ASSESSMENT OF RISK PERCEPTIONS BASED UPON PRIOR FLOOD OCCURENCES IN THE REGION OF SOUTH-CENTRAL TEXAS: THE INFLUENCE OF CARTOGRAPHIC VISUALIZATIONS AND EXPERIENCE ON ACCURATE RISK PERCEPTION

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ABSTRACT

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Natural hazards are normally occurring events posing a range of risks to society. Risk perception studies are especially useful for determining actions people may or may not undertake, due to a lack of understanding or incorrect perception of risk. The majority of risk communication and risk perception research conducted in the past twenty-five years have utilized traditional forms of cartographic products. This research focuses on participants experience with flood hazards, and how new techniques in Geographic Information Systems and Cartographic Visualization might influence one's perception of risk associated with historical precipitation events and their potential for flooding. The purpose of this research will be to expand upon theoretical risk perception studies, by focusing on how levels of experience contribute to one's ability to accurately assess risk associated with precipitation events. The findings from this research will also contribute to the theoretical and applied risk perception and risk communication literature, as well as literature and applied research relating to cartographic visualization.

CHAPTER 1

INTRODUCTION

Natural hazards are reoccurring events, ranging from commonplace to rare, thus, posing minor to serious challenges for society (Tobin and Montz 1997, 5). The term "natural hazards," is generally defined as representing the potential interaction between humans and extreme natural events (Tobin and Montz 1997, 5). The authors further clarify the term, emphasizing that a natural hazard represents the potential or likelihood of an event, but is not the event itself (Tobin and Montz 1997, 5). In the field of hazards research, a widely studied area is one's perception of his/her level of risk associated with a certain technological and/or natural hazard. Findings from risk perception research are especially useful for determining the actions that people may, or may not, engage in to protect their lives, properties, and communities. Communicating risk information to motivate action stems logically from conclusions and findings in the risk perception literature.

The findings from this research support the theoretical and applied risk perception literature, by focusing on how levels of experience contribute to one's ability to accurately assess risk associated with hazardous events. For this study, hazardous event selected are related to varying precipitation levels capable of producing flood events. Findings from this research also contributed to the theoretical and applied risk communication literature, in investigating how cartographic visualization might be used to study how levels of risk from historical precipitation events might be perceived by individuals following interactions with animated visualization models of those events.

Three questions that guided this study were as follows:

1) How might individuals' levels of professional training and experience influence their perceived levels of risk related to prior flood occurrences when subjected to computer visualizations that depict actual events representing varying levels of flood risk?

2) How might prior experience with a flood or any other hazard occurrence (that is, a severe precipitation or weather event), influence one's ability to accurately assess his/her level of risk associated with the event using cartographic visualization?

3) How might computer visualization aid individuals in correctly assessing levels of perceived risk, that is, be a substitute for actual professional and/or hazards experience?

Furthermore, for those with greater levels of flood hazard experience, the question arises: "Do individuals' perceptions of risk support the general findings in the hazards research literature, that experience with hazards improves one's ability to accurately perceive risk (Blanchard-Boehm 1998; Slovic, Fischhoff, and Lichtenstein 2000)?"

The south-central Texas region is considered one of the most flood prone regions of the United States, and provides the context within which to conduct this study (Leopold, Wolman, and Miller 1964, Fig. 3-16). One characteristic of the United States is the dense and vast network of flood hazard zones (Monmonier 1997). Major floods are produced by both short duration events, as well as, storms that last a number of days (Earl and Anderson 2004). Many cooperative gauging stations placed by the National Oceanic Atmospheric Administration (NOAA) have experienced 24-hour totals of "greater-than-expected" rainfall events using current precipitation models based on rainfall amounts within a 24-hour period. For instance, Earl and Anderson (2004) found that many flood events expected for the 100-year, 24-hour event, might need to be evaluated, specifically with regard to how flooding might occur given longer duration precipitation events for the region. Although the National Weather Bureau published rainfall probabilities for two to ten days (Miller 1964), data and analysis from those studies do not appear to have been considered in flood planning activities. Thus, recent events in July 2002 suggested that current precipitation potential estimates might be underestimated in light of storm events that span longer periods of time. As a result, this study will utilize an approach to communicating risks from precipitation events based on the precipitation model study conducted by Earl and Anderson (2004).

From a spatial perspective in risk communication, the majority of research conducted over the past two and a half decades has utilized static two-dimensional maps to communicate risks associated with hazards. In recent years, however, uses of Geographic Information Systems (GIS) and cartographic visualization have come to the forefront as applications pertinent to hazards research. Two promising techniques include animation and three-dimensional representation, which logically raises the question: "Might techniques such as these, when applied to a hazards risk perception study, yield different results in terms of risk perception across various levels of experiences?" Collins (1998) suggested that the use of such media might improve risk perception assessments, especially by those with a lower level of experience with a prior hazard event. Though Collins primarily focused on risk perceptions associated with hurricanes, his research suggested that other natural hazards might also be studied to determine if similar outcomes are possible.

The very nature of such data and research lends itself to cartographic techniques that are capable of leveraging the spatial and temporal aspect of climate data. This multi-dimensional understanding of historical climate data and its potential hazards-related impacts provide an opportunity for visualization and communication of information to emergency management officials. One such visualization technique is the use of animation to represent change in geographic space over time. Lobben (2003) quotes Moellering (1980) as having stated, "The appealing feature of [animation]…is not only the capability of showing surfaces from different viewing points, but also the ability to show change through time in a way that is more powerful than the creation of a series of static maps (327)." Furthermore, Jensen (2003) emphasizes, "…what happens between each frame is more important than what exists on each frame (1)." By understanding the processes and the magnitudes of events across time and geographic area, a better understanding of the spatial phenomena involved might be obtained.

Five computer visualizations of previous flood events in central Texas were developed for this study. Each precipitation event, took into account precipitation over longer periods of time by visualizing daily rainfall amounts across a seven-day period (sequence), versus using a timeframe of 24-hours. The visualizations used in the study were based upon the cumulative amount of rainfall for the period being displayed. The models, that is, the visualizations, were presented to groups of study participants with differing levels of experience with previous flood occurrences so that responses might be compared with other participants' various levels of experience. The participants were defined by groups and included: 1) experienced technical environmental and emergency management professionals; 2) geography graduate students; and, 3) laypersons. The five visualizations of precipitation events chosen for the study ranged from "extremely hazardous" in terms of flood producing potential, to events considered normal or non-threatening in terms of the amount of rainfall produced. The participants viewed an animation for each event, and then ranked each event from "most hazardous" to "least hazardous" based on levels of perceived risk. The findings from this research contributed to the existing theoretical and applied literature concerning perceptions of risk; especially in relation to understanding how individuals' might use computer visualizations to more properly synchronize perceived risk with actual risk.

The organization of this study begins with Chapter 2 where background information is presented on cartographic visualization in terms of current capabilities, with further explanations of how this technique might be used in future hazards research. Following a discussion of cartographic visualization methods, Chapter 3 sets forth prior research from the risk perception literature as it applies to this study. In addition, the literature review includes theories and conclusions from computer visualization studies as they relate to risk perception. Chapter 4 outlines and explains the design of this research with discussion of methods and procedures used for conducting the data collection and analysis. This research concludes with findings, interpretations, and potential contributions to the field of hazards risk perception.

CHAPTER 2

CARTOGRAPHIC VISUALIZATION METHODS AND PRACTICES

A Geographic Information System (GIS) and Cartographic Visualization (hence, referred to as visualization) are two methods presently employed in a variety of ways to plan, prepare, respond, and evaluate flood events, thereby, providing significant benefits over traditional paper-based and manual flood mapping techniques. Visualization is a growing subfield in geographic information science, and provides a method for exploring, analyzing, and verifying hypotheses from large quantities of spatially referenced data. When used together, GIS and visualization enables researchers to analyze large amounts of data in an interactive and scientific manner. Furthermore, visualization methods provide researchers with enhanced and creative ways to discover and expand bases of knowledge in analyzing complex phenomena and for developing testable hypotheses.

When using a tool, such as GIS or visualization to construct an emergency management plan, it is first necessary to create a map for identifying at risk locations as they appear in the geographical area under analysis. This includes consideration for geographic locations of buildings, infrastructure, and economic activities. One of the most important skills is the ability to visualize and depict spatial information, typically illustrated by the use of maps (Alexander 2002, 14).

Cartography may be considered both an art as well as a science due to the blending of aesthetic presentation and scientific data. It is this blend of functions that places the practice of developing maps in a unique position in the social sciences. By its very nature, geographic or spatial data has an extra dimension inherent in its structure, and, therefore, produces the need to visualize this extra dimension through the adoption of new visualization techniques (Orford et al. 1998, 15). Over the past two decades, computer-processing capabilities have assisted greatly in the field of cartography. Maps that were once developed by hand are now generated using computerized software and hardware. Aside from the benefits of automating formerly manual cartographic tasks, evolving technologies have further found alternative uses of maps to assist scientific efforts through the availability of geo-referenced information (MacEachren and Kraak 1997, 335).

Most computerized maps have been designed to mimic paper maps, however, with advances in computer technology, it is no longer logical to assume that maps produced by computers be identical to printed products (Campbell and Egbert 1990, 24). The representation of time or temporal aspects of phenomena has also undergone changes with advances in technology. According to Cartwright (1997), the presentation of time in maps prior to computer assisted mapping required the generation of several individual representations at points in time (449). Although, this process is still the basis of new technologies such as cartographic animation, the use of computers improves the efficiency in the development of a time series representation.

Although printed maps and most computer maps are static in their representations of spatial data, there is a common need to demonstrate the dynamic element of change over time. One such application is in the area of historical geography, where "time-series portrayal" is an element (Campbell and Egbert 1990, 25). Animation is a process whereby a presentation is developed that shows changes over time, space, and/or by attribute, and consists of thousands of slightly differing individual frames (Lobben 2003). Animation is different from other moving representations such as film, in that film-based techniques, although visually appealing, lack interaction with the map user (Hurst 1997, 654). Temporal cartographic animation is the process of showing interrelations among the geospatial data components of location, attribute, and time (Ogao and Kraak 2002, 23). Improvements in computer hardware and processing capabilities have allowed animation in industries, such as film and education, to explore alternative animation techniques. These techniques have further expanded into the field of cartography as a practical alternative for the display of maps (Jensen 2003).

As technological capabilities are improved, maps representing dynamic versus static views of spatial data are becoming increasingly popular and easier to produce (Dykes 1996, 345). The concept of time-series on multiple maps, takes multiple snap shots of space at various times, and then portrays them in a sequential manner. Time-series portrayal is one of the most common forms of cartographic animation, and may be the least complex form of animation (Campbell and Egbert 1990, 26). Through the use of dynamic representation, data may be observed over time (Lobben 2003). By understanding the process, one may gain a better understanding of the spatial phenomena involved, and how those phenomena unfold over time and geographic extent. Use of these geographical visualization techniques, characterized by enhanced interactive and dynamic tools are becoming commonplace in geospatial applications. These techniques are also being used in conducting qualitative analysis as a compliment to further qualitative study. Animations play an intuitive role when used to view geospatial transitions as they happen in time, as opposed to viewing the end states, and enable one to understand dynamic processes rather than phenomena as instances of time (Ogao and Kraak 2002, 23).

Cartographic animation has also furthered the processes associated with communicating and presenting information to further our understanding in academic theory/research development. As noted by Stanislav, Lapaine, and Poslončec-Petrič (2000), human learning capabilities allow the development of images mentally, which in turn make recognition of patterns and formation of ideas possible. The ability to view data as a process may also assist in communicating to those who may not have an in-depth knowledge of what is being presented. Through visual exploration of data and viewing of animated processes, people may explore solutions to problems otherwise not evident. Visualization tools give users the possibility of performing extensive investigation and transformation of data for observing phenomena from different viewpoints (Frangeš et al. 2003, 3). The importance of cartographic animation lies within the activity of describing something that would not have been evident if a series of maps had been viewed individually (Jensen 2003). The ability to gain insight into large amounts of data typically presented in tables or text format is a key advantage of scientific visualization. Research into the thematic method is important to understanding the best manner in which to visualize data. Experimentation with regards to information retention, visualization ability, statistical techniques and methods, may give insight into impacts that animation will have on an end user's mental imagery of a map (Campbell and Egbert 1990, 41). Cartographic visualization also contributes through the development of interactivity between the map user and the spatial data being analyzed. There are various classifications of interactivity with cartographic visualization, from a presentation style format where there is very little interaction by the map user, to full interaction where the map user controls the course of the animation (Lobben 2003). Current systems such as GIS may also benefit from the use of cartographic animation. Through the use of new multi-media and temporal query methods, geographers may query the GIS "container" to gain information on processes not seen through the viewing of static maps (Giordano and Gelpke 2003, 339).

The use of cartographic animation has contributed to the field of geographic information science through the use of techniques such as animation and interactivity. The area of interactivity appears to be the largest area of contribution, stemming from the number of articles and research efforts conducted to date. Through the use of interaction, new ideas may be formulated and different perspectives may be generated. Interaction also allows the map user to 'drill down' to gain further insight to geographic representations. The dissemination of visual data is another area gaining attention. The widespread availability of the Internet, and the ability to share information to a large audience at a low-cost through the use of the World Wide Web (WWW or "the Web"), has allowed cartographic visualization techniques to be shared quickly and with relative ease. Through the use of interactive approaches and improved methods of sharing information, educational processes are also improved.

Traditionally, one has only been able to map a spatial situation as a single instance in time. Comparison of elements over time and their rates of change were depicted through separate maps at the same instance of time. With the use of digital computers and displays, it is now possible to map situations and show the evolution in a continuous manner, making the rates of change appear smooth and as a single process.

For hazard mitigation activities, animation may assist with indicating where physical phenomena might be prevented or protected against, or to place structural defenses. As part of both mitigation and preparedness activities, zones of risk and vulnerability may be determined, as well as, in locating necessary resources following a disaster, response efforts may benefit through representation of the phenomena and the spatial boundaries of the incident, including understanding where the greatest damage exists and casualties are located (Campbell and Egbert 1990). New methods for map development and decision-making may stem from how maps are changed through time, space, and the attributes being presented. Through interaction with spatial data, analysis and hypothesis development may occur in an interactive way (Hurst 1997, 654). This might make a difference in the way users think and for the quality of solutions and theories developed; hence the emphasis is not on storing knowledge, but rather on the creation of knowledge (MacEachren and Kraak 1997, 336).

The goals of animation should be to move smoothly, with a purpose, and to be easily interpreted (Campbell and Egbert 1990, 41). The trend in cartography is towards constant need for quality practices in visual communications, considering that more people have access to the use of new cartographic technologies. Maps have served important functions over the past few centuries. They have been a medium for saving information about space, and were the image of the world that helped simplify the complexities of the environment. With regards to quality, the visual representations of phenomena over time have led to better understanding of spatial objects (Frangeš et al. 2003). As for quantity, the availability of faster and less expensive production tools have yielded a wide range of cartographic products. "The process of visualization is considered as a translation or transformation of spatial data from the database into a drawing" (Frangeš et al. 2003, 1). According to Frangeš and colleagues, cartographic visualization should meet certain demands in order to be effective: 1) Legibility; 2) Plainness; 3) Accuracy; 4) Clearness; and, 5) Aesthetics (2003, 2). Legibility includes minimal sizes, graphic density, and differentiation of known features. Plainness includes symbolism, traditionalism, and hierarchic organization. Accuracy involves positioning and symbolism. Clearness includes simplicity, contrasting quality, and layer arrangement. Aesthetics includes harmony and beauty.

Various levels of animation exist for cartographic visualization, which vary based upon the use of elements such as time, space, and attribute. Each element may either be static or dynamic in nature, and as identified and described by Lobben (2003), four schemes might be produced: 1) Time Series; 2) Areal; 3) Thematic; and, 4) Process (319). *Time Series* is represented through depicting change over time, where the timeframe may be almost any measure of time (for example, centuries, hours, or even seconds). One example of animated time series visualization would be depicting the migration of animals over a geographical area. A geographer would be able to depict direction, recurring movement patterns, and durations or pace of movement. *Areal* schemas focus on the phenomena at a particular attribute independent of time, but representing space dynamically. Typically this type of representation is used to explain changes due to other factors than time (Jensen 2003). The best illustration of areal visualization is in the use of 'fly-by' animations where an unchanging attribute may be studied at a fixed point in time. Fly-by animations may be of particular importance to physical geographers who do not have access to physical locations, or limited time to study geologic features on-site. *Thematic* schemas emphasize the attribute being studied at a particular location, where the attribute is dynamic and space is static. Thematic visualizations are one of the most common representations used in geography today through the development of choropleth maps. However, through animated visualization techniques, this method may also represent time as either static or dynamic. *Process* is the most advanced of the four schemas, as all three elements of time, space, and attribute are dynamic. This representation has significant value in studying dynamically changing environments, in particular that of natural or technological hazards. An example illustrated by Lobben (2003) is that of animating an offshore oil spill to represent flow of oil (direction), speed, and shape (325). The above visualization methods have advantages for communicating complex phenomena. Furthermore, as discussed later in this paper, there still remains much development to be done in the field as it relates to gathering detailed data from these representations.

This ability to improve timeliness of communications and the dissemination of information in a variety of formats may assist with delivering important information in a method that provides the opportunity for the public to interact with information. As noted by MacEachren and Kraak (1997), visualization techniques applied to public presentations and communications not only present known information, but also include elements of interactivity (339). Humans use visual images to build their concept of what is being explained. In cartography, "mental maps" may be developed incorrectly, and therefore, provide map users with an inaccurate view of reality. It remains to be seen whether visualization techniques will ever be able to completely replace the experience of actually visiting a location. Even the uses of virtual reality applications have many shortcomings to the actual experience -- touch, smell, temperature, and the sense of openness are just a few. In the meantime, several areas have been identified that may greatly enhance the visualization experience of the end user. One such technique is to link map features to resources and data that would enhance the visual experience and support the development of an accurate mental map (Cartwright 1997, 451). This linking would need to be done in a way that facilitates an interactive method of learning, and not just access to passive film-based media. Elements of interactivity may lead to the gathering of new data not previously known by researchers, have the potential to be included in the interactive process, and be used to gauge risk perceptions of events across a geographic area.

Geographic education has also benefited from advances in cartographic visualization. In a study by Hurst (1997) to evaluate the use of virtual field trips, it was found that students learned the most when they interactively designed a virtual animation (657). This fostered inquiries on the underlying data and discovery of new visualization methods students had not been known before, thereby, providing benefits not realized through traditional non-interactive methods such as film. The ability to explore data interactively was enhanced by the integration with other visualization techniques such as hypermedia (Lobben 2003, 318). As educators search for methods to gain students attention and foster exploration of ideas, the use of multi-media appears to be a valid choice when it comes to enhancing the educational experiences. As Orford and colleagues state, "The use of multimedia implies interactivity (1998 11)." It appears that as visualization techniques improve, and the ability to interact with spatial data becomes more advanced, the interactive experience will improve the educational process. Advances in visualization have the potential to shift once passive education methods, to new methods that imply interaction and exploring.

Over the past several years, there have been many advances in geographical software have taken place as an ongoing effort to better visualize complex spatial data.

Many GIS and mapping packages are still limited to static map displays. Interactivity and animation functionality have been developed outside of these tools. However, according to Huang (2003), research efforts in the area of three-dimensional programming techniques are moving forward. More capabilities need to be added to animation systems, including the ability to pause, zoom, and analyze in detail geographic phenomena in a temporal manner (Jensen 2003). As stated in a study led by Orford (1998), "A true 3D GIS must enable a realistic 3D representation of the data, normal GIS functions, free movement of the user within the 3D representation, and visibility functions, such as line of site (16)." Some of these capabilities are now available through extensions to GIS software. Future abilities for GIS' might be a 4D spatial system, where interactive analysis of data and animated 3D visual capabilities are combined with analysis across time. Multimedia GIS is a future research area for geographers, with questions such as how databases are queried, integrated with other digital sources, and represent changes across time in a physical environment (Giordano and Gelpke 2003, 340).

Cartography plays a significant role in the evolution and use of maps within visualization systems, spatial data systems, and information dissemination. Cartography has much to offer the scientific community ranging from its history in representing geographic relationships, to linking those with digital data and visual representations (MacEachren and Kraak 1997, 335). Furthermore, the integration and use of GIS, computer cartography, and visualization methods may be of great potential benefit in studying relationships between space and time (Giordano and Gelpke 2003, 339).

CHAPTER 3

REVIEW OF RISK PERCEPTION AND VISUALIZATION THEORY

In the field of natural hazards, risk perception involves the study of how people make decisions and take actions toward potential losses of lives and properties due to expected future occurrences, based on their personal perceptions of risk, rather than on some objectively derived measure of threat (Smith 1996, 54-55). Perception involves two major components: awareness of a hazard, and the expectation of the hazard (Moon 1971, 1). A significant amount of research has been conducted over the past several decades concerning individual's perceptions of risk. Various factors have been identified which influence how people differ in their perception of hazards, including one's level of experience. According to Smith (1996), the type and degree of perceived risk may vary greatly between people of the same age and sex due to factors such as location, occupation, and lifestyle (55). Furthermore, some individuals are bound by cultural and religious beliefs, and respond to risk accordingly (Tobin and Montz 1997). One theory within risk perception is that of "Knowledge Theory" which states that people perceive things to be dangerous because they know them to be dangerous (Wildavsky and Drake 1994, 166). This suggests that experience with events or objects allow people to understand the levels of danger better than those without prior experience. According to Moon (1971), awareness of a hazard has been shown to closely correlate with past experience with a hazard, and the expectations of hazards are a function of experience, written, and verbal information (1). Past experience with hazards has also shown to influence an individual's imagination of the hazard (Moon 1971, 38). For instance, Slovic, in a 1979 study, determined that one's perception of risk associated with different technological hazards varied based on one's level of experience (2000, 114). Other studies in the area of natural hazards, demonstrated a similar findings regarding perceptions of risk toward the earthquake hazards (Blanchard-Boehm 1998, Palm et al. 1990). Although experience emerges as a dominant factor in risk perception studies, there are other influences on hazards perception. These influences include: present attitudes, personality and values, and future expectations (Smith 1996).

Factors in Risk Perception

There have been many conflicts in conceptualizing and understanding risk as a result of difference between expert quantifiable risk assessments and public or layperson perception or risk (Slovic 1992). Research has suggested that technical experts and laypersons perceive hazards in different ways, particularly, in relation to frequency and impact of hazards. According to Smith (1996), experts perceive infrequent high-impact hazards equal to that of more commonplace hazards that are lower impact, whereas, laypersons tend to give a higher rating to infrequent high impact hazards. Risk means different things to different people. Slovic (2000) found that experts typically judge risks in a manner that correlates to technical estimates or fatalities of a risk, whereas laypeople sometimes rely upon other characteristics. If risk perception is not understood, it becomes difficult to comprehend and anticipate responses to risk, which further complicates risk reduction (Tobin and Montz 1997).

In another study by Mertz, Slovic, and Purchase (1998), comparisons among senior managers, toxicologists, and the public vary when asked about chemical related hazards. Their research found that senior managers and toxicologists employed in the chemical industry have lower risk perceptions of chemical hazards as compared to toxicologists employed in academia and the general public. Furthermore, when comparing all toxicologists to the general public, toxicologists demonstrated a more favorable attitude towards chemicals than the general public. Mertz and colleagues research also suggested that industrial workers who were highly educated, older, and male had lower risk perceptions of chemicals.

Similar findings may be found of research conducted in the natural hazards field, specifically that of flood hazards. Green, Tunstall, and Fordham (1991), found that engineers viewed flood risk as a statistical probability, whereas those in the general public who had experience with flooding, developed their own models of the causes of the flooding, which they use to predict the likelihood of future floods. That experience coupled with a personalized 'mental model' led to adaptations that help to protect against flooding. Further, such adaptations may include knowledge of when and how to evacuate, as well as, how to interpret other information for making predictions on their own. For some this might suggest a greater perception of their ability to deal with flood events than others. In an earlier study, Moon (1971) found that the impact of a hazard on an individual depends upon the degree to which the person felt protected and able to cope with the situation. Slovic (1992) reported that a person's perception and acceptance of a risk was determined by the context in which one is exposed. Although this article was primarily related to technical hazards, it might also be applicable to flood hazards, as well. Tobin and Montz found that geographic location was a factor in determining whether a particular event constitutes a hazard (1997), therefore, concluding that it might be more beneficial to study perceptions with regards to how flood events occur in urban settings by those located at ground level versus those located in high-rises or elevated areas.

Direct experience might also provide feedback on the nature, extent, and manageability of the hazard, and may also act as an amplifier, thereby allowing for a better perspective and enhanced capability for avoiding risks (Kasperson et al. 2000). One possible example of this finding may be applied to flooding in locations where excessive precipitation, leads to flash floods and dangerous low-water crossings. Here, a person's experience and understanding of the potential dangers associated with an event, may lead to better judgments in dealing with hazardous situations. In research conducted in the San Francisco Bay Area relating to response to earthquake risk, Blanchard-Boehm found that past experience strongly impacted beliefs, attitudes, risk perception, and response behavior. From the study, it seemed those with the most experience with earthquake events responded most favorably and took actions to mitigate their risks (1998). Another characteristic of personal experience is how recent an event has occurred, and how time can impact perceptions. As Tobin and Montz observed, hazardous events remain a focal point in peoples' lives for some time, but memories of the event inevitably wane and are replaced by thoughts that may or may not reflect the reality of the event (1997).

Risks may be divided into what researchers call objective risks and perceived risks (or subjective risks), and variances between the two types are a result of discrepancies between what is believed by respondents and what experts calculate using objective methods (Smith 1996). Laypeople, although they sometimes do not have the information on particular hazards, conceptualize risks in a manner different than experts (Slovic 2000). Smith viewed human perception as a, "filter through which hazards are viewed," and when faced with complex information and decisions to be made, a more simplified and personalized model is developed upon which to act (1996, 66). Those methods are sometimes omitted by experts, highlighting the importance of affected individuals in making significant contributions to risk assessment may have something to contribute (Slovic 2000), and should be incorporated into the process along with knowledge provided by the scientific community (Slovic 1992). However, there are not assurances that judgments made by experts are without fault, and may be the result of incorrect or missing information used in the decision-making process (Slovic et al. 2000). These judgments may also be the result of intentional over exaggeration of information, in order to persuade action by the general public. Also, risk assessment by laypeople seldom includes statistical information, and therefore, forces people to rely upon simple sets of rules call "heuristics" (Slovic et al. 2000). Such was the case with the 1997 Red River flood event in Canada, where the government exaggerated the level of potential flooding to intimidate residents into evacuating. In response, residents resisted the warnings, relying instead upon their own experiences with flooding in the area as a basis of when and if to evacuate (Heijmans 2001). However, according to Slovic, Fischhoff, and Lichtenstein, uses of heuristics are not always accurate, and may lead to biases and overconfidence by both experts and the general public. Furthermore, initial impressions tend to structure the way additional information is interpreted, and as a result, new information appears to be reliable only if it is consistent with one's initial beliefs (2000). This overconfidence is supported by Green, Tunstall, and Fordham (1991), where respondents acknowledged that the reality of dealing with flood events were much more difficult than one might imagine. Some reasons for this overconfidence may include: 1) failure to consider ways in which normal operating processes may fail to be followed, thus leading to human error; 2) failure to anticipate human response to measures that may give false sense of security; and, 3) bias in people's imagination and memory of the hazard may be biased leading to invalid perceptions (Slovic et al. 2000).

According to Slovic (1992), there seems to be a rising concern over risks as people become safer and healthier. The reason for such rising concerns points toward scientific, social, political, legal, institutional, and psychological factors. Research has shown that risks where the severity of a hazard is considered uncontrollable and/or rare tend to be seen as catastrophic and fatal (Slovic et al. 2000). In addition, it is suggested that frequently occurring events are typically easier to recall than rare events, and are sometimes underestimated due to a high level of adjustment to the hazard (Moon 1971). There is also evidence to support the notion that many hazards are distorted in terms of the estimated and actual level of risk associated with them. In particular, in a study by Slovic, Fischhoff, and Lichtenstein, respondents believed that greater risk should be tolerated or more beneficial and/or voluntary activities (2000). Tobin and Montz recognized that cognitive factors and situational factors interact to produce defined responses (1997). Cognitive factors include psychological and attitudinal factors, and situational factors include physical and socio-economic variables. For instance, the cognitive factor may include those who deliberately choose to live in a hazardous location because of the amenities offered, and the advantages far outweigh the rare occurrence of a hazard occurring. The situational factor might include residents expressing difficulty in leaving an area due to considerable investment in property, constraints, or dependence that prevents them from leaving. Thus, as stated by Tobin and

Montz, "Risk involves choices, but those at risk are not always the ones who make the decisions (1997)."

Risk Communication and Effects on Risk Perception

Risk communication in and of itself encompasses a large amount of theory and literature in the hazards research community. However, it is difficult to discuss the aspect of risk perception without encompassing some discussion of how to share information with those who develop perceptions of hazards, whether they are experts or the general public. In particular, research relating to who seek risk communication and the importance of issuing such communication are of importance. Although local residents have knowledge of their area, the history of disasters, and experience how hazards have changed over time, knowledge of scientists and experts are still needed to fully understand risk associated with rare and new hazards (Heijmans 2001). According to Tobin and Montz, floods have been the most common event in the past sixty years and account for 30 percent of all disasters, and are listed third behind hurricanes and earthquakes in terms of deaths. Furthermore, it is approximated that in the United States, 7 percent of the country may be defined as being part of a floodplain, accounting for 94 million acres, 9.6 million households, and $390 billion worth of property at risk. Of this area, approximately 3.5 to 5.5 million acres have been urbanized and potentially exposed to flood hazards, with urban development in wetlands, floodplains, and on steep slopes increasing risk and vulnerability (1997). This information seems to support the case for better understanding how changes to topology and land might affect people in the future.

In an article by Slovic (2000), it is mentioned that researchers Alfidi (1971), Fischhoff (1983), and Weinstein (1979) found that if the general public considers hazards to be well-managed by competent professionals, the public prefers to not confront the issues surrounding them. However, it is also pointed out that if assurances cannot be given, then the public prefers to be informed of the risks. Although the general public may feel comfortable with the management of hazards, there is still the need to inform those at risk. In research conducted by Blanchard-Boehm, the need for information is highlighted by the fact that most disaster households are likely to be "on their own" during the first 72 hours of a disaster. By educating a populace, individuals are provided with incentives to assume responsibility for their own lives and their properties, thus controlling their own destiny. Furthermore, one's experience with a disaster event heavily influences perceptions of vulnerability towards future events, and plays a powerful role in motivating individuals to respond to low-key non-urgent warning messages (1998). Aside from hazards associated directly with floodwaters, flooding and excessive rainfall can lead to health related issues such as exposure to salmonella, Hepatitis A, and Escherichia coli (Tobin and Montz 1997).

As discussed in the previous section, experience with hazards provides a significant framework for individuals in perceiving risks associated with hazards. Slovic found that risk judgments are influenced by past events, and how people will imagine future events. In addition, distortion of perceptions may come about by any factor that makes a hazard unusually memorable, including exaggeration of past events (2000). For those with more experience living in areas of high hazard risk, risk assessment and the development of perceptions is an ongoing self-educating process (Blanchard-Boehm 1998). Such findings seem to underscore the need for programs of continual hazards communications that no only provide the experienced public with information, but also attempt to educate those with less experience. One such method to provide information and reinforce risk communication might be to consider community or focus group presentations. Mileti suggests that such efforts, such as focus groups, will meet the needs of those involved in a 'risk information confirmation' process (1993). Furthermore, learning from experiences with regard to natural hazards may not be the most preferred method, as experiences may be rare and mistakes too costly (Slovic et al. 2000). Slovic and others also state there is a need to make the decision maker's perceptions of the hazard more accurate, and to develop an awareness of alternative courses of action (24).

As part of a hazards communication effort, it is critical to understand how different receivers view the information being provided. As stated by Mileti, interpretation of risk messages may vary among people, and may not match the intended purposes of those issuing the message (1993, 143). Maule also suggests risks might be interpreted differently by those with dissimilar world-views (2004). For instance, 'fatalists,' 'hierarchists,' 'egalitarians,' 'individualists,' and 'technology enthusiasts' may all perceive the same risk differently due to different frames of thinking and thus should be considered when forming communication strategies (24). Maule also suggests that differences may arise between those playing different roles in the hazards management process, and those differences may lead to variations regarding the severity of risks and appropriate actions (24). Slovic has observed that risk assessors and risk managers have often made false assumptions about conceptions of hazards, which has led to failures of communication. The fact that such conflicts might occur signifies a need for warning and education programs that go beyond just mentioning the hazard and potential outcomes (2000). Such instance might be where mass media highlights past outcomes and event exaggerates past events, but provides little or no helpful information to the general public as to what actions to take prior or during events. As discussed thus far in this literature review, perception is not only a result of experiences, but also a result of how information is presented, and, therefore, is a subjective process, which may be influenced in a negative way with false or misleading information. Furthermore, as observed by researchers, in the absence of personal experience, methods are needed to inform about risk, and this information flow is important to public response to ensure unwarranted fears, biased recollections, and inaccurate outcomes of events to not occur (Kasperson et al. 2000).

Visualization Practices and Risk Perception Theory

The past several years has seen a growth of cartographic visualization as an acceptable method or scientific practice. This growth has been accompanies by advances in multimedia technology, offering interactive and visual products to the public (MacEachren 1994). In light of these advances, it seems relevant to apply their capabilities to the field of hazards research in an effort to further understand how they might contribute to perceptions of risk. If all hazards events resulted in the same consequences, only the frequency of the occurrence of the event would be needed (Smith 1996). Observations such as the one offered by Smith point to a need for visualization to better understanding our natural environment. In particular, highly variable events such as precipitation and potential for flooding may be visualized using historical data to seek patterns and identify potential areas of risk. Furthermore, potential impacts from disasters and their impacts may be moving targets both spatially and temporally, and may lead to hazards affecting communities at different times and places. By better understanding how events unfold, opportunities may exist for emergency management organizations to better understand how to lessen the losses of future events (Tobin and Montz 1997).

Visualization is not a new aspect of cartography, but a renewed way of looking at an application of cartography that considers both new concepts of visual communication and traditional concepts of visual thinking (MacEachren 1994). Technology has enabled a growing amount of information to be stored digitally, with the ability to enhance that data to meet the endless needs of other systems or end-users. Tools such as a GIS and other statistical tools allow end-users to work through vast amounts of data to find trends, relationships, and potential solutions to the problems they are presented. Technology, when implemented correctly, may present information in a meaningful format, automate processes, integrate seemingly different functions, and in some cases, promote new capabilities. According to Peterson, visualization leverages computer graphic capabilities to display scientific multi-dimensional data for human interpretation, and is based on the human ability to impose order and identify patterns (1994). With vast quantities of data becoming available in digital format, the capability exists to produce spatio-temporal visualizations to communicate information about natural processes, and to communicate those processes through mediums readily available to the general public.

With advances in technology, it is essential to consider the implications of maps as dynamic interactive spatial information tools, as compared to their traditional role as static storage devices for spatial data (MacEachren 1994). As noted by Peterson, cartographers not only view computer technology as a tool to make maps, but as a medium for communication, with a renewed interest in the mental processes to gain greater insight into visual processing (1994, 28). Furthermore, new electronic products are different from paper maps and the human interpretation of electronic images is not the same as that of traditional products, thus leading to significant quantitative and qualitative changes (Taylor 1994). Maps have been used for centuries to develop representative models of our environment, and display both quantitative and qualitative information. Maps stimulate thought and provide the ability to display uncertainties and variability of parameters that contribute to risk (Husdal 2005). Thus, maps are considered by many to be an ideal media for effective presentation and communication of information in a wide variety of subject areas (Taylor 1994). In a study by Blanchard-Boehm on public response to increased earthquake hazards, it was determined that experience was a dominant factor in leading residents to correctly perceive risks associated with future events (1998). This study was conducted followed a visual public information program sponsored by the United States Geological Survey (USGS) utilizing static map products. Since this study, several advancements in cartography have been achieved, and one might question how perceptions of risk might change given the use of more recent methods for communicating spatial information? Is it possible that new media formats are capable of illustrating information and communicating risk to those with less experience with hazards? If so, such a finding may provide a method to reach many that are at risk from hazards, but do not possess the understanding of prior events upon which to make decisions to protect life and property. It is, therefore, necessary to create informational programs that are effective in presenting complex, uncertain, technical information in a manner that yields better decisions (Slovic et al. 2000). When dealing with the temporal aspect of events, Monmonier suggests that animations are most useful in describing the likely sequence of events and in relating a general explanation to the uniqueness of the locality (1994). In a dissertation study by Collins (1998) on risks perception of hurricane storm surge, study participant were shown either an animated visualization model of risk, or a storm surge informational brochure. Results of a follow-up survey indicated the animated visualization model altered the cognition of the majority of the people who viewed it. The results indicated an increased level of perceived vulnerability and improved evacuation behavior. The storm surge informational brochure also altered behavior, but in a manner that reduced the perception of risk. The study supports the idea that animated risk visualizations may be an effective method of communicating risks involved with hazards. The study also suggests that this type of research be conducted beyond hurricane hazards to other types of natural and technological hazards.

However, in order to provide such methods that might prove successful in accurate perceptions of risk, there are many challenges beyond merely making maps using the latest media capabilities. Many of these challenges deal with the cognitive aspects of how people process images and in turn form their perceptions. Only by conducting research among those with varying levels of skills, might information be obtained to further investigate the possibilities. One observation in the field of cognitive psychology, which involves the mental processing of static images, is that motion is essential to perception (Peterson 1994). Furthermore, Peterson notes this perception involves the ability to infer from ambiguous "clues" which utilize additional knowledge from memory that is brought to bear as part of the recognition process. This additional knowledge from memory appears to point towards experiences, and it is the challenge of visualization to provide knowledge without the true-life experience. As suggested by Slovic, Kunreuther, and White, imaginative presentation of probability data may not be enough, thus creative methods are needed to facilitate imaginability and break the 'prison of experience' that currently surrounds probabilistic thinking (2000, 24-25). Within the natural hazards field, there is variability in how people respond when asked general questions regarding the risk of events. For example, Moon mentions that questions such as "Is this place subject to flood?" or "Do you expect floods to occur here in the future?" are perceived differently due to different levels of awareness and understanding of the word "flood" (1971, 2-3). Based on this example, it might be better to focus on seeking responses following the presentation of risk information in a more spatial format. However, as Lundgren and McMakin point out, two of the most common faults with visually communicating risk are: 1) using pictorial representation that are out of proportion to actual numerical quantities; and, 2) using visual elements that obscure the meaning of data (1998, 203). This offers a challenge to the researcher attempting to communicate risk in a spatial format, in that classifications must accurately represent risk information so as to not mislead, while at the same time keeping information simple and easy to understand for the layperson. Therefore, feedback in any risk communication process appears to play a significant role in the continual improvement of risk communications. Using feedback in the field of public health and safety, it has been found that understanding the complex opinions that people have about risk, aids those involved in the risk communication effort by improving information sharing and risk sharing with the public (Slovic 2000). However, research by Lundgren and McMakin suggest that representing various aspects of risk in pictorial, visual, or graphics formats does allow people to understand and make decisions about risks, by clarifying abstract concepts and placing facts into context (1998). It is further stated that if representations of risk are clear, comprehensive, and non-manipulative, they may be powerful tools to help people understand risk.

CHAPTER 4

STUDY DESIGN

Background

This chapter discusses the design, procedures, and methods that were employed to perform this study. The methodology chosen for this research was a mixed method quantitative-qualitative risk perception study designed to assess how different groups of individuals with different levels of experience with natural hazards, estimated and perceive various levels of risk associated with historical precipitation events.

In this study, the method of communicating levels risk associated with historical flood events presented involved the use of cartographic visualization and animation products, which were presented via the Internet using computer browser software. Furthermore, this study used an Internet-based survey as part of the data collection process on which participants recorded event ratings after viewing cartographic flood visualizations as well as to ask for additional information on issues related to individuals' perceptions of risk and vulnerability toward future flood occurrences. The objective of this study was to measure how different groups of participants with varying levels of professional experience with hazardous events perceived various levels of risk, as a result of using cartographic visualization and animation risk communication methods. For continuity purposes, the study questions that were stated in the Introduction, are restated below:

1) How might individuals' levels of professional training and experience influence their perceived levels of risk related to prior flood occurrences when subjected to computer visualizations that depict actual events representing varying levels of flood risk?

2) How might prior experience with a flood or any other hazard occurrence (that is, a severe precipitation or weather event), influence one's ability to accurately assess his/her level of risk associated with the event using cartographic visualization?

3) How might computer visualization aid individuals in correctly assessing levels of perceived risk, that is, be a substitute for actual professional and/or hazards experience?

Thus, more formally stated as alternate (H_a) hypotheses:

1) When shown computer visualizations of prior flood hazard events, individuals' who have greater levels of professional training and experience with some aspect of a natural hazards occurrence, will be able to correctly identify levels of risk associated with each historical flood event, than those who do not have professional natural hazards experience.

2) When shown computer visualizations of prior flood hazard events, individuals' subjective estimations, that is, their perceptions, of the levels of risk associated with the prior flood events will strongly correlate with their actual, or objective, levels of exposure to flood and other hazardous events.

3) The ability of an individual to correctly understand and correctly identify risk associated with flood hazard events is correlated to his/her level of experience, and therefore, cartographic products cannot be a substitute for experience with flood events.

This study is similar to prior risk perceptions studies where participants of different skill levels and experiences were asked to rate hazards from "most hazardous" to "least hazardous" (Slovic et al. 2000). However, those studies primarily focused on a wide variety of hazards, whereas this study focuses on how participants perceived risk associated with different types of precipitation events, which may result in varying levels of flooding. In addition, this study attempted to build upon research conducted by Collins (1998), where visualization was found to be effective for communicating and influencing perceptions of risk associated with storm surge hazards.

Study Area

The location for this research included the south-central Texas region, which has experienced numerous major flood events over the past 40 years. Factors that contribute to the risk of flooding in this region include the presence of numerous hydrologic features such as lakes, rivers, and streams, as well as, the large supply of moisture originating from weather systems that form over the Gulf of Mexico, Caribbean Sea, and the Pacific Ocean. Earl and Anderson (2004) emphasized that major floods in the south-central Texas region are generated by both short and long duration storm occurrences. A major factor that contributes to the severity of these events includes rainfall amounts that accumulates over a number of days, thereby, exceeding the design capacity of many flood control facilities (Earl and Anderson 2004). For example, data from the National Climate Data Center (NCDC) indicate that many stations have experienced more than two "100-year" precipitation events in recent years. Thus, research of NCDC data suggests that perceptions of flood risk might best be evaluated in light of longer duration events, and not merely by analyzing single day rainfall amounts.

Study Approach and Process

This study involves a multi-phased approach to acquiring data, working with participants, and analyzing the results. There were three phases involved in conducting this research: 1) development of computer cartographic visualizations and survey instrument implementation; 2) survey data collection and recording participants' rankings of visualizations; and, 3) analysis of results. Each of these phases was performed in a sequential manner. The following diagram, Figure 1, illustrates the phases of this study, and will be discussed in more detail below:

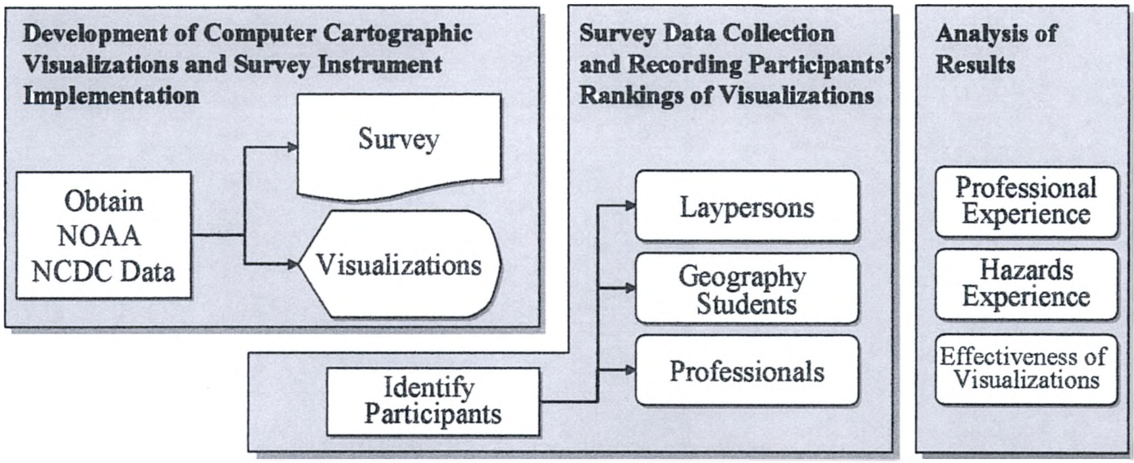


Figure 1. Study Methodology

This research required public participation through the use of electronic media for efficiency purposes in reaching the audience in a manner that did not negatively impact their personal and professional responsibilities. For this reason, the methods of Internet-based maps and surveys were developed, so as to minimize the need for one-on-one meetings to deliver visualizations and perform surveys. It was assumed that those participating in the study were capable of using the required resources, which included a personal computer, Internet access, and ability to view multi-media content. Thus, this study was limited to only those who believed they had the above-mentioned capabilities and resources. It was assumed that participants in this study ranged from novice to expert users of personal computers and the Internet, but generally, would be able to access, view, and interpret the five cartographic visualizations.

Furthermore, it was also assumed that participants followed the instructions in the survey letter and on the study website. Specifically, that participants were able to assess the risks of each event for the entire study area, and not rank events based upon risk to one particular place within the study area. Also, participants were asked to use a ranking scale of 1 thru 5 to rank the events, with 1 being the "most hazardous" and 5 being the "least hazardous." Finally, it was assumed that participants correctly interpreted and applied this scale. To assist their efforts, participants were given a precipitation legend, which cross-referenced the color scheme used to delineate precipitation amounts with their representation on the event visualization maps. It was assumed participants used this legend to understand the levels of precipitation.

Development of Computer Cartographic Visualizations and Survey Instrument Implementation

Obtaining NOAA NCDC Data. Data was obtained from the NOAA National Climate Data Center (NCDC) to serve as the basis for producing five computer visualizations of previous flood events in south-central Texas of various magnitudes, that is, levels of risk. Data was downloaded from the NCDC and imported into a GIS database for event identification and development of statistical maps used in the visualization exercises. The National Oceanic and Atmospheric Association (NOAA) collects climate data on a daily basis from approximately 150 weather stations in the south-central Texas Region (as of February 2004). These stations are managed by a network of volunteers and National Weather Service (NWS) employees, and provide the data collected to NOAA for use by climate and hazards researchers. Data is available through the NCDC for each of the active stations, as well as stations no longer in service, but which collected data in years past.

Study Instruments. This study used two primary instruments to present information to facilitate participant's rankings of risks associated with historical precipitation events: 1) a series of five cartographic visualizations of five historical flood events of varying magnitude and intensity; and, 2) an Internet-based survey on which participants ranked the visualized flood events according to their level of hazardousness, that is, perceived levels of risk.

Cartographic animations, or visualizations, consisted of a series of maps represented cumulative rainfall for each day in the event sequence. Thus, each event animation consisted of seven frames, for a total duration of approximately 10 seconds. The animations were used to visually communicate the levels of precipitation for different events in the study area.

The Internet survey established the participants' levels of perceived risk, levels of professional experience, experience with hazardous events, and preferences of communication channels for receiving short-term and planning related information relating to hazards. The survey also collected demographic data such as education levels, age, and gender. Both the survey and the visualizations were placed on a website, where participants' could access the visualizations and complete the survey using an Internet browser, such as Internet Explorer or other widely used products.

The process that this survey followed allowed for an efficient and effective manner in which to contact and disseminate the visualizations and survey to participants. The use of the online Internet-based survey allowed for various types of controls and data quality measure relating to the acquisition of survey responses. For instance, the web-based survey form permitted respondent to only select one ranking value across the five events, which ensured that no two events would be given the same ranking value. The survey form was also simple to complete, and many participants had positive feedback on the ease of use and speed of completing the survey questionnaire.

In addition, this study limited the number of events for viewing and ranking to five, so as to not extend the time to complete the visualization and survey process. Perhaps future studies could be completed with a larger number of visualizations, and assess the ability of participants to assess risk given a much large amount of data to process. To facilitate a large number of events, the format in which those events are displayed could also be modified. Instead of displaying each 7-day event separately, produced a tiled format, with multiple events shown simultaneously for each day of the sequence. This would permit the participant to view each event relative to others within the context of a multi-day event.

Selection of Events for Visualizations. Events chosen for this study included the following, and are listed in order their level of hazard due to cumulative precipitation:

1) June 30th to July 6th, 2002;
2) October 15th to 21st, 1998;
3) September 7th to 13th, 1952;
4) July 30th to August 5th, 1978; and,
5) November 21st to 27th, 1985.

When selecting the events for this study, it was necessary to represent varying levels of flood hazards. For instance, to present extreme differences in the hazards levels of events, two events were included in this study that were significantly different in their cumulative rainfall amounts. The June 30th to July 6th, 2002 event represented one of the most widespread and large amounts of rainfall in the history of the region, whereas, the November 21st to 27th, 1985 event represented a smaller level of rainfall for the region, and was not considered as hazardous of an event. These two events and their seven-day sequences representing cumulative rainfall are illustrated below in Figure 2 and Figure 3.

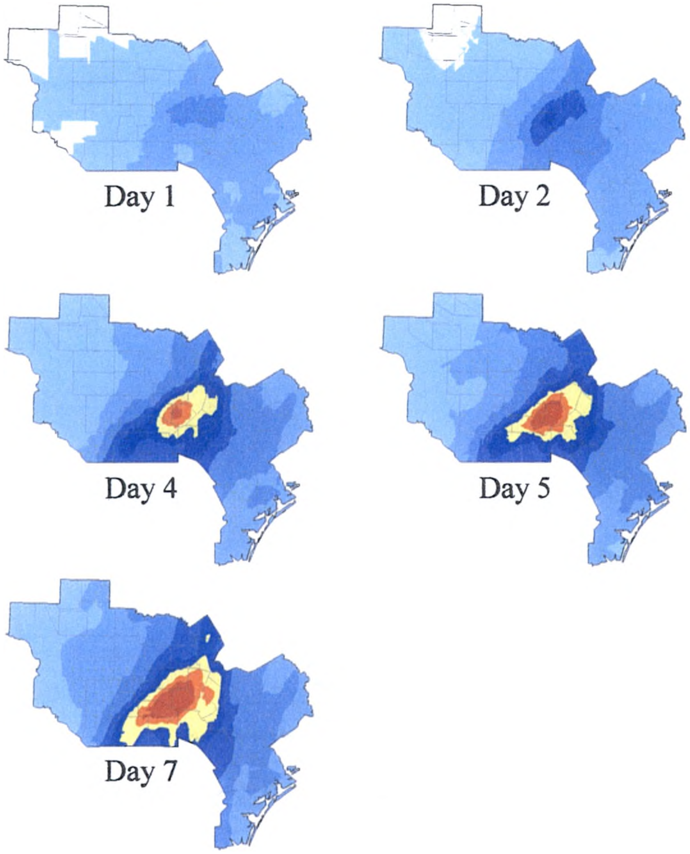


Figure 2. June 30th to July 6th, 2002 Event

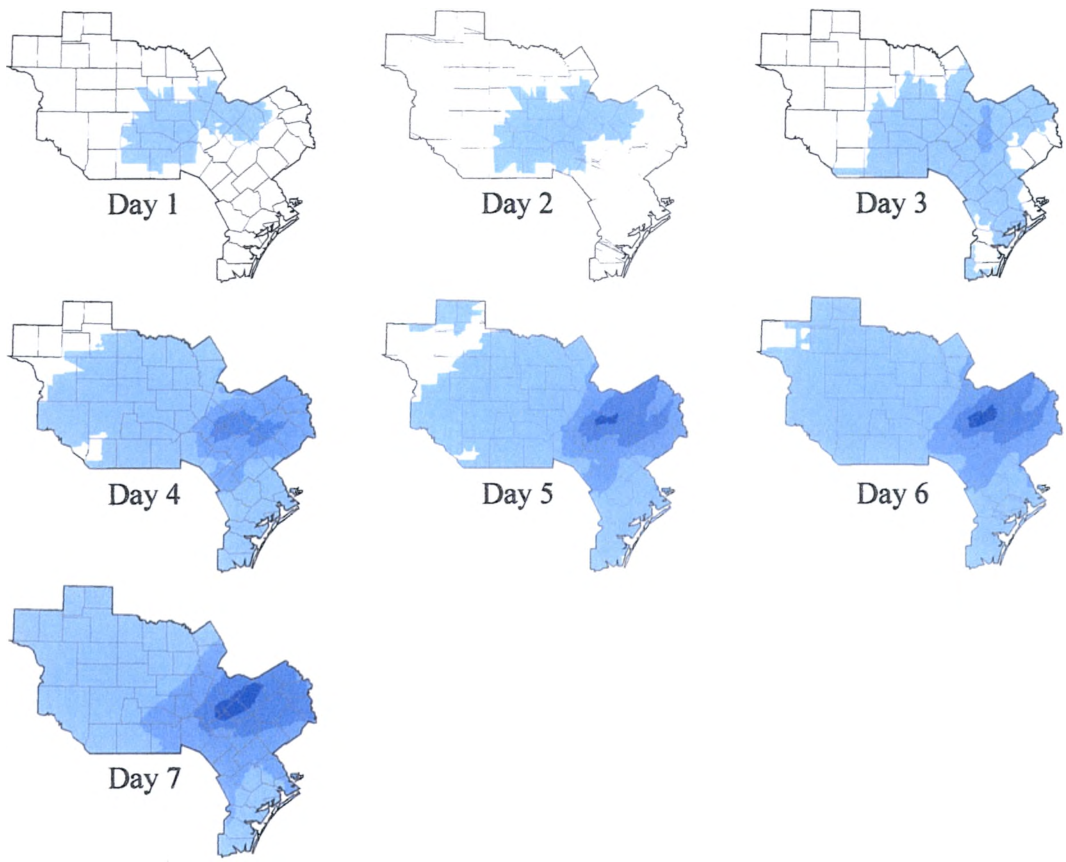


Figure 3. November 21st to 27th, 1985 Event

Furthermore, in order to present events much closer in their cumulative precipitation levels, three additional events were included in the visualization exercise: October 1998, September 1952, and July 1978. These three events and their seven-day sequences representing cumulative rainfall are illustrated below in Figures 4, 5, and 6.

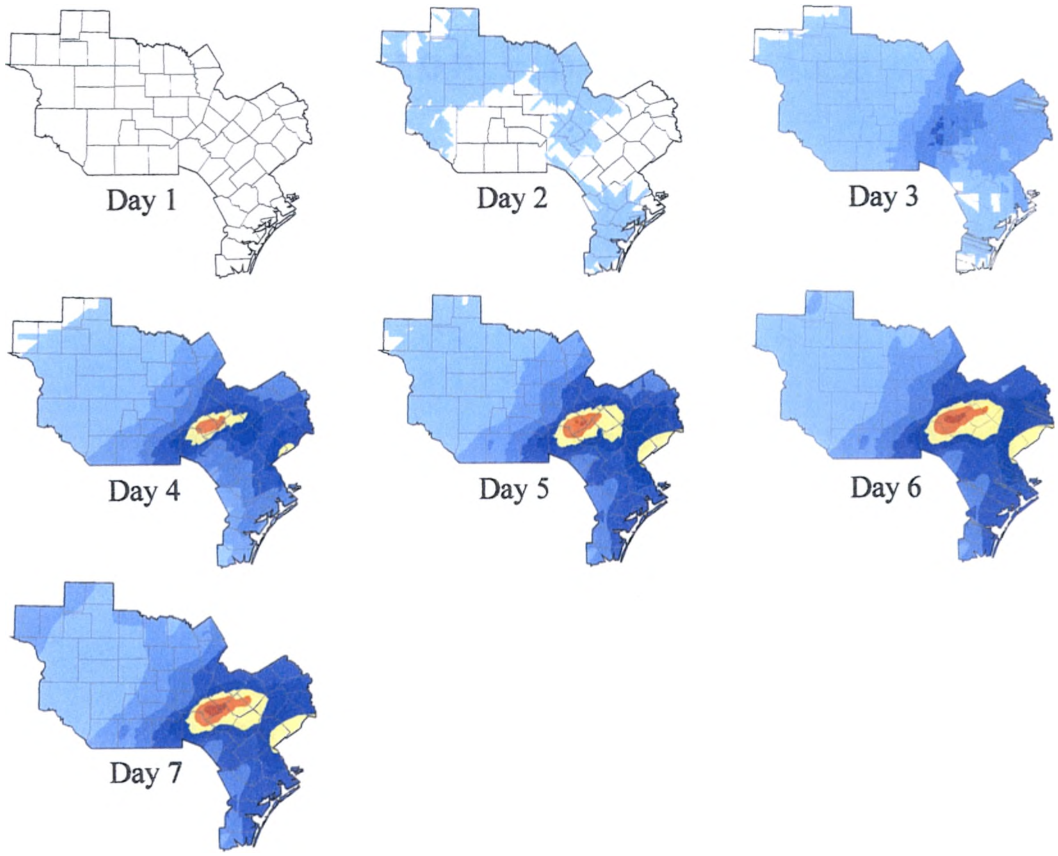


Figure 4. October 15th to 21st, 1998 Event

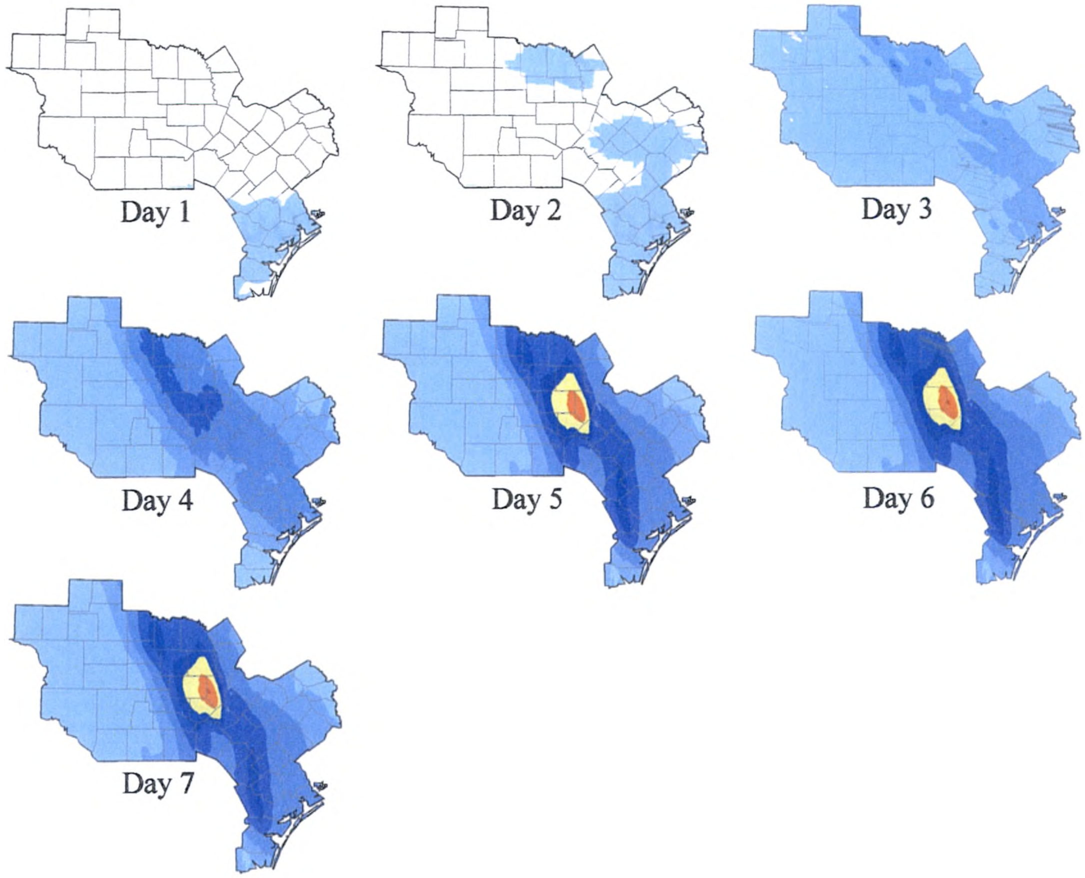


Figure 5. September 7th to 13th, 1952 Event

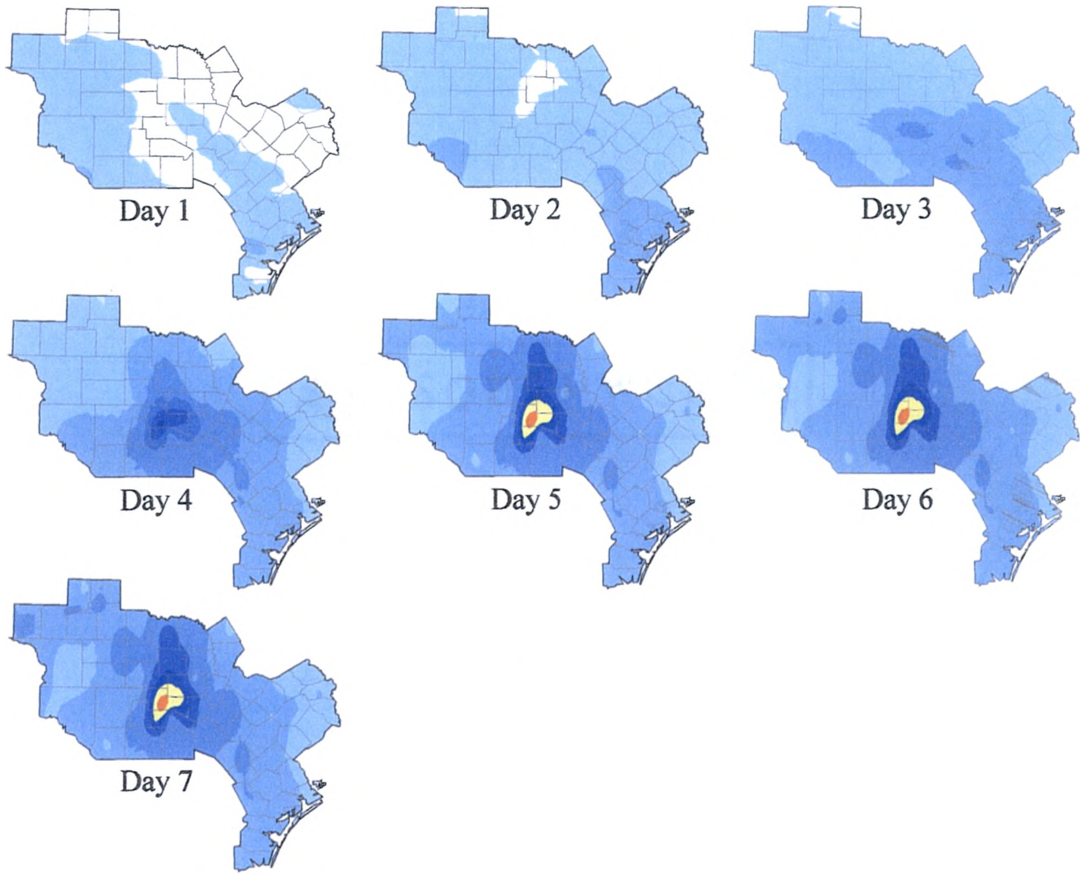


Figure 6. July 30th to August 5th, 1978 Event

These five events were selected to present a variety of rainfall events, and to understand how participants might differentiate between events that were both similar and different in their precipitation and flood hazard levels. This process was necessary to determine the extent to which cartographic visualizations aided in aligning participants' perceived levels of risk with actual risk associated with these events. For instance, "might participants be able to differentiate between the level of hazard for the June 2002 and October 1998 events, so as to correctly rank these events, even though the cumulative rainfall amounts for the region were similar?" In addition, "could participants correctly assess the level of hazard when comparing the November 1985 and September 1952 events, which were also similar in their cumulative rainfall measurements?"

Development of Cartographic Visualization Maps. The process for developing the visualization instruments first involved mapping precipitation data in a GIS. Maps representing precipitation were developed using NOAA's NCDC data loaded into a GIS database. Each station was mapped within the GIS for the daily precipitation map being developed, with the associated precipitation value for that station was used as the measurement value. For each mapped station, the measurement value represented the cumulative amount instead of the daily precipitation amount for reasons discussed earlier. For instance, for a seven-day event, the station's first day measurement value was the precipitation value for day 1, for day 2 the measurement value included day 2 plus the day 1 value, and for day 3, the measurement value included day 3 plus the cumulative amount used for day 2, and so forth. Therefore, the last day of the event sequence, day 7, was the cumulative precipitation amounts for all prior days in the sequence and represented the total precipitation for the seven-day period at a particular station. For each seven-day event, a series of daily cumulative precipitation isarithmic maps were created using ArcGIS Geostatistical Analyst 8.3. The individual maps that represented cumulative precipitation for each day in the date sequence, were referred to as an event sequence. The isarithmic maps were developed using Kriging (an interpolation technique) to estimate the precipitation amounts at un-sampled points using data collected at each gauging station. A table illustrating the Kriging setting used for each day in the event sequences may be found in Appendix E.

Classification Scale for Cumulative Precipitation. Different classes of precipitation are represented by isohyets represented in a color gradient format (e.g. clear to dark red) as illustrated below in Figure 7.

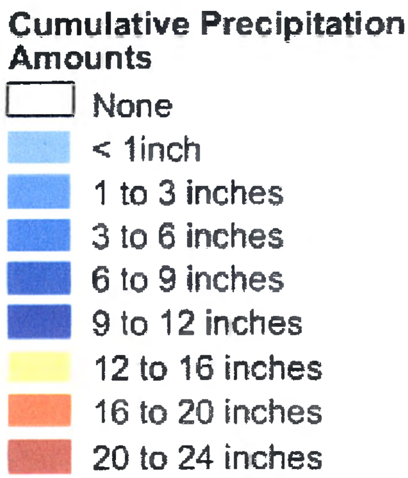


Figure 7. Event Precipitation Classification

These classification scales may be found in many weather forecasting models where they highlight extreme levels of precipitation using a yellow to dark red color gradient. All isarithmic maps in this research used a common scale to represent cumulative precipitation amounts so that events might be compared and ranked against one another on the basis of the perceived level of hazard from the visualization. In addition, events were chosen from the NOAA, NCDC data so that a range of hazard levels, from low/moderate to extreme danger, were represented in this exercise. All data that was used in the development of the precipitation maps were ratio-level data, and were presented in inches of precipitation.

Development of Cartographic Event Animations. Once all daily isarithmic precipitation maps were created, the animation of each day's cumulative precipitation values and spatial extent were animated. The animations of individual static maps were achieved through the use of Macromedia Flash. Flash is a multi-media authoring tool capable of combining static graphic images, and generating an animation to appear as if the data is being dynamically created. The use of animation was important to show the spatial extent of precipitation values for each event, and how the event evolved with time.

The static isarithmic map for each day that comprised an event sequence was placed into a Flash template file. The individual maps were then animated and published in a format that was capable of being viewed using a standard Internet browser application, such as Internet Explorer. Each event animation was designed to allow the participant to perform the following: play an animation, stop the animation, step frame-by-frame forwards or backwards, and replay the animation. This final animation product was then posted to an Internet website where it was available for viewing by participants. A sample of the visualization product is illustrated below in Figure 8. Each animation is initially presented showing the first day of the sequence. The participant is then able to use the controls to view the animation.

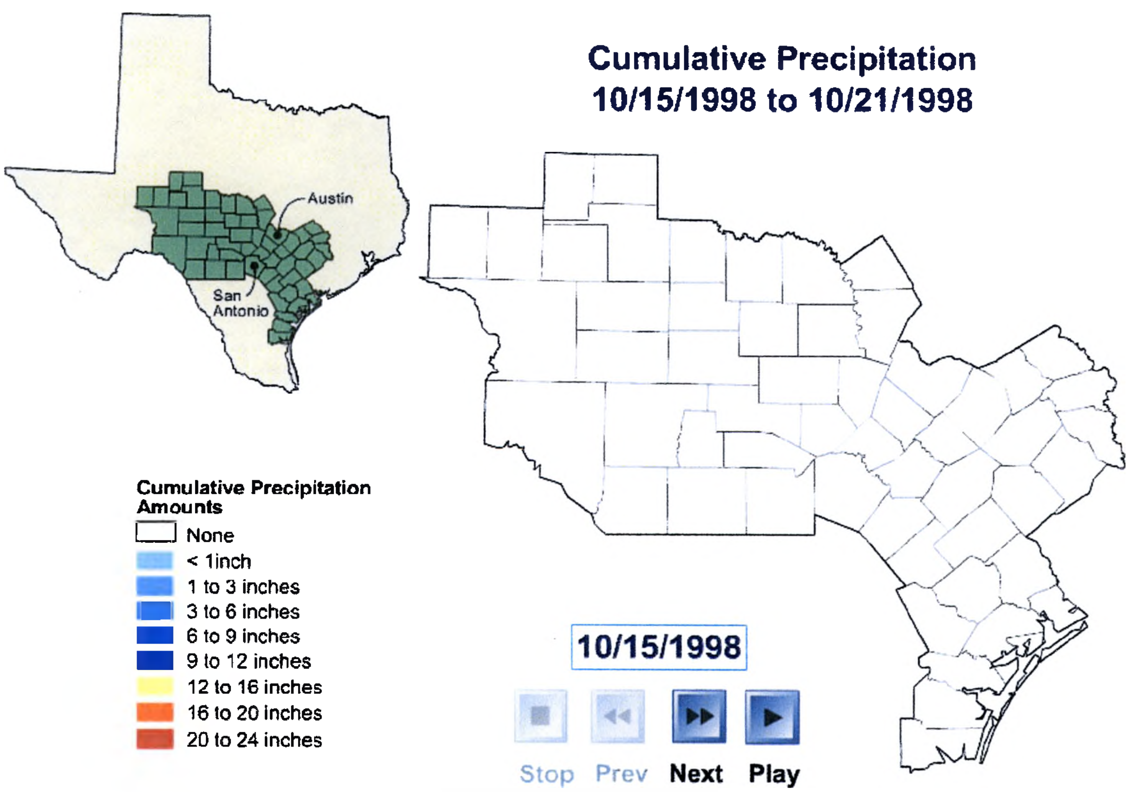


Figure 8. Sample Event Animation Start Page

Study Website. Following the development of the cartographic event animations and the participant survey, a study website was created to provide participants with a single location on the Internet to access and view event visualizations, and to complete the survey. Participants were given a website URL to visit based on their classification as either layperson, geography student, or professional, so that survey data could be tracked separately for the three groups of participants. Figure 9 illustrates the website which participants viewed to access the animations and submit their rankings and survey responses.

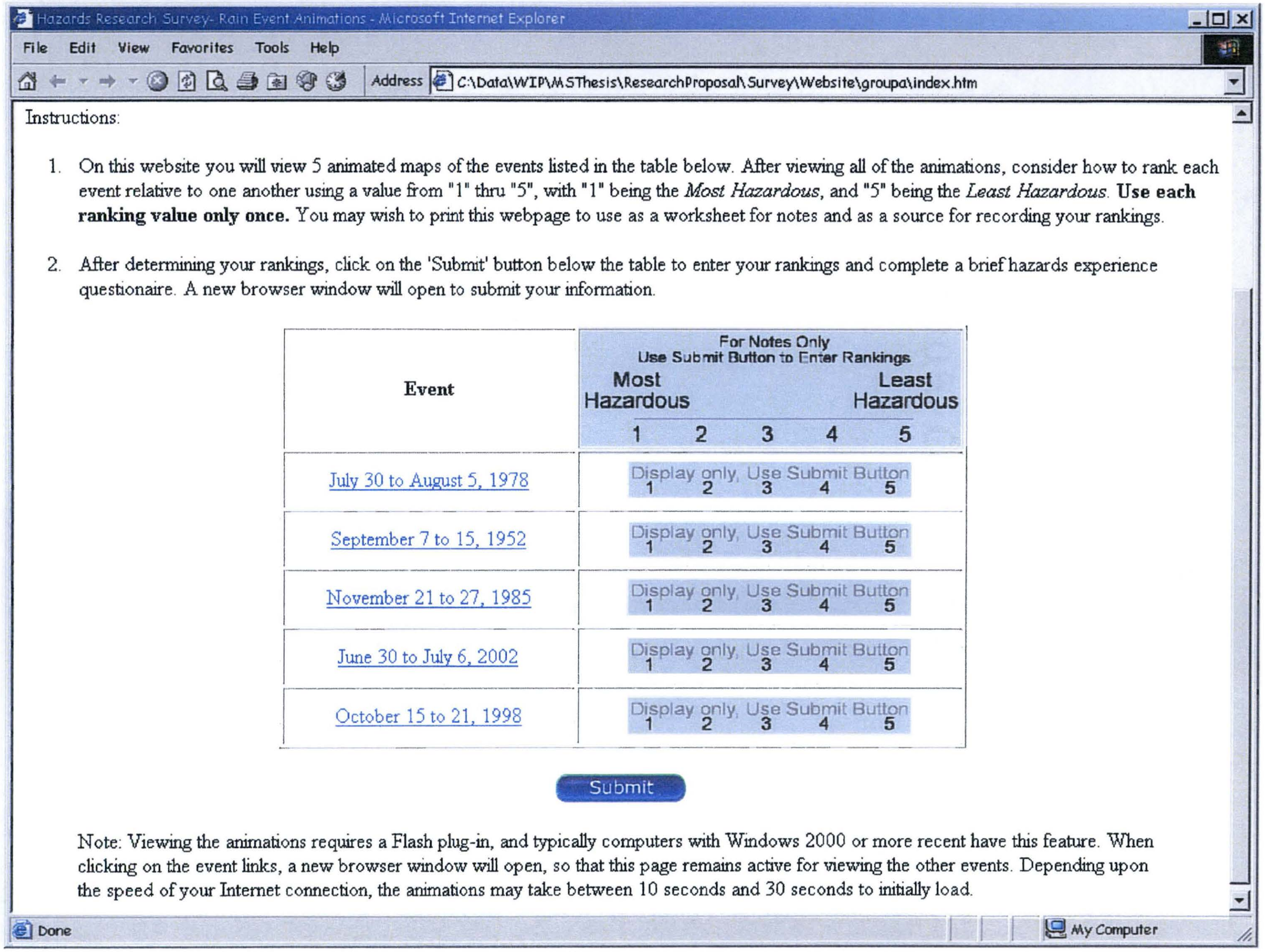


Figure 9. Study Website with Link to Event Visualizations and Survey

Survey Data Collection and Recording Participants' Rankings of Visualizations

Identifying Participants. The second instrument for recording participants' rankings of prior flood events was an Internet survey questionnaire. Participants were stratified into three groups, primarily based on their understanding and experience in dealing with natural hazard events on a regular basis, with each group having at least 30 participants. The first group included professionals in the areas of environmental protection, emergency management/response, and climatology. The second group included geography students that were either at the level of Masters or Doctoral. The third group included laypersons whose day-to-day professional work does not involve natural hazards or climate related research. Each of the 90 participants was contacted via either phone and/or e-mail to request their participation in the study. A letter/e-mail submitted to participants explained the purpose of the study, as well as, the procedures for viewing event visualizations via the Internet and completing the survey. A sample letter used to correspond with participants may be found in Appendix C to this study.

Survey Completion. The first step for participants in the survey and visualization exercise process was to view a series of five cartographic visualizations, one for each precipitation event identified as part of the study. Following the viewing of the visualizations, participants then completed a survey questionnaire, which included the submitting of their event rankings. The objectives of the visualization exercise were for the participants to rate the events listed above from "most hazardous" to "least hazardous," based on their perceptions of how the south-central Texas region was impacted after viewing the visualizations. The participants were allowed to view the visualizations as many times as necessary, and were given the ability to pause, step forwards, step backwards, or replay an event animation.

Analysis of Results

Following the completion of the survey and visualization phase of the study, the results were downloaded into a Microsoft Access database, where formal statistical tests were performed on the data. Due to the non-random selection of respondents for this study, non-parametric statistics were used to analyze the results. Specifically, three types of analysis were performed based on the alternative hypotheses defined above, which: 1) attempted to determine how one's professional experience, classification, or training related to work in the field of natural hazards affected his/her ability to accurately assess levels of risks associated with prior flood occurrences; 2) attempted to determine if general experience with floods and other hazards contributed to one's ability to accurately perceive risks from those events; and, 3) attempted to determine whether computer visualization aided individuals in correctly assessing levels of perceived risk, that is, to what extent might it be a substitute for professional and/or hazards experience. In addition, descriptive statistics were presented for all three groups of participants.

Three statistical methods were used to summarize and analyze the results of the surveys. First, a series of non-parametric descriptive statistics were used that cross-tabulated the results to identify any potential relationships and to summarize the responses of the surveys across the three groups.

Second, The Kruskal-Wallis test was used to analyze how each group performed relative to one another in terms of their overall score to accurate ranks events (total score). The Kruskal-Wallis test was selected, as it is a one-way analysis of variance by using ranks to test the null hypothesis that multiple independent samples come from the same population. It does not assume normality, and, therefore, meets the requirement of being a non-parametric test, that may be used to test ordinal variables. This test is well suited for assessing differences in performance between multiple groups, and measures how much the group ranks differ from the average rank of all groups. Furthermore, this test does not suggest how the groups may differ, but only that they are different in some way (2001 SPSS, Inc.). The Kruskal-Wallis test was used for two types of analysis: 1) assessing how one's professional experience contributes to accurate risk perception; and, 2) assessing how one's experience, in terms of frequency of exposure, with hazards events contributes to accurate risk perception.

The third test used was the Mann-Whitney U-test of two independent samples to determine if values of a particular variable differed between two groups. This statistical method tests the null hypothesis that two independent samples come from the same population. Like the other tests used in this study, the Mann-Whitney does not assume normality, and may be used to test ordinal values (2001 SPSS, Inc.). Since this test only compares two groups at a time against an independent variable (total score), analysis was performed against pairings of each of the three groups against one another- Layperson to Student; Layperson to Professional; and Student to Professional.

CHAPTER 5

FINDINGS AND CONCLUSIONS

This study relied upon a sample of 90 participants organized into three classifications as discussed in the "Chapter 4, Study Design" section of this research. Each classification, layperson, geography student, and professional, was comprised of 30 participants each. The participants were chosen as a sample of convenience versus a random sample from the population of the study area. This non-random selection of participants was necessary due to the study's requirements that participants have access to, and be able to successfully use, the appropriate tools to view the visualizations and complete the online survey. Participants within the geography student group were a combination of Masters and Doctoral level students. The professional group was comprised of participants with experience relating to areas such as emergency management/services, planning, environmental, and weather forecasting. Where possible, an attempt was made to include as even a mix as possible of participants with regards to gender. For this study, 37 percent of laypersons, 47 percent of geography students, and 37 percent of professionals, were female, and 63 percent of laypersons, 53 percent of geography students, and 63 percent of professionals were male. Overall, female participants accounted for 40 percent and male participants accounted for 60 percent of the study participants. There was not any attempt to include participants of a particular age category. However, all participants were at least 23 years of age, with the majority in each group being between 30 and 49 years of age. Furthermore, only participants who were at least 18 years of age or older were asked to participate in the study.

Preliminary Results

Each of the participants were presented with several survey questions in order to collect information on the number and types of hazards they have experienced, their exposure to flood risk, demographic information, and use of and preference for weather related information sources. One question in particular was gauged toward assessing the number of flood events the participants had experienced in their lifetimes. This question was included to obtain information relating to personal experience with flood event hazards, as prior studies have shown that experience with hazards is often a statistically significant factor in increasing one's level of risk awareness and perception resulting in individual behavior response to take action to protect life and property (Blanchard-Boehm 1998). The results of the flood hazard question are reported in Table 1 below, and present a cross-reference between the participant classification and the level of experience with flood hazards having experienced in a lifetime.

Table 1. Number of Floods Experienced in Lifetime

Number of Floods	Layperson		Student		Professional	
Experienced	N	Percent	N	Percent	N	Percent
0	6	20.0	3	10.0	1	3.3
1	2	6.7	4	13.3	4	13.3
2	8	26.7	5	16.7	2	6.7
3	6	20.0	4	13.3	6	20.0
4	3	10.0	3	10.0	4	13.3
5	3	10.0	1	3.3	1	3.3
6 or more	2	6.7	10	33.3	12	40.0
Total	30	100	30	100	30	100

For the layperson and geography student groups, the results of this question were positively skewed towards having experienced a lower number of flood events in their lifetimes. Approximately 73 percent of laypersons and 53 percent of geography students had experienced less than four flood events. The results of the professional group were negatively skewed towards having experienced more flood events in a lifetime, with approximately 57 percent having experienced four or more floods.

A similar question relating to exposure of other hazards was asked of the participants, designed to capture experienced with hazards other than flooding. These hazards included tornadoes, high winds, hail, lightning, volcanic eruptions, ice/snow, as well as technological related hazards. The results of this survey question are given in Table 2 below, and present a cross-reference between the participant classification and the level of experience with other types of hazards having experienced in a lifetime.

Table 2. Number of Other Hazards Experienced in Lifetime

Number of Other	Layperson		Student		Professional	
Hazards Experienced	N	Percent	N	Percent	N	Percent
0	5	16.7	6	20.0	2	6.7
1	3	10.0	3	10.0	4	13.3
2	7	23.3	7	23.3	6	20.0
3	5	16.7	6	20.0	1	3.3
4	2	6.7	1	3.3	3	10.0
5	0	0	0	0	2	6.7
6 or more	8	26.7	7	23.3	12	40.0
Total	30	100	30	100	30	100

As with the flood related experience question, group results for the layperson and geography student categories were positively skewed towards having experienced fewer hazards. Approximately 66 percent of laypersons and 73 percent of geography students had experienced less than four non-flood related hazards in their lifetimes. The results from the professional group were also similar in that the numbers of other hazard experiences were negatively skewed towards a greater number of occurrences. Approximately 56 percent of professionals had experienced at least four other hazards in their lifetimes.

Regarding flood hazard exposure, participants were asked if they were aware of whether, or not, their primary residence was located within a flood plain. The majority of participants across all three groups did not feel they resided within a floodplain. However, within the layperson group, 20 percent did not know whether their primary residence resided within a floodplain. Only 13 percent of participants from the geography student group, and 10 percent from the professional group knew they resided within a floodplain.

Several questions were presented to participants to obtain demographic information, and included: Years Lived in Texas; Education Level; Cartography Training; Gender; and, Age. The majority of participants across all three groups reported that they had lived in Texas for over 15 years. Only small percentages of participants lived in Texas for less than 3 years (none for laypersons; 10 percent of geography students; and. 3 percent from the professional group).

The highest level of education reported by participants was Bachelors Degree or graduate level, and percentages for both combined included: 80 percent of laypersons; and, 86 percent from the professional group. However, as shown in the table below, as compared to the layperson group, professionals reported greater numbers in having attained a graduate level degree. Finally, the geography student group was divided into two areas, Doctoral and Masters, with approximately 67 percent identified as Doctoral students, and 33 percent being Masters level students. The results of the level of education survey question are found in Table 3 below, and illustrate a cross-reference between the participant classification and their education levels having attained at the time the survey was conducted.

Table 3. Highest Education Level Attained

Highest Education Level Attained	Layperson		Student		Professional	
	N	Percent	N	Percent	N	Percent
High School	1	3.3	0	0	0	0
Some College	4	13.3	0	0	1	3.3
Associates Degree	1	3.3	0	0	0	0
Bachelors Degree	15	50.0	0	0	11	36.7
Some Graduate School	1	3.3	10	33.3	3	10.0
Graduate Degree	8	26.7	20	66.7	15	50.0
Total	30	100	30	100	30	100

Participants in all groups were asked as to whether they have ever received any cartographic training on the principles of developing maps and performing analysis using map products. Approximately 87 percent of laypersons, 33 percent of geography students, and 53 percent of professionals reported having never received cartographic training.

Participants were also asked questions about their use of weather-related sources via either television or the Internet. Approximately 57 percent of laypersons watched television weather broadcasts between 4 and 7 times per week, with approximately 17 percent watching those broadcasts 8 to 10 times per week. Use of television for weather-related information by geography students varied, with the highest concentrations being 31 percent watching 1 to 3 times, and 39 percent watching 4 to 7 times per week. Use of television by professionals was divided between three frequencies, with 30 percent watching 1 to 3 times, 33 percent watching 4 to 7 times, and 27 percent watching 11 or more times per week. Participants were also asked how they used online sources of weather information in terms of the type of information they viewed. The results of the survey question are shown in Table 4 below, and illustrate a cross-reference between the participant classification and how Internet-based weather resources are utilized.

Table 4. Use of Online Weather Sources

Use of Online Weather Sources	Layperson		Student		Professional	
	N	Percent	N	Percent	N	Percent
Not At All	3	10.0	3	10.0	2	6.7
Just to View Forecasts	9	30.0	6	20.0	1	3.3
Just to View Weather Maps	4	13.3	4	13.3	2	6.7
To View Forecasts & Weather Maps	14	46.7	17	56.7	25	83.3
Total	30	100	30	100	30	100

The majority of respondents stated they used these sources to view weather related maps and/or forecasts, with 10 percent or less in each group not using these sources at all. As reported in Table 4, online sources are widely used media by the participants for obtaining weather related information. Although the use of online sources is high among all groups, when asked their preferences for short-term warning messages and hazards preparedness information, all groups rated television as the most preferred media. The results of this question may also lend itself to future research, so as to further understanding which communications methods are most effective for different demographic and/or socio-economic groups.

Hypothesis #1: Greater levels of professional training and experience with natural hazards contributes to correctly identifying levels of risk associated with flood events

This section will explore the significance of how one's professional classification and experience with hazardous events influences their ability to accurately perceive risk. The statistical methods used in this analysis are the Kruskal-Wallis test, and the Mann-Whitney U-test. Both tests are non-parametric, and, therefore, do not require normality in distribution of the study sample.

For this study, the Kruskal-Wallis test was used to test the hypothesis that an individuals' level of professional training and experience contributes to their ability to correctly identify levels of risk associated with historical flood events. This statistical test measures how the extent to which the rankings of flood visualizations differed among each group as compared to the average rank of all groups. In this instance, the grouping variable is the participant classification (layperson, geography student, professional), and the testing variable is the percentage of events correctly ranked. The mean rank for each group is calculated by first ranking each case without regard to group membership. After ranking the cases, the ranks are summed within groups (2001 SPSS, Inc.). The chi-square summary statistic is obtained by squaring each group's distance from the average of all ranks, weighting by its sample size, summing across groups, and then multiplying by a constant (2001 SPSS, Inc.). Next, the number of groups is used to calculate the degree of freedom by taking that number and subtracting by one. The asymptotic significance estimates the probability of obtaining a chi-square value greater than or equal to the value calculated if there is not a difference between the group ranks (2001 SPSS, Inc.).

Results from the Kruskal-Wallis test indicated that there was not a statistically significant difference between the groups in terms of their ability to accurately assess and rank the events presented in the visualizations. This result demonstrates the abilities of participants across all three groups to accurately assess and rank hazardous events regardless of their profession and vocational training. The statistical results from the Kruskal-Wallis test are reported below in Table 5, and suggest that the hypothesis tested should be rejected, as there does not appear to be any difference between the groups of participants tested in this study for this set of variables.

Table 5. Kruskal-Wallis Test Comparing Groups on the Basis of Percentage of Events Ranked Correctly

	Layperson	Student	Professional
N	30	30	30
Mean Rank	48.63	43.35	44.52
Overall Test Statistics:			
Chi Square	0.832		
df	2		
Asymp. Sig. (2-tailed)	0.660		

Another statistical test used to analyze the difference between groups and test the hypothesis related to one's professional experience, was the Mann-Whitney U-test. The Mann-Whitney U-test is similar to the Kruskal-Wallis, but differs in that it compares only two groups. For this study statistics were calculated by comparing laypersons to students, laypersons to professionals, and students to professional on the basis of the total number of events ranked correctly, in order to better understand difference between the groups.

The comparison of layperson to geography student participants produced similar results to the Kruskal-Wallis test, in that between the two groups, there was no statistical significance in an individuals' group membership to that of being able to accurately perceive the risk of the events. Based on the results of this statistical test, the research hypothesis stating that one's professional experience contributes to correctly identifying levels of risk associated with historical flood events, was rejected, as there does not appear to be any difference between the two groups.

In a similar finding, the comparison of layperson to professional participants did not produce statistically significant difference between those groups. However, in this comparison, there were smaller difference in the mean rankings between the laypersons and professions. As with prior test results, the level of significance was insufficient to consider that one's classification as either a layperson or professional influenced their ability to accurately perceive and rank events based on the level of risk. Therefore, based on the results of this statistical test of the two groups, the hypothesis stating that one's professional experience contributes to correctly identifying levels of risk associated with historical flood events, was rejected on the basis of the results of this statistical test, as there does not appear to be any difference between the two groups for this set of variables.

The comparison of the geography student and professional groups also produced similar findings to the test results comparing laypersons to geography students, and laypersons to professionals. However, when comparing the geography students to professionals in terms of their mean rankings, there was very little statistical significance between the two groups. Although the mean rankings were closer in value as compared to the other group comparisons, the significance level of 0.840 was still not sufficient enough to conclude that a participant's classification influenced their ability to accurately perceive and assess risks with the events presented. Therefore, based on the results of this statistical test of the two groups, the hypothesis stating that one's professional experience contributes to correctly identifying levels of risk associated with historical flood events, was rejected on the basis of the results of this statistical test, as there does not appear to be any difference between the two groups for this set of variables. A summary of the Mann-Whitney U-test for comparing differences among variables of the three groups to one another is reported below in Table 6.

Table 6. Mann-Whitney Test Comparing Laypersons, Geography Students, and Professionals on the Basis of Total Number of Events Ranked Correctly

	Laypersons to Students		Laypersons to Professionals		Students to Professionals	
Mann-Whitney U	398.000		408.000		437.500	
Z-Score	-0.857		-0.694		-0.202	
Asymp. Sig. (2-tailed)	0.391		0.488		0.840	
	Laypersons	Students	Laypersons	Professionals	Students	Professionals
N	30	30	30	30	30	30
Mean Rank	32.23	28.77	31.90	29.10	30.08	30.92
Sum of Ranks	967.00	863.00	957.00	873.00	902.50	927.50

In summary, the results using the Kruskal-Wallis and Mann-Whitney tests, indicate that there is no statistically significant difference between the three groups- layperson, geography student, and professional- in terms of their abilities to perceive and correctly assess magnitudes (i.e. risk levels) associated with the five visualizations. This suggests that the visualization exercises were capable of representing risks in a manner that allowed participants from all groups to accurately perceive those risks and rank them relative to one another without having had any professional training and/or experience. Therefore, the hypothesis stating that cartographic products cannot be used as a substitute for experience is rejected on the basis of these test results.

Hypothesis #2: An individual's perceptions of risk associated with historical flood events strongly correlates to their level of exposure to flood and other hazardous events

Because there was no statistical significance between the groups in terms of one's ability to accurately perceive and assess risk associated with the visualizations, other factors such as number of flood events and other hazardous events experienced were analyzed to determine if they differentiated the three groups. This analysis was performed against each group as well as the entire sample using the Kruskal-Wallis test.

First, all participants were analyzed by using the total number of floods and other hazards as the grouping variables, and the percentage of ranking correct as the testing variable. When analyzing one's percentage of ranking correct on the basis of the number of flood experienced in a lifetime, the test results indicated that there was no statistical significance in the difference between one's experience with flood events, and his/her ability to correctly perceive and assess risk associated with the events presented.

Similar results were obtained when analyzing the total number of other hazardous events, as reported by the Kruskal-Wallis statistics for the level of significance in a participant's frequency of experiences with other hazards. For this study, participants were also asked to consider other natural hazards, and responses included hazards such as, tornadoes, ice storms, volcanic activity, and earthquakes. The test results indicated there was no statistical significance in the difference between one's experience with other hazards events, and his/her ability to correctly perceive and assess risk associated with the events.

The answers to survey questions regarding number of flood events and other hazards events were combined into a variable to measure total exposure to hazards. The result was a test statistic that did not demonstrate any statistical significance in one's frequency of experience with hazards in general, and their ability to accurately assess and rank risks associated with the events presented. The results of the Kruskal-Wallis test for all three of the hazards frequencies analyzed are illustrated below in Table 7.

Table 7. Kruskal-Wallis Test Comparing Quantity of Hazards Experienced on the Basis of Total Number of Events Ranked Correctly

	Floods		Other Hazards		Total Hazards	
Chi-Square	7.759		4.555		2.703	
df	6		6		6	
Asymp. Sig. (2-tailed)	0.256		0.602		0.845	
Number of Events Exerienced	N	Mean Rank	N	Mean Rank	N	Mean Rank
0	10	50.85	13	49.73	4	56.63
1	10	43.80	10	52.85	4	40.88
2	15	48.93	20	45.92	8	51.63
3	16	50.81	12	43.79	6	50.33
4	10	52.85	6	45.67	8	44.31
5	5	26.00	2	65.50	7	50.29
6 or more	24	39.29	27	39.67	53	43.08
Total	90		90		90	

In addition to analyzing the entire participant sample as a whole on the basis of experience with hazards, each group was tested using the Kruskal-Wallis test to determine if there were any significant findings within the groups. As with the overall tests, all three groups yielded no statistical significance terms of one's ability to accurately perceive and rank events based on their experience with hazards. The results of these individual group tests may be found in the Appendix D.

Discussion and Summary

The first goal of this research was to assess the degree to which professional experience contributed to one's ability to accurately assess risk associated with precipitation events. In addition, this research assessed how prior experience with a flood or other hazard occurrence might influence one's ability to accurately assess his/her level of risk associated with the event using cartographic visualization. Furthermore, this research attempted to understand whether computer visualizations might aid individuals in correctly assessing levels of perceived risk, and to consider whether visualization techniques might substitute for professional and/or hazards experience.

Experience was analyzed between three groups- laypersons, geography students, and professionals. Prior research suggests that experience, both in terms of one professional training and one's personal experiences, drives their ability to correctly assess and rate risk associated with natural and technological hazards. This study used prior rain events with varying levels of flood risk in a cartographic visualization format to test whether experience continues to play a major role in one's ability to accurately assess risk associated with flood events. In addition, this research attempted to determine whether cartographic visualization, where experience with a hazard event is lacking, might substitute for experience.

This study presented test results that rejected all three research hypotheses formulated. First, there was no statistically significant difference between the three groups on the research hypothesis/expectation stating that, those who have greater levels of professional training and experience with natural hazards would significantly be more able to correctly identify levels of risk associated with the flood events presented. This hypothesis was rejected in favor of the null hypothesis, stating that there is no difference between the groups based on professional experience.

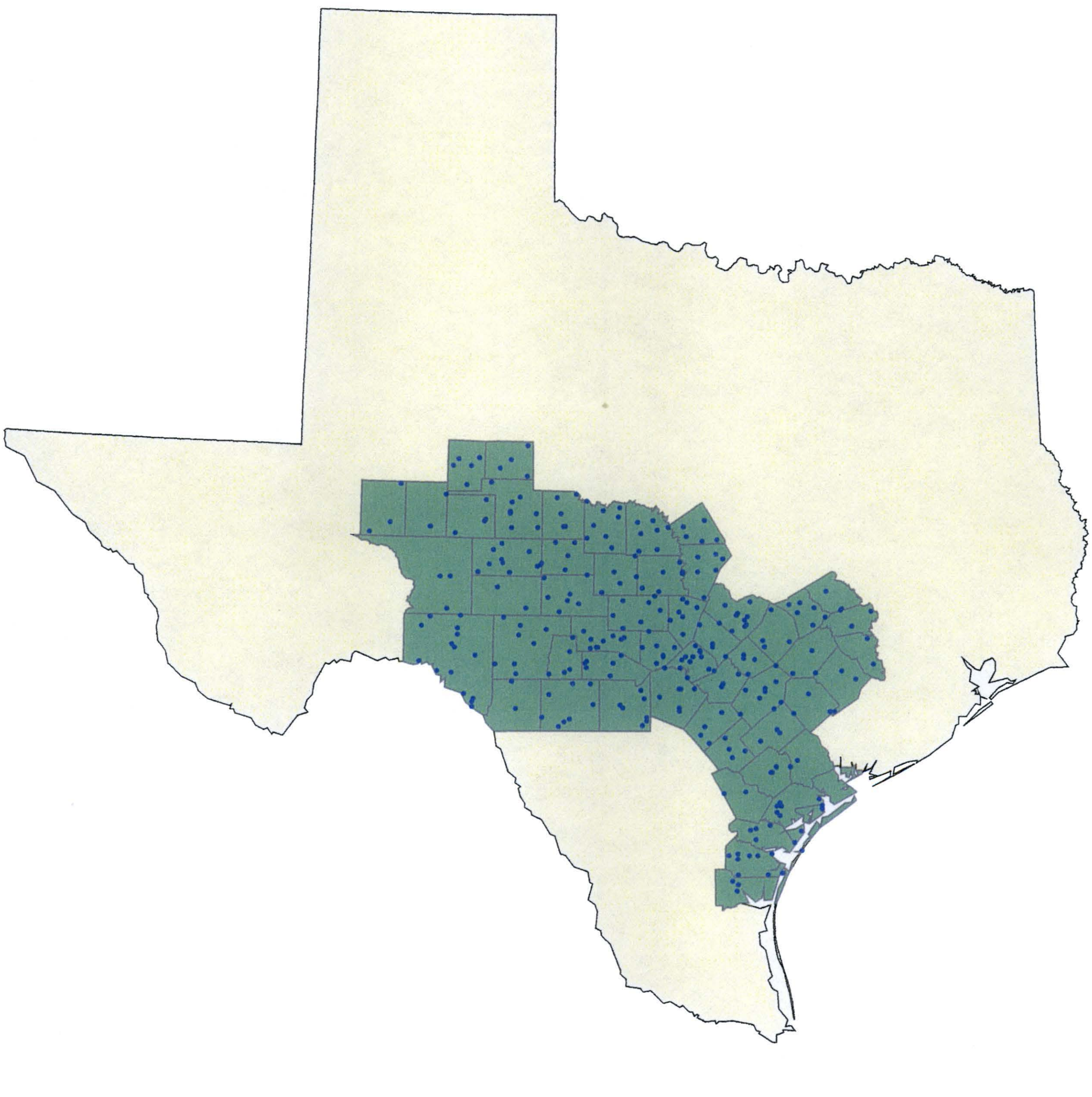
Second, when analyzing an individuals' level of experience with flood and other hazards, there was no statistically significant difference between the three groups in their ability to correctly assess risk associated with the events presented. Therefore, the research hypothesis stating that, the levels of risk associated with the flood events presented would strongly correlate with an individuals' actual levels of exposure to flood and other hazardous events, was also rejected in favor of the null hypothesis, that there is no difference between exposure levels.

Third, based on the results of this study, when analyzing an individuals' ability to correctly understand and identify risk associated with flood hazard events, it is apparent that cartographic products may be a substitute for experience when professional training and actual exposure is not possible. Therefore, the research hypothesis stating that, the ability of an individual to correctly understand and correctly identify risk associated with flood hazard events is correlated to his/her level of experience, and therefore, cartographic products cannot be a substitute for experience with flood events, was also rejected in favor of the alternative hypothesis, that cartographic visualizations can be substituted for experience when experience is lacking.

In conclusion, this study presented test results suggesting that cartographic visualization of rain events that have the potential to produce flood hazards, has the potential to be understood and used by a wide variety of individuals with varied levels of experience. In addition, visualization allows individuals to more accurately perceive and correctly assess object risk, independent of their professional classification, training and exposure to flood and other hazards in their lifetime. Furthermore, most hazards are capable of being portrayed in a visual manner, and, thus, cartographic visualization techniques will prove useful and of great benefit for educating a large populace with various levels of experience and capabilities, in an effort to build awareness and influence people to take action to protect lives and properties.

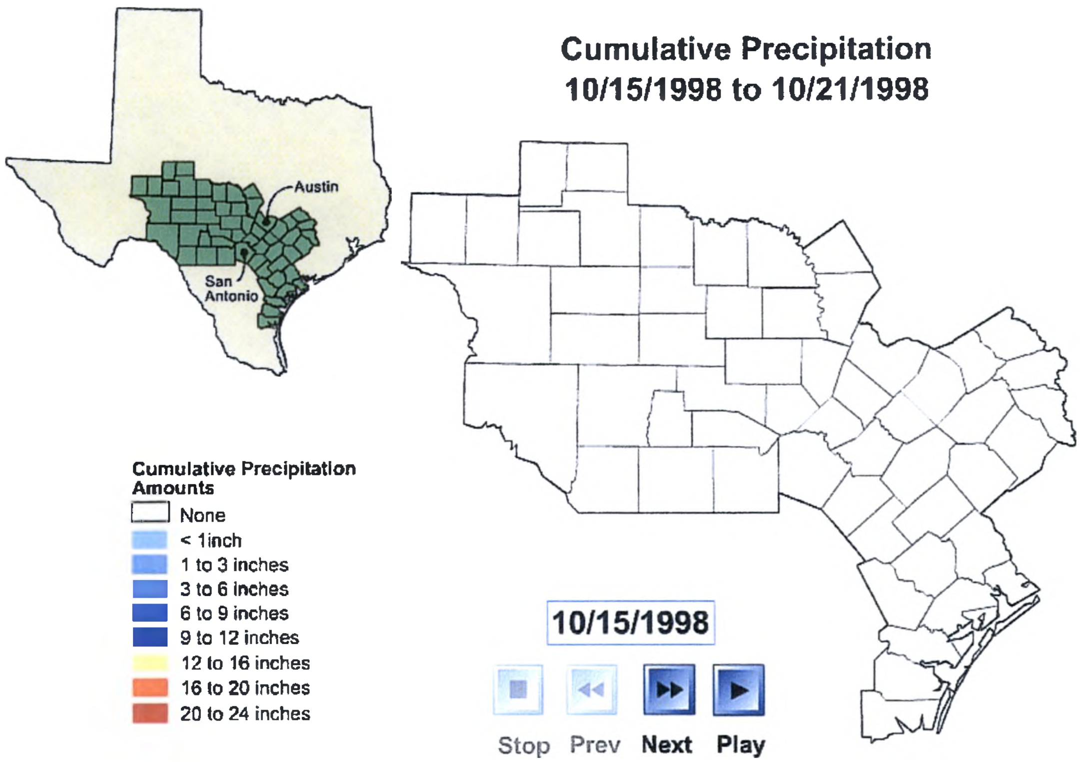
APPENDIX A

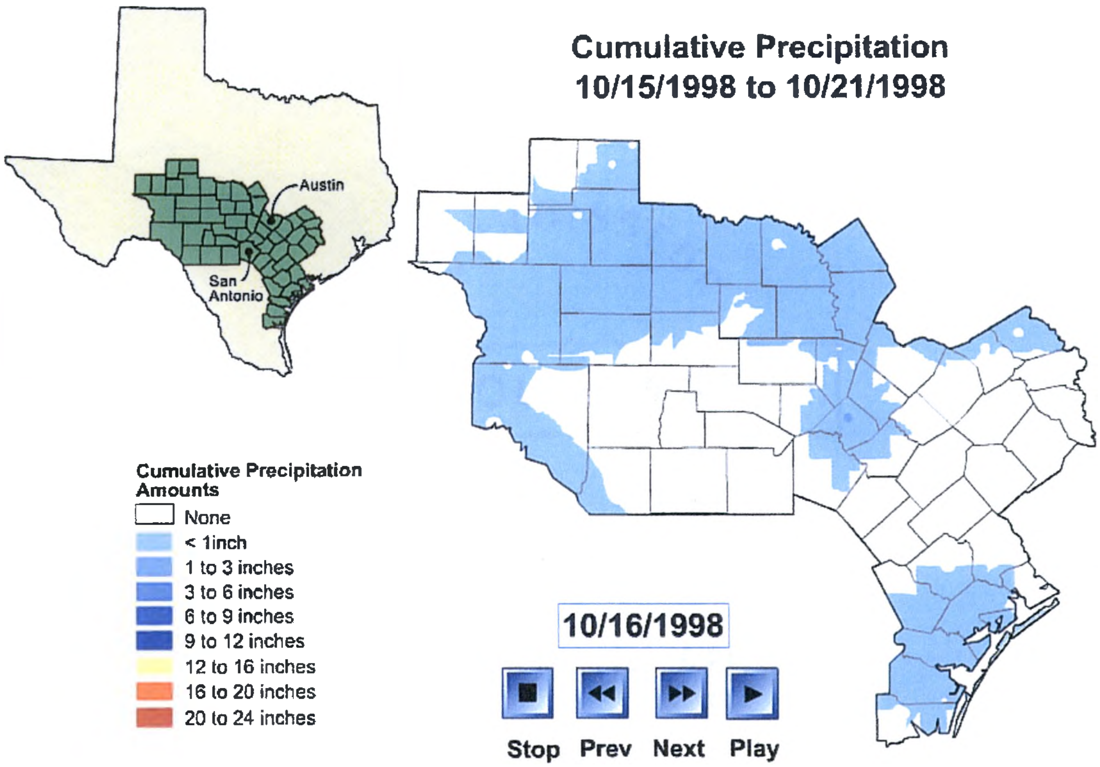
STUDY AREA AND GAUGING STATION LOCATIONS



APPENDIX B

SAMPLE VISUALIZATION SEQUENCE

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San Antonio
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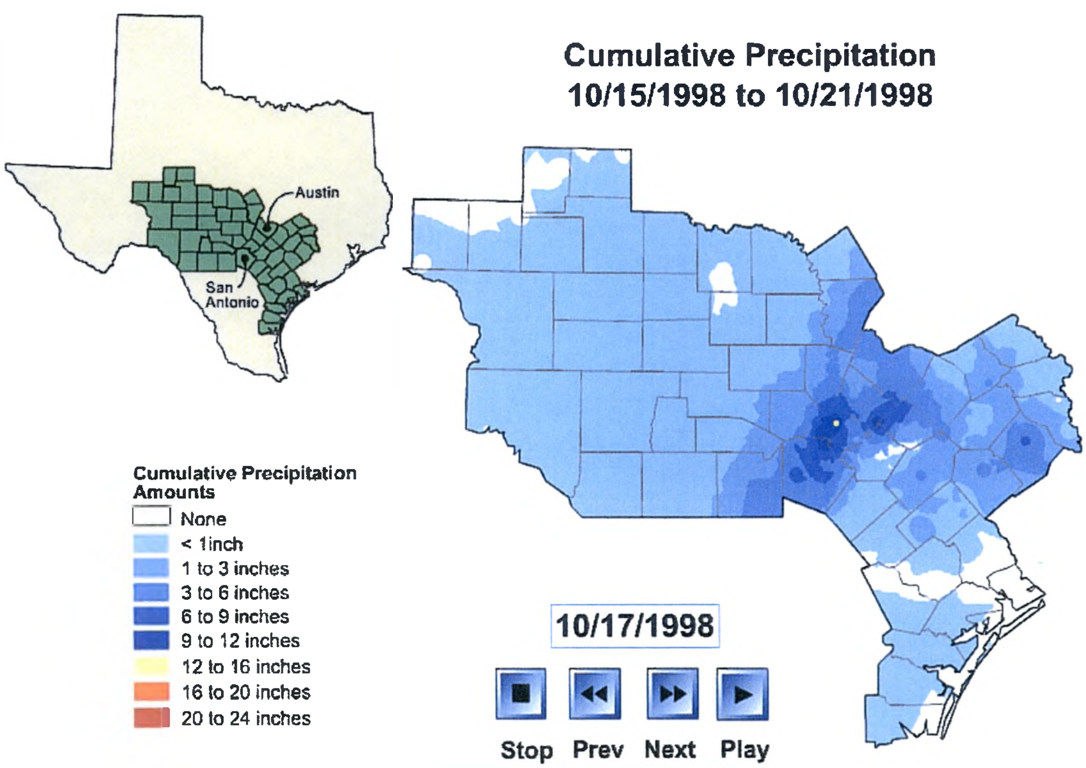
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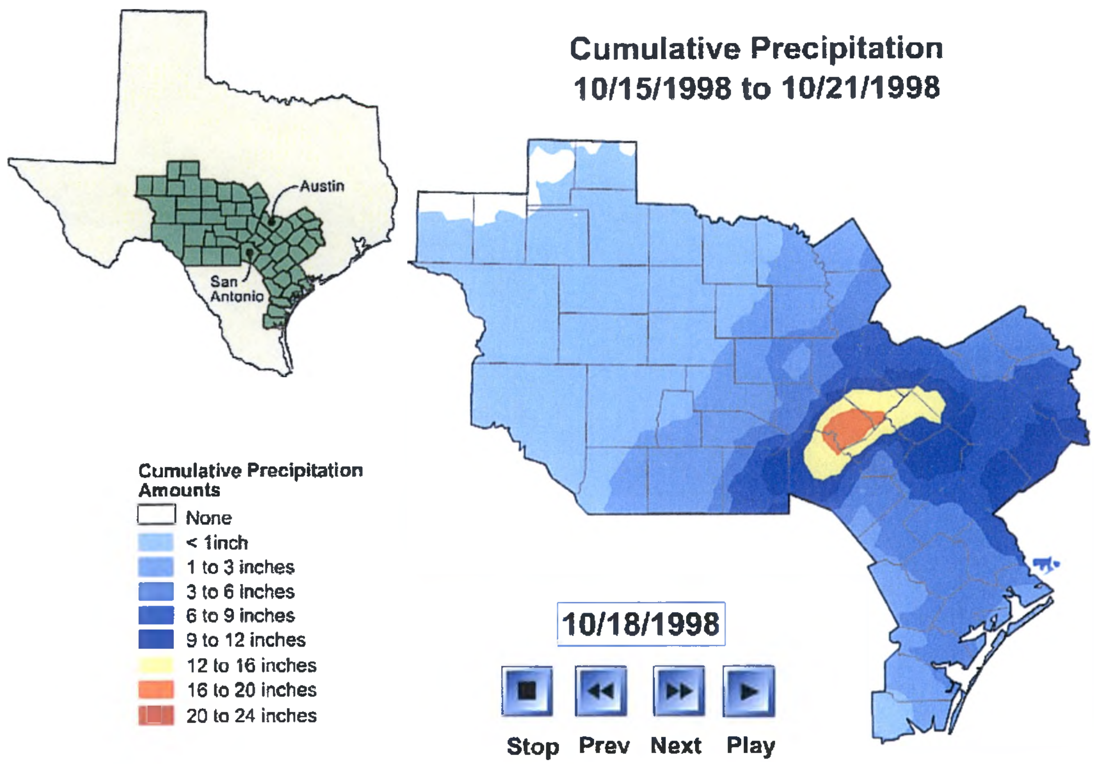
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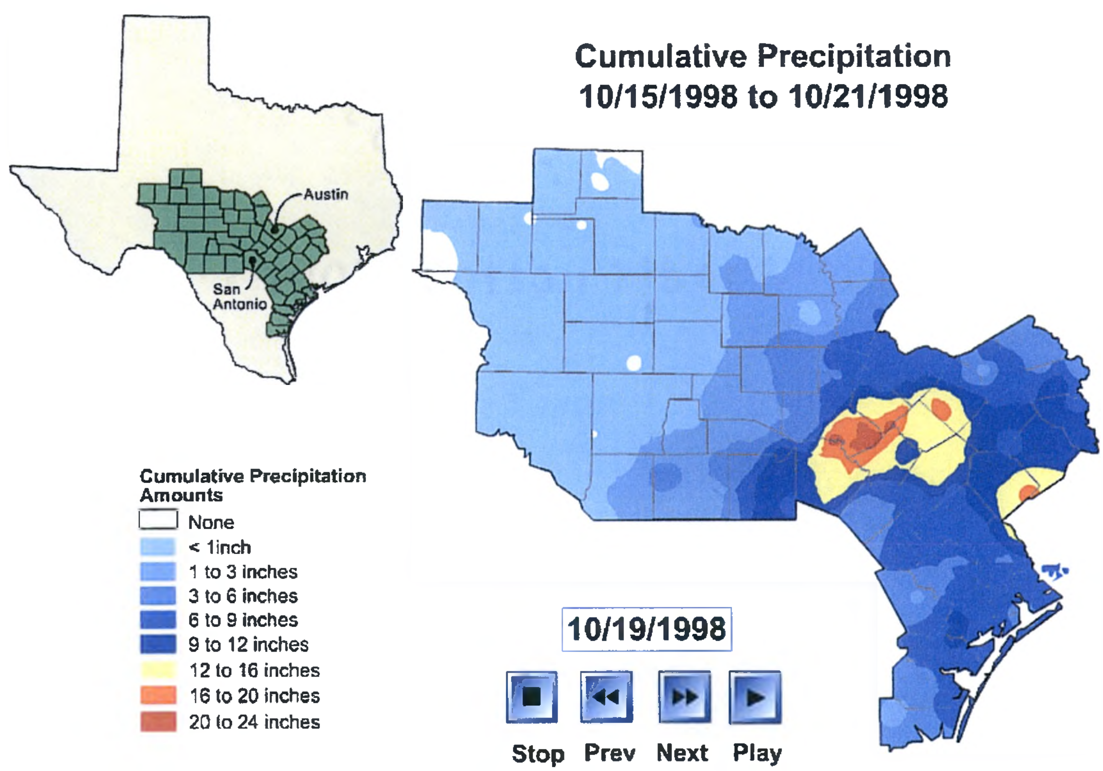
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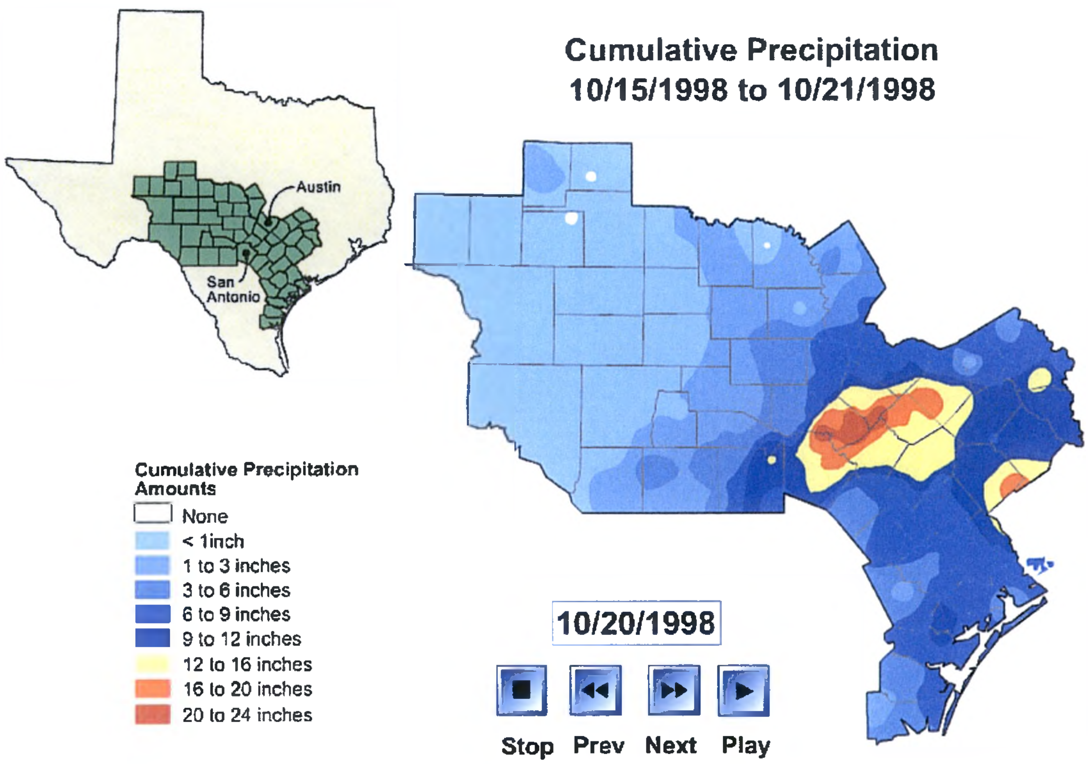
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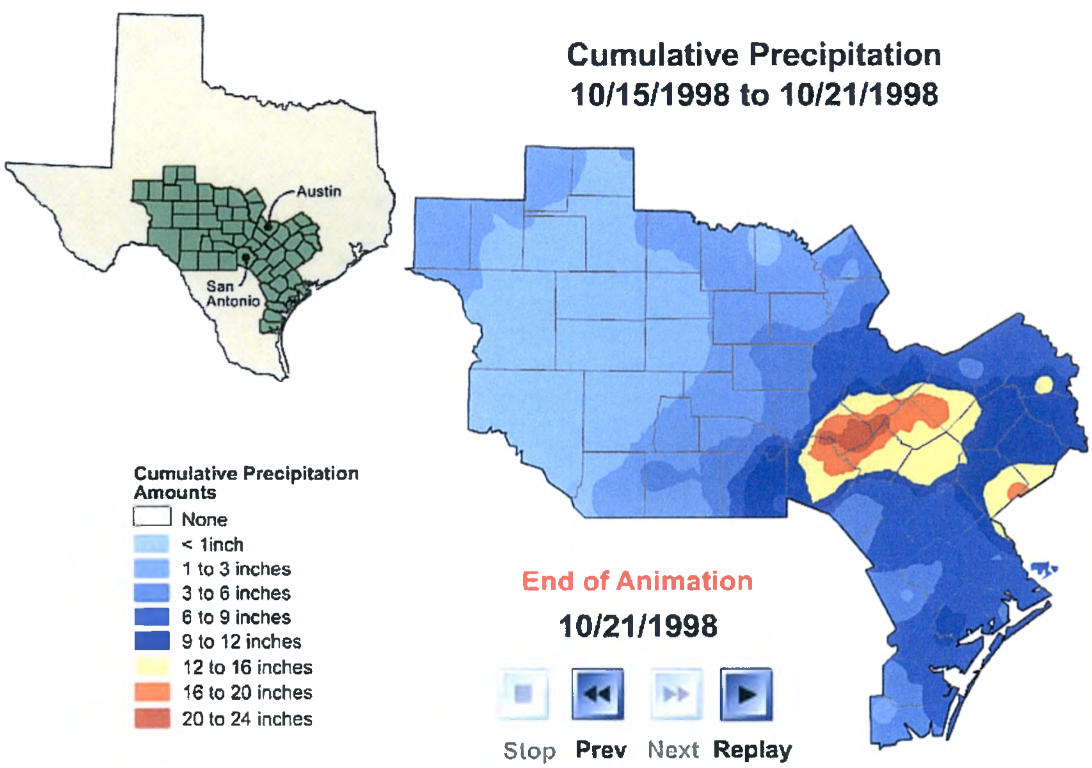
Cumulative Precipitation
10/15/1998 to 10/21/1998
Austin
San Antonio
Cumulative Precipitation Amounts
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1 to 3 inches
3 to 6 inches
6 to 9 inches
9 to 12 inches
12 to 16 inches
16 to 20 inches
20 to 24 inches
End of Animation
10/21/1998
Stop
Prev
Next
Replay

APPENDIX C

LETTER TO PARTICIPANTS AND RISK PERCEPTION SURVEY

Texas State University- San Marcos
Department of Geography

MMM DD, 2005

Dear [PARTICIPANT]

We are asking for your participation in a study of extreme rainfall events in south-central Texas either because of your status as a resident, academic knowledge regarding geographic and climate phenomena, or professional experience in environmental sciences. As you may know, south-central Texas experiences a variety of severe weather events, one of which is excessive rainfall (precipitation) that often leads to severe flooding. Through this study, we hope to learn more about your views and experiences associated with various levels of certain rainfall events. As a participant in this study, we will ask you to view 5 rainfall event animations on the Internet at the website listed below. After you have viewed the animations, you will be asked to rank those events relative to one another in terms of their impact on the study area, and complete a brief hazards experience questionnaire on the Internet. This activity will take approximately 20 minutes to complete. Further instructions will be provided on the website.
http://www.txstate.edu/~wb1028/thesis/group[a][b][c]

Your responses will be confidential and not known to anyone other than my supervising professor, Dr. Denise Blanchard, and myself. At the conclusion of my data collection, your responses, along with the other survey participants, will be aggregated and, thus, no names will be associated with final results of this study.

The purpose of this study is twofold: 1) to fulfill the requirements of completing a thesis for my Masters of Science degree in Geography, and 2) to assist me in building my experience and background in my career interests of combining computer visualization, geographic information systems (GIS), with risk and emergency management. We greatly appreciate your participation, and hope you will agree to participate in this study. Your help is essential to the study's success, and will ultimately provide a valuable contribution to the field of natural hazards research.

If you have any questions, please do not hesitate to contact us via phone or e-mail.

Sincerely,

Bill Bass
Department of Geography
Texas State University- San Marcos
Phone: (512) 694-5095
E-mail: wb1028@txstate.edu

Dr. Denise Blanchard
Department of Geography
Texas State University- San Marcos
Phone: (512) 245-3090
E-mail: rb06@txstate.edu

RAIN EVENT RANKING & HAZARDS EXPERIENCE QUESTIONNAIRE

Background Questionnaire: **All information provided will be kept completely confidential. Names are only used to track status of survey completion, and will not be published. First name and last initial is acceptable.*

Name:

Please rank each of the previously viewed events, using the scale of "1" thru "5" provided below. With "1" being considered the *Most Severe*, and "5" being considered the *Least Severe*. (Use each ranking value only once.)

Event	**Event Ranking (1-5)**	**Did you experience this event?**
July 30^{th} to August 5^{th}, 1978		☐ Yes ☐ No
September 7^{th} to 13^{th}, 1952		☐ Yes ☐ No
November 21^{st} to 27^{th}, 1985		☐ Yes ☐ No
June 30^{th} to July 6^{th}, 2002		☐ Yes ☐ No
October 15^{th} to 21^{st}, 1998		☐ Yes ☐ No

How many major flood occurrences have you experienced (where a major flood occurrence may be described as disrupting your daily routine)?

☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 or more

Other than flooding, how many major hazardous occurrences have you experienced (where a major hazardous occurrence may be described as disrupting your daily routine and may be either naturally or man-made events)?

☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 or more

Please indicate in writing the types of hazardous occurrences these were.

Do you currently reside in a floodplain?

☐Yes ☐No ☐Don't know

Enter a numeric value to complete this statement:

The chance of a major flood event severely impacting my community in the future (where "severely" might be defined as seeking a state or federal declaration for aid and assistance) is 1 in

(Note: a value of 10 equals a 10% chance)

Enter a numeric value to complete this statement:

The chance of a major flood event severely impacting my home in the future (where "severely" might be defined as seeking a state or federal declaration for aid and assistance) is 1 in ______
(Note: a value of 10 equals a 10% chance)

Please rank from "1" to "5" how you hear urgent, short-term warning messages of potential severe flood occurrences, where "1" would represent the *Most Used*, and "5" the *Least Used.* (Use each ranking value only once)

TV ______
Radio ______
Internet ______
Family/Friends ______
Observation ______

Please rank from "1" to "5" how you learn about precautions and preparations that you might take before a flood occurs, where "1" would be the *Most Relied Upon*, and "5" the *Least Relied Upon*? (Use each ranking value only once)

TV ______
Radio ______
Internet ______
Family/Friends ______
Printed Media ______

Using a scale of "1" thru "5," please indicate how valuable you find televised severe weather alerts and public warning messages that use maps to communicate severe weather conditions? (Select only one)

☐1 ☐2 ☐3 ☐4 ☐5
Not Valuable — Somewhat Valuable — Extremely Valuable

How many times per week on average do you watch weather information given on television?

☐0 ☐1-3 ☐4-7 ☐8-10 ☐11 or more times per week

How do you use Internet sites such as local news, Weather.com, or NOAA for weather related information?

☐Not at All ☐Just toView Forecasts
☐Just to View Weather Maps ☐To View Forecasts and Weather Maps

Within the timeframe of one week, specify the level at which you feel total accumulated rainfall becomes potentially hazardous, and may cause flooding and damage to property?

☐ Less than 1 inch ☐ 1-3 inches ☐ 3-6 inches
☐ 6-9 inches ☐ 9-12 inches ☐ 12-16 inches
☐ 16-20 inches ☐ 20-or more inches in a week

Using a scale of "1" thru "5," in your opinion, how useful are maps for communicating hazardous weather conditions? (Select only one)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Not Useful Somewhat Useful Extremely Useful

How many total years have you lived in Texas? (Individual responses will not be made public)

☐ Less than 1 year ☐ 1-3 years ☐ 4-7 years ☐ 8-10 years
☐ 10-15 years ☐ Over 15years

What is your occupation?

Have you ever had training in Cartography (map making)?

☐ Yes ☐ No

Education Level (Select one that represents the highest level attained, individual responses will not be made public).:

☐ High School ☐ Some College ☐ Trade School
☐ Associates Degree ☐ Bachelors Degree
☐ Some Graduate School (Masters or Doctoral)
☐ Gradate Degree (Masters or Doctoral)

Gender (Individual responses will not be made public):

☐ Male ☐ Female

Age Category (Individual responses will not be made public):

☐ <18 ☐ 18-22 ☐ 23-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69
☐ 70+

APPENDIX D

STATISTICAL ANALYSIS TABLES

Table D1. Sample Distribution

Participant Category	N	Percent
Layperson	30	33.3
Geography Student	30	33.3
Professional	30	33.3
Total	90	100

Table D2. Reside in Floodplain

Reside in a	Layperson		Student		Professional		Total	
Floodplain	N	Percent	N	Percent	N	Percent	N	Percent
Don't Know	6	20.0	4	13.3	3	10.0	13	14.4
No	22	73.3	21	70.0	24	80.0	67	74.4
Yes	2	6.7	5	16.7	3	10.0	10	11.1
Total	30	100	30	100	30	100	90	100

Table D3. Years Lived in Texas

Years Lived	Layperson		Student		Professional		Total	
In Texas	N	Percent	N	Percent	N	Percent	N	Percent
Less than 1 year	0	0	2	6.7	0	0	2	2.2
1 to 3 years	0	0	3	10.0	1	3.3	4	4.4
4 to 7 years	0	0	0	0	2	6.7	2	2.2
8 to 10 years	2	6.7	1	3.3	1	3.3	4	4.4
10 to 15 years	3	10.0	6	20.0	2	6.7	11	12.2
Over 15 years	25	83.3	18	60.0	24	80.0	67	74.4
Total	30	100	30	100	30	100	90	100

Table D4. Training in Cartography

Training in Cartography	Layperson N	Layperson Percent	Student N	Student Percent	Professional N	Professional Percent	Total N	Total Percent
No	26	86.7	10	33.3	16	53.3	52	57.8
Yes	4	13.3	20	66.7	14	46.7	38	42.2
Total	30	100	30	100	30	100	90	100

Table D5. Gender Distribution of Participants

Gender Distribution	Layperson N	Layperson Percent	Student N	Student Percent	Professional N	Professional Percent	Total N	Total Percent
Female	11	36.7	14	46.7	11	36.7	36	40.0
Male	19	63.3	16	53.3	19	63.3	54	60.0
Total	30	100	30	100	30	100	90	100

Table D6. Age Distribution of Participants

Age Distribution	Layperson N	Layperson Percent	Student N	Student Percent	Professional N	Professional Percent	Total N	Total Percent
23 to 29	2	6.7	10	33.3	7	23.3	19	21.1
30 to 39	20	66.7	11	36.7	8	26.7	39	43.3
40 to 49	4	13.3	4	13.3	8	26.7	16	17.8
50 to 59	1	3.3	5	16.7	6	20.0	12	13.3
60 to 69	2	6.7	0	0	1	3.3	3	3.3
70 or older	1	3.3	0	0	0	0	1	1.1
Total	30	100	30	100	30	100	90	100

Table D7. Times per Week Watch Weather Broadcasts on TV

Times per Week Watch TV Weather	Layperson N	Layperson Percent	Student N	Student Percent	Professional N	Professional Percent	Total N	Total Percent
0	0	0	5	16.7	1	3.3	6	6.7
1 to 3	7	23.3	12	40.0	9	30.0	28	31.1
4 to 7	17	56.7	8	26.7	10	33.3	35	38.9
8 to 10	5	16.7	4	13.3	2	6.7	11	12.2
11 or more	1	3.3	1	3.3	8	26.7	10	11.1
Total	30	100	30	100	30	100	90	100

Table D8. Ranking of Television as Source for Short-Term Warning Messages

Ranking of Television as Short-Term Warning Media	Layperson		Student		Professional		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
1	22	75.9	17	58.6	17	58.6	56	64.4
2	3	10.3	5	17.2	6	20.7	14	16.1
3	1	3.4	5	17.2	3	10.3	9	10.3
4	2	6.9	0	0	1	3.4	3	3.4
5	1	3.4	2	6.9	2	6.9	5	5.7
Total	29	100	29	100	29	100	87	100

Table D9. Ranking of Internet as Source for Short-Term Warning Messages

Ranking of Internet as Short-Term Warning Media	Layperson		Student		Professional		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
1	1	3.6	4	13.8	3	10.7	8	9.4
2	2	7.1	7	24.1	8	28.6	17	20.0
3	10	35.7	6	20.7	7	25.0	23	27.1
4	6	21.4	6	20.7	6	21.4	18	21.2
5	9	32.1	6	20.7	4	14.3	19	22.4
Total	28	100	29	100	28	100	85	100

Table D10. Ranking of Television as Source for Hazard Preparedness

Ranking of Television as a Hazards Preparedness Media	Layperson		Student		Professional		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
1	22	78.6	18	60.0	16	53.3	56	63.6
2	5	17.9	5	16.7	6	20.0	16	18.2
3	1	3.6	0	0	6	20.0	7	8.0
4	0	0	3	10.0	1	3.3	4	4.5
5	0	0	4	13.3	1	3.3	5	5.7
Total	28	100	30	100	30	100	88	100

Table D11. Ranking of Internet as Source for Hazard Preparedness

Ranking of Internet as a Hazards Preparedness Media	Layperson		Student		Professional		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
1	2	6.7	2	6.9	4	13.8	8	9.1
2	3	10.0	8	27.6	13	44.8	24	27.3
3	11	36.7	9	31.0	5	17.2	25	28.4
4	8	26.7	6	20.7	3	10.3	17	19.3
5	6	20.0	4	13.8	4	13.8	14	15.9
Total	30	100	29	100	29	100	88	100

Table D12. Kruskal-Wallis Test for Laypersons Comparing Frequencies of Flood, Other, and Total Hazards Experienced on the Basis of Total Number of Events Ranked Correctly

	Floods		Other Hazards		Total Hazards	
Chi-Square	5.518		0.472		4.671	
df	6		5		6	
Asymp. Sig. (2-tailed)	0.479		0.993		0.587	
Number of Events Experienced	N	Mean Rank	N	Mean Rank	N	Mean Rank
0	6	13.00	5	16.30	2	15.00
1	2	15.00	3	17.17	1	8.50
2	8	18.25	7	14.21	5	13.90
3	6	18.33	5	16.30	2	21.50
4	3	17.17	2	15.00	3	21.50
5	3	8.50	0	0.00	3	17.17
6 or more	2	12.00	8	15.13	14	14.14
Total	30		30		30	

Table D13. Kruskal-Wallis Test for Geography Students Comparing Frequencies of Flood, Other, and Total Hazards Experienced on the Basis of Total Number of Events Ranked Correctly

	Floods		Other Hazards		Total Hazards	
Chi-Square	6.222		2.578		3.472	
df	6		5		6	
Asymp. Sig. (2-tailed)	0.399		0.765		0.748	
Number of Events Experienced	N	Mean Rank	N	Mean Rank	N	Mean Rank
0	3	22.50	6	17.25	2	22.50
1	4	12.25	3	18.83	2	12.25
2	5	13.70	7	15.50	1	22.50
3	4	18.75	6	12.50	2	17.00
4	3	18.83	1	22.50	4	11.88
5	1	5.00	0	0.00	3	15.17
6 or more	10	14.35	7	14.14	16	15.38
Total	30		30		30	

Table D14. Kruskal-Wallis Test for Professionals Comparing Frequencies of Flood, Other, and Total Hazards Experienced on the Basis of Total Number of Events Ranked Correctly

	Floods		Other Hazards		Total Hazards	
Chi-Square	2.349		5.009		3.770	
df	6		6		5	
Asymp. Sig. (2-tailed)	0.885		0.543		5.830	
Number of Events Experienced	N	Mean Rank	N	Mean Rank	N	Mean Rank
0	1	22.50	2	16.75	0	
1	4	17.75	4	17.75	1	22.50
2	2	16.75	6	17.42	2	22.50
3	6	15.25	1	22.50	2	13.00
4	4	17.75	3	13.33	1	11.00
5	1	11.00	2	22.50	1	22.50
6 or more	12	13.71	12	12.38	23	14.70
Total	30		30		30	

APPENDIX E

KRIGING SETTINGS FOR VISUALIZATIONS

Start Date	End Date	Model	Anisotrophy	Partial Sill	Nugget	Lag Size	# Lags	# Neighbors	Include At Least	Shape	Angle	Major Semiaxis	Minor Semiaxis	Anisotrophy Factor	RMSE
7/30/1978	7/30/1978	Exponential	Y (auto calc)	930.08	30.227	48393	12	4	3	+	293.4	549,350	330,880	1.6603	23.38
7/30/1978	7/31/1978	Exponential	Y (auto calc)	5119.8	1330	48393	12	4	3	+	91.2	549,350	403,700	1.3608	51.55
7/30/1978	8/1/1978	Exponential	Y (auto calc)	11053	7051.6	33951	12	2	2	+	293.2	385,400	181,040	2.1288	86.32
7/30/1978	8/2/1978	Exponential	Y (auto calc)	101220	22631	26856	12	2	2	x	355.5	304,880	224,020	1.3609	189.9
7/30/1978	8/3/1978	Exponential	Y (auto calc)	177970	15453	26855	12	2	2	+	358.3	304,860	197,080	1.5469	203.2
7/30/1978	8/4/1978	Exponential	Y (auto calc)	173990	17158	26855	12	2	2	+	358	304,860	197,080	1.5469	205.2
7/30/1978	8/5/1978	Exponential	Y (auto calc)	172930	17334	26855	12	2	2	+	357.8	304,860	197,070	1.547	205.3
9/7/1952	9/7/1952	Exponential	Y (auto calc)	221.97	0	48393	12	4	3	x	87.6	549,360	379,420	1.4479	12.86
9/7/1952	9/8/1952	Exponential	Y (auto calc)	198.98	420.83	48393	12	4	3	+	274.5	549,350	209,520	2.6219	23.54
9/7/1952	9/9/1952	Exponential	Y (auto calc)	17992	0	3118.7	12	4	3	*	316.9	35,461	18,144	1.9544	111.9
9/7/1952	9/10/1952	Exponential	Y (auto calc)	56356	50331	21233	12	2	2	x	345.9	241,040	134,520	1.7919	218.6
9/7/1952	9/11/1952	Exponential	Y (auto calc)	225440	51213	33951	12	2	2	x	344.6	385,410	181,040	2.1289	203.8
9/7/1952	9/12/1952	Exponential	Y (auto calc)	229160	52260	33951	12	2	2	x	344.9	385,400	181,040	2.1288	204.6
9/7/1952	9/13/1952	Exponential	Y (auto calc)	229250	51939	33951	12	2	2	x	344.8	385,410	181,040	2.1289	203.5
11/21/1985	11/21/1985	Exponential	Y (auto calc)	0	35.19	48393	12	2	2	+	9	549,340	549,340	1	5.825
11/21/1985	11/22/1985	Exponential	Y (auto calc)	0	43.187	48393	12	2	2	+	9	549,340	549,340	1	6.437
11/21/1985	11/23/1985	Exponential	Y (auto calc)	0	3744.2	48393	12	2	2	+	9	549,340	549,340	1	59.13
11/21/1985	11/24/1985	Exponential	Y (auto calc)	12188	12398	48393	12	2	2	+	35.3	549,340	160,970	3.4127	110.2
11/21/1985	11/25/1985	Exponential	Y (auto calc)	26852	12401	48393	12	2	2	+	34.3	549,340	209,520	2.6219	102
11/21/1985	11/26/1985	Exponential	Y (auto calc)	28607	13686	48393	12	2	2	+	35.7	549,340	185,250	2.9654	107.1
11/21/1985	11/27/1985	Exponential	Y (auto calc)	44948	12430	48393	12	2	2	+	34	549,350	282,330	1.9458	108.4
6/30/2002	6/30/2002	Exponential	Y (auto calc)	9185.5	16578	21233	12	2	2	+	27.2	241,040	113,210	2.1291	110.1
6/30/2002	7/1/2002	Exponential	Y (auto calc)	59377	31015	33951	12	2	2	x	16.4	385,410	181,040	2.1289	163.8
6/30/2002	7/2/2002	Exponential	Y (auto calc)	150310	40516	42908	12	2	2	x	20.6	487,080	228,810	2.1288	193.3
6/30/2002	7/3/2002	Exponential	Y (auto calc)	244660	88236	42907	12	2	2	+	23.8	487,070	207,280	2.3498	240.9
6/30/2002	7/4/2002	Exponential	Y (auto calc)	352720	97287	42907	12	2	2	x	19	487,070	207,270	2.3499	273.6
6/30/2002	7/5/2002	Exponential	Y (auto calc)	531410	77019	42907	12	2	2	+	17.3	487,070	207,280	2.3498	293.8
6/30/2002	7/6/2002	Exponential	Y (auto calc)	581160	82265	42907	12	2	2	+	16.6	487,070	207,280	2.3498	319
10/15/1998	10/15/1998	Exponential	nv*	nv*	nv*	nv*	nv*	nv*	nv*	nv*	nv*	nv*	nv*	nv*	nv*
10/15/1998	10/16/1998	Exponential	Y (auto calc)	6145.5	0	1279.9	12	4	3	x	35.9	14,713	6,727	2.1871	33.05
10/15/1998	10/17/1998	Exponential	Y (auto calc)	6825.8	85754	48393	12	2	2	+	28.6	549,340	88,159	6.2312	251.7
10/15/1998	10/18/1998	Exponential	Y (auto calc)	241030	59997	48393	12	2	2	+	40.1	549,350	209,500	2.6222	224.2
10/15/1998	10/19/1998	Exponential	Y (auto calc)	345630	37878	48393	12	2	2	+	34.5	549,350	306,610	1.7917	192.5
10/15/1998	10/20/1998	Exponential	Y (auto calc)	386270	33702	48393	12	2	2	+	34.8	549,350	306,610	1.7917	189.1
10/15/1998	10/21/1998	Exponential	Y (auto calc)	386440	38578	48393	12	2	2	+	34.5	549,350	306,610	1.7917	195.8

*10/15/1998 did not have any precipitation values, non-rain event day, and was therefore not mapped.

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VITA

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