FLOOD RISK AND ENVIRONMENTAL JUSTICE:
A CASE STUDY OF
THURSTON COUNTY, WASHINGTON

by

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ABSTRACT

Flood Risk and Environmental Justice: A Case Study of Thurston County, Washington

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In the United States, flood events are a common and devastating phenomenon. Between 1996 and 2019, 99% of U.S. counties were impacted by floods. In the past 48 years, Thurston County has experienced 16 floods for which presidential disaster declarations were issued. Thurston Regional Planning Council completed a vulnerability analysis of populations in 100-year-flood areas. While this analysis identified Thurston County residents who are the most vulnerable to flooding, it did not analyze whether certain populations are more likely to live in a flood area. Research has shown that minorities and those living below the poverty level are more vulnerable to natural disasters. Specifically, recent research has identified African American and Latinx communities to be more at risk of flooding than white communities in urban U.S. cities. Environmental justice is a movement that stems from the belief that all people, regardless of race or socio-economic status, deserve to live in a safe environment. This thesis completed a quantitative spatial analysis of homes in flood hazard areas in Thurston County with ArcGIS Pro software using an environmental justice framework. It identified six income and race variables obtained from U.S. Census and American Community Survey data at the block group level for all block groups in Thurston County. Six t-tests were completed to identify differences between block groups with and without homes in flood areas. The t-test results indicated a statistically significant difference in household racial minority. Block groups without homes in flood areas are more racially diverse than block groups with homes in flood areas. However, the block group with the highest household racial minority percentage is located in the Nisqually Indian Reservation, which contains the highest concentration of homes in a flood area in Thurston County, with 17% of households below the poverty level. This finding suggests that there is environmental injustice related to flooding in Thurston County. Based on the results of the analysis, policy makers should consider use race and income data to determine recipients of FEMA grants to mitigate homes from flood damage, specifically for low-income areas and members of the Nisqually Tribe. Research should also be completed in other Washington State counties that are more racially diverse, lower income, and with more households living at or below the poverty line.

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I. Introduction

The United States experiences numerous types of natural disasters, yet flood events are the most destructive and deadly. In the 20^{th} century, floods were responsible for more deaths and damage costs than any other natural hazard (Perry, 2000). The U.S. Geological Survey estimates that 32 of the most significant riverine floods of the 20^{th} century resulted in more than 1,843 deaths and over $50 billion in damages, not including floods for which there is no data (Perry, 2000). Floods can greatly impact physical health, ranging from inaccessibility to safe food and water, exposure to molds and mildews, carbon monoxide poisoning, inadequate medical care to those with chronic health conditions, danger when reentering or cleaning damaged homes and buildings, temporary or permanent displacement, and homelessness (Brodie et al., 2006; Peacock et al., 1997; Thurston Regional Planning Council, 2013). In addition, floods can cause psychological distress, including Post Traumatic Stress Disorder (PTSD), depression, and anxiety (Brodie et al., 2006; Greene et al., 2015; Mason et al., 2010).

Thurston County experiences flood events more frequently than any other natural disaster, and floods incur the highest damage costs. In the past 48 years, Thurston County has experienced 16 floods for which presidential disaster declarations were issued (Table 1) (Thurston Regional Planning Council, 2013). Flood events are projected to occur more frequently as well as become more intense due to climate change (Mauger et al., 2015). Five types of flooding occur in Thurston County: riverine, groundwater, tidal, flash, and urban flooding (Thurston Regional Planning Council, 2013).

Riverine flooding happens when rivers or streams become inundated, which occurs from extended heavy rainfall and/or quickly melting snow pack (Thurston Regional Planning Council, 2013, p. 6-2). Based on past observations, riverine flooding has resulted from 2-3 consecutive days of rainfall which averages 2-5 inches per day, but the chance of occurrence also depends on the river height, the level of the groundwater table, and run-off conditions at the time of the rainfall. Thurston County contains 5 major rivers which drain to the Puget Sound: the Nisqually, Deschutes, Skookumchuck, Chehalis, and Black Rivers, as well as 3 inlets: Totten, Eld, and Henderson Inlets (**Error! Reference source not found.**) (Thurston Regional Planning Council, 2013).

Event Dates	Declaration #	Type of event	Estimated Damage[a]
2/1/1972 – 2/1/1972	DR-322	Severe storms & flooding	N/A
3/24/1972 – 3/24/1972	DR-328	Heavy rains & flooding	N/A
1/25/1974 – 1/25/1974	DR-414	Severe storms, snowmelt & flooding	$50,000
12/13/1975 – 12/13/1975	DR-492	Severe storms & flooding	$38,461,538
12/10/1977 – 12/10/1977	DR-545	Severe storms, mudslides, & flooding	$159,300
1/6/1990 – 1/14/1990	DR-852	Severe storms & flooding	$3,846,153
11/9/1990 – 12/20/1990	DR-883	Severe storms & flooding	$7,738,098
11/7/1995 – 12/18/1995	DR-1079	Severe storms, high wind, and flooding	$556,575
1/26/1996 – 2/23/1996	DR-1100	High winds, severe storms and flooding	$22,000,000
12/26/1996 – 2/10/1997	DR-1159	Severe winter storms, land & mudslides, flooding	$2,840,000
3/18/1997 – 3/28/1997	DR-1172	Heavy rains, snow melt, flooding, land & mud slides	$133,333
10/15/2003 – 10/23/2003	DR-1499	Severe storms and flooding	$863,636
11/2/2006 – 11/11/2006	DR-1671	Severe storms, flooding, landslides, and mudslides	$100,000
12/1/2007 – 12/17/2007	DR-1734	Severe storms, flooding, landslides, and mudslides	$4,600,000
1/6/2009 – 1/16/2009	DR-1817	Severe winter storm, landslides, mudslides, and flooding	$3,200,000
1/14/2012 – 1/23/2012	DR-4056	Severe winter storm, flooding, landslides, and mudslides	N/A

a. Data obtained from Spatial Hazard Events and Losses Database for the United States

Table 1: List of Thurston County flood events for which presidential declarations have been issued (Thurston Regional Planning Council, 2013).

Groundwater flooding occurs in low lying areas as the result of a period of heavy, prolonged rainfall that occurs when the ground water table, the level of water located in underground aquifers, is higher than usual (Thurston Regional Planning Council, 2013; U.S. Geological Survey, 2020a). Rainfall seeps down into a permeable layer of soil that sits on top of a hard stratum of impermeable soil. As it rains, the water table rises until it exceeds the ground's surface. The U.S. Army Corps of Engineers estimates that a groundwater flooding event occurs once every 25 years in Thurston County. The last major groundwater flooding event in Thurston County occurred in 1998-1999, preceded by a slightly less severe groundwater flood in 1996-1997. It was estimated that there is a 70% chance of a groundwater flooding event that equals or surpasses that of the 1996-1997 flood occurring before 2027 (Thurston Regional Planning Council, 2013).

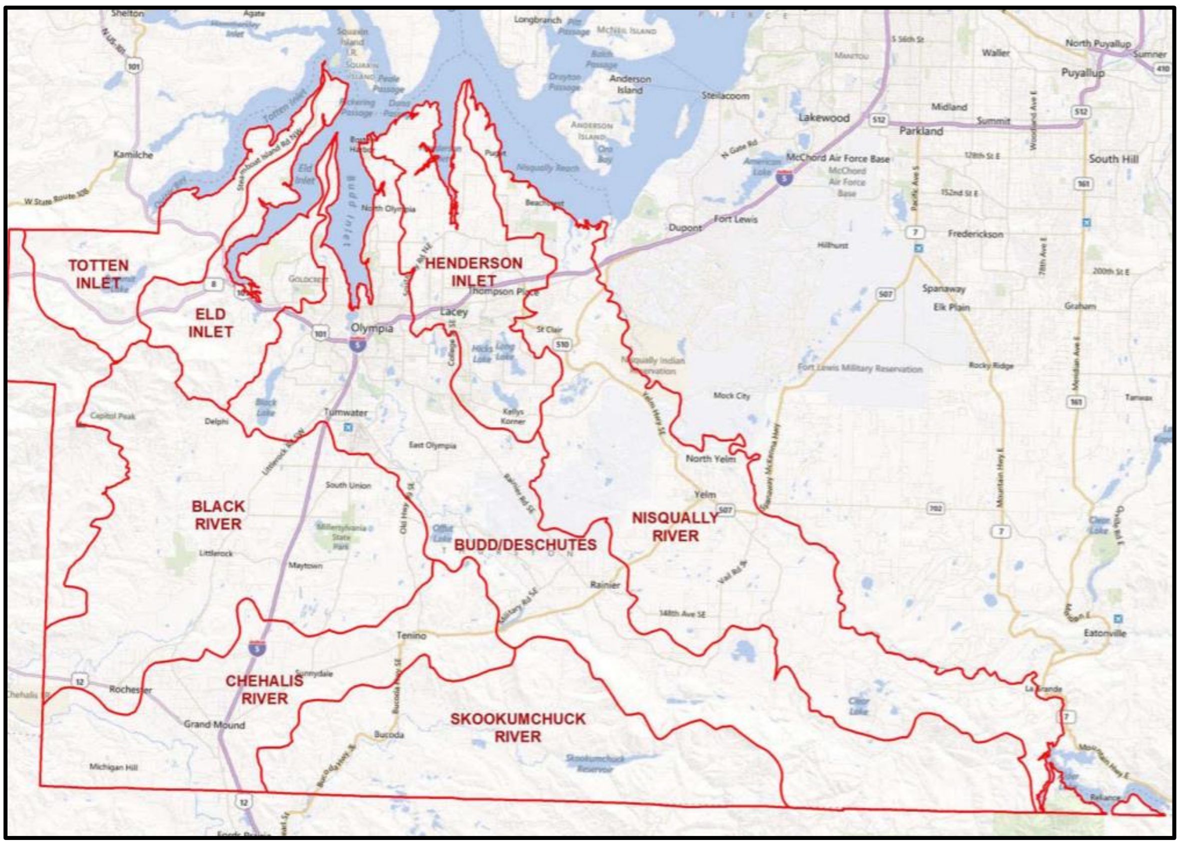

Figure 1: Map of Thurston County displaying river and inlet drainage basins which flow into the Puget Sound. Sourced from Thurston Regional Planning Council.

Tidal flooding is the result of the highest tides of the month occurring simultaneously with winds from the north, causing the sea level of the south Puget Sound to rise. Tidal flooding occurs in coastal areas as well as in and around deltas when river levels are higher than average.

Areas at risk in Thurston County include the coast of Olympia and low-lying areas, such as agricultural land in the Nisqually Valley and sections along McLane Creek. Climate change is predicted to increase the risk of tidal floods due to sea level rise projections (Thurston Regional Planning Council, 2013).

Flash floods occur when exorbitant amounts of rain fall within a short time frame, typically under 6 hours, and the ground is unable to absorb the water (NOAA, 2020). Flash floods often occur in urban areas where impervious infrastructure like pavement create runoff (Perry, 2000). They are also the most likely of all flood types to result in deaths due to their rapid accumulation and difficulty to forecast. Thurston County's vegetation and natural terrain allow rainfall to absorb into the ground, reducing flash flooding risk, however, flash floods have occurred around the Deschutes River, as well as numerous streams in Thurston County (Thurston Regional Planning Council, 2013).

Urban floods are the result of land development that prevents the ground from absorbing rainfall naturally. Urbanized areas rely on drainage facilities such as pipes, roadside ditches, and channels to manage rainfall. Urban flooding can occur during heavy rainfall when these infrastructures become overwhelmed and are not able to adequately channel runoff to rivers and streams, causing water to accumulate on roads and other transportation corridors (Thurston Regional Planning Council, 2013).

There are 2 main types of flood area classifications: 1%-annual-chance flood areas, also referred to as 100-year-flood zones, and 0.2%-annual-chance flood areas, also known as 500-year-flood zones. These flood areas have a 1% and 0.2% chance of equaling or exceeding the flood area boundary each year, respectively (FEMA, 2020c). FEMA considers 1%-annual-chance flood areas to be high-risk and 0.2%-annual-chance flood areas to be moderate-to-low risk (FEMA, 2020b). 1%-annual-chance areas make up most of Thurston County's flood zones (FEMA, 2018a). FEMA creates Flood Insurance Rate Maps (FIRMs) for communities that participate in the National Flood Insurance Program (NFIP), a FEMA program that offers discounts on insurance premiums for communities who enact minimum floodplain regulations (Brown et al., 2019). FIRMS are maps that display the location and type of flood areas. All communities in Thurston County participate in the NFIP, with the exception of the Nisqually Indian Reservation, so FIRMs have been created for the county (Figure 2).

The Puget Sound, including parts of Thurston County, is the ancestral home of the Nisqually Tribe, who have inhabited this area for thousands of years. The location of their present-day reservation was determined by the Medicine Creek Treaty of 1854 (Nisqually Indian Tribe, 2020). The Nisqually Indian Reservation's flood areas and type have not yet been determined, but that area is vulnerable to flooding and is likely a 1%-annual-chance flood area (Thurston County Emergency Management, 2020; Thurston Regional Planning Council, 2013; Walter, 2020).

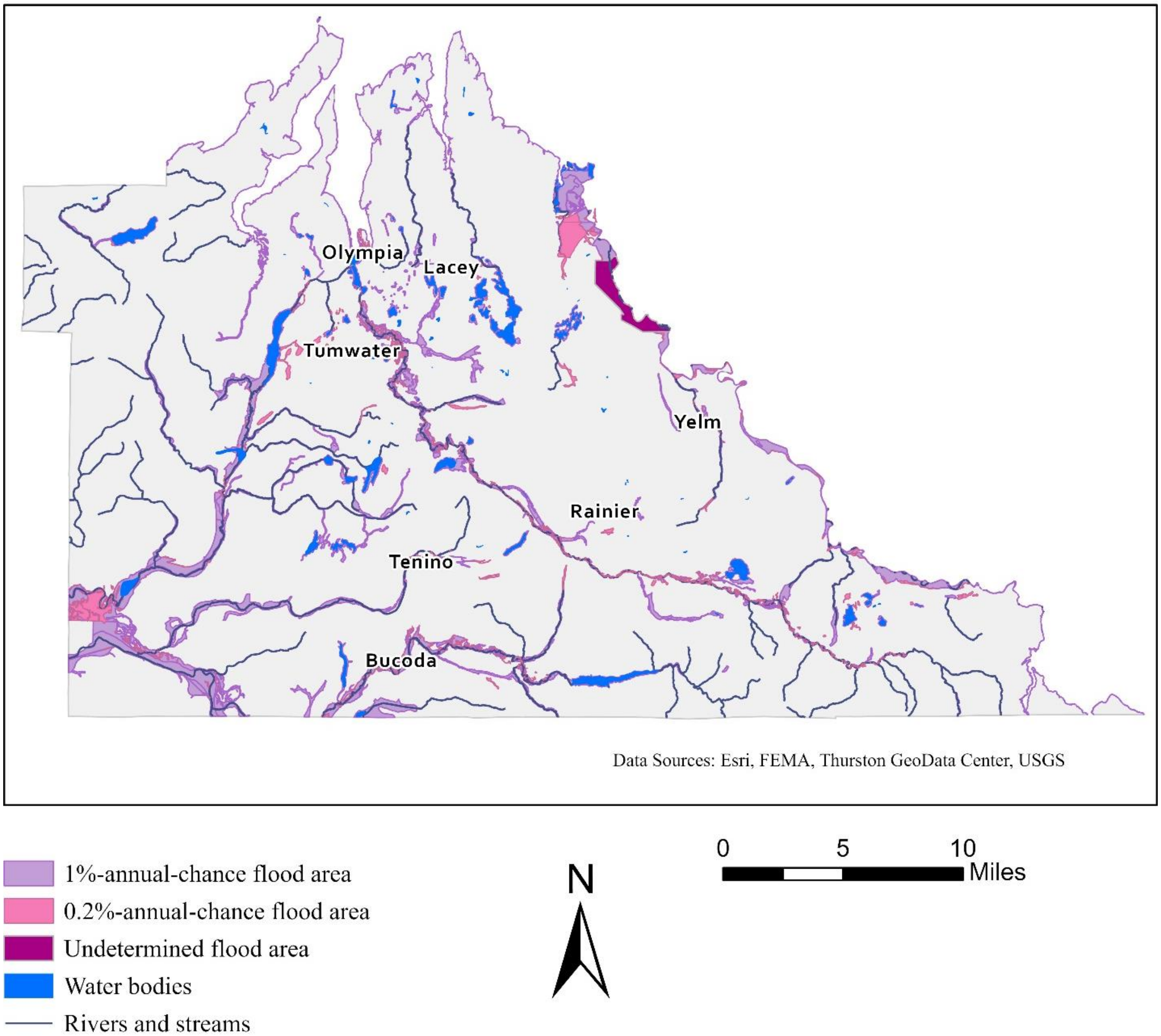

Figure 2: Map of flood areas, rivers, streams, and water bodies in Thurston County.

In 2019, Thurston County had an estimated population of approximately 286,000 and median annual household income of approximately $72,000 (Thurston Regional Planning Council, 2020c). 2014-2018 American Community Survey 5-year estimates concluded that Thurston County was comprised of 84% white and 16% racial minorities (Figure 3) (Thurston Regional Planning Council, 2020a).

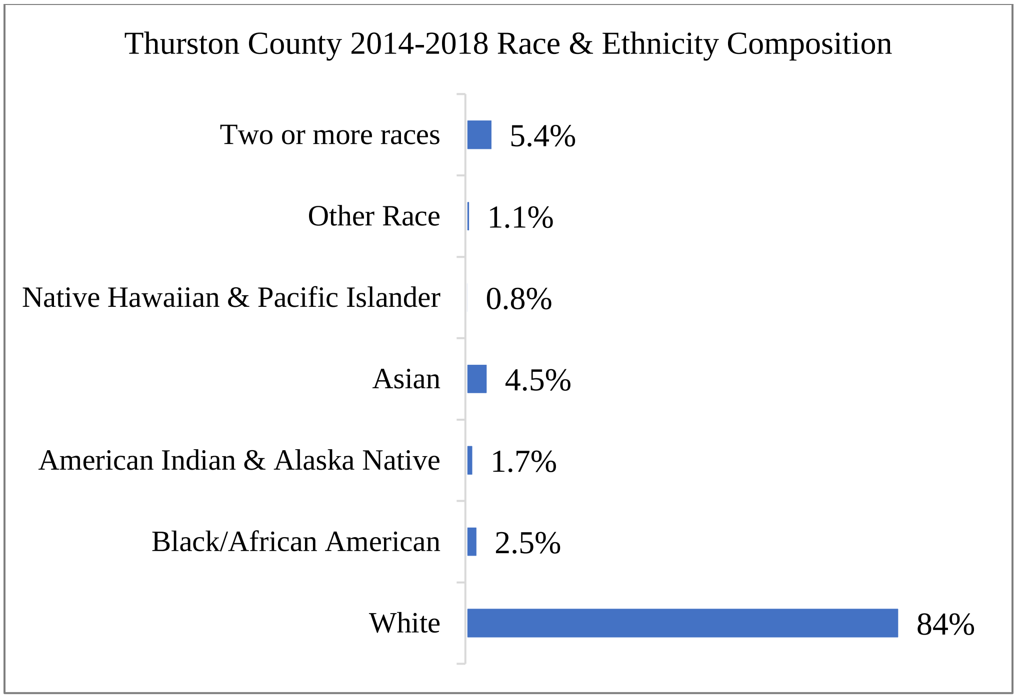

Figure 3: Race and ethnicity composition of Thurston County based on the 2014-2018 American Community Survey 5-year estimate.

In 2012, Thurston Regional Planning Council (TRPC) completed a social vulnerability analysis of residents in 1%-annual-chance flood areas using FIRMs and past flood data[1]. Social vulnerability refers to the demographic and socio-economic factors that affect a person's resilience to environmental stressors; in this case, flood events (Flanagan et al., 2011). The results of the analysis identified that vulnerable populations in these areas include people who are economically disadvantaged, over the age of 65, or under the age of 16 (Thurston Regional Planning Council, 2013, p. 7-9). The analysis concluded that approximately 16% of Thurston County residents living in 100-year-flood areas had an annual gross income of $15,000 or less. The results of the analysis did not present data on race or ethnicity (Thurston Regional Planning Council, 2013).

[1] TRPC's vulnerability analysis did not include the Nisqually Indian Reservation because a FIRM has not been created for this area.

While this analysis identified Thurston County residents who are the most vulnerable to flooding, it did not analyze whether certain populations are more likely to live in a flood area. There is a growing body of research which has identified African American, Latinx, and low-income communities to be more at risk of floods than white and higher income communities in urban U.S. cities (Chakraborty et al., 2019; De Sherbinin & Bardy, 2015; Douglas et al., 2012; Maldonado et al., 2016; Thaler et al., 2018). Environmental justice is a theoretical framework founded in the belief that all people, regardless of racial identity or socioeconomic status, deserve to live in a healthy and safe environment (Bullard, 1983, 1990; Bullard et al., 2007). This research project seeks to answer the following research question: "Is there is a difference in race and income in residents who live in flood areas compared to those who live outside of flood areas in Thurston County?".

This thesis includes a Literature Review, Methods, Results, and Discussion & Conclusion chapter. The Literature Review provides an overview of environmental justice, including its history, how it has expanded, and its relation to flood events. It presents several case studies of large-scale urban floods and how environmental justice applies to these events, as well as FEMA's role in flood mitigation, specifically FEMA's flood mitigation grant program. Lastly, it gives a thorough overview of Thurston County's demographic composition, the county's flood mitigation strategies, historic floods of the area, and how climate change impacts flood risk.

The Methods chapter describes the different data used and study design of the project. There are several data sources, including the following GIS layers: Thurston County parcels[2], Thurston County land use, Thurston County building blueprints, Thurston County block groups[3],

[2] Census parcels are a geographical unit used by the U.S. Census. Parcels are property boundaries; they are the smallest of Census geographical units (U.S. Census Bureau, 2012).
[3] A Census block group is a geographical unit used by the United States Census Bureau that is made up of Census blocks. Smaller than a Census tract, Census block groups contain anywhere between 600 and 3,000 people.

the national flood hazard layer from FEMA, and aerial imagery from the National Agriculture Information Program (NAIP). These data layers were used to create a layer of households that reside in flood hazard areas in Thurston County. For the purposes of this study, 1%-annual-chance and 0.2%-annual-chance flood areas were grouped together. Homes located in either of these flood areas were included in the layer. In addition, the undetermined flood area in the Nisqually Indian Reservation was included because this area has experiences major flood events (Thurston County Emergency Management, 2020; Thurston Regional Planning Council, 2013; Walter, 2020)

Once all households in flood areas were mapped, demographic data was obtained for all Census block groups in Thurston County. This data includes 6 variables, including 2019 median household income, income less than $15,000, income between $15,000 and $24,999, income between $25,000 and $34,999, households below the poverty level, and percent minority population. These variables were sourced from Esri, American Community Survey (ACS) 5-year estimates, and the U.S. Census. Depending on the variances, either a Welch's or a 2-sample t-test was completed for each demographic variable to examine differences between block groups that do and do not contain households in flood areas.

The Results chapter presents the results of the analysis. Of all 6 variables, only household racial minority percent was statistically significant. Block groups without households in flood hazard areas, on average, have a higher percent of minorities than block groups with households in flood hazard areas. The other 5 demographic variables were not found to be statistically significant.

Census block groups are the smallest unit for which the decennial Census publishes sample data (U.S. Census Bureau, 2012).

The Discussion and Conclusion chapter provides an interpretation of the results and presents an outlier in the data, along with the practical and theoretical implications of this study. The block group with the highest percent of household racial minority is located in the Nisqually Indian Reservation. This block group also contains the most households in a flood hazard area of all Thurston County block groups, and 17% of households are below the poverty line. This finding suggests that there is environmental injustice related to flooding in Thurston County. The practical implications of this study include recommendations for policy makers to research flood risk in other nearby municipalities, especially those with more racial diversity, higher poverty rates, and more low-income areas. In addition, the chapter discusses specific characteristics of Thurston County that may explain why this study was not consistent with environmental justice research regarding flooding.

This chapter also explains the limitations of this study, including errors and disclaimers in the data and human error in mapping households in flood areas. In addition, the binary measure of whether or not block groups contain households in flood areas does not include a sense of scale for the total households in each block group. Finally, this chapter provides recommendations for future research on flood risk in Thurston County and other areas at risk of flooding in the U.S.

II. Literature Review

A. History of Environmental Justice

Environmental justice arose in response to the Civil Rights Movement and environmental factors that were affecting the health of African American and Latinx communities. Dr. Robert Bullard, a sociologist, is considered the father of the environmental justice movement because of his research that exposed African Americans and Latinxs to be more at risk of exposure to toxic waste than white individuals (Bullard, 1983, 1990; Bullard et al., 2007).

In the 1960's, the Civil Rights Movement brought to light the glaring disenfranchisement of African Americans in the United States, including many unsafe black communities that were dumping grounds for hazardous environmental waste. One of the first public accounts of this occurred in 1968 in Dickson, Tennessee, the same year Dr. Martin Luther King, Jr. was assassinated (The U. S. National Archives and Records Administration, 2016). Dickson, Tennessee is considered to be the "poster child" for environmental racism (Bullard & Wright, 2008). The town of Dickson was, and still is, a predominately white town. However, a small African American community was located in the town along Eno Road (R. D. Bullard et al., 2007).

In 1964, Scovill-Schrader, an automotive plant that specialized in manufacturing tire valves and gauges, opened in Dickson. That plant, along with other local industries including the manufacturing of metal, boats, and printing, generated industrial solvents, a hazardous waste that can cause harm if not properly disposed of. In 1968, drums filled with these industrial solvents were buried in an unlined landfill that permitted open dumping just off Eno Road. Over 1,400 residents in the community obtained water from private drinking wells and springs located within a 4-mile-radius of the landfill, which were contaminated as a result of the dumping

(Bullard, 1990; Bullard et al., 2007; Tetra Tech EM Inc., 2004). The Dickson landfill served as a dumping grounds for a variety of hazardous waste for nearly 40 years, and was cited for a number of violations, including a violation of Groundwater Protection Standards, and for groundwater and spring cadmium levels which exceeded the Maximum Concentration Level (MCL) (Bullard & Wright, 2008). According to the Environmental Protection Agency (EPA), acute cadmium exposure can cause “nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure,” and long-term exposure can lead to “kidney, liver, bone and blood damage.” There is a lack of research to confirm whether lifetime exposure is linked to cancer (U.S. EPA, 1992).

The impacts of the landfill can be seen in the example of the Holt family, an African American family who has spent generations in the Eno Road community. The Holt family’s home is located just 54 feet from the Eno Road landfill. In 1988, a hazardous waste containing trichloroethylene (TCE), a carcinogen known to harm reproductive organs, the nervous system, and is linked to kidney cancer, was dumped in the landfill. As a result, the Holt family’s drinking well became contaminated TCE. Although the family’s well tested at high levels of TCE, the Tennessee Department of Health and Environment issued a letter to the Holt family in 1988 stating that the TCE levels in their well were safe for water consumption, claiming that the high TCE level test results were an error. Nearby white neighbors also received letters from the Tennessee Department of Health and Environment which informed them that their water was not safe for consumption and were provided with alternative safe drinking water resources.

A second test in 1990 revealed TCE levels to be 5 times that of the MCL of 5 parts per billion, and subsequent tests performed over the following decade found varying levels of TCEs, many above the MCL. Yet, it wasn’t until 2000 that the Holt family was notified of unsafe TCE levels in their well water and were switched to the municipal water supply. The members of the Holt family experience a variety of serious health issues, including cancer, which Harry Holt died of in 2007. In 2003, the family sued the city of Dickson, the state of Tennessee, and the company responsible for dumping the TCE-laden waste. Although there is not sufficient evidence that links the family's serious health conditions to their exposure to TCEs, the Holt family's decades-long struggle for access to safe drinking water illustrates an example of environmental injustice (Bullard et al., 2007).

In the 1970s, Robert Bullard found that landfills and incinerators in Houston, Texas were more often located in African American neighborhoods than in white communities, despite the fact that at the time, Houston was approximately 75% white (Bullard, 1983, 1990). In 1982, the catalyst of the environmental justice movement took place in Afton, a small, predominantly African American town in Warren County, North Carolina. At the time, Warren County was 65% African American and the poorest county in the state (Geiser & Waneck, 1983). At a public hearing in 1979, the town was selected to be a dumping ground for 6,000 truckloads of soil containing polychlorinated biphenyl (PCB). PCB is a toxic chemical known to cause a number of adverse health effects, including cancer, and harm to immune and reproductive health (U. S. Environmental Protection Agency, 2019b). The PCB-contaminated soil was from a clean-up of an illegal dumping of transformer oil containing PCBs from a transformer manufacturing plant by Robert Burns and his two sons. The Burns' were paid to properly dispose of the hazardous waste, but instead they sprayed it along 210 miles of roadsides in South Carolina (Bullard, 1990; The New York Times, 1979).

More than 800 people attended the 1979 hearing to protest the dump-site, but Afton was selected for the landfill site (The New York Times, 1979). Protests continued for the next several years, and in 1982, when the trucks entered Afton containing the contaminated soil from the clean-up, residents of the town and environmental justice activists marched along the streets in protest. Some people laid down in front of the trucks in an attempt to stop the dumping. The protestors lost the fight, however, and the waste was deposited in a landfill in Afton (Bullard, 1990; Bullard et al., 2007). The contaminants remained in the landfill until 2003, when state and federal agencies spent $18 million to finally clean up the waste site (Bullard & Wright, 2008).

In 1987, the Commission for Racial Justice of the United Church of Christ initiated research on commercial toxic waste facilities and toxic waste sites. A report of their findings was published in 1987 and was an important step in the environmental justice movement (R. D. Bullard et al., 2007; United Church of Christ Commission for Racial Justice, 1987). The report summarized that race, above any other variable, was determined to be the most statistically significant association to the proximity to hazardous waste areas. A that time, 3 out of 5 African American and Latinx Americans resided in communities with unregulated waste sites (United Church of Christ Commission for Racial Justice, 1987, p. 13). The research also found that areas with the highest number of toxic waste sites also had the highest percentage of people of color. Specifically, communities with 1 commercial toxic waste site had an ethnic minority percentage that was twice the national average, while communities with 3 or more commercial toxic waste sites had an ethnic minority percentage three times the national average. Socio-economic status followed race in the strength of association with proximity to hazardous waste (United Church of Christ Commission for Racial Justice, 1987, p. 13).

Also in 1986, the U. S. General Accounting Office (GAO) published a report that stressed the Environmental Protection Agency's (EPA) incompetence in controlling hazardous waste. The report states:

"EPA does not know whether it is controlling 90% of existing hazardous wastes—or 10%; likewise, it does not know if it is controlling the wastes that are most hazardous. At present, the disposal of dangerous wastes, such as certain pesticides and known carcinogens, is not being regulated by EPA" (U. S. General Accounting Office, 1986, p. 14).

In response to the GAO report, the Commission for Racial Justice of the United Church of Christ expressed their disturbance of the EPA not knowing the number of toxic waste sites that were under its control. The Commission urged the EPA and the President of the United States to take action (United Church of Christ Commission for Racial Justice, 1987). In response, the EPA introduced the Office of Environmental Justice (OEJ) in 1992. The OEJ was created to coordinate environmental justice issues for the EPA by ensuring that hazardous waste sites threatening the health of communities was addressed (Bullard et al., 2007; U. S. Environmental Protection Agency, 2017).

In 1994, President Clinton signed Executive Order 12898 that required all federal policy to include environmental justice. The Executive Order specifies that federal agencies are to identify and address environmental impacts on minority and low-income populations (Clinton, 1994). This marked the first instance of federal agencies to implement environmental justice in their action plans (Huang, 2019). The EPA defines Environmental justice as follows:

> *"Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. This goal will be achieved when everyone enjoys the*

same degree of protection from environmental and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn, and work" (U. S. Environmental Protection Agency, 2019a).

B. The Expansion of Environmental Justice

Environmental justice initially focused solely on race, but it has since expanded to include other factors. For instance, ecofeminism and gender issues in environmental justice is a growing body of research. One study examined women who live in Central Appalachia in coal country who support the coal industry, but advocate for more ecological methods to mine coal that do not threaten the safety of nearby communities (Bell, 2013). Literature on environmental justice activism and women's empowerment has also been explored (P. Brown & Ferguson, 1995), along with gender inequalities of environmental justice (Buckingham & Kulcer, 2009; Gaard, 2004). Environmental justice literature has also concentrated on indigenous rights and tribal sovereignty (Holifield, 2012; Ishiyama, 2003; Warner, 2017). The well-documented Dakota Access Pipeline at Standing Rock is one example (Nagle, 2018).

Additionally, environmental justice and immigrant rights is an emerging field (Marcelli, Power, & Spalding, 2001; Siqueira & Jansen, 2012). Park and Pellow researched Latinx immigrants in Aspen, Colorado, an economically rich and popular tourist destination. While the tourist population is dominated by the white middle class, the work force in Aspen that makes up the tourist industry is comprised of mostly Latinx immigrants. These immigrant communities live in the outskirts of town in low-income areas that are exposed to environmental hazards and pollutants (Park & Pellow, 2011).

Environmental justice regarding climate is another research area. A recent NPR study completed an analysis of temperature and socio-economic status in major U.S. cities. The results indicated moderate-to-strong correlations between the two variables in many cities; Anchorage, Oakland, Las Vegas were among the cities with the strongest correlations ("NPR Investigation: Low-Income Urban Areas Are Often Hotter Than Wealthy Ones: NPR," 2019).

In the U.S., local sustainability and climate initiatives are lacking environmental justice. Schrock et al. analyzed Sustainability- and Climate-Action Plans in 28 cities for the inclusion of equity. They found that while approximately 90% of the plans mentioned equity, only 36% included specific objectives for inclusivity. The plans acknowledged that low-income individuals are more impacted by climate change than the middle and upper class, but most lacked action plans and the resources for addressing this issue. The few cities that included specific action plans, including Philadelphia, Boston, and Portland, OR, were often the result of local activist groups raising awareness of racial and economic disparities (Schrock, et al., 2015).

C. Environmental Justice and Flooding Events

Research has identified minorities and low-income communities to be disproportionately impacted by flood events (Chakraborty et al., 2019; Elliott & Pais, 2006; Maldonado et al., 2016; Brodie et al., 2006; Montgomery & Chakraborty, 2015). Research also shows that low-income and black households are less likely to evacuate during or after a flood event than higher income and white households (Elliott & Pais, 2006; Peacock et al., 1997). Although these studies do not provide sufficient evidence that race and ethnic background are indicators of greater stress from disaster-related events on a national scale, research that is focused on regional areas and specific flooding events is conclusive (Elder et al., 2011; Elliott & Pais, 2006; Peacock et al., 1997). Studies on flood risk in Miami and Houston indicate that African American and Latinx communities are at a greater risk of flooding than other racial groups (Grineski et al., 2014; Maldonado et al., 2016). New Orleans, New York and New Jersey, and Houston have all experienced record flood events in the past 15 years (U.S. Geological Survey, 2020b). Environmental justice literature has researched these events and how their communities were impacted, which is explored in the following sub-sections.

i. New Orleans

Hurricane Katrina was a category 5 storm that struck the city of New Orleans on August 29th, 2005. This catastrophic event resulted in an estimated $81 billion in damage and destroyed more than 800,000 housing units (Hurricanes: Science and Society, 2015). The storm impacted New Orleans, Mississippi, Alabama, and Florida (U.S. Department of Commerce et al., 2016). In New Orleans, areas of the city were flooded for several weeks, and 1.36 million people applied for federal housing assistance (Allen, 2007). A total of 1,833 people died from the impacts of the hurricane (U.S. Department of Commerce et al., 2016), including 971 deaths in New Orleans. Of New Orleans deaths, 51% were black, 42% were white, and 7% were another minority. In Orleans Parish, a historic black neighborhood, black people had a mortality rate that was up to 4 times as high as white people. People over the age of 75 made up 49% of the total deceased (Brunkard et al., 2008).

In New Orleans, there was a disparity between people who evacuated before Katrina and those who stayed. Research discovered that low-income, black families in New Orleans were the least likely to evacuate New Orleans for a variety of reasons, including lack of resources, such as access to a vehicle, no nearby family members, and financial stress (Colten, 2008; Dyson, 2007; Elder et al., 2011). Many families stayed in the city due to their reliance on government checks that are dispensed at the end of the month (Elder et al., 2011). Other groups that were less likely to evacuate were low-income, white people, disabled, and/or elderly. On the contrary, people with higher incomes, who were physically capable, and had access to vehicles were able to evacuate (Johnson, 2008). Those who remained in New Orleans during and after the storm experienced extreme hardship. FEMA directed residents to the Superdome, a football arena in the city which was designated as the pick-up site for buses that evacuated thousands of victims out of the city to shelters. Upon arrival to the Superdome, people discovered that supplies were limited, and they were stranded in there for days awaiting the evacuation buses. There was no available water supply because FEMA took 5 days to deliver water, and the conditions inside the Superdome were unsanitary and unsafe (Gold, 2005; Katz, 2015).

Even after being evacuated, victims experienced both physical and psychological strain. A study conducted in shelters in the Houston area found that these evacuees were predominately low-income, African Americans with serious health conditions. They did not have access to adequate health care because Hurricane Katrina wiped out the New Orleans public hospital system. There were also reports of people not having access to food or water (Brodie et al., 2006).

Hurricane Katrina also created toxic waste in New Orleans. Prior to the storm, the New Orleans area had numerous chemical plants, oil refineries, superfund sites, and hazardous waste storage areas that were disproportionately located near African American neighborhoods (Bullard & Wright, 2009). The storm exposed toxic chemicals which remained in the sediment for months afterwards (Johnson, 2008). Toxic levels of lead found in the soil was widespread throughout the city. According to the CDC, lead exposure can cause a range of symptoms from abdominal pain and depression to increased risk for "high blood pressure, heart disease, kidney disease, and reduced fertility" (Centers for Disease Control and Prevention, 2018). Lead exposure in children can cause damage to the nervous system and can inhibit development (Centers for Disease Control and Prevention, 2020). In New Orleans, children, who often come into contact with soil during play, were found to have unsafe blood lead levels after Hurricane Katrina (Zahran et al., 2010). In some black neighborhoods, 67% of children experienced lead poisoning, although research did not find a statistically significant difference in child lead poisoning between white and black children (Bullard & Wright, 2009; Rabito et al., 2012).

By 2006, the EPA's efforts to clean up the toxic waste generated by Katrina were mostly successful, with the exception of Agriculture Street, a mostly African American, low-income neighborhood located near a toxic landfill. A toxin known to cause cancer was found in residents' yards at 50 times the safe level determined by the EPA. FEMA provided trailers to residents in order to mitigate their exposure to the chemical, but the trailers were found to be unsafe as well (Bullard & Wright, 2009). Between 2005 and 2006, FEMA administered trailers to over 120,000 Hurricane Katrina victims, many of whom lived in the trailers for several years. The trailers, however, were found to be contaminated with formaldehyde, a highly toxic gas that causes respiratory and gastrointestinal problems at low concentrations, and cancer and "chronic pulmonary injury" at high concentrations (Agency for Toxic Substances & Disease Regulation, 2014). FEMA was highly criticized for neglecting to address specific cases where formaldehyde levels in trailers appeared to be at toxic levels. Although FEMA stopped buying and selling these trailers in 2007, it was 6 years before FEMA removed all the trailers from New Orleans neighborhoods (Babington, 2007; Bullard & Wright, 2009; Centers for Disease Control and Prevention, 2008; Muskal, 2012; Spake, 2007).

Once people were allowed to return to their homes to assess the damage and clean up, they were exposed to additional toxic household hazards that still remained (Roach, 2005). Local, state, and federal agencies did not inform the residents of protocols for protecting themselves from the hazards. Initially, FEMA did not recommend residents use protective equipment, but eventually FEMA gave residents a list of recommended personal protective equipment after facing pressure from environmental groups. However, the equipment they recommended was unavailable to purchase nearby, and many couldn't afford to purchase it if it had been available. Wealthier people were less likely to be exposed to household hazards because many hired people to clean up their homes (Allen, 2007).

Prior to Hurricane Katrina, New Orleans was polarized by race and socio-economic status. According to research, minorities and low-income communities of any city are often the least prepared for disasters, and New Orleans was no exception (Allen, 2007; R. Bullard & Wright, 2009). Hurricane Katrina was not the first instance of major flooding in New Orleans, a city that is familiar with flooding. Because of the high risk of flooding in this area, many homes and businesses were historically elevated in order to mitigate flood impacts on property and residents. Not all infrastructure was elevated, however, leaving many homes vulnerable to flooding (FEMA, 2012; NASA, 2005). In September 2019, FEMA awarded New Orleans $12.5 million in grants for home elevations. This funding is to be used to elevate 52 homes that have experienced repeated flooding. Latoya Cantrell, the city's mayor, deemed the grant a "huge win" for New Orleans, but, of these 52 homes, 22 are listed on the National Register of Historic Places. These historic homes are a part of the history and culture of New Orleans, but the people who can afford to own these homes are likely not low-income, and do not have the highest need for FEMA grants (Occupational Health & Safety, 2019).

Hurricane Katrina was one of the deadliest hurricanes in history, and was a catastrophic disaster. The racial and socio-demographic inequalities that existed in New Orleans before the storm were amplified after Katrina struck. FEMA's negligence further complicated the situation and left thousands of people without access to food and water, shelter, health care, and exposed to environmental toxins. African American and low-income communities were disproportionately impacted by the hurricane, which is congruent with environmental justice research.

ii. New York City and New Jersey

Hurricane Sandy hit the eastern coast of the U.S. in October 2012. It impacted a total of 24 states, and caused sea levels to rise along the east coast from Florida to Maine. New York, New Jersey, and Connecticut were impacted the hardest by record-breaking storm surges, with the greatest concentrated in the New York metropolitan area. Record storm surges, which are unusual rises in sea levels following a storm (NOAA & National Weather Service, 2018), took place throughout New York City, with the highest around Staten Island and Manhattan between 4-9 feet above ground level. The highest recorded storm surge in New York rose 12.6 feet above ground level at Kings Point in Long Island Sound (Blake et al., 2013). FEMA estimates that the storm resulted in $70.2 billion in total damage (FEMA, 2018b).

In New Jersey, low-income communities were found to be more at risk, and were disproportionately impacted by the storm compared to economically stable groups (Burger et al., 2019). Over 2 million people lost power, and over 346,000 homes were destroyed or damaged (FEMA, 2018b). People of color experienced longer durations of evacuation along with longer power outages than white individuals. African American and Latinx people identified that they used New Jersey's Federally Qualified Health Centers (FQHC) more than white individuals (Burger et al., 2019). Approximately 95% of people treated at FQHCs are either "uninsured, under-insured, or below the poverty line" (Burger et al., 2019, p. 128). De Sherbinin and Bardy completed an analysis on Hurricane Sandy and social vulnerability which did not produce conclusive results due to the inaccuracy of Census block level data. There is a need for more precise, accurate data in order to draw conclusive results on connections between vulnerability and Hurricane Sandy (De Sherbinin & Bardy, 2015). However, there is conclusive research that shows a correlation between low-income communities and a lack of knowledge about flood risk and mitigation (Douglas et al., 2012; Elder et al., 2011; Elliott & Pais, 2006). Given the data on the socio-economic disparity of the impacts of Hurricane Sandy, there appears to be a need for better public education of flood risk and aid to assist with mitigation strategies.

iii. Houston

Hurricane Harvey was a category 4 storm that struck Houston on August 25, 2017. National Oceanic & Atmospheric Association (NOAA) deemed the storm "the most significant tropical cyclone rainfall event in [recorded] United States history" (Blake et al., 2017). The peak total rainfall in the Houston metropolitan area was between 36 and 48 inches. In parts of Southeastern Texas, peak total rainfall reached 65-70 inches, exceeding the previous highest recorded rainfall in the continental U.S. of 48 inches, which occurred in Medina, Texas in 1978. The extreme flooding caused Houston to sink 2 centimeters due to the heavy weight of the water. 13 million people from 5 states were impacted, and there were 68 direct fatalities, including 36 in the Houston metropolitan area, and a damage estimate of approximately $125 billion (Blake et al., 2017).

A socio-economic analysis of flooded areas in Houston due to Hurricane Harvey determined that African American and Latinx neighborhoods and communities with low socio-economic-status experienced statistically significant increases in flood extent, including flood depth and flood area, compared to non-Hispanic white and average socio-economic-status neighborhoods (Chakraborty et al., 2019). Another socio-economic analysis on Hispanic immigrants in flood areas in Houston indicated that Hispanics not born in the U.S. are more likely to reside in 1%-annual-chance flood areas than Hispanics born in the U.S., Non-Hispanic blacks, and non-Hispanic whites. Specifically, non-Hispanic whites were found least likely to inhabit a flood area (Maldonado et al., 2016). These findings are consistent with environmental justice literature.

D. Record Floods in Thurston County

Thurston County is at a high risk of flood events. From 1955-2016, the county was declared a federal disaster area 16 times in relation to flooding. Thurston County does not have data for all past recorded flood events that have occurred in flood areas, but there is data on numerous major floods in the region (Thurston Regional Planning Council, 2013). Among the most notable are floods that occurred in 2009, 2007, 1996, and 1990.

i. January, 2009 Flood

In January 2009, heavy rainfall struck western Washington, following one of the biggest snow storms in several decades. Nine counties were impacted, including Thurston County, and a presidential disaster declaration was issued for each (U.S. Geological Survey, 2010). The Chehalis, Nisqually, Black, Deschutes, and Skookumchuck rivers all reached high levels, and several rose significantly above their flood stages (Thurston Regional Planning Council, 2013). A flood stage is the level a body of water reaches that is determined to cause damage to surrounding areas (Langbein & Iseri, 1960). The Skookumchuck crested at a record 17.7 feet (4 feet above the flood stage), and the Chehalis crested at 18.1 feet (4 feet above the flood stage) (Thurston Regional Planning Council, 2013, p. 6-9). Olympia reached a daily record of 4.8 inches of rainfall (U.S. Department of Commerce, NOAA, 2020). Interstate-5 was flooded and a 20-mile section of the interstate was closed for 2 days. A peak total of 49 county roads were closed during the flood (Thurston Regional Planning Council, 2013, p. 6-9). A total of 497 homes were destroyed and over 2,000 were damaged. Approximately $72 million in total damages resulted from this flood (U.S. Department of Commerce, NOAA, 2020). The damaged cost for homes in Thurston County is estimated at $3 million (Thurston Regional Planning Council, 2013).

ii. December, 2007 Flood

In December 2007, three storms caused torrential rain and flooding in western Washington, impacting Snohomish, King, Mason, Lewis, Kitsap and Thurston Counties. The total rainfall was over 19 inches (U.S. Department of Commerce, NOAA, 2020). The Deschutes and Black Rivers flooded over their banks, and the Chehalis River experienced record flooding due to rain combined with heavy amounts of snowfall, cresting at 20.2 feet (6 feet above the flood stage). A 20-mile stretch of Interstate-5 was closed for 5 days, and 44 roads and bridges closed in Thurston County (Thurston Regional Planning Council, 2013). More than 130 people were evacuated by helicopter, and 2 people died (U.S. Department of Commerce, NOAA, 2020).

The west side of Olympia experienced its most severe flooding in history, receiving a total of 10 inches of rain. The third storm caused rainfall at 100-year-flood levels in just 6 hours. The intense rainfall and subsequent run-off overwhelmed the Budd Inlet Sewer Treatment Plant so much that it was forced to discharge untreated wastewater into Budd Inlet at a rate of 1 million gallons per hour, contaminating wells and water supplies in unincorporated Thurston County. An estimated 267 Thurston County residents applied for FEMA aid, and property damage claims exceeded $6 million (Thurston Regional Planning Council, 2013). The flooding also caused more than 2,000 landslides throughout the region, resulting in further damage and need for aid (U.S. Department of Commerce, NOAA, 2020).

iii. Other Notable Floods

In December 1996, the Pacific Northwest experienced record rainfall, including western Oregon, western Washington, and northern California, resulting in flooding. In western Washington, the rainfall was twice the monthly average (U.S. Department of Commerce, NOAA, 2020). The flood inundated 200 homes and contaminated hundreds of drinking wells in Thurston County. Many uninsured homes and other private properties were damaged or destroyed, resulting in uninsured losses totaling $1.75 million (Thurston Regional Planning Council, 2013).

In February 1996, heavy rains caused flooding that impacted 24 counties in Washington. A total of 2,600 homes were flooded, and total damage costs in all counties is $120 million from floods, mudslides, and avalanches. There were 2 deaths (U.S. Department of Commerce, NOAA, 2020). The flood also destroyed nearly 50 homes in the Nisqually Valley, and almost 1,000 people were evacuated from their homes in Thurston County (Thurston Regional Planning Council, 2013).

In January 1990, an intense storm flooded Oregon and western Washington. A federal disaster declaration was issued for 6 counties in Washington, including Thurston County (U.S. Geological Survey, 1996). The Chehalis, Nisqually, Deschutes, Skookumchuck, and Puyallup Rivers all experienced major flooding (Thurston Regional Planning Council, 2013; U.S. Geological Survey, 1996). The Chehalis River experienced the most significant flooding, cresting at 17.1 feet (6 feet over the flood stage). A portion of Interstate-5 was under 5 feet of water and was closed for several days. In Bucoda, floods got up to 4 feet on some streets, and more than 600 people were evacuated. Two people died in Lewis County (Thurston Regional Planning Council, 2013).

E. FEMA Flood Mitigation Programs

FEMA offers flood protection through the National Flood Insurance Program (NFIP), which is made available to business owners, renters, and homeowners in flood areas. The NFIP was created through the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1972. The National Flood Insurance Act marked the initial availability of flood insurance. Prior to this act, flood insurance was unavailable. The Flood Disaster Protection Act required homeowners and businesses in flood areas to purchase flood insurance (FEMA, 2014). Communities that elect to participate in the NFIP receive discounted premiums in exchange for implementing minimal floodplain regulations (FEMA, 2020d; Thurston Regional Planning Council, 2013). The regulations are as follows:

- *"New buildings and those undergoing substantial improvements must, at a minimum, be elevated to protect against damage by the 100-year flood."*
- *"New floodplain development must not aggravate existing flood problems or increase damage to other properties."*
- *"New floodplain development must exercise a reasonable and prudent effort to reduce its adverse impacts on threatened salmonid species."*
  (Thurston Regional Planning Council, 2013, p. 4-1).

FEMA creates Flood Insurance Rate Maps (FIRMs) for communities that participate in the NFIP. These maps classify flood areas and determine insurance premiums for buildings within these areas. Buildings that are constructed after FIRMs are created qualify for reduced insurance premiums and are less vulnerable to floods due to updated building construction regulations that mitigate flood damage. These updates were not incorporated in buildings constructed before FIRMs were established, making these buildings more vulnerable to floods (Thurston Regional Planning Council, 2013).

According to the U.S. General Accounting Office (GAO), as of 2018, the NFIP is $20.5 billion in debt. This debt is due to FEMA's efforts to make NFIP premiums affordable, which has led to insufficient funds to cover damage costs. Catastrophic flood damage from hurricanes, notably Hurricanes Irma, Harvey, Maria, and Katrina have worsened this issue. The GAO recommends a comprehensive reform of the NFIP. FEMA has taken initiatives to follow the GAO's recommendations, including updating its methodology for determining premium rates in 2019 to improve the NFIP's fiscal solvency; however, Congress has yet to enact a comprehensive reform of the program (U.S. Government Accountability Office, 2019).

Thurston County has participated in the NFIP since 1982, and unincorporated Thurston County is a participant in the Community Rating System (CRS) (Thurston Regional Planning Council, 2013). The CRS is a FEMA program that communities elect to participate in which exceeds minimal flood mitigation regulations required by the NFIP. The CRS rates communities based on their adherence to flood mitigation strategies including "public information, mapping and regulations, flood damage reduction, and flood preparedness" (Thurston Regional Planning Council, 2013, p. 4-2). The rating scale is from 1-10, 1 being the highest possible rating. The ratings determine how much of a discount on NFIP premiums an area receives. Thurston County received a rating of 2 in 2016, which qualifies county residents for a 40% discount (Thurston Regional Planning Council, 2020b). Thurston County is among the top 9 regions in the U.S. that have the highest CRS score. Roseville, California has the highest rating of 1, and the other 8 communities have class 2 ratings, including Thurston, King, and Pierce Counties (FEMA, 2020a).

Some NFIP-insured properties experience repetitive flood damages. The NFIP considers some of these homes or buildings to be "repetitive loss" properties. Repetitive loss properties are properties that have experienced at least one of the following since 1978:

- at least 4 paid losses exceeding $1,000

- 2 paid losses exceeding $1,000 within a 10-year period
- 3 or more paid losses equal or greater to the value of the home (FEMA Federal Insurance and Mitigation Administration, 2019).

In 1998, FEMA estimated that there are 75,000 repetitive loss properties nationally, for which the NFIP has paid $2.8 billion in insurance claim payments. Repetitive loss properties qualify for FEMA grants to assist with flood mitigation. FEMA keeps record of repetitive loss properties, but communities that participate in the CRS are also required to keep record of repetitive loss properties. This is to account for repetitive loss properties in areas where NFIP coverage was not available at the time of the flood damage. Unincorporated Thurston County has approximately 42 repetitive loss properties (Figure 4). No data is available for incorporated Thurston County because those communities do not participate in the CRS (Thurston Regional Planning Council, 2013).

The NFIP's minimum floodplain regulations do not include retrofitting existing homes to prevent flood damage, but FEMA recommends several strategies for flood mitigation in order to make homes more resilient to flooding. FEMA offers flood hazard mitigation grant programs to help individuals with the cost of these retrofits. Of these, FEMA has a home elevation grant program to help with the costly process of elevating a home above the 100-year-flood line. These grants are available to homeowners who 1) have a flood insurance policy, 2) reside in a flood hazard zone, and 3) are repetitive loss properties, or have had at least one damage claim (FEMA, 2015; FEMA Federal Insurance and Mitigation Administration, 2019; Thurston Regional Planning Council, 2013).

TRPC states in their Flood Hazard Mitigation Plan that their priorities include identifying residences that are at high risk for floods for which home elevation or other mitigation strategies like relocation or buyout are attainable, and locating and allocating funds for these projects. TRPC has also expressed an interest in developing an equitable system for allocating FEMA grants for home elevations, for which the requirements are based on the number of insurance claims a property has filed (A. Osterberg, Personal Communication, Oct 30, 2019; FEMA, 2015). FEMA grant awards do not factor in race or income, which are identifiers for flood vulnerability and environmental justice (FEMA, 2015).

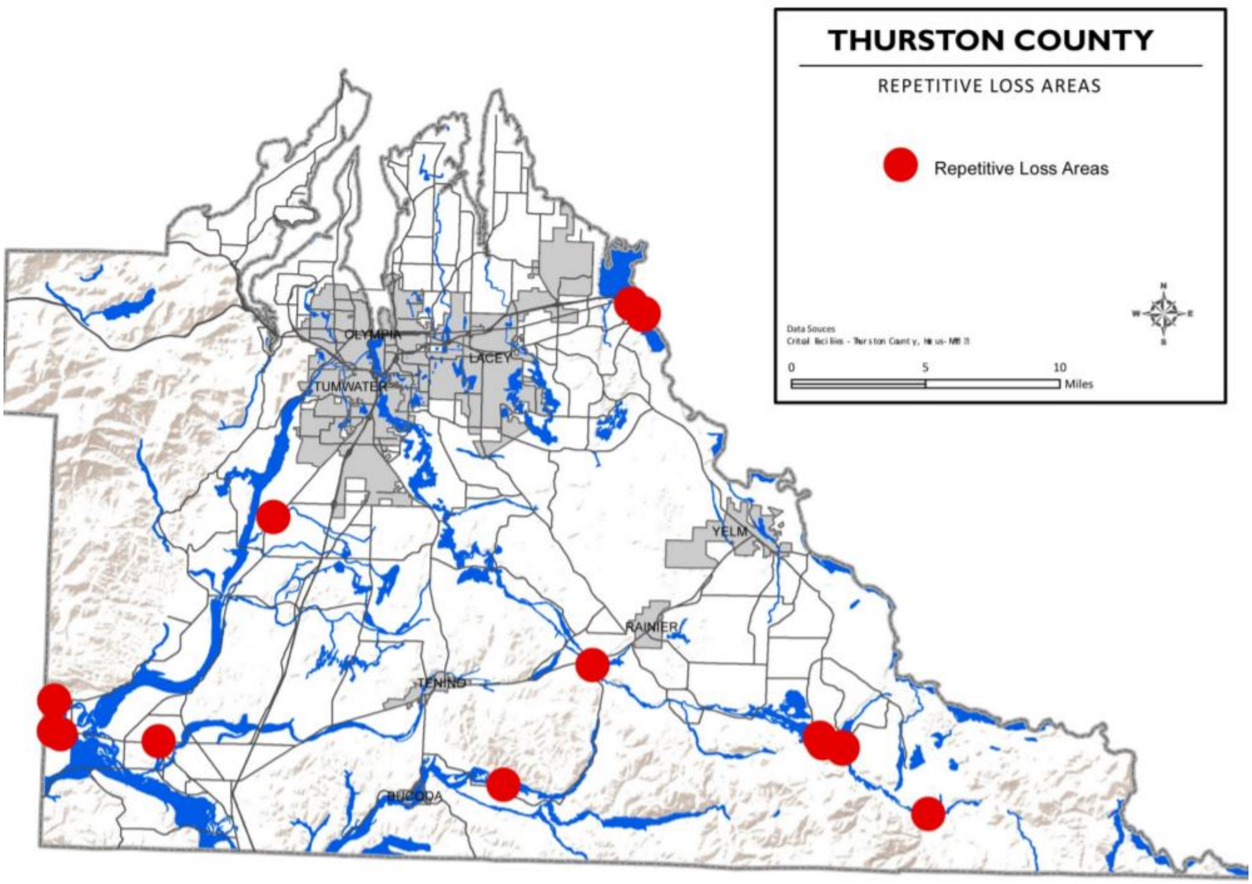

Figure 4: Map of repetitive loss properties in unincorporated Thurston County. Map sourced from Thurston Regional Planning Council.

F. Flood Mitigation in Other Western Washington Counties

Thurston County is not the only western Washington county committed to flood mitigation. Pierce and King counties also participate in the NFIP and the CRS, and are alongside Thurston County in the top 9 municipalities in the U.S. for flood mitigation. These counties also prioritize socially vulnerable populations by creating goals to support these communities.

i. Pierce County

In Pierce County's Hazard Mitigation Plan, the county identifies areas that are at risk of flooding by doing a vulnerability assessment, as well as estimating the economic impacts of a flood event. However, the county has not completed a vulnerability analysis that is focused on identifying populations who are most vulnerable to floods (Pierce County, 2019a). Pierce County Emergency Management recognizes populations who are at a higher risk of natural disasters, including flooding. These populations include people who are disabled, elderly, children, and/or low-income; race is not included in their assessment of vulnerable persons.

Pierce County is making efforts to support hazard mitigation for vulnerable populations. Pierce County Emergency Management offers free emergency preparedness workshops and classes to individuals who are disabled, caregivers, or work with the elderly. These offerings are geared towards the inclusivity of disabled persons in disaster operations (Pierce County, 2019b). Although these workshops may be helpful to the disabled, the county is not including all vulnerable populations in their hazard mitigation efforts.

The county has acknowledged that it has more work to do in order to meet the needs of all at-risk populations. Pierce County Emergency Management is actively holding meetings to develop solutions to support vulnerable persons during a hazard event. One of their goals is to provide alerts and emergency preparedness materials in multiple languages, including American

Sign Language. These goals are anticipated to be incorporated into the updated Hazard Mitigation Plan (Mcwha, 2019).

ii. King County

King County is committed to creating a more equitable community and reducing social vulnerability as much as possible. The county's Regional Hazard Mitigation Plan (RHMP) provides an overview of natural disasters King County is vulnerable to. In the plan, King County outlines their vulnerability assessment of populations at risk of disasters, including floods, using an extensive list of 29 data factors that have been found to increase losses and/or recovery times following hazard events. Race and income are included in the list of factors, along with population, socio-economic, and accessibility variables. The county mapped several of these data factors, including median household income, people of color, people with disabilities, and homeowners, and found that the areas with the highest social vulnerability are also areas with the highest risk to floods and other hazards. In the RHMP, the county expresses that investing in these areas is one way they aim to reduce social vulnerability to hazards (King County Emergency Management, 2020). Specifically, the county identifies 14 determinants of equity and social justice to invest in. These range from access to health and human services to affordable housing. These key areas for investment will be featured in the 2020 update of the King County Regional Hazard Mitigation Plan which has not yet been completed (King County Emergency Management, 2019).

The county also has an Office of Equity and Social Justice (OESJ) which launched in 2008. The OESJ's vision is to create a "King County where all people have equitable opportunities to thrive" (King County Office of Equity and Social Justice, 2014). The OESJ recognizes that "race and place" play an important role in a community's safety and well-being.

It identifies that minorities, low-income populations, immigrants, and refugees do not benefit from the same resources and opportunities as white and higher socio-economic status communities (Beatty & Foster, 2015). In 2016, the OESJ created an Equity and Social Justice Strategic Plan which outlines objectives for achieving their vision. For example, investing in community partnerships and social services like education, jobs, affordable housing, and health care. Many of these overlap with the investment areas to be included in the updated RHMP. Although these objectives do not seem to be directly related to reducing flood risk, they are helping to create more resilient communities. As a result, reduced social vulnerability in flood areas is likely to lead to more disaster preparedness and better mitigation strategies (King County, 2015).

G. Climate Change and Flood Risk

Climate change is predicted to impact Thurston County significantly over the course of the 21st century (Mauger et al., 2015; Thurston Regional Planning Council, 2013). The main areas of impact on flooding are temperature, heavy rainfall, and sea level rise. Temperatures are rising at a faster rate than ever before. From 1894 to 2014, the Puget Sound area warmed 1.3°F (Vose et al., 2014). By the 2050s, temperatures are projected to rise anywhere between 3°F and 7°F, depending on greenhouse gas emissions (Mote et al., 2015). Warmer temperatures affect flooding in several ways. During the winter, warmer temperatures result in less snow pack and more rain. Increased rainfall will lead to higher winter stream flows, which can cause riverine flooding. Warmer springs are causing existing snow pack to melt more quickly, creating more runoff which can also cause flooding. In addition, warmer temperatures are contributing to the melting of alpine glaciers in the Puget Sound, which also creates runoff and higher stream flows (Mauger et al., 2015).

Rising sea levels can also increase flood risk. Sea levels are rising in response to warmer temperatures due to melting glaciers and ice caps and a process called thermal expansion (Mauger et al., 2015). Thermal expansion is the expansion of water in response to warmer temperatures, which is causing the global sea level to rise (Mauger et al., 2015; NASA, 2020). Sea level is projected to increase flood risk for the coastal areas of Thurston County. Higher sea levels are expected to inundate parts of downtown Olympia which were not previously affected, and coastal flood areas will change as a result. By the year 2030, sea levels are projected to rise an estimated 6 inches and up to 12 inches by 2050. Sea level rise can also increase the risk of tidal flooding. 100-year-storm tides, which are a temporary rise of coastal sea levels due to storm surges and high astronomical tides, are expected to increase (Clark et al., 2019).

Heavy rainfall is another area of concern. Heavy rains are expected to occur more frequently and intensify as a result of climate change. As mentioned in the Introduction chapter, heavy rains can lead to riverine, groundwater, flash and urban floods (Mauger et al., 2015; Thurston Regional Planning Council, 2013). Warmer temperatures, rising sea levels, and heavy rainfall can impact 1%-annual-chance and 0.2%-annual-chance flood areas by increasing the probability of flooding in these areas (Mauger et al., 2015; Thurston Regional Planning Council, 2013).

III. Methods

Thurston County experiences floods more than any other natural disaster and has been declared a presidential disaster 16 times from major flooding events in the past 48 years (Thurston Regional Planning Council, 2013). The goal of this study is to determine if there is a difference in race and income between block groups with and without homes in flood areas in Thurston County. Research on environmental justice and flooding in cities has identified that minorities and low-income communities are at a higher risk of floods and experience a greater impact from floods (Chakraborty et al., 2019; De Sherbinin & Bardy, 2015; Grineski et al., 2014; Montgomery & Chakraborty, 2015). These cities include New York City, New Jersey, Miami, Houston, and New Orleans.

Thurston County has a smaller population than these cities and is considerably less diverse in terms of poverty and race. On a macro level, Thurston County is predominately white and upper middle class. However, there are pockets of racial diversity as well as poverty in areas of the county. For example, the Nisqually Indian Reservation is partially located in Thurston County, which, at the block group level, has the highest racial minority percentage in the entire county. Because the reservation is located near the Nisqually River, it is also prone to significant flood events. Due to its high flood risk and the variability in race and income that exists, Thurston County is a good candidate for research on environmental justice and flooding.

Six GIS data layers were used (Table 2) in ArcGIS Pro to create a GIS data layer containing all households located in flood areas in Thurston County, including 1%-annual-chance, 0.2%-annual-chance, and undetermined flood areas. There is a total of 1,054 households in the layer. The layer includes homes located in a flood area and excludes residences with only land in a flood area. Homes that are partially located in a flood area were counted with the assumption that the home would be impacted by a flood. Based on where the homes in flood areas were located, 2 block group samples were created: block groups with homes in flood areas and block groups without homes in flood areas. Six demographic variables were selected to test, including 5 income variables and 1 racial minority variable (Table *3*). A 2-sample or Welch's t-test was completed for each variable.

This chapter includes the data sources used for this research and explains how the data was used, as well as disclaimers for using the data. It also describes the methodology for identifying homes located in flood areas to create a GIS layer. In addition, this chapter lists the study design of this research project, including the demographic variables that were selected, where this data is sourced from, and how these variables were used in the analysis.

A. GIS Data Sources and Uses

GIS Data Layers	Sources
National Flood Hazard Layer	FEMA, 2018
Imagery of Thurston County	NAIP, 2017
Thurston County Land Use	TRPC, 2014
Thurston County Parcels	Thurston GeoData Center, 2020
Thurston County Block Groups	Thurston GeoData Center, 2019
Thurston County Building Footprints	Thurston GeoData Center, 2000
Tribal Lands of Washington*	Washington Department of Ecology, 2019

Table 2: GIS data layers and sources used to create GIS layer of homes located in flood areas in Thurston County. *Tribal Lands of Washington was used to determine the Nisqually Indian Reservation boundary.

Six GIS data layers were used to create a layer of all homes located in flood areas in Thurston County (**Error! Reference source not found.**). The National Flood Hazard Layer (NFHL) is created by FEMA and is updated on a monthly basis. The flood risk classifications are primarily 1%-annual-chance, 0.2%-annual-chance flood areas, and minimal risk flood areas. There are several data disclaimers in the NFHL[i].

Aerial imagery of Thurston County from the National Agriculture Imagery Program (NAIP) was used to visualize where homes are located. NAIP imagery is aerial photography taken of agriculture areas during the growing season on a nearly yearly basis and is conducted by the USDA's Farm Service Agency (U.S. Department of Agriculture, 2020). The Thurston County imagery was captured in 2017.

Four data layers sourced from Thurston County were used, including parcels, land use, block groups, and building footprints data. All Thurston County data sets include disclaimers[ii]. The parcel layer contains parcels, which are property boundaries, for all of Thurston County. The parcels data layer indicates whether a parcel is residential or not. The land use data layer includes more specific information about the parcel, including the property type, either residential or commercial, and the use code for the property. Use codes indicate the type of residential or commercial property.

The building footprints layer was created from aerial photography and features polygons that represent buildings (Thurston GeoData Center, 2000). This layer classifies buildings as residential, nonresidential, or "building unsure" if unknown. In this study, the building footprints layer was used to pinpoint the approximate location of homes within parcels to determine if the home lies in a flood area. If the home is not located in a flood area, but the land inside the parcel is, the home was not included in the layer. The building footprints layer was also used to confirm that a specific building was residential, since the parcel and land use layers only list the number of residences and not which buildings are residences. In addition, this layer was used in conjunction with the land use layer to determine the number of homes within parcels when the NAIP imagery did not clearly show visible structures. Lastly, Census block groups, which are boundaries roughly the size of neighborhoods, but vary in size in urban and rural parts of the county, were used to obtain the demographic data at the block group level (Figure 5).

In addition to the GIS data layers used to identify homes in flood areas, 6 demographic variables were used to compare block groups with and block groups without homes in flood areas (Table 3). The data was sourced from Esri[iii], the American Community Survey 5-year estimates[iv], and the U.S. Census[v]. The variables from Esri are 2019 projections based on Census and ACS (American Community Survey) data, along with other public and private data sources, and are conducted on a yearly basis (Esri, 2020). The American Community Survey (ACS) is conducted as an annual, ongoing survey. The ACS releases new data annually and compiles 5-year-estimates (U.S. Census Bureau, 2020a). The 2014-2018 household income below the poverty level is an average based on ACS data from 2014-2018 (Esri, 2020).

Demographic Variable	Source
2019 median household income	Esri, 2019
2019 household income < $15,000	Esri, 2019
2019 household income $15,000-$24,999	Esri, 2019
2019 household income $25,000-$34,999	Esri, 2019
2014-2018 household income below poverty level	Esri, 2019; ACS, 2014-2018
2010 household racial minority	U.S. Census, 2010

Table 3: List of demographic variables selected to measure percentage of income and race in both block group samples.

The federal poverty level is a yearly, national income threshold that is determined by various forms of income before taxes and is adjusted for inflation based on the Consumer Price Index (CPI-U). The threshold varies depending on household makeup and size. A household whose total income falls below the threshold is considered to be in poverty (U.S. Census Bureau, 2020b). The 2018 poverty threshold for a family of 4 with 2 adults and 2 children was $25,465 (U.S. Census Bureau, 2019a). Household racial minority refers to households that contain races and/or ethnicities that are not categorized as white/Caucasian. This variable was calculated by subtracting the percentage of white/Caucasian households from 100%.

B. Methodology for Mapping Homes in Flood Area

All homes located in flood areas were mapped on a GIS layer (Figure 5). This layer contains a total of 1,054 homes. The National Flood Hazard Layer (NFHL) was used to determine where flood areas are located in Thurston County. This analysis included homes in all flood areas in the county, including 1%-annual-chance, 0.2%-annual-chance, and undetermined flood areas. These areas area all referred to as “flood areas”. The GIS layers, excluding the block groups layer, were used in conjunction to determine the number of homes located in a flood area. The parcels layer was used as a visual guide for locating homes in flood areas.

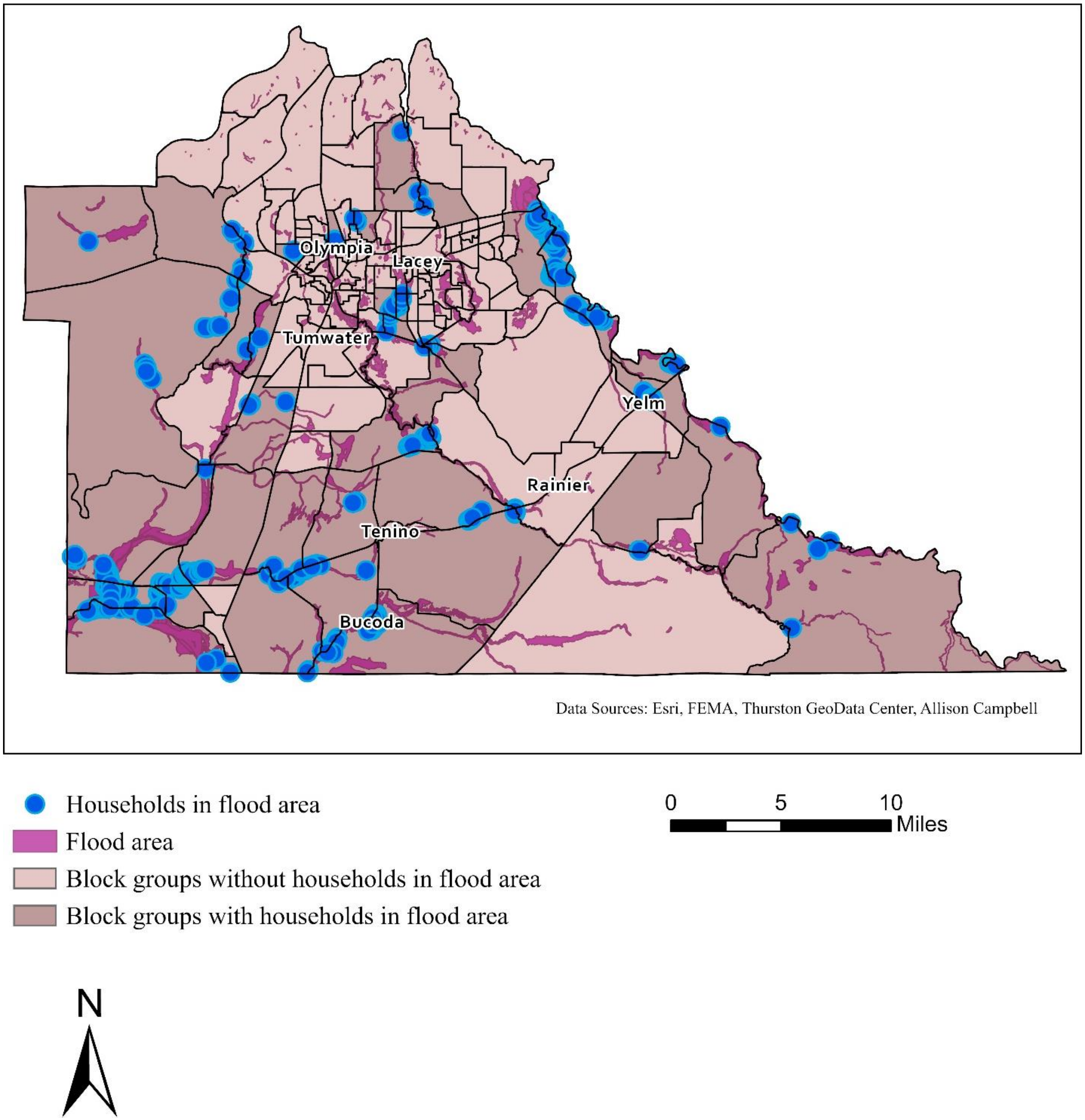

Figure 5: Households in flood areas, flood area, and block group samples. Flood area includes 1%- and 0.2%-annual-chance flood areas, and undetermined flood area.

The land use data layer was used to determine if a parcel was residential, and if so, the number of homes within a parcel. Residential dwellings are classified as either single family dwellings (SF), multiple-family dwellings (MF), or mobile homes (MH), and the quantity of each is listed for every parcel. Some parcels in the county contain multiple single-family homes, in which case, each home was counted. For multiple-family living units, such as apartment buildings and condos, each individual living unit was counted. In some cases, multiple-family living units straddle a flood area boundary. In these cases, the number of living units located in a flood area was determined by dividing up the total number of units by the estimated percentage of the building that is in the flood area. For parcels partially located in a flood area, NAIP and the building blueprints layer were used to determine if the home itself, not the land, is located in a flood area. Parcels with only land in a flood area were excluded. Homes partially located in a flood area were included.

The land use layer also helped differentiate between parcels that contain homes and parcels that are undeveloped land. This was often the case in neighborhoods when the NAIP imagery was not clear enough to see if a home existed within a parcel. The use code given in the land use layer was also used to identify mobile home parks. In Thurston County, there are numerous mobile home parks located in flood areas. Each individual mobile home located in a flood area was counted for this study.

In numerous cases, there were discrepancies between the land use, NAIP, and building footprints layers. In general, the NAIP and land use layers were assumed to be more accurate than the building footprints layer, since they were created more recently. In situations where 2 of the 3 layers had the same information, the two layers in agreeance were assumed to be correct. For example, if the land use layer indicated there is one household located in the parcel, the

NAIP imagery shows two structures, and the building footprints layer confirms that one building is residential, but the other is listed as “building unsure,” it was assumed that the land use and NAIP imagery layers were correct, because they agree with one another. The building footprints layer is from the year 2000, so it is assumed that some residences may not have existed when it was created and may not be accounted for in this layer. There were also instances where the land use layer listed residences in a parcel, but there appeared to be no structures on the NAIP imagery, and the building footprints layer listed no structures. In these situations, it was assumed that no households existed in that parcel.

There were also many instances where the home appeared to be between a parcel boundary. As listed above in the data disclaimers, the parcels boundary, along with all other data layers, contains errors. In these cases, it was assumed that the home was located in one of the parcels. Using the land use layer to confirm the number of dwellings in each parcel, the homes were assumed to be in the parcel that matches the number of dwellings. For example, for a home that appears to be on the boundary of a parcel that contains 1 home to its left and a parcel that contains no home to its left, if the land use confirmed that both parcels contain 1 dwelling, it was assumed that the home was located in the parcel to the right. Confirming which parcel the home belongs to ensured that homes in flood areas were not counted twice. More examples of discrepancies in the data layers and assumptions made can be found in Table 4.

GIS Data Layer Discrepancies	Assumptions
Land use: 1 mobile home dwelling Building footprints: 2 residences NAIP: 2 structures	There are 2 homes, since 2 out of three layers confirm this.
Land use: 1 multiple-family dwelling Building footprints: "Building unsure" NAIP: 1 structure	There is 1 home, since 2 out of three layers confirm this.
Land use: 2 single family dwellings Building footprints: 1 residence, 1 non-residence NAIP: unclear	There are 2 homes, since Land Use layer (2014) is more up-to-date than Buildings Blueprint layer (2000).
Land use: Private/undeveloped land Building footprints: 1 residence NAIP: unclear	There is 1 home, since Land Use layer is more up-to-date than Buildings Blueprint layer.
Land use: 3 single family dwellings Building footprints: 2 residences, 1listed as "building unsure" NAIP: 3 structures	There are 3 homes, since 2 out of 3 layers confirm this.
Land use: 2 mobile home dwellings Building footprints: 1 residence, 1 non-residence NAIP: Unclear	There are 2 mobile homes, since land use layer is more up-to-date than building footprints layer.

Table 4: Examples of GIS data layer discrepancies and assumptions.

C. Study Design

The unit of analysis for this study is all Census block groups, and all Census block groups in Thurston County were analyzed. The dependent variable is a binary indicator of whether or not a block group contains any homes within a flood area. This categorical variable was named Flood, and groups containing homes in flood areas were given a value of 1 and groups not containing homes in flood areas were given a value of 0. For block groups containing homes in flood areas, n=39, and for block groups that do not contain homes in a flood area, n=121. An enrichment was completed on the two Flood variables. An enrichment is a geoprocessing tool that is used to obtain demographic data, such as population, race, income, and education levels. Six demographic variables were selected at the block group level for all block groups in Thurston County, which are the independent variables in this study (Table 3).

Once the enrichment was complete, the attribute table containing all the demographic variables for each block group was exported from ArcGIS Pro to Excel. A t-test was performed using JMP software for each demographic variable; Welch's t-tests were completed for median household income, household income less than $15,000 and households below the poverty level because these variables each had unequal variances. 2-sample t-tests were completed for household income between $15,000-$24,999, household income between $25,000-$34,999, and household racial minority because they each had equal variances. A standard alpha value of 0.05 was selected for all t-tests. One block group was excluded from the analysis[4]. This block group is located in Northeast Thurston County in the Nisqually Reach portion of the Puget Sound. It has a land area of zero and therefore has a population of zero.

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[i] *"Data contained in the NFHL reflects the content of the source materials. Features may have been eliminated or generalized on the source graphic, due to scale and legibility constraints. With new mapping, FEMA plans to maintain full detail in the spatial data it produces. However, older information is often transferred from existing maps where some generalization has taken place. Flood risk data are developed for communities participating in the NFIP for use in insurance rating and for floodplain management. Flood hazard areas are determined using statistical analyses of records of river flow, storm tides, and rainfall; information obtained through consultation with the communities; floodplain topographic surveys; and hydrological and hydraulic analysis…The NFHL consists of vector files and associated attributes produced in conjunction with the hardcopy FEMA FIRM [Flood Rate Insurance Maps]. The published effective FIRM and FIRM Database are issued as the official designation of the SFHAs. As such they are adopted by local communities and form the basis for administration of the NFIP. For these purposes they are authoritative. Provisions exist in the regulations for public review, appeals and corrections of the flood risk information shown to better match real world conditions. As with any engineering analysis of this type, variation from the estimated flood heights and floodplain boundaries is possible"* (FEMA, 2018a).

[ii] *"The Data is collected from various sources and will change over time and without notice. The geographic position of the GIS data may be modified to improve spatial accuracies. Thurston County disclaims responsibility or legal liability for the spatial location of GIS features, and makes no warranty concerning same. It is highly suggested you refresh your copy of the Data at least annually. The Data is provided to you on an 'as is' and 'as*

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[4] The Geographic Identifier (GEOID) of the excluded block group is 530679901000. GEOIDs are ID codes used to identify geographic areas used to gather census data. Block groups are sometimes delineated around large areas without population, such as water bodies and military reservations (U.S. Census Bureau, 2020c).

available' and 'with all faults' basis without any warranty of any kind, express or implied, including without limitation the implied warranties of merchantability, fitness for a particular purpose, accuracy and non-infringement, nor shall the distribution of this information constitute any warranty. The Data is not intended to constitute advice nor is it to be used as a substitute for specific advice from a professional" (Thurston GeoData Center, 2020).

[iii] Esri projections are calculated based on the American Community Survey 5-year estimates. Errors include the same sampling and nonsampling errors associated with the ACS (listed below).

[iv] The American Community Survey 5-year estimates are subject to sampling errors because the data is obtained from population samples, rather than the entire population. Therefore, there is uncertainty in the estimates. In addition, ACS 5-year estimates are subject to nonsampling errors, which include issues with the questionnaire, mistakes when coding responses, and issues with processing data (U.S. Census Bureau, 2016).

[v] The U.S. Census completes a decennial count for population and housing. Errors in counting can occur, including when homes who do not complete the questionnaire, errors in recording the data, and errors in processing the data (U.S. Census Bureau, 2013).

IV. Results

This analysis tested whether there is a difference between block groups with and without households in flood areas for each of the 6 demographic variables: 2019 median household income, 2019 household income less than $15,000, 2019 household income between $15,000 and $24,999, 2019 household income $25,000-$34,999, 2014-2018 household income below poverty level, and 2010 household racial minority. Six t-tests were performed: three 2-sample t-tests for variables with equal variances, and three Welch's t-tests for variables with unequal variances. This section includes the descriptive statistics of the demographic variables as well as the results of each t-test. In addition, graphs that show the distribution of each demographic variables are presented, and each variable is displayed on a map of Thurston County.

	Block groups with households in flood areas	Block groups **without** households in flood areas	Total Sample (Thurston County)
Median household income	$73,579	$71,602	$72,338
Household income < $15,000	1.6% (1,915)	4.7% (5,442)	6.4% (7,357)
Household income $15,000-$24,999	1.8% (2,115)	5.0% (5,748)	6.8% (7,863)
Household income $25,000-$34,999	1.6% (1,827)	4.8% (5,558)	6.4% (7,385)
Households below poverty level	2.4% (2,805)	7.1% (8,179)	9.5% (10,984)
Household racial minority	5.2% (6,036)	18.6% (21,514)	23.9% (27,550)
Total households	24.7% (28,401)	75.3% (86,748)	115,149

Table 5: Descriptive statistics for each variable in block group samples and Thurston County as a whole. Percentages are rounded to the nearest tenth.

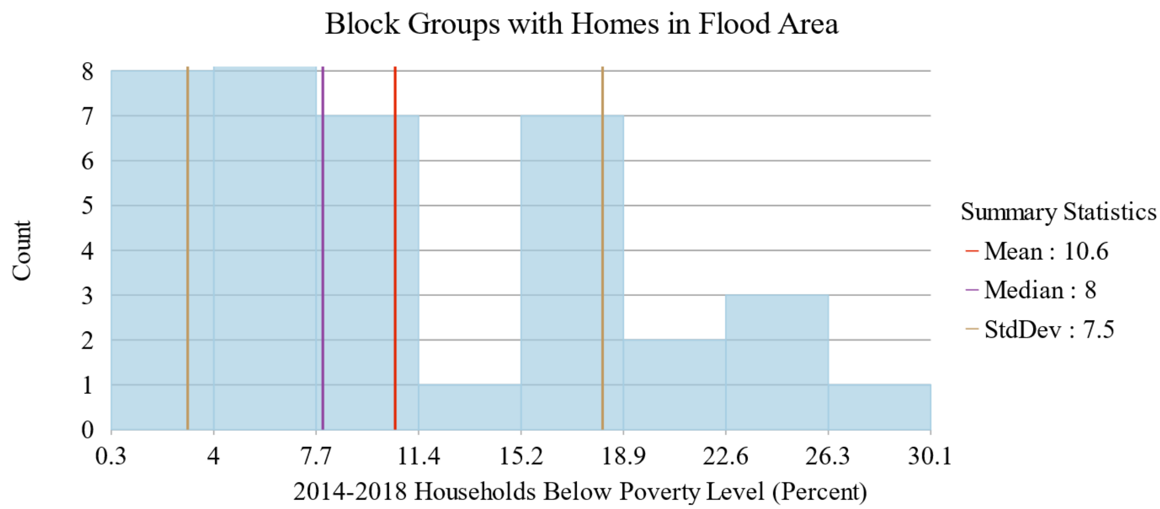
The t-test results for all five income variables indicate no statistical significance; the p-values for each of these values were higher than the alpha value of 0.05 (Table *6*). The Welch's t-test for household racial minority was statistically significant ($p<0.0113$). The block groups without homes in flood areas have a higher percentage of household racial minority than block groups with homes in flood areas.

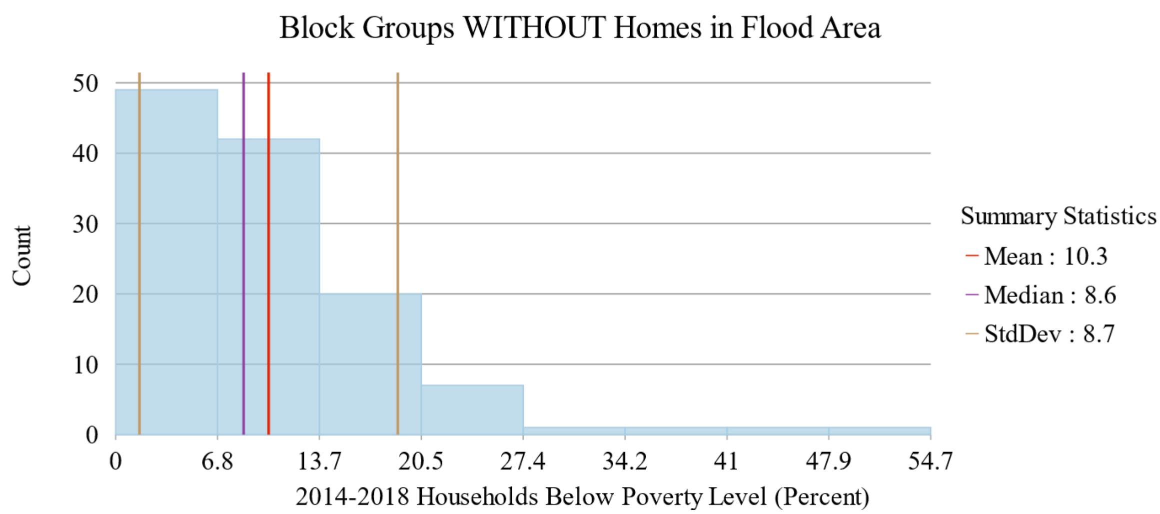
Variable	P-value	T-ratio	Mean Difference	Std. Error Difference
Household income < $15,000	0.8784	0.153769	0.1783	1.1597
Household income $15,000-$24,999	0.7503	0.318844	0.3361	1.0540
Household income $25,000-$34,999	0.7566	-0.31046	-0.2408	0.7757
Median household income	0.8227	0.22495	812.3	3611.1
Households below poverty line	0.8765	0.155916	0.2248	1.4416
Household racial minority	0.0113	-2.56442	-3.4848	1.3589

Table 6: t-test results for all demographic variables.

A. Minority and Poverty Variables

A Welch's t-test was completed for the households below the poverty level variable (Table *6*). Household income below the poverty level was not statistically different between the block group samples ($p<0.877$). The statistics for household income below the poverty line are similar for block groups with and without homes in flood areas. Both samples have a mean of approximately 10%. There are several outliers in the control sample with high minority percentages. The highest is 54.7%, followed by 43.8%, 37.2%, and 31.5%. The highest value in block groups with homes in flood areas is 30%.

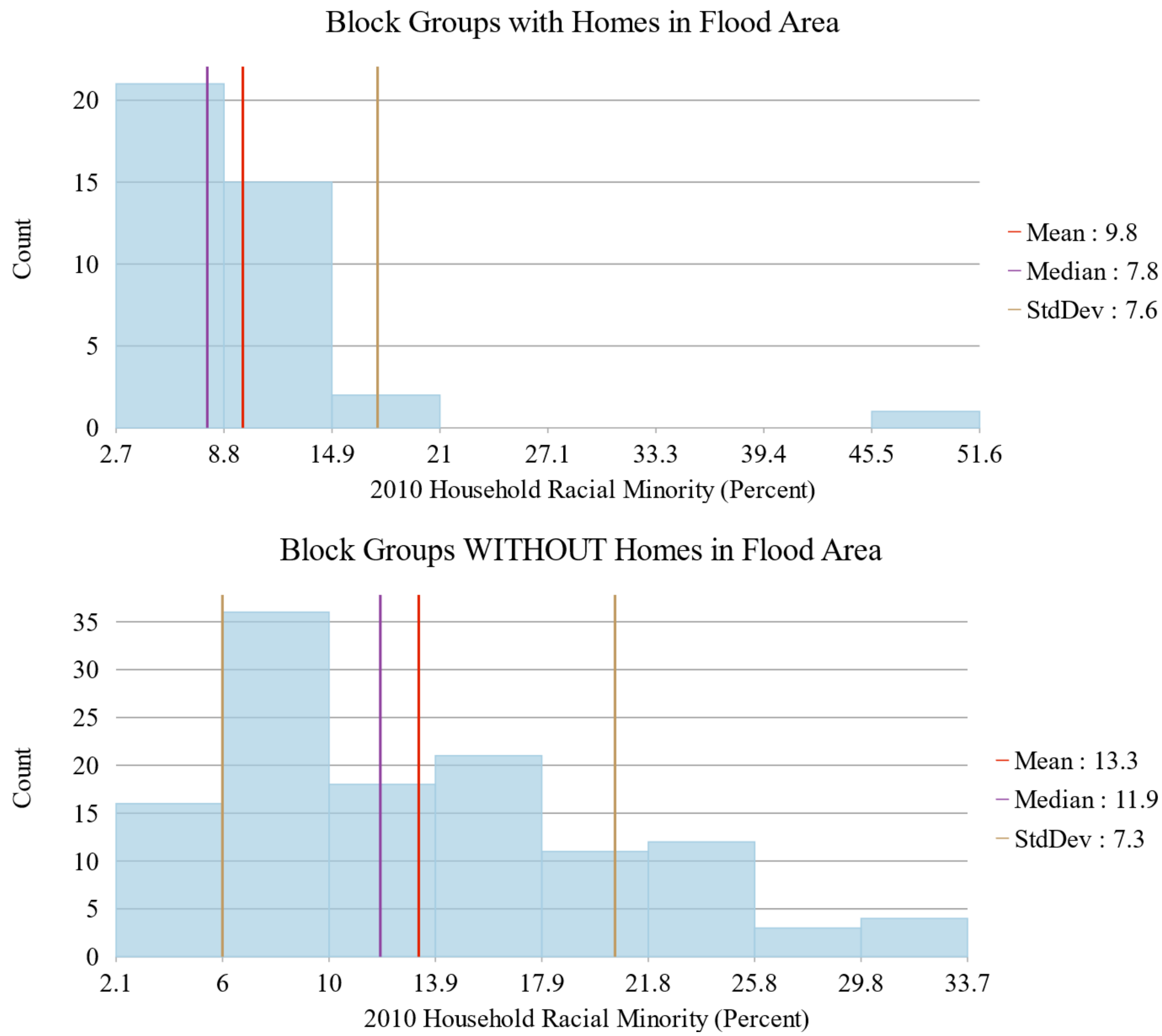




Note: Y-axis scales are different.

Figure 6: Comparison of distribution between 2014-2018 households below the federal poverty level for block groups with and without homes in flood area.

A Welch's t-test was completed for the 2010 household racial minority population variable. The results of the Welch's t-test suggested that the minority population is statistically different between the two block group samples ($p<0.011$). The mean values for block groups with homes in flood areas is 9.8% and 13.3% for block groups without homes in flood areas. Block groups without homes in flood areas have a slightly higher percentage of household racial minority than the block group with homes in flood areas. There is 1 outlier in the block groups with homes in flood areas with a minority percentage of 51.6%. Without this value, the mean and median values for these block groups would be lower.



Note: Y-axis scales are different.

Figure 7: Comparison of distribution between 2019 household racial minority population for block groups with and without homes in flood area.

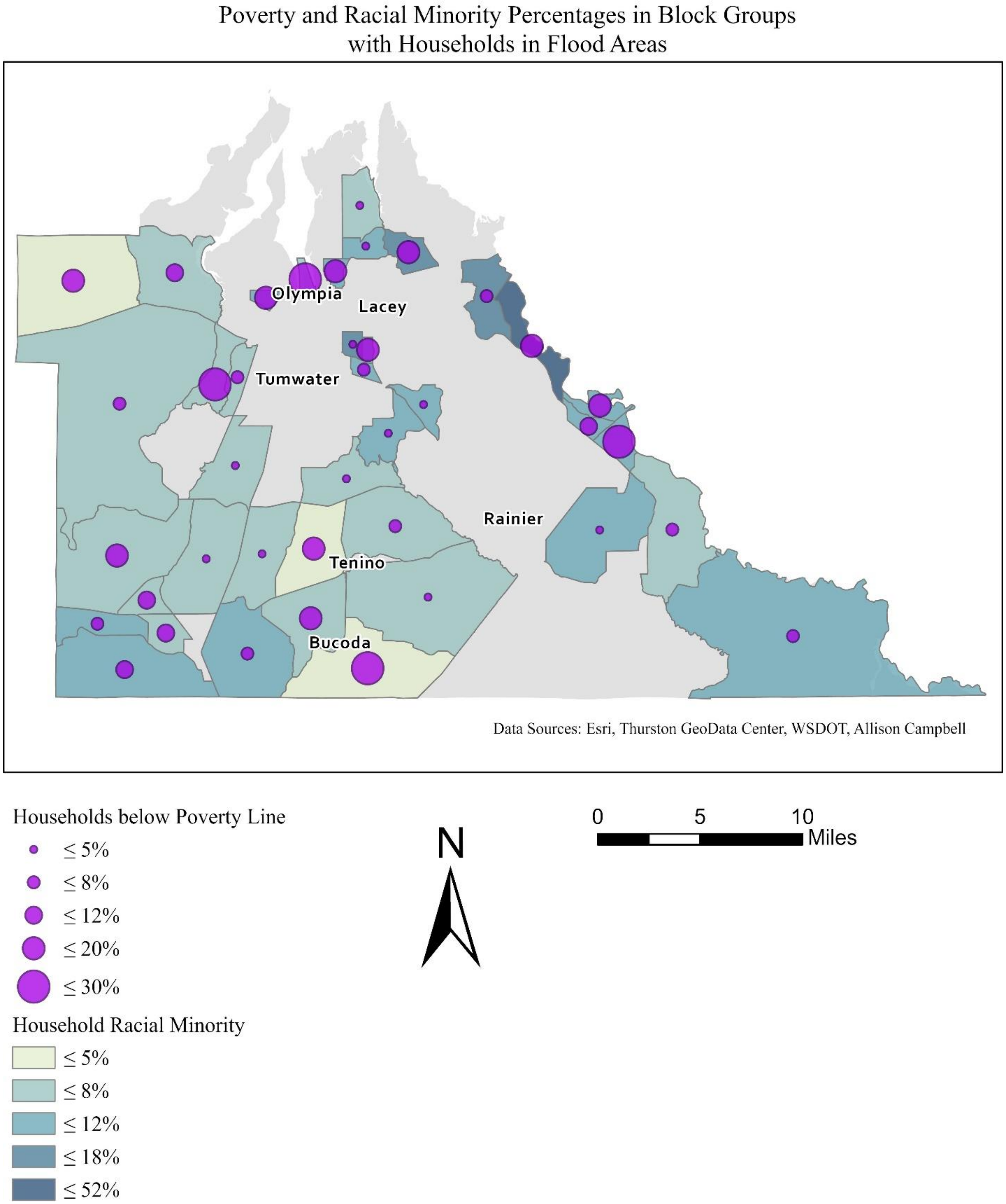


Figure 8: Map of household racial minority and households below poverty line for block groups with households in flood areas.

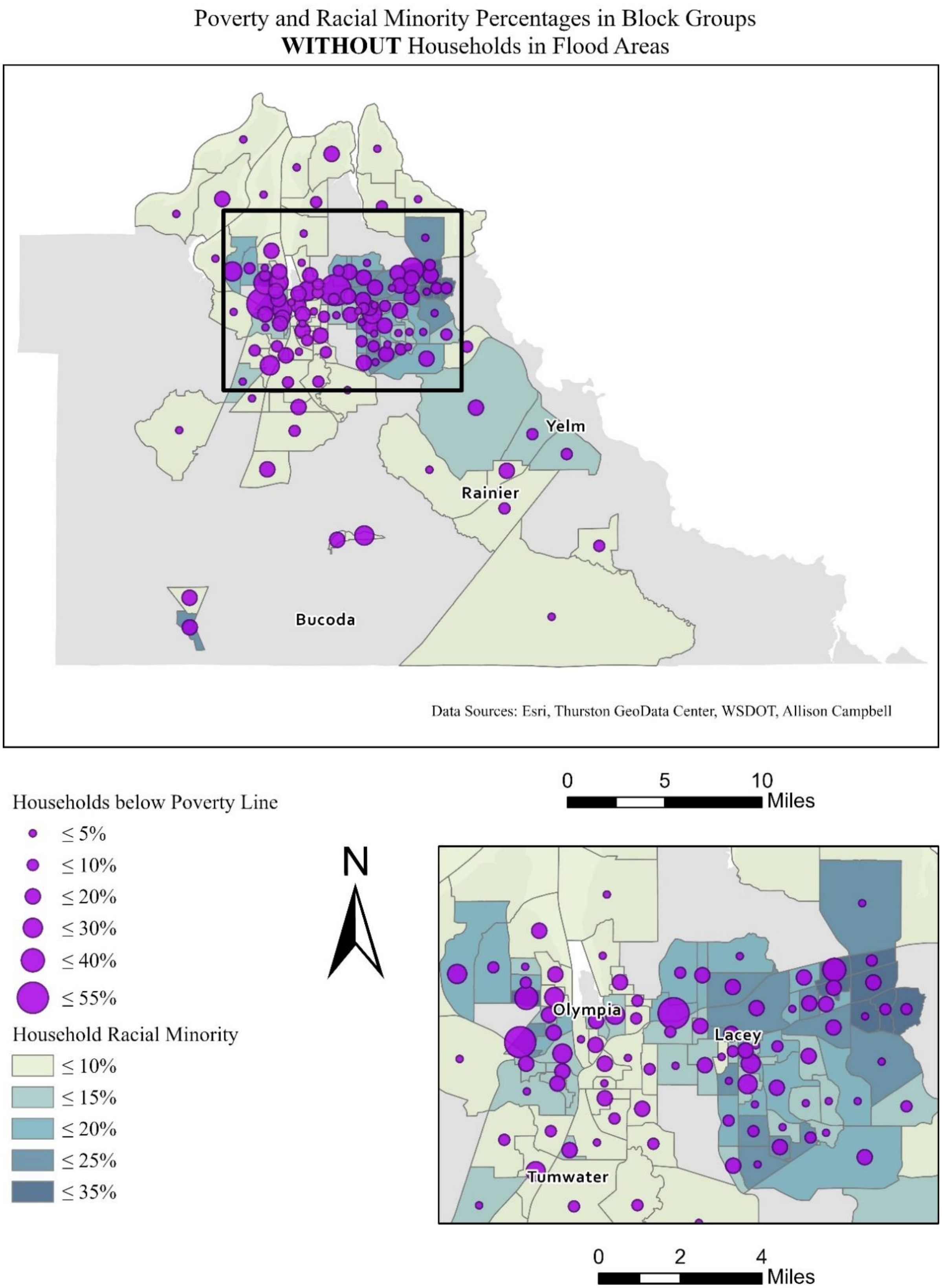
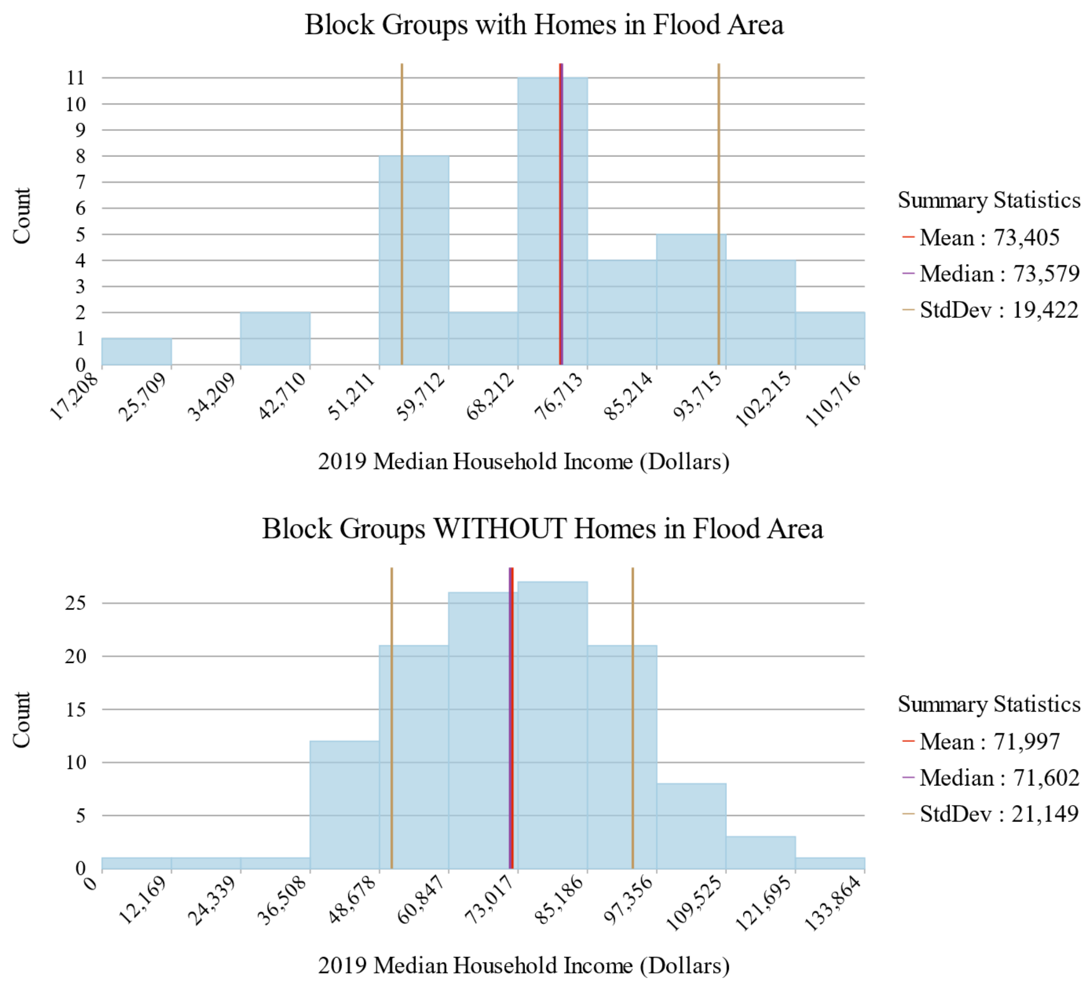


Figure 9: Map of household racial minority and households below poverty line for block groups WITHOUT households in flood area.

B. 2019 Median Household Income

A Welch's t-test was completed for 2019 median household income, and the results are not statistically significant ($p<0.823$). The block group samples have similar statistics. Block groups with homes in flood areas have a slightly higher median of $73,579 compared to $71,602 in block groups without homes in flood areas (Figure 8 and Figure 9). The means for each sample are nearly equal, with a mean of $72,592 for block groups with no homes in a flood area and a mean of $73,404 for block groups that do have homes in a flood area.



Note: Y-axis scales are different.

Figure 10: Comparison of distribution between 2019 median household income for block groups with and without homes in flood area.

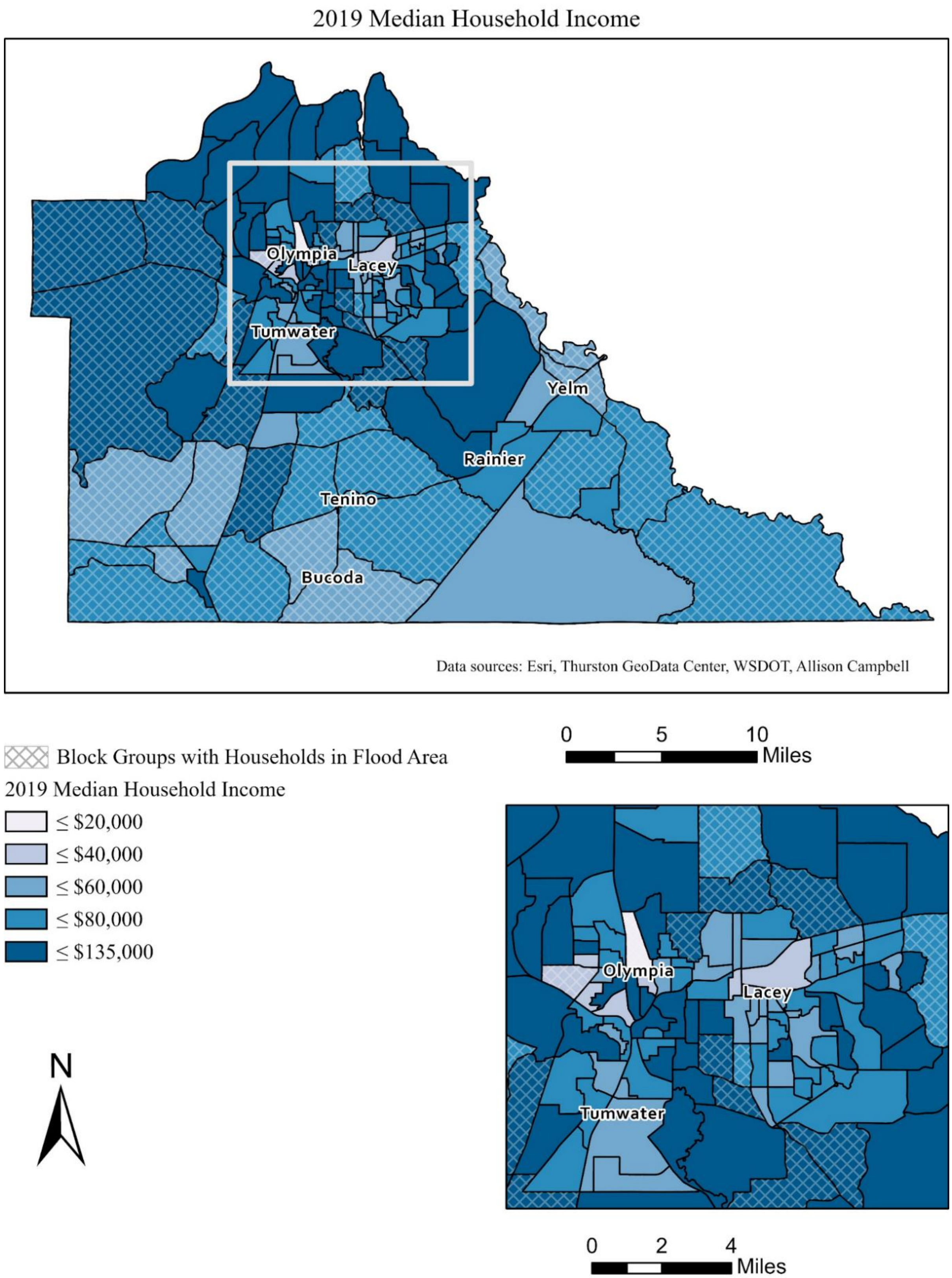
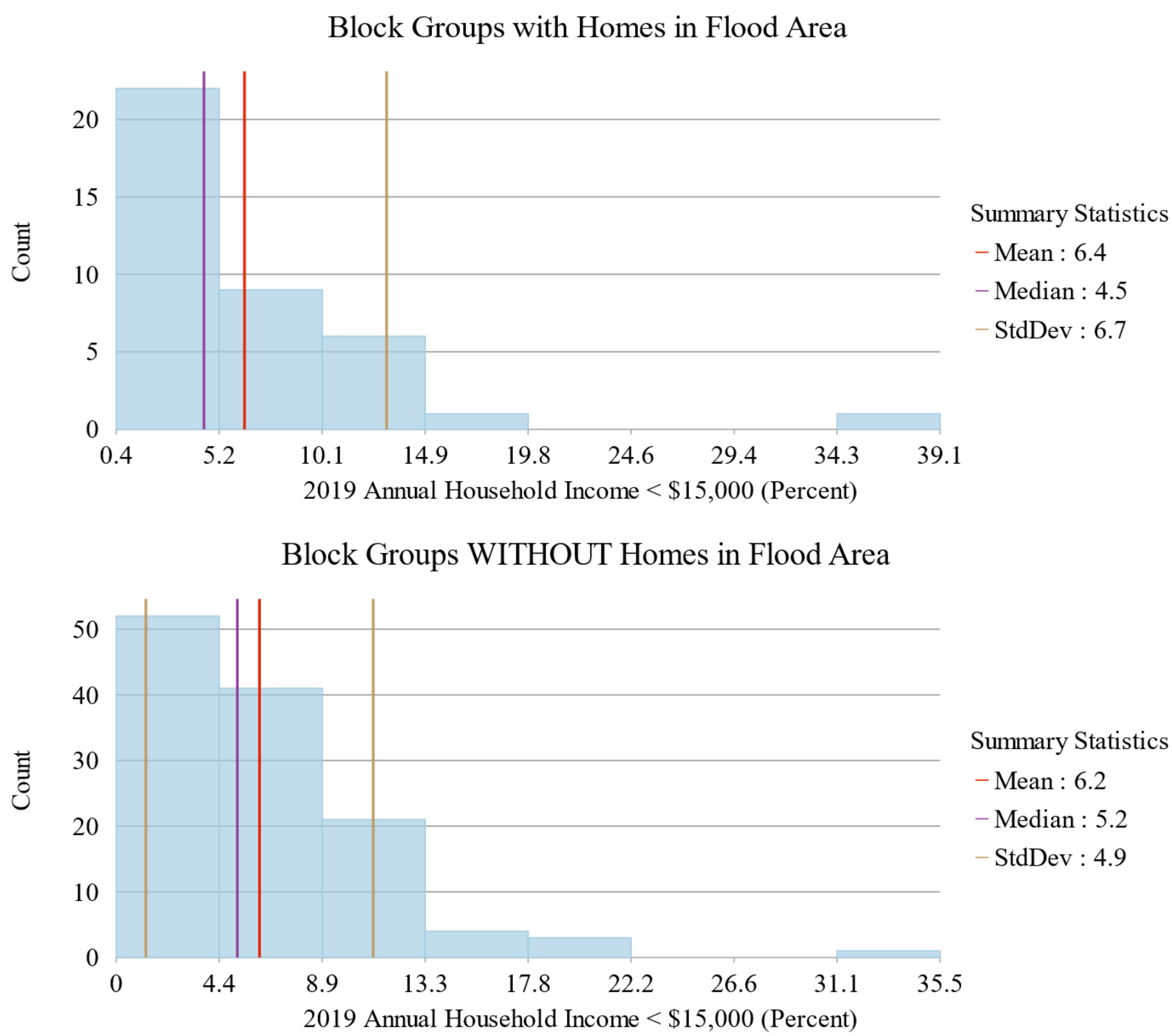


Figure 11: 2019 median household income for block groups with and without homes in flood area.

C. 2019 Household Income less than $15,000

The results of the Welch's t-test for 2019 annual household income less than $15,000 were not statistically significant (p<0.878). This variable is similar between block groups with homes in flood areas and block groups without homes in flood areas, with mean values of 6.4% and 6.2%, respectively (Figure 12). Each distribution is positively skewed due to the low percentage of households with an income of less than $15,000.



Note: Y-axis scales are different.

Figure 12: Comparison of distribution between 2019 annual household income < $15,000 for block groups with and without homes in flood area.

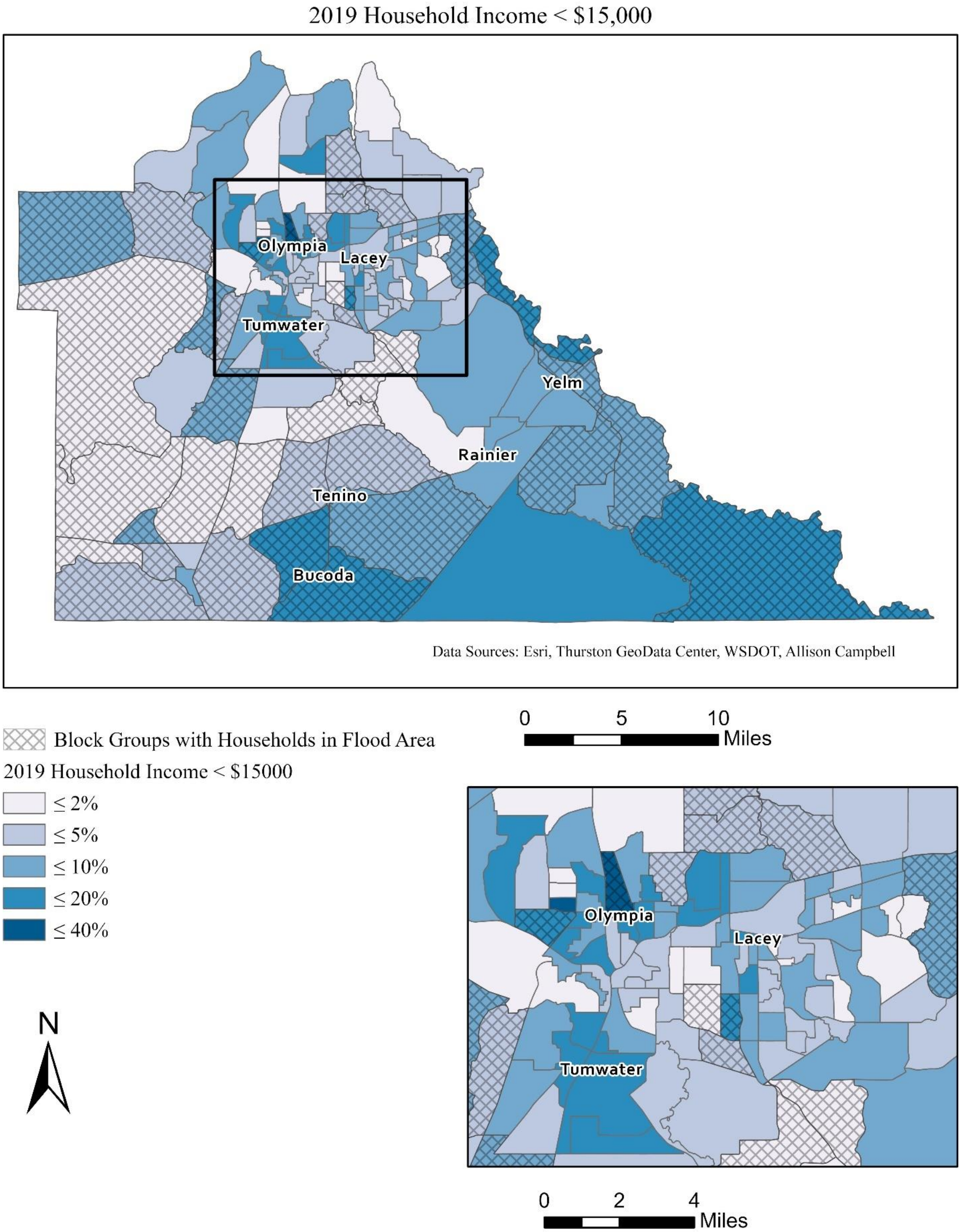
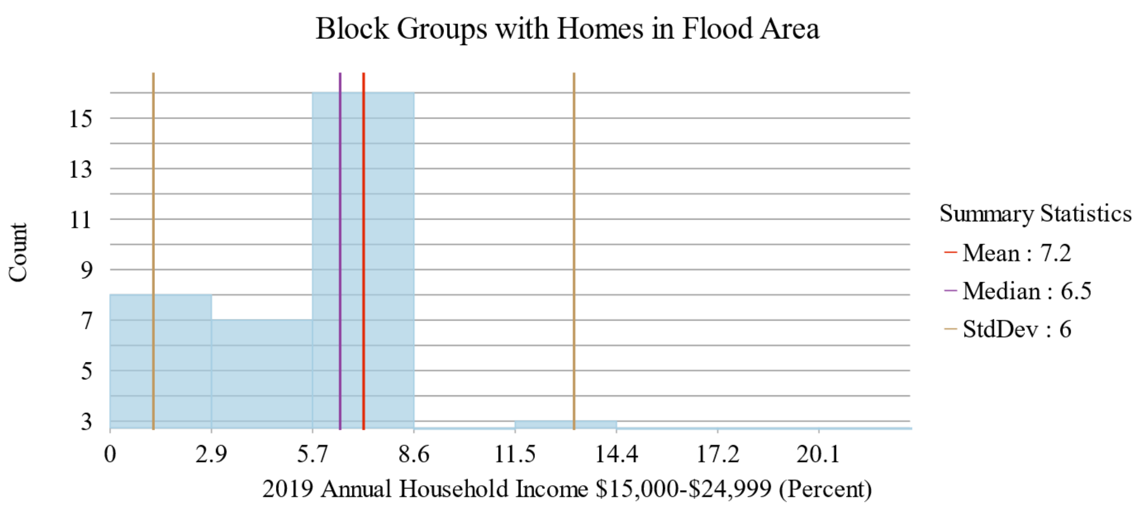
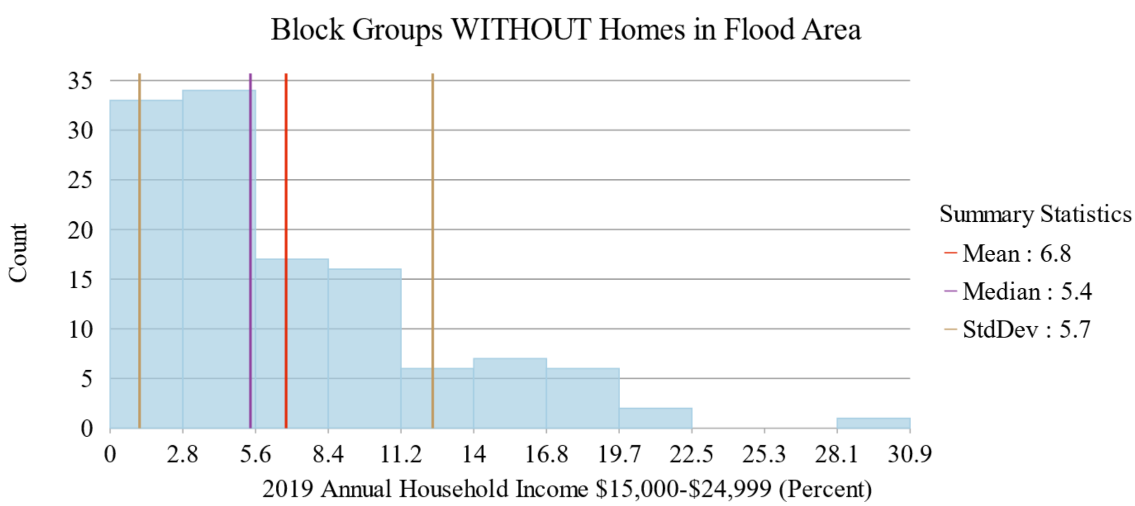


Figure 13: Map of household income < $15,000 for block groups with and without homes in flood area.

D. 2019 Household Income $15,000-$24,999

The 2-sample t-test for 2019 annual household income between $15,000 and $24,999 was not statistically significant ($p<0.750$). The distributions are similarly low between the block group samples. The means are similar; 7.2% for block groups with homes in flood areas and 6.8% for block groups without homes in flood areas. The distributions of each sample are positively skewed.





Note: Y-axis scales are different.

Figure 14: Comparison of distribution between 2019 annual household income of $15,000-$24,999 for block groups with and without homes in flood area.

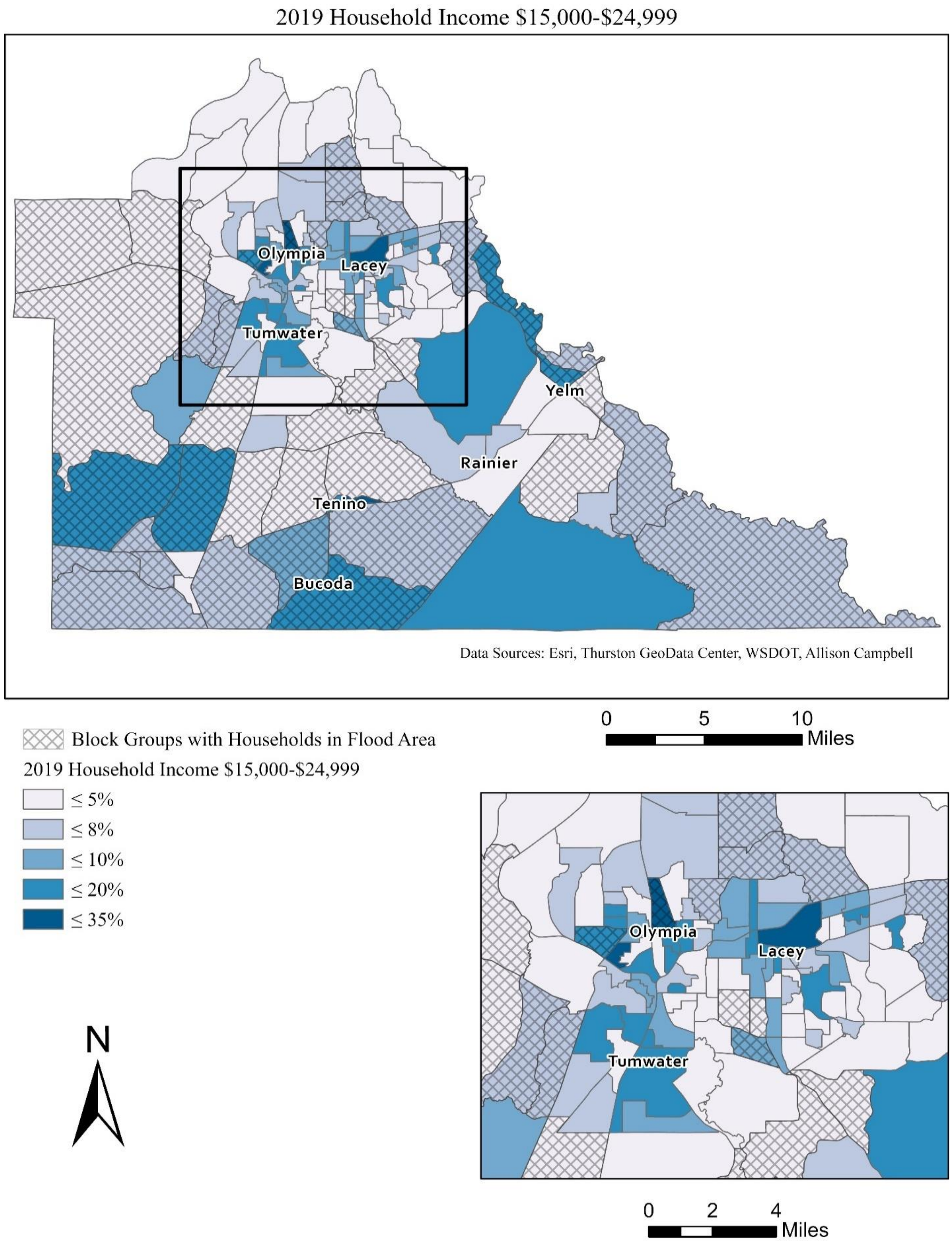
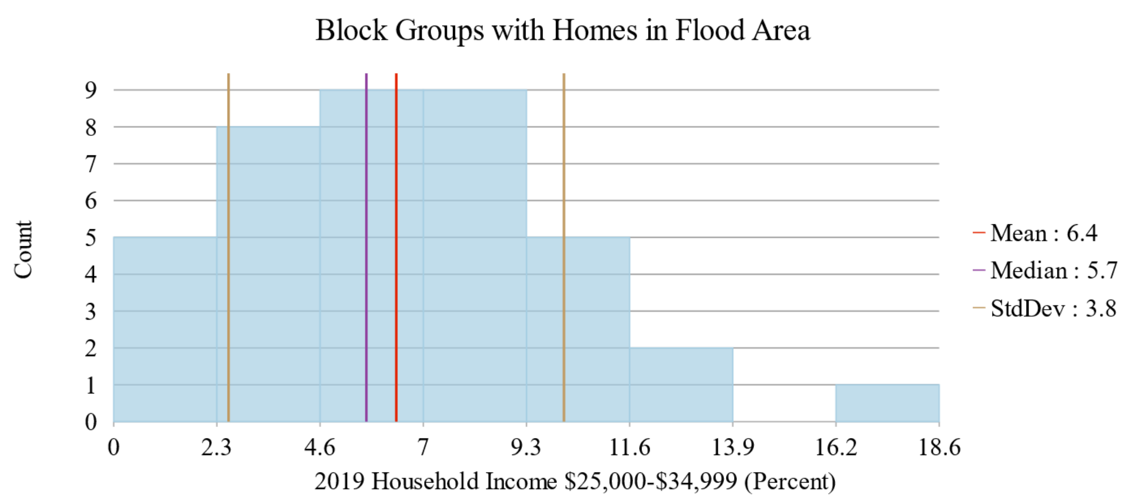
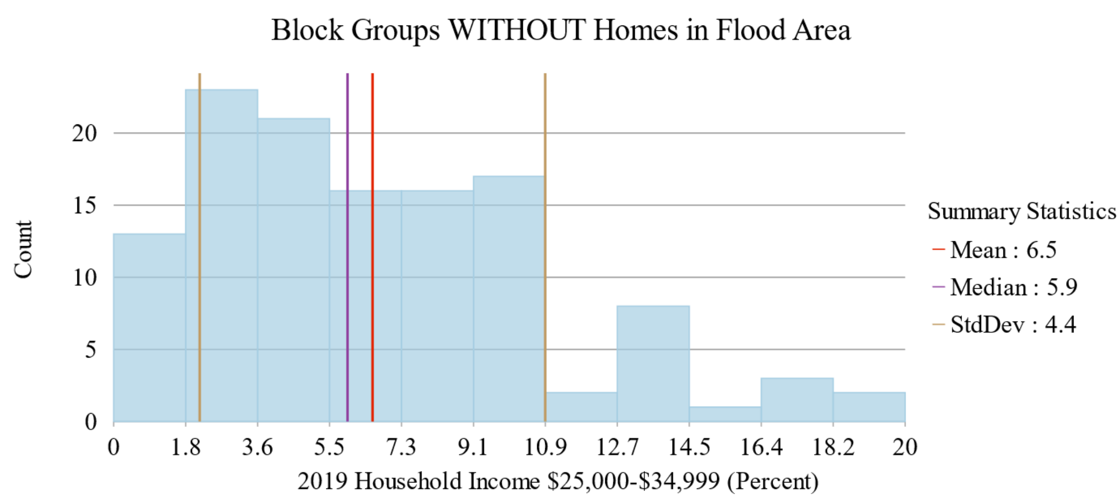


Figure 15: 2019 household income $15,000-$24,999.

E. 2019 Household Income $25,000-$34,999

The 2-sample t-test for 2019 household income of $25,000-$34,999 was not statistically significant (p<0.757). The distribution was similar between block group samples. Block groups with homes in flood areas have mean of 6.4%, while block groups without homes in flood areas have a mean of 6.5%. Each distribution is positively skewed due to the low percentage of households that fall into this income bracket (Figure 16).





Note: Y-axis scales are different.

Figure 16: Comparison of distribution between 2019 household income $25,000-$34,999 in block groups with and without homes in flood area.

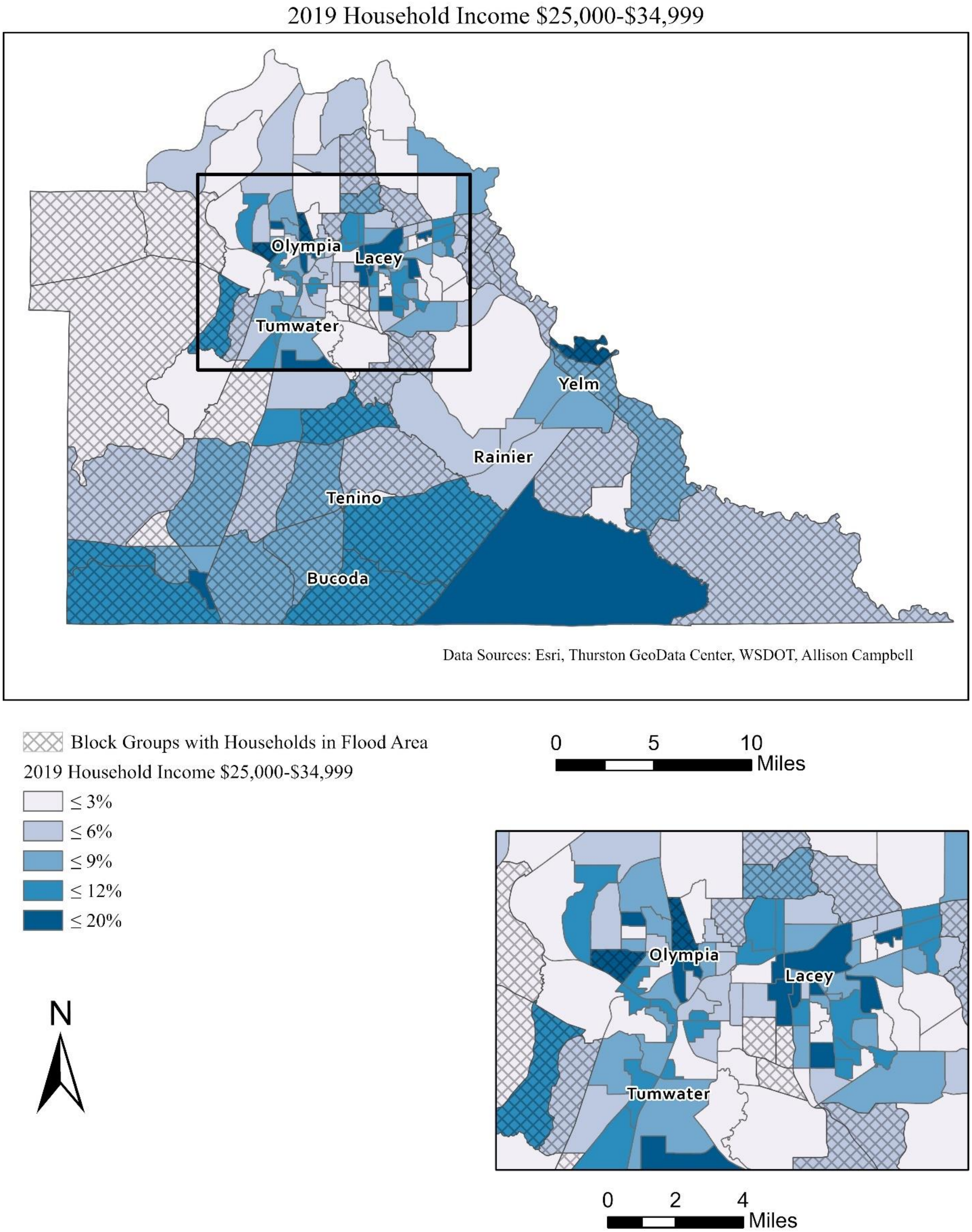


Figure 17: Map of 2019 household income $25,000-$34,999 for block groups with and without homes in flood area.

V. Discussion & Conclusion

A. Discussion

The results of this study indicate that block groups without homes in flood areas have a statistically significant higher percentage of household racial minority than block groups with homes in flood areas. This chapter provides a summary of results and explains the significance of these results. It then takes a closer look at areas of higher minorities and low-income in Thurston County. It also presents the practical and theoretical implications of this study, as well as recommendations for further research in environmental justice and flood risk in Thurston County and other areas at risk of flooding.

i. Thurston County Results

Block groups with homes in flood areas were found to be less racially diverse than block groups without homes in flood areas. Research on environmental justice and flooding has found that in other larger metropolitan areas in the U.S., racial minorities and low-income communities are often more likely to live in a flood area (Maldonado et al., 2016; Montgomery & Chakraborty, 2015). The results of this study are not consistent with much of the literature.

There are several theoretical implications of these results that provide insight into how Thurston County fits into the environmental justice literature on flood risk. First, Thurston County's demographic profile differs from the cities that have been researched: New York City, New Jersey, New Orleans, Miami, and Houston. Thurston County has a much lower population, is mostly white and has a high median household income relative to the national average[5]. These differences offer one explanation as to why the results of this analysis did not reveal

[5] The national median household income was $61,937 in 2018 (U.S. Census Bureau, 2019b).

environmental injustice related to flooding in Thurston County on a macro-level. However, taking a closer look at specific areas of the county paint a different story.

ii. Waterfront Properties

The results of the analysis suggest that residents living in water front properties, specifically those adjacent to lakes and rivers, in Thurston County are predominately white and middle-to-upper class. A closer look at the income and race variables for these block groups reveals that waterfront residents are predominately white; however, the income levels of these block groups vary from low-income to middle-to-high income, relative to the county average. Waterfront properties that are located within flood areas are mainly near rivers and are predominately in more rural parts of the county, including the southwestern portion near Bucoda, Tenino, and unincorporated Thurston County.

On the contrary, most lakefront homes, which typically have higher property values, are located outside the flood area boundary with only the land portion of the parcel inside the flood area. For this reason, these homes were included in the sample of block group without homes in a flood area. These include homes along Black, Hicks, and Long Lakes. Because of the strategic placement of these homes, they were likely built after 1982, when FIRMs were already created and residential planners intentionally constructed homes outside of the flood area boundary. It appears that wealthier Thurston County residents can afford to live in waterfront properties that are not located within a flood area. Had these homes been included in the sample of block groups with homes in a flood area, the results may have shown higher household incomes or lower poverty rates for this block group sample compared to block groups without homes in a flood area.

iii. Nisqually Indian Reservation and Vicinity: A Closer Look

A secondary analysis of Thurston County identified a block group with by far the highest percentage of household racial minority, at 52%, with 17%[6] of households below the poverty level. These figures are substantially higher than the county average[7]. This block group partially overlaps the Nisqually Indian Reservation (Figure *18*). There are 252 homes located in flood areas in this block group, and 201 of these homes are located within the Nisqually Indian Reservation. This is the highest density of homes in a flood area in all of Thurston County.

Thirty percent of the Nisqually Indian Reservation is located in a presumed 1%-annual-chance flood area. This provides evidence that a Nisqually Tribal Member has a higher probability of living in a flood area than a non-tribal member in Thurston County. In addition, when considering relocation as a flood mitigation strategy, tribal members have far fewer options for relocation if they wish to stay within the reservation, compared to a non-tribal member.

The second largest cluster of homes in a flood area is located to the north of the Nisqually block group. 18% of households in this block group belong to a racial minority, and 6% of households are below the poverty level. This block group is slightly more racially diverse and has less households living in poverty than Thurston County as a whole.[8] 152 homes are located in a flood area in this block group, compared to over 200 in the Nisqually block group.

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[6] Percentages have been rounded to the nearest tenth.
[7] In Thurston County, 16% of households belong to a racial minority and 11% are below the poverty line (Thurston Regional Planning Council, 2020a).
[8] In Thurston County, 16% of households belong to a racial minority and 11% are below the poverty line (Thurston Regional Planning Council, 2020a).

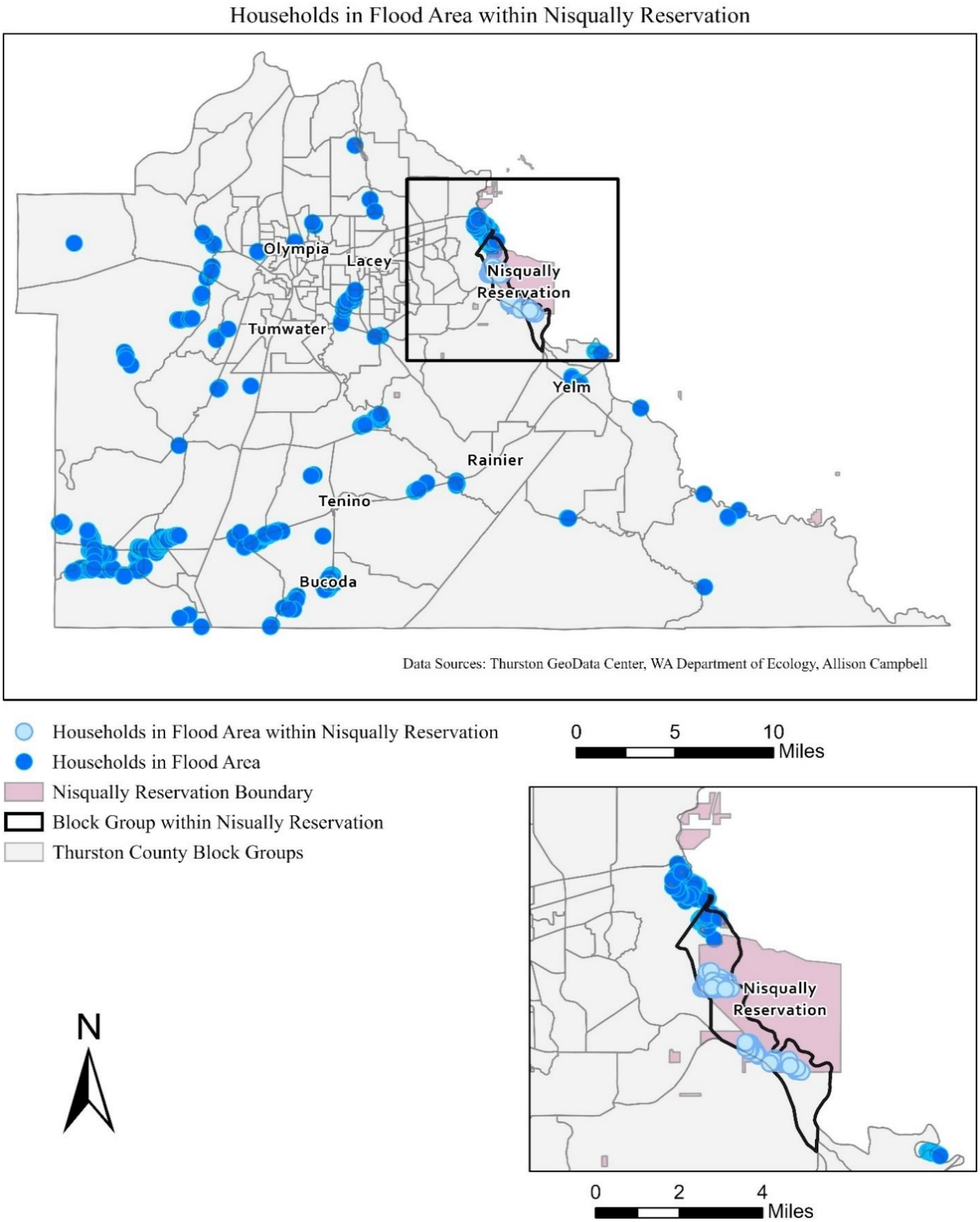

Figure 18: Map of households located in flood areas in Thurston County with emphasis on block group within Nisqually Indian Reservation boundary.

One possible explanation for the slightly higher minority percentage is that Nisqually members may also reside in this block group, as it is near the reservation; however, only 3% of residents in this block group identify as Native American (Esri, 2019). Another reason could be the block group's proximity to the Joint-Lewis McCord Military Base (JBLM), as military families are sometimes more diverse. Because less than half of households in this block group belong to a racial minority compared to the Nisqually block group, and due to its low poverty rate, it is unlikely that race and poverty are indicators of living in a flood zone for Thurston County as a whole, but the Nisqually Indian Reservation provides insight into tribal rights issues.

iv. Budd Inlet and Port of Olympia

The block group with the highest percentage of households below the poverty level, at 30%, is located in downtown Olympia along the coast of Budd Inlet. This block group also has the lowest median household income, approximately $17,000, of all block groups in Thurston County. Possible explanations of this is the location of low-income housing and retirement communities in this block group. The total population in this block group is also on the low end, around 1,000 people, which can possibly skew the poverty proportions. Based on the GIS data layers used to map homes in flood areas, there are only three households located in a flood area in this block group, which is minimal. However, climate change is predicted to impact flood areas due to sea level rise and increased rainfall during the winter due to warmer temperatures. This area is vulnerable to sea level rise, which is projected to increase vulnerability to flooding in coastal areas (Clark et al., 2019; Mauger et al., 2015).

v. Study Limitations

It is important to note the limitations of this study. First, there are known errors in the GIS data layers used to determine households in flood hazard areas. There is variation in estimated flood heights and boundaries in the National Flood Hazard Layer (FEMA, 2018a). The data sourced from Thurston County is not as updated as it could be and may need to be modified to improve spatial accuracies (Thurston GeoData Center, 2020). The demographic data sources also contain limitations worth noting. The American Community Survey 5-year-estimates are based on population samples rather than the entire population, thus they are subject to sampling errors, as well as errors in processing the data (U.S. Census Bureau, 2016).

In addition, there is the possibility of human (researcher) error in creating the households' layer since there were discrepancies between each of the data source layers, and since identification of households was done by hand. Third, a binary measure of whether the block group contains or does not contain households in flood hazard areas does not include a sense of scale for the total households in each block group, so it may not as accurate as nonbinary analysis would be.

vi. Policy Recommendations

Based on the results of this analysis, there are several recommendations for policy makers for Thurston County, other western Washington counties, and other U.S. municipalities at risk of flooding. Firstly, Thurston County should adopt a plan that prioritizes equity and social justice modeled after the King County Office of Equity and Social Justice. Despite Thurston County's high median household income, there are areas of the county that experience high rates of poverty. With growing urbanization trends and rising cost of homes and rental properties in this area and nationally, investing in areas like affordable and safe housing will help to balance out income disparities.

An additional analysis of Thurston County at the block group level should be completed. This data could be used to develop an equitable system for allocating FEMA grants for home elevations, relocations, and buyouts. People of color, low-income/high poverty communities, and disabled individuals should be prioritized for these grants. Members of the Nisqually Tribe should also be prioritized for FEMA grants. In addition, Thurston and Pierce Counties should consider designating an additional portion of land to the Nisqually Tribe in order to relocate communities that are within a flood area. This land would need to be outside of a flood area and would be in addition to the tribe's current reservation. This would be a complex, arduous process that would require numerous stakeholders and negotiations with the tribe and County officials, but it is arguably a crucial step in establishing environmental justice within the tribe.

A similar example is the Quinault Indian Nation, who faces more extreme flood risk. Situated at the coast of the Pacific Ocean and the mouth of the Quinault River, the village of Tahola is at risk of sea level rise, storm surges, and riverine flooding. In order to mitigate flood damage, the Quinault Indian Nation purchased land from the National Park Service. The land is a half mile from the village and outside of a flood area, and the tribe plans to relocate 650 village residents to this area (U.S. EPA, 2019). Similarly, Thurston and/or Pierce County could work with the Nisqually Indian Tribe to allocate an area of land outside a flood area that tribal members could relocate to.

In addition, policy makers should consider completing a similar analysis on flood risk and environmental justice in neighboring counties in western Washington. More specifically, this research should target counties with higher rates of diversity, poverty, and more low-income areas, such as Pierce County, where environmental justice research related to flood risk has not been completed.

vii. Future Research

There are several recommendations for future research on flood risk and environmental justice. First, a more refined analysis of Thurston County could be completed using race and income data at the block level. Census blocks are smaller than the block groups and would provide more accurate results. In addition, the analysis could use nonbinary variables that factor in the number of households in a flood area per block. This would improve the accuracy of the analysis by measuring the density of residents in flood areas in each block. This more refined analysis would also be beneficial to other counties in western Washington, especially those with higher percentages of people of color and low income/poverty.

Another potential research area is to analyze the recipients of FEMA flood mitigation grants. The analysis could obtain demographic variables of the grant recipients, such as race and income. Attributes specific to the home could also be identified, such as property value, year the home was constructed, and whether or not the property is waterfront. These variables would help to determine whether the grants are being allocated to homeowners with the greatest need.

Finally, research could be done on tribes related to environmental justice and flood risk. As mentioned in the previous section, the reservations of the Nisqually and Quinault Tribes are located in a flood area. This research could identify other tribes in the state whose reservations are also located in a flood area.

B. Conclusion

This thesis sought to measure differences in race and income for people who live within and outside of a flood area in Thurston County. Research on hurricane victims in coastal U.S. cities has identified African American, Latinx, and low-income communities to have a higher risk of flood events. The results of this analysis indicated that block groups without homes in flood areas are more racially diverse than block groups with homes in flood areas, which is inconsistent with the scholarship on environmental justice related to flooding. On a macro-level, Thurston County is predominately white, has a higher-than-average median household income, and has a much smaller population than the cities where previous environmental justice and flood risk research was conducted. However, a micro-analysis revealed that lakefront homeowners can afford to live outside of a flood area, compared to riverfront properties that have pockets of low-income and poverty, which are more commonly located within a flood area. In addition, the Nisqually Indian Reservation has the largest cluster of homes in a flood area, the highest percentage of racial minority, and a high rate of poverty. Because of this, tribal members are more likely to live in a flood area than non-tribal members. In conclusion, while the research implied a relatively equitable distribution of flood risk amongst the Thurston County population as a whole, there are several policy recommendations that should be considered in order to mitigate the suggested instances of environmental injustice related to flood risk in Thurston County, as well as areas for future research on flood risk and environmental justice.

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