.3%)	80 (20.3%)	103 (26.1%)	93 (23.6%)	58 (14.7%)	17 (4.3%)	18 (4.6%)	394	3.51	1.464
Flash Flooding	6 (1.5%)	31 (7.8%)	77 (19.3%)	100 (25.1%)	80 (20.1%)	69 (17.3%)	35 (8.6%)	398	4.42	1.469

2) How much personal control do people in the United States have over the impacts on themselves from each of the following hazards? *Check the box of your answer for each hazard.*

Sub-question	Little Personal Control (1)	(2)	(3)	(4)	(5)	(6)	Much Personal Control (7)	n	Mean	Std Dev
Air pollution	82 (20.2%)	95 (23.5%)	76 (18.8%)	49 (12.1%)	58 (14.3%)	25 (6.2%)	20 (4.9%)	405	3.15	1.752
Global climate change	120 (29.6%)	106 (26.1%)	80 (19.7%)	40 (9.9%)	39 (9.6%)	12 (3.0%)	9 (2.2%)	406	2.62	1.551
Earthquakes	255 (62.5%)	68 (16.7%)	34 (8.4%)	23 (5.6%)	16 (3.9%)	4 (1.0%)	7 (1.7%)	407	1.81	1.359
Lead paint	17 (4.2%)	18 (4.5%)	30 (7.4%)	42 (10.4%)	70 (17.4%)	89 (22.1%)	137 (34.0%)	403	5.34	1.717
Hurricanes	175 (43.9%)	69 (17.3%)	46 (11.5%)	51 (12.8%)	29 (7.3%)	14 (3.5%)	15 (3.8%)	399	2.48	1.732
Influenza	24 (5.9%)	47 (11.6%)	84 (20.7%)	105 (25.9%)	82 (20.2%)	39 (9.6%)	24 (5.9%)	405	3.96	1.526
Flash Flooding	109 (26.8%)	69 (17.0%)	78 (19.2%)	55 (13.5%)	45 (11.1%)	33 (8.1%)	18 (4.4%)	400	5.95	1.343

3) How many people are exposed to these hazards in the United States? *Check the box of your answer for each hazard.*

Sub-question	Few are Exposed (1)	(2)	(3)	(4)	(5)	(6)	Almost all are exposed (7)	n	Mean	Std Dev
Air pollution	2 (0.5%)	8 (2.0%)	17 (4.3%)	33 (8.3%)	60 (15.0%	82 (20.5%)	198 (49.4%)	400	5.95	1.343
Global climate change	16 (4.1%)	12 (3.0%)	15 (3.8%)	15 (3.8%)	25 (6.3%)	45 (11.4%)	266 (67.5%)	394	6.10	1.653
Earthquakes	37 (9.4%)	116 (29.6%)	112 (28.6%)	78 (19.9%)	24 (6.1%)	15 (3.8%)	10 (2.6%)	392	3.05	1.368
Lead paint	50 (12.8%)	106 (27.1%)	98 (25.1%)	76 (19.4%)	28 (7.2%)	16 (4.1%)	17 (4.3%)	391	3.11	1.524
Hurricanes	14 (3.5%)	105 (26.6%)	157 (39.7%)	83 (20.3%)	20 (5.1%)	7 (1.8%)	9 (2.3%)	395	3.12	1.155
Influenza	2 (0.5%)	6 (1.5%)	24 (6.1%)	56 (14.2%)	65 (16.5%)	96 (24.4%)	144 (36.6%)	393	5.65	1.379
Flash Flooding	43 (10.8%)	95 (23.9%)	112 (28.1%)	82 (20.6%)	35 (8.8%)	15 (3.8%)	16 (4.0%)	398	3.20	1.475

4) In the diagram below, please put an "X" on the line the describes your best estimate of how likely it is that flash flooding will occur in Boulder in the next year.

n	# missing	Mean	Std Dev	Mode	Min	Max
396	12	17.79	19.949	10	0	90

5) In the diagram below, please put an "X" on the line that describes your best estimate of how likely it is that flash flooding will occur in Boulder in the next 30 years.

n	# missing	Mean	Std Dev	Mode	Min	Max
394	14	44.10	31.029	30	0	100

6) If a flash flood warning is issued for Boulder, please put an "X" on the line that describes your best estimate of how likely it is that flash flooding will occur in Boulder in the next 24 hours.

n	# missing	Mean	Std Dev	Mode	Min	Max
394	14	45.13	33.198	50	0	100

7) If a flash flood watch is issued for Boulder, please put an "X" on the line that describes your best estimate of how likely it is that flash flooding will occur in Boulder in the next 24 hours.

n	# missing	Mean	Std Dev	Mode	Min	Max
392	16	33.14	26.891	30	0	100

8) If a flash flood hit Boulder, how likely do you think each of the following impacts would be? *Check the box of your answer for each type of impact.*

Sub-question	Not at all likely (1)	Not very likely (2)	Somewhat likely (3)	Very likely (4)	Extremely likely (5)	Don't Know (6)	n	Mean	Std Dev
Damage to buildings or other property	1 (0.3%)	3 (0.8%)	53 (13.4%)	137 (34.6%)	201 (49.3%)	1 (0.3%)	396	4.36	0.761
People injured	1 (0.3%)	32 (8.2%)	133 (33.9%)	134 (34.2%)	90 (23.0%)	2 (0.5%)	392	3.73	0.932
People killed	15 (3.8%)	96 (24.5%0	161 (41.1%)	73 (18.6%)	41 (10.5%)	6 (1.5%)	392	3.12	1.062
People separated from loved ones or pets	6 (1.5%)	29 (7.4%)	107 (27.2%)	141 (35.9%)	109 (27.7%)	1 (0.3%)	393	3.82	0.980
Disrupted transportation	1 (0.3%)	7 (1.8%)	35 (8.9%)	121 (30.9%)	226 (57.7%)	2 (0.5%)	392	4.45	0.759
Economic losses or effects	1 (0.3%)	10 (2.5%)	31 (7.8%)	107 (27.1%)	242 (61.3%)	4 (1.0%)	395	4.50	0.782
Degraded water quality	3 (0.8%)	29 (7.4%)	69 (17.5%)	128 (32.5%)	147 (37.3%)	18 (4.6%)	394	4.12	1.040
Ecological damage	3 (0.8%)	11 (2.8%)	69 (17.5%)	126 (32.5%)	175 (44.4%)	10 2.5%)	394	4.24	0.919

9) If a flash flood hit Boulder and a person were in the following locations, how likely do you think they would be injured or killed? *Check the box of your answer for each type of location.*

Sub-question	Not at all likely (1)	Not very likely (2)	Somewhat likely (3)	Very likely (4)	Extremely likely (5)	Don't Know (6)	n	Mean	Std Dev
In a house	14 (3.6%)	142 (36.3%)	156 (39.9%)	49 (12.5%)	18 (4.6%)	12 (3.1%)	391	2.87	1.039
In a commercial building	33 (8.5%)	188 (48.3%)	117 (30.1%)	33 (8.5%)	7 (1.8%)	11 (2.8%)	389	2.55	1.018
In a car	2 (0.5%)	34 (8.7%)	164 (42.1%)	115 (29.5%)	63 (16.2%)	12 (3.1%)	390	3.61	0.976
Outside on foot or bicycle	4 (1.0%)	30 (7.9%)	124 (32.5%)	118 (32.5%)	94 (23.0%)	12 (3.1%)	382	3.80	1.032
Crossing a bridge or stream	1 (0.3%)	5 (1.3%)	54 (13.9%)	125 (32.1%)	194 (49.9%)	10 (2.6%)	389	4.38	0.821

10) If a person were injured or killed in a flash flood, how likely do you think it would be from each of the following causes? *Check the box of your answer for each cause.*

Sub-question	Not at all likely (1)	Not very likely (2)	Somewhat likely (3)	Very likely (4)	Extremely likely (5)	Don't Know (6)	n	Mean	Std Dev
Drowning	1 (0.3%)	10 (2.5%)	106 (26.9%)	162 (41.1%)	115 (29.2%)	0 (0.0%)	394	3.96	0.828
Being swept away by water	2 (2.0%)	8 (2.0%)	70 (17.7%)	159 (40.2%)	155 (39.1%)	0.5%)	396	4.17	0.829
Trauma from being hit by debris	2 (0.5%)	12 (3.0%)	84 (21.3%)	148 (37.6%)	148 (37.6%)	0 (0.0%)	394	4.09	0.866
Electrocution	9 (2.3%)	112 (28.4%)	149 (37.8%)	70 (17.8%)	38 (9.6%)	16 (4.1%)	394	3.16	1.132

11) The likelihood of flash flooding at a given location depends on several factors. How important do you think each of the following factors is in determining the likelihood of flash flooding at a given location? *Check the box of your answer for each factor.*

Sub-question	Not at all important (1)	Not very important (2)	Somewhat important (3)	Very important (4)	Extremely important (5)	Don't Know (6)	n	Mean	Std Dev
Elevation compared to stream or street level	3 (0.8%)	4 (1.0%)	27 (6.9%)	132 (33.6%)	226 (57.5%)	1 (0.3%)	393	4.47	0.739
Nearness to a creek, stream, or drainage ditch	2 (0.5%)	4 (1.0%)	30 (7.6%)	132 (33.4%)	226 (57.2%)	1 (0.3%)	395	4.47	0.727
Nearness to a lake, pond, or detention basin	5 (1.3%)	47 (12.1%)	144 (36.9%)	125 (32.1%)	64 (16.4%)	5 (1.3%)	390	3.54	0.987
Nearness to a dam	6 (1.5%)	43 (25.3%)	100 (25.3%)	100 (25.3%)	135 (33.1%)	11 (2.8%)	395	3.88	1.126
Nearness to a canyon	1 (0.3%)	7 (1.8%)	52 (13.3%)	115 (29.3%)	212 (54.1%)	5 (1.3%)	392	4.39	0.817
Amount of rainfall during last hour	4 (1.0%)	5 (1.3%)	47 (11.9%)	98 (24.9%)	235 (59.6%)	5 (1.3%)	394	4.45	0.843
Amount of rainfall during the last 24 hours	2 (0.5%)	2 (0.5%)	33 (8.4%)	131 (33.2%)	224 (56.9%)	2 (0.5%)	394	4.47	0.721
Burned land from past wildfires in area	6 (1.5%)	19 (4.8%)	97 (24.5%)	150 (37.9%)	115 (29.0%)	9 (2.3%)	396	3.95	0.977

12) How much do you agree or disagree with the following statement? "Only those on or near Boulder Creek are at risk from flash flooding in Boulder." *Check the box of your answer.*

Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)	Don't Know (6)	n	Mean	Std Dev
10 (2.5%)	65 (16.3%)	24 (6.0%)	139 (34.6%)	156 (38.8%)	8 (2.0%)	402	3.97	1.183

13) If you had damages or losses to your property or possessions due to a flash flood, how much of your losses would be covered by insurance? *Check the box of your answer.*

None (1)	Some (2)	About half (3)	Most (4)	Everything (5)	Don't know (6)	n	Mean	Std Dev
121 (30.5%)	56 (14.1%)	15 (3.8%)	69 (17.4%)	9 (2.3%)	127 (32.0%)	397	3.43	2.081

14) If you hear a flash flood warning and you are on the ground floor or below in a building, you should

n	# missing
392	16

15) If you hear a flash flood warning and you are driving, you should

n	# missing
393	15

16) If you hear a flash flood warning and you are outdoors walking, biking, recreating, or working, you should

n	# missing
392	16

17) The deepest amount of fast-flowing water that is safe to cross by foot is

n	# missing	Mean	Std Dev	Mode	Min	Max
364	44	8.07	7.892	12	0	42

18) The deepest amount of fast-flowing water that is safe to cross by automobile is

n	# missing	Mean	Std Dev	Mode	Min	Max
362	46	8.65	7.963	12	0	54

19) The following are statements some people tell us about not personally taking action in response to a flash flood warning. Please indicate the extent to which you agree or disagree with these statements. *Check the box indicating your level of agreement for each statement.*

Sub-question	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)	Don't Know (6)	n	Mean	Std Dev
I believe I am safe from flash flooding	29 (7.3%)	139 (35.1%)	72 (18.2%)	78 (19.7%)	73 (18.4%)	5 (1.3%)	396	3.11	1.298
I don't know what I am supposed to do	34 (8.6%)	101 (25.4%)	50 (12.6%)	118 (29.7%)	93 (23.4%)	1 (0.3%)	397	3.35	1.318
I have young or elderly family members that make it difficult to take action	16 (4.1%)	55 (14.0%)	55 (14.0%)	58 (14.8%)	204 (51.9%)	5 (1.3%)	393	4.00	1.281
I don't trust flash flood warnings enough to be willing to respond	6 (1.5%)	51 (13.0%)	54 (13.7%)	102 (26.0%)	173 (44.0%)	7 (1.8%)	393	4.03	1.143
I don't want to get wet	25 (6.4%)	29 (7.4%)	55 (14.0%)	41 (10.4%)	238 (60.6%)	5 (1.3%)	393	4.15	1.283
I don't have transportation to take action	14 (3.5%)	21 (5.3%)	42 (10.6%)	60 (15.2%)	252 (63.6%)	7 (1.8%)	396	4.35	1.105
I don't want to leave my home or business unprotected	21 (5.3%)	73 (18.5%)	49 (12.0%)	75 (19.0%)	174 (44.2%)	2 (0.5%)	394	3.80	1.331
I am not in good enough health to take action	17 (4.3%)	29 (7.3%)	26 (6.5%)	52 (13.0%)	271 (67.9%)	4 (1.0%)	399	4.36	1.154
I have a family member with a health issue or disability and that makes it difficult to take action	12 (3.0%)	48 (12.2%)	40 (10.1%)	39 (9.9%)	250 (63.3%)	6 (1.5%)	395	4.36	1.154
I have a pet or pets and that makes it difficult to take action	24 (6.1%)	65 (16.5%)	38 (8.6%)	54 (13.7%)	209 (53.0%)	4 (1.0%)	394	3.94	1.370

20) How useful to you is the following information that may be provided in a flash flood forecast or warning? *Check the box of your answer for each type of information.*

Sub-question	Not at all useful (1)	Not very useful (2)	Somewhat useful (3)	Very useful (4)	Extremely useful (5)	Don't know (6)	n	Mean	Std Dev
Where flooding is expected	2 (0.5%)	2 (0.5%)	7 (1.8%)	73 (18.3%)	315 (77.2%)	1 (0.3%)	400	4.75	0.564
When flooding is expected	2 (0.5%)	1 (0.3%)	8 (2.0%)	81 (20.3%)	307 (76.8%)	1 (0.3%)	400	4.73	0.563
Depth of expected flooding	3 (0.8%)	12 (3.0%)	62 (15.6%)	103 (25.9%)	214 (53.9%)	3 (0.8%)	397	4.31	0.904
What impacts the flooding is expected to cause	4 (1.0%)	17 (4.3%)	76 (19.0%)	120 (30.1%)	180 (45.1%)	2 (0.5%)	399	4.16	0.949
Information about what to do to protect myself and others	2 (0.5%)	7 (1.8%)	24 (6.0%)	74 (18.5%)	292 (73.0%)	1 (0.3%)	400	4.63	0.725

21) In your opinion, how accurate are flash flood forecasts and warnings in general at this time? *Check the box of your answer.*

Not at all accurate (1)	Not very accurate (2)	Somewhat accurate (3)	Very accurate (4)	Extremely Accurate (5)	Don't know (6)	n	Mean	Std Dev
1 (0.3%)	37 (9.4%)	144 (36.7%)	71 (18.1%)	7 (1.8%)	132 (33.7%)	392	4.13	1.457

22) In your opinion, how important is it to improve the accuracy of flash flood forecasts and warnings? *Check the box of your answer.*

Not at all important (1)	Not very important (2)	Somewhat important (3)	Very important (4)	Extremely important (5)	Don't know (6)	n	Mean	Std Dev
2 (0.5%)	6 (1.5%)	56 (14.3%)	178 (45.4%)	115 (29.3%)	35 (8.9%)	392	4.28	0.907

23) How much do you, or would you, trust flash flood forecasts and warnings? *Check the box of your answer.*

I don't trust them at all (1)	I do not trust them very much (2)	I trust them somewhat (3)	I trust them very much (4)	I trust them completely (5)	Don't know (6)	n	Mean	Std Dev
0 (0.0%)	17 (4.3%)	142 (36.1%)	174 (44.3%)	41 (10.4%)	19 (4.7%)	393	3.75	0.879

24) How likely is it that you would take protective action if you were to receive the following flash flood notifications for your location? *Check the box of your answer for each type of notification.*

Sub-question	Not at all likely (1)	Not very likely (2)	Somewhat likely (3)	Very likely (4)	Extremely likely (5)	n	Mean	Std Dev
Flash Flood Warning	8 (2.1%)	24 (6.2%)	70 (18.1%)	135 (35.0%)	149 (38.6%)	386	4.02	1.002
Flash Flood Watch	21 (5.5%)	59 (15.4%)	137 (35.9%)	104 (27.2%)	61 (16.0%)	382	3.33	1.087

25) What differences, if any, are there between a flash flood warning and a flash flood watch?

n	# missing
374	34

26) How would you define "100-year flood"?

n	# missing
366	42

Say it was 9:30PM, you were in Boulder, and you received the following message:

THE NATIONAL WEATHER SERVICE IN DENVER HAS ISSUED A

* FLASH FLOOD WARNING FOR...
CENTRAL AND EAST BOULDER COUNTY IN NORTHEAST COLORADO

* UNTIL 1145 PM MDT

* AT 927 PM MDT...NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATED VERY HEAVY RAIN FROM A THUNDERSTORM IN THE WESTERN PART OF BOULDER. THIS STORM WAS MOVING EAST AT 5 MPH.

* LOCATIONS IN THE WARNING INCLUDE BUT ARE NOT LIMITED TO BOULDER.

THIS INCLUDES THE FOLLOWING STREAMS AND DRAINAGES... BOULDER CREEK, SKUNK CREEK, BEAR CREEK, GOOSE CREEK, AND FOURMILE CANYON CREEK.

DOPPLER RADAR ESTIMATES THAT RAIN FROM THE STORM IS FALLING AT THE RATE OF 2 TO 3 INCHES IN 45 MINUTES. ANOTHER 1 TO 2 INCHES OF RAIN CAN BE EXPECTED BEFORE DIMINISHING.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

A FLASH FLOOD WARNING MEANS THAT FLOODING IS IMMINENT OR OCCURRING. IF YOU ARE IN THE WARNING AREA MOVE TO HIGHER GROUND IMMEDIATELY. RESIDENTS LIVING ALONG STREAMS AND CREEKS SHOULD TAKE IMMEDIATE PRECAUTIONS TO PROTECT LIFE AND PROPERTY. DO NOT ATTEMPT TO CROSS SWIFTLY FLOWING WATERS OR WATERS OF UNKNOWN DEPTH BY FOOT OR BY AUTOMOBILE. TURN AROUND...DO NOT DROWN.

27) Again, if it was 9:30PM and you were in Boulder, what would you do?

n	# missing
372	36

28) What would you tell your neighbor the warning above said if you did not have the warning in hand?

n	# missing
386	22

ABOUT YOU AND YOUR HOUSEHOLD

H1) What previous experience, if any, do you have with flash flooding?

n	# missing
366	42

H2) Which of the following, if any, have you done to prepare for a flash flood event? *Check the box of your answer.*

Sub-Question	No (0)	Yes (1)	n	Mean	Std Dev
Planned an evacuation route	290 (77.1%)	86 (22.9%)	376	0.23	0.421
Packed an emergency kit	323 (85.7%)	54 (14.3%)	377	0.14	0.351
Made plans with family members who live within your residence	324 (85.9%)	53 (14.1%)	377	0.14	0.348
Made plans with family or friends who do not live in your residence	354 (93.7%)	24 (6.3%)	378	0.06	0.244
Made changes to my home or property to protect it from flash floods	340 (89.9%)	38 (9.3%)	378	0.10	0.301

H3) What is your age? _____ years

n	Mean	Std Dev	Min	Max
379	50.98	16.890	19	94

H4) What is your gender? *Check the box of your answer.*

Male	Female	n
220 (53.9%)	162 (42.4%)	382

H5) Which of the following best describes the place you live (your residence)? *Check the box of your answer.*

House (1)	Apartment or Townhouse (2)	Mobile Home (3)	Other (4)	n
285 (73.5%)	92 (23.7%)	2 (0.5%)	9 (2.3%)	388

H6) Do you rent or own your residence? *Check the box of your answer.*

Own	Rent	n
301 (78.0%)	85 (22.0%)	386

H7) Do you have homeowners or renters insurance? *Check the box of your answer.*

No (1)	Yes (2)	Don't know (3)	n
333 (86.0%)	49 (12.7%)	5 (1.3%)	387

H8) Do you have flood insurance? *Check the box of your answer.*

No (0)	Yes (1)	Don't know (9)	n
241 (62.9%)	47 (12.3%)	95 (24.8%)	383

H9) Is your residence in a designated 100-year or 500-year floodplain? *Check the box of your answer.*

100-year floodplain (1)	500-year floodplain (2)	Neither floodplain (3)	Don't know (4)	Other (5)	n
48 (12.6%)	26 (6.8%)	161 (42.1%)	137 (35.9%)	10 (2.6%)	382

H10) Please tell us whether you work, study, or live in Boulder or are visiting from outside Boulder. *Check the box of your answer for each question.*

Sub-question	No (0)	Yes (1)	n
Student at the University of Colorado	327 (93.4%)	23 (6.6%)	350
Work in Boulder	150 (36.8%)	217 (59.1%)	367

If resident, how long have you lived in Boulder? _____ (years)

n	Mean	Std Dev	Min	Max
351	21.01	15.031	1	70

H11) What is your home zip code? __________

n	# missing
399	9

H12) Which of the following best describes the highest level of education you have completed? *Check the box of your answer.*

Did not complete high school (1)	High school diploma or equivalent (2)	Some college, 2-year college degree or technical school (3)	4-year college degree (4)	Master's degree (5)	Professional degree or doctorate (6)	n
1 (0.2%)	16 (4.0%)	49 (12.2%)	155 (38.6%)	116 (28.9%)	65 (16.2%)	402

H13) How many people are there in your household, including yourself? __________

n	Mean	Std Dev	Min	Max
391	2.36	1.191	1	8

H14) What is your present employment status? *Select all that apply to you.*

Employed full time (1)	Employed part time (2)	Retired (3)	Homemaker (4)	Student (5)	Unemployed (6)	n
217 (54.0%)	51 (12.7%)	95 (23.6%)	15 (3.7%)	13 (3.2%)	11 (2.7%)	402

H15) Which of the following best describes your race? *Select all that apply to you.*

Sub-question		n
White	356 (92.0%)	387
Black or African American	3 (0.8%)	387
American Indian or Alaska Native	2 (0.5%)	387
Asian	14 (3.6%)	387
Native Hawaiian or other Pacific Islander	0 (0.0%)	387
Other	12 (3.1%)	387

H16) What is your primary language?

n	# missing
378	30

H17) What was your total household income for 2008 before taxes? *Check the box of your answer.*

Under $15,000 (1)	$15,000 to $29,999 (2)	$30,000 to $44,999 (3)	$45,000 to $59,999 (4)	$60,000 to $74,999 (5)	$75,000 to $99,999 (6)	$100,000 to $124,999 (7)	$125,000 to $149,999 (8)	$150,000 to $199,999 (9)	$200,000 or more (10)	n	Mean	Std Dev
26 (7.7%)	38 (11.2%)	37 (10.9%)	33 (9.8%)	32 (9.5%)	49 (14.5%)	34 (10.1%)	27 (8.0%)	23 (6.8%)	39 (11.5%)	338	2.50	0.999