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PERCEPTIONS AND VISUAL AWARENESS OF URBAN KARST FLOODING TO INFORM PREPAREDNESS PLANNING AND MANAGEMENT ACTIONS

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ABSTRACT

PERCEPTIONS AND VISUAL AWARENESS OF KARST FLOODING IN URBAN AREAS TO INFORM PREPAREDNESS PLANNING AND MANAGEMENT ACTIONS

Awareness and perception of flooding can heavily affect how an individual or community prepares for flooding. Flood awareness can be affected by factors like past flood experience and demographics. Flood experience and demographics can affect flood awareness differently based on factors including the types and cause of flooding. Flooding in karst landscapes can vary from other types of flooding and neither perception nor awareness of karst flooding has been directly studied before. This study explored both expert and non-expert flood awareness and perception and flood policies in a karst landscape through interviews with experts, surveys, and cognitive mapping activities. The purpose is to increase the understanding of flood awareness in karst environments. Warren County, Kentucky was used as a case study, because it is a developed karst landscape with frequent flooding issues. The survey responses indicated that low to medium level flood awareness exists in Warren County, though few participants made connections between the karst landscape and flooding. Flood experience, race, gender, age, and ownership status were not found to be statistically significantly connected to flood awareness. About a quarter of respondents were aware of flood policies and less than half felt the flood policies were effective. Recommendations included karst flood education, flood policy education, citizen engagement in flood monitoring, and more frequent flood policy updates.

Keywords: Flood Awareness, Karst Flooding, Flood Perceptions, Warren County, Flood Risk

I dedicate this thesis to the support and love of my parents and siblings and to the encouragement of my friends. This project would not have been completed without you.

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Chapter 1: Introduction

Flooding affects millions of people and causes billions of dollars in damage globally every year (Centre for Research on the Epidemiology of Disasters 2022). Even if a flood does not cause major damage, it can still heavily affect people's daily life and routines (WHO 2019; Hemmati et al. 2020; FEMA nda). Urbanization can worsen the effects of flooding as it alters the land and hydrology, potentially increasing the extent and depth of floods (Wells et al. 2016; Mashi et al. 2020; Hemmati et al. 2020; Hemmati et al. 2021a; Hemmati et al. 2021b; Hemmati et al. 2022). Flooding may become more widespread in the future as the world continues urbanizing and as climate change potentially increases the risk of flooding (Hemmati et al. 2022). The potential for more widespread flooding makes it important to understand society's flood awareness and perception.

Flood awareness and perception studies focus mainly on riverine and flash flooding in surface catchments, with less attention focused on flood awareness in karst areas (Fanta et al. 2019; Maryati et al. 2019; Mashi et al. 2020; Ferreira et al. 2021; Ge et al. 2021; Oubennaceur et al. 2022; Bhatti et al. 2023). Karst flooding often involves flooding through sinkholes and springs, rather than from surface streams, since most water flows underground in karst landscapes (Zhou 2007). The type of flooding may influence the public's flood awareness (Hopkins and Warburton 2015), which necessitates understanding the awareness of flooding in karst areas.

Warren County, Kentucky is one karst landscape prone to flooding. Flooding is one of Kentucky's most frequent disasters (Kentucky Energy and Environmental Cabinet 2022), with Warren County, where Bowling Green (BG) is located, having a 400% chance of a flood annually (BRADD 2021). Warren County is developed on a karst landscape with a large number

of karst-related features, as well as a limited number of surface streams (Zhou 2007; Nedvidek 2014; City County Planning Commission 2019a). Recent research found that flood prone areas are strongly associated with known and potential sinkholes in BG and Warren County (Cooper 2022), which makes it pertinent to add to the understanding of how flooding is viewed by individuals living throughout Warren County and similar karst areas.

This research aimed to explore flood perception and awareness in Warren County using questionnaires, interviews, and a cognitive mapping activity to better understand both the interactions between the causes, perception, and awareness of factors related to karst flooding and its mitigation and management. These data were used to identify where gaps in flood awareness are located and to help inform future management and policy practices for flood mitigation in karst areas using a data-driven approach.

Research Questions

This research aims to explore the following questions:

- What are the community perceptions and awareness of flooding in the urban karst area of Warren County?
    - What is the relationship between awareness of flooding and karst features in Warren County?
    - What are the factors that influence awareness of flooding in karst environments and how do these factors influence flood awareness in Warren County?
- Does current policy and regulation adequately address perceived flood risk and vulnerability in the urban karst area of Warren County?

Chapter 2: Literature Review

2.1 Flooding

There are many definitions of flooding; for the purposes of this study, flooding is "a temporary overflow of water onto land that is normally dry. It is the most common natural disaster in the U.S." (FEMA 2018). Flooding is a common disaster across the world, causing an extensive amount of damage and disruption to communities (Marfai et al. 2014; Mashi et al. 2020; Hemmati et al. 2021b; Chan et al. 2022; Cooper 2022). On average, from 2001-2020, flooding annually caused over 5,000 deaths globally, affected 82.7 million people globally, and caused U.S. $34.1 billion in economic damages (Centre for Research on the Epidemiology of Disasters 2022). The most well-known effect of flooding is the risk of physical injury or death, especially the risk of drowning, as well as mental health effects resulting from the emergency situation flooding can create (WHO 2019; FEMA n.d.). Flooding can damage and pollute essential infrastructure, such as the water and food supply, along with contribute to disease outbreaks from polluted water (WHO 2019; FEMA n.d.). Flooding can disrupt communities by damaging homes and roads, affecting access to goods and services including health services, disrupting transportation and supply chains, and causing economic losses (WHO 2019; Hemmati et al. 2020; FEMA n.d.). Landslides and mudslides can be caused by flooding, creating a secondary disaster connected to the original flooding event (FEMA n.d.).

Coastal flooding, riverine flooding, and flash flooding are three main flood types typically researched (Centre for Research on the Epidemiology of Disasters 2009). In 2021, out of the 432 major disasters related to natural hazards that occurred, 223 of these events were related to flooding (Centre for Research on the Epidemiology of Disasters 2022). Around 52% of major natural hazard related disasters were major floods, with the typical proportion of major

natural hazards being major floods annually being around 46% (Centre for Research on the Epidemiology of Disasters 2022).

2.1.1 Flooding and Climate Change

Flooding is the result of interactions between climate, hydrology, and human management, meaning changes in any of the three can have profound effects on flooding in a given area (IPCC 2021). Flooding is affected by climate change, which intensifies the consequences and frequency of flood events (Hemmati et al. 2021b; Hemmati et al. 2022). The effect of flooding is intensified partially because climate change potentially increases the risk of extreme rainfall and slow-moving weather systems, meaning a likely increase in both the number of extreme rainfall and long-duration flood events (O'Donnell and Thorne 2020; IPCC 2021; Hemmati et al. 2022).

2.1.2 Urban Flooding

Flooding is affected by urbanization (Wells et al. 2016; Mashi et al. 2020; Hemmati et al. 2021b; Hemmati et al. 2022). Urban flooding tends to occur when precipitation exceeds the capacity of drainage systems, whether natural or artificial (IPCC 2021). Flood depths and extents are dependent on variables, such as topography, geology, land use, and intensity and duration of precipitation with an increase in impervious surfaces associated with urban areas especially increasing the risk of flooding (Wells et al. 2016; Hemmati et al. 2020; Mashi et al. 2020; O'Donnell and Thorne 2020).

Urbanization increases flood risk by increasing the number of people in the area; this has often been the result of population and economic growth in flood-prone areas, as these areas are often close to recreational areas and fertile agricultural lands, making them attractive for urbanization and therefore often densely populated (Balica and Wright 2010; Nasiri and

Shahmohammadi-Kalalagh 2013; Hemmati et al. 2020). The higher the human population and infrastructure present in flood-prone areas, the larger the increase in severe flood damage and flood losses as more is present to be damaged in floods (Hemmati et al. 2020). Overall, the extent of urban areas in regions of flood risk are increasing as is the frequency of flooding in these urban areas (Hemmati et al. 2021a; Hemmati et al. 2021b; Hemmati et al. 2022).

2.1.3 Karst Flooding

For the purposes of this study, karst is defined as a landscape characterized by the presence of caves, springs, sinkholes, sinking streams, etc and consists of water mainly moving underground (Kemmerly 1981; Ford and Williams 2007; Zhou 2007). Flooding is a common and frequently underestimated karst hazard affecting the approximately 20% of the world's population that lives in or near karst regions (de Waele et al. 2011; He et al. 2021). The interconnectedness of flooding instances and karst environments is not always considered, since karst flooding often occurs during rain events that can lead to surface waters in the area flooding (Kentucky Geological Service 2021). When surface waters flood, people often do not consider the potential effect of karst processes on the flooding.

Karst flooding is categorized in myriad ways, with general agreement in the main types of karst flooding: 1) recharge-related sinkhole flooding, where more water enters a sinkhole's system than it is capable of holding; 2) flow-related flooding, where more water is entering a part of the karst system than can actually flow through that part of the system at that time; and 3) discharge-related flooding, where the amount of water leaving the karst system is reduced (Bonacci et al. 2006; Zhou 2007; Gutiérrez 2011; Gutiérrez et al. 2014; Kentucky Geological Service 2021). Figure 2.1 displays diagrams showing primary types of karst flooding. Karst flooding requires an understanding of the relationship between surface water and groundwater; a

relationship that is not always entirely understood (Gutiérrez et al. 2014; Naughton et al. 2017; Kentucky Geological Service 2021). The relationship between surface and groundwater differs from location to location, with features within the same karst areas potentially having different relationships between the surface water and groundwater leading to different processes for karst flooding between location (Gutiérrez et al. 2014; Naughton et al. 2017; Kentucky Geological Service 2021).

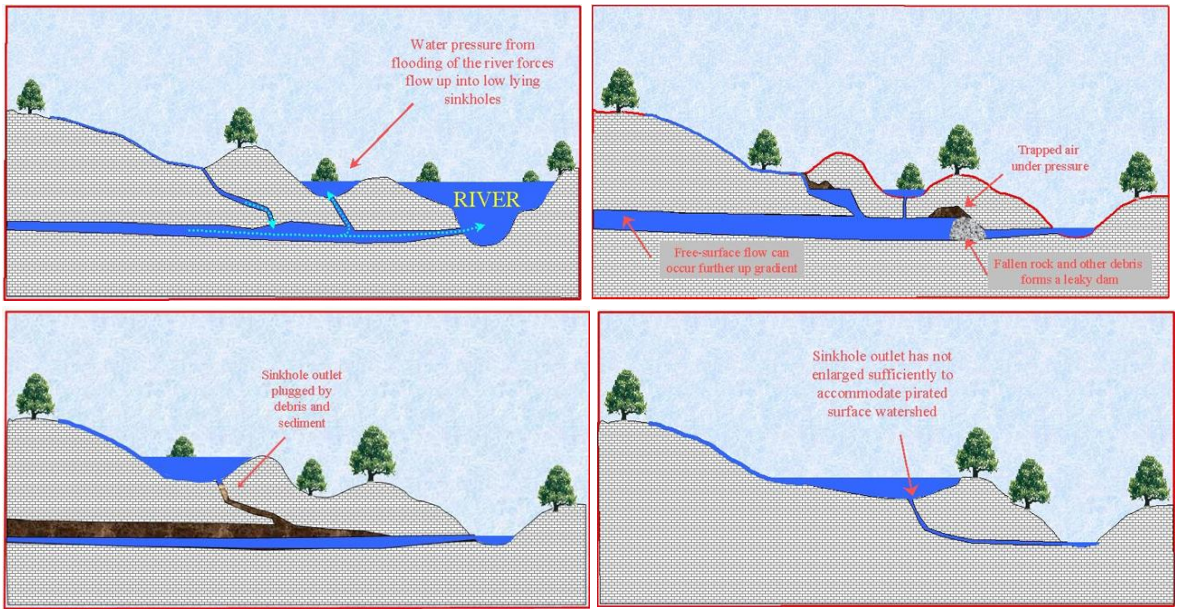

Figure 2.1. Types of Karst Flooding (Source: Currens 2021).

Flooding in karst areas often occurs through sinkholes, though flooding from either existing or intermittent springs are common as well (Kemmerly 1981; Zhou 2007; Gutiérrez et al. 2014; Nedvidek 2014; Naughton et al. 2017; Kentucky Geological Service 2021). Karst flooding may occur at long recurrence intervals, meaning areas can be dry for extended periods of time before an extreme weather event or change in hydrogeology causes the area to flood (Naughton et al. 2017). Karst flooding can be particularly challenging as the karst system can allow for flooding to occur downstream or upstream from where the precipitation occurred, meaning areas can receive no precipitation and still experience flooding, because other areas

within the karst drainage system experienced precipitation (Troxell 2021). Karst flooding is also challenging as the connection to sinkhole flooding means that karst flooding can be discontinuous with areas of flooding separated by dry areas. (Naughton et al. 2017). Sinkhole floodplains differ from river floodplains, because river floods crest and then return to baselevels, while sinkholes collect and store runoff until water evaporates into the atmosphere or drains into the subsurface (Kemmerly 1981). With river floodplains, the flood threat is often readily visible while with karst floodplains, the threat remains under the ground until flooding occurs, leaving individuals unprepared for flooding.

2.1.4 Humans Effects on Karst Flooding

Flooding in karst areas can be heavily affected by human actions (Zhou 2007; Kovacic et al. 2010; de Waele et al. 2011). Actions affecting karst flooding include increased erosion, plugged sinkholes, and increased runoff (Ford and Williams 2007; Zhou 2007). Humans can also affect flooding in karst areas by reducing the amount of area water can infiltrate into the karst system, increasing the amount of water in a sinkhole, potentially above what the sinkhole is capable of holding (Zhou 2007; Gutiérrez et al. 2014).

Kentucky Geological Survey (2021) determined that annually the average loss from flood damage in karst areas in Kentucky exceeds $1 million; yet, individuals do not always understand how human actions on the surface affect the subsurface, and how these effects can increase the risk of flooding (Gutiérrez et al. 2014; Naughton et al. 2017). The lack of surface water, and the lack of a perceived risk of flooding due to its absence, can lead communities to unknowingly build in areas affected by chronic flooding, especially sinkhole flooding, thereby increasing the cost of flood damage in Kentucky (Kemmerly 1981).

2.1.5 Community Response to Flooding

Understanding how to manage flooding is important, especially with a projected increase in the frequency of future flooding events. Knowing why flooding occurs and how urbanization affects flooding can help improve flood management. Additionally, Mashi et al. (2020) found the culture of the community can affect how the community is planned and built, the government can determine what flood mitigation and adaptation measures are undertaken, and the economic status can affect whether communities and individuals can undertake mitigation or adaptation measures; all of these factors influence how flooding is managed in a community. Communities are often not heterogenous groups and, instead, are made up of diverse groups that differ in how they view risks such as floods and how they react to different perceptions of risks (Andráško 2021).

Studies on flood awareness exist across the world but are mainly concentrated in Europe (Grothmann and Reusswig 2006; Siegrist and Gutscher 2006; Terpstra et al. 2006; Terpstra et al. 2009; O'Sullivan et al. 2012; Mullins and Soetanto 2013; Hopkins and Warburton 2015; Strathie et al. 2015; Fanta et al. 2019; Lemée et al. 2019; Vasileva and Georgiev 2022). Many of these European studies provide the foundations for the evolution of flood perception studies, especially Grothmann and Reusswig (2006), Terpstra et al. (2006), and Terpstra et al. (2009). Now, there is a growing effort to complete flood perception studies outside of these European countries (Bubeck et al. 2012; Franklin et al. 2014; Pitpreecha et al. 2016; Wells et al. 2016; Chowdhooree et al. 2018; Maryati et al. 2019; Mashi et al. 2020; Oubennaceur et al. 2021; Pitidis et al. 2022).

Communities perceive increased flooding in the future (Hopkins and Warburton 2015; Wells et al. 2016), though this is specific to surface flooding as this flood type is often explored in flood perception studies. A lack of studies focusing on non-surface water flooding, like that

which often occurs in karst areas, leaves a gap in understanding how people perceive karst flooding. Factors such as flood experience, home ownership, and ages have been found to increase flood risk perceptions (Grothmann and Reusswig 2006: Siegrist and Gutscher 2006; Kellens et al. 2013; Vasileva and Georgiev 2022). Understanding flood risk, though, may not lead to flood mitigation and protection actions due to social, economic, and cultural factors (Bubeck et al. 2012; Franklin et al. 2014; Maryati et al. 2019; Mashi et al. 2020). The government is responsible for flood mitigation measures rather than individuals is a prevalent idea connected to the lack of flood protection actions taken by those who understand their flood risk (O'Sullivan et al. 2012; Maryati et al. 2019), though the authorities are not always perceived to inform communities about their flood risk (Terpstra et al. 2006). Understanding differences between what the general population and authorities perceive about flood risk is valuable for determining if any disconnect is occurring between community flood risk perception and authority flood risk perception.

2.1.6 Flood Policy

Flood policies are a way communities respond to flooding threats with the goal of making communities safer using past experiences. For example, the Disaster Mitigation Act of 2000 (DMA2K) requires public participation in creating disaster and hazard plans (Olonilua 2022). DMA2K has not been found to be as effective as intended, and Federal Emergency Management Agency (FEMA) has not yet published regulations and policies to provide incentives to reduce damage to infrastructure, nor implemented several aspects of the act (OIG 2021). While the DMA2K was passed in 2000, parts of the act, such as the need for public participation have been implemented, with other aspects not being executed due to other agency priorities.

The National Flood Insurance Policy (NFIP), managed by FEMA, was created by Congress in 1968, with updates in 1973, 1994, 2004, 2012, and 2014 (FEMA 2021; FEMA 2022; KAMM 2022). The NFIP is intended to provide flood insurance policies to those who live or own businesses in communities covered by the NFIP by requiring flood insurance on properties holding a mortgage within the 100-year floodplain (Zinda et al. 2021; FEMA 2022; KAMM 2022). NFIP is based on the 100-year floodplain and provides minimum floodplain management regulations while allowing states, cities, and territories to implement further policies as needed, though issues often arise through the complexity in delineating the 100-year floodplain as well as how the extent of 100-year floodplains can change faster than the maps are updated (Patterson and Doyle 2009). All communities who participate in the NFIP are required to create and enforce floodplain management ordinances that at least meet FEMA requirements (FEMA 2021; KAMM 2022). There have been concerns about NFIP's long-term sustainability as the price of claims has exceeded the amount paid by insurance holders (Gourevitch and Pinter 2022). To help solve this issue, a NFIP program, the Community Rating System (CRS), which was established in 1990, aimed to encourage communities to participate in floodplain mitigation efforts by providing incentives for voluntary participation (Berke et al. 2014). Gourevitch and Pinter (2022) found that CRS participation is connected to fewer flood damage claims, which is assumed to mean less flood damage, but also cautions that improvements in which actions gain incentives may need to be revised to ensure more effective mitigation efforts.

While Olonilua (2022) argues there is often a low interest in public participation in forming hazard mitigation policies of all kinds, partially because of the lack of focus on local concerns, Chowdhooree (2018) argues that before flood policies are created, community knowledge about flooding must be fully understood; this means community participation needs

to be enhanced. Engaging the community in flood and hazard mitigation policy creation can be done through surveys, public meetings, websites with information and comment areas, hazard brochures, and hazard maps displayed for community comment (Olonilua 2022).

One of the many benefits of community participation in flood and hazard policy development is communities often better understand areas of risk in their community (Chowdhooree et al. 2018; Olonilua 2022; Pitidis et al. 2022). Community members may also have new ideas of solutions to flood-related issues and may help develop targeted policies to address flooding issues in specific areas rather than broader and more general policies that may not have a large effect (Chowdhooree et al. 2018; Olonilua 2022). On the other hand, for those who may not have a high awareness of flooding in their community, assisting in creating flood policies is an opportunity to increase their knowledge about their flood risk (Tyler et al. 2019). Relating to these flood policies, communities can create and provide data before, during, and after flooding events to help design, implement, and evaluate flood policies and their effects (Pitidis et al. 2022). Overall, involving a community in flood policy planning allows for communities to provide their understanding of flooding to create policies that can reduce the risk of flooding (Pitidis et al. 2022) while further allowing the public and flood managers to build trust in the event of a flood (Tyler et al. 2019) and establishing the base of knowledge the community holds that can later be built upon (Knocke and Kolivras 2007). Participating in flood policy creation, especially in the early steps can increase the likelihood of implementing provided recommendation or actions (Paul and Millman 2017; Olonilua 2022).

Floods are typically managed by structural measures including dams, levees, and floodwalls among infrastructural efforts and nonstructural measures including public policies, buyouts, zoning, and other incentives focusing on behavior change rather than building

infrastructure (Hemmati et al. 2021a; Hemmati et al. 2021b; Hemmati et al. 2022). Mashi et al. (2020) found that for communities to manage floods, especially on an individual level, support is needed, usually from governments, and the community must have an awareness of their flood risk to ensure they see the necessity of taking proactive flood mitigation and adaptation measure. Individuals who rely on the efficacy of public flood protection measures often take fewer personal precautionary actions due to underestimating the risk of flooding or ability for structural measures to mitigate flood effects (Grothmann and Reusswig 2006; Andráško 2021). Flood mitigation measures can increase or decrease public perception of flood risk to a degree that the community underestimates the community's risk of flooding because of how they view the measure used to respond to previous floods.

2.2 Flood Awareness

Since the 1960s, studies have acknowledged how community perceptions of the environment and its effect on well-being and safety, specifically in regard to hazards perception, provides a valuable new theme in human geography (Bunting and Guelke 1979). Specifically, the relationship between aspects of the environment and individuals is determined by personal experience and knowledge, and this relationship affects individuals' behavior toward aspects of the environment (Brawn et al. 1980; Marques et al. 2020). People and their environment share a reciprocal relationship, where the environment affects people and people influence the environment (Brawn et al. 1980; Marques et al. 2020), which is evident in cases of severe events, like sinkhole flooding.

The term flood awareness has ambiguity in its use in research; in the context of this research, flood awareness refers to an individual's knowledge about flooding and the flood risk in their community (Franklin et al. 2014; Hopkins and Warburton 2015; Lemée et al. 2019;

Mashi et al. 2020; Vasileva and Georgiev 2022). Because of the localized nature of flooding, understanding flood awareness needs to be completed at smaller, community-level scales, especially as flood awareness can vary widely across communities leading to differing abilities to cope with floods between these areas (Mullins and Soetanto 2013; Hemmati et al. 2022). People who directly experience flooding tend to be more aware of their flood risk and have a higher flood risk perception (Weinstein 1989; Raška 2015; Lechowska 2018; Harlan et al. 2019; Kellens et al. 2013; Fanta et al. 2019; Maryati et al. 2019; Mashi et al. 2020; Ferreira et al. 2021; Ge et al. 2021; Oubennaceur et al. 2022; Bhatti et al. 2023). Hopkins and Warburton (2015), though, found that being directly affected by a flash flood can be associated with lowered flood risk perceptions; this contradiction may result from different types of flooding being explored, with many studies including Fanta et al. (2019), Maryati et al. (2019), and Mashi et al. (2020) focusing on river flooding, while Hopkins and Warburton (2015) focused on a flash flood event. Experiences of past flooding events can cause individuals to take flood protective measures, though flood experience is not necessary for flood protective measures (Grothmann and Reusswig 2006), and not all of those affected by floods will take action to mitigate problems from a potential future flood (Andráško 2021). Both flood awareness and flood protective measures have a complex relationship with flood experience as various studies find flood experience increasing, decreasing, or not affecting flood awareness or flood mitigation actions.

Flood awareness is also influenced by those who may not be directly affected by flooding but remember flooding events (Siegrist and Gutscher 2006; Hopkins and Warburton 2015; Fanta et al. 2019). Fanta et al. (2019) argue that the flood awareness and flood memory depend on having eyewitnesses who experienced a flooding event, especially a major flooding event, present within the community and, without these individuals who can ensure the memory of the

flood is present in the community, the community's awareness of flooding potential lessens. Similarly, local flooding knowledge, carried by those who experienced flooding or those who are aware of previous flooding events, including local flooding knowledge of flood frequency, can have a large effect on how flooding is perceived in a community (Hopkins and Warburton 2015). Siegrist and Gutscher (2006) also found greater perceptions of flood risks among individuals who could remember flood events than among people who could not recall them.

The way the public perceives risk and how professionals perceive risk often differs as the public typically emphasizes experiences and feelings in determining how they perceive flood risk, while professionals often emphasize the use of the risk equation (Terpstra et al. 2006; Lemée et al. 2019; Mashi et al. 2020):

$$\text{Risk} = \text{Hazard} * \text{Vulnerability} * \text{Exposure}$$

To understand flood awareness in a community, how flooding is perceived by the public must be understood (Hopkins and Warburton 2015; Mashi et al. 2020). Understanding how communities perceive flooding will allow relevant authorities to understand what aspects of flooding are perceived as high risk (Bubeck et al. 2012; Hopkins and Warbuton 2015; Mashi et al. 2020; Hemmati et al. 2022). Authorities can then disseminate needed information needs to the public about flooding as well as how to best develop flood preparedness plans that account for differences in risk, vulnerability, and awareness within communities (Bubeck et al. 2012; Hopkins and Warbuton 2015; Mashi et al. 2020; Hemmati et al. 2022).

Flood awareness is often linked to flood mitigation and flood adaptation measures in studies (Grothmann and Reusswig 2006; Bubeck et al. 2012; Franklin et al. 2014; Maryati et al. 2019; Mashi et al. 2020; Hemmati et al. 2021a; Hemmati et al. 2021b; Hemmati et al. 2022). There are two types of flood mitigation measures: structural measures involving built

infrastructure and nonstructural measures involving incentives focusing on behavior change (Hemmati et al. 2021a; Hemmati et al. 2021b; Hemmati et al. 2022; Kuang and Liao 2022). The housing sector is one area where flood awareness and flood mitigation measures intersect. Hemmati et al. (2021b) found that when home buyers are more aware of the flood risk for properties, fewer home buyers purchase floodplain properties, even if the properties are cheaper than properties outside the floodplain. Flood awareness, though, may not keep communities and individuals from building and living on floodplains as population growth and a lack of land to expand on can push populations to build and live on floodplains and in high flood risk areas even as communities are aware that the land they are building on it at risk of flooding (Fanta et al. 2019). Understanding flood awareness can be used to develop methods of flood adaptation more accepted and used by a community.

Mashi et al. (2020) found the public understood what the main causes of flooding were for their community and could also explain which flood mitigation strategies were taken and why; this made it easier to identify actions that could help decrease the flood risk. Hopkins and Warbuton (2015) argue for using local knowledge and history to increase flood awareness; this approach emphasizes local flooding knowledge and experience being shared and taught. These two examples both offer a way of utilizing flood awareness data to understand and recommend solutions to gaps identified in community flood awareness in the study areas. Mashi et al. (2020) focus more on educating about a specific action identified as increasing flood risk, while Hopkins and Warbuton (2015) focus more on educating about local risks. The context and awareness of flooding in a community can help determine what information is most useful to increase their flood awareness.

An important consideration for flood awareness studies is acknowledging the lack of consistency and potential for bias in terms used. These considerations include the use of emotive terms which can introduce biases, especially for those affected by flooding and the ambiguity in the terms threat awareness and risk perceptions with these phrases having differing definitions for different researchers and studies, limiting the ability to truly compare these studies to each other (Bunting and Guelke 1979; Andráško 2021). Andráško (2021) also argue that because of the often loose and ambiguous definition used in risk perception studies, the term flood awareness is oftentimes more appropriate, especially when exploring what people understand and know about a threat like flooding.

2.3 Methods of Determining Flood Awareness

There are four broad methods that tend to be used to understand flood awareness: 1) workshops and focus groups, 2) questionnaires and interviews, 3) models, and 4) finding other sources to corroborate the perceptions of those in the studies (Table 2.1). These methods can be combined in a study or only one method may be used. For example, Strathie et al. (2015) used focus groups to explore the public's perceptions of flood risk maps to understand how flood risk is communicated visually and used a questionnaire to explore how the public perceived flood risk statements. Strathie et al. (2015) used both focus groups and questionnaires to explore how flood risk is perceived through written word and visually. In contrast, Franklin et al. (2014) used only a questionnaire to explore perceptions of flooding and risky flood behavior. A study exploring how flood risk is communicated to the public uses more methods, because there are several ways to communicate flood risk, meaning several flood risk communication methods to explore. In contrast, a study exploring risky behaviors during flooding could be explored using only one method. Using a single method or combining methods depends on the aim of the study.

Table 2.1. Methods of Determining Flood Awareness (Created by Author).

Method	Advantages	Disadvantages	Use Examples
Workshops and Focus Groups	Focus on conservations and group interactions than on individuals. Focus on group consensus and divisions.	Limit the number of participants. Limit individual input in favor of the group.	Terpstra et al. (2009) used workshops and focus groups to give participants direct experience with flood mitigation measures to determine the effectiveness of flood educational methods. Strathie et al. (2015) used focus groups and workshops to determine what information flood maps communicated to the public.
Cognitive Mapping	View information visually. Elicit information about geographical distributions of risk. Reducing potential bias from question phrasing. Non-language dependent.	Unfamiliarity with the geography of the study area. Unfamiliarity with mapping software.	Chowdhooree et al. 2018 used cognitive maps to identify areas of risk in a settlement. Pitidis et al. 2022 is to identify where participants feel there is the highest flood risk.
Questionnaires and Interviews	Many variations in format. Can be used to gain large amounts of information from a small number of individuals or a small amount of information from a large number of individuals.	Responses can be limited by lack of interest or lack of time. Questionnaire data is limited without an ability to follow-up on answers. Limited number of participants in interviews.	Wells et al. (2016) used interviews to gain large amounts of information about flooding in villages. Hopkins and Warburton (2015) used questionnaires to explore perceptions of flooding and semi-structured interviews to gain information

			from those affected by the studied flood.
Models	Use past data and/or theories to explore change over time. Can be used to predict future changes and affects.	Uncertainty and/or bias in the model development.	Fanta et al. (2019) used models to explore how the locations of settlements changed before and after floods. Hemmati et. al. (2021b) used models to explore the relationship between flood awareness and urbanization through modeling potential effects flood awareness could have on the housing market.

In flooding cognitive mapping activities, a blank map of the study area, potentially with a couple of features identified, is provided to participants to identify areas more and less at risk of flooding and features participants believe influence this risk of flooding (Chowdhooree et al. 2018; Pitidis et al. 2022). Cognitive mapping activities are growing in use, especially when used with workshops or focused groups, but are not only used in association with these methods. Most of the research exploring flood awareness involves questionnaires or interviews (Grothmann and Reusswig 2006; Terpstra et al. 2006; O'Sullivan et al. 2012; Franklin et al. 2014; Hopkins and Warburton 2015; Wells et al. 2016; Lemée et al. 2019; Mashi et al. 2020; Cook et al. 2022; Vasileva and Georgiev 2022). Research using solely questionnaires is the most common way to gain information about flood awareness and flood perceptions, though, survey design varies. Terpstra et al. (2006) used only Likert scale statements to gain an understanding of flood

awareness and flood perceptions. Terpstra et al. (2006), Hopkins and Warburton (2015), Lemée et al. (2019), and Mashi et al. (2020) split the surveys into sections each containing statements pertaining to one specific variable. Franklin et al. (2014) used mainly open response questions and explored the themes in the responses, while Mullins and Soetanto (2013) and Hopkins and Warburton (2015) used a mixture of open response and Likert scale statements. Mullins and Soetanto (2013) used cognitive mapping to explore the relationships between flood risk perceptions and ethnicity using the results from a questionnaire while Strathie et al. (2015) used questionnaires to assess understanding and perception of flood probability statements.

2.3.1 Corroborating Study Perception

Comparing perceptions and associated data is useful to identify discrepancies in perception and reality. For example, Hopkins and Warburton (2015) used a questionnaire to ask questions about flooding, including whether flooding and precipitation was becoming more common. To determine if respondents were able to accurately perceive what was occurring in their environment, precipitation and gauged river flow data were used from the area to determine the actual amount of precipitation and flooding to compare to the survey responses. In a separate study, Wells et al. (2016) analyzed how often and the extent of floods using newspaper flooding reports to compare to respondents' perceptions of how often and where flooding occurred. Mashi et al. (2020) also used observation and photos to understand what factors could be affecting flooding and what flood adaptation measures were being used in the study area. Using flood maps and hazard maps to understand where flooding is known to occur in flooding studies is also common (Oubennaceur et al. 2021). These maps could be used to corroborate awareness study results. All four of these examples used other data to compare how perceptions compared to what

was actually occurring with flooding in the study areas, but none were conducted on karst flooding.

2.3.2 Underlying Flood Awareness Conceptual Models

There are an array of conceptual models underpinning flood perception studies with Table 2.2 displaying often used conceptual models in designing research, though not every conceptual model is discussed (Andráško 2021); most of these models focus on exploring the relationship between flood perception and flood protection measures. These models were created either through developing new conceptual models or by adapting conceptual models from other fields to be used with flood awareness studies (Andráško 2021). Of these models, the Rationalist View and the Constructivist Paradigm are broader theories that underpin the formation of other models and studies (Andráško 2021). The other common models all approach flood perception from a different direction with focuses in both the Social Cognitive Model of Disaster Preparedness and the Hazard to Action Chain on personal ability and trust and responsibility with differences in how risk perceptions are considered and how the relationship between risk perceptions and flood protective action adoptions are explored. Researchers have a large focus in flood perceptions and awareness research on both Protective Action Decision Model (PADM) and Protection Motivation Theory (PMT). Flood perceptions form a large part of the basis of these models. The difference is between the focus in the PADM in creating more flood awareness to increase motivation to adopt flood prevention actions while the PMT focuses on how people perceive their risk of flooding and their ability to cope with floods. PMT is a theory being focused on in recent flood awareness/perception research (Grothmann and Reusswig 2006; Franklin et al. 2014), though its use has also been criticized by researchers such as Lemée et al. (2019), who argued that PMT does not consider the relationship between individual's risk

perceptions and their relationship in the area where they live. While studies such as Grothmann and Reusswig (2006), Franklin et al. (2014), and Lemée et al. (2019) mention the theory guiding their research, most studies do not explicitly state the theory underpinning their approach to their research.

Table 2.2. Conceptual Models and Theories to Study Flood Perception/Awareness (Source: Adapted from Andráško 2021).

Conceptual Model Name	Conceptual Model Description
Rationalist View	Emphasizes cognitive processes and judgments of individuals in a decision-making process focused on adopting protective behaviors.
Constructivist Paradigm	Emphasizes social relationship's role in shaping decision-making processes.
Social Cognitive Model of Disaster Preparedness	Emphasizes links between intentions and preparedness by exploring factors encouraging people to prepare, intention forming from these factors, and decisions to prepare for disasters.
Hazard to Action Chain	Explores the weak relationship between personal action and risk perception using experience and motivation, personal ability, and trust and responsibility.
Protective Action Decision Model (PADM)	Emphasizes role of risk perception in protective action adoption with awareness of a threat serving of motivation to take a protective action.
Protection Motivation Theory	Emphasizes use of threat appraisal and coping appraisal in determining self-preservation behavior and protection motivation.

Note: This table shows more commonly used flood perception conceptual models and their descriptions.

2.4 Flood Education

Flood education can help to reduce the effects of flooding (Franklin et al. 2014; Maryati et al. 2019; Cooper 2022). Flood education, especially focused on community risks and concern, can be a form of flood management (Cooper 2022). One aspect of flood education Terpstra et al. (2009) recommends is to increase awareness of the risk of natural hazards through education by public authorities. Siegrist and Gutscher (2006) add that not only must communities be educated about flood hazards and their risk, but they must also be educated about how they can mitigate or

prevent flood damages. Flood education may also be more effective to focus on in areas where there is higher vulnerability based on social, economic, and environmental factors to ensure these populations understand flood mitigation and what policies and assistance are available for them to use in regard to flooding (Cooper 2022). Bubeck et al. (2012) found that while most studies link flood awareness and better flood preparedness, their study found increasing flood awareness did not necessarily increase community flood preparedness. Related to this finding, Andráško (2021) found that research availability does not necessarily raise flood awareness as there can be a lack of interest in being informed about the risk of flooding that keep people from learning, a concern because if people are not interested in flood education, they likely will not search out and gain this information and the benefits from this education.

Flood education and information can be disseminated in many formats including focus groups, social media and other digital methods, pamphlets/brochures, banners, newspapers, radios, and televisions (Rana et al. 2020). Flood education can also take the form of information tools such as maps that focus on specific communities (Oubennaceur et al. 2021). Flood education can also take the form of community flood discussions and neighborhood meetings that allow for public participation. Terpstra et al. (2009), Siegrist and Gutscher (2006), and Hopkins and Warburton (2015) argue that disseminating flood information on a neighborhood level is one of the most effective ways of providing flood education. The argued effectiveness of focusing on the neighborhood level for flood information dissemination may be because neighborhood meetings can be tailored to the specific risks and risk factors being faced in the neighborhood where the meeting is taking place as well as providing an opportunity for individuals to discuss in groups about risks. Overall, for sharing flood information about more localized areas, it may be more effective to share the information through community

interactions whether with a neighborhood meeting or through individuals in the community gaining and sharing the information. Though, Terpstra et al. (2009), did find that a small-scale flood risk educational program had only a small influence on changing risk perceptions.

Some studies find that people believe flood education is supposed to come from the government (Terpstra et al. 2006; Terpstra et al. 2009; Maryati et al. 2019); these studies only looked at specific areas and held a small number of study participants. Studies looking at other locations with a larger number of participants may find different results. The belief that flood education is the responsibility of the government is backed up by the idea that there is no agreement as to who is ultimately responsible for flood protection, mitigation, and adaptation (Andráško 2021). Arguments put responsibility for flood mitigation on various actors such as individuals, governments, agencies, and experts with a concept of shared responsibility being used more often where multiple actors share some degree of responsibility to provide flood protection measures (Andráško 2021). A lack of agreement as to who is ultimately responsible for flood mitigation measures agrees with Terpstra et al. (2006; 2009) in the belief that flood education is the government's responsibility; this may partially arise from the fact that the majority of flood risk management comes from local governments (Tyler et al. 2019; Douthat et al. 2023). Understanding the public's belief about the government's role in flood mitigation and response is important to determine if there is agreement between community member's views of responsibility and statutory responsibility.

One reason flood risk perception studies are useful is they can determine what the public understands and misunderstands about flooding to help identify what local flood education needs to cover to ensure the community is aware of their flood risk and what actions should be taken (Mashi et al. 2020). Topics that are often important to cover include documenting and

communicating about previous flood events, locations of flood zones in the community, and what to do when the public receives a flood warning (Franklin 2014; Batanero and Martinez 2017; Fanta et al. 2019; Rana et al. 2020; Hemmati et al. 2022). Siegrist and Gutscher (2006) suggest hosting an annual *Flood Day* or other flood education events to ensure information about floods and flood warning systems are understood by the public, as these events provide an opportunity for the community to ask questions about flooding and flood warning systems and to raise awareness of local flood risks. Individuals in the community may be aware of what flood knowledge their fellow community members lack and have ideas of how to best educate them about flooding (Franklin et al. 2014). Overall, there is a large emphasis from a range of studies on ensuring flood education is localized to both fill in the gaps in the local community's flood awareness, as well as to focus on communicating in a way the local community needs to effectively educate the public about flood risks.

2.5 Flooding in Warren County and Bowling Green

Flooding is Kentucky's most frequent and most costly natural disaster with a risk that evolves over time due to factors such as new construction changing a watershed and changes in weather patterns (Kentucky Energy and Environmental Cabinet 2022). In Kentucky, within a 100-year floodplain, there are approximately 227,000 properties with a substantial risk of flooding (BRADD 2021). Warren County, the county where the city of Bowling Green (BG) is located, has a high risk of flooding with an average of four flood events annually, meaning Warren County has a 400% chance annually of a flood event (BRADD 2021). Warren County has flooding issues even with few surface streams and rivers because flooding occurs not only from surface waters but also from the karst systems it is built upon (City County Planning

Commission 2019a). Understanding the context of flooding in Warren County can help improve flood mitigation in an urbanized karst area.

Warren County and BG sit on a karst landscape. Karst is defined as a landscape characterized by the presence of caves, springs, sinkholes, sinking streams, etc and consists of water mainly moving underground (Kemmerly 1981; Ford and Williams 2007; Zhou 2007). Figure 2.2 shows a map of karst terrain in Kentucky. As can be seen in this map, Warren County and BG sit in a karst area.

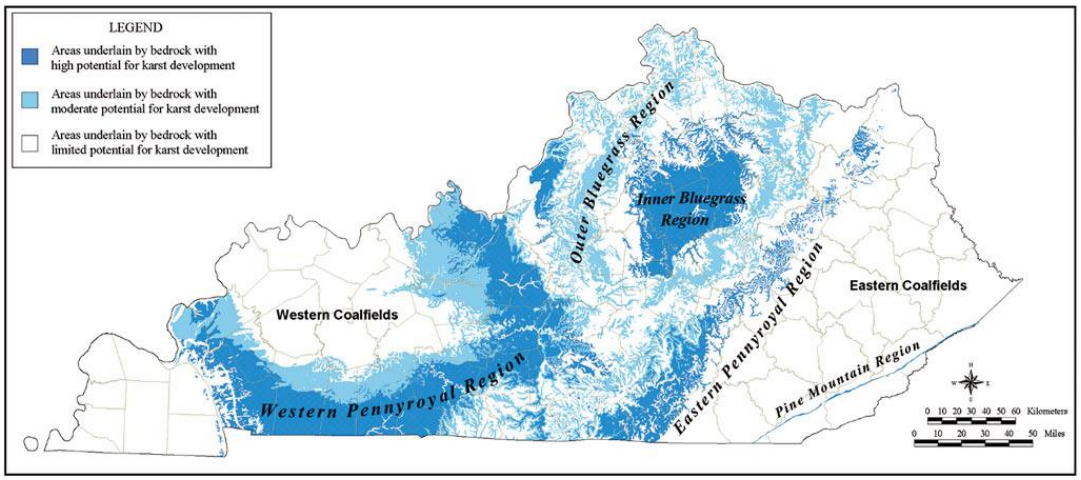

Figure 2.2 Map of Karst Geography in Kentucky (Source: Florea et al. 2003).

BG is built in a karst area that frequently floods, especially after rain events (Bowling Green, Kentucky Code of Ordinances 2007; Nedvidek 2014; Cooper 2022). Some areas of BG have seen an increased flood height and velocity due to changes in the floodplains, as well as more damage because of the location of infrastructure in flood hazard areas that are not adequately prepared for flood events (Bowling Green, Kentucky Code of Ordinances 2007). BG has implemented flood management strategies to attempt to reduce the risk from flooding, but the karst landscapes still pose a risk from flooding due to lack of drainage capacity (Nedvidek

2014; Cooper 2022). Damage from flooding has been partially reduced by restricting construction in flood-prone areas and requiring the construction of floodwater detention basins where needed (Ford and Williams 2007). One aspect of flooding in karst landscapes is that flood zones are not only around surface streams and rivers but are often around sinkholes, meaning there are small areas spread around BG that are designated as FEMA flood zones rather than having all the flood zones concentrated in one area (Ford and Williams 2007; Cooper 2022). The dispersed nature of flood zones in BG can make flood risk management difficult.

2.5.1 Flood Awareness in Warren County and Bowling Green

Several factors affect flood awareness in Warren County and BG, including how karst flood-prone areas can remain dry for long periods of time because surface flow is often absent for long periods of time (de Waele et al. 2011). The long intervals between floods in flood prone areas, as well as the lack of surface flow, can cause people to underestimate the risk of flooding in an area. There can be an assumption that because they do not see surface water or they have not experienced flooding, individuals are not at risk of flooding; this is a false assumption, as much of the water in karst systems are not surface waters but flow under the surface.

Another factor influencing flood awareness, especially when purchasing a home, is the requirement in Kentucky that home sellers must disclose to home buyers whether the basement and roof leaks, wherein flooding is included in basement leaks, and if anything has been done to repair these issues (Kentucky Revised Statutes 2000). The City County Planning Commission for Warren County, Kentucky did set out subdivision regulations including a checklist of information needing to be reviewed and submitted, increasing the amount of information provided about flooding when purchasing a home (City County Planning Commission 2019b). Flooding information is limited, though, and does not apply to newly built houses.

In BG, all building permit applications for new constructions or substantial changes to existing constructions have to be reviewed to determine if the construction would be reasonably safe from flooding (Bowling Green, Kentucky Code of Ordinances 1991). BG also set forth an entire chapter of ordinances focused on minimizing flooding loss by restricting land uses that could increase flood levels, as well as discussing Special Flood Hazard Areas (SFHA), which are the areas that are at risk for a 100-year flood, but these areas have not been updated since 2007 when the FEMA maps were last updated (Bowling Green, Kentucky Code of Ordinances 2007). Flood information and flood maps used in the city are available for the public to view (Bowling Green, Kentucky Code of Ordinances 2007). Altogether, there are various laws and ordinances that guide how aware individuals in BG are of flooding. Many of these laws and ordinances are over 15 years old, and, even with these laws and ordinances, BG and its citizens still have flood issues that occur (Lawler 2023).

In 2010, a major flooding event occurred in BG with the Barren River experiencing its highest flood crest since 1962 (NWS, 2015). In 2010, BG broke Kentucky's two-day precipitation record with 258 mm falling in 48 hours with this precipitation event also causing widespread flooding and over $2 billion in damages across Kentucky and Tennessee (Durkee et al. 2012). In 2017, flooding occurred in BG in the areas where flooding commonly occurs including in several residence halls and a parking garage on Western Kentucky University's campus (French 2017; Herald Staff 2017; WKU Public Radio News 2017). In 2021, flooding again occurred in BG with flooded roadways and flooded neighborhoods, with water receding quickly in some areas but remaining for days in other areas as the cave systems were draining into the Barren River before more water could enter their systems (Brooks 2021; Garrison 2021; Schweinert 2021). Further, parts of the BG have been described as flood-prone (Kleine-Kracht

2022). Several articles describe areas in BG that are flood prone or where flooding is common, especially after heavy rains (French 2017; Herald Staff 2017; WKU Public Radio News 2017, Kleine-Kracht 2022). There is an awareness, at least, on the professional side, that some areas have a higher flood risk than others in BG, but the public is still often uninformed or unaware of these threats.

2.5.2 Flood Education in Warren County and Bowling Green

Kentucky is required to have a public information program aimed at increasing public awareness and preparedness of floodplains which may include flood information training workshops, example floodplain development ordinances, and floodplain informational booklets (Kentucky Revised Statutes 1980). The law requiring a public flood information program, and any materials initially created from it, would be over forty years old. There is no requirement included in the law that this program and the material produced from it be updated regularly.

Kentucky hosts websites with links and sheets to explore flooding, flood adaptation, and flood recovery in Kentucky. Examples of Kentucky web resources include the "Kentucky Government's Flood Resources" page (Flood resources 2022), the "Kentucky Government's Find Your Flood Zone" page to help the public find if their homes are located in a flood zone (Kentucky Energy and Environment Cabinet 2022), and the "Kentucky Flood Hazard Portal" to help citizens explore the flood hazard in their area using an interactive map (Kentucky Division of Geographic Information 2019). Warren County, Kentucky also has a Floodplain Management page providing information and link to information on a national, state, and local level with the local level including information on water monitoring ventures in the county as well as information on stormwater management in the county (City County Planning Commission 2019a).

Yes, without a knowledge of risk, individuals may not seek information about flooding as they may believe it does not and will not impact them even if the information is available. When discussing flooding, the City County Planning Commission (2019a) mentions that Warren County is located in a karst environment and that flooding can occur in karst systems, but karst is not the focus. Instead, karst is briefly mentioned before focus shifts to other flood-related topics; therefore, conducting a flood perception and awareness study for karst groundwater areas is important to understand how to best work with the public to mitigate flood threats and protect lives and property.

2.6 Conclusion

Overall, understanding flood awareness in the context of Warren County and BG is valuable due to the large effect flooding has on this region. A focus on flood awareness in a karst region is needed as the topic of flood awareness in connection to karst is not widely studied. Flooding in karst areas can differ from non-karst flooding, making understanding potential differences in flood awareness between karst and non-karst landscapes important. Developing a better understanding of flood awareness in Warren County and BG can help improve preparedness for flood events and reduce the individual's flood risk to better protect the community. A better understanding of flood awareness in Warren County and BG can provide a basis for updates to policies relating to flooding within the city by supplying an opportunity for individuals to provide information about how they view the risk of flooding within Warren County and BG.

Chapter 3: Perceptions and Visual Awareness of Urban Karst Flooding to Inform Preparedness Planning and Management Actions

3.1 Introduction

Flooding has a large effect on millions of people and causes billions of dollars of damage annually (Centre for Research on Epidemiology of Disasters 2022). Urbanization and climate change potentially increase the risk of flooding making it integral that community's flood awareness and perception is understood (Wells et al. 2016; Mashi et al. 2020; Hemmati et al. 2022). Flood awareness and perception studies tend to focus on riverine, flash, and other types of surface flooding with limited research exploring flood awareness in karst areas (Fanta et al. 2019; Maryati et al. 2019; Mashi et al. 2020; Ferreira et al. 2021; Ge et al. 2021; Oubennaceur et al. 2022; Bhatti et al. 2023). Karst flooding differs from other types of flooding as it often involves flooding through sinkholes and springs since most water flows underground in these landscapes (Zhou 2007), thus limiting the amount of surface water present for communities to see and anticipate as a threat. The lack of surface water, presence of sinkhole flooding, and complexity of flooding in karst landscapes may influence flood awareness in karst communities, necessitating an investigation of flood awareness in karst areas.

Warren County, Kentucky is a karst landscape prone to flooding. Specifically, Warren County has a 400% chance of a flood annually (BRADD 2021), and recent research indicates that flood prone areas in the city of Bowling Green, which is located within Warren County, are associated with sinkhole, a karst feature (Zhou 2007; Nedvidek 2014; City County Planning Commission 2019a; Cooper 2022). As such, Warren County an ideal location to study flood awareness in an urban karst landscape.

This study used surveys, interviews, and a cognitive mapping activity to understand flood awareness and flood perceptions in an urban karst landscape. These data were used to explore connections between flood awareness, flood experience, flood policies, flood damage, and karst landscapes. These results were used to determine gaps in flood awareness and to help inform future management and policy practices for flood mitigation in urban karst areas.

The questions explored in this research are:

- What are the community perceptions and awareness of flooding in the urban karst area of Warren County?
    - What is the relationship between awareness of flooding and karst features in Warren County?
    - What are the factors that influence awareness of flooding in karst environments and how do these factors influence flood awareness in Warren County?
- Does current policy and regulation adequately address perceived flood risk and vulnerability in the urban karst area of Warren County?

3.2 Study Area

3.2.1 Warren County, Kentucky

The study area for this research is Warren County, Kentucky, home to the 3rd largest city in Kentucky, Bowling Green (BG). Warren County is located in south-central Kentucky about 96.5 kilometers north of Nashville, Tennessee and about 177 kilometers south of Louisville, Kentucky, with BG being the largest city within Warren County (Bowling Green Area Convention & Visitors Bureau 2022). BG is an entertainment, educational, and commercial center for the eleven counties surrounding it (Bowling Green Area Convention & Visitors Bureau 2022). Warren County is also one of the ten counties that are a part of the Barren River

Area Development District (BRADD); this district is a regional collaboration between counties in southcentral Kentucky on a range of objectives including hazard mitigation and economic development (BRADD 2022).

3.2.2 Physical Characteristics of Warren County

Warren County, Kentucky has an average temperature of 14.1°C and 1,265 mm of precipitation falls annually (USA Facts 2024). Temperature varies by 23.6°C throughout a year, with the hottest month being July with an average temperature of 26.1°C, and the coldest month being January, with an average temperature of 2.5°C (Climate Data 2015). Warren County has a range of precipitation, with an average difference between the driest and wettest months being 44 mm of precipitation (Climate Data 2015). Precipitation is lowest in August, with an average of 84 mm, and is highest in April, with an average of 128 mm (Climate Data 2015).

Considering the number of rainy days in a month is valuable as months with a larger amount of precipitation over a smaller number of days have more heavy rainfall, a variable connected to flooding in the region where Warren County is situated (BRADD 2021a). In BG, June has the largest number of rainy days with an average of 12.20 rainy days annually while October has the smallest number of rainy days on average annually with 7.73 rainy days (Climate Data 2015). While flooding can occur at any time during a year, flooding in Warren County is often connected to heavy rainfall, meaning spring and summer months have a higher risk of flooding (BRADD 2021a). Knowing when there is a higher risk of flooding is important because BG in Warren County has had 31 flood events since 2000 and is considered to have a high vulnerability in regard to flooding (BRADD 2021a).

BG has a history of flooding with flooding issues occurring during and following most large storm events (Nedvidek 2014; Lawler 2023). BG has a FEMA designated floodplain

referred to as a Special Flood Hazard Area (SFHA) (Figure 3.1), but all of the floodplains were designated before 2007, with no updates since then (CCPC 2019a). A SFHA is a flood zone where the purchase of flood insurance is mandatory and where the National Flood Insurance Program's (NFIP) floodplain management regulations are required to be enforced (FEMA 2020). As Figure 3.1 shows, parts of BG, especially in the northern, northwestern, and eastern sections of the city, contain areas that are considered to be SFHA that are not adjacent to riparian zones, but located in karst areas (CPCC 2019a).

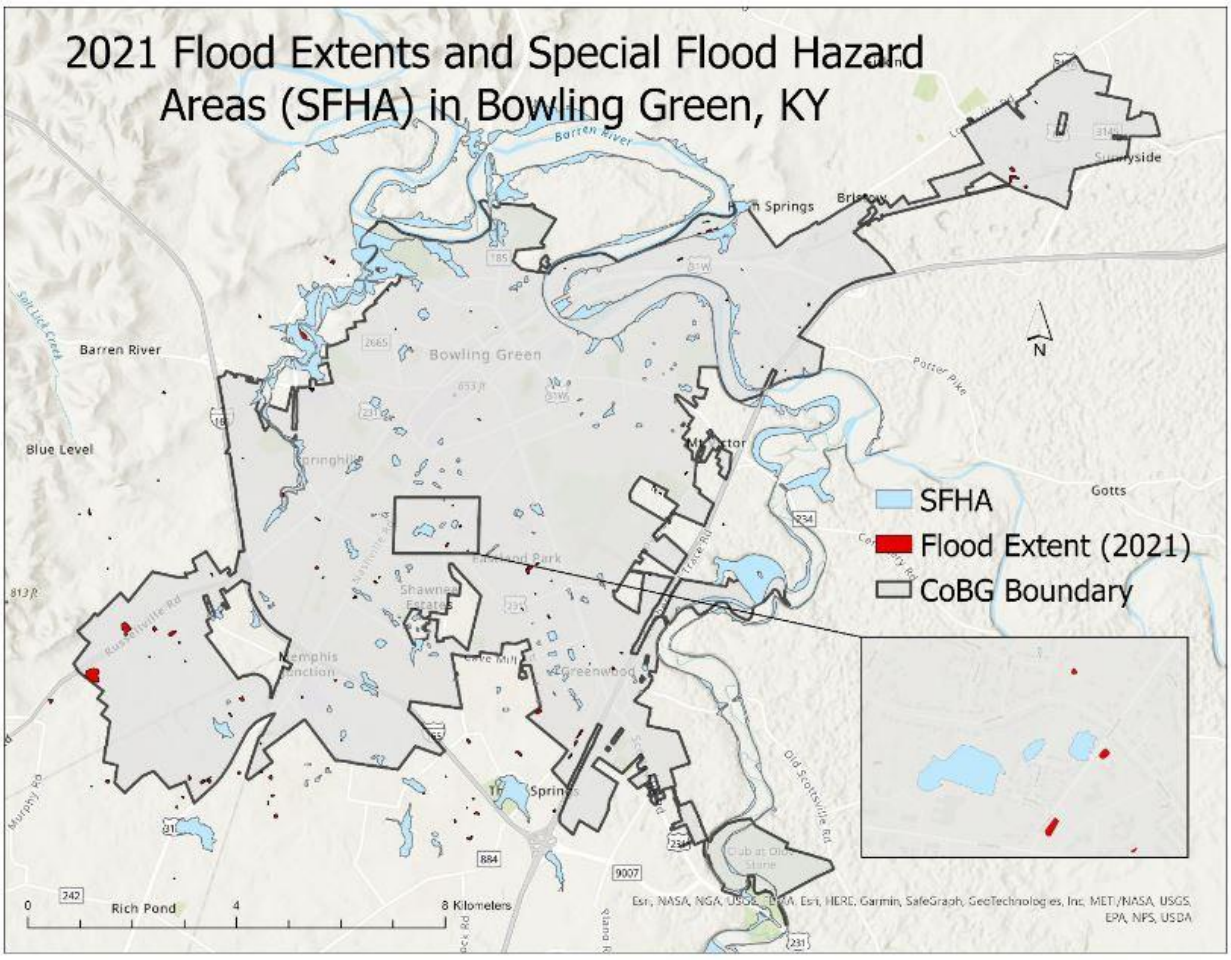

Figure 3.1. SFHA and 2021 Flood Extents in Bowling Green, KY (Source: Cooper 2022)

Warren County and BG are built on top of a large region of carbonate rocks, limestone in this case; carbonate rocks facilitate the development of karst features, including caves and sinkholes when precipitation occurs (Kuehn and Weisenfluh 2003; BRADD 2021b). BG is situated over the Lost River Cave system, which developed within Mississippian-aged St. Louis and Ste. Genevieve limestones (Jackson 2017). Warren County and BG are within one of the most highly developed karst regions in the state with a large number of karst features. BG is on a broad, low-relief sinkhole plain (Ford and Williams 2007; Jackson 2017). BG alone has over 1,500 sinkholes and is considered to have a high vulnerability to sinkholes (BRADD 2021b). The location of sinkholes in BG is shown in Figure 3.2.

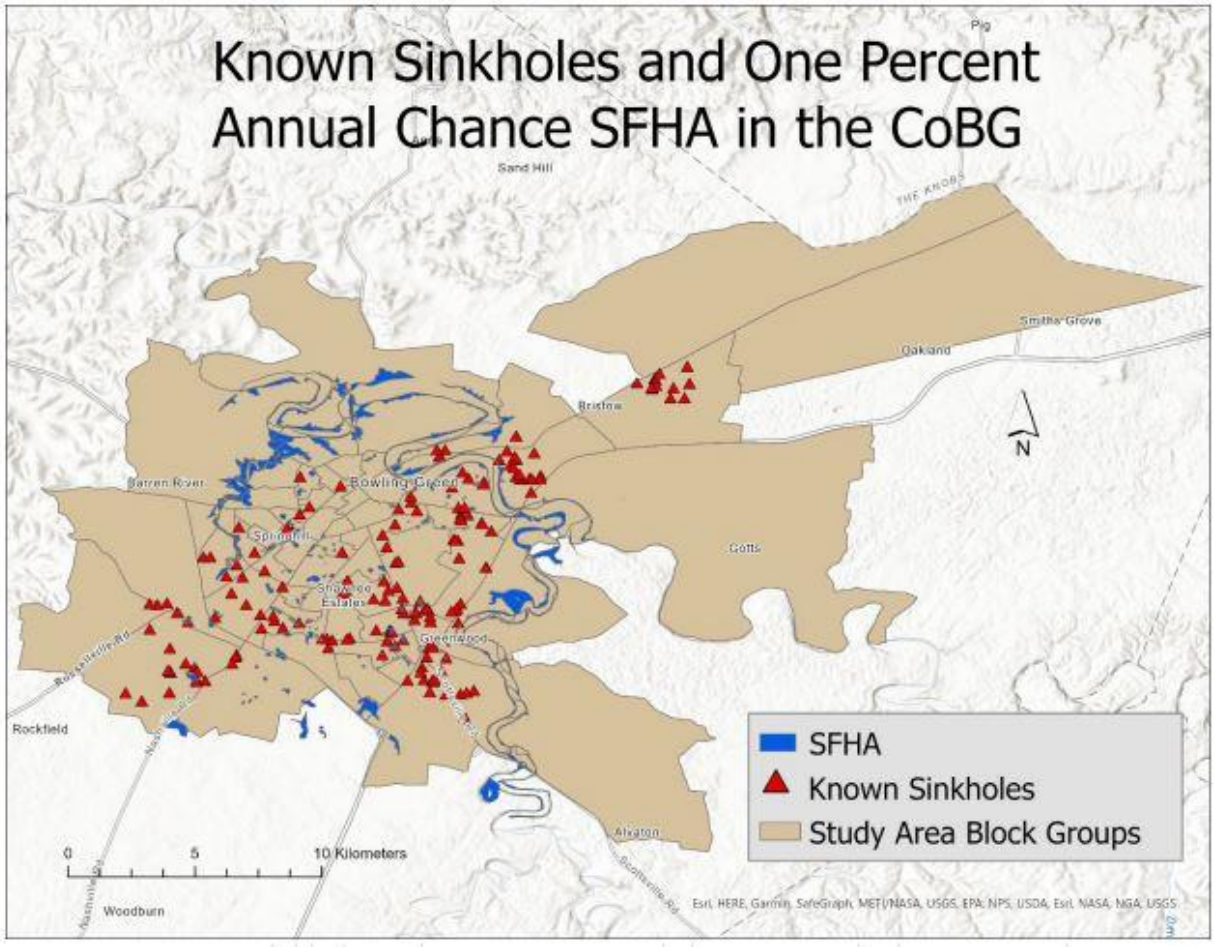

Figure 3.2. Known Sinkholes and SFHA in BG (Source: Cooper 2022).

Sinkholes are heavily connected to flooding in karst areas (Cooper 2022) because there are few surface streams in karst areas, and water is, instead, funneled into sinkholes or drainage wells to drain into the subsurface where caves move and store water (Kuehn and Weisenfluh 2003; Ford and Williams 2007). Sinkholes are often prone to flooding in periods of high rainfall as water fill the sinkhole faster than the water can be discharged into caves (Kuehn and Weisenfluh 2003; BRADD 2021b). The conditions that cause sinkhole flooding can vary widely depending on the amount of rainfall, depth of the sinkhole, and local soil conditions along with other variables (Kuehn and Weisenfluh 2003). Sinkhole flooding is common in BG, contributing to small pockets of FEMA flood zones throughout BG near many sinkhole locations (Cooper 2022). In fact, the majority of current SFHA in BG, nearly 87%, directly intersect or are within 200 m of potential sinkholes (Cooper 2022).

3.2.3 Cultural Characteristics of Warren County

Warren County, Kentucky has a population of 134,554 as of the 2020 Census (U.S. Census Bureau 2021); the median age of the population was 33.5 as of the 2022 American Community Survey (U.S. Census Bureau 2021). Warren County has a population density of 96 individuals per square kilometer as of 2020, and Warren County spans1403.05 square kilometers (U.S. Census Bureau 2023). BG is the largest city by both area and population in Warren County with 53.72% of Warren County's population living in the 102.05 square kilometers that make up BG (BRADD 2021c). BG's a population density is 736 people per square kilometer (World Population Review 2022). BG is not only the largest city in Warren County, but it is the third largest city in Kentucky with an annual population growth rate of 1.93%, a rate projected to continue as BG's location along several major interstates and near major population centers have positioned BG well for more growth (World Population Review 2022). Growth in BG is relevant

when considering flooding because as the population increases, more development occurs, expanding Bowling Green and, at times, pushing expansion into floodplains.

The proportion of the population in Warren County that is white is 73.9%, with 9.6% of the population being Black or African American, and 5.4% of the population being Asian as per the 2020 Census (U.S. Census Bureau 2021). Table 3.1 shows a full breakdown of races for Warren County. As of the 2021 American Community Survey, 50.6% of Warren County's population is female (U.S. Census Bureau 2023). Of Warren County's population, 87.6% speaks only English at home meaning 12.4% speak a language other than or in addition to English at home which connects with the 12.2% of the population that is foreign born as of the 2021 American Community Survey (U.S. Census Bureau 2021; U.S. Census Bureau 2023). As can be seen in Figure 3.3 below, percentages of minority populations are highest in the center of Warren County around where the BG is located.

Table 3.1 Racial Demographics of Warren County, Kentucky (Source: U.S. Census Bureau 2021).

Race	Number	Percentage
Total Population	134,554	100%
American Indian and Alaska Native Alone	481	0.36%
Asian Alone	7,326	5.44%
Black or African American Alone	12,933	9.61%
Native Hawaiian and Pacific Islander Alone	682	0.51%
White Alone	99,453	73.91%
Other Race	5,156	3.83%
Two or More Races	8,523	6.33%
Hispanic or Latino (Any Race)	9,441	7.02%
Not Hispanic or Latino (Any Race)	97,744	72.64.%

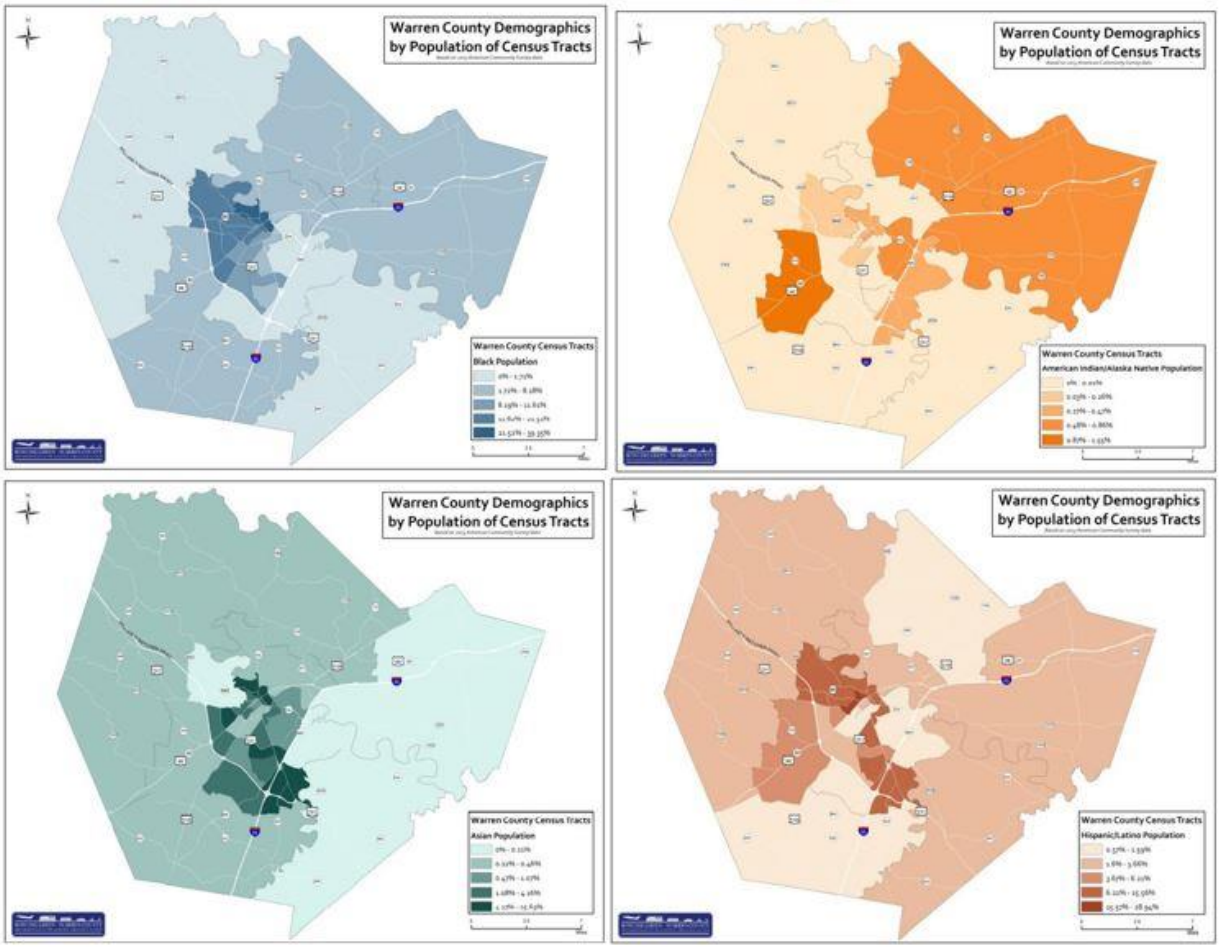

Figure 3.3. Warren County 2013 Racial Demographics. Top Left: African American. Top Right: American Indian/Alaska Native. Bottom Left: Asian. Bottom Right: Hispanic/Latino (Source: Bowling Green-Warren County MPO 2016).

Warren County has a median income of $59,784, an employment rate of 58.9%, and a poverty percentage of 19.5% (U.S. Census Bureau 2021). Figure 3.4 shows the percentage of the population below poverty across Warren County in 2013, with a higher percentage of the population below poverty located toward the center of Warren County, where BG is located. Warren County has 56,881 housing units and a homeownership rate of 54.3% (U.S. Census Bureau 2021). Nearly two-thirds of those in BG rent housing, which may be connected to the presence of Western Kentucky University within Bowling Green and the transient population

that comes with a university. The presence of a major Kentucky public university likely connects to the high education rate with about 88.6% of Warren County having at least a high school diploma and 32.9% having a Bachelor's degree or higher (U.S. Census Bureau 2023).

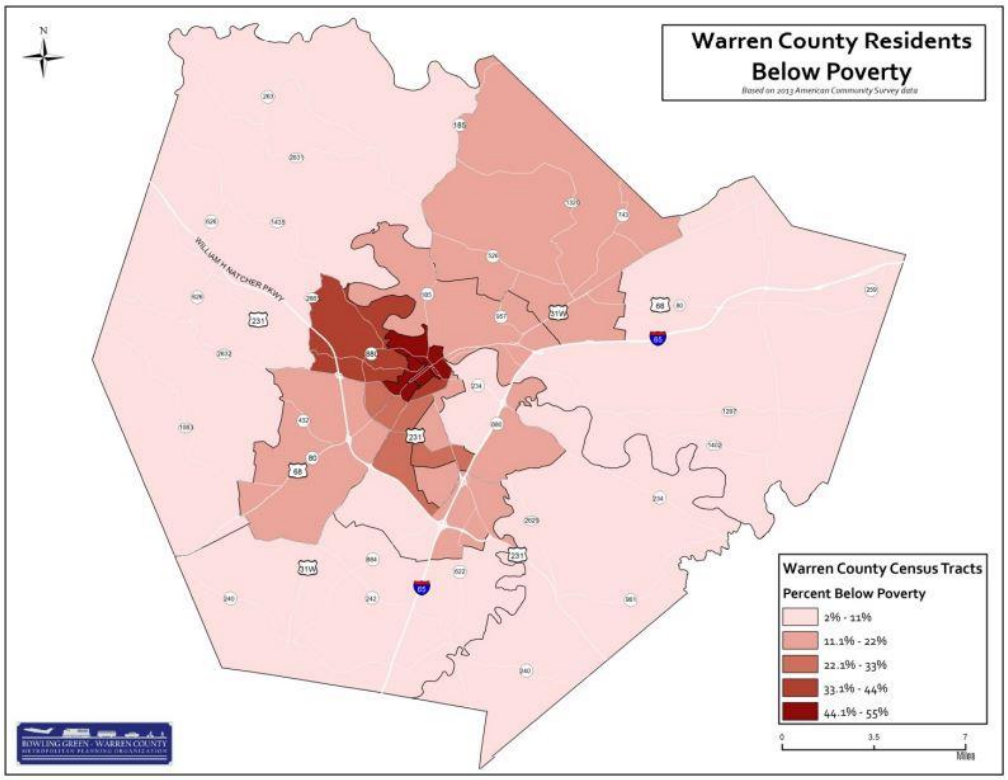

Figure 3.4. 2013 Map of Warren County Population below the Poverty Line (Source: Bowling Green-Warren County MPO 2016).

Varying flood vulnerabilities exist across the BG, with the south-central area having both higher vulnerability and a denser concentration of karst features, such as sinkholes and known flood zones (Cooper 2022). A recent study focusing on flood vulnerability in karst regions found that about 16.6% of BG's population resides within a low vulnerability area, 74.9% of BG's population resides in a vulnerable area, and 8.5% of BG's population resides in a moderate vulnerability area (Figure 3.5) (Cooper 2022). Block groups in BG with higher poverty rates, lower income values, higher unemployment rates, and higher percentages of people of color

among other variables, were associated with higher flood vulnerability levels (Cooper 2022). There are a few ordinances in BG that relate to flooding, meaning there is at least some awareness of flooding by the local government, even if there are differences in flooding vulnerability in BG (Kentucky Revised Statutes 1980; Kentucky Revised Statutes 2000).

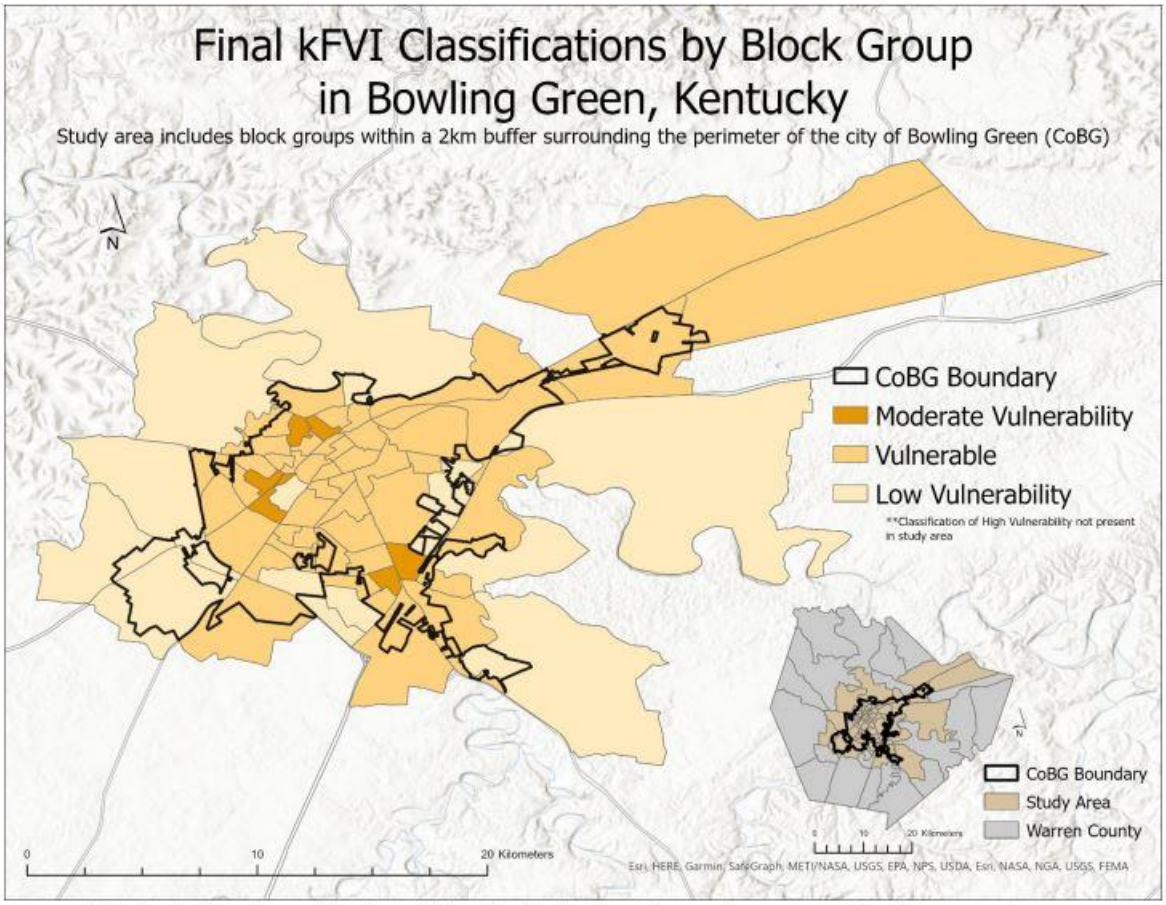

Figure 3.5. Flood Vulnerability in CoBG by Block Group using kFVI Scores (Source: Cooper 2022).

3.3. Methodology

3.3.1 Survey Development

A survey was developed with four sections, each focusing on a flood perception and awareness topic: flood experience, flood policy, karst flooding, and participant demographics (Terpstra et al. 2006; Mullins and Soetanto 2013; Franklin et al. 2014; Hopkins and Warburton

2015; Strathie et al. 2015; Lemée et al. 2019; Mashi et al. 2020). The sections used in the survey were selected using past studies (Table 3.2). Table 3.3 displays an overview of the topics and subtopics that were covered within the survey.

Table 3.2. Studies Used to Develop Research Topics and Questions (Source: Created by Author).

Study	Topic(s)	Subtopics	Dataset
Grothmann and Reusswig (2006)	Flood Experience Flood Risk Perception, Reliance on Public Flood Protection	N/A	Telephone Interviews with 5-point Likert Scale Questions
Terpstra et al. (2006)	Flood Risk, Water Nuisance Risk	Flood Awareness, Trust in Authorities	Questionnaire with a 5-Point Likert Scale
Mullins and Soetanto (2013)	Flood Experience, Demographic Differences, Resilience Measures, Flood Policies	N/A	Questionnaire with Likert Scale and Open Response Questions, Cognitive Mapping
Franklin et al. (2014)	Flood Experience, Human Behavior in Floods	N/A	Online Questionnaire
Hopkins and Warburton (2015)	Local Flood Risk, Effects of Flooding, Flood Experience, Flood Knowledge	N/A	Semi-Structured Interviews, Postal Questionnaire
Strathie et al. (2015)	Flood Risk Communication	Visual Flood Risk, Flood Risk Statements	Focus Group, Questionnaire
Lemée et al. (2019)	Risk Perception, Anxiety-State, Self-Efficacy, Coping, and Place Identity	N/A	Questionnaire
Maryati et al. (2019)	Flood Experience, Flood Knowledge, Flood Management	Role of the Government in Flooding	Questionnaire
Mashi et al. (2020)	Flood Awareness, Flood Perception, Flood Resilience, Flood Adaptation, Flood Response	Protection, Housing Adaptation, Evacuation, Relocation, Preventative Warning	Questionnaire
Andráško (2021)	Flood Perception, Flood Management	Flood Experience, Flood Awareness	Literature Review
Vasileva and Georgiev (2022)	Flood Awareness, Flood Preparedness	N/A	Questionnaire

Table 3.3 Summary of Survey Topics and Subtopics (Source: Created by Author).

Survey Question Topic	Survey Question Subtopic
Demographics	Age; Gender; Race, Renter vs. Owner; Duration of residence
Flood Experience	Whether participant lives in a flood zone; Directly or indirectly affected by floods, Severity of flood experience; Frequency of flood experience
Flood Policy	Who is responsible for addressing flood affects; Awareness of flood policies.
Karst Flooding	Influence of karst on flooding; Knowledge of karst

As the term flood awareness still has ambiguity in its use in research, in the context of this research, flood awareness refers to an individual's knowledge about flooding and the flood risk in their community (Franklin et al. 2014; Hopkins and Warburton 2015; Lemée et al. 2019; Mashi et al. 2020; Vasileva and Georgiev 2022). Some of the questions in this section focused on flood perception by asking about how various aspects of flooding were perceived by participants. The terms flood awareness and flood perception are often connected together and are sometimes used interchangeably between different research papers, but for this study, perception focused on how and why people think flooding occurred, rather than if they were aware of it. Other potentially ambiguous terms were also defined for the purposes of this study (Table 3.4).

Table 3.4 Defined Terms (Source: Created by Author).

Terms	Definitions
Flood Awareness	An individual's knowledge about flooding and the flood risk in their community.
Flood	"A temporary overflow of water onto land that is normally dry. It is the most common natural disaster in the U.S." (FEMA 2018)
Karst	Landscape characterized by the presence of caves, springs, sinkholes, sinking streams, etc. and consists of water mainly moving underground.
Neighborhood	Within one mile of your current address.

A survey using a 5-point Likert strongly disagree to strongly agree scale, open-response, and yes/no questions was designed and conducted (Goddard and Villanova 2005). By using both Likert scale questions and open-response questions, the hope was to gain a large amount of surface level information with the Likert scale questions and gain a smaller amount of more in-depth information with the open-response questions (Goddard and Villanova 2005). The survey instrument is in Appendix A. Table 3.5 shows the research questions with the survey questions associated with them. The survey was validated by ten individuals with differing backgrounds and was approved by the Western Kentucky University Institutional Review Board.

Table 3.5 Research Questions and Survey Questions (Source: Created by Author).

Research Questions	**Survey Questions**
What are the community perceptions and awareness of flooding in an urban karst area?	• Define flooding in your own words. • Do you reside within a flood zone? • Are there specific characteristics of your neighborhood or home that you feel increases your likelihood of flooding? • Your current address floods more frequently than other properties in Bowling Green. • Some areas of Bowling Green flood more frequently than others. • You personally have been affected by flooding more than others since you have lived at your current address. • The amount of flooding has increased since you started living at your current address.
What is the relationship between awareness of flooding and karst features?	• Please select any of the following karst features you know of that are within a mile of where you live. • Do you know of any karst feature(s) that directly affect your residence? If so, list the feature(s). • Flooding in karst landscapes can differ from flooding in non-karst landscapes.

What are the factors that influence awareness of flooding in karst environments and how do these factors influence flood awareness?	• Have you ever experienced flooding at your current address? • If the home at your current address has experienced flooding, please check if any of the following types of effects or damage occurred? • Has the exterior property of your current address experienced flooding? • Have other areas in your current neighborhood (within one mile of your address) experienced flooding? • If your neighborhood (within one mile of your address) has flooded, please check if any of the following types of effects or damage occurred. • What is your gender? • What is your age? • What is your race? • Do you own or rent your residence?
Does current policy and regulation adequately address perceived flood risk and vulnerability in urban karst areas?	• Who do you think is responsible for addressing flooding issues on private property such as homes or businesses? • Who do you think is responsible for addressing flooding issues on public property such as roadways, schools, or parks? • Are you aware of any policies, regulations, or laws aimed at flooding? If yes, what topics do they cover? • Do you feel current policies, regulations, or laws aimed at reducing flood risks in your community are effective? Please explain your answer.

3.3.2 Survey Dissemination

The survey was open from April 1st, 2024, when it was approved for dissemination to July 6th, 2024, when it was closed to complete analysis before the grant deadline. The survey was disseminated online to various homes, businesses, and other entities around BG and open to any person over the age of 18 living in BG. The survey was distributed and collected using an iPAD,

through a Qualtrics link and QR code, and through paper copies. Surveys were administered and promoted using tabling (community) events, social media, flyers, radio interviews, and postcards mailed to the community. The list of distribution methods is in Appendix D. Tabling occurred at already planned community events occurring throughout BG. Postcards were sent using Every Door Direct Mail (EDDM). EDDM is run through the U.S. Postal Service and allows for postcards to be sent through the U.S. Postal Service to specified zip codes, which can be chosen using age, income, or household size (United States Postal Service 2024). The routes were chosen by randomly selecting three mail routes in the study area. The postcards and social media allowed for a random sample to be collected. A total of 2,000 postcards were distributed throughout the community. At the end of the survey, respondents were provided with an opportunity to be entered to win one of 25 $20 gift cards as an incentive to take the survey

The method of sampling used in the survey dissemination was voluntary response sampling, permitting those who are willing to participate in the survey to do so. This allowed for the survey to be distributed throughout the study area quickly. The different methods of dissemination aimed to increase the number of potential participants reached while also limiting biases that may occur if participants are unable to complete the survey electronically. The drawback with voluntary response sampling was the introduction of bias into the results as some people are more likely to volunteer to participate in a survey than others are (Salkind 2010). All methods of survey dissemination had a description of the project, as well as a way to provide informed consent for participation before the survey was completed. All surveys and community mapping data were confidential with the only identifiable information collected was addresses through the surveys. The addresses were only used to determine broader neighborhoods of

participants to analyze geographic patterns. These data were protected through the use of password protected folders on the researcher's laptop.

3.3.3 Survey Analysis

Community mapping and survey participants were identified using only numerical identifiers. All survey responses were coded to allow for analysis. The data from the survey were inserted into Origin Pro software for statistical analysis. All data were tested for normality and found to be non-parametric, so appropriate testing was used for analysis.

The data from the Likert scale questions in the survey was analyzed by determining the median, mode, range, and percentage of the responses. When the median and mode responses differed, the data were graphed to see the visual differences in the data. The yes/no questions and multiple response questions were analyzed looking at the percentages of responses.

There were three questions focused on flood experience: one for address, one for exterior, and one for neighborhood. These three questions were also used to determine whether participants had experienced flooding at any location by marking down whether participants had experienced flooding at any of the locations asked about. Questions about experiencing address damage or neighborhood disruption were used to determine whether survey participants had experienced any type of damage or disruption as well as the type of damage or disruption experienced. This was done by marking down whether any type of address damage or neighborhood disruption was experienced. Responses focused on flood frequency were averaged and had the median determined for the provided number results. It was found that some individuals provided numbers when asked how many times they had been flooded, while other participants provided annual numbers of flood experiences. Only the numbers were used in determining the average and median number of floods experienced.

All the data from the open-response section of the survey was first analyzed in Microsoft Excel through thematic coding (Franklin et al. 2014; Mashi et al. 2020; Xie et al. 2022). Each open response question had the results looked at for common phrases and ideas. The common phrases and ideas were the questions' themes. The frequency and percentage of the theme was determined.

For the first question, exploring the definition of flooding, three of the themes: 'Too Much Water,' 'Water Where it Normally is Not,' and 'Damage or Disruption' were determined before the participant responses were examined. The three pre-determined themes were developed from the FEMA definition of flooding and were used to determine if participants were aware of the full definition of flooding using the FEMA definition. While the results of the definition of flooding question were compared to the pre-determined themes, other themes were developed from common responses that were not part of these pre-determined themes. The question focused on the definition of flooding was the only question to use pre-determined themes. For all other open-response questions, the themes came from common ideas in the participant answers.

Survey responses were used to determine a Composite Flood Awareness score. Scoring was completed using six questions relating to flood awareness and adding the numerical results together from the coded responses. For the question "Do you reside in a flood zone", the code used to provide points was Do Not Know = 0, No = 1, Yes = 2. For the question about characteristics increasing the likelihood of flooding, the code used to provide points was no characteristics identified = 1 and any characteristics provided = 1. For the four Likert scale questions, the code used was Strongly Disagree = 1, Disagree = 2, No Opinion = 3, Agree = 4, and Strongly Agree = 5. Based on the potential range of results, the numerical scales for what

would constitute as Low Flood Awareness, Medium Flood Awareness, and High Flood Awareness was determined (Tables 3.6 and 3.7).

Table 3.6 Composite Flood Awareness Level Questions and Points (Source: Created by Author).

Question	Potential Number of Points
Do you reside in a flood zone?	0-2
Are there specific characteristics of your neighborhood (within one mile of your address) or home that you feel increases your likelihood of flooding?	1-2
Your current address floods more frequently than other properties in Bowling Green.	1-5
Some areas of Bowling Green flood more frequently than others	1-5
You personally have been affected by flooding more than others since you have lived at your current address.	1-5
The amount of flooding has increased since you have started living at your current address.	1-5

Table 3.7 Composite Flood Awareness Level Ranges

Flood Awareness Level	Point Range
Low	≤11
Medium	12-18
High	≥19

The coded responses were used to complete statistical differences based on flood experience, gender, age range, or race (Hopkins and Warburton 2015; Mashi et al. 2020). Flood address damage was also used in testing for statistical differences as a part of the flood experience. Flood experience, gender, age range, or race were tested against flood awareness,

flood policy effectiveness, and karst perceptions. All data was tested in Origin Pro using the Mann-Whitney U Test except when the age ranges were used; then the Kruskal-Wallis Test was used. Table 3.8 shows the topics and test used in more detail. A P-Value of 0.05 was used for significance testing.

Table 3.8 Survey Analysis Statistical Tests (Source: Created by Author).

Analytical Test	Tested Topics
Mann-Whitney U Test*	Flood Experience and Demographics
Mann-Whitney U Test*	Flood Zone and Demographics
Mann-Whitney U Test*	Flood Policy Effectiveness and Demographics
Mann-Whitney U Test*	Composite Flood Awareness Level and Demographics
Mann-Whitney U Test	Flood Zone and Address Damage
Mann-Whitney U Test	Address Damage and Personally Feeling Affected by Flooding More than Others
Mann-Whitney U Test*	Karst Perceptions and Demographics

* Kruskal-Wallis Test was used with age comparisons.

The survey asks participants for their address. A buffer of one mile to match the definition of flooding in the neighborhood questions in the survey was created from the addresses to allow a general area to be used to explore the data spatially without showing participant addresses. These addresses were mapped using ArcGIS Pro to create a map of the neighborhood represented by survey responses. The FEMA Flood Zone layer, a Karst GIS layer, and a Warren County Sinkhole layer were brought into ArcGIS Pro to use with analysis as well.

Layers were then created showing where no flooding was reported, where both address and neighborhood flooding was identified, and where only neighborhood flooding was identified. Each of these layers were used to create their own maps. Then, these layers were compared using the intersect tool to find the areas the different layers had in common. The tabulate intersection tool was used to determine the percentage of the overlap between the layers.

The no flooding and both neighborhood and address flooding layer were intersected, the neighborhood flooding and no flooding layer were intersected, and the neighborhood flooding and neighborhood and address flooding layers were intersected and had the tabulate intersection tool used.

Next, a layer was created using the participants who had marked that they lived in the flood zone. A spatial intersection was run to determine how many of the survey respondents lived in the flood zone using the FEMA Flood Zone layer. When none were found using those who marked they lived in the flood zone, the spatial intersection was run again on all of the addresses to identify the one address that was within the flood zone. The layer with the neighborhood buffers of those who marked they lived in the flood zone and the FEMA Flood Zone layer had the tabulate intersection tool run on it to determine the overlap between the FEMA Flood Zone and those who believed they lived in the flood zone.

A layer was created using the survey respondents who marked that they could not identify karst features that affected their address within their neighborhood (one mile of their address). The tabulate intersection tool was run to determine the percentage of overlap between the created layer of no identified karst features affecting their address and the Karst GIS layer. A second tabulate intersection analysis was then run to determine the percentage of overlap between the layer of no identified karst features affecting their address and the Warren County sinkhole layer.

Another layer was created using the survey respondents who identified poor drainage as a characteristic increasing the likelihood of flooding. The Near tool was used to determine the minimum, maximum, mean, and median distances between all addresses and sinkhole locations, between addresses with neighborhood flooding reported and sinkhole locations, and between

addresses with both address and neighborhood flooding reported and sinkhole locations. The Near tool was also used to determine the minimum, maximum, mean, and median distances between addresses with address and neighborhood flooding reported and flood zones and between addresses with neighborhood flooding reported and flood zones.

3.3.4 Cognitive Mapping Activity

Participants were able to take part in a cognitive mapping activity. In this activity, participants were able to map areas where flooding occurs within their own communities. The cognitive mapping activity used Arc FieldMaps on an iPad for participants to map areas of flooding in their perspective. The map for the cognitive mapping activity contains layers showing the boundary of Warren County, labeled major roads, and labeled landmarks. First, participants were asked to find their address using the provided map to help provide familiarity with the map and Arc FieldMaps. Participants then "drew" where they believed flooding occurred in their communities on the provided map and were able to scroll into and out of locations as they needed. While the use of a pre-made map limited cognitive mapping, it ensured these modified cognitive mapping activities could be compared to each other (Chowdhooree et al. 2018). The data from the cognitive mapping exercise was mapped to determine overlap with the FEMA Flood Zone. The results of the cognitive mapping activity is in Appendix C.

3.3.5 Semi-Structured Interviews

Semi-structured interviews were completed with eight flood professionals; these were individuals who are involved in decision-making in flood management and policy creation affecting Warren County, as well as those involved in flood response and hazard planning (Tyler et al. 2019). For this study's purpose, flood professionals were those who dealt with flooding in the City of Bowling Green, Warren County, Barren County Area Development District, or the

state of Kentucky. Interviewing flood professionals from the city, county, region, and state levels provided a way to explore the layers of flood management and policy affecting flooding in Warren County. Respondents were identified by searching for individuals who deal with flooding, and then each participant was asked for recommendations for more experts to interview at the end of each interview. Participants were asked about flood policy, flood awareness, and their own role in dealing with flooding (O'Sullivan et al. 2012; Hopkins and Warburton 2015; Wells et al. 2016; Paul and Milman 2017; Hewawasaj and Matsui 2022).

The semi-structured interviews were held over Zoom and ranged from 14 and 59 minutes in length. Questions for the semi-structured interviews are shown in Appendix B. Each semi-structured interview was recorded and then transcribed. Notes were also taken during and immediately after the interviews and were stored with the interview's transcript. Dovetail Software was utilized in determining themes in interviews and the frequency of each theme. The theme from these interviews were compared to the themes from the surveys in order to compare professional's perception and awareness of flooding in karst areas and a non-professional's perception and awareness of flooding in karst areas.

3.3.6 Comparisons of Data

Data collected from these various methods (Table 3.9) were compared to each other statistically and spatially as appropriate. Table 3.10 shows the comparisons by data source. The survey data results and themes and the interview data themes were compared to each other to determine common views and differences between awareness of flooding and flood policies. The survey data results and themes were compared to the FEMA Flood Zones and the karst GIS data through ArcGIS Pro mapping and tabulate intersections to determine the percentage of overlap between the data sources. Comparisons between the survey data and the FEMA Flood Zones and

the survey data and the karst GIS data were completed to compare awareness and perceptions from the surveys to the actual flood zones and karst data. The cognitive mappings results and the FEMA Flood Zones were compared to see if there was overlap between the official flood zones and areas where participants are aware of flooding.

Table 3.9 Sources of Data to Compare (Source: Created by Author).

Data	Data Source	Data Description	Data Type
Participant Survey Data	Surveys	Survey questions including an address question	Excel Sheet
Sinkhole GIS Data	ArcGIS Online Barren River Area Development District	Mapped data of sinkholes within BRADD provided by BRADD	Shapefile
Karst GIS Data	Kentucky Geological Survey	Mapped Kentucky Karst Data	Shapefile
National Flood Hazard Layer GIS	FEMA	Mapped FEMA Flood Zones	Shapefile
Semi-Structured Interview Data	Interviews	Recorded interviews, interview notes, and interview transcriptions	Word Documents, Excel Sheet
Cognitive Maps	ArcGIS Field Maps	Maps of where flooding occurs done by community members	Shapefiles

Table 3.10 Data Comparisons (Source: Created by Author).

Data Source 1	Data Source 2
Survey Data Results and Themes	Interview Data Themes
Survey Data Results and Themes	FEMA Flood Zones
Survey Data Results and Themes	Karst GIS Data
Cognitive Mapping Results	FEMA Flood Zones

3.3.7 Limitations

There were several limitations to the methodology of this study. Relying on volunteers, as this research did, introduced bias into the data as those who volunteer to participate and those who do not volunteer may have systemic differences between them (Salkind 2010). The potential participants were only those who know the survey exists, meaning the survey distribution method had the potential to limit responses to the survey. Partnerships, snowball sampling, and a variety of distribution methods combated this limitation to a degree, but this limitation could not be fully removed, only minimized. Sharing of the survey through social media introduced bias into the results as participants who may have been more interested in flooding than a community member or participant may have otherwise been took and shared the survey. Disseminating the survey through multiple sources and in a variety of methods from digital surveys on social media to physical copies at tabling events reduced this bias.

Another limitation to these methods was the subjectivity of the research with many of the used questions and terms being subjective with their meanings prescribed by individual experiences. The surveys were validated to minimize potential biases. Defined phrases were used to limit this subjectivity that individuals may have perceived differently to ensure common definitions were used when answering questions in the survey. A mix of Likert-scale questions and open-response questions also limited the influence of the subjectivity as the open-response questions allow for respondents to provide explanation as to how the participant approached the question. The validation process helped to minimize the risk from acquiescent response bias. The acquiescent response bias is a tendency of respondents to agree with questions in a survey regardless of whether they actually agree with the statement (Salkind 2010). The validation process helped to recognize and minimize the risk of this bias. This method was also limited in

that it can only represent a snapshot in time. Awareness can quickly change, necessitating more research into awareness and how awareness changes over time. When research is done on awareness in an area, the research will have to be completed again to ensure the information remains up to date and accurate.

3.4. Results and Discussion

3.4.1. Demographics

A total of 119 responses were recorded from the survey from Warren County. Table 3.11 shows the demographics for the survey respondents compared to Warren County demographics. The age distribution of respondents is spread out evenly between the age ranges. The minimum duration of residence was one month, the maximum duration of residence was 49 years, with the average duration of residence being 9.5 years. The average duration of residence at a survey participant's current address differed depending on whether the respondent was an owner (12.5 years) or a renter (3.7 years).

Table 3.11 Respondents and Warren County Demographics (Source: Created by Author).

Demographic Factor	Warren County	Survey Respondents
American Indian and Alaska Native Alone	0.4%	0.9%
Asian Alone	5.4%	3.4%
Black or African American Alone	9.6%	9.4%
Native Hawaiian and Pacific Islander Alone	0.5%	0.9%
White Alone	73.9%	76.1%
Other Race:	3.8%	0.9%
Two or More Races	6.3%	1.7%
Hispanic or Latino (Any Race)	7.0%	3.4%
Median Age	33.5	40-49
Ownership Rate	54.3%	62.8%
Percent Female	50.6%	53.8%

Addresses were provided by 77 survey respondents, equivalent to 64.7% of survey participants. Figure 3.6 displays the addresses with a one-mile buffer to match the provided definition of a neighborhood in the survey. Any use of the term neighborhood below referred to this one-mile buffer around the addresses. The large number of survey respondents in the south-east of the map corresponds to BG.

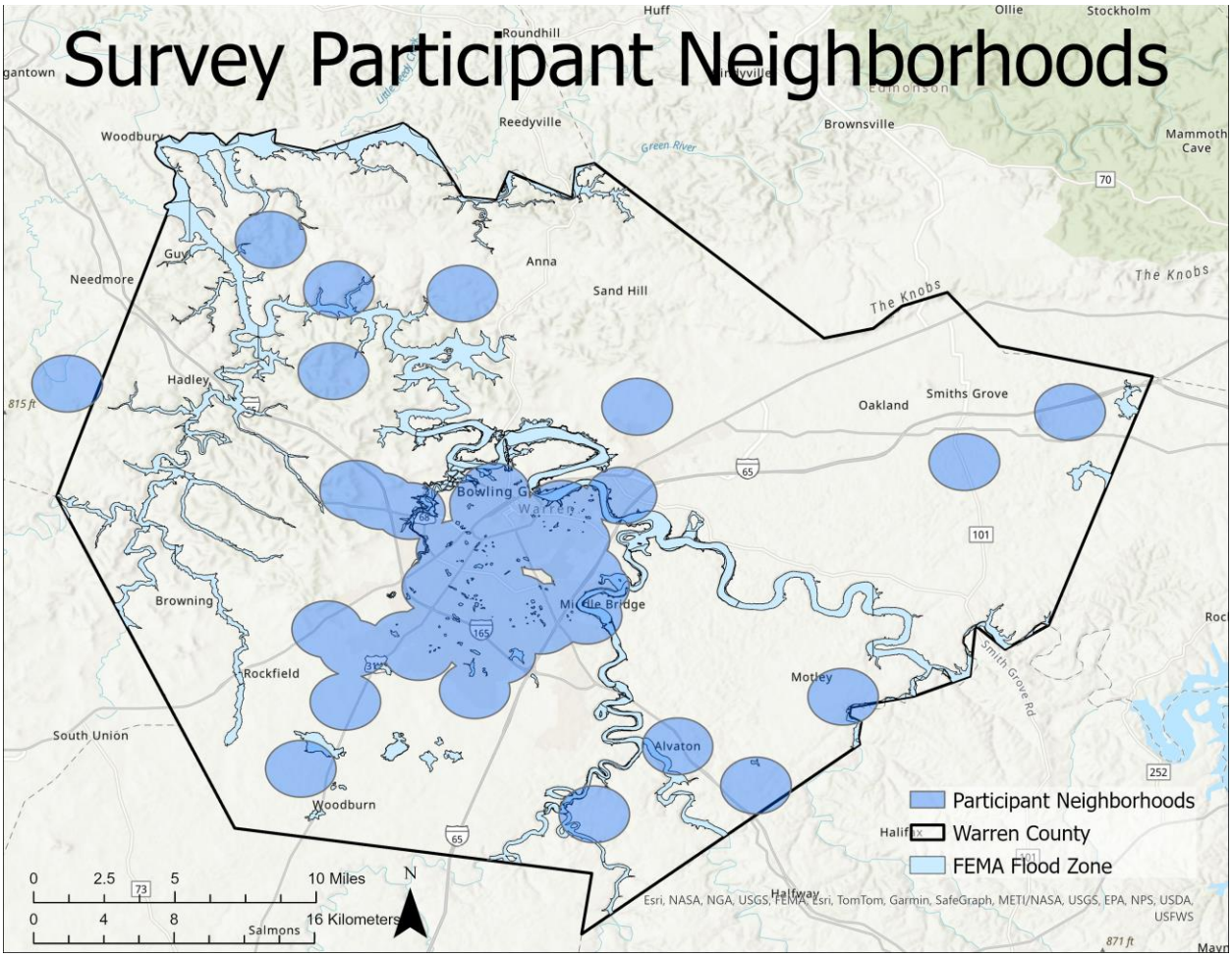

Figure 3.6. Survey Participant Neighborhoods (Source: Created by Author).

Eight participants participated in the expert interviews. Participants were from the city, county, regional, and state levels with three participants from the city, two from the county, one from the region, and two from the state. Interviews were conducted with individuals holding

roles involving floodplain coordination, planning and development, hazard mitigation grants, engineering, environmental management, and stormwater management.

3.4.2. Community Awareness of Flooding

Appendix E shows the results from the survey that were sorted into a matrix to explore potential connections between the survey responses. There were few patterns and groupings seen in the matrix. The few patterns seen in the matrix, such as the link between flood damage at addresses and flood zones, were explored. The limited number of survey responses and respondent demographics did not allow for exploring some of the groupings or patterns in the dataset.

Flooding Definition

Question 1 had survey respondents define flooding, and the coded themes are in Table 3.12. The most prevalent theme present in the definitions was 'Too Much Water,' which is present in 81% of the responses (n=90). The second and third most prevalent themes are 'Water Where It Normally Is Not' and 'Damage or Disruption,' which are present in 28.9% and 22.2% of responses, respectively. 'Drainage,' 'Rainfall,' and 'Quickly' were present in the definitions, but were not top themes.

Table 3.12 Respondent's Definition of Flooding (Source: Created by Author).

Theme	Percentage of Responses
Too Much Water	81.1%
Water Where It Normally Is Not	28.9%
Damage or Disruption	22.2%
Drainage	8.9%
Rainfall	7.8%
Quickly	4.4%

The three top themes provided in the survey respondent's flooding definitions were also the themes present in the FEMA definition of flooding. FEMA describes flooding as "a temporary overflow of water onto land that is normally dry. It is the most common natural disaster in the U.S." (FEMA 2018). An overflow of water corresponds to the 'Too Much Water' theme, the normally dry section corresponds to the 'Water Where It Normally Is Not' theme, and the 'Damage or Disruption' theme is used as a proxy for considering flooding a disaster.

The majority of survey respondents had a partial idea of what flooding is, but were not able to fully define flooding. Table 3.13 shows how many of the three themes used in the definition of flooding ('Too Much Water,' 'Water Where It Normally Is Not,' and 'Damage and Disruption') survey respondents used in their definitions of flooding. The majority of responses included one of the three FEMA themes in their definition, though few (3.3%) included all three FEMA themes. Flooding consisting of too much water was recognized by survey participants, but water where it normally is not and damage and disruption were not as widely recognized.

Table 3.13 Respondent's Correct Definitions of Flooding (Source: Created by Author).

Parts of Definition Met by Respondent's Definition	**Percentage of Responses**
0 parts	7.8%
1 part	55.5%
2 parts	33.3%
3 parts	3.3%

Characteristics Increasing Flooding

Question 11 had survey respondents identify characteristics they felt increased the likelihood of flooding in their neighborhood, and Table 3.14 shows the identified characteristics (n = 68). 'Hills/Topography' was the most commonly identified characteristic associated with flooding with 23.5% of responses, and 'Poor Drainage' was the second most common with

19.1% of responses. Karst features increasing the likelihood of flooding in neighborhoods was only identified by 5.9% of survey respondents and were identified by specific karst features, such as caves or sinkholes rather than as karst areas. Specific karst features were recognized as influencing flooding in a few locations, but karst as a whole was not recognized as affecting flooding by survey participants. The lack of surface features in karst may limit the characteristics survey participants were able to see and identify as karst features contributing to flood risk. 'Creeks' was only identified in 7.4% of responses, likely due to the lack of surface waters present in Warren County.

Table 3.14 Characteristics Respondents Feel Increase the Likelihood of Flooding in their Neighborhood. (Source: Created by Author).

Characteristic	Percentage
Hills/Topography	23.5%
Poor Drainage	19.1%
Creeks	7.4%
Karst (Cave and Sinkholes)	5.9%
Retention Ponds	5.9%
Building in High-Risk Areas	2.9%
Paved Surfaces	1.5%
No Characteristics	30.9%

Flood Zone

Question 2 asked survey participants whether they resided in a flood zone (n = 119). About 28% said they resided in a flood zone, with another 20% saying they did not know. Of the 33 survey respondents who said they resided in a flood zone, 97% provided their address, and none lived in a FEMA Flood Zone. Only one participant lived in a FEMA Flood Zone of the almost 65% of the total survey participants who provided their address, and they had identified that they did not know if they resided in a flood zone. The inaccuracy in survey participants

believing they lived in FEMA Flood Zones when they did not indicate a lack of awareness of their flood risk. Individuals' knowledge of whether they live in a flood zone is often unclear **(**Oubennaceur et al. 2022).

Addresses where survey respondents reported only neighborhood flooding were 0-0.024 km from FEMA flood zones with a mean distance of 0.007 km and a median distance of 0.005 km. Addresses where neighborhood flooding was reported tended to be close to FEMA Flood Zones. Addresses where survey respondents reported both address flooding and neighborhood flooding were 0-0.03 km from FEMA flood zones with a mean distance of 0.0075 km and a median distance of 0.0046 km. Addresses where both address flooding and neighborhood flooding occurred also tended to be close to FEMA Flood Zones. The short distance between addresses that reported flooding suggested that FEMA Flood Zones may have expanded from their current boundaries and provided another reason as to why the FEMA Flood Zone in Warren County needs to be updated.

A Mann-Whitney U test found a statistically significant (P-value = <0.0001) difference between those who experienced flood damage at their address and those who said they lived in the flood zone. Survey respondents who had experienced damage at their address were more likely to say they lived in a flood zone than those who had not experienced damage at their address. Survey participants' incorrect assessment of whether they lived in flood zones may have stemmed from experiencing flood damage at their address and determining that if they are experiencing flood damage, they must be living in a flood zone. The lack of updates to FEMA flood maps (since 2007) could also play a role with the changes in flooding since the last update to the maps, meaning some of these areas may be in the flood zone when the next update occurs.

In fact, only 5% of the areas where neighborhood and address flooding were reported overlaps with a FEMA Flood Zone.

A separate Mann-Whitney U test found there is a statistically significant (P-value = 0.01424) difference between race and survey participants saying they live in the flood zone. Fewer white survey respondents said they lived in the flood zone than minorities respondents. This finding supports Cooper (2022) who found that areas of BG with variables including higher percentages of people of color were associated with higher flood vulnerability levels. Minorities and marginalized communities were also associated with higher perceptions of flood risk than non-minorities, and this association may have led to a larger number of minority survey respondents saying they lived in flood zones (Harlan et al. 2019; Oneto and Canepa 2023).

Two of the interviewees also brought up the issue of outdated and inaccurate flood maps. Both interview participants who discussed issues with flood maps focused on BG. The city interviewees discussed the slow and infrequent updates of the flood maps with cities growing faster than maps are updated. This can cause issues as areas that were not recognized as part of the flood zone can quickly become an area that would be recognized as part of the flood zone if updated occurred more frequently due to growth and development. Specifically, one of the interviewees points to issues with FEMA Flood Maps in Warren County not only being the infrequent updates, but also the difficulty of creating flood maps in karst areas where a lot of the sinkholes are not mapped as part of the flood zone.

The cognitive mapping activity also showed activity participants' awareness of flooding. Figure 3.7 shows the areas identified by the three cognitive mapping participants. The lack of activity participants was a large limitation of these data. Potential activity participants tended to prefer completing a survey instead of completing the mapping activity, likely due to a lack of

familiarity with the mapping activity. Having more community members participate in similar activities where they can show visually where flooding is occurring may be helpful. As seen in Figure 3.5, many of the areas identified were near to the FEMA Flood Zones but were not in them. This was likely due to the age of the FEMA Flood Maps in Warren County (2007), and the amount of growth and development Warren County had undergone since 2007, affecting where flooding occurred. The identified areas of flooding being near to but outside of the FEMA flood zones suggested that the area that should be in the FEMA flood zones may have expanded from their previous boundaries to include areas adjacent to the current FEMA flood zones.

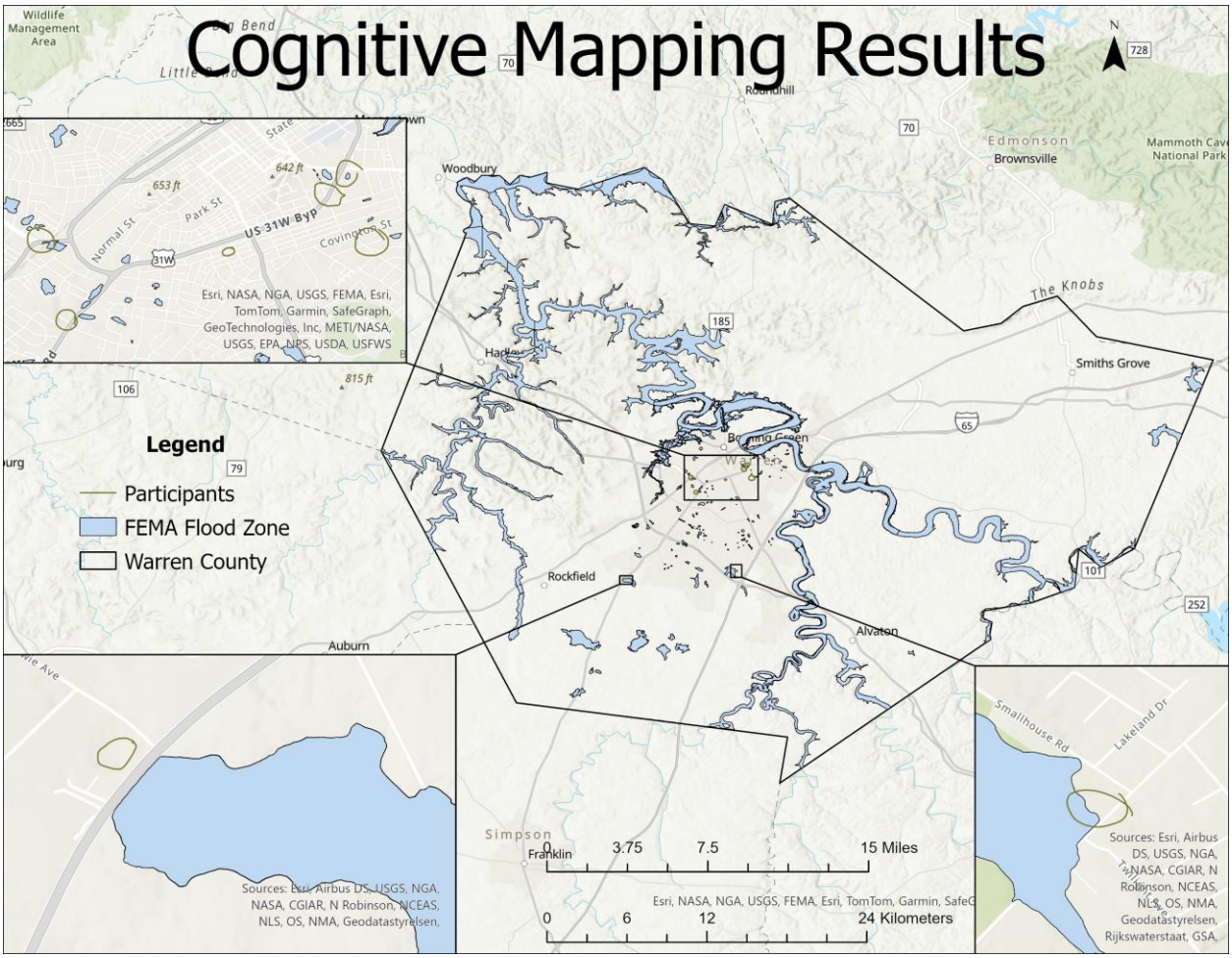

Figure 3.7 Cognitive Mapping Results (Source: Created by Author).

Composite Flood Awareness Levels

Composite Flood Awareness Levels provided an overview of survey respondent's flood awareness (Table 3.15). Overall, the majority of survey respondents had a low or medium Flood Awareness Level with only a few having a high Flood Awareness Level, which meant there was a need to increase flood awareness in Warren County. Previous research found that individuals who were interested in specific topics were more likely to take surveys focused on those topics (Groves et al. 2004; Saleh and Bista 2017). Based on the previous research, it is likely that those who were interested in flooding were more likely to participate in the survey, introducing bias into the survey responses. Even with the higher likelihood of being interested in flooding, few survey participants had a high Flood Awareness Level, indicating survey respondents may have been less aware of flooding than they believed they were.

Table 3.15 Composite Flood Awareness Levels (Source: Created by Author).

Composite Flood Awareness Level	**Percentage**
Low	27.7%
Medium	64.7%
High	7.6%

The Composite Flood Awareness Levels were supported by the results from the expert interviews. Half of the interviewees focused on the lack of flood awareness discussed how community members did not understand their flood risk unless it was immediately after a flood, community members especially did not understand the role the karst system plays in flooding, and how the karst flooding was less direct than other types of flooding making individuals less aware than they should be. All of which led to the idea that flood awareness is lacking. The other

half of the interview participants focused on a limited amount of flood awareness existing with more awareness needing to be raised. A lack of flood awareness in the interviews was similar to the Low Flood Awareness Level in the survey results. Some flood awareness in the interviews was similar to the Medium Flood Awareness Level in the survey results. Both the survey results and the interviews agree that there is more work needed to increase flood awareness in Warren County.

Differences in the Composite Flood Awareness Level due to race, age, gender, and ownership status were tested for as all three were connected to flood awareness levels in other studies. No statistically significant differences were found between flood awareness and race, age, or ownership status in this study. This differs from studies where older individuals tended to perceive higher flood risks, minorities were more likely to perceive higher flood risks, women tended to perceive higher flood risks, and property owners were more likely to perceive higher flood risks (Grothman and Reusswig 2006; Kellens et al. 2013; Lechowska 2018; Harlan et al. 2019). The lack of statistically significant differences may be a result of a limited number of survey participants and the complexity of flooding in karst areas.

Overall, a few major ideas were found when exploring flood awareness in Warren County. Few survey participants were able to fully define flooding, indicating a lack of knowledge of what constitutes a flood. A lack of awareness of whether survey participants lived in a flood zone was present with connections between participants saying they lived in the flood zone and being a minority or experiencing damage from flooding at their address. Both survey participants and interview participants agreed that respondents had a low to medium Composite Awareness Flood Level, meaning there is opportunity to increase flood awareness in Warren County. Survey participants may be less aware of flooding than they believed they were,

indicating a need to increase flood awareness even among those who may have more familiarity with flooding. Results from survey participants, interview participants, and cognitive mapping activity participants all suggested that the FEMA Flood Maps needed to be updated, particularly with potentially expanded flood zones encompassing identified areas of flooding near to the current flood zones.

3.4.3. Awareness of Flooding and Karst Features

Karst Features

Flooding is affected by the landscape it takes place in; this section explores flood awareness set in a karst area. Question 20 asked survey participants to identify karst features within a mile of their address; 84% of respondents were able to (n=119). Table 3.16 shows a breakdown of the type of karst features identified. The two most common types of karst feature identified were caves and sinkholes at 32.4% and 32.0%, respectively; these tend to be some of the most well-known karst features in research (Nedvidek 2014). Question 21 then asked survey respondents if they could identify karst features that directly affected their residence with only 21.1% of respondents being able to do so (n=114).

Table 3.16 Karst features Within a Mile of Participant's Address (Source: Created by Author).

Type of Karst Feature	Percentage of Respondents
Cave	32.4%
Sinkhole	32.0%
Spring	18.2%
Sinking Stream	13.6%
Other	2.8%

Karst's Effect on Addresses

Figure 3.8 displays where survey participants felt karst did not affect their address. There was a large amount of karst and sinkholes shown in Figure 3.8, in fact, 90.4% of the area where

survey participants felt karst did not affect their address overlapped karst areas. It was unlikely that survey participants were in an area where karst was not present and able to affect a participant's address.

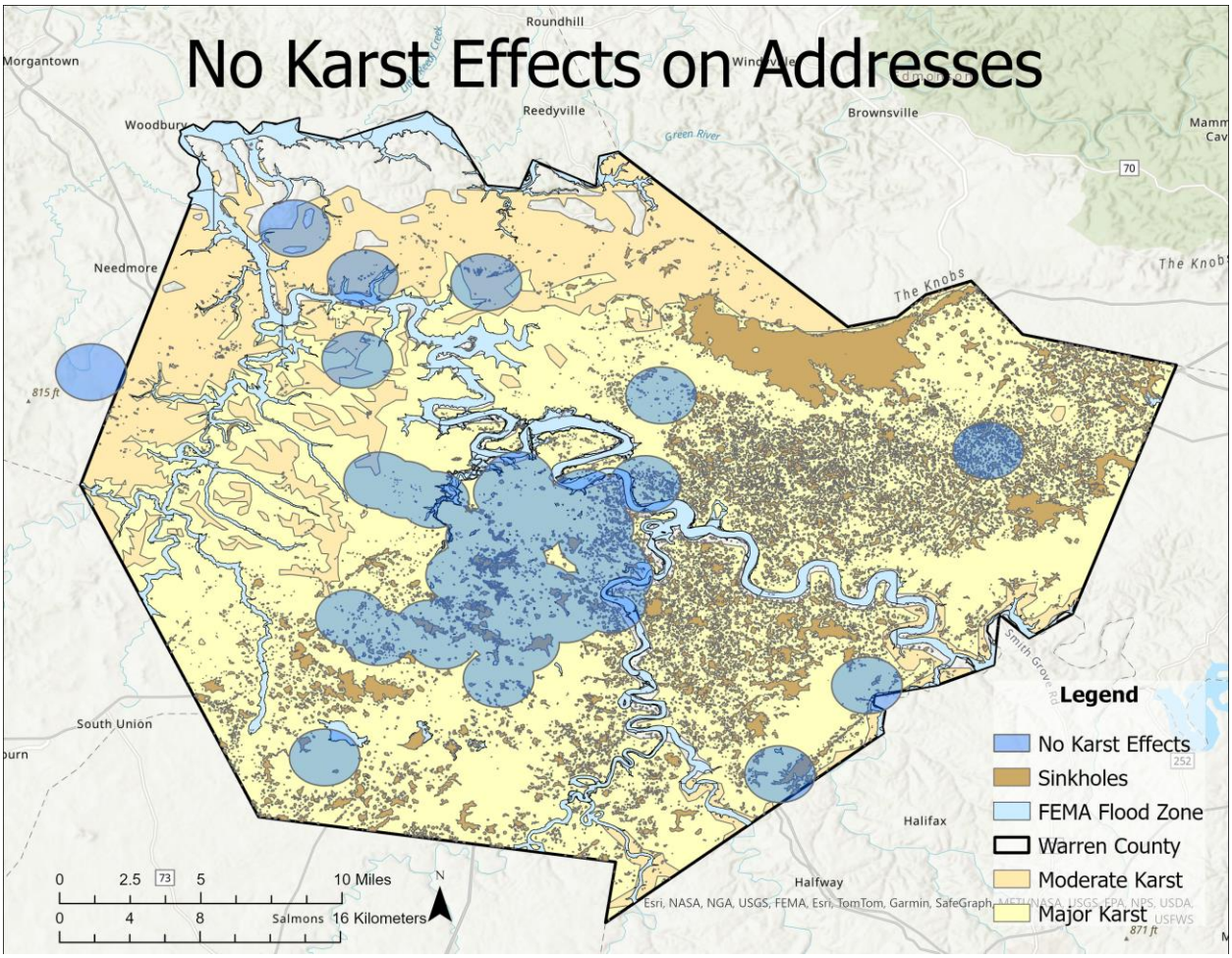

Figure 3.8. Area Where Respondents Feel There is No Karst Effecting Addresses (Source: Created by Author).

Sinkholes and Flooding

Sinkholes, specifically, are often associated with flooding (Kemmerly 1981; Kuehn and Weisenfluh 2003; Zhou 2007; Naughton et al. 2017; Cooper 2022) and 8.9% of the area where survey respondents feel karst does not affect their address overlaps sinkholes. There are many small sinkholes overlapping the area, limiting the amount of overlap between sinkholes and the

area where survey participants feel karst does not affect their address. The distance between the provided survey addresses and sinkholes was determined with the range of distances between addresses and sinkholes being 0 km-0.017 km, a mean distance of 0.002 km, and a median distance of 0.001 km. Sinkholes and survey addresses tended to be near to each other, reducing the likelihood that addresses were not affected by nearby sinkholes.

Looking specifically at the relationship between sinkholes and flooding in Warren County, addresses that experienced both address and neighborhood flooding were located 0.0003 km-0.006 km from sinkholes with a mean distance of 0.002 km and a median distance of 0.001 km. Addresses that experienced only neighborhood flooding were 0-0.018 km from sinkholes with a mean distance of 0.0026 km and a median distance of 0.005 km. Addresses that experienced flooding at either the address or neighborhood flooding were nearby sinkholes. The lack of distance between addresses that experienced flooding and sinkholes reduced the likelihood that there was no connection between the sinkholes and the flooding. The lack of distance between addresses that experienced flooding and sinkholes agreed with Cooper (2022), who found that flood prone areas and sinkholes were strongly associated with known in BG and Warren County.

Karst and Flooding Disconnect

Survey respondents were able to recognize karst features were nearby their addresses, but the majority did not make a connection between the karst features and effects on their address including flood effects. This is supported by only 5.9% of survey participants recognizing karst as a characteristic that increased the likelihood of flooding, even though 21.1% of participants recognized karst features as affecting their address, and 84% of respondents recognized karst features near their address. Of survey participants who provided a reason for an increased

likelihood of flooding, 86.6% later identified a karst feature within one mile of their address, and 23.5% identified that their residence was directly affected by a karst feature. Survey participants did identify Hills/Topography and Poor Drainage as characteristics that increased their likelihood of flooding but did not connect these to karst; this could be because of a lack of understanding or knowledge of the role karst plays in the drainage systems and topography of Warren County preventing survey respondents from connecting karst features to the drainage system or topography (Bonacci et al.2006; Zhou 2007; Kovacic and Nastaša 2010). Survey participants understood that karst existed around their addresses but did not connect the karst features with flooding or as affecting their residence. Overall, there is a disconnect between the idea of karst nearby and karst being related to flooding issues.

Karst and Flooding Likert Statements

Results for Questions 22 and 23 are in Table 3.17. Both statements focused on the relationship between karst landscapes and flooding had responses ranging from Strongly Disagree to Strongly Agree. Survey respondents most commonly agreed that flooding in karst landscapes can differ from flooding in non-karst landscapes. Survey participants also most commonly agreed that karst landscapes increase flood risk in their community. While there is a disconnect between the idea of karst being nearby and karst being related to flooding issues, when asked directly about the relationship between karst and flooding, survey respondents tended to agree that karst landscapes influenced flooding in karst areas.

Table 3.17 Karst Flood Awareness and Perceptions (Source: Created by Author).

Statement	n	Minimum	Maximum	Mode	Median
Flooding in karst landscapes can differ from flooding in non-karst landscapes.	118	1	5	4	4
Karst landscapes increase flood risk in your community.	116	1	5	4	4

Relationship Between Karst and Flooding

The relationship between karst features and flooding was discussed in five of the eight interviews: all three city-level interviews and both county-level interviews. These five interviewees discussed the lack of understanding of the relationship between karst and flooding by community members. One city-level interview participant argued that "because it's not a riverine system, they have zero awareness at all that this is a karst system that occasionally it can be fully charged and ultimately surcharge." Differences between flooding in karst landscapes and non-karst landscapes and how these differences meant less flood awareness in a karst landscape than a non-karst landscape was discussed. A county-level interview participant explained that "there is a whole lot of room for explaining karst flooding. You know we have such a unique feature here that so many people don't know, that either don't know about it at all or they don't know the extent of it." Community members lack understanding of flooding in karst landscapes; an idea that agreed with the disconnect found between recognizing karst features and recognizing the influence karst features had on flooding.

A Mann-Whitney U Test found that there is a statistically significant (P-value = 0.03673) difference between White and minority views of whether flooding in karst landscapes can differ from flooding in non-karst landscapes. These differences focus on how White survey participants tended to more strongly agree that flooding in karst landscapes can differ from flooding in non-karst landscapes. Minorities tended to have a higher risk perception than non-minorities, which is common in many areas, so this difference is interesting and may suggest that an unexamined factor exists that explains why White survey participants tend to more strongly agree with this statement than minorities (Kellens et al. 2013; Lechowska 2018; Harlan et al. 2019). Another Mann-Whitney U Test found that there are no statistically significant differences between ages

and views on whether flooding in karst landscapes can differ from flooding in non-karst landscapes. Two more Mann-Whitney U Tests found no statistically significant differences between race or gender and the view that karst landscapes increase flood risk in communities.

Overall, a few connections were found when exploring flood awareness and karst features in Warren County. The majority of participants identified nearby karst features but did not make a connection with flooding in karst areas, showing a disconnect between identifying karst and connecting karst to flooding. Sinkholes were also near addresses where flooding was reported, indicating a potential connection between flooding and sinkholes and supporting Cooper (2022) who found a connection between flooding and sinkholes in BG and Warren County. Survey respondents and interview participants agreed community members did not understand the relationship between karst features and flooding while acknowledging that differences existed between flooding in karst areas and flooding in non-karst areas.

3.4.4. Flood Awareness and Flood Experience

Flood awareness has often been associated with flood experience (Weinstein 1989; Raška 2015; Lechowska 2018; Harlan et al. 2019; Kellens et al. 2013; Fanta et al. 2019; Maryati et al. 2019; Mashi et al. 2020; Ferreira et al. 2021; Ge et al. 2021; Oubennaceur et al. 2022; Bhatti et al. 2023). Flood experience increasing flood awareness was also mentioned in half of the interviews. As can be seen in Table 3.18, 63.9% of survey participants responded that they had experienced flooding at either their current address, exterior property, or within their neighborhood (1 mile of their address) in Warren County (Questions 3, 7, and 8). The amount of flooding reported by survey respondents depended on location with 34.2% reporting flooding at their address (n=117), 49.6% reporting flooding on their exterior property (n=115), and 57.4% reporting flooding in their neighborhoods (n=115). The further from a participant's addressed

asked about, the more survey respondents had reported flooding with more survey participants reporting flooding in their neighborhoods than at their address.

Table 3.18 Survey Participant's Flood Experience (Source: Created by Author).

Topic	Percent Yes	Percent No
Experienced Flooding (Address, Exterior, or Neighborhood)	63.9%	36.1%
Experienced Flooding at Current Address	34.2%	65.8%
Exterior Property at Current Address Experienced Flooding (Flooded Roads, Yards, Etc.)	49.6%	50.4%
Areas Within the Neighborhood (1 mile) Experienced Flooding	57.4%	42.6%

Based on Groves et al. (2004) and Saleh and Bista (2017), it was expected that those who were more interested in flooding took the survey. With the higher interest in flooding, there was a potential for bias with those who experienced flooding being more likely to take the survey. While 63.9% of survey respondents had experienced flooding, a large proportion of respondents had not experienced flooding, providing views from both those who had experienced flooding and those who had not experienced flooding.

Two Mann-Whitney U tests found no statistically significant differences between race or ownership status and flood experience for survey respondents. This differed from other studies that found marginalized communities, such as minorities tended to have a higher flood risk than non-marginalized communities and live in areas of higher risk (Oneto and Canepa 2023). Finding no statistical difference between flood experience and race was unexpected and may be due to the limited number of survey responses and the locations of the survey respondents.

A total of 33 survey participants reported the number of floods they experienced at their address, with both the average and median number of floods experienced at an address being

three floods. Some survey participants did not report a specific number of floods experienced at their current address, but instead reported annual floods or a specific number of floods per year showing consistent repetitive flooding at some properties. From the responses, 70% of those who have experienced flooding at their address have experienced multiple flooding events. For the majority of the survey respondents who experienced flooding at their address, they had multiple flooding events rather than one-time flooding events.

A total of 49 survey participants reported the number of floods they experienced in their neighborhood, with the average number of floods experienced in a neighborhood being three floods and the median number of floods experienced in a neighborhood being 2.5 floods. Some survey participants did not report a specific number of floods experienced in their neighborhood, but instead reported annual floods, a specific number of floods per year, or flooding occurring every time, there is a "significant rain flooding." When survey respondents reported an annual number of floods, it showed consistent repetitive flooding in some neighborhoods. Of those who have experienced neighborhood flooding, 71.2% experienced multiple flooding events.

Understanding reported repetitive flooding events is important; this includes knowing if these flood events were reported to the appropriate authorities. Whether survey respondents understood who should be informed and how to inform the appropriate authorities must also be understood. Perspectives of who was responsible for addressing flooding issues is addressed more in depth later but ensuring that the topic of who was responsible for flooding, as well as how to report flooding issues is understood by community members is needed, especially with the knowledge that some survey participants are reporting consistent repetitive flood events both at their address and in their neighborhood.

Figures 3.9, 3.10, and 3.11 illustrate the spatial spread of flooding reported by survey participants in Warren County. *Neighborhood and address flooding* was referred to as general flooding below. The area where *general flooding* occurred was the smallest of the three maps and was concentrated around BG. The area covered by just *neighborhood flooding* was larger than the area covered by *general flooding*, showing that there were more survey respondents that have experienced just *neighborhood flooding* than participants who experienced *general flooding*. The largest area is covered in the *no flooding* map, where survey participants reported *no flooding*. In all three maps, the majority of overlap occurs in the vicinity of BG.

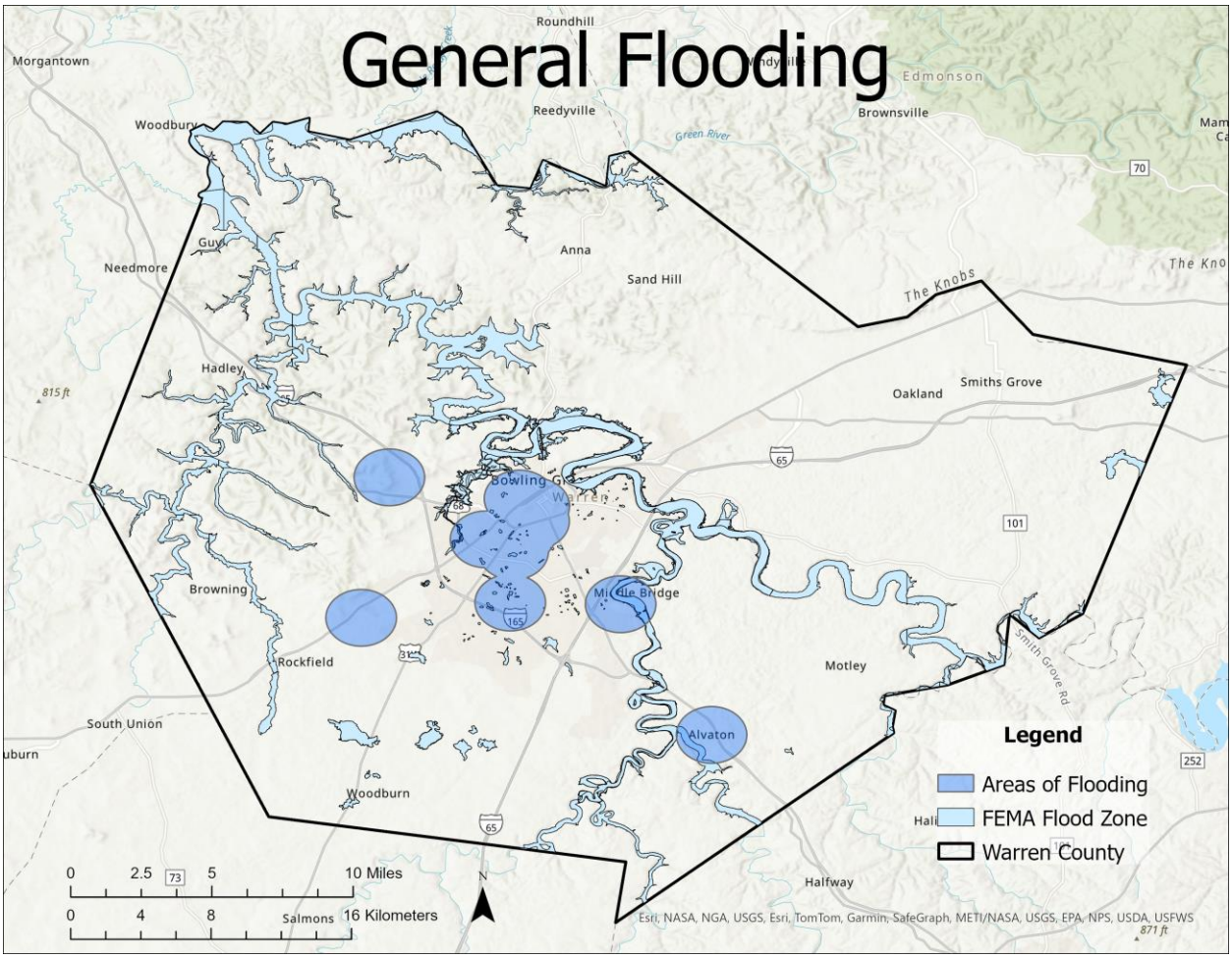

Figure 3.9. General Flooding. (Source: Created by Author).

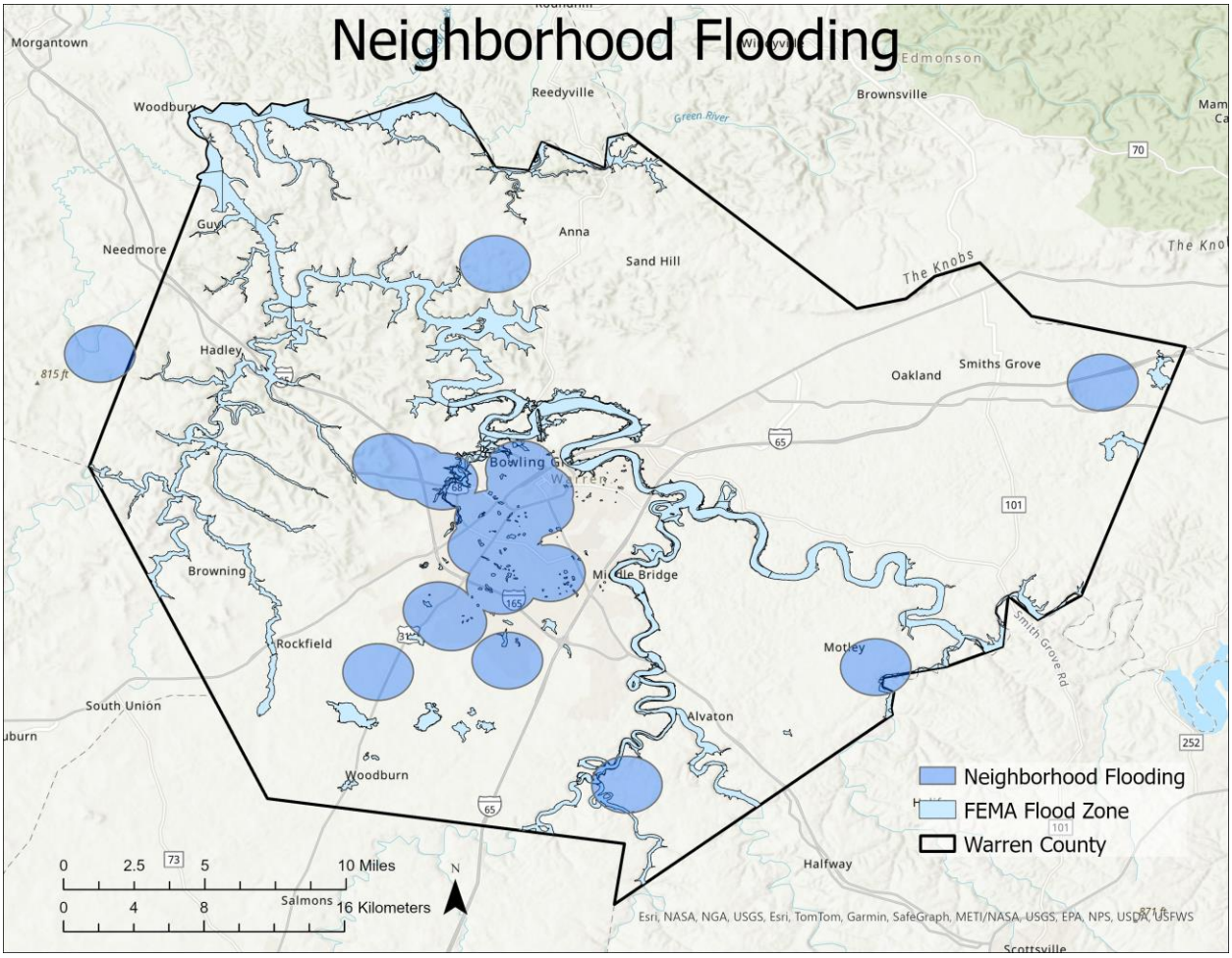

Figure 3.10. Only Neighborhood Flooding (Source: Created by Author).

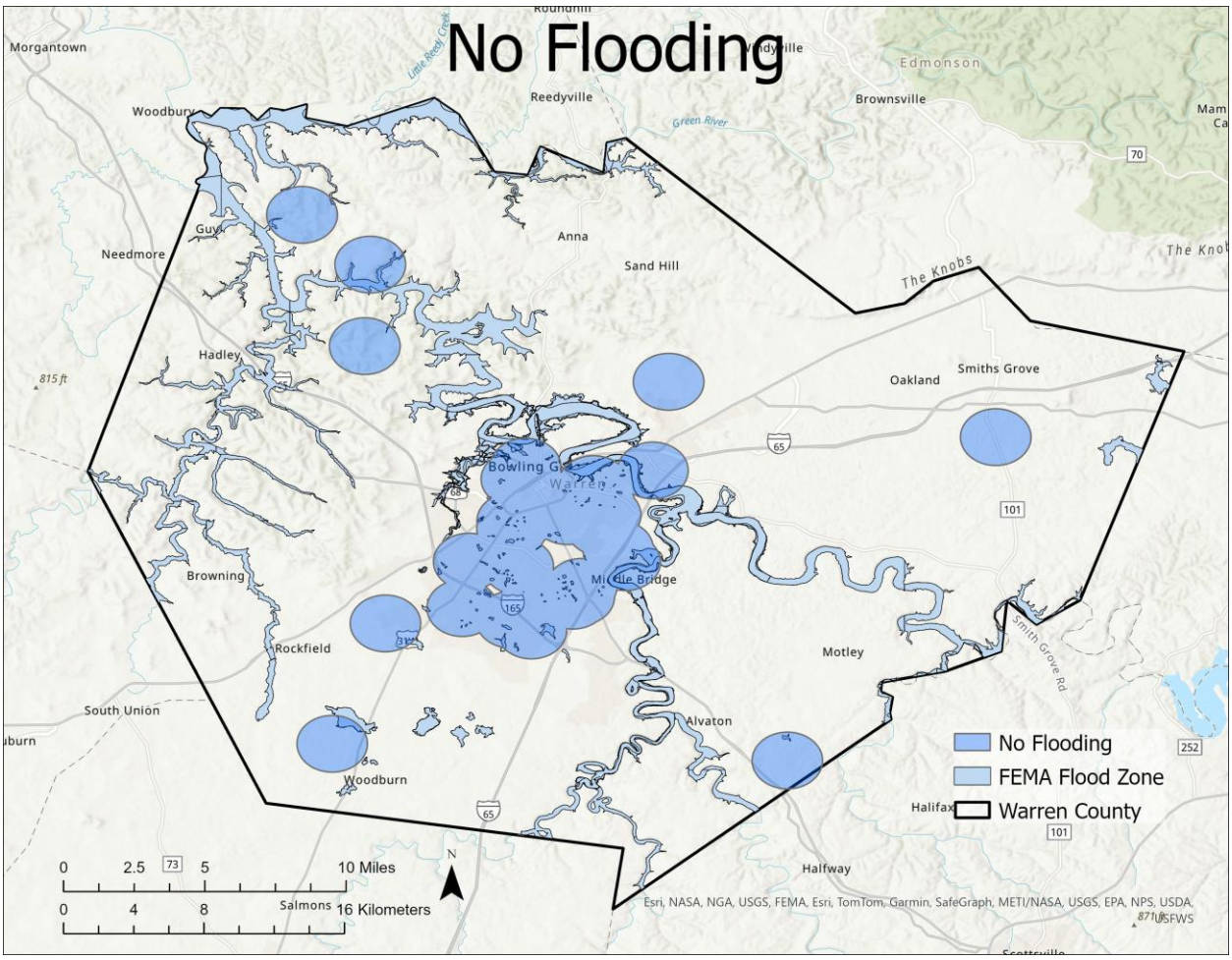

Figure 3.11. No Flooding (Source: Created by Author).

Areas close to each other can have very different flooding experiences, because of the complexity of the karst system. The differences in flooding experiences can be seen through the maps in Figure 3.12, 3.13, and 3.14 which showed overlapping areas between the maps in Figure 3.9, 3.10, and 3.11. Figure 3.12 displayed the areas of overlap between only *neighborhood flooding* and *general flooding*; while the entire area experienced *neighborhood flooding*, some addresses reported flooding while others did not. Areas of overlap between *neighborhood flooding* and *no flooding* are shown in Figure 3.13, indicating where some survey participants have experienced *neighborhood flooding*, while other respondents have experienced *no flooding*.

Figure 3.14 shows areas of overlap between *general flooding* and *no flooding*, demonstrating individuals near each other had different flooding experiences.

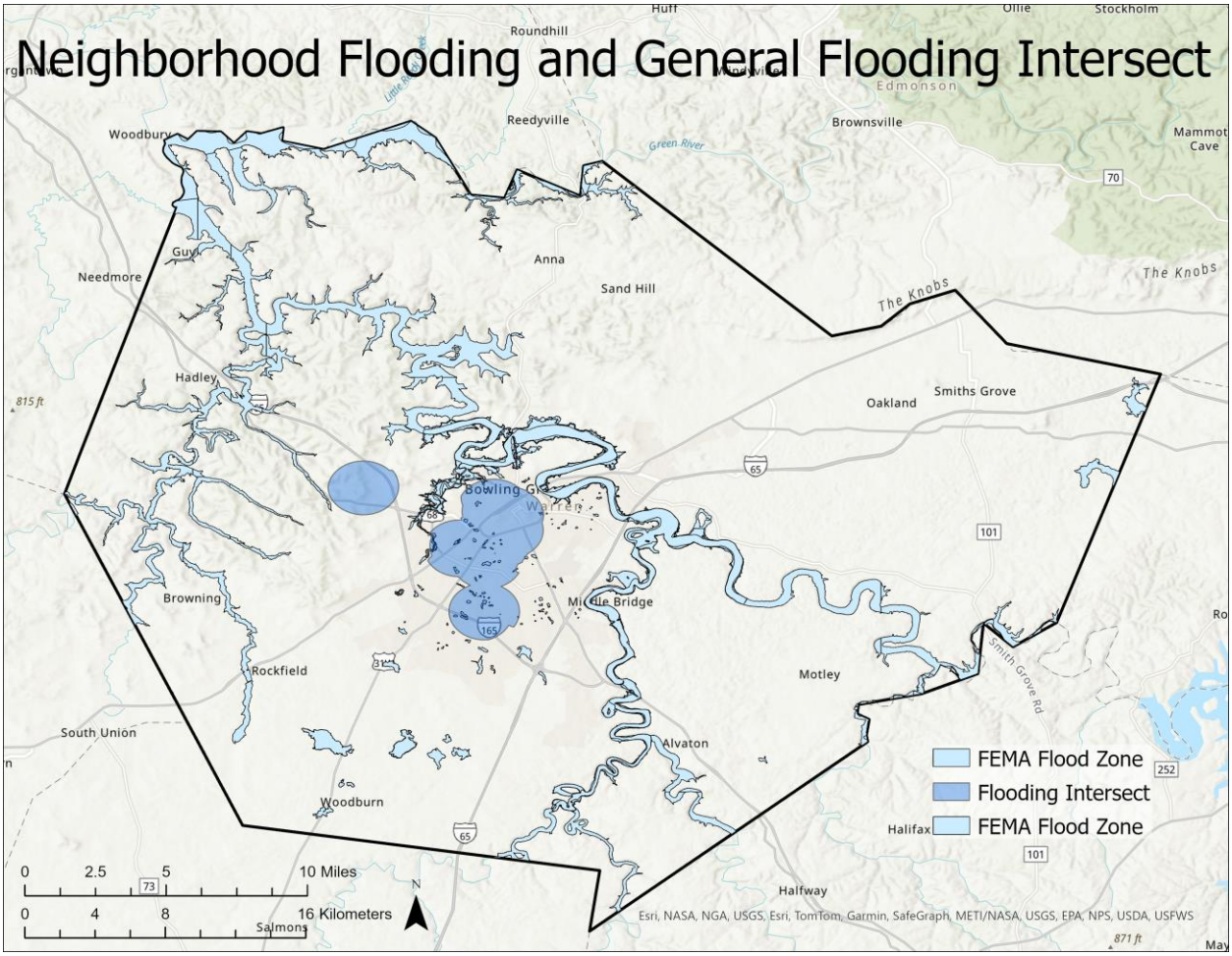

Figure 3.12. Neighborhood Flooding and General Flooding Intersect (Source: Created by Author).

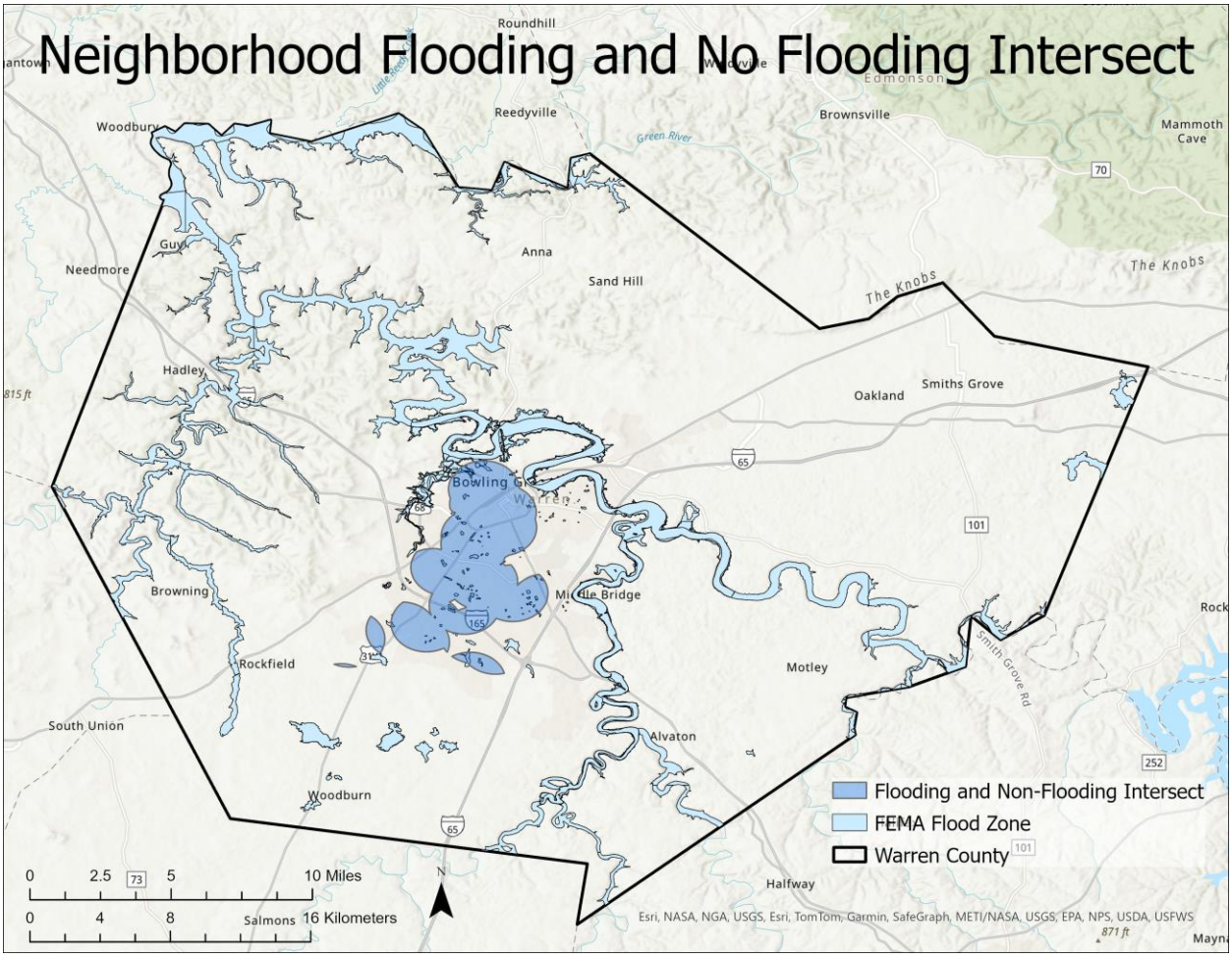

Figure 3.13 Neighborhood Flooding and No Flood Intersect (Source: Created by Author).

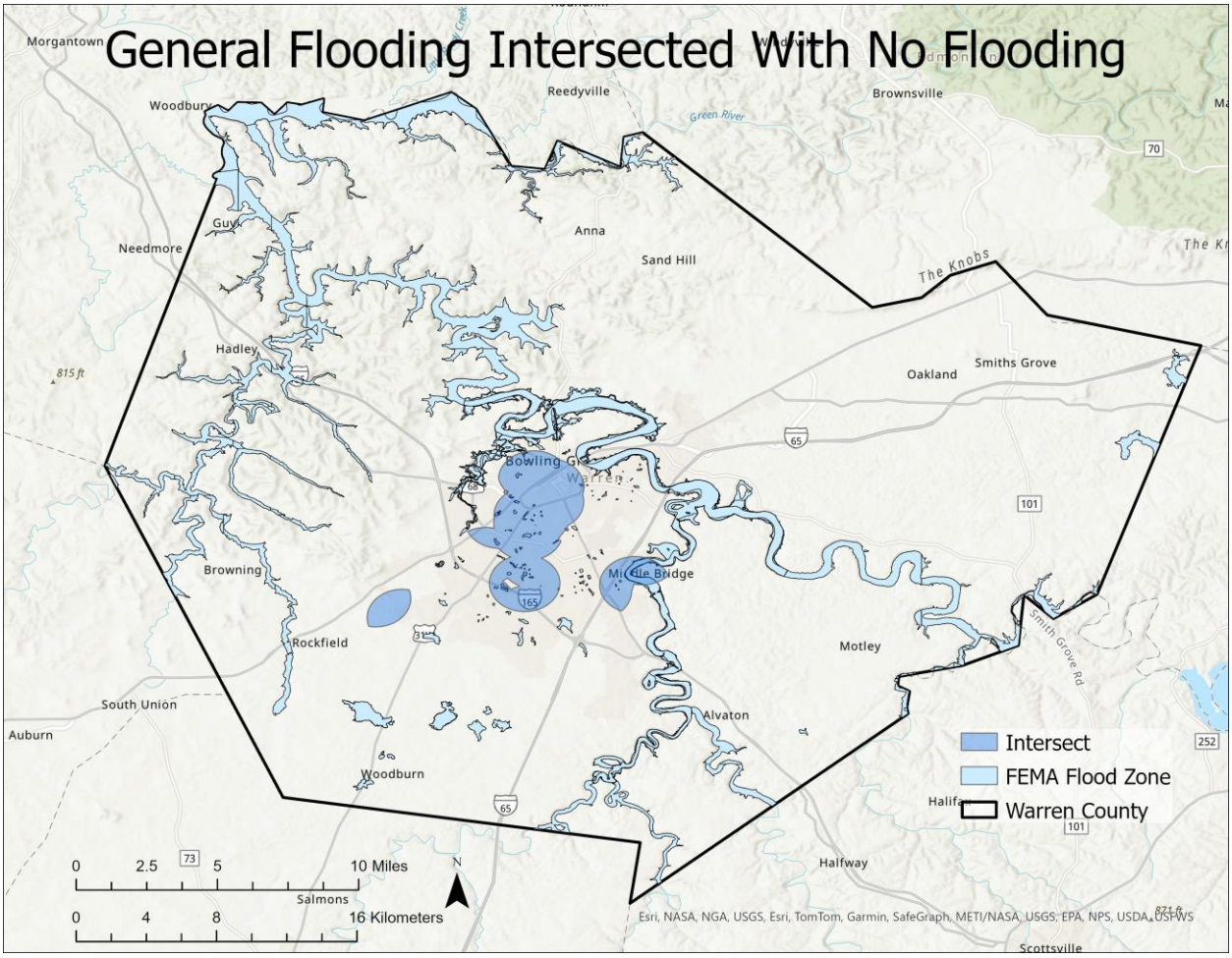

Figure 3.14 Flooding Areas Intersected with Non-Flooding Areas (Source: Created by Author).

Table 3.19 shows the percentage of overlap between these areas. There was a 59.6% overlap between the *general flooding* area and the *neighborhood flooding* area; there was a 37.3% overlap between *neighborhood flooding* and *no flooding*; and there was a 57.8% overlap between *general flooding* and *no flooding*. Areas of overlap between different experiences with flooding showed the complexity of flooding in karst landscapes, specially that flooding events in karst landscapes can be discontinuous (De Waele et al. 2011; Naughton et al. 2017).

Table 3.19 Percentage of Overlap Between Intersections (Source: Created by Author).

Intersection	Percentage of Overlap
Neighborhood and Address Flooding and Neighborhood Flooding	59.6%
Neighborhood Flooding and No Flooding	37.3%
Neighborhood and Address Flooding and No Flooding	57.8%

Survey respondents were asked four questions focused on perceptions of their flood experience (Questions 12, 13, 14, and 15). Results for these questions are in Table 3.20. All four statements relating to perceptions of flood experience had responses ranging from Strongly Disagree to Strongly Agree. Question 12 focused on the survey respondent's perception of flooding at their address where the mode and median response was respondents disagreed that their address flooded more frequently than other properties. Question 13 focused on Bowling Green, with the mode and median response being survey participants agreed some areas of Bowling Green flooded more frequently than others. Generally, survey respondents felt there were areas in Bowling Green that are more likely to flood than others but did not feel their addresses flooded more frequently than other addresses. Similar to how more survey respondents experienced more floods farther away from their address, agreement increased when questions shifted from focusing on an address to focusing on Bowling Green. There was a greater likelihood of a flood being experienced and more agreement in areas flooding frequently when attention shifted from addresses to more generalized areas.

Table 3.20 Perceptions of Flood Experience (Source: Created by Author).

Statement	*n*	Minimum	Maximum	Mode	Median
Your current address floods more frequently than other properties in Bowling Green.	118	1	5	2	2
Some areas of Bowling Green flood more frequently than others	116	1	5	4	4
You personally have been affected by flooding more than others since you have lived at your current address.	118	1	5	1	2
The amount of flooding has increased since you have started living at your current address.	117	1	5	3	2

*One is equivalent to Strongly Disagree, two is equivalent to Disagree, three is equivalent to No Opinion, four is equivalent to Agree, and five is equivalent to Strongly Agree.

Survey respondents were more likely to agree with the idea that there are areas that flood more often than others in Bowling Green than they were to agree with personally experiencing more flooding. Sjöberg (2002) found individuals tended to be more concerned about risks to others than themselves. Further exploring the role of indirect flood experience, which often increases flood awareness though not as much as direct flood experience does, may also provide an explanation, if the amount of indirect flood experience is larger than the amount of direct flood experience (Harlan et al. 2019). Survey participants have indicated having multiple or consistent repetitive flood events, but still disagreed that they have experienced more than other addresses. Comprehending how survey respondents determine their experience with flooding relative to others will create a better understanding of perceptions of flood experience.

Question 14 focused on whether the survey respondent had personally been affected by flooding more than others, and the mode response was to strongly disagree, while the median response was to disagree. Figure 3.15 shows the distribution of the Likert results for this

statement. While strongly disagreeing was the mode, there were many survey respondents who indicated less strong disagreement, moving the response median to disagree. Overall, survey respondents disagreed they were personally affected by flooding, an interesting result considering many respondents had reported multiple or consistent repetitive flooding events at their addresses. A Mann-Whitney U test was used to explore the relationship between feelings of being personally affected by flooding more than others and experiencing address damage. A statistically significant (P-value = <0.0001) difference exists between those who experienced address damage and a feeling of being personally affected by flooding more than others. For those who experienced flooding, their median response to the third statement was to have no opinion and to have more responses agree with the feeling of being personally affected by flooding than those who did not experience address damage.

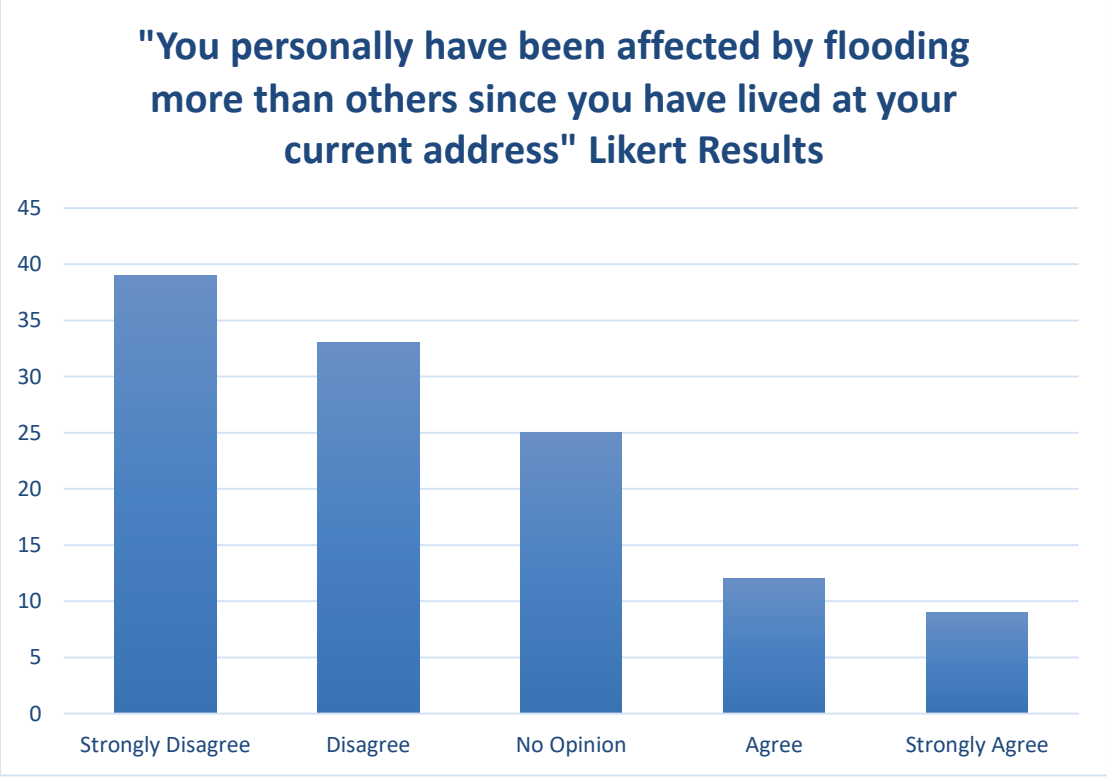

Figure 3.15 Personally Affected by Flooding Likert Results (Source: Created by Author).

Question 15 focused on whether the amount of flooding a survey participant had noticed increased since the respondent began to live at their current address and had the mode response of no opinion while the median response is to disagree. As seen in Figure 3.14, a large number of survey respondents disagreed or strongly disagreed with the idea that the amount of flooding increased, moving the median response to be to disagree with the statement. Overall, survey participants tend to not agree at any level that flooding has increased; whether participants feel the amount of flooding has decreased or remained constant is unknown.

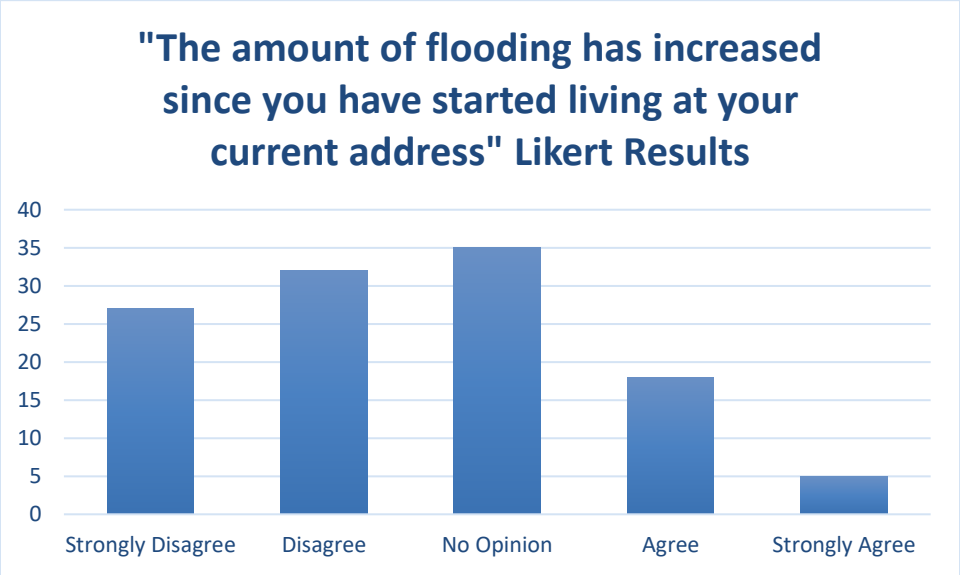

Figure 3.16 Increased Flooding Likert Results (Source: Created by Author).

Overall, no statistically significant relationship between flood experience, race, age, gender, or ownership status and flood awareness was found in the survey data. One statistically significant relationship in the surveys was between respondents residing in flood zones and minorities, where minorities were more likely to report residing in flood zones. The lack of significant relationships in the surveys in this study differed from studies completed in non-karst areas that found statistically significant relationships between flood experience and flood

awareness, race and flood awareness, age and flood awareness, gender and flood awareness, or ownership status and flood awareness. The lack of connection between flood experience and flood awareness also differed from the interview responses where four of the eight interview participants discussed the idea that flood experience increased flood awareness. The differences between the lack of statistically significant relationships in the survey data in this study compared to studies that took place outside of karst landscapes may have resulted from the karst landscape differing from non-karst landscapes (Zhou 2007; Gutiérrez 2011; Gutiérrez et al. 2014; Kentucky Geological Service 2021) and changing the factors that influence flood awareness or could be the result of the small number of survey respondents. The differences between this study's survey results and non-karst study's results may also come from both the differences between flooding in karst landscapes and flooding in non-karst landscapes as well as the small number of participants.

3.4.5. Flood Damage or Disruption

The damage experienced from flooding events is shown in Table 3.21. The results from Question 6 shows that over 30% of survey participants experienced flooding that resulted in an insurable loss, though respondents were not asked whether they had flood insurance, so that percentage is unknown (n=107). Question 5 focused on damage at addresses from flooding while Question 10 focused on disruptions from flooding in survey participant's neighborhoods. Nearly 40% of survey respondents experienced some sort of damage at their address from flooding (n=119) and 63% of participants experienced some sort of disruption in their neighborhood from flooding (n=119).

Table 3.21 Flood Damage and Disruption Overview (Source: Created by Author).

Topic	Percent Yes	Percent No
Flooding Resulted in an Insurable Loss	30.8%	69.2%
Flood Damage at Address	39.5%	60.5%
Flood Disruptions in Neighborhood	63%	37%

Table 3.22 shows the types of damage that occurred during address flooding. A little less than a third of survey participants experienced flood damage at their address. Those who experienced flood damage, experienced on average two type of flood damage with the median number of floods being also being two. The most common types of flood damage at addresses reported by survey respondents were ‘Appliance Damage,’ followed by ‘Water in the Basement.’

Table 3.22 Types of Damage to Addresses Due to Flooding (Source: Created by Author).

Type of Damage	Percentage of Participants Reporting that Type of Damage
Appliance Damage	45.5%
Water in the Basement	38.6%
Structural Damage	36.4%
Mold or Mildew	34.1%
Electrical Damage	29.5%
Other	9.1%
Inundated HVAC	6.8%

Table 3.23 displays the types of neighborhood disruptions caused by flooding. A little less than two-thirds of survey respondents reported experiencing a neighborhood disruption due to flooding. On average, those who experienced a flooding related neighborhood disruption, experienced about one disruption with a median number of disruptions being one. The most common type of disruption was flooded roads with over 55.7% of neighborhood disruptions reported by survey participants being flooded roads. More survey participants experienced

disruptions in their neighborhood than at their address, similar to how more respondents reported experiencing flooding in general in their neighborhood than at their address. While neighborhood flooding is more common than address flooding, on average, it was more likely to experience damage or disruption from address flooding than neighborhood flooding.

Table 3.23 Types of Disruption to Neighborhoods Due to Flooding (Source: Created by Author).

Type of Disruption	Percentage of Participants Reporting that Type of Disruption
Roads Being Flooded	55.7%
Damage to Businesses	12.9%
Parking Lots Being flooded	11.4%
Other	10.0%
Parks Being Flooded	7.1%
Damage to Schools	4.3%
Yards Being Flooded	4.3%
Fields Being Flooded	2.9%

Experiencing damage at their address was statistically significantly related to survey respondents feeling they were more affected by flooding than others and survey respondents feeling that they lived in the flood zone. The statistically significant relationship may be due to damage from flooding at survey respondent's address' leading participants to feel they were affected by flooding more than just experiencing a flood without damage did. Experiencing damage from flooding at their address may have also been considered a part of living in a flood zone by survey participants, leading those who experienced damage from flooding at their address to believe they lived in a flood zone. Survey participants were not asked to define what a flood zone was, so it was unknown what was included in the definition of flood zones for participants who responded.

3.4.6 Flood Policies, Laws, and Regulations

Awareness and perceptions of flood policies, regulations, and laws were also analyzed based on survey responses. Table 3.24 displays an overview of survey respondents' views of flood policies, regulations, and laws. Nearly 25% of survey participants were aware of flood policies, regulations, or laws. The majority of survey participants were unaware of these policies, but, when focusing on the effectiveness of these flood policies, regulations, and laws in their community, nearly 40% of respondents felt these policies were effective. There were survey respondents who felt the policies were effective even if they were unaware that the policies existed. No statistically significant differences were found between ownership status, race, or flood experience and perception of effectiveness of flood policies.

Table 3.24 Overview of Awareness and Perceptions of Flood Policies (Source: Created by Author).

Topic	n	Percent Yes	Percent No	I do not think there are policies
Awareness of Policies, Regulations, or Laws Aimed at Flooding	119	24.4%	75.6%	N/A
Current Policies, Regulations, or Laws Aimed at Reducing Flood Risks in Your Community Are Effective	111	39.6%	27.0%	33.3%

Question 18 asked survey respondents to identify what topics they were aware of in flood-related policies, regulations, or laws. To identify topics, survey participants needed to be aware of flood policies, regulations, or laws (n=29). Table 3.25 shows the flood policy topics identified (n=20). The top topic was 'Drainage Regulations' with 45% of survey respondents

identifying it, ‘Construction/Building Codes’ was second with 30% of respondents identifying it, followed by ‘Insurance Laws,’ ‘Mitigation/Flood Prevention,’ and ‘FEMA.’

Table 3.25 Topics Covered by Policies, Regulations, or Laws Aimed at Flooding (Created by Author).

Topic	Percentage of Respondents
Drainage Regulations	45%
Construction/Building Codes	30%
Insurance Laws	20%
Mitigation/Flood Prevention	15%
Other	15%
FEMA	5%

Survey respondents focused on the issue of drainage and how it related to flooding as the topic of drainage was the top topic identified for policies and laws (45%), and poor drainage was the second most common characteristic identified as increasing the likelihood of flooding in their neighborhood (19%). There was recognition that drainage was connected to flooding and that flood policies aimed to control drainage. The effectiveness of these drainage regulations needs to be determined as drainage was recognized as a topic covered by flooding policies while poor drainage was recognized as a characteristic that increased flood risk. With the connection to an increased flood risk by survey participants, understanding where poor drainage exists according to respondents and whether the current drainage regulations are effective is needed. Figure 3.17 shows the areas where survey participants identified poor drainage as increasing the likelihood of flooding. Poor drainage reports were concentrated in two clusters around BG.

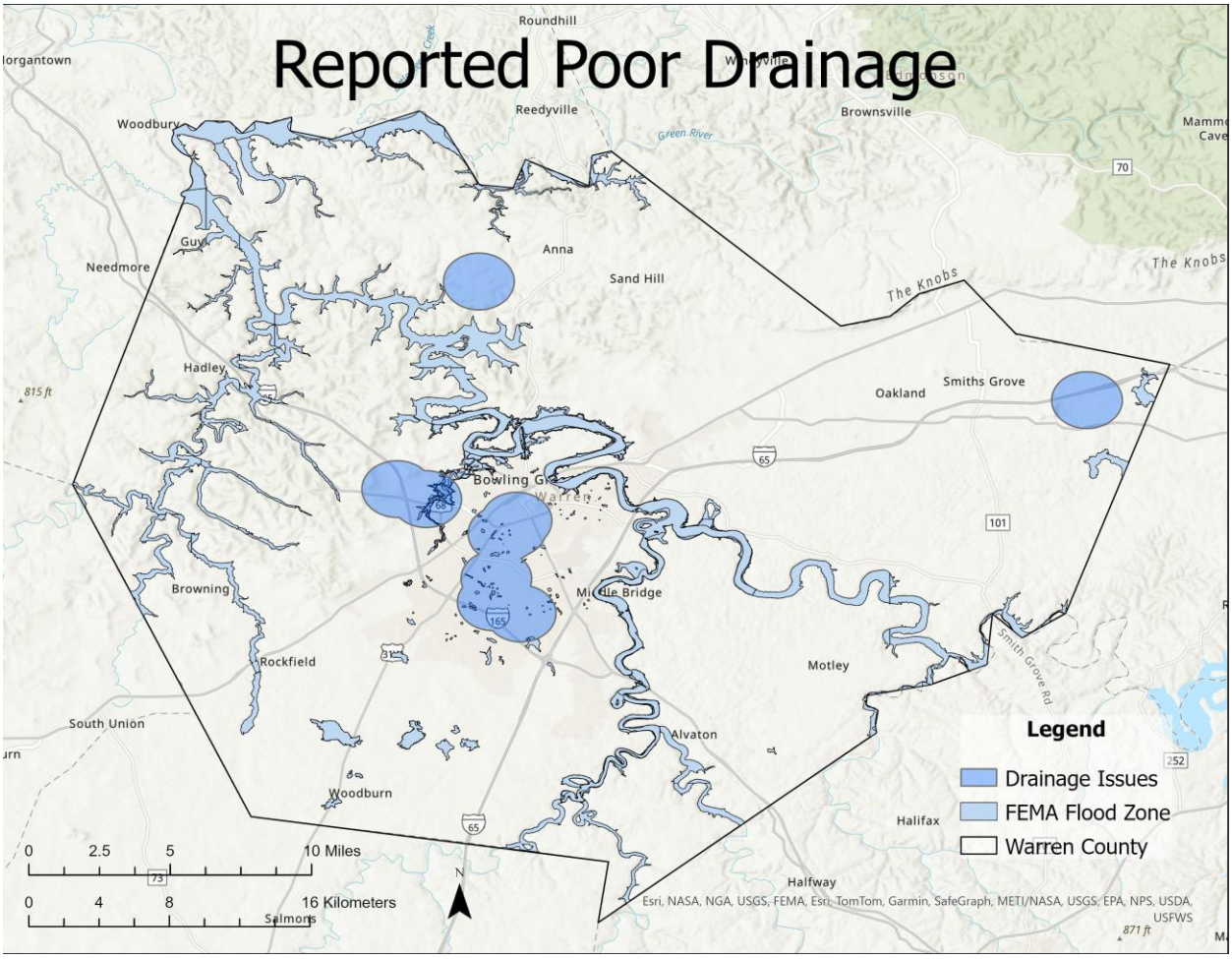

Figure 3.17. Reported Poor Drainage Areas (Source: Created by Author).

As part of Question 19, survey respondents provided reasons as to why they felt current policies, regulations, or laws were effective (Table 3.26) (n=22). To provide a reason as to why current flood policies were effective, survey participants had to answer that they felt current flood policies were effective (n=44). The top reason survey respondents felt flood policies were effective included mitigation measures, which included ‘Planning and Zoning,’ ‘Water Management Programs,’ and ‘Drainage Areas.’ The provided mitigation measures aimed to prevent flooding and limit the potential effects before flooding occurred. All eight interviews also discussed the effectiveness of flood policies with similar mitigation measures including

‘Planning and Zoning,’ ‘Drainage Areas and Regulations,’ ‘Floodplain Building Restrictions,’ and the ‘Construction of Retention Basins’ being mentioned.

Table 3.26 Why Current Flood Policies, Regulations, or Laws are Effective (Source: Created by Author).

Topic	Percentage of Respondents
Mitigation Measures	54.5%
Lack of Flooding	18.2%
Flood Warnings	4.5%
Limited Protection	9.1%
Other	13.6%

The second most common reason flood policies were considered effective was a lack of flooding. If survey participants did not experience flooding, then they felt flood policies were effective. The third most common reason flood policies were considered effective was the presence of flood warnings when flooding did occur; flooding occurred, but the warnings beforehand made survey participants feel flood policies were effective. The fourth most common reason flood policies were considered effective was focused on the feeling that flood policies only provided limited protection, meaning there was room for improving flood policies. Similarly, seven of the interviewed flood experts discussed that they felt that flood policies, while effective, could be improved. Other studies found that flood policy effectiveness is generally higher in areas of higher flood risk, and that, while the effectiveness of flood policies depends on how they have implemented them, there is always room for improvement in flood policy (Patterson and Doyle 2009; Berke et al. 2014; Paul and Milman 2017).

As part of Question 19, survey respondents also provided reasons as to why they feel current policies, regulations, or laws were ineffective (Table 3.27) (n=15). To provide a reason as to why current flood policies were effective, survey participants had to answer that they felt

current flood policies were ineffective (n=30). Table 3.23 displays these reasons, with the most common reason being that flooding continued to occur (46.7%). For survey respondents, there was a view that if flooding was occurring, then flood policies were ineffective. The second most common reason was the idea that the flood policies were only doing the bare minimum required, and the bare minimum was not enough to provide effective flood policy (26.7%).

Table 3.27 Why Current Flood Policies, Regulations, or Laws are Ineffective (Source: Created by Author).

Topic	Percentage of Respondents
Flooding Continues to Occur	46.7%
Bare Minimum	26.7%
Growth and Development	13.3%
FEMA Maps are Incorrect	6.7%
Unaware of Policies	6.7%
Risk is Increasing Faster than Policy Changes	6.7%
Expensive Flood Insurance	6.7%

The third most common reason survey participants felt flood policies were ineffective was growth and development as this growth and development changed flooding and flood risks faster than policies changed. Half of the eight interview participants discussed the idea that future flood effects need to be considered when planning for flooding, especially when considering growth and development, to ensure that flood policies were effective. Both the expert interviews and the survey results display a recognition that growth and development can heavily affect the effectiveness of flood policies. The survey results had participants who felt that growth and development has already affected the effectiveness of flood policies, while experts in the interviews focused on the potential for growth and development to decrease the effectiveness of flood policies in the future. There was agreement that growth and development had the

potential to make flood policies ineffective, but the timeframe focused on differed with survey respondents focused on the present and experts focused on the future.

The last four reasons for ineffective flood policies were mentioned by the same number of survey respondents. These topics were 'FEMA Maps are Incorrect' 'Unaware of Policies,' 'Risk is Increasing Faster than Policy Changes,' and 'Expensive Flood Insurance.' Issues with FEMA Flood Maps are discussed above, with the lack of overlap between reported areas of flooding and the flood zones and the time since the last update showing the need for an updated map in Warren County. The perception that if survey participants were unaware of policies, then flood policies were ineffective was important because it suggests that by providing more flood-focused education, the view of flood policy ineffectiveness can be reduced. All eight expert interview participants discussed the struggle to get community members to pay attention to flood information, especially if community members had not been directly affected by flooding. The eight expert interview participants then provided methods of flood communication including local champions, flyers, social media, websites, and signs with the idea that multiple methods of communication would be used. The idea that risk is increasing faster than policy changes is connected to the idea of growth and development above but is also connected to how infrequently flood policies are updated with flood policies affecting Warren County being created or updated in 1980, 1991, 2000, and 2007 (Kentucky Revised Statutes 1980; Bowling Green, Kentucky Code of Ordinances 1991; Kentucky Revised Statutes 2000; Bowling Green, Kentucky Code of Ordinances 2007). The final reason flood policies were considered ineffective was flood insurance is expensive and the cost may potentially prevent those who were eligible and would like flood insurance from having accessing.

Many of the topics related to the ineffectiveness of flood policies were also discussed under the idea of challenges in flood management in the expert interviews. Out of the eight interview participants, six brought up challenges in flood management including a lack of funding, slow processes, outdated data, climate change, and a lack of flood awareness. Outdated data, slow processes, and a lack of funding all connected to how growth and development negatively affect the effectiveness of flood policies, as updates to flood policies do not happen often because there is a lack of funding and the process to update policies is often long and slow, meaning that policy can quickly become outdated, especially when there were changes to the landscape from growth and development. The slow process and lack of funding are also reasons why FEMA Flood maps were not updated quickly after they became outdated. The slow process and lack of funding were also why risk often increased faster than policy changed. The flood management challenges discussed by interview participants were similar to the reasons why current flood policies were considered ineffective by survey respondents.

Questions 16 and 17 focused on understanding survey respondent's perceptions of responsibility for addressing flooding issues. Table 3.28 shows survey participant's beliefs of who was responsible for addressing flooding issues on private property versus public property. Survey respondent's most commonly felt that the government was responsible for addressing flooding issues on both private property and public property, though the percentage of participants changed based on whether it is private property (43.2%) or public property (82.9%). Survey respondents were least likely to feel that businesses were responsible for addressing flooding issues on both private property (5.9%) and on public property (2.6%). While the majority of participants felt the government was responsible for flooding issues on public property, there was more variety in who was considered responsible for flooding on private

property: 43.2% said the Government, 33.1% said private citizens, and 17.8% said other, most commonly mentioning the owner of the property as responsible for flooding issues on private property.

Table 3.28 Responsibility for Addressing Flooding Issues (Source: Created by Author).

Entity	On Private Property	On Public Property
Businesses	5.9%	2.6%
The Government	43.2%	82.9%
Private Citizens	33.1%	9.4%
Other	17.8%	5.1%

All eight interview participants also discussed who is responsible for flooding issues with a variety of entities mentioned. Governmental agencies such as FEMA, Public Works departments, Emergency Management departments; non-profit organizations; and individuals who owned property affected by flooding were brought up as being at least partially responsible for flooding issues in the expert interviews. A mixture of entities was discussed as being responsible for dealing with flooding issues and there was no single organization that was brought up as the organization responsible for flooding; instead, flooding is the perceived as the responsibility of multiple entities.

A variety of entities were considered responsible for addressing flooding issues, and, in terms of private property, there was an uncertainty as to who was responsible. All eight of the expert interviews agreed that the question of responsibility for flooding issues was complicated and depended on an array of factors, but that there tended to be several entities sharing responsibility for addressing flooding issues including stakeholders, all levels of government

(city, county, state, and federal), and people who own the flooding property. Uncertainty in responsibility for addressing flooding issues was also found in Andráško (2021).

Overall, nearly 25% of survey participants were aware of flood policies and nearly 40% of respondents felt flood policies were effective, though survey respondents and interview participants both acknowledged room for improvement in flood policies. More survey participants felt flood policies were effective than those who were aware of flood policies. Both interview and survey participants discussed growth and development and slow policy updates as reducing the effectiveness of flood policies. Designing flood policies to account for predicted growth and development as well as updating flood policies regularly may help to prevent flood policies from becoming ineffective. Survey participants were uncertain as to who was responsible for flooding issues on private property, though the majority of survey respondents agreed that flooding on public property was the responsibility of the government.

3.4.7 Differences in Flood Awareness

Survey responses suggest that the differences in flooding between karst and non-karst landscapes led to differences in flood awareness. While those who participated in these surveys were more likely to be interested in flooding (Groves et al. 2004; Saleh and Bista 2017), survey respondents in this research tended to have a low or medium Flood Awareness Level. Survey respondents likely had less awareness of flooding than they thought they had. Participants may have been interested in flooding but did not understand flooding in karst landscapes, reducing the Flood Awareness Level.

Studies in non-karst landscapes recognized statistically significant relationships between flood experience, race, gender, age, or ownership status and flood awareness (Weinstein 1989; Grothman and Reusswig 2006; Kellens et al. 2013; Hopkins and Warburton 2015; Lechowska

2018; Harlan et al. 2019; Fanta et al. 2019; Maryati et al. 2019; Mashi et al. 2020; Andráško 2021). This study did not find statistically significant relationships between flood experience, race, gender, age, or ownership status and flood awareness in the karst landscape. The lack of statistically significant relationships may have been a result of the complexity of flooding influencing the relationships between flood awareness and the demographic factors. The lack of a statistically significant relationship between flood experience and flood awareness may have been the result of participants living very close to each other and having very different experiences with flooding as seen in Figure 3.12, Figure 3.13, and Figure 3.14. The lack of continuous flooding and the potentially long interval periods between floods in karst landscapes may have resulted in no statistically significant relationship between flood experience and flood awareness based on the data.

FEMA Flood Zones in karst landscapes can also be discontinuous with a large number of small SFHA across the landscape because of the discontinuous flooding from sinkholes in karst landscapes. Survey participants struggled to identify whether they lived in flood zones. Part of survey participants' inability to accurately identify whether they lived in flood zones may have come from the large number of small SFHA across Warren County. The presence of these SFHA away from features such as river that are recognized as able to cause flooding may have confused participants and reduced their ability to recognize whether they lived in flood zones or not, leading survey participants to use other factors, such as experiencing flood damage, to determine whether they lived in flood zones rather than identifiable features such as rivers.

3.5 Conclusions

Few survey participants in this study were able to fully define a flood. The study aimed to understand whether survey participants knew what a flood was before focusing on flooding in

karst areas. A lack of awareness of whether survey participants live in the flood zone is also documented in this study. Being unsure of whether survey respondents live in the flood zone has been seen in other studies (Oubennaceur et al. 2022). A statistically significant relationship was found between those who experienced address damage also being more likely to say they live in the flood zone. Survey participants may incorrectly believe they live in a flood zone because of the amount of time since the FEMA Flood Zone map was last updated. A second reason may be the complexity and discontinuous nature of karst flooding, making it difficult to determine which areas should be included in the flood zone (De Waele et al. 2011; Naughton et al. 2017).

Overall, both the survey responses and interviews responses agree that participants have a low to medium Composite Flood Awareness levels. Groves et al. (2004) and Saleh and Bista (2017) found that individuals are more likely to participate in surveys for topics they were interested in, though, meaning that survey participants were less flood aware than they likely believe they were. The low and medium Composite Flood Awareness levels as well as survey participants likely being less flood aware than they believed they were means that flood awareness needs to be increased in Warren County.

The majority of survey participants were able to identify nearby karst features, but did not make a connection between karst flooding, especially when considering how karst affects them personally. A disconnect existed between the awareness of nearby karst features and the nearby karst having an effect on nearby addresses. Few individuals listed karst as a characteristic increasing the likelihood of flooding in their neighborhoods, though it has been found that community members often do not understand causes of flooding (Bhatti et al. 2023). Topography and poor drainage were two characteristics identified as increasing the likelihood of flooding, but these characteristics were not connected to karst by survey participants, even though karst

features influence both topography and the drainage system (Bonacci et al.2006; Zhou 2007; Kovacic and Nastaša 2010). Interviewees also discussed a lack of or limited amount of awareness about flooding, especially karst flooding. The survey respondents and interviews participants both suggested that community members did not understand the relationship between karst features and flooding.

Studies have found flood experience increases flood awareness (Weinstein 1989; Kellens et al. 2013; Raška 2015; Lechowska 2018; Harlan et al. 2019; Fanta et al. 2019; Maryati et al. 2019; Mashi et al. 2020; Andráško 2021; Ferreira et al. 2021; Ge et al. 2021; Oubennaceur et al. 2022; Bhatti et al. 2023), and studies have found flood experience decreases flood awareness (Hopkins and Warburton 2015; Andráško 2021; Kuang and Liao 2022); part of this contradiction has been attributed to the type of flooding being studied Nearly two-thirds of survey participants experienced flooding, but no statistically significant differences were found between experiencing flooding and flood awareness. The lack of connection between flood experience and flood awareness documented in this study may have resulted from the limited number of survey participants but may also be connected to the complexity of karst flooding and the lack of surface waters in karst landscapes. A large amount of overlap occurred between areas where flooding was reported by survey participants and areas where no flooding was reported by survey participants, showing the complexity of flooding in karst areas (De Waele et al. 2011; Naughton et al. 2017). Other studies also found connections between race, age, gender, and ownership status and flood awareness (Grothman and Reusswig 2006; Kellens et al. 2013; Lechowska 2018; Harlan et al. 2019). This study found no statistically significant differences between race, age, gender, or ownership status and flood awareness, a difference that may have resulted from

the limited number of survey participants and differences between flooding in karst areas and flooding in non-karst areas.

Nearly 25% of survey participants were aware of flood policies, and nearly 40% of survey respondents felt flood policies were effective. Interview participants discussed how they felt flood policies were effective but also recognized room for improvement. Both interview participants and survey participants discussed how growth and development and slow policy updates reduced the effectiveness of flood policies, especially when considering the future. The perception from community members that flood policies were effective, but that there was always room for improvement was common in research studies (Patterson and Doyle 2009; Berke et al. 2014; Paul and Milman 2017). With only 40% of survey respondents feeling flood policies were effective, there was room for improving flood policy awareness and perception of effectiveness. Survey participants also had uncertainty as to who was responsible for flooding issues on private property, though the majority agreed that flooding on public property was the responsibility of the government (Lechowska 2018).

3.6 Recommendations

There are several recommendations from the outcomes of this study:

- Provide simple ways for community members to report areas of flooding. This may be completed through an activity similar to the cognitive mapping project attempted in this study. A site where individuals can share where flooding is occurring and when could provide community members with the ability to communicate where they see flooding occurring and when.

- Provide easy to access information about who is responsible for flooding issues in common circumstances, such as on private property versus public property, or on roads to reduce uncertainty around who is responsible for flooding issues.
- Provide more education to increase awareness of flood policies and of flooding in karst areas. Interviewees discussed this topic, and methods mentioned included social media pages, newspapers, local champions, websites from agencies connected to flooding, community groups, public service announcements, FEMA mailers, radio, television, direct conversations with individuals in areas of flood risk, video billboards, physical educational signs, and lessons for school-aged students. There was agreement that multiple methods are needed, and it can be difficult to get information across a diverse population that may not be interested in the topic. Developing a low budget method to share information about how to report flooding and causes of flooding could be useful. One method could be using community members who have experienced flooding to share information about flooding and flood policies where they live. Another method could be implementing a karst and karst flood awareness program for student.
- Assessing and updating flood policies and maps more frequently along with assessing community awareness and perceptions of flood policies to determine gaps in awareness or flood policies. Engaging the community in this process could increase perception of effectiveness of flood policies in Warren County.

Understanding the reasons why flood policies are believed to be ineffective and what characteristics are associated with flooding in neighborhoods begins to determine where gaps in flooding policy and flood policy communication exist as these are areas flood policies are not covering or participants are unaware of, meaning they are places to begin assessing current flood

policies. The development of flood policy and flood awareness educational outreach programs can also begin using these reasons of ineffectiveness and an increased likelihood of flooding.

Setting up a site to report flooding through mapping, providing images, or another method of reporting floods is also a simple way to gain more information about flood experience and awareness. The testing and education about the site could be implemented in the areas where neighborhood and address flooding are shown to occur. The site could provide the ability for users to communicate their experiences with and awareness of flooding with their local government while also gaining information about responsibility for flooding.

Chapter 4: Conclusions

A large and growing population lives in karst areas around the world making comprehending the hazards present in these areas valuable. Understanding how flooding in karst areas, a prevalent hazard, is perceived is needed to identify potential gaps and improve flood policies and management in these karst areas. While some studies have explored the physical factors involved in flooding in karst areas, and other studies have focused on understanding flood awareness, few studies have looked at flood awareness of flooding in karst areas. Acknowledging and understanding differences between flooding and flood awareness in karst areas versus non-karst areas is integral to developing effective flood policies and management.

Flood awareness is important to understand in order to determine how to best manage and mitigate flooding risk. Flood awareness in an urban karst landscape had not been focused on before. This study focused on flood awareness in karst areas and the factors that influence flood awareness in karst areas as well as awareness of and perceptions of effectiveness of flood policies. The following questions were investigated in this research:

- What are the community perceptions and awareness of flooding in the urban karst area of Warren County?
    - What is the relationship between awareness of flooding and karst features in Warren County?
    - What are the factors that influence awareness of flooding in karst environments and how do these factors influence flood awareness in Warren County?
- Does current policy and regulation adequately address perceived flood risk and vulnerability in the urban karst area of Warren County?

Flood awareness and flood policies were explored using surveys, expert interviews, and a cognitive mapping activity. In total, 119 survey responses were received, eight expert interviews were completed, and three cognitive mapping activities were completed. Survey participants had low to medium composite flood awareness levels; a view corroborated by the expert's views of flood awareness. Survey participants lacked an understanding of whether they lived in a flood zone, with those who had experienced address damage from flooding more likely (P-value = <0.0001) to say they lived in the flood zone. Flood awareness in this study was not found to be statistically significantly connected to flood experience, race, gender, age, or ownership status, though nearly two-thirds of survey participants had experienced flooding.

Survey participants identified nearby karst features and characteristics they felt increased the risk of flooding but did not connect karst to flooding or to these landscape characteristics. Survey respondents and interview participants agreed community members did not understand the relationship between karst features and flooding. Nearly 25% of survey participants were aware of flood policies, and nearly 40% of survey respondents felt flood policies were effective, leaving room for improvement. Survey respondents and interview participants agreed growth and development and slow policy updates reduced the effectiveness of flood policies. Growth and development and slow policy updates meant the future needed to be considered when designing flood policies. Perceptions of who was responsible for flooding on private property was unclear with no entity taking a clear majority. A majority of survey participants agreed flooding on public property was the responsibility of the government.

Four recommendations were developed from this research. The first recommendation is to provide a simple way for community members to report areas of flooding. The second recommendation is to provide easy access to information about who is responsible for flooding

issues. The third recommendation is to provide education to increase awareness of flooding in karst areas and of flood policies. The final recommendation is to assess and update flood policies, including flood zone maps, more frequently.

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APPENDIX A.

Survey Instrument

Part 1: Flood Experience

1. Define flooding in your own words.
2. Do you reside within a flood zone?

   Yes, No, Do Not Know
3. Have you ever experienced flooding at your current address?

   Yes, No
4. If so, how many times?
5. If the home at your current address has experienced flooding, please check if any of the following types of effects or damage occurred?

   Structural Damage, Electrical Damage, Appliance Damage, Mold or Mildew, Water in the Basement, Inundated HVAC, Other (Text Box)
6. Has any flooding resulted in an insurable loss covered by an insurance policy?

   Yes, No
7. Has the exterior property of your current address experienced flooding? This could include flooded roads next to the property, flooded yard, etc.

   Yes, No
8. Have other areas in your current neighborhood (within one mile of your address) experienced flooding?

   Yes, No
9. If so, how many times?

10. If your neighborhood (within one mile of your address) has flooded, please check if any of the following types of effects or damage occurred.

    Roads being flooded, Parking lots being flooded, Damage to Businesses, Damage to Schools, Parks being Flooded, Other (Text Box)

11. Are there specific characteristics of your neighborhood (within one mile of your address) or home that you feel increases your likelihood of flooding? Please explain your answer.
12. Your current address floods more frequently than other properties in Bowling Green.

    Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree

13. Some areas of Bowling Green flood more frequently than others.

    Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree

14. You personally have been affected by flooding more than others since you have lived at your current address.

    Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree

15. The amount of flooding has increased since you started living at your current address.

    Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree

Part 2: Flood Preparation and Policy

16. Who do you think is responsible for addressing flooding issues on private property such as homes or businesses? Check all that apply.

    The Government, Private citizens, Businesses, Other (Text)

17. Who do you think is responsible for addressing flooding issues on public property such as roadways, schools, or parks? Check all that apply.

    The Government, Private citizens, Businesses, Other (Text)

18. Are you aware of any policies, regulations, or laws aimed at flooding? If yes, what topics do they cover?

    Yes (Text), No

19. Do you feel current policies, regulations, or laws aimed at reducing flood risks in your community are effective? Please explain your answer.

    Yes (Text), No (Text), I don't think there are any policies/regulations/laws

Part 3: Karst Flooding

Please use the following definition of karst to answer the questions in this section.

Karst refers to a landscape characterized by the presence of caves, springs, sinkholes, sinking streams, etc and consists of water mainly moving underground.

20. Please select any of the following karst features you know of that are within a mile of where you live.

    Spring, Cave, Sinkhole, Sinking Streams, Other (text)

21. Do you know of any karst feature(s) that directly affect your residence? If so, list the feature(s).

    Yes (Text), No

22. Flooding in karst landscapes can differ from flooding in non-karst landscapes.

    Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree

23. Karst landscapes increase flood risk in your community.

    Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree

Part 4: Demographics

1. What is your gender?

Male

Female

Other

Prefer not to say

2. What is your age?

18-24

25-29

30-39

40-49

50-59

60+

3. What is your race?

White

Black or African American

American Indian or Alaska Native

Asian

Native Hawaiian or Other Pacific Islander

Other

Prefer not to say

4. What is your address?

* This information will be used only to determine participant's census block to aggregate data. This information will not be utilized in any other way.

5. What is your duration of residence?
6. Do you own or rent your residence?

   Own

   Rent

   Other
7. Are you considered a flood professional through your job? (Have a job involving flood recovery, flood response, or flood mitigation?)

   Yes

   No

   a. If so, what is your job?

Part 5: Optional Gift Card Drawing Entry

If you are interested in being entered into a drawing for one of twenty digital $25 Visa gift cards please provide your name and email below. The names and emails provided here will only be

used for the gift card drawing and will not be associated with the rest of the provided information in the rest of the survey.

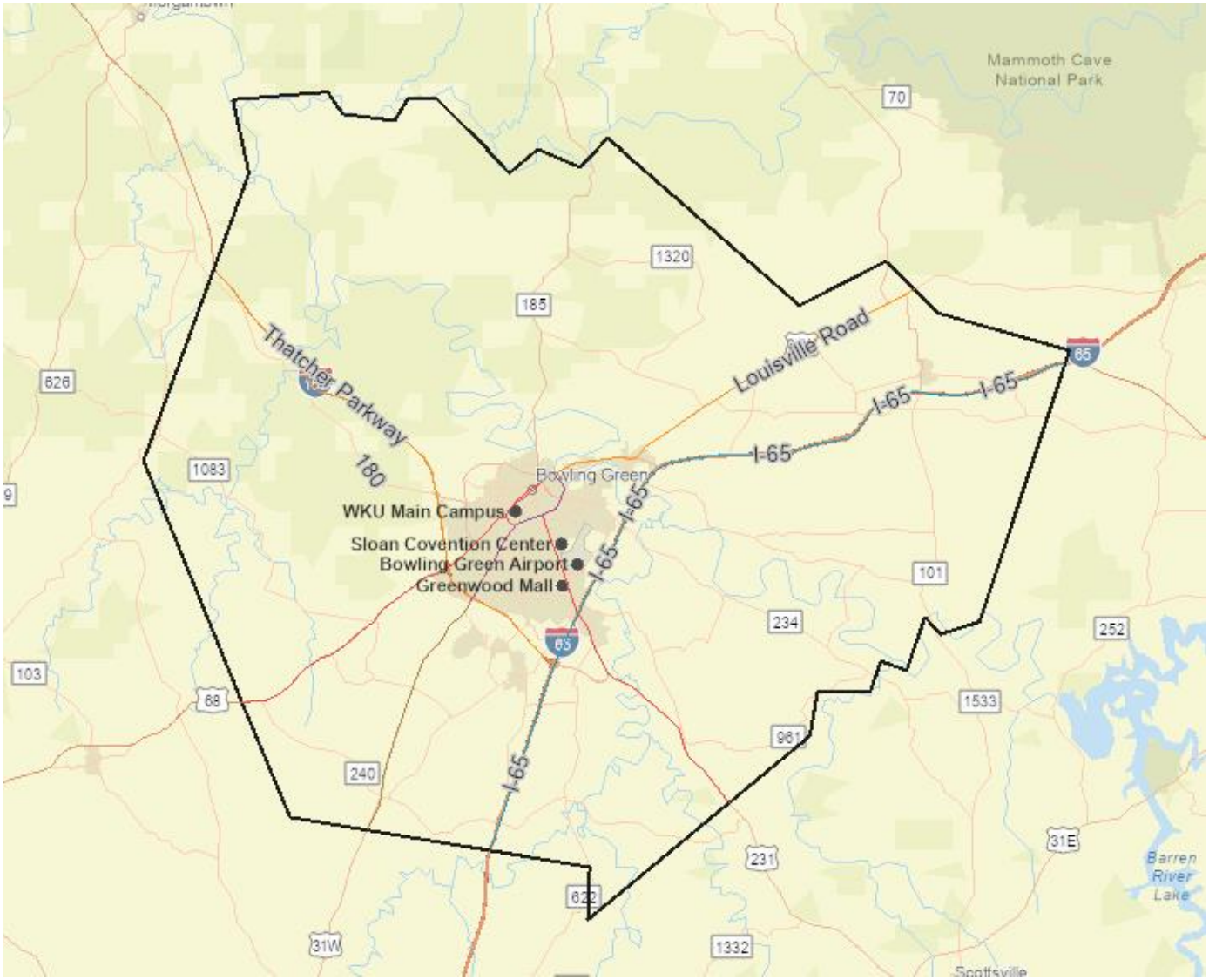
APPENDIX B.

Semi-Structured Interviews Instrument

1. Do you feel there is awareness of the risk of karst flooding in the community?
2. What role do you play, if any, in managing karst flooding?
3. What are some strategies to spread karst flood awareness?
4. Do you feel current policies, regulations, or laws aimed at reducing flood risks in your community are effective and why?
5. Who is responsible for spreading information about karst flood awareness?

APPENDIX C.

Cognitive Mapping Instrument



APPENDIX D.

Survey Distribution Locations

Location	Method
Bowling Green Rotary Noon Club	Newsletter
Spencer's Coffee Shop	Flyer on Bulletin Board
Warren County Public Library Lisa Rice Branch	Flyer on Bulletin Board
Griff's Deli	Flyer on Bulletin Board
Bowling Green KY Experience Facebook Group	Digital Flyer
Spotted in Bowling Green Facebook Group	Digital Flyer
Simply Ramen	Flyer on Bulletin Board
Boba Lounge	Flyer on Bulletin Board
Meltdown	Flyer on Bulletin Board
Puerto Vallerta	Flyer on Bulletin Board
El Mazatlan	Flyer on Bulletin Board
Candlemakers	Flyer on Bulletin Board
Greatest American Donut Shop	Flyer on Bulletin Board
Q's Coffee Shop	Flyer on Bulletin Board
Baskin Robbins	Flyer on Bulletin Board
Becky Brooke Vintage and Mary Jane's Chocolate Lobby	Flyer on Bulletin Board
Melodies and Memories	Flyer on Bulletin Board
Vette City Vintage	Flyer on Bulletin Board
Western Kentucky University Environmental Science and Technology Building	Digital Flyer
Western Kentucky University (WKU) Office of Sustainability	Flyer on Bulletin Board
WKU Earth, Environmental, and Atmospheric Sciences Social Media	Digital Flyer
WKU Office of Sustainability Social Media	Digital Flyer
Warren County KY Gov Social Media	Digital Flyer
Providence Coffee	Flyer on Bulletin Board

Hunters Crossing Neighborhood Association	Digital Flyer
D93 Tony Rose Show	Live Radio Interview; Streamed Interview
Community Farmer's Markert	Tabling Three Times
Bendix Earth Day Event	Tabling
Hot Rods Baseball Game	Tabling
Cruise for a Cure	Tabling
Flea Land	Tabling
Russel Sims Aquatic Center	Tabling
Every Door Direct Mailing	2000 Postcards
PostcardMania Google Advertisements	50,145 Digital Advertisements
PostcardMania Facebook Advertisements	38,527 Digital Advertisements

APPENDIX E.

Survey Result Matrix

	Scored Flood Definitions	Flood Zone	Address Flooding	Damage at Address	Insurable Loss	Experienced Flooding	Composite Awareness Score	Aware of Policies	Effective Policies	Identify Karst Feature	
S1	1	Do Not Know	No	No	No	No	Low	No	I don't think there are any policies	Yes	Yes
S2	1	Yes	Yes	Yes	Yes	Yes	Medium	No	No	Yes	No
S3	1	Yes		Yes	Yes	Yes	Medium	No	No	Yes	No
S4	1	Yes	Yes	Yes	Yes	Yes	Medium	No	Yes	Yes	No
S5	1	Yes	Yes	Yes	Yes	Yes	Medium	No	No	Yes	No
S6	1	No	Yes	Yes	Yes	Yes	Medium	No	No	Yes	No
S7	0	No	Yes	Yes	Yes	Yes	Medium	No	No	Yes	No
S8	1	Yes	Yes	Yes	No	Yes	Medium	No	I don't think there are any policies	Yes	No
S9	2	No	No	Yes	No	Yes	Medium	No	I don't think there are any policies	No	No
S10	2	Do Not Know	No	No		No	Low	No	I don't think there are any policies	Yes	No
S11	2	No	No	No	No	Yes	Low	No	I don't think there are any policies	Yes	No
S12	1	No	No	No	No	Yes	Low	Yes	Yes	Yes	Yes
S13	1	Do Not Know	Yes	Yes	Yes	Yes	High	Yes	No	Yes	No

S14	1	Do Not Know	No	No		Yes	Low	Yes	Yes	Yes	No
S15	1	No	No	No	No	Yes	Low	No		Yes	No
S16		Yes	Yes	Yes	No	Yes	High	No	Yes	Yes	Yes
S17	2	No	No	Yes	Yes	Yes	Medium	Yes	No	Yes	Yes
S18		Do Not Know	No	No	No	Yes	Medium	No		Yes	No
S19	2	No	Yes	Yes	Yes	Yes	Low	No	I don't think there are any policies	Yes	No
S20	1	Do Not Know	No	No	No	No	Medium	No	Yes	No	No
S21	1	Do Not Know	No	No	No	No	Medium	Yes	Yes	Yes	No
S22		No	No	No	No	Yes	Low	Yes	No	Yes	No
S23	1	No	No	Yes	Yes	No	Medium	No		Yes	No
S24	2	No	No	No	No	Yes	Low	No	No	Yes	No
S25	1	No	No	No	No	Yes	Low	Yes	Yes	Yes	No
S26	1	No	No	No	No	No	Medium	No	I don't think there are any policies	No	
S27		No	No	No		No	Low	No	I don't think there are any policies	Yes	No
S28	1	Do Not Know	No	No	No	Yes	Low	No	No	Yes	Yes
S29		Yes	No	Yes	No	Yes	Medium	No	Yes	Yes	Yes
S30		No	Yes	Yes	Yes	Yes	Medium	No	I don't think there are any policies	Yes	No

S31	1	No	Yes	Yes	Yes	Yes	Medium	No	I don't think there are any policies	Yes	No
S32	1	No	No	No	No	No	Medium	Yes	Yes	Yes	No
S33	2	Yes	Yes	Yes	Yes	Yes	Medium	No	No	Yes	No
S34	1	No	No	No	No	No	Medium	No	I don't think there are any policies	Yes	No
S35	1	Do Not Know	Yes	No	No	Yes	Medium	No		Yes	Yes
S36	1	Yes	No	No		No	Medium	No		Yes	
S37	2	No	No	No	No	No	Low	No	Yes	Yes	No
S38	1	No	No	No		No	Low	No	I don't think there are any policies	Yes	No
S39		Do Not Know	No	No	No	Yes	Medium	No	No	No	No
S40	1	No	No	No	No	Yes	Medium	No	Yes	Yes	No
S41	1	No	No	No	No	Yes	Medium	No	I don't think there are any policies	Yes	No
S42	2	Do Not Know	No	No	No	No	Medium	No	Yes	Yes	No
S43	1	No		Yes	No	No	Medium	No		Yes	No
S44		No	No	No	No	No	Medium	No	Yes	Yes	No
S45	1	Do Not Know	No	No		No	Low	Yes	No	Yes	No
S46		Yes	No	No	No	Yes	Medium	No	I don't think there are any policies	Yes	Yes

S47	1	No	No	Yes	No	Yes	Medium	No	I don't think there are any policies	Yes	No
S48	1	No	No	No	No	No	Medium	No	Yes	Yes	No
S49	1	No	No	Yes	No	No	Low	No	I don't think there are any policies	Yes	No
S50	2	No	No	No	No	Yes	Medium	Yes	Yes	Yes	Yes
S51	2	No	No	No	No	No	Low	Yes	Yes	No	No
S52	2	No	No	No		No	Medium	Yes	No	Yes	No
S53	2	Do Not Know	No	No	No	Yes	Medium	No		Yes	No
S54	1	Do Not Know	No	No	No	No	Medium	No	No	No	No
S55	2	No	No	No	No	No	Medium	No	I don't think there are any policies	Yes	No
S56	2	Yes	Yes	Yes	Yes	Yes	Medium	No	I don't think there are any policies	Yes	No
S57		Yes	Yes	Yes	Yes	Yes	Medium	Yes	Yes	Yes	Yes
S58	1	No	No	No	No	Yes	Medium	No	Yes	Yes	No
S59	1	No	No	No	No	Yes	Medium	No	I don't think there are any policies	Yes	No
S60	1	Yes	No	No	No	No	Low	No	Yes	Yes	No
S61	1	No	No	No	No	No	Medium	No	No	Yes	No
S62	0	No	No	No		No	Medium	No	Yes	No	No
S63	1	Yes	Yes	Yes	Yes	Yes	Medium	No	Yes	Yes	No
S64	1	Yes	No	No	No	No	Medium	No	No	No	No

S65	3	No	No	No	No	Yes	Medium	No	I don't think there are any policies	Yes	No
S66		No	Yes	No	No	Yes	Medium	No	No	Yes	No
S67	1	No	No	No	No	No	Medium	No	Yes	Yes	No
S68	1	Yes	Yes	Yes	Yes	Yes	High	No	I don't think there are any policies	Yes	No
S69		Yes	Yes	Yes	Yes	Yes	Medium	No	I don't think there are any policies	Yes	No
S70		No	Yes	Yes	Yes	Yes	High	Yes	Yes	Yes	Yes
S71		Yes	Yes	Yes	Yes	Yes	Medium	Yes	Yes	Yes	Yes
S72	2	No	Yes	Yes	Yes	Yes	Medium	Yes	Yes	Yes	Yes
S73	1	No	Yes	No	No	Yes	High	Yes	Yes	Yes	Yes
S74	2	Yes	Yes	Yes	No	Yes	Low	Yes	Yes	Yes	Yes
S75		No	No	No	No	Yes	Medium	No	No	No	No
S76	3	Yes	No	No		Yes	Medium	Yes	No	No	No
S77		No	No	No	No	No	Low	No	Yes	Yes	No
S78		No	No	No	No	No	Low	No	I don't think there are any policies	Yes	No
S79	0	No	No	No	No	No	Low	No	Yes	Yes	Yes
S80		No	No	Yes	No	No	Medium	No	No	No	No
S81		No	No	No	No	Yes	Low	No	Yes	No	No
S82	2	Do Not Know	Yes	No	No	Yes	Medium	No	I don't think there are any policies	No	No
S83	2	No	No	No	No	No	Low	No	Yes	Yes	No
S84	2	No	No	No	Yes	No	Low	No	No	Yes	No

S85		Do Not Know	No	Yes	No	Yes	Medium	No	Yes	Yes	No
S86	3	Do Not Know	Yes	Yes	No	Yes	Low	No	Yes	Yes	Yes
S87		No	No	No	No	Yes	Medium	No	I don't think there are any policies	Yes	No
S88		Yes	Yes	Yes	Yes	Yes	Medium	No	I don't think there are any policies	Yes	No
S89	2	No	No	No	No	Yes	Medium	Yes	Yes	Yes	Yes
S90	1	No	No	No		Yes	Medium	No		No	No
S91	1	No	No	No	No	No	Low	No	Yes	No	No
S92	1	Yes	Yes	Yes	Yes	Yes	Medium	No	I don't think there are any policies	Yes	No
S93		No	No	No		Yes	Medium	No	No	Yes	No
S94	2	Do Not Know	No	No	No	No	Low	No	I don't think there are any policies	Yes	No
S95	0	Yes	Yes	Yes	Yes	Yes	Medium	No	No	Yes	No
S96		Yes	Yes	Yes	Yes	Yes	Medium	Yes	Yes	Yes	Yes
S97		Yes	Yes	Yes	No	Yes	Medium	No	I don't think there are any policies	Yes	No
S98	1	Do Not Know	No	No		Yes	Medium	No	I don't think there are any policies	Yes	No

S99	2	Do Not Know	No	Yes	No	Yes	Medium	No	I don't think there are any policies	Yes	No
S100	2	Do Not Know	No	No	No	No	Low	No	Yes	No	No
S101	1	No	No	No	Yes	No	Low	Yes	No	Yes	No
S102	1	No	Yes	No	No	Yes	Medium	No	Yes	No	No
S103	1	No	No	No	No	No	Low	No	Yes	Yes	No/Yes (Marked
S104	2	Do Not Know	No	Yes	No	No	Medium	No	I don't think there are any policies	Yes	No
S105	1	Do Not Know	No	No	No	No	Low	No	No	No	No
S106	1	No	No	No	No	No	Medium	No	I don't think there are any policies	No	No
S107	2	No	No	No	No	Yes	Medium	No	I don't think there are any policies	Yes	Yes
S108	1	No	No	No	No	No	Low	Yes	I don't think there are any policies	Yes	No
S109	2	No	No	No	No	No	Medium	Yes	Yes	Yes	No
S110	2	No	No	No	No	Yes	Medium	No	I don't think there are any policies	Yes	Yes
S111	2	Yes	Yes	Yes	Yes	Yes	High	No	No	Yes	No
S112	0	Yes	Yes	Yes	Yes	Yes	High	Yes	No	Yes	Yes
S113	0	Yes	Yes	Yes	No	Yes	Medium	No	No	Yes	Yes
S114	0	Yes	Yes	Yes	No	Yes	Medium	No	No	Yes	No

S115	2	Yes	Yes	Yes	Yes	Yes	Medium	Yes	Yes	Yes	No
S116	0	Yes	Yes	Yes	Yes	Yes	High	Yes	Yes	Yes	
S117	0	Yes	Yes	Yes	Yes	Yes	Medium	Yes	Yes	Yes	Yes
S118	0	Yes	Yes	Yes	Yes	Yes	High	Yes	Yes	Yes	No
S119	0	Do Not Know	No	No	No	Yes	Medium	No	I don't think there are any policies	Yes	

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