MEASURING COMMUNITY RESILIENCE

TO NATURAL DISASTERS

A CASE STUDY OF THURSTON COUNTY, WASHINGTON

by

Kyli Anne Rhoads

A Thesis
Submitted in partial fulfillment
of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
June 2014

This Thesis for the Master of Environmental Studies Degree

by

Kyli Anne Rhoads

has been approved for

The Evergreen State College

by

____

Edward Whitesell, Ph. D.
Member of the Faculty

____

Date

ABSTRACT

Measuring Community Resilience to Natural Disasters: A Case Study of Thurston County, Washington

Kyli Anne Rhoads

Strengthening our communities to improve resilience to natural disasters is a growing focus, as many regions are already seeing an increase in frequency and intensity of climate change impacts. Additionally, a strong push from the Federal Emergency Management Agency (FEMA) has encouraged communities to focus on natural hazard mitigation projects to avoid and reduce impacts from a variety of disasters before they occur. Overall, this push has been greatly successful in strengthening community recoveries from disaster events. However, new research in social resilience and vulnerability science has found that most natural hazard mitigation plans lack an understanding of and attention to populations vulnerable to natural hazards and how these affect community resilience. In an effort to address this research gap, this study used GIS to identify vulnerable populations and rank community resilience to flood hazards within Thurston County, Washington by identifying social indicators and combining them to see how they interact to affect overall community resilience. Social demographic data from the 2000 census, in combination with 100-year floodplain data, were used to analyze the levels of community resilience according to a 100-year flood event among county census block groups. Levels of community resilience were calculated according to four social characteristics: per capita income, populations living below 150% of the federal poverty level, populations over the age of 65, and racial minority populations. Findings indicate that, at the 2000 census block group level, low resilience areas are not disproportionately exposed to the 100-year floodplain. With an understanding of the flood risks and the ability of a community to rebound from a natural disaster, specific areas can be identified where natural hazard mitigation projects should be focused. Additionally, community development, emergency response, and climate adaptation plans can be improved to specifically address low-resilient areas.

Table of Contents

List of Figures

List of Tables

Acknowledgements

The completion of this thesis would not have been possible without the tireless help and guidance from my faculty and thesis reader, Dr. Edward Whitesell. His persistent guidance throughout planning, writing, revising, and editing processes continually challenged and encouraged me over the past year. I am very thankful and grateful for the amount of time and thought he put into helping me produce this body of research. I also would like to thank Dr. Martha Henderson, who offered inspiration and continual support in my understanding and passion toward my thesis research topic, as well as my other faculty of The Evergreen State College: Dr. Kevin Francis, Dr. Carri LeRoy, Dr. Erin Martin, and Dr. Gregory Steward. To the individuals and organizations that directly contributed to my research, I would also like to express my thanks and appreciation for making time to meet with me or provide feedback on my research: the Thurston County Regional Planning Council, Thurston County Housing Authority, Homes First! of Thurston County, and Tom Crawford of Thurston Climate Action Team. Lastly, many thanks to my wonderful fiancé, friends and family who constantly provide me with encouragement, motivation and inspiration.

Chapter 1: Introduction

There is a general consensus in the scientific community that global climate change, in combination with rising populations of people exposed to natural hazards, the frequency and severity of natural disasters are increasing globally (IPCC, 2013). Natural hazard research and mitigation planning have greatly decreased structural and financial exposure to a variety of natural disasters. It is estimated that for every one dollar spent on mitigation, four dollars are saved in recovery efforts, greatly reducing the impacts felt by a community in a disaster event (Multi-Hazard Mitigation Council, 2005). Over the last two decades, a significant paradigm shift within the field of natural disasters has led to an increase in more active planning and mitigation efforts before a disaster ensues, rather than depending so heavily on a strong response effort after a disaster ensues.

This paradigm shift began with the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 (2013). This act amended the Disaster Relief Act of 1974 (1988) which states that the Federal Emergency Management Agency (FEMA) is responsible for government-wide assistance to victims of a presidentially declared disaster. The Stafford Act amendment was passed following a series of devastating disasters in the United States during the 1980's and required FEMA to place natural hazard mitigation as the highest priority prior to a disaster, forcing FEMA to begin shifting from a strong response-driven effort to a more planning and mitigation mindset on the federal level. It did not take long for communities to begin seeing the benefits and importance of natural hazard mitigation and planning. In 2000, the Stafford Act was amended with the Disaster Mitigation Act (DMA) of 2000 (2000) which replaced former mitigation requirements with new requirements that each state must meet to qualify for disaster assistance, creating strong incentives for states and local governments to implement and coordinate their own natural hazard mitigation plans (NHMPs). Incentives for local governments to create their own NHMPs included access to grants and funding that would allow communities to strengthen their communities through mitigation projects like structural reinforcements or raising buildings in a floodplain, as well give communities who have enacted NHMPs access to more disaster funding in the case of a natural disaster in their area (Lindell, Prater, & Perry, 2006).

While this shift has been a significant one, mitigation and disaster research continue to work to enhance our understanding of what makes our communities vulnerable and how to decrease those vulnerabilities before a natural disaster strikes. Many communities are beginning to see the growing importance of climate adaptation due to climate change as weather events become more extreme and frequent, and in many ways, this requires us to step outside of our single-discipline mindset and incorporate various fields of knowledge to understand how the different facets of natural disasters influence each other. However, adopting the interdisciplinary mindset required to accomplish this is no small feat. It involves incorporating disciplines that range from emergency management, climatology, and community development planning to social science, environmental justice, economics and education. A combination of some of these disciplines has led to the creation of more specific, but interdisciplinary fields, such as vulnerability science and community resilience science.

Research in these fields studies the relationships that a multitude of variables have on a community, and how, in turn, these variables interact with each other to increase or decrease the overall health of the community when stressed by a natural event. Although community resilience and vulnerability science are relatively new fields, significant progress has been made on what these terms mean, why they're important, and even how to measure or model them for specific communities. Research on these subjects has repeatedly shown that we are more in control of how our communities are affected by disaster than originally thought. Disasters are not entirely randomly distributed, or evenly damaging across the affected populations (Godschalk, 1999). These fields of research have led many communities all over the United States to develop and implement NHMPs and climate adaptation plans.

Thurston County, Washington (Figure 1) has been one of the many places that have worked hard to develop plans that reduce their vulnerability to natural disasters. FEMA has declared a total of twenty-three natural disasters in Thurston County since 1962, six of which were between 2003 and 2009 (Thurston County NHMP, 2009). And the overall average is one almost every two years. Besides the Thurston County NHMP, which was first developed and implemented in 2003 by the Thurston County Regional Planning Council, other examples of measure the community has taken to increase awareness and better prepare for climate adaptation can be found within organizations like Thurston Climate Action, and Transition Olympia. These examples encompass the understanding that a more proactive stance is in order to make the places we live safer and more resilient to future natural disasters through community education and re-establishing connections and cohesion within our communities. While this need is easier to see now, approaching such a complex subject and changing the way we handle emergencies is not such a simple task.

Already, developing an NHMP on a city, county or statewide scale involves enormous collaboration with community and city planners, emergency management, fire and school districts, city transit organizations, colleges and the public. Drafting and implementing an NHMP combined with a budget that shifts from year-to-year can seriously limit the resources available and ability of planners to incorporate every item they might like to include within the county NHMP. Past research has addressed that NHMPs tend to carry more weight in the 'fact-based elements' and 'economic risk assessment' portions, and leave much to be desired as far as socioeconomic data and vulnerable populations go (Frazier, Walker, Kumair, & Thompson, 2013b). Gathering useful social information can be more difficult and time consuming than gathering economic data or outlining facts about hazards that exist in a given area, and some planning councils just do not have the time or resources to carry their plans much further than is absolutely required. Not only can gathering social information be difficult, but each community, city, or county will vary in which vulnerable populations they need to work to include in NHMPs. Another difficult hurtle, is how to assemble all of this information in a useful, meaningful way that will truly benefit planning efforts.

Geospatial Information Systems (GIS) have provided a solution to these problems over the last few years. Combined with useful social census data like age, race, and financial income, we now have a powerful tool to input all of these data into and see how they interact with each other over a given region and gather an approximate idea of how impacted specific areas would be impacted by a natural disaster event. Foundational studies world-wide in this area of research have provided helpful methods that can be implemented in most parts of the United States to study how our societal factors work in combination to affect vulnerability to natural hazards and show community resilience to natural disasters in an area (Cutter, Boruff, & Shirley, 2003; Cutter, Mitchell, & Scott, 2000; Frazier, et al., 2013b; Gunawardhana, Budge, & Abeyrathna, 2013). Some of these studies helped serve as a valuable guide in developing the research design and methods for this study to identify vulnerable populations and measure community resilience using Thurston County as a case study. The vulnerable populations in Thurston County that are focused on in this study have also been identified in previous research of this kind; populations over the age of 65, racial minorities, persons living below 150% of the federal poverty threshold, and per capita income are identified on the block-group level.

The purpose of this study was to identify vulnerable populations within Thurston County using publicly available social demographic data and spatial technology to determine a foundational "community resilience" ranking in relation to the 100-year floodplain. More specifically, this study shows how certain factors can be usefully incorporated to spatially analyze ways in which areas might be affected by natural disaster and which areas might be at an increased risk to an event. In this study, Thurston County is the study area and focus, but these methods are applicable to other counties, cities, and communities as well and can serve as a basis for other regions to better understand vulnerable populations and community resilience in their own areas. Although the Thurston County NHMP includes a basic demographic profile for the region, which includes many tables and graphs of statistics, this study takes some of this information and combines them into a useful tool to create a stronger understanding of how those variables interact to increase or decrease vulnerability, and ultimately impact community resilience across the spatial plane.

Figure 1: Map of Washington State. Thurston County is identified in black.

Like much of the Pacific Northwest, Thurston County is exposed to a variety of natural disasters, most notably earthquakes, volcanic activity, tsunamis, and extreme flooding. As was stated before, Thurston County is not a stranger to federally declared disasters. Of the various natural hazards that exist in this region, flooding poses the most frequent and expensive problem to the county. Roughly 5.1% of the county exists in a floodplain (Washington State NHMP, 2010), and since 1962, Thurston County has had twenty-three federally declared disasters, seventeen of which were major flooding events (Thurston County NHMP, 2009). This information has encouraged local planners to heavily stress floodplain management techniques within the county plans, and this is the reason this study has chosen to look at community resilience in relation to the 100-year floodplain. While this natural hazard was chosen for this study to contain scope and keep this thesis manageable, it should be noted that Thurston County's community resilience is also relevant and important to study in relation to other natural hazards in the area that pose a disaster risk to local communities. Although there are differences in how a community will be impacted depending on what type of disaster event happens, if a community is socially vulnerable (i.e. high populations of low income families, elderly, or high populations of diverse, racial minorities) they are likely to be more severely impacted by any natural disaster than less vulnerable communities, whether it be a flood, earthquake, or severe winter storm due to more limited resources, physical inabilities, language barriers or cultural barriers; understanding this is why it's important to view and increase community resilience to a variety of hazards rather than just to one in particular. Before delving into the past research on these subjects, it is important to define some basic but important terms, and to discuss the current state of the Thurston County NHMP.

Important Terms and NHMP Basics

A hazard is defined as something that has the potential to cause harm, generally used in the English language to describe something that can cause damage to life or property (Merriam-Webster, 2013). Hazards can be human induced, like hazardous waste sites, hazardous fumes, or hazardous commercial structures. A natural hazard is a physical, biological, or ecological process that exists in nature as part of Earth's meteorological, ecological, and/or geological systems. Some of the most frequent natural hazards in the Pacific Northwest, for instance, are earthquakes, landslides, severe storms, volcano eruptions, flooding, and wildfires. A natural hazard becomes a disaster when the hazard impacts human life or developments (Abbott, 2012; Tierny, 2007). In the absence of humans, there are no natural disasters, only natural hazards. As Earth becomes more densely populated, natural hazards have increasingly become natural disasters, causing over 2 million deaths globally since 1970, and costing over $210 billion globally in 2011 alone (Abbott, 2012).

Emergency Management (EM) is "the management of risk so that societies can live with environmental and technical hazards and deal with the disasters they cause," (Waugh, 2000, p. 3). Within EM, they identify four primary phases of the EM process—natural hazard mitigation (NHM), preparedness, response, and recovery (FEMA, 1998). Prior to the last two decades, EM strongly focused on responding to natural disasters as they happened, but over the last twenty years, there has been a shift in this disaster-response focus, to a stronger emphasis on mitigation, planning, and community resilience to help avoid as much damage as possible prior to an disastrous event taking place (Berke & Campanella, 2006; Board on Natural Disasters, 1999; Cutter, Barnes, Berry, Burton, Evans, Tate, & Webb, 2008; Manyena, 2014; McEntire, Fuller, Johnson, & Weber, 2002; Allen, 2006). This paradigm shift is the result of Earth's growing populations, climate change, and the realization of the limited capabilities of large response organizations.

Natural Hazard Mitigation (NHM) is defined as "any sustained action taken to reduce or eliminate long-term risk to people and property from natural hazards and their effects" (FEMA, 2013). The differences between mitigation and preparedness can be difficult to separate because the two terms are often used interchangeably and overlap each other in several aspects, however, the two do have differences. Mitigation can best be understood as long-term, on-going actions that provide "passive protection" at the time of an event (Godschalk, 2005; Lindell & Perry, 2007). These actions can be handled by individuals, city, county, state and federal agencies, and can include, but are not limited to the following: establishing flood-plains and appropriate land-use codes; changing development zoning; strengthening building codes; and public education campaigns about home, property, and business damage reduction. Preparedness, on the other hand, can involve active planning on individual, community and government levels and aims to enhance effective response once a disaster happens. Preparedness tasks can include, but are not limited to, stock piling food and water; preparing emergency kits for homes; collaborating with other community or state organizations; and becoming educated about individual and local emergency management plans. Mitigation and preparedness give local communities, and state and federal agencies the opportunity to plan ahead of a disaster, reducing exposure and making our communities capable of a quicker recovery after an event occurs. Primary agencies responsible for mitigation and preparedness range from small local organizations (e.g., schools and churches) to city and county jurisdictions or larger state and federal organizations (e.g., State Emergency Management Divisions and FEMA).

Plans are comprised of structural and non-structural mitigation strategies (Lindell, et al., 2006). Structural strategies consist of five primary areas of focus—hazard source control, community protection works, land use practices, building construction practices, and building contents protection. Non-structural mitigation strategies are more vague, but various, including things such as “reducing chemical quantities stored at water treatment plans,” and “purchasing undeveloped floodplains and dedicating them to open space,” (Lindell, et al., 2006, p. 195).

As was stated earlier, Thurston County first introduced its NHMP in 2003. Since then, significant progress has been made to make the area safer in the face of a variety of natural hazards. The plan includes structural and non-structural mitigation strategies for earthquakes, storms, floods, landslides, wildfires, and volcanic eruptions, as well as potential climate change impacts in Thurston County's future. Thurston's NHMP is a multi-jurisdictional plan, meaning the plan covers Thurston County as a whole, but nineteen cities, tribes and local organizations have decided to adopt the plan as their own, rather than writing a localized plan for their areas of jurisdiction. It is important to note the differences in each community's needs, strengths, and weaknesses when looking at a multi-jurisdictional plan. Thurston's NHMP includes urban areas such as Olympia and Lacey, as well as smaller rural areas such as Bucoda, Yelm, and Rainier (see Table 1).

Thurston's NHMP also includes social and economic data in the form of basic profiles and tables for each area that has adopted the plan. While the profiles and tables are informative, this section is not conducive to showing how these populations are distributed throughout the county, understanding how these different characteristics interact with one another, or what part they play in community resilience to the natural disasters being mitigated. By using GIS, these data can be compiled into a more useful tool to better understand what these characteristics mean for regions throughout the county, and how these areas might be differently impacted by a natural disaster.

Moving forward, the literature review chapter of this study compiles the primary research done in the fields of community resilience to natural disasters; these studies cover a multitude of factors that influence how humans are affected by natural disasters, including vulnerability science, vulnerable population identification, environmental justice, community planning, and modeling and measuring community resilience to natural disasters. This chapter also helps define many of the more complex terms like community resilience and vulnerability and addresses why much work is still needed in our planning and mitigation activities to incorporate a systems view to strengthen our NHMPs.

Table 1: Jurisdiction Adoption and Approval Dates of the 2003 NHMP for the Thurston Region. Plan is updated every five years; the latest version will be available by November, 2014.

Jurisdiction	**Adoption**	**Approval**
Thurston County	August 4, 2003	October 6, 2003
Town of Bucoda	May 24, 2005	August 17, 2005
City of Lacey	September 11, 2003	October 6, 2003
City of Olympia	December 9, 2003	October 6, 2003
City of Rainier	March 2, 2005	April 6, 2005
City of Tenino	July22, 2003	October 6, 2003
City of Tumwater	July15, 2003	October 6, 2003
City of Yelm	August 13, 2003	October 6, 2003
Confederated Tribes of the Chehalis Reservation	July 19, 2003	October 6, 2003
Fire District 4 – Rainier	August 12, 2003	October 6, 2003
Fire District 9 – McLane	August 14, 2003	October 6, 2003
Fire District 13 – Griffin	August 14, 2003	October 6, 2003
Intercity Transit	June 2, 2004	October 6, 2003
Providence St. Peter Hospital	May 6, 2004	August 25, 2004
School District, North Thurston Public Schools	January 18, 2005	February 28, 2005
School District, Olympia	August 9, 2004	October 6, 2003
School District, Rainier	----------------	October 6, 2003
School District, Tumwater	June 12, 2003	October 6, 2003
School District, Yelm Community Schools	November 23, 2004	December 23, 2004
The Evergreen State College	July 9, 2003	October 6, 2003

In chapter three, the research methods involved in this study will be addressed and discussed. Methods for this study were chosen based on previous, similar studies covered in chapter two. Variables used were chosen based on availability of data (only publicly available census data were used) and on whether these vulnerable populations had been identified in past research as indicators of community resilience. Spatial analyses are discussed and explained, as well as the final, spatial weighted overlay analysis, which resulted in a ranked community resilience map of Thurston County. These methods were chosen to produce foundational methods for measuring community resilience to natural disasters in Thurston County, and to provide meaningful information about what community resilience in Thurston County looks like in relation to the 100-year floodplain.

The 100-year floodplain used in this study was created using HAZUS, rather than depending on existing floodplain maps. This was done for two reasons. By using HAZUS, a more detailed depth grid and floodplain can be developed using more current elevation data provided by the USGS. Further, using HAZUS allows us to go beyond just mapping a natural hazard area. HAZUS incorporated hundreds of useful tools and data within its disaster models. Although no other HAZUS capabilities were included in this particular study (e.g., damage estimations for the study region), it was used to provide future research with a stronger format for measuring community resilience in Thurston County. With the inclusion of HAZUS, the foundation is laid for similar studies to incorporate flood and earthquake models for the region, and to see in more detail how areas of low and high community resilience might be impacted by an event. This will be further discussed in the section on considerations for future research, in chapter six.

Chapter four covers the results of all spatial analyses done on the four variables and the spatial weighted overlay. Maps that display the spatial statistics conducted are provided and explained. The spatial analyses provided information about the degree to which a variable influences itself. If each of the individual social variables is correlated with themselves, this is important to understand before combining the variables into the spatial weighted overlay. These relationships also help show how community resilience throughout the county could also be auto-correlated with itself—in other words, by strengthening or weakening one jurisdictions community resilience to natural disasters, the neighboring jurisdictions might also indirectly experience increased or decreased community resilience. The analyses of social indicators in this study helped show the complex and systemic nature of community resilience.

The spatial weighted overlay analysis and the ultimate findings of community resilience in Thurston County are the result of the final analysis. The outcome of the weighted analysis assigned a community resilience ranking to each individual area within Thurston County. Identifying areas of highest and lowest resilience within the county provided a very useful tool for things such as conducting hazard mitigation projects, educational preparedness campaigns, or community planning and restructuring. It will also allow planners and community members to identify where particularly low resilience areas lie within proximity to specific hazards.

This study used the 100-year floodplain as a natural hazard for comparison, but the resilience ranking could also be studied in relation to fault lines, landslide zones, or areas prone to wildfires. Knowing the community resilience information of an area can also allow emergency responders to better prepare. For example, knowledge about low resilience due to lower-than-average financial income would allow groups like the American Red Cross to be better prepared to dispatch aid to those specific areas, to provide needed resources and locate alternative housing for impacted populations. Included in this chapter is the final map of Thurston County with a choropleth map indicating block groups with their corresponding community resilience ranking. The highest and lowest groups are identified and shown up close in relation to the 100-year floodplain.

Lastly, the discussion chapter goes further in depth on the areas of highest and lowest resilience within Thurston County. Some of the social characteristics that strongly influenced their ranking are looked at in detail for the block groups of highest and lowest community resilience. Implications for this study and considerations for future research are discussed, to identify ways this research is helpful and what is needed from further research on this topic.

The transition of natural disaster management from a response mindset to a stronger focus on mitigation and planning has greatly decreased many communities' exposure to natural hazards. As is discussed in chapter two, most NHMPs tend to place a higher priority on mitigating for structural and economic damage than on understanding the underlying social structures that interact with each other to increase or decrease community resilience to natural disasters. Recent research has focused on these shortcomings, and many have interrogated the meanings of terms like "community resilience" and "vulnerability." These studies have greatly strengthened our understanding of the importance of underlying social factors and the roles they play in how a community is impacted by and recovers from an event. Other studies have taken community resilience and vulnerability sciences further into modeling stages, and even measuring stages. The following chapter addresses and reviews the primary existing literature on these subjects, and helps clarify the methods chosen for this study.

Chapter 2: Literature Review

As was mentioned in the first chapter, research in the fields of natural hazard mitigation and emergency management have come a long way in the past two or three decades in revealing inter-linking and underlying factors that influence and affect the way populations are impacted by disasters. These areas of study are constantly growing and incorporating a more systemic perspective, which continues to influence and strengthen overall community resilience and reduce vulnerability. In the first portion of this review, research on the quality and effectiveness of NHMPs is discussed and two major consistent themes are found throughout these studies. The first is that there is a general lack of inclusion of many important social indicators that should be taken into consideration when creating an effective NHMP that encourages community resilience to natural disasters. Secondly, multiple researchers have emphasized the need to incorporate community-specific and interdisciplinary aspects outside of the "cookie-cutter" format that FEMA currently requires from all NHMPs to make our mitigation more effective and localized to each community's needs. A review of these studies leads us into the second half of the review, into more complex questions. What does community resilience really mean? What has vulnerability and who are vulnerable? How can we begin to measure our own community resilience? Fortunately, research has made significant progress in these areas as well.

Natural Hazard Mitigation Plans

Since the implementation of the Disaster Management Act of 2000, some work has been done to try and measure the quality and effectiveness of the implemented

NHMPs. One of these studies focused on 139 cities across five states, including Washington State. This study (Berke & Roenigk, 1996) sought to find out if state-mandated NHMPs resulted in an increase in the development and effectiveness of local community mitigation plans within the state. What they found was that not only were local communities more likely to develop and implement their own NHMPs if plans were mandated on the state level, but many of the plans developed were of higher quality than communities who developed plans in a state without state-mandated NHMPs. Washington State was unique in this study, because it has a state mitigation plan, but does not mandate local communities to implement their own. Despite the lack of a state mandate, 29 of the 30 local governments examined in this study have prepared and adopted local NHMPs. The researchers attributed this anomaly to the fact that Washington State may have a more "progressive and environmentally conscious culture to take collective action through planning," (Berke & Roenigk, 1996, p. 5). While this very well might be the case, this study looked at plan effectiveness based on requirements and recommendations set by FEMA. The effectiveness of these plan requirements within Washington State have been seen by some as less effective than their potential, due to deficiencies in several areas. It has been argued that this is due to the low, "cookie-cutter" style standards that FEMA requires of them, and the lack of incentive for county planners to go further than required to create NHMPs that are more specially designed for their specific communities.

One such study has analyzed county plans within Washington State, to look at their effectiveness on the county level based on FEMA requirements, and then to analyze them a second time based on further needed additions recommended in NHMP research.

Keeping with the same methods and analysis style of previous studies, this study was conducted by performing a comparative analysis of eight Washington State county NHMPs—Skagit, Clallam, King, Kitsap, Pierce, Thurston, Pacific, and Lewis (Frazier, et al., 2013b). The researchers found significant differences between rural and urban counties, and they argued that the base-level criteria that FEMA requires of NHMPs is broad and is not always sufficient for smaller, local community needs. Of all eight plans included in the study, Thurston County was scored the highest (88%) out of the basic FEMA mitigation plan requirements (a total of 57 requirements). This high score was mostly attributed to the fact that Thurston County developed its plan internally (through the Thurston County Regional Planning Council), rather than contracting it out, and is better established, resourced, and sophisticated when compared to smaller or rural jurisdictions. However, since FMEA produced the format recommendations for NHMPs, other research has expanded on areas that should be included in a strong plan (Berke, Smith, & Lyles, 2012; Godschalk et al., 1999; Hoch, 2002; Hopkins, 2001). These expanded areas included topics such as "issue identification and visioning, internal consistency, implementation, monitoring and evaluation, organization and presentation, and integration and coordination with other plans and compliance with governmental mandates" (Frazier, et al., 2013b, p. 55). Frazier, et al., then re-evaluated the eight Washington counties a second time within the same study (2013b) to include these expanded items, for a total possible score of 293. When factoring in these expanded items, Thurston County again scored highest, but at a mere 54%, showing potential for improvement in many of the expanded factors.

These authors determined that overall, most of the NHMPs were strongest in the risk assessment and “fact-based elements,” while “sections requiring more analysis and time-consuming detail and review, such as socioeconomic analysis and identification of special needs populations” were less focused on, and therefore less effective, in all plans studied (Frazier, et al., 2013b, p. 58). The researchers concluded that sub-par mitigation plans are the result of jurisdictions following the “cookie-cutter” format of local mitigation planning, based on the large, general NHMP format recommendations provided by FEMA. Counties generally follow this format, performing close to the bare minimum necessary to qualify for mitigation and post-disaster funding. Overall, this research found that local hazard mitigation planning is in need of a “more place-based approach,” which includes more specific mitigation based on local hazards and community needs. Frazier et al. concluded with the recommendation that a, “collaborative, interdisciplinary approach to hazard mitigation planning and NHMP development has the potential of increasing overall plan quality. This in turn increases community resilience and reduced vulnerability,” (Frazier, et al., 2013b, p. 59). While including socioeconomic information and identifying vulnerable populations in an NHMP might be more time-consuming, incorporating it would offer a useful tool for understanding the relationships between hazards and particularly vulnerable populations, and would increase over-all community resilience by providing information of where resources would be most needed. It also would offer planners a better idea of weak areas where mitigation projects should be prioritized, to increase over-all community resilience.

Other groups of researchers have performed similar comparative analyses. One study selected fifty-seven counties spread over three different states in the southeastern United States, and found that significant differences existed among county NHMPs within each state, separated by rural and urban areas (Horney, Naimi, Lyles, Simon, Salvesen, & Berke, 2012). Counties that classified as "urban" had stronger direction setting principals (goals, fact bases, and policies) than counties classified as "rural," while the "urban" county plans were inferior to "rural" plans in the action-oriented principals (implementation and monitoring, inter-organizational coordination, and participation). The significant differences in the urban NHMPs compared to the rural NHMPs show that there is room for improvement at both scales. While the states focused on in this study were Florida, Georgia, and North Carolina, the results suggest that similar weaknesses may lie within other state and county NHMPs, including Washington State. As was noted earlier, Thurston County's NHMP is a multi-jurisdictional plan, and has been adopted by large and small cities within the county, so for an NHMP to be most effective for all communities included, it must take into account the differences in each community's needs, strengths, and weaknesses when mitigating natural hazards.

In sum, reviewing the literature on quality and effectiveness of NHMPs reveals two strong themes: (1) there is a general lack of inclusion of many important social indicators that should be taken into consideration when creating an effective NHMP; and (2) in order to include factors outside of the "cookie-cutter" format currently used to develop plans, an interdisciplinary approach must be taken. Incorporating data from social disciplines provides a more rounded picture of where community vulnerability exists, and ultimately, leads to a strengthened NHMP. These conclusions raise questions about two particular terms and concepts that need to be addressed and better understood before moving on, namely “community resilience” and “social vulnerability.”

Community Resilience

As discussed, past NHMPs have been strongest in providing natural hazard factual information along with structural and economic risk assessments. This rings true for Thurston County’s mitigation plan, as well. Although the plan does incorporate social demographic profiles for each jurisdiction covered, these lists and tables are not useful for understanding the relationship these characteristics have with each other (social vulnerability), nor the impact they have on community resilience in the area. In Thurston’s NHMP, as well as in most NHMPs in general, risk assessments only measure potential economic loss in terms of workforce and infrastructure (Washington State Enhanced Mitigation Plan, 2010). The main reason for a purely economic focus in measuring vulnerability and risk is due to the difficulty in measuring social factors, such as social capital, value of place and income disparity. However, by including other non-economic factors into our assessment of what is at risk in times of natural disasters, and including economic data as one piece of the puzzle (rather than *the main* piece), we can begin to measure a community’s resilience to natural disasters.

Community resilience is a broadly used and still shifting term, without one single definition. However, the Community And Regional Resilience Institute (CARRI) has been helping track community resilience-related research since 2009, while compiling and implementing the Community Resilience System (CRS), later adopted by FEMA in 2011. CARRI (2013) provides the various accepted definitions of resilience and shows the evolution of the term from 1978 to present day. The most common definitions used today in the natural hazard emergency management fields are the ecological system versions (rather than their older, strictly physics and engineering-based definitions), and CARRI lists forty-six separate definitions that have been cited throughout resilience-related literature. Although the early ecological versions of the definition were not originally developed with human community resilience in mind, many disaster researchers have adopted these versions because of their capacity to capture the complex changes involved in community resilience with respect to a natural disaster event (Gunderson, 2010).

Two commonly cited definitions listed by CARRI stem from Holling, who defined resilience as, “the persistence of relationships within a system; a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist,” (Holling, 1973, p. 17) and as the “buffer capacity or the ability of a system to absorb perturbation, or the magnitude of disturbance that can be absorbed before a system changes its structure,” (Holling, 1996, p. 53). Both of these definitions of ecological resilience include the importance of absorbance, but the second, more recent definitions, incorporates the specific terms ‘perturbation,’ and ‘disturbance,’ stressing the importance of stress or disruption along with system response. Klein, Nicholls, and Thomalla, (2003) go further, to say that resilience is, “the ability of a system that has undergone stress to recover and return to its original state; more precisely (i) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction and (ii) the degree to which the system is capable of *self-organization* [emphasis added],” (Klein, et al., 2003, p. 43). This definition has been adopted by many researchers to help increase communication between natural hazard research communities and climate change research communities. It incorporates important climate change language so that natural hazard discussions can more easily incorporate aspects of climate change into discussions about hazard prediction, disaster prevention and mitigation (Klein, et al., 2003). Another benefit to this definition is its incorporation of the term 'self-organization,' which is an important characteristic of any system and necessary for resilience to take place at all. While the Klein, et al., (2003) version isn't the most frequently cited definition of resilience, it will be the definition used throughout the rest of this paper when speaking of community resilience. This study will identify characteristics that influence a community's resilience to natural disasters by using a holistic, systems perspective, thus it is important to keep in mind the importance of self-organization as a trait of a resilient community.

Resilience

"The ability of a system that has undergone stress to recover and return to its original state; more precisely (i) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction and (ii) the degree to which the system is capable of *self-organization*" (Klein, et al., 2003, p. 43).

Systems are characterized by several factors, including emergent properties, self-organization, non-linear change, and unpredictability (Gunderson, 2010; Meadows, 2008), so to view community resilience through a systems approach, it is important to understand that resilience is a system process rather than an achieved state or stability (Norris, Stevens, B. Pfefferbaum, Wyche, & R. Pfefferbaum, 2008). Because social, physical and economic variables within a community are constantly changing, so is a community's resilience to natural disasters. It is helpful to understand that although community resilience and social vulnerability are closely, negatively correlated, the absence of vulnerability does not necessarily mean high community resilience. Community resilience is complex and includes many, interlinking factors, including physical and economic facets, all of which are constantly changing, and it would be extremely difficult to incorporate them all. It is necessary to keep this in mind, and understand that this study is only the beginning in understanding local community resilience.

It has been discussed that the economic aspects of NHMPs tend to be given priority in identifying and executing mitigation projects. The physical aspect plays a somewhat less predictable role, but NHMPs also have been shown to be stronger in their hazard fact-based elements, to provide as much information as possible about the potential hazard at hand. Where does this leave the social variables? How do they interact with each other and what can they tell us about a community's over all resilience to a natural disaster? These types of social vulnerability questions are the focus of vulnerability science, and they have helped contribute to our understanding of community resilience.

Social Vulnerability

Vulnerability science is another social science field that, like resilience science, depends on an ever-shifting system as the population increases and decreases. Also, like resilience science, it is an evolving field with large degrees of uncertainty due to the difficult nature of measuring and quantifying vulnerability (Cutter, Mitchell, & Scott, 2000). Vulnerability is generally accepted in the natural hazard realm as a term referring to the potential loss of life or property due to hazards (Cutter, 1996). Other researchers stress the importance of identification and inclusion of vulnerable people into preparedness and mitigation plans; such as the elderly, poor, children, disabled, and minority communities (Berke & Campanella, 2006; Colten, 2008; Kiter-Edwards, 1998; Tobin, 1999; Vink & Takeuchi, 2013). Cutter, et al. (2000) created a "place vulnerability" map and scoring system that used GIS mapping and social data to visualize biophysical and social vulnerability in Georgetown County, South Carolina. Their study was able to delineate areas where vulnerable people (females, non-whites, <18 and >65 years of age, and low income neighborhoods) were spatially situated in relation to areas with high risk of hazards such as chemical spills, earthquakes, floods, hurricanes, windstorms, tornados and wildfires. Like previous studies that assessed the effectiveness and quality of NHMPs, this study showed the need for the inclusion of social indicators when assessing and mitigating a community's vulnerability to natural hazards. Because vulnerability and social factors are linked, effective mitigation strategies must usefully incorporate these factors into the overall mitigation plan in order to increase community resilience. With this understanding, other studies have worked to determine exactly which social characteristics are most helpful and important to include when identifying vulnerable populations and assessing a community's resilience to natural disasters.

In a study of all 3,141 counties in the United States, researchers developed a Social Vulnerability Index (SoVI) to quantitatively measure factors that most strongly influenced a county's vulnerability to natural disasters (Cutter, Boruff, & Shirley, 2003). In their review of the literature, these authors identify seventeen factors that past research has shown to influence vulnerability. Within these seventeen factors, these authors note that four factors are most commonly cited in literature as influential on vulnerability—(1) age, (2) gender, (3) race, and (4) socioeconomic status. These researchers then used 1990 U.S. census data to quantitatively assess each of the seventeen factors that past research had attributed as an influence on vulnerability to identify the amount of variance each trait individually contributed to overall vulnerability.

They found that of the seventeen factors identified in past research, eleven of these showed a stronger influence on overall vulnerability. These eleven factors explained the highest percentage of variance when assessing vulnerability, and when combined, explained 76.3% of the variance in vulnerability from county to county—personal wealth, age (children), age (elderly), density of the built environment, single-sector economic dependence, house stock and tenancy, race (African American and Asian), ethnicity (Native American), ethnicity (Hispanic), Occupation, and infrastructure dependence (Cutter et al., 2003). Density of the built environment describes how developed an area is; explaining that areas that are more structurally dense contain higher vulnerability than areas with less structural development because there are more buildings and homes that could be damaged during a natural disaster. Single-sector economic dependence represents areas that are heavily dependent on one or two major industries for their economic stability, such as a town where a large portion of the residents are employed in the logging industry, or oil refineries. Areas that are largely dependent on these areas tend to see over-all economic growth in times of prosperity, but the entire area suffers when these industries struggle or suffer. The characteristic of racial inequality show areas where racial minorities have unequal access to resources or a tendency to be marginalized due to social, cultural, or language differences. This study identifies African Americans (particularly African American women-led households) and Asian populations as the most vulnerable.

While this study further shows the importance of understanding social vulnerability and helps show the complex relationship these factors have with each other to ultimately increase or decrease vulnerability, these methods could be applied at a more local scale to identify vulnerability in more detail. Incorporating social aspects into our understanding of natural disaster impacts helps us understand that, ultimately, we are more in control of how we are impacted by natural disasters. This relationship between vulnerability and community resilience to natural disasters is being called by some in the disaster research community the "social construction of disasters."

The Social Construction and Interdisciplinarity of Disasters

The primary theme behind much of the research surrounding disaster resilient communities lies in the foundational understanding of the social construction of disasters. This concept addresses specific measures a community takes that can have the ability to increase or decrease a community's resilience as a whole. Literature on the social construction of disasters (Clarke, 2006; Klinenberg, 2002; Peacock, Hearn, Morrow, & Gladwin, 1997; Wisner & Walker, 2005) has stressed the need for understanding the theory of how social factors—such as inequality, political structure, gender, racial and ethnic relations, the environment, and culture—all tie together to either enhance or hinder a community's resilience to disasters. "Structured Destruction," a term referring to "patterns of suffering that follow divisions of race or class" (Clarke, 2006, p.134), is a concept that calls attention to the relationship between devastation following a disaster and the "ways humans organize their societies: along lines of wealth and poverty, division of labor, access to healthcare, and membership in organizations," (Clarke, 2006, p.129). Sociologists have made some headway in showing that "disasters are not random or equal probability events but are the result of existing social and economic conditions. Therefore, it should come as no surprise that those disenfranchised from political and economic power disproportionately suffer the consequences of these events and have the greatest difficulties in recovering from them. In fact, disasters serve to bring to the forefront the social inequalities that characterize contemporary societies," (Rodriguez & Barnshaw, 2005, p.222).

Joining social aspects with the physical and economic aspects of natural disaster research requires tying together multiple disciplines of research, such as community development and planning, local and federal policy, hazard mitigation and emergency management, climate science, and local voices. This provides a systems view that allows us to better plan for future events for everyone in the community. Viewing community resilience through the social constructionist and interdisciplinary lens can help us identify weak areas in our communities that can become starting points for building community resilience. Understanding the social construction of disasters brings light to the environmental justice portion of the literature on these subjects, which begin to address the moral and ethical issues associated with how we socially construct natural disasters.

Environmental Justice

Environmental Justice (EJ) is an area of social science research that studies how evenly environmental benefits and burdens are distributed across various populations (Schlosberg, 2008). It posits that "environmental safety and health cannot be a luxury reserved for the privileged classes or wealthy countries," (Bolin & Stanford, 1998). Environmental justice research varies widely, but includes research on minorities and vulnerable populations' exposure to hazardous pollution from activities such as nuclear facilities and natural gas production sites, as well as studies of populations most affected by climate change and natural disasters. Bolin and Stanford (1998) point out that "disasters occur at the intersection of environmental hazards and vulnerable people, and as such are social products," … "their risks and effects are mediated by prevailing social practices and their material forms in a given place," (Bolin & Stanford, 1998, p.218). Low-income populations and racial minorities have been identified as bearing a heavier burden of environmental hazards such as pollution, contaminated drinking water, and exposure to waste sites than their white and/or wealthier counterparts (Bullard, 1993); this is just one example of the necessity of studying the relationships between community social characteristics and hazards. Environmental justice is inherently interdisciplinary and, when discussing community resilience and vulnerability to natural disasters, environmental justice is an essential component.

Cohen and Bradley (2008) argue that the higher exposure to natural hazards by vulnerable populations is not just a community planning failure, or a shortcoming in our understanding, it is a human rights issue; many of our own vulnerabilities are within our power to prevent, or at least reduce. These researchers agree with previous studies discussed here in regards to the social construction theory of disasters and reiterate that disasters expose serious social inequalities that already exist in a community or population. They recommend that we begin increasing awareness through public policy, and that local and national leaders need to be repeatedly reminded to keep vulnerable populations and their rights at the top of their list of priorities. It is ultimately their job to be a voice of protection for these underserved and vulnerable populations, and to ensure they get the help they need before and after natural disaster events. This will only prove more urgent as the frequency and severity of natural disasters due to climate change rise and continue to affect our ever-increasing populations.

Not only is prioritizing in this way the right thing to do, but as we have seen with natural hazard mitigation—although expensive at times—prevention and active planning are more economically efficient as well, when compared to the damages incurred when these vulnerabilities are neglected. Cohen and Bradley discuss examples of governments that are learning that neglecting to put vulnerable populations at the forefront of hazard planning and community development has proven costly. Examples they give are global, but some reside here in the United States as well, such as the on-going lawsuits being filed in the courts showing "monumental negligence" in failing to take sufficient preventative measures in New Orleans," for hurricane Katrina (Cohen and Bradley, 2010, p.126). The onset of these types of lawsuits is reminding leaders of their responsibility to protect the people they represent, and of the serious consequences when they fail to do so.

In essence, vulnerability, community resilience, and human rights issues are strongly intertwined, and many researchers have repeatedly encouraged solutions that involve methods that address the social inequalities underlying community vulnerabilities; these solutions would include political change, economic reform, and focusing public policy to protect people and nature across all scales from risk (Wisner, Blaikie, Canon, & Davis, 2003). Clarke (2006) suggests that we need to change what we deem "critical infrastructure," to include social network structures (the social fabric upon which we all ultimately depend in times of crisis), and reduce our dependence on large organizations for help, which are often strangled by red tape in moments when they need to make quick, life-saving decisions. Clarke advocates *preemptive resilience,* allowing every day citizens (who are often some of the most effective first responders in a disaster) to play a larger role in policy and planning efforts.

This review has discussed many topics—natural hazard mitigation, emergency management, social vulnerability, and environmental justice. The connections, importance and shortfalls of these topics are well summarized by Bolin and Stanford when they say:

> "…people, particularly low income minorities, elders, and financially stressed middle-class households, often have to balance limited resources against the constant hazards of illness, unemployment, rising living costs, and even homelessness. Given persistent general risks, it should not be overly surprising that many appear willing to 'take their chances' against the infrequent earthquake or occasional flood and do not purchase expensive but minimal coverage insurance"…"If disasters are to be taken as opportunities to make safer communities, developing an informed understanding of the local realities of daily life surely must be as important as imposing new building codes, zoning regulations, or insurance requirements. Efforts to discipline disaster victims by denying them assistance if they have not taken adequate self-protection measures may fit

> neoliberal ideological agendas, but are likely to only increase the social inequalities that are too often already amplified by disaster," (Bolin & Stanford, 1998, p.226).

Past research has significantly contributed to the importance of interdisciplinarity and incorporating social factors when looking at how a community is affected by, and recovers from, a natural disaster. So far, this review has helped identify reoccurring factors that intermingle to affect a regions' overall vulnerability. But what does this mean for community resilience? What specific factors have been found useful in determining community resilience? And how has knowing these factors helped in strengthening community resilience? Specific characteristics of a resilient community can be even more difficult to identify and measure than identifying the definition of community resilience. There is, however, a substantial body of research working on identifiable traits of a resilient community, how these traits connect to one another, and how they influence community resilience to natural disasters.

Determinants of Community Resilience

One group of researchers (Norris, et al., 2008) takes a systems perspective, and identifies four primary capacities of a resilient community—economic development, social capital, information and communication, and community competence—which are networked (interlinked) and adaptive (changing), as shown in Figure 2. Factors within the four primary capacities include resource equity and diversity, social network structure and support, effective systems for informing and communicating with the public, and collective action and empowerment. They also present a basic model of stress resistance and resilience over time (Figure 3) that expresses the pre-event environment (social, economic and physical structures) as vital to the system's ability to either absorb stress with existing resources (resistance) or adapt when resources are exhausted (resilience). Failure to resist or adapt leads to persistent dysfunction within the community and, ultimately, a longer recovery period.

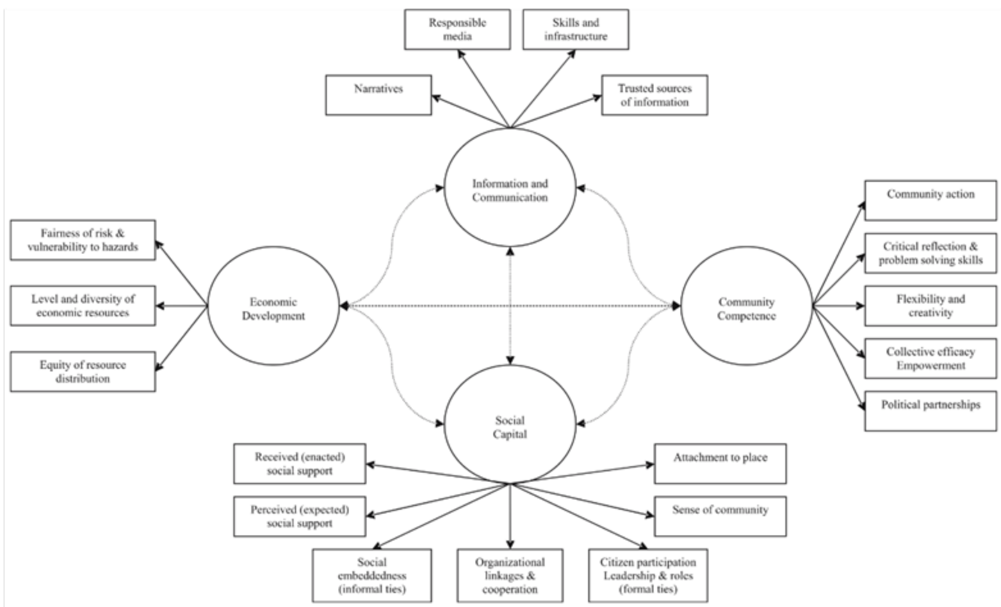

Figure 2: Community resilience as a set of networked adaptive capacities (Norris, et al., 2008).

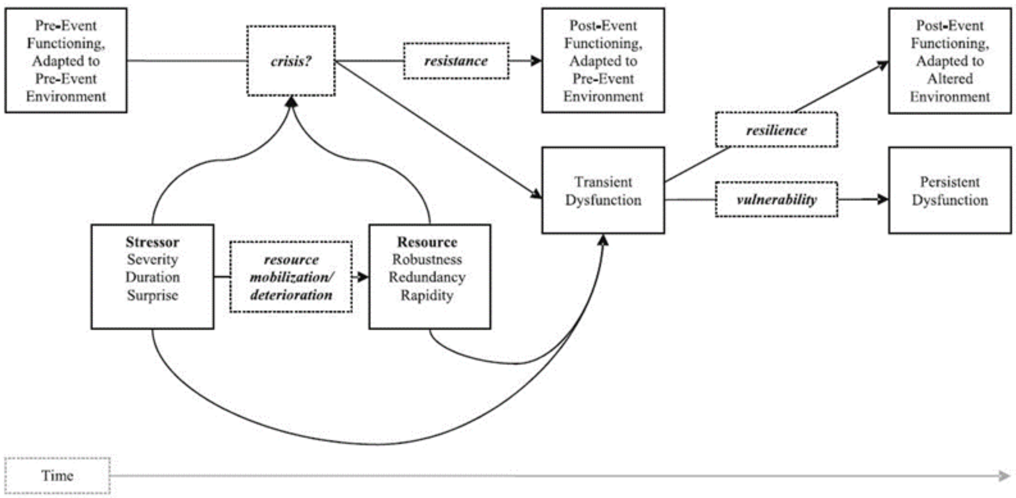

Figure 3: Model of stress resistance and resilience over time (Norris, et al., 2008). When a community is struck by a crisis, it either resists and adapts, or resilience/vulnerability systems take root. Resilient communities adapt and adopt a new environment, whereas communities outweighed by vulnerabilities continue in a state of persistent dysfunction.

Godschalk (2003) lists the primary elements of a resilient community as effective land-use and raw materials, physical capital, accessible housing, health services schools, and employment opportunities. Godschalk stresses that natural hazard mitigation needs to be incorporated into sustainable development plans to increase resilience to future disturbance without debilitating damage to physical, social or economic community systems. Another group of researchers (B. Pfefferbaum, Reissman, R. Pfefferbaum, Klomp, & Gurwitch, 2005) identified seven interrelated factors that contribute to over-all community resilience; connectedness, commitment, and shared values; structure, roles and responsibilities; resources; support and nurturance; critical reflection and skill building; and communication. They placed part of the responsibility on the leadership of public health officials to incorporate strategies that focus on community risk as a whole (termed *prevention paradox*) and to work toward a more community-based approach to disaster prevention. This technique stresses the importance of addressing underlying issues causing low public health prior to a disaster by linking public health with sectors of the community, such as education, criminal justice, faith communities, and businesses.

Research in urban and sustainable development has also contributed to our understanding of community resilience, by working to improve future development plans and land-use codes as a part of enhanced new urbanist design. This coincides with recommendations from Godschalk (2003) to merge natural hazard planning and sustainable development. Recommendations show the continued need for a paradigm shift about how humans interact with their environment, enhanced preparedness and mitigation techniques such as larger green spaces, wetland restoration, and reinforcing vertically built living structures, thus improving overall community resilience (Berke & Campanella, 2006; Stevens, Burke, & Song, 2010).

The existing research on these topics identify a variety of factors that may be determinants of community resilience, and while they definitely all contribute toward community resilience, some factors might play a larger role in overall community resilience than others depending on the strengths and weaknesses of the individual communities the researchers are assessing. Although these researchers do not all commonly agree on the specific determinants of community resilience, the overall theme is that a variety of social factors are underutilized in planning and mitigation efforts, and communities need to find ways of incorporating social components that are important in their regions of planning and mitigation to increase their overall community resilience.

Modeling Community Resilience: Advantages and Disadvantages

Identifying key traits of a disaster-resilient community is the first step in modeling or measuring a community's resilience in the face of natural disasters. Over the last fifteen years, significant research has emerged using a systems approach to design a model that communities can use to visualize or measure the networks involved in the natural disaster process. By doing so, communities are better able to identify areas of strength and weakness, or continue the model over time to show temporal increases or decreases in resilience.

Two examples from the research on modeling community resilience are the Disaster Resilience of Place Model (DROP) and the Baseline Resilience Indicators for Communities (BRIC) model (Cutter, et al., 2008; Cutter, et al., 2010). In the DROP model, a working set of indicators is identified for measuring community resilience, using factors of ecological, social, economic, institutional, infrastructure, and community competence systems as a framework (Table 2). The BRIC model, developed two years after the DROP, simplifies the model further by listing just five major categories; societal, economical, institutional, infrastructure, and community capital (Cutter, et al., 2010).

As was discussed earlier, ecological models have been used as of late to incorporate a more interdisciplinary view of disasters. Kiter-Edwards (2008) explains that using ecological models to view the multiple social, physical and political systems involved in a natural disaster provides the advantage of incorporating different levels of components. For example, including current community and organization factors, as well as relationships involved in an individual's development ties, such as mental development gained in a persons' lifetime from experiences through local family and neighborhood networks, community networks, and ultimately state, national, or even global network structures that help explain a persons' current social, physical or political state. Using an ecological approach also allows researchers to incorporate difficult-to-measure factors like an individual's mental health before and after a disaster. Boon, Cottrell, King, Stevenson, & Miller (2012) take this same approach by using Bronfenbrenner's bioecological theory as a framework for modeling community resilience. This theory was originally designed for modeling human development by incorporating individual factors (microsystem) and working outwards to social and environmental factors that influence human development on the meso-system, exo-system, and macro-system scale (Bronfenbrenner, 2005). Using this as a framework for studying how different system levels tie together to influence how a person or community is affected by and responds to a natural disaster has several advantages. It allows researchers or a community to benchmark social resilience, target priority interventions required and measure progress over time (Boon, et al., 2012). This model, as illustrated in Figure 4, also allows the incorporation of sociological and psychological perspectives, resulting in a more holistic "snap-shot" of a community's health and stability. Although modeling has been foundational in our understanding of the complex systems involved in community resilience, modeling is not well suited if the objective is to quantitatively measure community resilience and provide specific spatial context of these resilience indicators.

Table 2: Community Resilience Indicators, DROP Model (Cutter, et al., 2008)

Dimension	Candidate variables	Dimension	Candidate variables
Ecological	Wetlands acreage and loss, erosion rates, % impervious surface. biodiversity # coastal defense structures	Institutional	Participation in hazard reduction programs (NFIP, Storm Ready), hazard mitigation plan, emergency services, zoning and building standards, emergency response plans, interoperable communications, continuity of operations plans
Social	Demographics (age, race, class, gender, occupation), social networks and social embeddedness, community values-cohesion, faith-based organizations	Community Competence	Local understanding of risk, counseling services, absence of psychopathologies (alcohol, drug, spousal abuse), health and wellness (low rates mental illness, stress-related outcomes) quality of life (high satisfaction)
Economic	Employment Value of property Wealth generation Municipal finance/revenues		
Infrastructure	Lifelines and critical infrastructure, transportation network, residential housing stock and age commercial and manufacturing establishments		

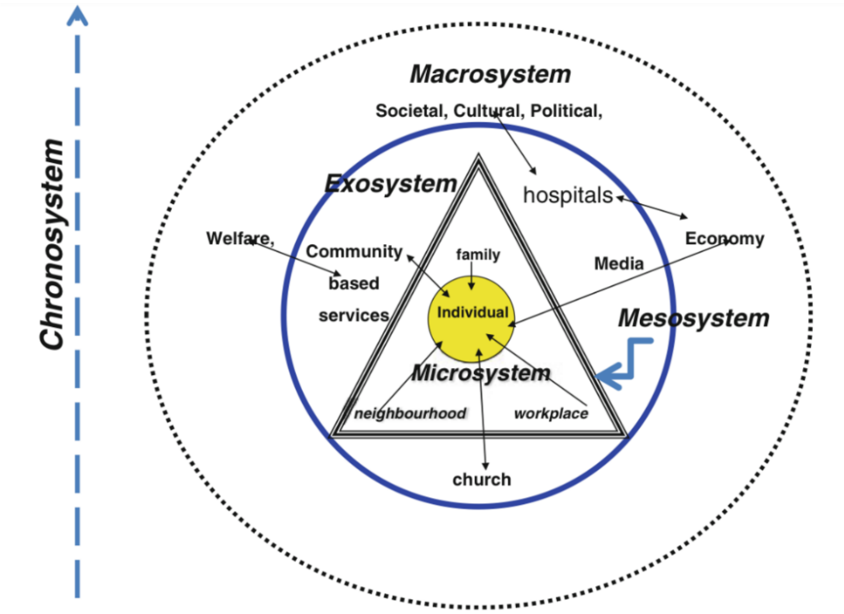

Figure 4: Conceptual scheme of Bronfenbrenner's systems and their interactions. Diagram constructed by Boon et al. (2012).

The Next Step: Measuring Community Resilience

While community resilience models have been a big step forward, new research is now emerging that works to quantify the indicators of resilience. These measurements have begun to provide a much more detailed and precise idea of what community resilience looks like in a defined area, and they address the spatial relationships between variables, making the results easier to understand and incorporate into existing NHMPs. For example, Frazier et al. (2013a) use a framework similar to the Place Vulnerability Model discussed earlier (Cutter, et al., 2000), but take it several steps further by focusing on overall resilience, rather than only vulnerability. In this research, they conducted a case study of Sarasota

County, Florida, which consisted of four phases—interviews with planning officials, reviews of existing plans, a focus group, and a spatial analysis. A univariate analysis was conducted on Sarasota County's elevation, per capita income, percent below poverty level, populations over 65, and the total populations. The data were then combined with the other three phases of the study to produce a countywide spatial indicator map. With this study, these researchers effectively demonstrated that, "although national resilience quantification metrics are useful, local scale resilience estimates appear more useful if community hazard mitigation and climate change adaptation are the primary goal," (Frazier, et al., 2013a, p.1). Their findings and recommendations laid the groundwork for a very helpful tool for quantitatively and spatially measuring community resilience to natural disasters.

Conclusion: Community Resilience in Thurston County

As this review of the literature shows, past research has identified a multitude of important, interrelated factors that contribute to community resilience to natural disasters. The implementation and growth of local natural hazard mitigation plans has helped sway the focus from response-style emergency management to a more preventative approach. Many of the NHMPs that exist today tend to carry a stronger focus on economic and structural damage mitigation due to time and financial limitations. Despite this, disaster and community resilience research continues to call for more emphasis on social factors and their effects on overall community resilience. In fact, we are reaching a day and age where not incorporating these social factors is growing more costly and unjust the longer this is neglected.

Several studies discussed have identified a variety of vulnerable populations that can help understand a communities overall resilience. Of the vulnerable populations discussed, a few are reoccurring and/or overlapping, and have frequently been cited as important factors when determining a community's resilience; children and elderly, females, racial minorities, and low income populations (Bolin & Stanford, 1998; Buckle, Marsh, & Smale, 2001; Cutter, et al., 2003; Cutter, et al., 2000; Frazier, et al., 2013a; Freudenburg, et al., 2008). While modeling community resilience has advanced the conceptualization of community resilience, it has not proven to be as useful for designing NHMPs or for implementing disaster management and response measures. More recent research is now emerging, using GIS tools and spatial statistics, that allow us to quantitatively measure vulnerability and community resilience in our local communities, providing a helpful new tool by which to view our own communities (Cutter, et al., 2003; Cutter, et al., 2000; Frazier, et. al., 2013a). By measuring community resilience with a holistic, systems approach including social data, a baseline of strengths and weaknesses can be provided that can help influence various aspects of our communities, including enhanced emergency management plans and response, development regulations, environmental conservation and restoration, local policies, climate change adaptation, and an enhanced NHMP.

Chapter 3: Methods

The object of this study is to provide a foundational understanding of the spatial distribution of community resilience in Thurston County by quantitatively measuring specific vulnerable populations and comparing results to the 100-year floodplain. It is important to note that although they are closely negatively correlated, community resilience is not simply the absence of vulnerability, but vulnerability is a very important component. Future studies should incorporate other indicators of community resilience to provide a more accurate picture of what community resilience looks like in Thurston County, as will be discussed in the final chapter. This study combines HAZUS, ArcGIS, and publicly available data to answer the question of where the highest and lowest areas of community resilience lie in relation to the 100-year floodplain. Of the determinants of community resilience usable in a quantitative measurement such as this, only a few are appropriate for the scope of this paper. Thurston County has done an excellent job and accomplished great strides in decreasing vulnerability to natural hazards that are prevalent in the Pacific Northwest. As discussed earlier, primary hazards in the county are earthquakes, severe storms, landslides, flooding, and volcanic activity. Flooding is by far the most frequent event, with devastating floods happening about every three years (Washington State NHMP, 2010). In their 2012 Natural Hazard Mitigation report summary, members of the Thurston County Regional Planning Council indicated that they have continued to update and enhance flood risk maps and will be using recently available data from the

FEMA software modeling program, HAZUS-MH, to include potential impacts for a variety of different flooding scenarios.

HAZUS is an extremely powerful natural disaster modeling software created by FEMA and ESRI to give damage estimations for floods, earthquakes and hurricanes. Because flooding is the most frequent hazard in the study area, it was chosen as the natural hazard to view spatially in relation to community resilience. However, the earthquake model could also be powerful to use in future studies since many areas in the Pacific Northwest lie on or near fault lines that are at risk of earthquakes. HAZUS is not merely a mapping software, but provides the ability to know in a very short amount of time the extent of damage done to a specific area in a disaster scenario. For instance, by using Thurston County as the study area and running a 100-year flood model, HAZUS can provide the user with information about the water depth levels all across the county based on elevation; demographic data; hazardous wastes; critical structures at risk; the amount of structural damage and type of building material that sustained the damage; the amount of building contents that are damages; economic loss estimations; business disruptions, human lives lost, and the amount of debris generated in the area, as well as time and cost estimations for debris removal. This is not an exhaustive list of all of HAZUS's capabilities, but provides the reader with a brief understanding of how monumentally helpful this type of information can be to local emergency planners and responders in the stressful moments following a disaster event. While these estimations are not error-proof, they are the most accurate information available to planners and responders at this time.

To keep this paper manageable, these loss estimations available from HAZUS were not included in this study. However, HAZUS was used to build the 100-year floodplain in the study area (Thurston County) to provide the most accurate floodplain based on most recent elevation data, and to ‘set the stage’ for future studies to incorporate this portion further if they choose. By creating the 100-year floodplain using HAZUS, rather than using federally provided floodplain maps, a more detailed flood map was created based on current USGS data elevation models. The floodplain was then compared with the community resilience rankings. By combining the understanding that a community resilience measurement offers with a powerful disaster modeling software like HAZUS affords researchers, planners and responders access to significantly more information, a much more realistic understanding of how their local areas would be impacted by an event, and knowledge about which areas are going to have the most difficult times recovering. This will be discussed further in the discussion chapter.

Variables were chosen for this study based on identification of important characteristics in the literature, specifically, Cutter, et al., (2003) and Frazier et al. (2013b). Chose indicators for this study were per capita income, income to poverty ratios, racial minority populations, and populations over the age of sixty-five. All variable data were taken from the U.S. Census Bureau’s 2000 census. One limitation to this study was the use of 2000 census data, rather than 2010 census data. All four variable data were available at the census tract level for 2010, but census tracts are significantly larger than block groups and would result in a much less well-defined picture of community resilience in the study area. The size and shapes of census tracts and block groups vary widely, and change from census-to-census depending on a variety of factors. For instance, for the 2000 census, Thurston had 49 census tracts, some of which included multiple cities or combinations of rural and urban areas. These tracts were further broken down into block groups (132 total), and conducting the spatial analyses at the block group level allowed for a much more defined look at community resilience in Thurston County.

Age and racial demographics were available at the block group level for 2010, but financial data were not incorporated into the 2010 census. Due to lack of responses and privacy issues with the financial information that used to be included in the census, these data are no longer collected. Since 2005, the U.S. Census Bureau began sampling about 250,000 individuals per month through the American Community Survey, and this is now the primary means of obtaining and tracking financial data on an annual basis. These data are only released in two formats, either at the census tract level, or as a summary document at the block group level. Because the block group location, shape, and area vary significantly between the 2000 census and the 2010 census, data integrity was preserved by using all social indicator data from the 2000 census only. This makes the data used in this study fourteen years old at the time it was conducted. This issue will be revisited in the discussion section. All data used were free and public, and were taken from the 2000 census at the block group level. Social indicators (SIs) used in this study were chosen to represent populations that are vulnerable to a flooding event in Thurston County based on social demographics presented in the literature that influence or help identify community resilience.

While these social indicators have been identified in the literature as strong indicators of community resilience, another limitation to this study is its small scope. To make this study manageable and meet time requirements and deadlines, only four SIs were used for these analyses and the study was conducted in relation to one natural hazard (i.e., floods). While these variables are sufficient to express and display a foundation for measuring community resilience using these methods, they represent only a small percentage of all the facets that encompass true community resilience. By identifying and incorporating other detailed social variables—homes with children, single parent homes, disabled populations, housing vacancy rates, or areas with high homeless populations, for example—the accuracy and helpfulness of a community resilience measurement like this would be increased. This will be discussed further in the discussion chapter; for now, a brief explanation of each SI will be presented and its purpose within this study will be explained.

The 100-Year Floodplain

To achieve the greatest stream definition specific to the elevation and hydrology network within Thurston County, a 100-year floodplain was mapped for this study using HAZUS, and all of Thurston County was selected for the study region. All shapefiles and data used were re-projected into the NAD83 UTM Zone 10 coordinate system to preserve shape, area and distance. A digital elevation model for Thurston County was then imported from USGS using the HAZUS Digital Elevation Model (DEM) extent tool. The purpose of the DEM extent tool is to overlay the most recent elevation information from the National Elevation Dataset onto the study region. A stream network was created with an input of 1.0 square mile, to show areas in the region that accumulate water in a rain or storm event. The output results show the highly defined stream network system within all of Thurston County's watersheds. Since some of these streams begin or flow outside of the study area, all stream segments that fall within Thurston County were selected for the spatial analysis of SIs. Hydrology analysis was run, and a 100-year flood event was chosen for the delineation of analysis. The result is a polygon representing the 100-year floodplain in Thurston County (Figure 5) and this is the floodplain layer used in all analyses in this study.

HAZUS offers the opportunity for a user to model a 100-, 200-, or 500-year flood. The term "100-year flood," despite the misleading name, means that in any given year, there is a one-percent chance that this level of a flooding event would take place. For a "200-year flood," there is a 0.2 percent chance of it occurring in any given year, etc. Of these different flooding levels, a 100-year flood is the most likely and probabilistic event in Thurston County (although more extreme flood events are not impossible) and is the base-line boundary that is used by many flood-related agencies when assessing flood-prone areas (Thurston County Flood Plan, 2013). The Thurston County Flood Plan provides information based on a 100- and 200-year flood. Floodplains created in HAZUS and used by FEMA are measured,

> …using a discharge probability, which is the probability that a certain river discharge (flow) level will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels. The flood frequency equals 100 divided by the discharge probability. For example, the 100-year discharge has a 1-percent chance of being equaled or exceeded in any given year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. The same flood can have different recurrence intervals at different points on a river (Thurston County Flood Plan, 2013, p. 6-1).

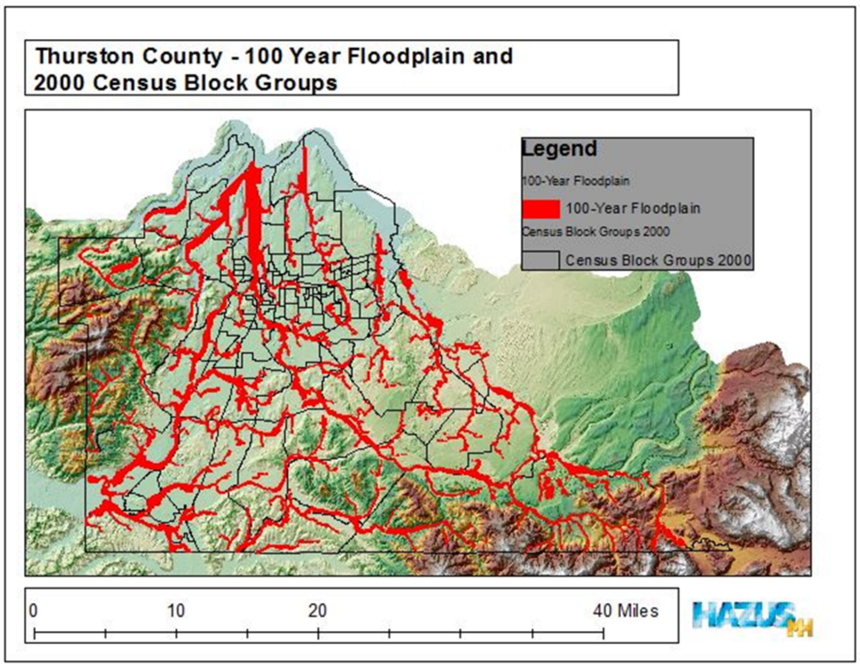

Figure 5: Hydrology and delineation results for water accumulation of $1mi^2$. Thurston County 100-Year Flood Plain overlaying the Digital Elevation Model (DEM).

Social Indicators

Low Income and Poverty Status

Individuals and families that are considered low-income or living below the federal poverty threshold are at greater risk of a difficult recovery from a natural disaster like a major flooding event due to financial and resource limitations. This SI uses two resources to create the layers used in the final analyses—ratio of income to poverty and per capita income data—which were retrieved from the 2000 census (U.S. Census Bureau, 2000). Low income is defined, per the U.S. Census Bureau American Community Survey and the U.S. Department of Education, as taxable income not exceeding 150% of the federal poverty threshold. In 2000, the federal poverty threshold for a singled individual was $8,350 and a family of four qualified at $17,050. To incorporate persons living below 150% of the poverty threshold, ratio data was used to show the percent of individuals per block group living below $12,525 annually (Figure 6). Per capita income is a mean figure for income in a given area, so it is influenced by high and low figures. Per capita income figures include these outliers, which can raise or lower the per capita income figures. This is why per capita income ranges for 2000 are between $11,796 and $40,250, despite the fact that there are probably many people living above and below those figures (Figure 7). Median income is not affected by high and low outliers, but since past studies similar to this study aim to identify areas where concentrations of outliers (specifically low-income) lie, per capita has been chosen as a more representative means to include low-income and poverty stricken individuals. A Global Moran's I analysis was applied to census data to test for autocorrelation, followed by a Local Indicator of Spatial Analysis (LISA).

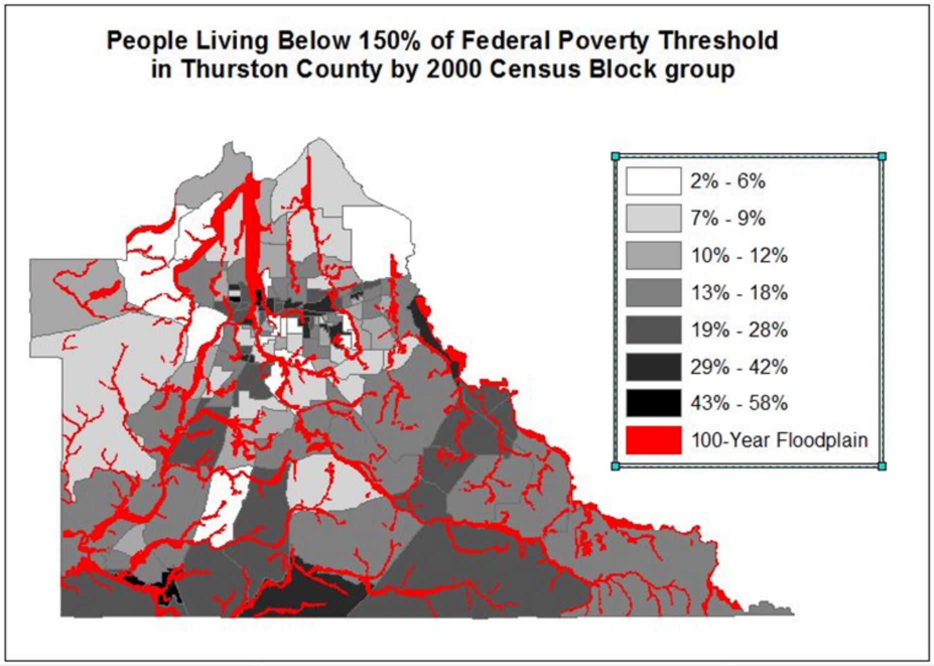

Figure 6: Percentage of people living below 150% of the poverty threshold in 2000 by block group (U.S. Census Bureau, 2000). Flood Plain and map created using HAZUS and ArcMap.

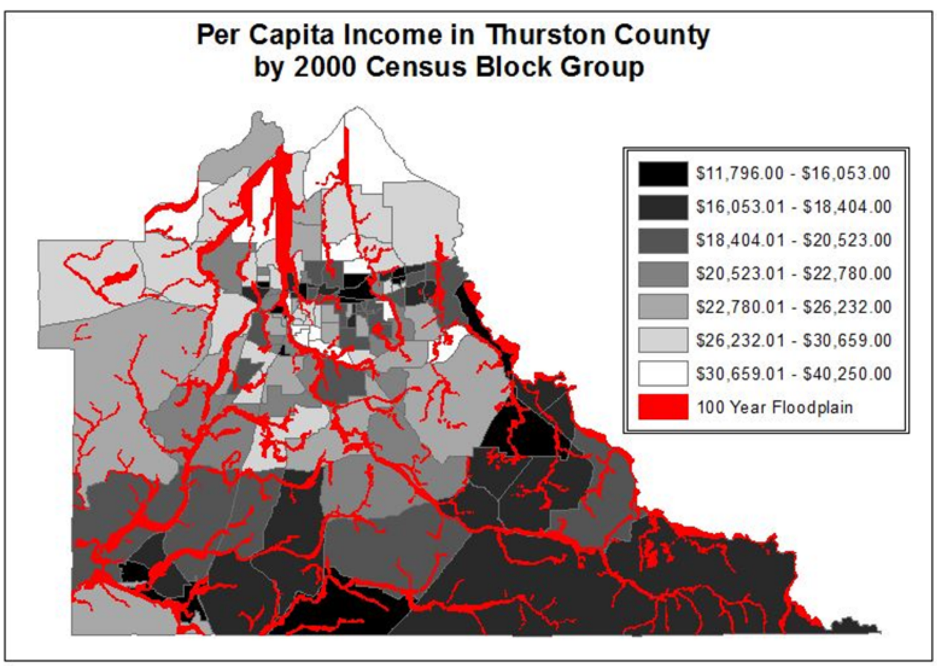

Figure 7: Distribution of per capita income in Thurston County by block group (U.S. Census Bureau, 2000) and the 100-year floodplain. Flood Plain and map created using HAZUS and ArcMap.

Racial Minority Populations

Minority populations make up about 17% of Thurston County's 2000 total population. A review of the literature shows that minority populations may have a more difficult recovery from an event due to cultural, language, or economic barriers. Census data (2000) defines minority populations as non-white persons that are Hispanic/Latino, African American, Native American, Hawaiian/Pacific Islander, Asian, Other, or two or more of these races combined. By identifying where racial minorities are spatially distributed throughout the county, natural hazard mitigation planners and emergency response groups can strengthen their plans prior to an event, or strengthen their response after an event occurs. Planning and response organizations can effectively plan for response to certain areas that contain a higher racial minority population by incorporating educational campaigns in predominant minority languages, provide translators within planning or response teams to encourage these populations input and feedback in planning and mitigation efforts, or connect with local cultural groups prior to an event to help aid in response efforts in communities that contain potentially marginalized groups during a disaster.

Persons of different races can be of Hispanic/Latino ethnicity, including Caucasians. Because of this, all non-Hispanic racial minority groups and persons who only identified as Hispanic or Latino were combined to avoid "double-counting" individuals that identify as Hispanic/Latino and as a member of an already included, non-white race. Groups were selected and totaled per census block group, then normalized by total census block group population (Figure 8). A Global Moran's I analysis was applied to the census data to test for autocorrelation, followed by a Local Indicator of Spatial Analysis (LISA).

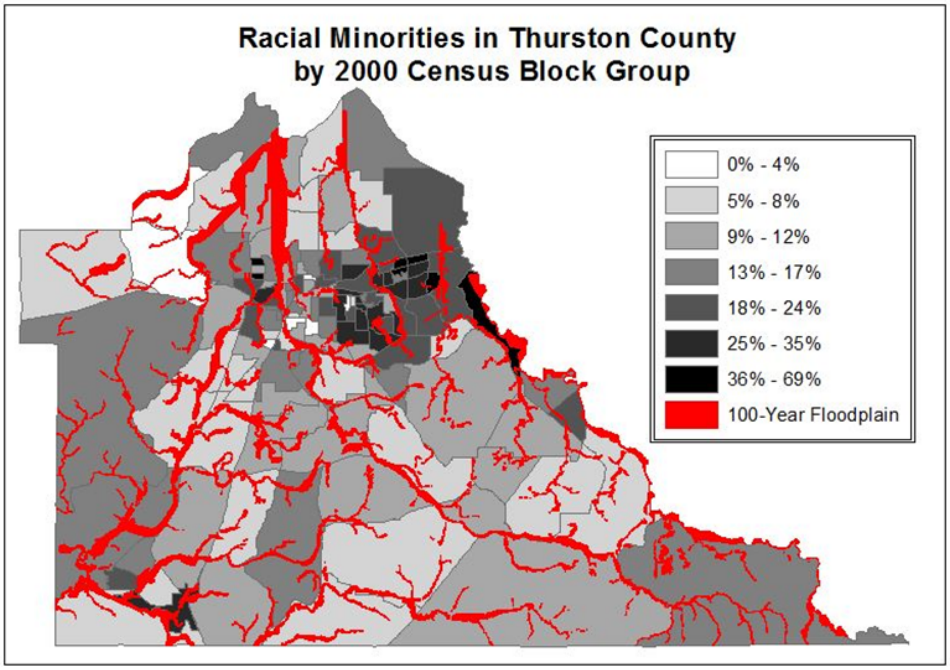

Figure 8: Percentage of racial minorities per block group (U.S. Census Bureau, 2000). Flood Plain and map created using HAZUS and ArcMap.

Elderly Populations

Populations over the age of 65 may be more vulnerable to effects of a natural disaster due to various factors such as decreased mobility, financial limitations, or lack of a support network. In the instance of a flood, mold and water borne illnesses can also be a significant problem in affected areas. People in this age range are more likely to be immunocompromised, making them more susceptible to illness and disease. Locating areas with high concentrations of this age group can help communities prepare to have necessary resources available to help elderly populations in a disaster event. Census demographic data from 2000 were used to identify the number of person over the age of 65 at each block group in Thurston County (Figure 9). A Global Moran's I analysis was applied to census data to test for autocorrelation, followed by a Local Indicator of Spatial Analysis (LISA).

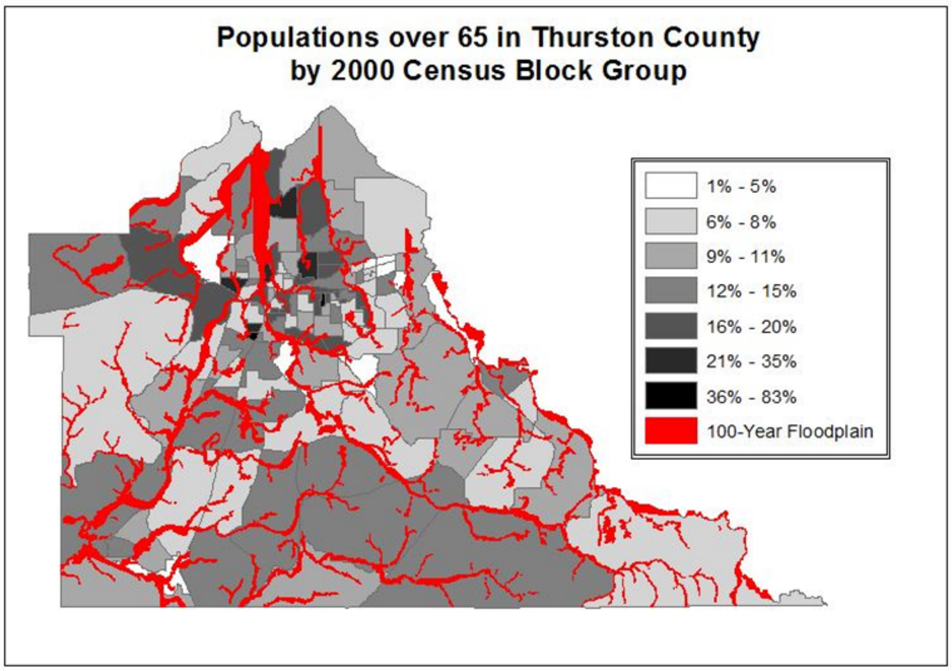

Figure 9: Percentage of elderly populations by block group (U.S. Census Bureau, 2000). Flood Plain and map created using HAZUS and ArcMap.

Moran's I Analysis

After individual maps were created for each SI, a Global Moran's I analysis was applied to the census data to test for autocorrelation, followed by a Local Indicator of Spatial Analysis (LISA) called an Anselin Local Moran's I. Due to the complexity of community resilience, it is important to be aware of how much each individual variable is correlated with itself. The Global Moran's I statistic provides three helpful values to test for autocorrelation—an I Index, a z-value, and a p-value. This spatial analysis is used to determine the amount of “clustering” of a single variable and explains how much the variable influences itself. It answers the question, for instance, whether a block group that contains a high rate of low-income individuals tends to be spatially organized next to other block groups that also contain high rates of low-income individuals, and if so, how significant is this clustering? A positive I value indicates a positive spatial autocorrelation, a negative I value indicates a negative spatial autocorrelation, and zero shows that the variable is perfectly randomly dispersed. The p-value shows at what significance the variable is autocorrelated with itself, with significance being a p-value<0.05.

The Local Indicator of Spatial Analysis (LISA) statistic used within ArcGIS is a more precise cluster and outlier analysis called the Anselin Local Moran’s I. This statistic identifies the same three values as the Global Moran’s I, but rather than three single values for the entire county, the output is for each individual block group. This test results in either a High-High (HH), High-Low (HL), Low-High (LH), or Low-Low (LL) value association for each block group to identify specific block groups that are surrounded by block groups that either share similar values (HH or LL), or are surrounded by block groups with different values (HL or LH). The analysis also provides a p, z, and I value for each individual block group. Natural Jenks classifications were used in the spatial statistic mapping process to preserve natural breaks in the data distributions.

Spatial Weighted Overlay

The last step in this study's analyses was a weighted spatial overlay using the weighted spatial weighted overlay tool in ArcGIS. This tool takes multiple data layers (variables) into account using a common measurement scale, and weights identified variables according to their importance. For the purposes of this study, the output values identify community resilience in Thurston County for each block group based on chosen SIs according to the evaluation scale defined in the weighted overlay tool. To begin to identify and quantify community resilience in this study, four vulnerability indicators were chosen—per capita income, poverty status, elderly populations and minority populations. Values within each variable for each block group were ranked along a scale from one to ten according to the spread of the variable values across the county. This gave all block groups containing SI values of the highest percentage of people living below 150% of the federal poverty threshold, highest elderly populations, highest racial minority populations, and lowest per capita income a value of one. On the other end of the scale, block groups containing SI values with the highest per capita incomes, and lowest percentages of poverty, elderly populations and racial minority populations were given a value of ten. All four SIs were then evenly weighted (25%) and assessed in each block group with equal importance to identify the community resilience ranking per block group. In other words, only individual variable values were weighted, while each of the variables themselves were deemed to be just as important in determining community resilience as each of the other three variables.

The spatial overlay tool output resulted in a single ranking for each block group. The resulting map was then overlaid with the 100-year floodplain.

As was discussed in the literature review chapter, the field of environmental justice and research on vulnerable population exposure to natural hazards shows that vulnerable populations are often marginalized to areas that are at an increased risk to natural hazards (Cutter, et al., 2003; Rodriguez & Barnshaw, 2005; Clarke, 2006; Cohen & Bradley, 2008). To assess the relationship between low community resilience and increased exposure to the 100-year floodplain, the 100-year floodplain was then intersected with the ranked block group layer. The area of the 100-year floodplain was totaled for each block group, then all block groups within each ranking were totaled and divided by the summed area of all block groups within that rank to give an average percentage of the area per block group that is exposed to the 100-year floodplain.

By conducting autocorrelation analyses on the SIs, the relationship a variable has with itself over an area can be better understood. If a variable or variables are strongly autocorrelated and then combined to measure community resilience, it would indicate that community resilience is also autocorrelated. In other words, areas of low community resilience would be spatially distributed closer to other areas of low community resilience and the other way around. After understanding where community resilience is low and high throughout the county, natural hazard areas can be compared to identify if low resilience areas tend to exist within or closer to natural hazards than areas of higher community resilience.

This study sought to compare ranked community resilience to the 100-year floodplain to find out if, in fact, areas with concentrations of vulnerable populations do tend to be exposed at a higher rate to this natural hazard in Thurston County.

Chapter 4: Results

Social Indicators

Low Income and Poverty Status

The Global Moran's I analysis indicated that block groups with populations living below 150% of the 2000 federal poverty threshold were slightly autocorrelated, but not significantly (I=0.87, p=0.068). The Anselin Local Moran's I identified eight individual block groups that were significantly similar to or different from neighboring block groups. The low number of significant individual block groups confirms the Global Moran's I analysis' findings of non-significance. For the Local Moran's I, I value ranged from -5.88 – 9.37, and p-values for significant block groups ranged from p=0.000 – 0.032. Block groups identified as HH and LL are of particular interest, since these areas show where clustering occurs.

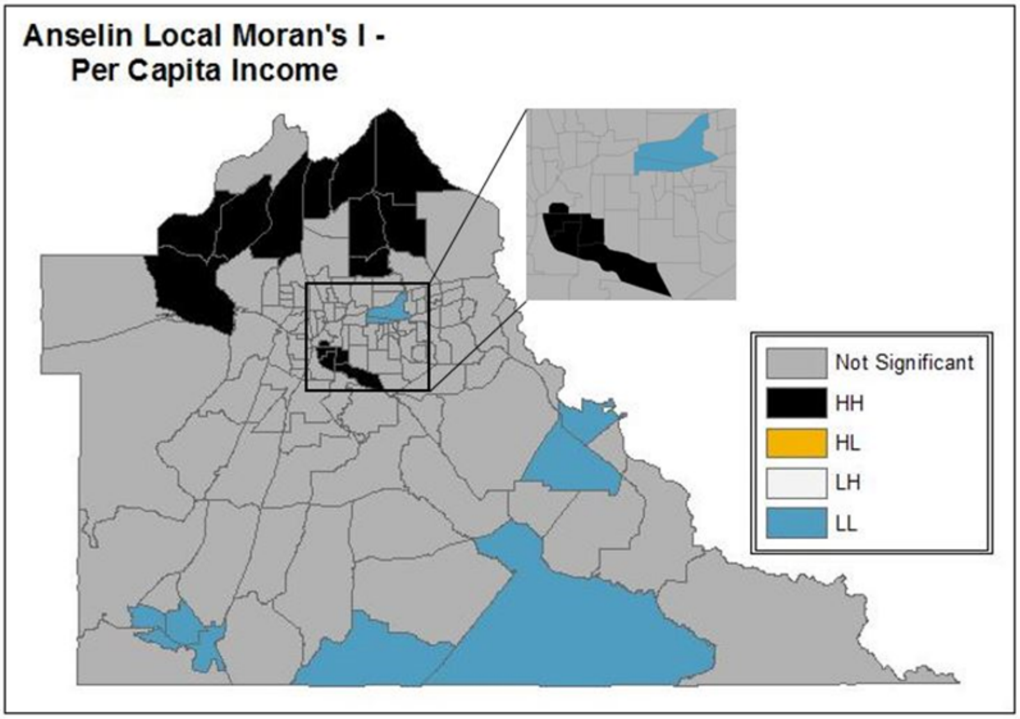

Figure 10: Anselin Local Moran's I for Ratio of Income to Poverty (2000). I-value Range: -5.88 – 9.37. p-value range for significant block groups only: 0.000 – 0.032.

Per Capita Income

The Global Moran's I analysis indicated that the per capita income of a block group is significantly autocorrelated with the per capita income of a neighboring block group (I=0.327, p<0.000). The Anselin Local Moran's I identified twenty-four block groups that were significantly similar to or different from neighboring block groups. The high number of significant block groups confirms the Global Moran's I value of significance. The individual I-values for statistically significant block groups ranged from 3.337 – 14.638, and the p-values ranged from p=0.000 – 0.049. Block groups identified as HH and LL are of particular interest, since these areas show where clustering (HH, LL) exists.

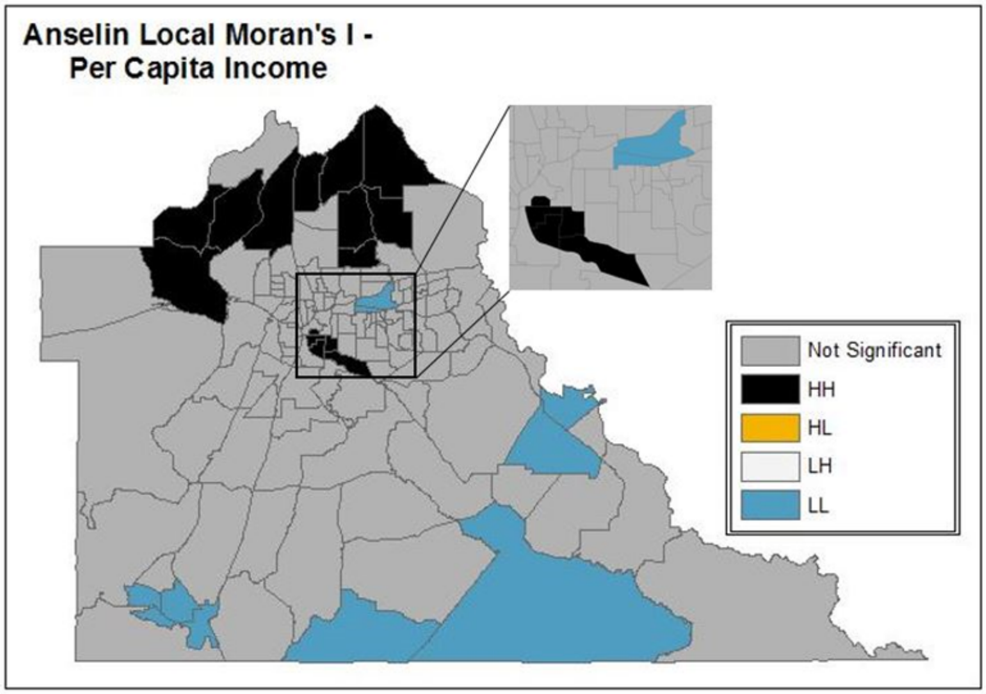

Figure 11: Anselin Local Moran's I for Per Capita Income (2000). I-value range: 3.337 – 14.638. p-value range for significant block groups only: 0.000 – 0.049.

Racial Minority Populations

The Global Moran's I analysis indicates that the racial minority populations of a block group are significantly autocorrelated with neighboring block groups (I=0.327, p<0.000). The Anselin Local Moran's I identified thirteen block groups that were significantly similar to or different from neighboring block groups. The high number of significant block groups identified confirm the Global Moran's I value of significance. I-value ranges for statistically significant block groups ranged from I=4.205 – 24.516, and p-values ranged from p=0.000 – 0.048. Block groups identified as HH and LL are of particular interest, since these areas show where clustering (HH, LL) exists.

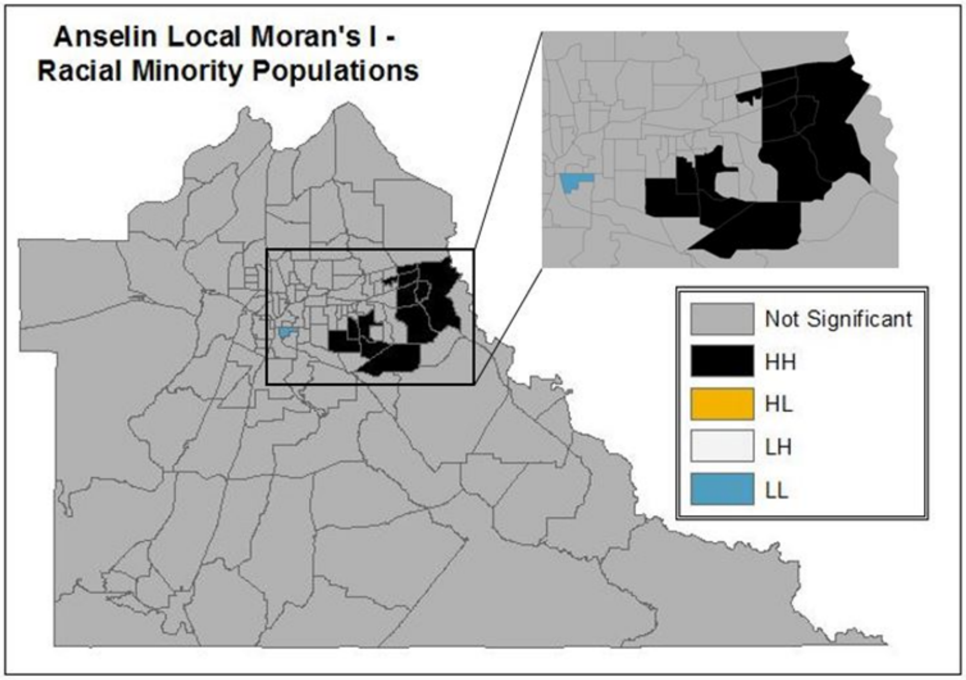

Figure 12: Anselin Local Moran's I for Racial Minorities (2000 Census Data). I-value range: 4.205 – 42.516. p-value range: 0.000 – 0.048.

Elderly Populations

Results from the Global Moran's I analysis indicate that the elderly populations (over 65) were positively correlated with neighboring block groups, but not significantly (I=0.40, p=0.329). The Anselin Local Moran's I identified six block groups that were significantly similar to or different from neighboring block groups. The low number of significant block groups confirm the Global Moran's I statistic of non-significance. Statistically significant Local Moran's I values ranged from -5.178 – 11.617, and p-values ranged from 0.000 – 0.033. Block groups identified as HH and LL are of particular interest, since these areas show where clustering (HH, LL) exists.

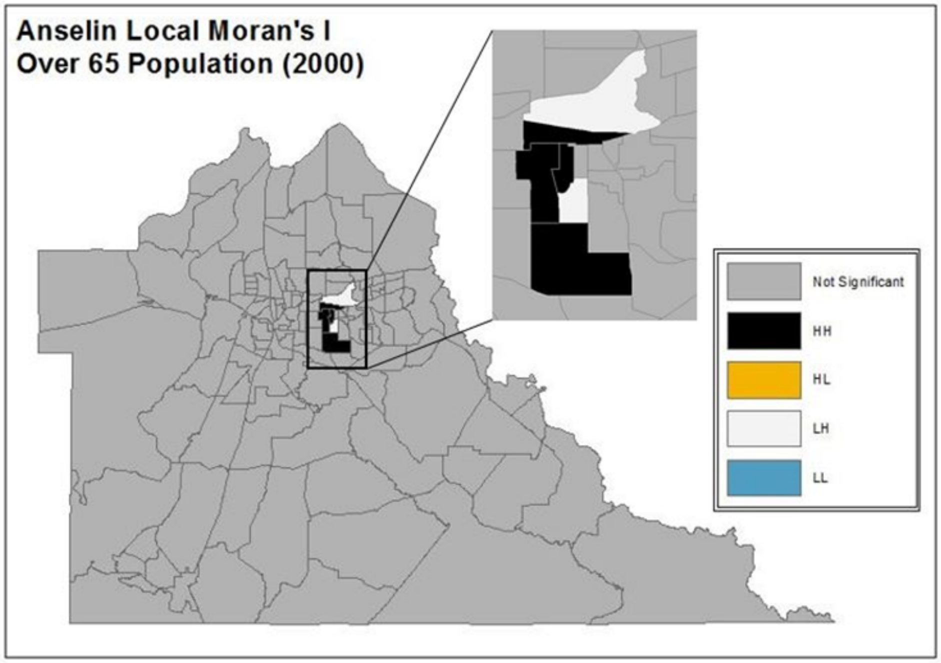

Figure 13: Anselin Local Moran's I for Over 65 population (2000 Census Data). I-value range: -5.178 – 11.617. p-value range: 0.000 – 0.033.

Spatial Weighted Overlay

Results from using the spatial weighted overlay tool measure community resilience based on the four chosen SIs and gave each block group a community resilience ranking on a scale from one to ten. This analysis output maps the spatial arrangement of community resilience across Thurston County in 2000. A full output table, ranking each block group from least resilience to most resilient, as well as showing original social indicator values, is appended to the end of this study (Appendix A). A ranking of one indicates block groups with the lowest community resilience based on the four chosen SIs, while a ten indicates block groups with the highest community resilience based on the four chose SIs. The spatial weighted overlay, along with community resilience with respect to the 100-year floodplain is shown in Figures 14 and 15.

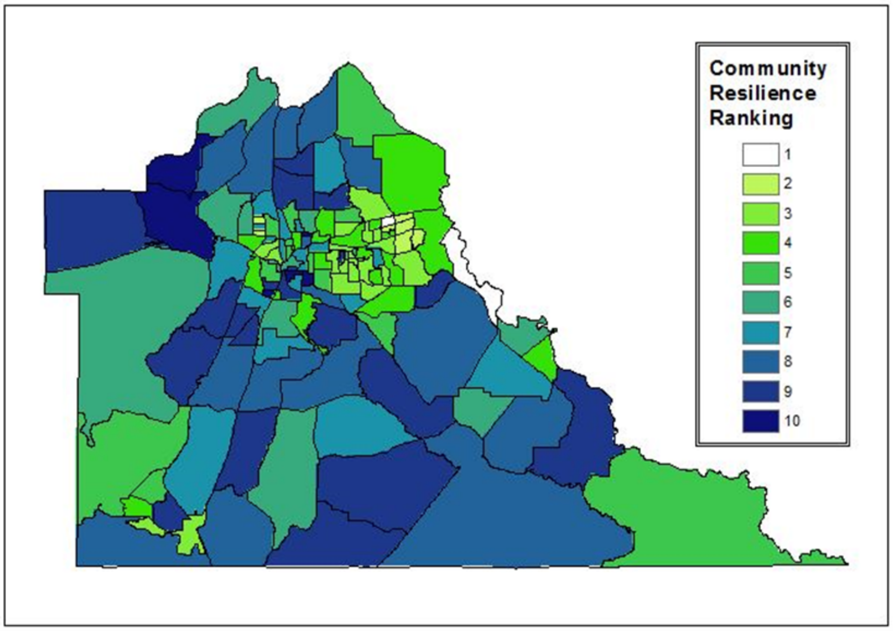

Figure 14: Spatial weighted overlay results show community resilience ranking based on four chosen social indicators. Block groups given a rank of ten indicate areas of high per capita income, low rates of people living below 150% of the 2000 federal poverty threshold, and low rates of elderly and racial minority populations. A rank of one indicates areas of low per capita income, high rates of people living below 150% of the 2000 federal poverty threshold, and high rates of elderly and racial minority populations (U.S. Census Bureau, 2000).

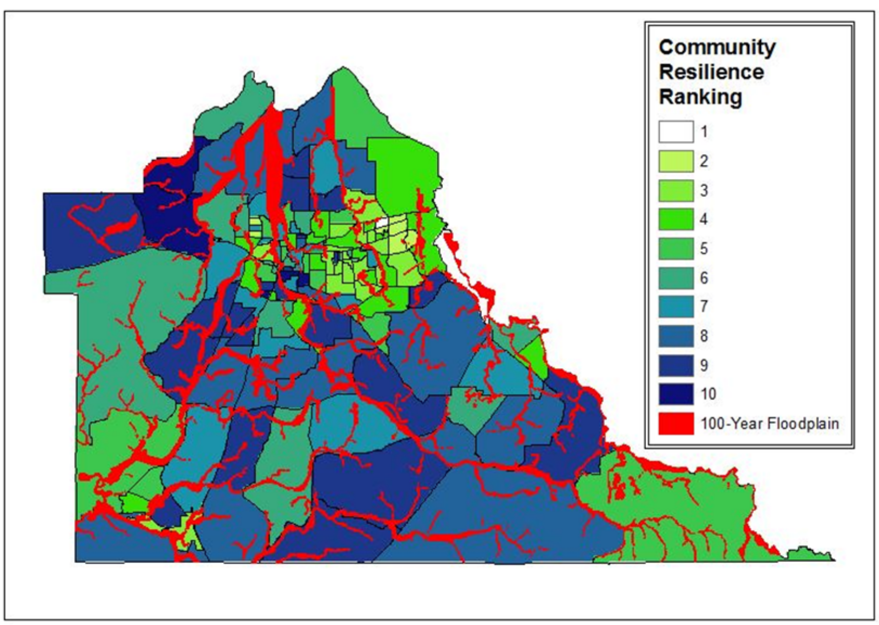

Figure 15: Spatial weighted overlay results with 100-year floodplain. Both of the block groups identified as a rank one either partially or fully intersect with the 100-year floodplain. Map created using HAZUS and ArcGIS.

Two block groups were identified that were identified that were given a ranking of one, making them the least resilience block groups based on chosen SIs. These block groups contain the highest combination of low-value SIs based on 2000 census data; low per capita income, high populations living below 150% of the federal poverty threshold, and high rates of elderly and racial minority populations. One block group is located in Lacey while the other is the block group incorporating the Nisqually Indian Reservation on the eastern side of the county. The 100-year floodplain covers almost half of the block group containing the Nisqually Indian Reservation, while the block group in Lacey only slightly intersects with the floodplain in its northwestern corner. These block groups can be seen in Figure 16, along with Table 3 showing the specific social demographic data from the 2000 census that corresponds with each block group.

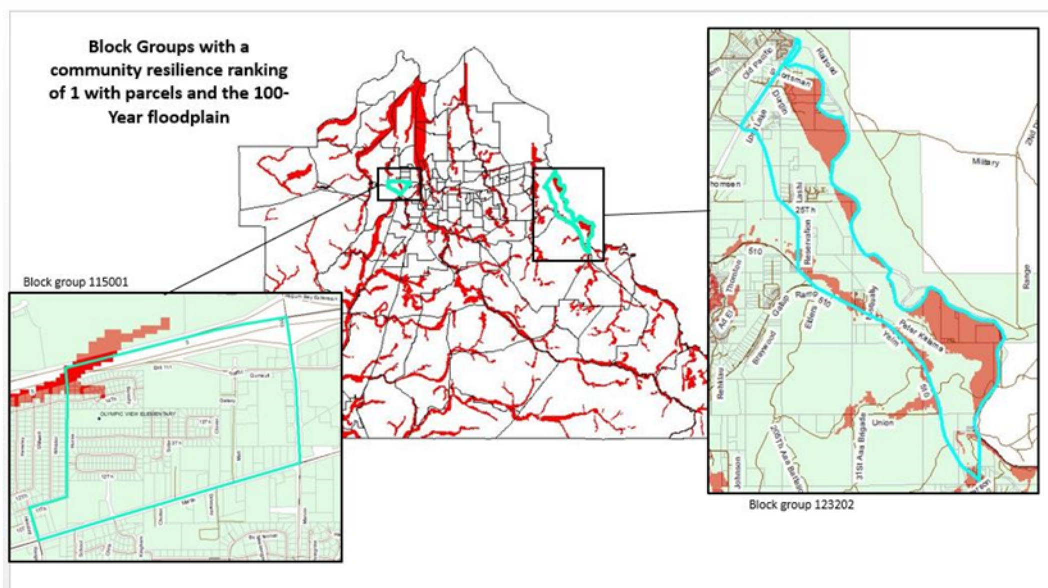

Figure 16: Block groups with a community resilience ranking of 1 with parcels and the 100-Year floodplain. Maps created using ArcGIS and HAZUS.

Table 3: Social demographics for the two block groups with a ranking of 1 (U.S. Census Bureau, 2000).

Block Group	Population	Per Capita Income	% Below 1.5 of Poverty Threshold	% Racial Minorities	% Over 65
115001	818	$14,448	24.2	50.9	3.8
123202	752	$15,248	3.6	68.6	4.4

The spatial weighted overlay identified six block groups that fulfilled criteria for a ranking of ten. These block groups represent areas of the highest community resilience based on the chosen social indicators—high per capita income, low percentage of people living below 150% of the federal poverty threshold, and low percentages of elderly and racial minority populations. Two are located in Olympia, two are located in Tumwater, and the last two fall in unincorporated areas in the northern portion of Thurston County. They can be seen in Figure 17, along with the specific social demographic data from the 2000 census that coincides with each block group in Table 4.

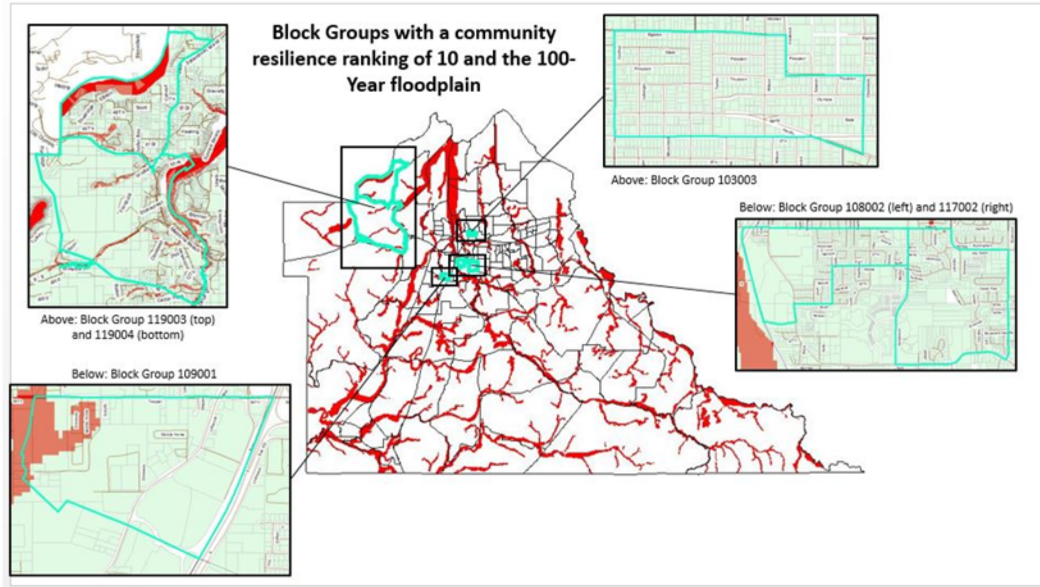

Figure 17: Block groups with a community resilience ranking of 10 with parcels and the 100-Year floodplain. Maps created using ArcGIS and HAZUS.

All other block groups fell within the two-to-nine range and will not all be discussed here. A table has been included in the appendix at the end of this study, showing each block group ranked from one to ten and their corresponding social demographic data as well within the county.

The exposure of block groups to the 100-year floodplain may be shown as the percentage of the area of each block group that contains the 100-year floodplain. The average of such exposures is summarized in Table 5 per group ranking.

Table 4: Social demographics for the six block groups with a ranking of 10 (U.S. Census Bureau, 2000).

Block Group	Population	Per Capita Income	% Below 1.5 of Poverty Threshold	% Racial Minorities	% Over 65
119003	1083	$39.798	2.6	4.2	13.7
119004	1082	$29,674	5.1	2.8	19.5
103003	855	$18,191	21.8	3	9.9
109001	498	$21,185	34.5	0	56.8
108002	949	$34,201	5.5	6	16.2
117002	968	$30,942	9.5	3.2	8.1

Table 5: Average exposure area to the 100-year floodplain (%) by community resilience ranking.

Group Rank	Number of Block Groups with this rank	Average exposure per CR rank (%)
1	2	17.87
2	7	.42
3	19	8.13
4	19	6.97
5	13	7.81
6	12	5.33
7	18	10.69
8	15	12.71
9	21	11.47
10	6	5.64

Chapter 5: Discussion and Conclusion

Thurston County planners work on mitigation projects to increase the county's community resilience to natural disasters, but they face increasing challenges with populations growth, increasing urban density, an aging population, climate change, and an economic recession that continues to impact local planning budgets as well as the financial health of communities large and small. Likewise, the emergency response community continues to work to increase efficiency and response efforts in their communities, but suffer from many of the same challenges. The research community that focuses on community resilience continues to stress the importance of incorporating meaningful social demographic data into mitigation planning efforts, shifting our NHMPs from the current "cookie-cutter" plans heavily laden with natural disaster facts and economic and structural risk assessments. There is not yet an official protocol on how planners should go about incorporating social demographic data more meaningfully. This study offers one example of how social demographic within the local NHMPs can be more usefully implemented for education, planning, preparedness programs, and motivation for other local officials to reduce existing social inequality.

Income and Poverty as Social Indicators

Individual and family incomes are major factors to take into consideration when looking at community resilience to natural disasters, and are repeatedly stressed as strong indicators of community resilience in the literature. People and families with a higher expendable income would have increased purchasing power to replace lost resources or obtain alternative housing if needed, whereas those with less expendable income would have significantly more difficulty. As was mentioned in the methods section, availability of 2010 financial data restricted the use of 2010 data for all four variables. There is a significant difference in the individual and family income between 2000 and 2010, mostly due to the effects of the national economic recession that began in 2007, which are currently still being felt in 2014. A comparative analysis of the changes between the 2000 and 2010 censuses indicate that most Americans have seen a decrease in financial income while cost of living expenses continue to increase (Bishaw, 2013). The same study found that the percentage of people living below 150% of the federal poverty threshold in Washington State increased from 11.6% in 2000 to 13.5% in 2010, meaning that, if the study were conducted again using all 2010 census block group data, income figures would probably be lower when inflation adjustments are taken into consideration.

The clustering analyses were particularly interesting for the percentage of people living below 150% of the federal poverty threshold, because their insignificant p-value seems to contradict the significant p-value of the per capita income analysis. It would make sense that either both financial variables would show significant clustering or both would not. The ratio of income to poverty did output a positive variable, showing correlation ($p=0.0676$), just not as significantly as per capita income ($p<0.000$). The ratio of income-to-poverty used for this study focused on individuals living at or below 150% of the federal poverty threshold, because that is the standard “low-income” line in the United States. To put this into perspective for this discussion, 150% of the federal poverty threshold in 2014 dollars equates to $17,505. But earning this figure or just above this figure might not be enough to increase community resilience by much, and therefore, 150% might be too low of a threshold when using this as an indicator of community resilience.

The Massachusetts Institute of Technology has created the “Living Wage Calculator,” which calculates the minimum required annual income for survival and is dependent on the number of individuals in the household (Glasmeier, 2014). According to the MIT calculator, for a single individual living in Thurston County, the minimum income required to cover very basic living expenses is $17,697 before taxes are deducted, and an annual income of $15,768 after tax deductions. The costs incorporated into this figure are extremely basic and not very realistic for the average person, and greatly under-estimate the cost of living expenses for individuals and families. For example, monthly expenses for housing are estimated at $609 per month, according to the MIT calculator. This estimation is intended to cover rent/mortgage and utilities. According to the Thurston County 2013 Profile, the average (2013) monthly mortgage for home buyers was $719 per month, while the average (years 1995-2012) one-to-two bedroom home or duplex rental cost was $745 per month in Lacey, $719 per month in Olympia, and $895 per month in Tumwater. These average rates for local rental and mortgage rates do not include utility costs. An individual making 200% of the federal poverty threshold would be earning an annual income of $23,340 and it could be argued that even this person would be extremely financially strained if they were to be seriously impacted by a flooding event or other natural disaster. If this person were paying $745 per month on rent in Lacey, they would be spending 38% of their monthly income on housing. According to the Housing Authority of Thurston County (HATC), low-income housing is offered to people who are spending more than 30% of their monthly income on housing, so this person would qualify for low-income housing, despite not being defined as "low-income" per the current definition of 150% of the federal poverty threshold (HATC, 2013). For future studies, researchers should try to identify and incorporate realistic income values that would enable a family to have the purchasing power required to recover from an event, and then weight the income social indicator accordingly. As has been explained here, 150% of the federal poverty threshold is far too low for Thurston County, to realistically represent all persons vulnerable to natural hazard events due to low-income.

Race as a Social Indicator

The Global and Local Moran's I analyses indicated a significant positive relationship between block groups with a high and low racial minority population. Because income to poverty ratio data and age both showed a relatively low influence in this analysis, it was surprising to see that race played a stronger role. Areas with higher racial minority populations tend to be concentrated in the northeastern portion of Thurston County.

One of the two least resilient block groups identified in this study was the block group that includes a portion of the Nisqually Indian Reservation. In 2000, this block group had a total population of 752, a per capita income of $15,284, 3.6% of the population was living below 150% of the federal poverty threshold, and only 4.4% of its population was over the age of 65. When comparing only these variable to other block groups, this area would have ranked higher on the community resilience scale than it did when including racial minority populations, but because the four variables were ranked at 25% importance, this block group was identified lower on the resilience scale due to its high racial minority population of 68.6%.

A high minority population does not necessarily decrease community resilience. One could argue quite the opposite, in fact. A majority (60%) of the non-white population in this block group is Native American. It could be argued that this is an instance of a culture that can have a very strong social cohesion and a tight community network—traits that increase community resilience. One of the primary reasons that racial minorities are identified as vulnerable populations in emergency situations is that language and/or cultural barriers may exist and be exacerbated by natural disasters when emergency responders are of a different culture and/or speak a different language. While language and cultural barriers may still exist between the residents of the Nisqually Tribe and some emergency responders in the event of a natural disaster, the fact that this racial minority group exists so densely in this area could serve more strongly as a positive trait than a negative one.

In contrast to the Nisqually block group, the second identified block group that was given a ranking of one lies within Lacey. It has a population of 818, per capita income in 2000 was $14,488, 24.2% of the block group was living below 150% of the federal poverty threshold, 3.8% were over the age of 65, and 50.9% identify as a racial minority. Unlike the Nisqually block group, this block group is inhabited by a more diverse array of different races; 49% white, 12.7% black, 2.4% Native American, 13.8% Asian, 0.01% Hawaiian or Pacific Islander, 12.5% Hispanic or Latino, and 8.9% being of two or more of these races. While there are many advantages to a culturally diverse community, in times of emergency and high-stress situations, it can inhibit very important communication between community members due to language and/or cultural differences. This does not, however, need to be the case. Emergency responders and community members can be trained to learn how to effectively communicate important information to populations of another race or background. This can be done by forming emergency response teams that speak the predominant minority population's language, or by training other emergency responders about ways to better address certain issues to avoid cultural conflict or increased confusion. Planners could also connect with local cultural organizations that may be willing to help in response and/or translation with non-English speaking residents. Sometimes, simple steps such as these can greatly increase the effectiveness of a community's recovery following a disaster.

Age as a Social Indicator

As was discussed in the literature review, a significant amount of research has been done to study how natural disasters affect elderly populations, and there is overwhelming evidence that seniors are disproportionately negatively impacted by natural disasters when compared to other age groups. Several reasons exist for this—decrease mobility, isolation, or compromised immune systems and pre-existing conditions that are exacerbated by natural-disaster-induced stress. A community resilience ranking can help local areas become aware of a high percentage of elderly populations within their own community. In the event of a natural disaster, the first people on site are generally the community members impacted. If community members are aware of specific vulnerable populations that exist in their neighborhood or block group, they can begin right away searching for isolated elderly individuals still in their hopes, or be prepared for earlier treatment of exacerbated health issues, such as heart attacks or other stress-induced problems.

Further, by being aware of where high densities of elderly populations exist, community groups and members that work with elderly populations can help educate them on the hazards in their area and how to prepare. From a preparedness and mitigation perspective, areas of low community resilience due to high elderly populations could be very helpful to know about when implementing new mitigation projects, or attempting to target this specific population for natural disaster awareness, as organizations like the American Red Cross frequently do.

Block Groups and the 100-Year Floodplain

Both block groups with a community resilience ranking of one intersected the 100-year floodplain. The Nisqually block group contains the Nisqually River along its east side, with the 100-year floodplain extending substantially into this block group. Of the highest ranked groups, the 100-year floodplain only intersected three out of six identified block groups. Throughout all 132 block groups, there was not a significant relationship between ranking score and percentage of floodplain area. Each ranked group had at least 50% of the block groups intersecting the floodplain, but to varying extents, as can be seen in Table 3. This was unexpected because the literature shows that vulnerable populations tend to be marginalized toward more hazard-prone areas. This study found that, with respect to the 100-year floodplain in Thurston County, this is not the case.

It is possible that exposure to the 100-year floodplain is equally dispersed across the county. The stream network and floodplains in Thurston County are extensive, and many areas are at high risk due to low elevation, geological structures, and high annual precipitation. However, since community resilience is fluid, future studies could incorporate more detailed variables, use a smaller, more defined scale than block groups, or incorporate more recent data. By doing these things, the ranking of community resilience would be different than is found here, and patterns of vulnerable populations and exposure to flood hazards might come into view. This will be further discussed in the section on considerations for future research.

Implications

As with the definition of community resilience, the study of this concept using GIS is still in the early stages of its development. It was noted in the literature review that community resilience is not a state to be achieved, but rather an ongoing process. By incorporating and attempting to measure community resilience on a county, city, or neighborhood level, municipalities and local governments can enhance their own natural hazard mitigation plans or preparedness plans to address weak areas identified by their own community resilience measurements, to strengthen their overall community resilience to natural disasters. The social indicators chosen for such a study would be unique to each individual area, and based upon prevalent vulnerable groups for that specific region.

Awareness of community resilience at this scale could help local agencies such as natural hazard mitigation planners, the Red Cross, emergency management divisions, or local leaders to target especially vulnerable areas for education campaigns, more detailed plans for specific resources needed from vulnerable populations during an emergency, or policies that actively try to reduce social vulnerability. Currently, Thurston County's inclusion of social data into the NHMP and flood management plans consists of several table profiles for each incorporated area within the county. While this format offers a general understanding of the social state of the area, the inclusion of a more detailed spatial distribution of these social factors and how they interact with one another in reaction to a natural disaster carries much more potential. A paradigm shift happened when people became aware of the effectiveness of mitigation and planning, and the same paradigm shift can happen when people become aware of the social construction of disasters, environmental justice and importance of community resilience. The Frazier, et al. (2013b) study showed that Thurston County is already a leader in NHMPs across the state, and it should continue to be so by embracing community resilience and striving to understand the underlying factors of how our community is affected by natural events and why.

As Cohen and Bradley (2008) point out, the inclusion of social data into our mitigation and disaster sectors is now a human rights issue, and vulnerable populations need to have a stronger voice and presence in the way we plan for and respond to natural disasters. Historically, disasters in the U.S. are increasingly bringing social inequalities to the forefront, and many governments are learning the hard way that, with the knowledge and research available on the importance of these issues and their connectedness to environmental justice, ignoring them is neglectful and irresponsible.

Following Tropical Storm Irene and Hurricane Sandy, Mayor Michael Bloomberg and New York City were sued for neglect and discrimination with respect to the city's 900,000 disabled people. The court ruled that the city violated the American's with Disabilities Act, the Rehabilitation Act, and New York City human rights laws. Victims spent several days trapped in high-rise housing due to lack of preparedness and evacuation plans (*Brooklyn Center for Independence of the Disabled, Center for Independence of the Disabled, and Tania Morales v. Michael Bloomberg and the City of New York*, 2011). In 2005, Hurricane Katrina posed a significant threat to elderly populations in the area. This storm system killed 1,330 people, and 71% of these victims in Louisiana were over the age of 60 (Klein, 2009). Over 200 of these victims lived in nursing homes, and another class action lawsuit was filed after the owners chose to "wait out the storm," resulting in the drowning and heat exhaustion in m any of their patients (Klein, 2009). These are just two examples, of many, where vulnerable populations had not been included in emergency preparedness, mitigation and response plans and local city governments were hit with expensive legal fees and penalties for it.

On March 22, 2014, during the writing of this thesis, the town of Oso, Washington was struck by a massive, devastating landslide that wiped out 24 homes and resulted in the death of at least 41 people. This area has suffered severe landslides of similar proportions, with the most recent event happening just in 2006, but Snohomish County officials are now under investigation to learn why these areas were redeveloped and new housing developments permitted, despite the known hazard. As of April 29, 2014, $3.5 million dollars in claims have been filed (Vaugn, 2014). The population of Oso in 2010 was 180 (U.S. Census Bureau, 2010). The American Community Survey estimated that the per capita income in 2012 was $15,801, and 42% of the population was living with some form a disability (ACS, 2012), indicating that there were high percentages of vulnerable populations living in this area. Families filing lawsuits against the city officials and Snohomish County say they were not warned of the landslide hazard, despite multiple studies finding the region to be extremely hazardous (Brunner, Doughton, & Welch, 2014). It is not yet known whether the courts will find these city and county official guilty of negligence, but a significant amount of damage and devastation could have been avoided, had city and county officials taken preemptive action through natural hazard mitigation and zoning to protect these families from being sold homes they believed to be safe. If it is found that prior knowledge of this dangerous hazard was ignored, and developers were allowed to re-build homes in this area, knowingly putting dozens of vulnerable families in harm's way—this could stand as a prime example of structured destruction.

Understanding community resilience and ways in which we "structured destruction" in our own communities can prove invaluable in times of a natural disaster. By implementing an effective community resilience map into Thurston County's NHMP, areas of low community resilience and where they lie in proximity to natural hazards can be better understood, and if needed, mitigated to avoid a devastating event. Thurston County's NHMP is strong, and has proven effective in many aspects, but could be greatly strengthened by including the inter-linked social factors that make up our community's resilience.

Considerations for future research

The four indicators used here are not exhaustive of all the factors that influence a community's resilience to natural disasters. As was stated in the methods chapter, inclusion of other variables, such as homeless populations or housing vacancy rates, would help strengthen the accuracy of a community resilience measurement and provide a more accurate picture of the health of the community. A more defined measurement of community resilience in Thurston County may provide a more accurate representation of vulnerable populations exposed to natural hazards such as floods, earthquakes, or landslides.

Further, incorporating critical facilities or structures would allow consideration of where these communities lie in relation to needed resources, or more hazards, during a natural disaster. This element would further enhance accuracy and provide a more realistic picture of community resilience in the study area. For instance, while this study identified two block groups that were ranked lower than all the other block groups in the county, these variables could potentially be weighted differently if we knew that emergency facilities, such as hospitals, emergency shelters, or fire stations also existed in close proximity to affected populations. Communities could also be identified that might exist closer to hazards that could be exacerbated by a natural disaster, such as a water treatment facility or building that houses large amounts of toxic chemicals. By identifying and incorporating resources and other hazards that are important or valuable during an emergency, the community resilience ranking could be more accurately detailed.

Lastly, the four chosen indicators were each weighted evenly at 25% to not give preference to one indicator over another. Low per capita income, high rates of elderly, minorities and persons living below the poverty threshold were viewed as equally impactful on the community's resilience. In reality, some variables may play a stronger role in community resilience than others. If more variables are included in future studies, the weighting of each variable should be carefully selected to accurately represent how much influence each variable has on an area's resilience. In times of economic depression or recession, income variables might be weighted slightly higher than other variables, since financial resources will be more strictly limited. Another example of a variable that might be considered a higher influence on community resilience would be disabled populations. If an area contains a high percentage of physically or mentally disabled individuals, that would indicate an area of increased need during an emergency. Incorporating data that include locations of high populations of disabled (assisted living centers, retirement communities, rehabilitation centers or psychological treatment facilities) and then weighting this variable higher than some others that may not be as influential on community resilience would present a more accurate measurement of how that area might actually be affected by a natural disaster.

HAZUS offers a multitude of opportunities in future community resilience research. This software allows users the opportunity to run a simulation of a natural disaster in any chosen study area. The output of these powerful simulation models is the most accurate estimate currently available of the damage that would ensue from a flood, earthquake, or hurricane. If cities and counties have available community resilience data to identify areas of lower community resilience, a simulation model could be run in that area to see specific types of damage that would result from the assigned event. Output values include a variety of information, such as casualties, impact of event (depth of water in any given area, in a flood or hurricane scenario), number and types of residences and businesses affected, which residences and business had insurance for such a disaster, amount and type of debris generated, cost estimation and time estimates for cleanup and recovery, and effects of employment and labor disruption. By incorporating these simulation models in areas of low community resilience, these specific areas can be targeted for enhanced mitigation projects to reduce possible damage in the future or educational awareness campaigns to help people actively prepare.

Conclusion

This study examined the spatial relationships of community resilience in Thurston County in relation to the 100-year floodplain. Although Thurston County planners have made great strides in their natural hazard mitigation plans and projects to reduced damage in the event of a natural disaster, social demographic data could be more strongly incorporated. As of now, the Thurston NHMP contains fifty-two pages of tables with social demographic data on each incorporated area. While this information is helpful in providing a general understanding of a city's social demographic makeup, the current format does not help planners or community members understand the interlinked complexity of what these demographic characteristics reveal about our own social construction of natural disasters. By including and strengthening the concept of community resilience rankings, these complex relationships come to light and bring into focus many areas of weakness that should be actively targeted in future mitigation projects. If Thurston County wants to continue as a leader in Washington State Natural Hazard Mitigation, and embrace true environmental justice, these social inequality need to be included and addressed to be more effective in mitigating disaster.

In the bigger picture, cities, counties and states which choose to embrace the concept of community resilience and actively include the social construction of disasters into their community development and mitigation plans, would be setting the stage for the continuing paradigm shift in natural disaster preparedness, planning and response. As climate change impacts continue to increase in frequency and intensity, communities who most strongly embrace this concept of community resilience and begin working toward strengthening it now will be communities who buffer disaster impacts better than communities who continue to stick to the basic FEMA, "cookie-cutter" format. Research in community resilience and social vulnerability have significant strides to make before they will be incorporated and implemented at the federal level, so a localized, ground-up approach would be more effective at this time. By understanding how community resilience is spatially situated in our communities, we can identify areas of weakness to enhance mitigation, preparedness, education, and response efforts nation-wide. This would result in an overall increase in local community resilience, but also community resilience as a nation.

List of References

Abbott, P. L. (2012). *Natural disasters* (9th edition). New York, NY: McGraw-Hill Companies Inc.

Allen, K. M. (2006). Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines. *Disasters, 30,* 81–101. doi: 10.1111/j.1467-9523.2006.00308.x.

Berke, P. R., and Campanella, T.J. (2006). Planning for post-disaster resiliency. *Annals of the American Academy of Political and Social Science, 604,* 192–207. doi: 10.1177/0002716205285533.

Berke, P.R., and Godschalk, D. (2009). Searching for the good plan: A meta-analysis of plan quality studies. *Journal of Planning Literature, 23,* 227-240. doi: 10.1177/0885412208327014.

Berke, P. R., and Roenigk, D. J. (1996). Enhancing plan quality: Evaluating the role of state planning mandates for natural hazard. *Journal of Environmental Planning & Management*, *39*,79-96. doi: 10.1080/09640569612688.

Berke, P., Smith, G., and Lyles, W. (2012). Planning for resiliency: Evaluation of state hazard mitigation plans under the Disaster Mitigation Act. *Natural Hazard Review*, 13, 139-149. doi: 10.1061/(ASCE)NH.1527-6996.0000063.

Bishaw, A. (2013) Poverty: 2000 to 2012. *American Community Survey Briefs.* Retrieved from http://www.census.gov/prod/2013pubs/acsbr12-01.pdf.

Boon, H., Cottrell, A., King, D., Stevenson, R., and Millar, J. (2012). Bronfenbrenner's bioecological theory for modeling community resilience to natural disasters. *Natural Hazards,* 60, 381–408. doi: 10.1007/s11069-011-0021-4.

Brooklyn Center for Independence of the Disabled, Center for Independence of the Disabled, and Tania Morales *v*. Michael Bloomberg and the City of New York, 11 CIV 6690 (New York City, 2011). Retrieved from: http://www.dralegal.org/sites/dralegal.org/files/casefiles/bcidbloombergcomplaint.pdf

Bronfenbrenner, U. (2005). *Making human beings human: Bioecological perspectives on human development.* Thousand Oaks, CA: Sage.

Brunner, J., Doughton, S. and Welch, C. (2014, April 26). County mudslide warning failed to reach hill's residents. *Seattle Times*. Retrieved from http://seattletimes.com/html/localnews/2023468682_mudslidenotificationxml.html.

Buckle, P., Marsh, G., and Smale, S. (2001). Assessing resilience and vulnerability: Principles, strategies, and actions - Guidelines. *Emergency Management Australia*. Retrieved from http://www.gripweb.org/gripweb/sites/default/files/EMA_2001_meth.pdf.

Bullard, R. (1993). Race and environmental justice in the United States. *Yale Journal of International Law,* 18,319-335.

Clarke, L. (2006). *Worst cases: Terror and catastrophe in the popular imagination*. Chicago, IL. University of Chicago Press.

Cohen, R. and Bradley, M. (2010). Disasters and displacement: Gaps in protection. *International Humanitarian Legal Studies,* 1, 95-142.
Colten, C.E., Kates, R.W., and Laska, S.B. (2008). Three years after Katrina: Lessons for community resilience. *Environment: Science and Policy for Sustainable Development,* 50 (5), 36–47.
Community And Regional Resilience Institute (CARRI) and Meridian Institute. (2012). Community resilience system phase 1 report: Community experiences, observations and implications for FEMA. Retrieved from http://recoverydiva.files.wordpress.com/2012/10/crs-phase-1-report-general-release.pdf
Community And Regional Resilience Institute (CARRI). (2013). Definitions of community resilience: An analysis. Retrieved from http://www.resilientus.org/wp-content/uploads/2013/08/definitions-of-community-resilience.pdf
Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., and Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change Part A: Human & Policy Dimensions*, 18, 598–606. doi:10.1016/j.gloenvcha.2008.07.013.
Cutter, S.L., Boruff, B.J., and Shirley, W.L., (2003). Social vulnerability to environmental hazards. *Social Science Quarterly,* 84, 242-261.
Cutter, S.L., Mitchell, J.T., and Scott, M.S. (2000). Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Annals of the Association of American Geographers,* 90, 713-737.
Disasters, Board on Natural. 1999. Mitigation emerges as major strategy for reducing losses caused by natural disasters. *Science* 284, 1943–1947. doi: 10.1126/science.284.5422.1943
Disaster Mitigation Act of 2000. Pub. L. No. 106-390. 114 Stat. 1552 (2000) Retrieved from http://www.fema.gov/media-library-data/20130726-1524-20490-1790/dma2000.pdf
Disaster Relief Act of 1974. Pub. L. No. 100-707. 102 Stat. 4869 (1988) Retrieved from http://www.gpo.gov/fdsys/pkg/STATUTE-102/pdf/STATUTE-102-Pg4689.pdf.
Federal Emergency Management Agency (FEMA). (1998). Building a disaster resistant community. *Project Impact Guidebook*. Retrieved from http://training.fema.gov/EMIWeb/edu/docs/hazriskmanage/Hazards%20Risk%20Mgmt%20-%20Session%204%20-%20Project%20Impact%20Guidebook.pdf
Federal Emergency Management Agency (FEMA). (2010). Hazard mitigation: Integrating best practices into planning. Retrieved from http://www.fema.gov/media-library-data/20130726-1739-25045-4373/pas_560_final.pdf
Frazier, T. G., Thompson, C.M., Dezzani, R.J., and Butsick, D. (2013a). Spatial and temporal quantification of resilience at the community scale. *Applied Geography,* 42, 95–107. doi:10.1016/j.apgeog.2013.05.004.

Frazier, T. G., Walker, M.H., Kumari, A., and Thompson, C.M. (2013b). Opportunities and constraints to hazard mitigation planning. *Applied Geography,* 40, 52–60. doi:10.1016/j.apgeog.2013.01.008.

Geis, D. E. (2000). By Design: The disaster resistant and quality-of-life community. *Natural Hazards Review*, 1, 151-160.

Glasmeier, A. K. (2014). Poverty in America: Living wage calculator. Massachusetts Institute of Technology. Retrieved from http://livingwage.mit.edu/

Godschalk, D. R. (2003). Urban hazard mitigation: Creating resilient cities. *Natural Hazards Review*, 4, 136-143.

Godschalk, D., Beatley, T., Berke, P., Brower, D., and Kaiser, E. (1999). *Natural hazard mitigation: Recasting disaster policy and planning*. Washington D.C: Island Press.

Gunawardhana, M.R., Budge, T., and Abeyrathna, K. (2013) Measuring community disaster resilience capacity for natural hazards: Case study of Rathnapura, Sri Lanka. *International Journal of Climate Change: Impacts and Responses*, 4, 133-146.

Gunderson, L., Holling, C.S., Pritchard, L., and Peterson, G.D. (2002). Resilience. *The Earth system: Biological and ecological dimensions of global environmental change,* 2, 530-531.

Gunderson, L. (2010). Ecological and human community resilience in response to natural disasters. *Ecology & Society,* 15 (2), 1–11.

Hazard (n.d.) In Merriam-Webster's Collegiate Dictionary (11th ed.).(2003). Springfield, MA: Merriam-Webster.

Holling, C. S. (1973). Resilience and stability of ecological systems, *Annual Review of Ecology and Systematics*, 4, 1-23.

Holling, C. S. (1996). Engineering resilience versus ecological resilience. In Gunderson, L.H., Allen, C.R., and Holling, C.S. (Eds.) *Foundations of ecological* resilience (51-66). Washington D.C., Island Press.

Hopkins, L.D. (2001). *Urban development: The logic of making plans.* Washington, D.C.: Island Press.

Horney, J.A., Naimi, A.I., Lyles, W., Simon, M., Salvesen, D., and Berke, P. (2012). Assessing the relationship between hazard mitigation plan quality and rural status in a cohort of 57 Counties from 3 states in the southeastern U.S. *Challenges,* 3, 183–193. doi:10.3390/challe3020183.

Housing Authority of Thurston County (2013). Income eligibility fact sheet. Retrieved from http://hatc.org/?page_id=323#incomeeligibility.

Intergovernmental Panel on Climate Change (IPCC) (2013). Climate change 2013: The physical science basis. Retrieved from http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf.

Kiter-Edwards, M. L. (1998). An interdisciplinary perspective on disasters and stress: The promise of an ecological framework. *Sociological Forum,* 13, 115–132.

Klein, R.J.T., Nicholls, R.J., and Thomalla, F. (2003). Resilience to natural hazards: How useful is this concept? *Global Environmental Change Part B: Environmental Hazards,* 5, 35–45. doi:10.1016/j.hazards.2004.02.001.

Lindell, M.K., and Perry, R.W. (2007) Planning and preparedness. In: Tierney, K.J., and Waugh, W.F. (Eds) *Emergency management: Principles and practice for local government,* (2nd ed). Washington, D.C.: International City/County Management Association, 113-141.

Lindell, M.K., Prater, C.S., and Perry, R.W., (2006). Hazard mitigation. *Fundamentals of Emergency Management (Chapter 7)*. Retrieved from http://training.fema.gov/EMIWeb/edu/docs/fem/Chapter%207%20-%20Hazard%20Mitigation.doc.

Lindell, M.K., and Prater, C.S. (2003). Assessing community impacts of natural disasters. *Natural Hazards Review*, 4, 176–185. doi:10.1061/(ASCE)1527-6988(2003)4:4(176).

Manyena, S.B. (2014). Disaster resilience: A question of ‘multiple faces’ and ‘multiple spaces’? *International Journal of Disaster Risk Reduction, 8, 1-9. Retrieved from http://ac.els-cdn.com.bay.evergreen.edu/S2212420913000721/1-s2.0-S2212420913000721-main.pdf?_tid=954b5bac-b761-11e3-9314-00000aacb360&acdnat=1396111729_512adfbe2492827b6023c138a720e874*

Margret, S. and Romang, H. (2010). Effectiveness of mitigation measures against natural hazards. *Cold Regions Science and Technology*, 64, 199–207. doi:10.1016/j.coldregions.2010.04.013.

Masten, Ann S., and Obradovic, J. (2008). Disaster preparation and recovery: Lessons from research on resilience in human development. *Ecology & Society*, 13, 1–16.

McEntire, D., Fuller, C., Johnston, C. & Weber, R. (2002). A comparison of disaster paradigms: The Search for a Holistic Policy Guide. *Public Administration Review,* 62, 267-281.

Meadows, D. (2008). *Thinking in systems: A primer*. White River Junction, VT: Chelsea Green Publishing Company.

Multihazard Mitigation Council (2005). Natural hazard mitigation saves: An independent study to assess the Future Savings from Mitigation Activities. Retrieved from http://www.floods.org/PDF/MMC_Volume1_FindingsConclusionsRecommendations.pdf

Norris, F., Stevens, S.P., Pfefferbaum, B., Wyche, K.F., and Pfefferbaum, R.L. (2008) Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology*, 41, 127-150. doi:10.1007/s10464-007-9156-6.

Peacock, W.G., Hearn Morrow, B., and Gladwin, H. (1997). *Hurricane Andrew: Ethnicity, gender and the sociology of disasters*. Abingdon, Oxon: Routledge.

Perry, R. W. and. Lindell M.K. (2003). Preparedness for emergency response: Guide-lines for the emergency planning process. *Disasters*, 4, 336-350.

Prater, C. S., and Lindell, M.K. (2003). Politics of hazard mitigation. *Natural Hazards Review, 1,* 73–82.

Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988, Pub. L. No. 42 U.S.C. 5121 et seq. (2013). Retrieved from http://www.fema.gov/robert-t-stafford-disaster-relief-and-emergency-assistance-act-public-law-93-288-amended

Rodriquez, H. and Barnshaw, J. (2006). The social construction of disasters: From heat waves to worst-case scenarios. *American Sociological Association,* 35, 218-223.

Schlosberg, D. (2007). *Defining environmental justice*. Oxford Scholarship Online, Oxford.

Sherrieb, K., Norris, F., and Galea, S. (2010). Measuring capacities for community resilience. *Social Indicators Research,* 99, 227-247.

Stevens, M., Berke, P., and Song, Y. (2010). Creating disaster-resilient communities: Evaluating the promise and performance of New Urbanism. *Landscape and Urban Planning,* 94, 105-115.

Thurston County Regional Planning Council. (2013). The Profile 2013. Retrieved from http://www.trpc.org/data/Documents/ProfileDec2013/chapters/04_Profile13_Ch02_PopulationDemographics%20with%20maps.pdf

Tierney, K. J. (2006). Foreshadowing Katrina: Recent sociological contributions to vulnerability science (Review) *American Sociological Association,* 35, 207-212.

Tierney, K. J. (2007). From the margins to the mainstream? Disaster research at a crossroads. *Annual Review of Sociology*, 33, 503-525.

U.S. Census Bureau. (n.d.). Oso, Washington: Mean income in the past 12 months. In 2008 - 2012 American Community Survey. Retrieved April, 27, 2014, from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_5YR_S1902&prodType=table

U.S. Census Bureau. (n.d.). Oso, Washington: Occupation by sex and median earnings in the Past 12 Months (In 2012 Inflation-adjusted dollars) For the civilian employed population 16 and over. In 2008 - 2012 American Community Survey. Retrieved from 2014, from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_5YR_S2401&prodType=table

U.S. Census Bureau. (n.d.). Oso, Washington: Disability characteristics. In 2008 - 2012 American Community Survey. Retrieved April, 27, 2014, from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_5YR_S1810&prodType=table

Vaugn, A. (2014, April 29). More claims filed on behalf of Oso mudslide victims. *Seattle Times*. Retrieved from http://blogs.seattletimes.com/today/2014/04/more-claims-filed-on-behalf-of-oso-mudslide-victims/

Vink, K., and Takeuchi, K. (2013). International comparison of measures taken for vulnerable people in disaster risk management laws. *International Journal of Disaster Risk Reduction,* 4, 63–70. doi:10.1016/j.ijdrr.2013.02.002.

Waugh, W. L. Jr. (2007). EMAC, Katrina, and the governors of Louisiana. *Public Administration Review*, Special Ed., 107-113. Accessed at: http://www3.interscience.wiley.com/cgi-bin/fulltext/118485143/PDFSTART

Wisner, B. and Walker, P. (2005). The world conference on disaster viewed through the lens of political ecology: A Dozen Big Questions for Kobe and Beyond. *Capitalism, Nature, Socialism,* 16, 89-95.

Wisner, B., Blaikie, P., Cannon, T., and Davis, I. (2003). At risk: Natural hazards, people's vulnerability and disasters. Routledge: Psychology Press.

Wood, N. J., Good, J.W., and Goodwin, R.F. (2002). Vulnerability assessment of a port and harbor community to earthquake and tsunami hazards: Integrating technical expert and stakeholder input. *Natural Hazards Review* 3, 148.

Appendix

List of block groups from lowest to highest resilience rank.

Rank	Census tract	Block group	City/area	Population	Per cap. income	Under 150% of federal pov. threshold per block group	% of pop. racial minority per block group	% of pop. over 65 per block group	% of area that is 100-year floodplain
1	115	1	Lacey	818	14,448	24.2%	50.9	3.8	2.14
1	123	2	Nisqually Reservation	752	15,248	3.6%	68.6	4.4	33.59
2	106	1	Olympia	616	22,017	30.8%	36.7	12.5	0.00
2	106	3	Olympia	1512	14,930	46.5%	38.3	5.4	0.00
2	115	4	Lacey	1628	15,632	32.4%	41.5	7.7	0.00
2	123.1	1	Unincorp.	1,658	18,404	11.6%	43.3	3.5	2.21
2	123.1	2	Unincorp.	2629	13,233	14.2%	31.3	12.7	0.72
2	123.3	1	Lacey	1,741	19,368	13.7%	35.3	5.1	0.00
2	123.3	2	Lacey	206	18,342	21.0%	37.6	4.2	0.00
3	105	3	Olympia	2,469	22,255	23.3%	26.6	5.5	11.03
3	105	4	Olympia	1,399	15,097	39.7%	22.8	15.6	30.04
3	112	2	Lacey	2304	15,203	38.2%	24.7	18.8	7.11
3	112	3	Lacey	1289	21,454	20.6%	25.4	11.2	11.31
3	113	1	Lacey	1440	19,865	32.1%	25.0	19.5	5.21
3	113	4	Lacey	1,072	18,214	16.6%	23.6	9.6	0.00
3	114.1	1	Lacey	961	18,926	6.1%	29.8	9.5	0.00
3	114.1	2	Lacey	879	19,216	32.7%	25.4	7.5	0.00
3	114.2	1	Lacey	2,635	23,371	10.4%	25.2	12.1	0.00
3	114.2	2	Lacey	2,123	19,149	29.0%	26.1	5.4	12.38
3	115	3	Unincorp.	1144	26,966	14.4%	31.0	13.9	0.00
3	116.1	1	Lacey/Unincorp.	1991	18,983	10.1%	26.0	6.6	9.12
3	116.1	3	Lacey	1,472	21,977	3.1%	26.4	20.2	20.39
3	116.2	1	Lacey	5,057	18,872	14.6%	25.1	9.7	2.63
3	116.2	2	Lacey	4,724	21,398	7.8%	26.4	6.7	8.54

Rank	Census tract	Block group	City/area	Population	Per cap. income	Under 150% of federal pov. threshold per block group	% of pop. racial minority per block group	% of pop. over 65 per block group	% of area that is 100-year floodplain
3	122.1	4	Olympia/ Lacey	1,710	15,434	27.8%	26.3	15.6	0.38
3	122.2	3	Lacey	785	29,162	11.6%	22.5	14.8	10.73
3	123.1	3	Unincorp.	2,105	25,506	9.6%	22.7	6.3	1.34
3	127	8	Unincorp.	1,332	11,796	55.1%	24.8	2.5	24.20
4	103	1	Olympia	2030	15,677	40.8%	19.8	6.0	11.66
4	103	4	Olympia	686	18,091	38.0%	21.7	19.0	0.00
4	105	1	Olympia	1,470	16,646	20.5%	21.5	35.0	12.50
4	107	1	Olympia	2,417	24,840	4.0%	19.1	5.9	0.00
4	108	4	Tumwater	937	16,053	38.3%	22.3	13.8	0.00
4	109	3	Tumwater	1,826	20,216	16.5%	22.5	7.6	6.36
4	112	1	Olympia/ Lacey	715	12,989	31.5%	22.2	11.9	6.38
4	114.1	4	Lacey	2,446	19,898	14.0%	20.9	13.1	0.00
4	114.2	3	Lacey	1,665	19,098	2.9%	18.5	6.3	9.93
4	115	2	Lacey	1,041	17,642	15.9%	20.4	7.0	10.42
4	115	5	Lacey	1,024	29,482	9.4%	17.4	7.6	0.00
4	116.1	4	Unincorp.	2170	21,701	10.6%	19.0	8.1	12.04
4	116.2	4	Unincorp.	2699	23,371	8.2%	20.8	5.7	6.02
4	117	4	Unincorp.	1,423	22,160	5.5%	17.2	1.1	23.90
4	122.1	3	Olympia	3,823	19,566	14.9%	18.9	23.9	9.51
4	122.2	4	Lacey	3,298	28,160	4.2%	20.3	6.9	2.02
4	123.2	1	Lacey	1,946	20,330	17.5%	20.2	10.4	9.25
4	124.1	2	Yelm	1,555	16,365	19.9%	20.2	7.7	6.83
4	127	3	Unincorp.	863	14,827	18.3%	20.7	11.6	5.68
5	101	2	Olympia	588	18,252	41.6%	16.4	5.8	14.94
5	101	4	Olympia	832	23,740	18.9%	16.6	9.4	0.00
5	102	1	Olympia	1239	29,828	3.2%	15.9	17.8	24.03

Rank	Census tract	Block group	City/area	Population	Per cap. income	Under 150% of federal pov. threshold per block group	% of pop. racial minority per block group	% of pop. over 65 per block group	% of area that is 100-year floodplain
5	106	4	Olympia	2,509	26,989	22.1%	15.7	8.6	14.52
5	107	3	Olympia	15,555	27,250	5.7%	15.5	12.5	0.00
5	109	5	Tumwater	3,237	25,485	8.4%	15.6	5.8	5.38
5	117	1	Olympia/ Unincorp	2,291	24,405	6.3%	15.4	9.1	2.50
5	122.1	5	Unincorp.	1,197	33,579	6.5%	17.1	15.8	2.02
5	122.2	1	Unincorp.	1,234	31,840	8.1%	15.0	10.7	4.10
5	124.2	3	Unincorp.	1,355	20,693	7.2%	14.8	3.8	7.49
5	125	5	Unincorp.	1,567	16,597	13.0%	16.1	7.0	8.27
5	127	1	Unincorp.	1,697	20,014	18.2%	15.3	13.7	15.33
5	127	4	Unincorp.	1,944	17,466	9.5%	14.8	8.7	2.96
6	102	3	Olympia/ Unincorp.	2,101	19,823	15.1%	13.6	9.4	0.00
6	104	2	Olympia/ Tumwater	1,004	28,517	9.9%	13.3	7.8	12.25
6	108	5	Tumwater	2,307	24,906	23.9%	13.3	13.7	1.15
6	109	4	Tumwater	756	23,230	9.2%	13.0	14.3	0.00
6	111	2	Olympia	1143	27,049	10.1%	13.1	9.0	9.21
6	114.1	3	Lacey	820	20,329	10.1%	13.8	18.8	0.00
6	118.1	1	Unincorp.	2,022	26,198	7.1%	14.3	6.5	1.96
6	119	1	Unincorp.	2,022	24,829	10.3%	13.6	6.8	0.89
6	120	2	Unincorp.	2598	20,700	13.0%	13.1	4.3	13.27
6	124.1	3	Yelm/Unincorp.	4,132	17,285	21.0%	13.5	12.2	13.58

Rank	Census tract	Block group	City/area	Population	Per cap. income	Under 150% of federal pov. threshold per block group	% of pop. racial minority per block group	% of pop. over 65 per block group	% of area that is 100-year floodplain
6	125	6	Rainier/ Unincorp .	1357	17,052	18.8%	12.5	10.4	4.95
6	126	3	Tenino/U nincorp.	1,659	17,123	26.3%	13.7	12.4	6.71
7	101	1	Olympia	696	16,504	58.2%	11.1	24.7	51.42
7	101	3	Olympia	610	31,564	11.5%	10.5	17.0	33.69
7	102	2	Olympia	1,462	21,764	13,2%	9.7	7.2	0.00
7	104	1	Olympia	1,678	26,877	5.3%	9.8	16.2	7.81
7	105	2	Olympia	1,690	22,780	22.6%	10.7	12.1	0.00
7	106	2	Olympia	1,153	28,099	7.2%	11.1	13.4	0.00
7	107	2	Olympia	793	18,864	23.6%	12.0	13.7	17.07
7	108	1	Tumwate r	926	31,068	6.5%	10.5	14.4	0.02
7	109	2	Tumwate r	1778	26,667	15.0%	12.3	14.4	5.97
7	110	1	Tumwate r/Unincor p.	1482	27,124	5.6%	9.9	15.7	6.07
7	111	1	Unincorp .	1309	29,669	16.9%	10.8	10.9	18.99
7	116.1	2	Lacey/U nincorp.	1,064	31,655	4.6%	11.4	19.5	5.74
7	116.2	3	Lacey	2,061	29,157	12.3%	12.0	19.1	14.58
7	118.2	3	Tumwate r/Unincor p.	1,890	20,742	8.4%	9.8	7.0	5.30
7	122.1	1	Unincorp orated	1,078	30,659	5.9%	11.7	16.5	5.50
7	124.1	1	Yelm	2,382	15,962	26.3%	11.4	10.0	6.48
7	126	4	Tenino/U nincorp.	1,585	22,709	8.5%	10.5	12.4	5.77
7	127	6	Unincorp .	1,867	20,523	13.0%	11.5	6.8	8.00
8	103	2	Olympia	1577	18,864	23.1%	8.9	8.2	0.01
8	117	3	Unincorp	1899	33,807	2.3%	9.6	17.6	16.02

Rank	Census tract	Block group	City/area	Population	Per cap. income	Under 150% of federal pov. threshold per block group	% of pop. racial minority per block group	% of pop. over 65 per block group	% of area that is 100-year floodplain
			.						
8	118.2	4	Unincorp.	2,035	28,991	11.2%	9.0	14.2	14.33
8	118.2	5	Unincorp.	1378	20,899	20.9%	8.3	13.3	12.32
8	119	2	Unincorp.	1,297	29,692	5.6%	8.0	7.6	18.71
8	120	1	Unincorp.	2,585	40,250	8.4%	9.2	15.2	32.79
8	121	1	Unincorp.	902	32,279	7.0%	8.4	9.5	6.54
8	121	2	Unincorp.	709	28,435	11.8%	9.2	15.8	40.72
8	122.2	2	Unincorp.	1787	27,886	7.7%	7.8	8.5	5.50
8	124.2	2	Unincorp.	716	23,706	16.8%	9.1	9.8	3.70
8	125	2	Unincorp.	2083	17180	14.0%	8.5	6.0	5.13
8	125	4	Unincorp.	1,244	16,467	20.0%	9.5	13.7	4.83
8	126	1	Unincorp.	1,785	23,205	14.1%	9.3	8.0	13.38
8	127	2	Unincorp.	736	23,341	19.8%	8.0	10.6	11.73
8	127	7	Unincorp.	1499	17,778	24.1%	9.1	11.6	4.99
9	104	3	Olympia/ Tumwater	813	27,613	13.7%	6.6	17.1	0.00
9	108	3	Tumwater	1,122	20,799	7.8%	7.0	8.4	33.24
9	109	6	Tumwater	931	21,405	19.2%	7.4	22.3	5.90
9	110	2	Tumwater/Unincorp.	3,498	23,853	10.2%	7.7	8.0	24.85
9	113	2	Lacey	1277	26,232	19.5%	4.4	76.8	0.00
9	113	3	Lacey	772	18,063	9.7%	6.7	15.4	0.00

Rank	Census tract	Block group	City/area	Population	Per cap. income	Under 150% of federal pov. threshold per block group	% of pop. racial minority per block group	% of pop. over 65 per block group	% of area that is 100-year floodplain
9	117	5	Unincorp.	1,565	20,067	6.1%	7.3	9.0	9.30
9	118.1	2	Unincorp.	1,450	21,552	13.7%	6.9	9.8	14.09
9	118.2	1	Unincorp.	843	18,682	8.0%	6.2	8.8	6.17
9	118.2	2	Unincorp.	587	27343	12.8%	5.6	7.5	13.58
9	119	5	Unincorp.	765	27,585	11.9%	7.1	13.3	4.96
9	121	3	Unincorp.	776	25,654	9.9%	6.3	25.5	18.83
9	121	4	Unincorp.	1,525	26,102	9.2%	7.5	10.6	32.89
9	122.1	2	Unincorp.	1,016	31,367	15.7%	7.3	13.4	8.01
9	124.2	1	Unincorp.	1,368	31,557	6.1%	7.0	9.3	9.88
9	125	1	Rainier/ Unincorp.	1464	21695	13.1%	7.2	8.1	7.81
9	125	3	Unincorp.	2135	20052	16.1%	6.8	11.3	12.82
9	126	2	Unincorp.	1069	20031	2.7%	6.7	7.1	6.56
9	126	5	Tenino/Unincorp.	1511	19243	16.8%	6.3	11.9	4.08
9	126	6	Bucoda/ Unincorp.	817	15637	32.6%	7.0	11.1	10.12
9	127	5	Unincorp.	1162	17281	16.5%	5.7	9.9	17.88
10	103	3	Olympia	855	18191	21.8%	3.0	9.9	0.00
10	108	2	Tumwater	949	34201	5.5%	0.6	16.2	0.00
10	109	1	Tumwater	498	21185	34.5%	0.0	56.8	10.56
10	117	2	Unincorp.	968	30942	9.5%	3.2	8.1	0.06

Rank	Census tract	Block group	City/area	Population	Per cap. income	Under 150% of federal pov. threshold per block group	% of pop. racial minority per block group	% of pop. over 65 per block group	% of area that is 100-year floodplain
10	119	3	Unincorp.	1083	39798	2.6%	4.2	13.7	18.34
10	119	4	Unincorp.	1082	29674	5.1%	2.8	19.5	4.87