A SPATIAL ANALYSIS OF SUSTAINABLITLITY AND CLIMATE VULNERABILITIES IN SAVANNAH GEORGIA

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II. ACKNOWLEDGEMENTS

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We would also like to extend a large thank you to all of our Community Partners: Nick Deffley, City of Savannah's Director of Sustainability; Michael MacMiller, Youth and Student Coordinator at Partnership for Southern Equity; and Dr. Mildred McClain, Executive Director and Founder of the Harambee House. They all helped in propelling this project forward, giving us the insight we needed to make sure we provide the community with propositions that they can use as a guide for their own implementations.

We would also like to thank our research partners: Dr. Kim Cobb, Director of the Global Change Program and ADVANCE Professor at Georgia Tech; and Dr. Matt Cox, CEO and Founder of Greenlink Analytics. Their expertise and data across our teams provided us with the tools we need to build our maps and complete our analysis.

III. EXECUTIVE SUMMARY

Sustainable Cities Studio is the capstone course for the Sustainable Cities Minor at Georgia Institute of Technology. This year's studio was tasked with producing a Climate Vulnerability Assessment for the city of Savannah. By applying the three dimensions of sustainability (environment, social equity, and economic development) and approaching each vulnerability through the framework of the United Nations Sustainable Development Goals, we were able to identify, spatially analyze, and recommend solutions toward addressing policy areas most pertinent to at-risk communities in Savannah.

Our environmental spatial analysis revealed disproportionate climate impacts such as flooding on communities of color in Savannah. This analysis showed a strong correlation between marginalized communities that live along the two rivers that border the city of Savannah, the Savannah river to the north and Ogeechee River to the south, and the likelihood of high levels of flooding in the coming decades.

Our social-equity analysis revealed that the Black community in downtown Savannah has the highest rates of housing burden and unemployment in an area that is prone to groundwater pollution. Financial stressors and poor living conditions can cause environmental challenges that affect these communities more severely.

Our economic analysis revealed that high business density areas are exposed to high degrees of flood hazard vulnerabilities, with pluvial flooding compounded by sea level rise being the common looming threat faced by businesses in all areas.

Despite limitations in the scope and availability of data and the COVID-19 pandemic limiting community engagement, our report provides a succinct yet robust spatial analysis of the climate vulnerabilities that at-risk populations in Savannah may face. We hope that our spatial analysis application will provide the city of Savannah with a foundational tool towards integrating the recommended policy solutions.

You can visit the project's website to use the interactive GIS tool: https://cpcapstone2020.wixsite.com/mysite

IV. INTRODUCTION

a. Sustainability

In 1987, the United Nations World Commission on Environment and Development published a report titled Our Common Future, which provided the first definition for sustainable development. Our Common Future - also known as the Brundtland Report in honor of the Chairman of the commission, Gro Harlem Brundtland - defines sustainable development as development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 1987, pg. 15). The term "sustainable development" has become synonymous with "sustainability" in planning and policymaking (Thies & Tomkin, 2018). Any analysis of sustainability must include its three core dimensions as determined by the Brundtland Report: economic productivity, ecological quality, and social equity.

The diffusion of sustainable development has been gradual, with significant progress made in the years since the Brundtland report. The primary catalyst of sustainable development is the growth of cities and migration of people to urbanized centers in the latter half of the twentieth century into present day (Bettencourt et al., 2007). A primary challenge of rapid urbanization is the propensity for densely populated areas to develop inequitably - in all regions of the world, it is estimated that at least 30% of the population live in slum developments (Cohen, 2006). Poor patterns of development and land distribution thus lead to inequities in the social and economic welfare of a population, as well as put the health of humans and the environment at risk (Yeh & Li 1998).

b. City of Savannah

Located along Georgia's coast, the city of Savannah is the seat of Chatham County and the oldest city in the state. It is known for its historic architecture, laid out around a number of park squares that date back to the original plans of founder James Ogelthorpe. The city is a major industrial and shipping hub, as well as a popular tourist destination. Roughly 150,000 people live within the city limits, with around 400,000 people in the greater Savannah metropolitan area (US Census Bureau, 2017).

The city of Savannah is majority-minority, with 55% of the population being Black as of the 2010 census. The median household income was $40,000 and 24% of the population lives at or below the poverty line. Savannah is governed by the mayor and eight aldermen. Over a hundred unique neighborhoods make up the city, which is famous for its historic character.

Sustainability efforts in the city of Savannah are directed by the Office of Sustainability, currently headed by Nick Deffley. The office is responsible for developing sustainability initiatives for the city and developing community partnerships. The Office of Sustainability also created a Sustainability Assessment in 2016, which identifies methods to reduce the city's carbon footprint.

c. The Course

Sustainable Cities Studio (CP 4052) is the capstone course for the Sustainable Cities Minor at Georgia Institute of Technology. The minor is in collaboration with Georgia Tech's sustainability program, Serve-Learn-Sustain (SLS). The primary organizational mission of SLS is to work with students and other members of the Georgia Tech community to "use the knowledge and skills they are acquiring at GT to help 'create sustainable communities'" (Serve-Learn-Sustain, 2020, p. 1). The SLS program is also working to integrate the 17 United Nations Sustainable Development Goals across Georgia Tech and the greater Atlanta community.

The purpose of the project is to analyze climate and social vulnerabilities in the city of Savannah, and to then recommend sustainable solutions for those vulnerabilities. The course is divided into four teams based on the three dimensions of sustainability (environment, social, economic) and overall design.

i. Design Team

The primary role of the design team is to coordinate consistent branding throughout the deliverables being produced as part of the sustainability analysis. Responsibilities include creating a logo, designing the website and poster, and integrating existing information provided by partners. Throughout this process, the goal is to develop a design that is accessible and visually appealing.

The design team created a logo that represents each team as well as the City of Savannah. The logo includes the color that represents each team surrounding a shape used to represent cities and city planning. Maya Neal created the logo using Illustrator.

The design team is also responsible for assisting the other teams in creating GIS visualizations. The team handles data management and provides technical assistance, enabling the equity, economic, and environmental teams to create geospatial representations of their identified risk factors.

ii. Environmental Team

The environmental team is responsible for the collection and analysis of some environmental-related data and trends in the area around the City of Savannah. These data sets that we identified go over the rising sea levels and urban temperatures, as well as the air and groundwater pollution that threatens the entire livelihood of the people of Savannah.

As a team, we will further this research by working to analyze different climate vulnerabilities in the city of Savannah. Additionally, recommendations to combat these vulnerabilities that balance effectiveness and costliness will be displayed at the end of our research in order to offer assistance for the City of Savannah.

iii. Social Equity Team

As the social equity team, we identified several social injustice issues in the Savannah region that cause certain populations to be disproportionately vulnerable to climate change and climate disasters (U.S. Global Change Research Program, 2016). In order to attain an equitable society, cities must act to protect vulnerable communities (Equitable Development and Environmental Justice, 2019). From our research, some of the most relevant social injustices existing in Savannah include food insecurity (USDA, 2015), crime (Savannah Police, 2020), unequal and segregated education (Georgia School Reports, 2020), and a lack of affordable housing (Mosaic Community Planning, 2017).

The various maps our team developed on GIS help identify where these vulnerable groups are concentrated in the city. By seeing the physical locations of these groups, we can offer some potential solutions to the city of Savannah, so they may target the most vulnerable areas with reforming plans and policies.

iv. Economic Development Team

The economic development team collected and visualized data sets from various sources in order to conduct future spatial analysis and establish interactions between climate change and economic vulnerability. To approximate an area's vulnerability to climate change, we used flood insurance and energy burden as proxy variables. For approximation of the economic vulnerability of an area, we employed proxy variables for poverty rate, unemployment rate, and location of business by area. We'll be using these chosen economic variables in combination with environmental and equity variables to contribute to a full-scale, sustainable Climate Vulnerability Impact Analysis.

V. METHODS

a. Sustainable Development Goals

In the years since the Brundtland Report was published, the United Nations has determined indicators to metricize the progress toward sustainable development. In 2000, the United Nations' Millennium Development Goals were published. These goals "form a blueprint agreed to by all the world's countries and all the world's leading development institutions… [towards] efforts to meet the needs of the world's poorest" (UN, 2015, p. 1). The Millennium Development Goals laid the groundwork for the United Nations' 2030 Agenda for Sustainable Development, through which the 17 Sustainable Development Goals (SDGs) were introduced in 2015.

The United Nations' 2030 Agenda for Sustainable Development introduced the SDGs in 2015 to make "an urgent call for action by all countries - developed and developing - in a global partnership" (UN, 2020, p. 1). The 17 SDGs provide specific goals with measurable outcomes concerning the three pillars of sustainability, and their prevalence at the global level. The SDGs address policy areas in sustainable development such as Zero Hunger (SDG 2), Quality Education (SDG 4), Sustainable Cities and Communities (SDG 11), and Climate Action (SDG 13). At the core of this Climate Vulnerability Assessment are the 17 Sustainable Development Goals.

b. Climate Vulnerability Assessment

The Intergovernmental Panel on Climate Change (IPCC) is the global scientific body which researches, produces, and distributees guidance and knowledge about climate change through its Assessment Reports. In Assessment Report 4 (AR4), the IPCC defines climate change vulnerability as "the degree to which [social, biological, and geophysical] systems are susceptible to, and unable to cope with, the adverse impacts" of climate change (Schneider et.al., 2007, pg. 782). Assessment Report 5 specifically outlines that climate hazards directly impact the lives of those living in poverty, particularly in populations which are already marginalized. The effects of climate change harm the poor through means such as increasing food insecurity, slowing down economic growth, and increasing coastal flood risks due to sea level rise (IPCC, 2014). These risks, as well as others identified by our team, are explored within the context of the city of Savannah in this Climate Vulnerability Assessment.

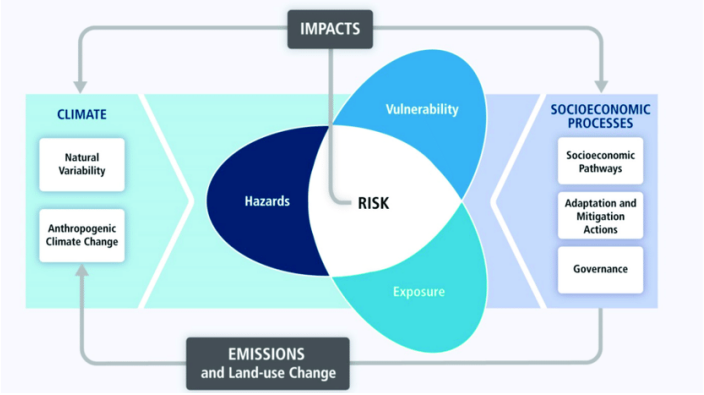

Figure 1. *(IPCC AR5 Framework 2014)*

Climate Vulnerability Assessments can be conducted at global, national, state, or local levels and can encompass all dimensions of sustainability. The primary purpose of this Climate Vulnerability Assessment is to identify vulnerabilities across the three dimensions of sustainability and provide recommendations towards policy solutions for the city of Savannah. Emphasis will be placed on communities which are most vulnerable to the effects of climate change: low-income minority communities.

c. Geographic Information Systems

According to the United States Geological Survey, Geographic Information Systems (GIS) is "a computer system that analyzes and displays geographically referenced information. It uses data that is attached to a unique location" (USGS, 2020, p. 1). Data which are tied to a unique location are known as spatial data. GIS is the type of digital tools that are used to collect, manage, analyze, and visualize spatial data. Today, the largest GIS firm in the world is Esri, which offers a range of GIS products under its ArcGIS suite (Aguire, 2014). The spatial analysis tool in this report has been designed and implemented using ArcGIS products, specifically ArcMap and ArcGIS Online.

Spatial analysis can be implemented to explore a wide range of problems in sustainable development and beyond. Examples of implementation of GIS toward sustainable development include mapping of environmental flood risk vulnerabilities, population demographics such as poverty, and economic stressors such as energy burden. GIS can be used to spatially analyze these vulnerabilities at national, state, and various local levels, making it a useful tool in completing Climate Vulnerability Assessments.

VI. MAPS

a. Environmental Maps

i. 5ft Flood Projection

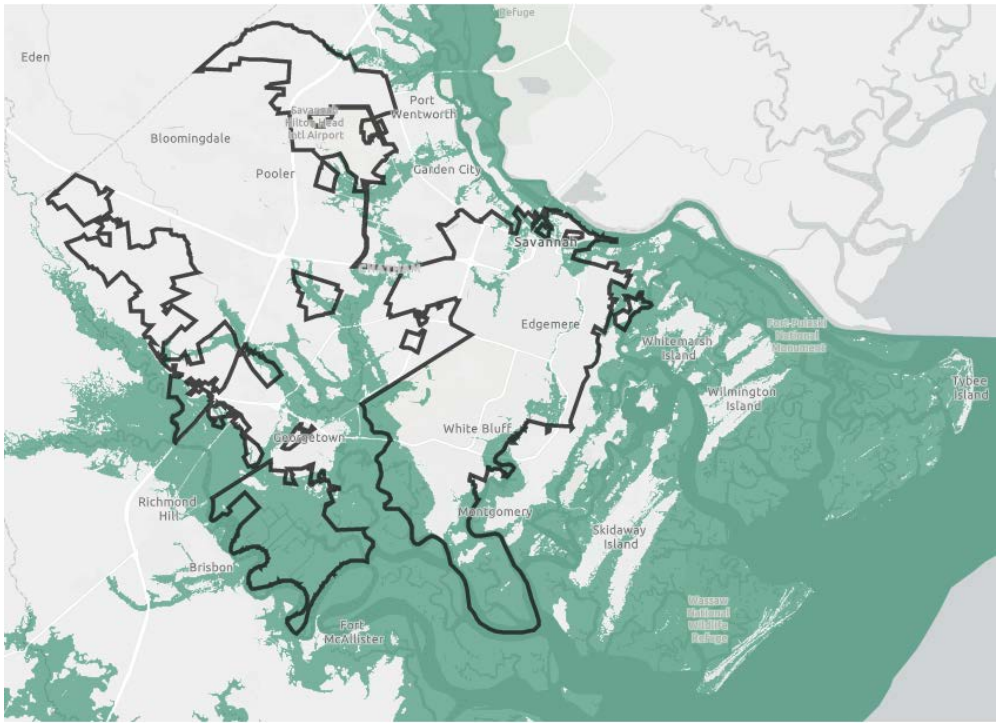

Figure 2. *5 ft Flood Projection, the Savannah City Boundary*

This map shows exactly what areas in Savannah that would be affected by a single flood that is 5 feet higher than the longer high-tide line. It is also the new projected shoreline if sea-levels were to rise 5 feet higher than they are now. A 5-foot flood is projected to happen at least once by the year 2080.

Due to Savannah's low elevation and close proximity to the ocean, chronic flooding and rising water levels are a relevant environmental vulnerability (Surging Seas, 2016). Storm surges cause intense, sudden flooding when strong storms from the ocean make landfall on the cost. These storm surges are projected to only get worse as global warming raises sea levels and produces stronger storms every year. This map, taken from elevation and water-level data available from the National Oceanic and Atmospheric Association (NOAA), shows the areas in and around Savannah that experience flooding in the event of a flood 5 feet above the local normal high tide. According to experts, there is a 23% likelihood of such a flood occurring between now and 2060, and is 100% likely by 2080 (Surging Seas, 2016). This map can be cross-examined with spatial analysis of various social and economic issues to determine which demographics of Savannah would be most impacted by potential sea level rise-induced flooding.

The map only demonstrates projected areas of flooding given a 5-ft flood above the high tide, so it does not show the actual levels of flooding that will currently occur. Additionally, the projected floods only come from rising sea levels, not from other sources such as heavy rain storms.

ii. Urban Heat Island Effect

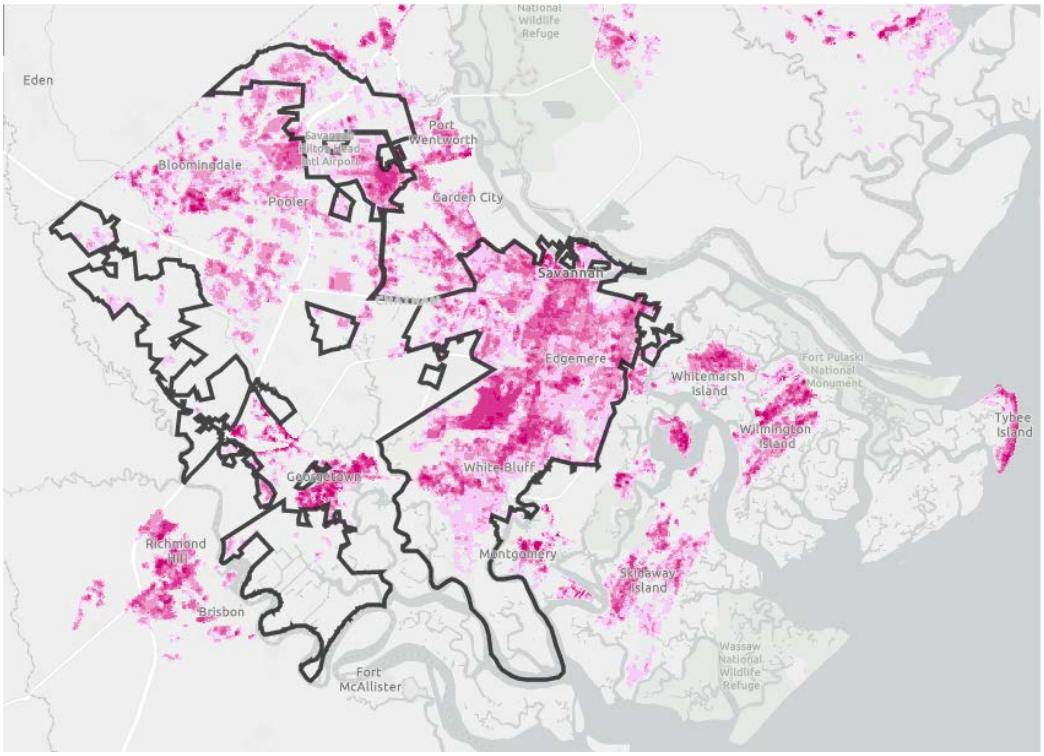

Figure 3. *Urban Heat Island Effect, the Savannah City Boundary*

This map shows the ground temperature of the areas around the City of Savannah. Notice the higher heat levels in the more developed regions, demonstrating the idea that cities are generally hotter than their surroundings.

A heat island occurs when the built infrastrastructure in a city traps heat near the ground level, causing higher temperatures than nearby rural areas. The heat island effect causes an increase in energy consumption and air pollutants and it also affects human health. This map shows the urban heat island effect in Savannah and indicates areas in the city where the effect is most severe. This map only looks at temperatures relative to the average of the city, meaning it does not indicate actual temperatures. Severity is rated from 1 to 5, where 1 is a relatively mild heat area (slightly above the mean for the city) and 5 is a more severe heat area (significantly above the mean for the city). The map was sourced from the Trust for Public Land and shows the urban heat island effect for every major metropolitan area in the United States. The data was originally obtained from Landsat 8 imagery with thermal band 10, which is a ground-level thermal sensor, from the summers of 2018 and 2019. Using Python and the Descartes Lab platform the Trust was able to create these urban heat island effect maps (The Trust for Public Land, 2020).

The urban heat island map is limited in that it does not define the scale from 1 to 5 used to rate the areas of the city. For example, when the map describes an area as being significantly above the mean temperature for the city. The map does not state how many degrees above the mean occur in a zone rated 5. The vagueness in the scale thus makes it hard to understand and analyze this map.

iii. Groundwater Pollution

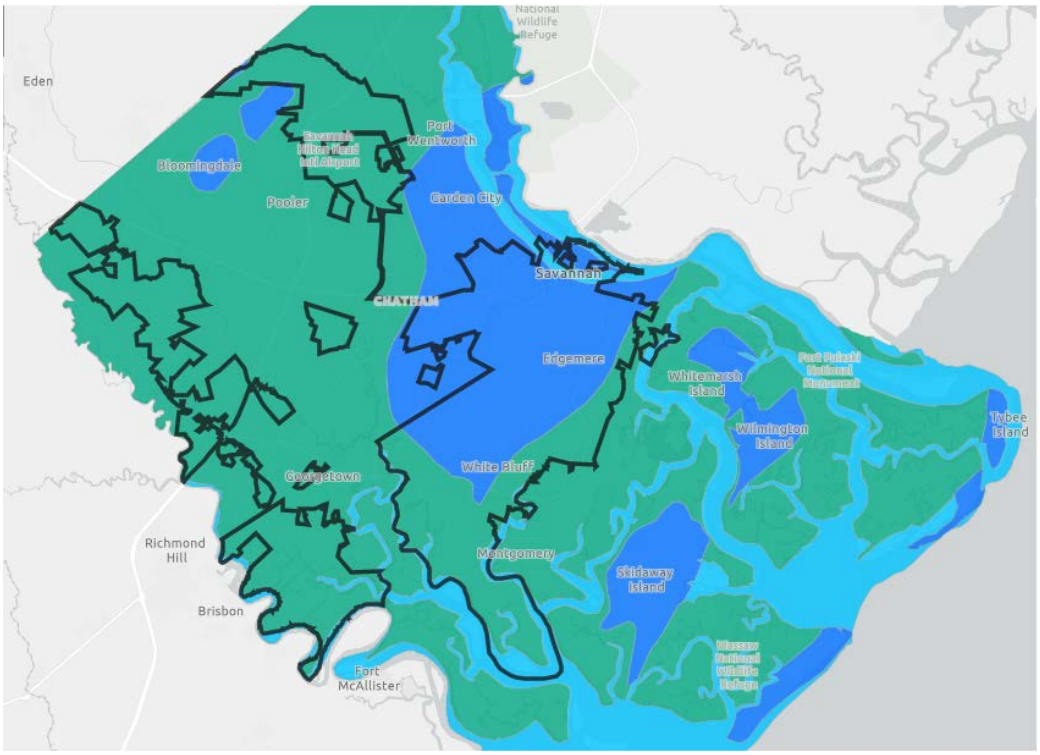

Figure 4. *Groundwater Pollution, the Savannah City Boundary*

The city of Savannah sources its water from either the Savannah River or the Floridan aquifer, which is an underground layer that contains water. In the map above, we show which areas of the city are more likely to be affected by pollution trickling down into this underground layer.

Savannah sources most of its water from two different sources: the Savannah River and the Floridan Aquifer. However, these two different water sources face issues such as pollution as a result of chemical waste and aquifer depletion (Groundwater Pollution, 2020). The map, sourced from the Savannah Area GIS Open Data, helps provide a rating for which areas of the city are more susceptible to groundwater pollution. The map above uses a DRASTIC-index to measure groundwater vulnerability. This index measures seven different parameters: depth to water, net recharge, aquifer media, soil media, topography, vadose zone and hydraulic conductivity (Trent 1992). The first parameter measures the depth from the ground surface to the water table. The net recharge measures the total amount of rain water that infiltrates to reach the shallow unconfined aquifer. The aquifer media analyzes which earth materials from the aquifer. The soil media pertains to the upper portion of the vadose zone that consists of significant biological activity. Topography looks at the slope and slope variability in that parcel of land. The vadose zone refers to the area above the water table which is unsaturated or discontinuously saturated and finally, the hydraulic conductivity determines the ability of a material to transmit water (Trent 1992).

The limitation that this map offers is that it demonstrates and calculates the susceptibility of a location to groundwater pollution and it does not calculate the current groundwater pollution. Also, since the map was created in 1992, there may have been

some infrastructure changes in the city that affect the way that pollution seeps into the water table. These changes may include new roads, more trees, new buildings and land level.

iii. Factory CO2 Emissions

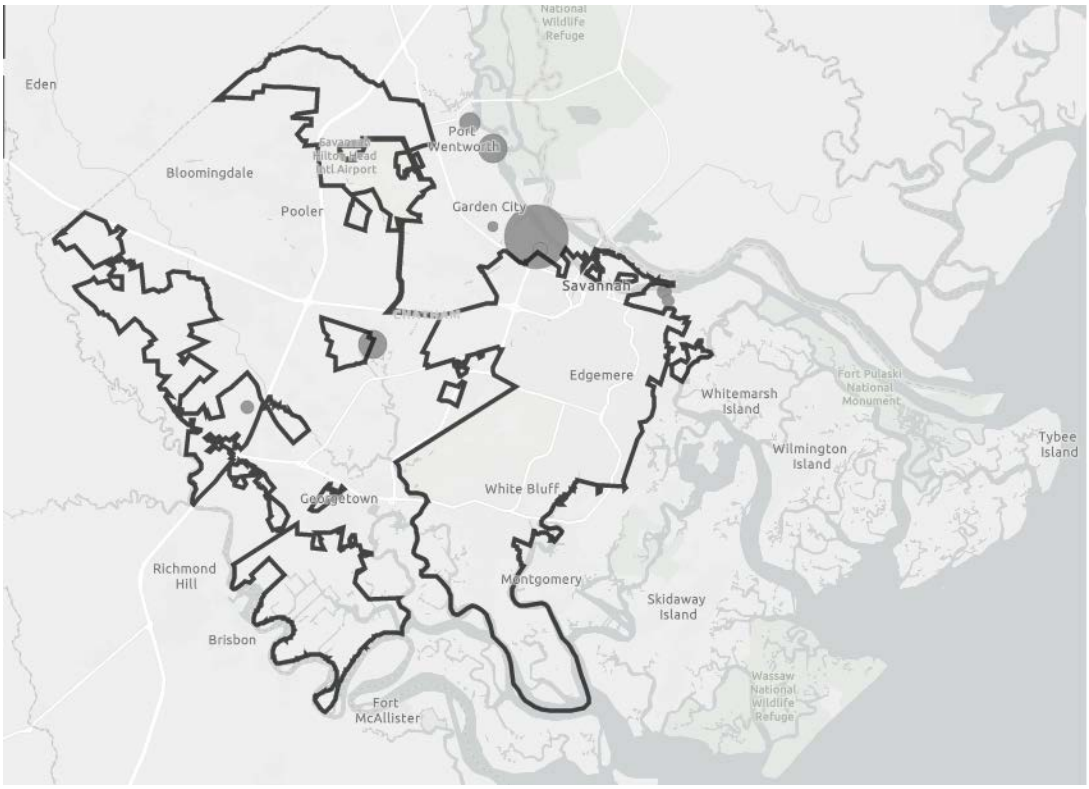

Figure 5. *Factory CO2 Emissions, the Savannah City Boundary*

This map shows the locations of factories in the Savannah area that produce the most pollutants. Most of these factories lie along the river, which pollute the river along with the air. The larger the grey circle representing the factory, the more pollutants that factory produces.

To better understand the air quality of Savannah, we plotted nine factories with substantial greenhouse gas emissions using data from 2018 from the EPA's FLIGHT tool. All emissions data is presented in units of metric tons of carbon dioxide equivalent using GWP's (Global Warming Potentials) from IPCC's AR4 (EPA, 2018). Greenhouse gas emissions are known to cause climate change by trapping heat, along with the potential to cause respiratory diseases due to increased air pollution. With this information, a rough extrapolation can be made about what areas of the city of more polluted air and overall lower air quality.

The greenhouse gas emissions are reported and collected by each individual factory which can offer up some doubts about the accuracy of the numbers. Furthermore, under the Trump administration, the EPA has been

more vulnerable to policy changes and many factories nationwide have stopped reporting their data for "valid reasons" as the map states (EPA, 2018). This then affects the accuracy of the data that may severely underreport the amount of emissions released in the air.

vi. Tree Canopy

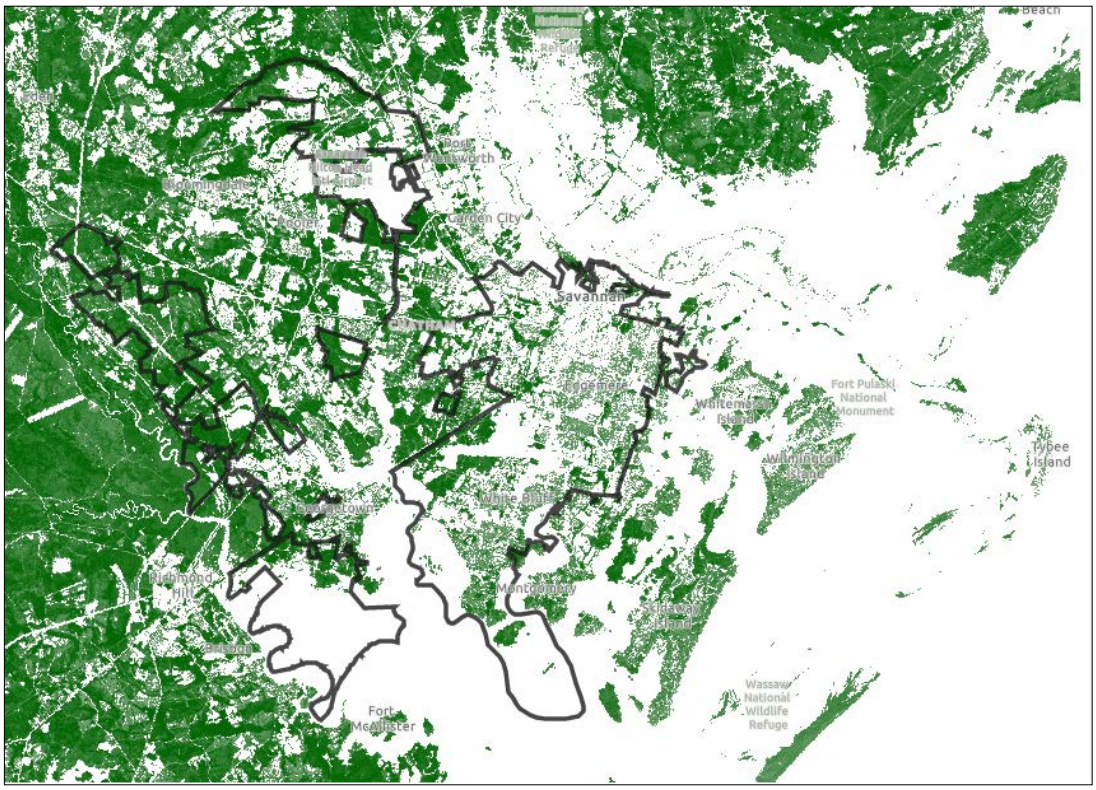

Figure 6. *Tree Canopy, the Savannah City Boundary*

The city of Savannah is known for its large trees and iconic Spanish moss. This foliage also helps cool down the city, especially in Savannah's 22 Historic Squares. This map shows the density of tree coverage in the city of Savannah and the surrounding areas.

A city's tree canopy has a strong effect on the local ground temperature and air quality, so plotting this for the city of Savannah was crucial in understanding the full environmental scope of the present green infrastructure of the region (Fragomeni, 2019). This map, available through the U.S. Forest Service as part of the National Land Cover Database 2016 (NLCD2016), was developed using satellite imaging and medium spatial resolution (1 pixel = 30m). Each pixel is weighted by percent tree canopy cover on a scale of 0 to 100 percent (U.S. Forest Service, 2019).

The data we mapped was collected in 2016 before Hurricane Matthew hit the United States between October 7 and 10, 2016 (Associated Press, 2016). Many residents noted that a number of trees had been knocked down because of the hurricane the city reported that about 220 fell onto public roads or onto houses (Associated Press, 2016). Additionally, these are also only trees accounted for by the city, there may have been more that felled and affected

the tree canopy cover. Therefore, the limitation of this map comes from the fact that it was created before Hurricane Matthew hit Savannah and changed the tree canopy.

v. SLR Sensors

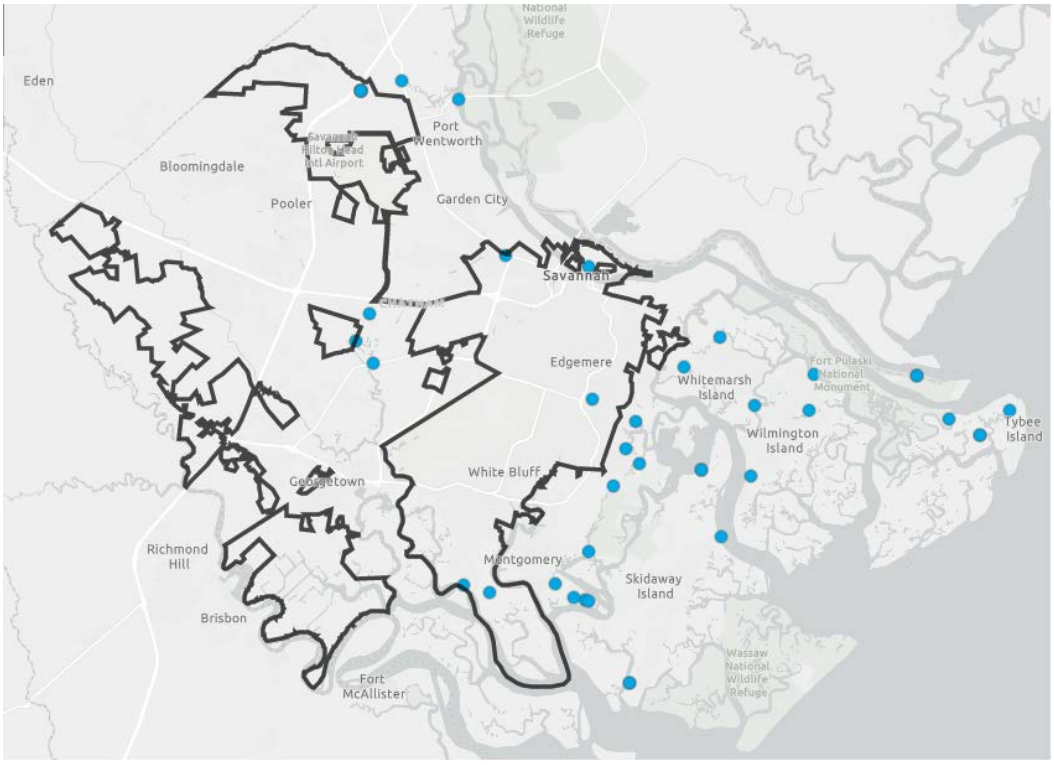

Figure 7. *Sea Level Rise Sensors (SLR), the Savannah City Boundary*

The map above shows the location of different sea level sensors installed through Dr. Kim Cobb's research. These sea level sensors continuously collect and report data on water level, air temperature, and air pressure.

Flooding can occur rapidly without much warning. Properly warning residents of incoming floods requires real-time monitoring of environmental characteristics like air temperature, water levels, and atmospheric pressure. In collaboration with Dr. Kim Cobb, we have created a map detailing the locations of each of her Smart Sea Level Sensors around the Savannah area. Each sensor measures different metrics based on their capabilities (i.e. one sensor measures air temperature and water level while another measures water level barometric pressure). Clicking on a sensor on our map leads to a link detailing that device's real time data, along with any past data the sensor may have collected. This map was created by plotting the latitude and longitude of each sensor as points on our map, and attaching links to each point corresponding to the appropriate sensor (Cobb, 2020).

Data collection for the Smart Sea Level Sensors begins in 2018, therefore it is difficult to identify notable trends over such a short period of time. Additionally, two of the sensors have not collected data since 2018, resulting in gaps in knowledge for these locations.

b. Social Equity Maps

i. Food Deserts

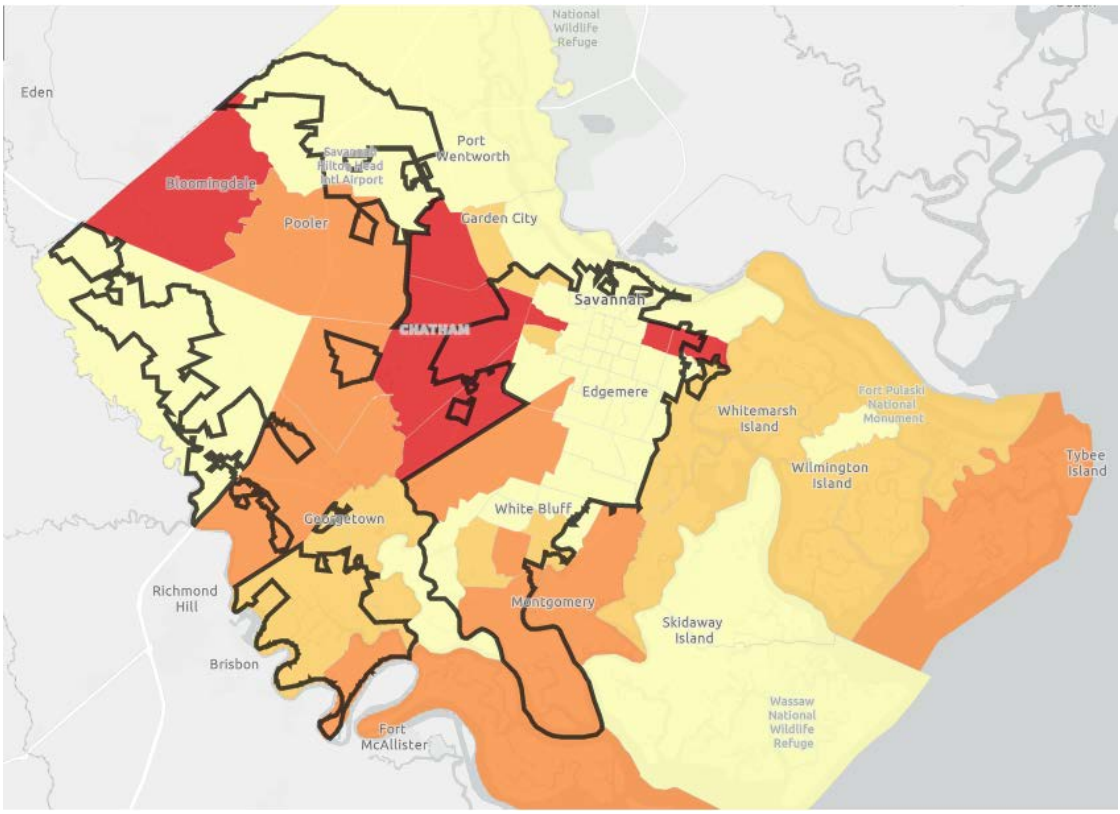

Figure 8. Food Deserts, the Savannah City Boundary

This map shows low-income census tracts where a significant portion of the population has low-access to grocery stores and supermarkets. A darker red represents a higher percentage of the population with low-access to grocery stores and supermarkets.

The USDA defines food desert census tracts as: Low-income census tracts where a significant number (at least 500 people) or share (at least 33 percent) of the population is greater than 1.0 mile from the nearest supermarket, supercenter, or large grocery store for an urban area or greater than 10 miles for a rural area. Low income census tracts are any tract where: The tract's poverty rate is 20 percent or greater; or the tract's median family income is less than or equal to 80 percent of the State-wide median family income; or the tract is in a metropolitan area and has a median family income less than or equal to 80 percent of the metropolitan area's median family income. It is important to note that a food desert by USDA definition is low access and low income (USDA, 2015).

Access to affordable, healthy foods is an important indicator of a community's health and well-being. By mapping this data, we can see which areas of Savannah need assistance in accessing nutritious food, either by increasing accessibility to grocery stores, or by offering more affordable options.

ii. Supplemental Nutrition Assistance Program (SNAP)

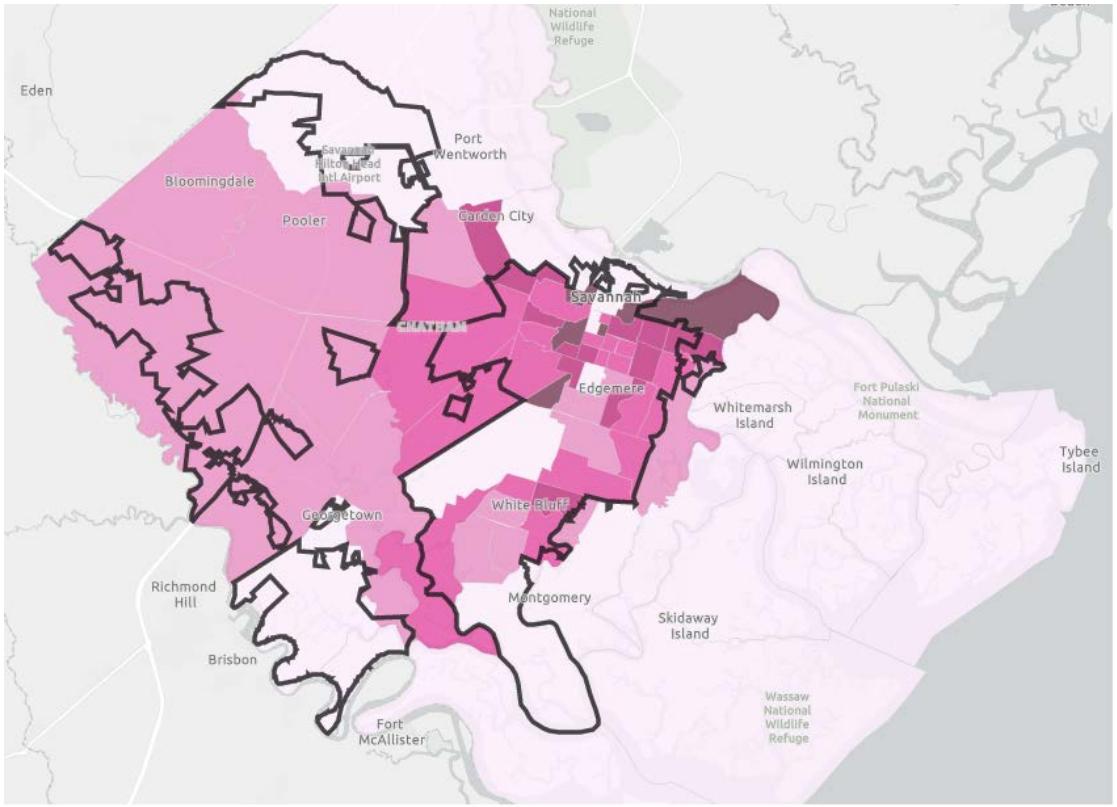

Figure 9. *SNAP receiving Households, the Savannah City Boundary*

This map shows the percentage of households receiving Supplemental Nutrition Assistance Program (SNAP) benefits in each census tract. A darker purple color represents an area with a higher percentage of households receiving SNAP benefits.

The Supplemental Nutrition Assistance Program (SNAP, formerly the Food Stamp Program) is the Nation's largest domestic food and nutrition assistance program for low-income Americans. This data comes from the United States Department of Agriculture. As stated by the USDA, SNAP provides nutrition benefits to supplement the food budget of families so they can purchase healthy food and move towards self-sufficiency. A spatial analysis of the SNAP benefits data can provide insight into different issues surrounding food insecurity such as which communities may typically be less food secure.

iii. Grocery Stores

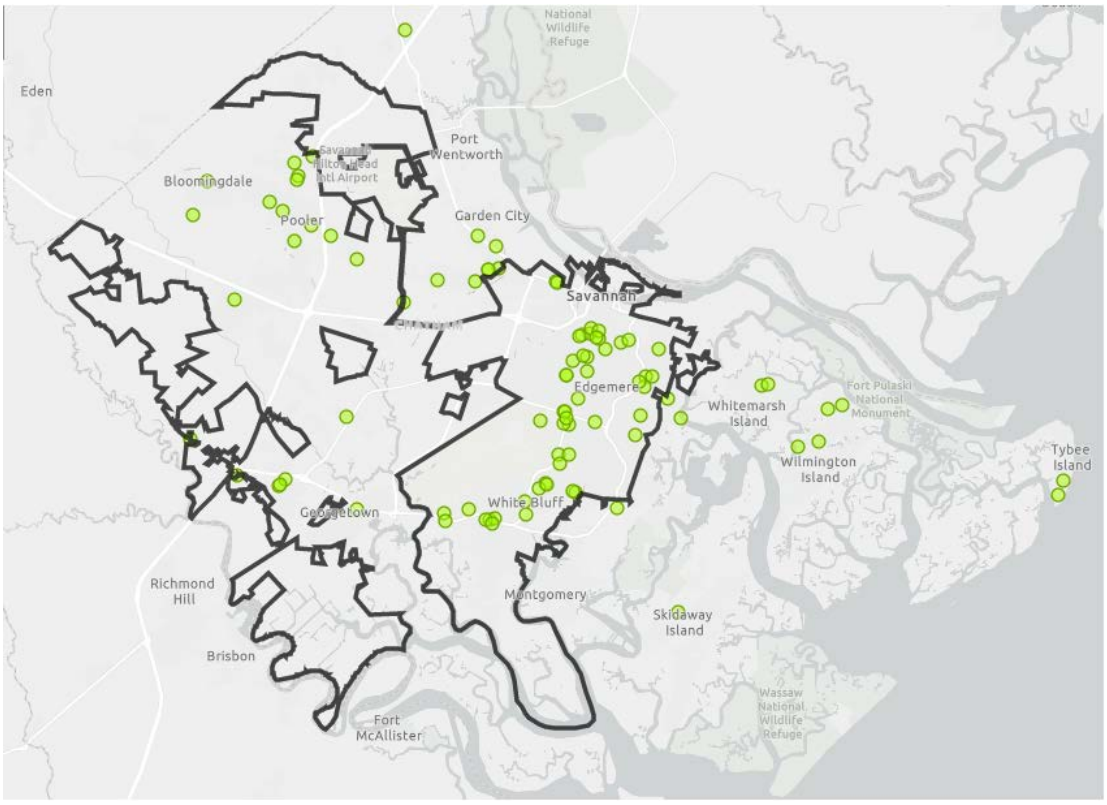

Figure 10. *Grocery Stores, the Savannah City Boundary*

This map shows the location of grocery stores in the city of Savannah.

According to the SAGIS, the map was made from point data for all grocery stores and food markets within Chatham County, including specialty markets and grocery department stores. The type and subtype fields can be used to classify grocery stores by category and purpose.This map does not include membership-based wholesale stores or small markets with minimal selection, such as gas stores or drug stores.This data is from Savannah Area GIS Open Data and was published in 2017. This map helps us to better understand food deserts and how accessible grocery stores are to communities. Using a map to show specific locations is a good way to show if and where more grocery stores are needed.

vi. Crime

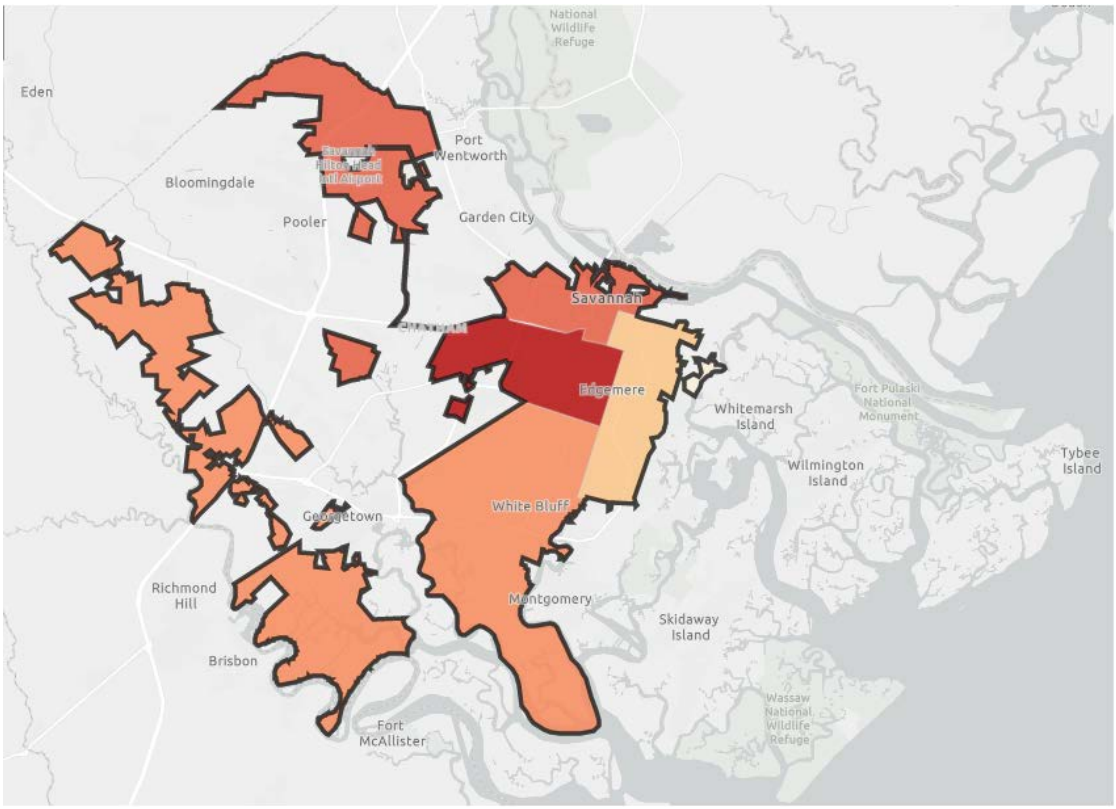

Figure 11. *Crime by Precinct, the Savannah City Boundary*

This map shows the concentration of crime in the 4 police precinct zones in Savannah, GA. A darker red represents an area with a higher crime rate.

The city of Savannah consists of four police precincts: Northwest, Southside, Central, and Eastside. The map shows the amount of crime, which is defined as all gun crimes, drug crimes, and felony crimes, in each of the precinct's respective zones from January of 2020 to June of 2020. In the map, the central precinct is clearly the zone with the highest concentration of crime (Savannah Police, 2020). This data was received from the city of Savannah's police department weekly crime report. Crime is an indicator of poverty and correlates with residents' health, safety, and well-being. Additionally, how the police respond and react to crime, especially in relationship to the race of the resident, is an extremely relevant and urgent equity issue that must be addressed in Savannah, and in the rest of the United States.

v. Housing Burden

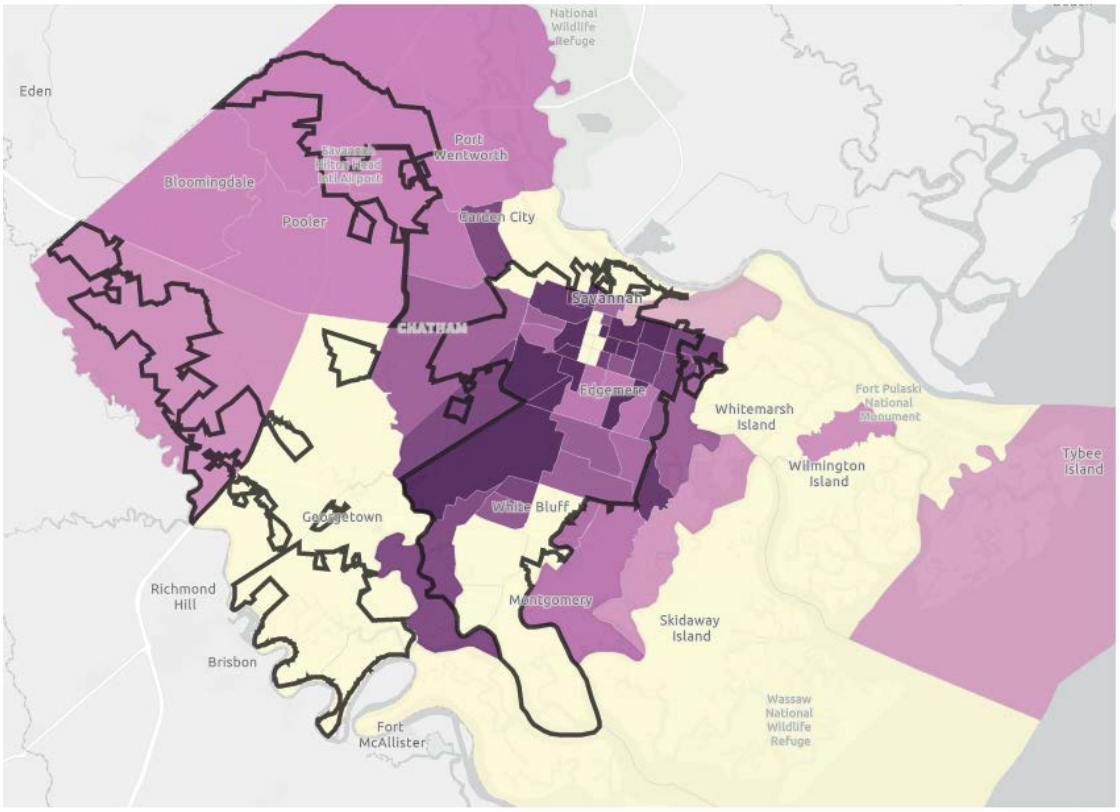

Figure 12. *Housing Burden, the Savannah City Boundary*

This map shows the percentage of households in each census tract that are burdened with housing problems. A darker purple represents an area with a higher percentage of burdened households.

This map shows the percentage of households in each census tract with at least one of four housing problems. There are four housing problems in the CHAS data: 1) housing unit lacks complete kitchen facilities; 2) housing unit lacks complete plumbing facilities; 3) household is overcrowded; and 4) household is cost burdened. When it comes to the climate crisis, those with poor living conditions or those with no place to live are arguably the most vulnerable to a changing climate.Because of this, we must identify where these groups are concentrated and find solutions to mitigate the burden. This map was developed from the US Department of Housing and Urban Development Data along with the help of Mosaic Community Planning.

vi. Libraries

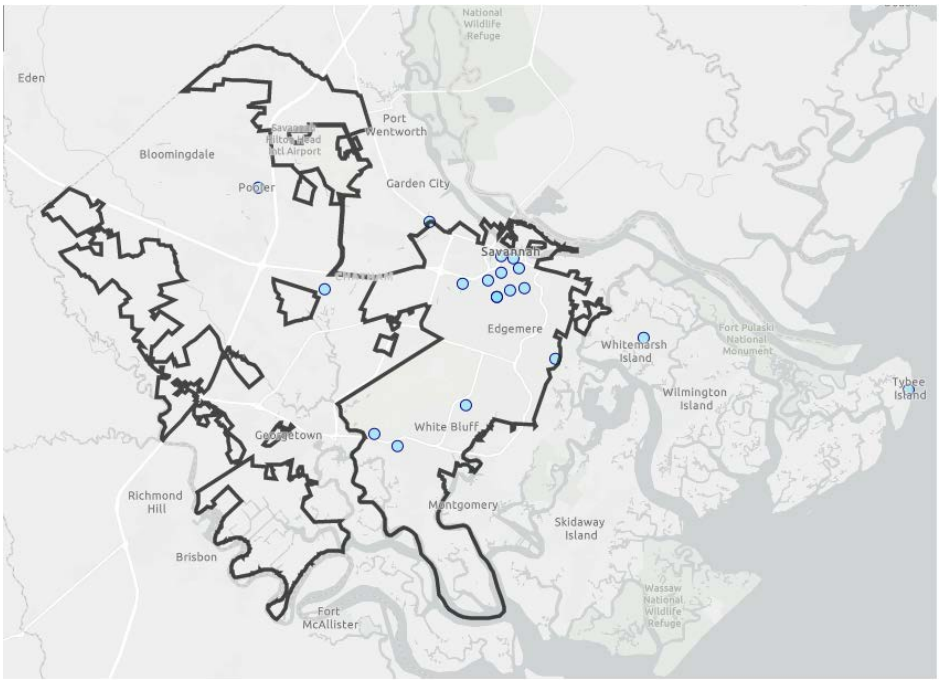

Figure 13. *Location of Libraries, the Savannah City Boundary*

This map shows the geographical locations of all public libraries in Chatham County.

This map comes from the SAGIS site from 2020. Public Libraries are used as evacuation centers in case of hurricanes. Knowing the locations can help us understand how accessible these places are to which communities.

vii. Schools

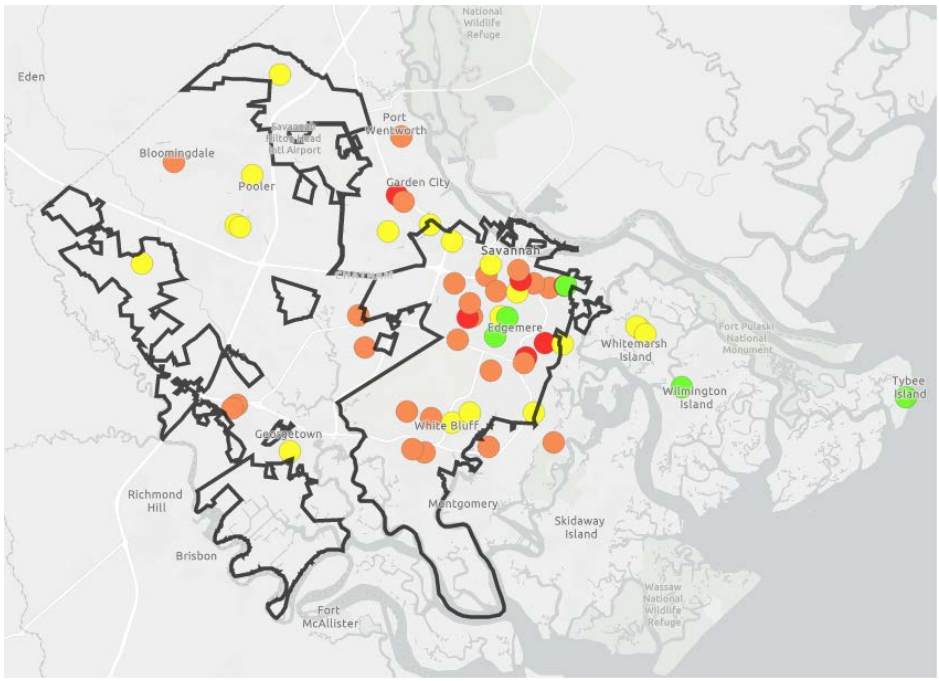

Figure 14. *Educational Institution, the Savannah City Boundary*

This map shows academic performances for all public elementary, middle, and high schools in Chatham County. Green represents a high score, yellow is mediocre, and red is a failing score.

The measurement used is the CCRPI (College and Career Ready Performance Index) scores which is managed by the Georgia Department of Education and incorporates several variables including content mastery, progress, closing gaps, readiness, and graduation rate. The data is compiled from the Georgia School Grades Report, created by the Governor's Office of Student Achievement. This map identifies disparities between school performances and which areas are underperforming, so that further assistance can be focused on where it is needed.

viii. Percentage of Black Population

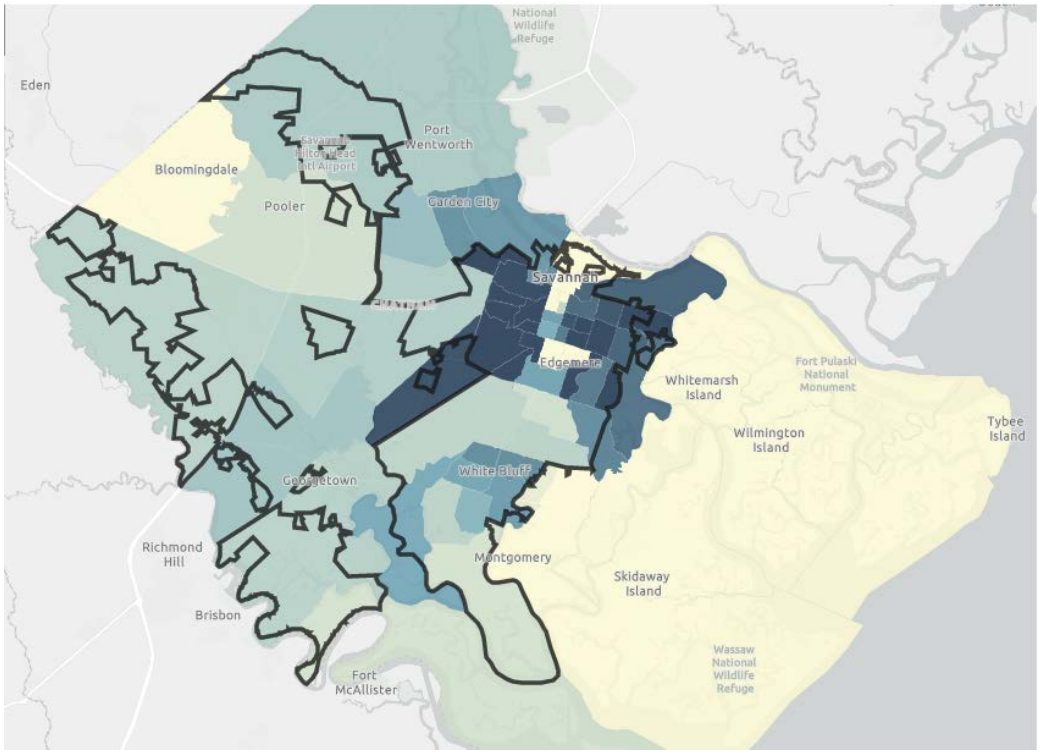

Figure 15. *Percentage of Black Population*

This map shows the percentage of Black residents of each census tract in Chatham County. A darker blue represents an area with a higher concentration of Black residents.

This information comes from the Atlanta Regional Commission Open Data. Black individuals in the United States continue to be neglected and suppressed by the government which can be seen in how they are disproportionately affected by the changing climate. By seeing where Black citizens reside in Savannah, we can see which vulnerabilities are concentrated in Black communities to give a better understanding if and why they need more help than others in order to obtain an equitable society.

c. Economic Development Maps

i. All Businesses by Major Category (Percent)

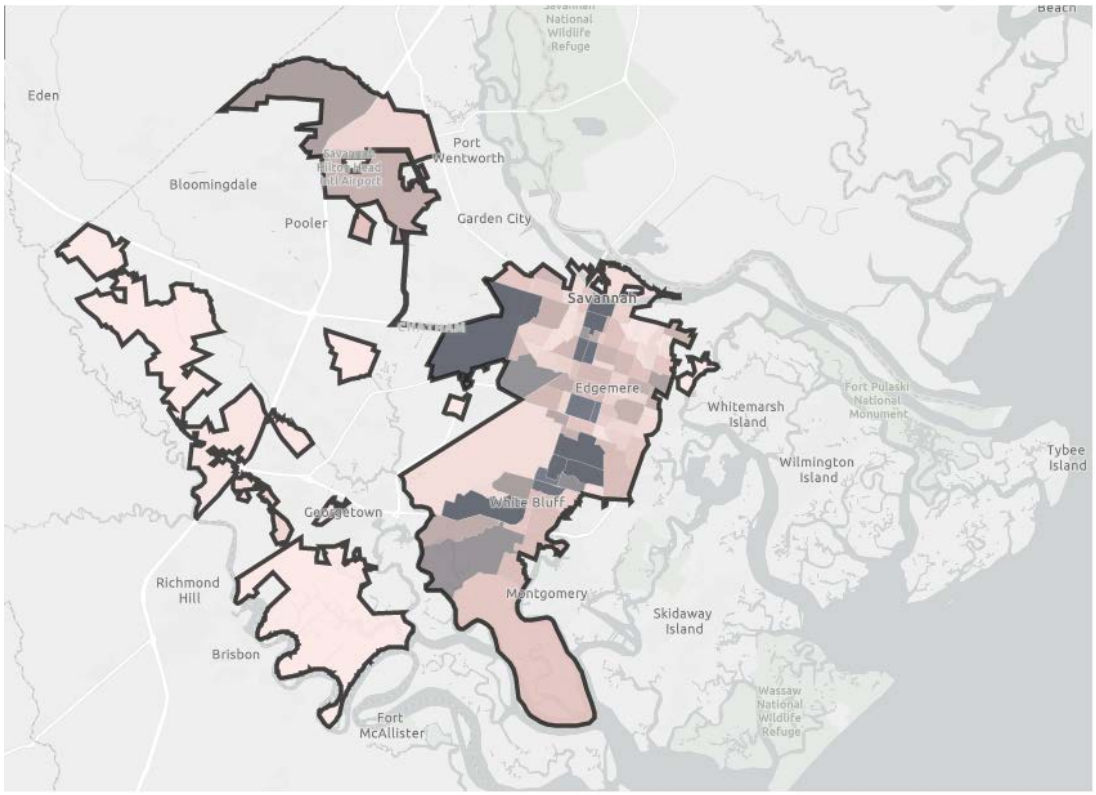

Figure 16. *All Businesses by Major Category (Percent), the Savannah City Boundary*

This map showcases the density of all businesses registered with the City of Savannah, by percentage of the business in a specific neighborhood. Darker grey areas have a higher concentration of businesses while lighter pink areas have a lower concentration of businesses.

The city of Savannah provided our team with their member businesses information such as names, addresses and business type. The businesses were organized by type into the following categories: private businesses & resources, events, tourism & arts, civic organizations, advertising & design, cargo, and other. The 'All Businesses by Major Category Map' can be used to layer with other maps like the food desert map to guide developers in making sustainable urban development planning decisions. Also, the map can be used by residents and tourists to locate a type of business and get a better idea of the areas in Savannah.

ii. Flood Zone Insurance

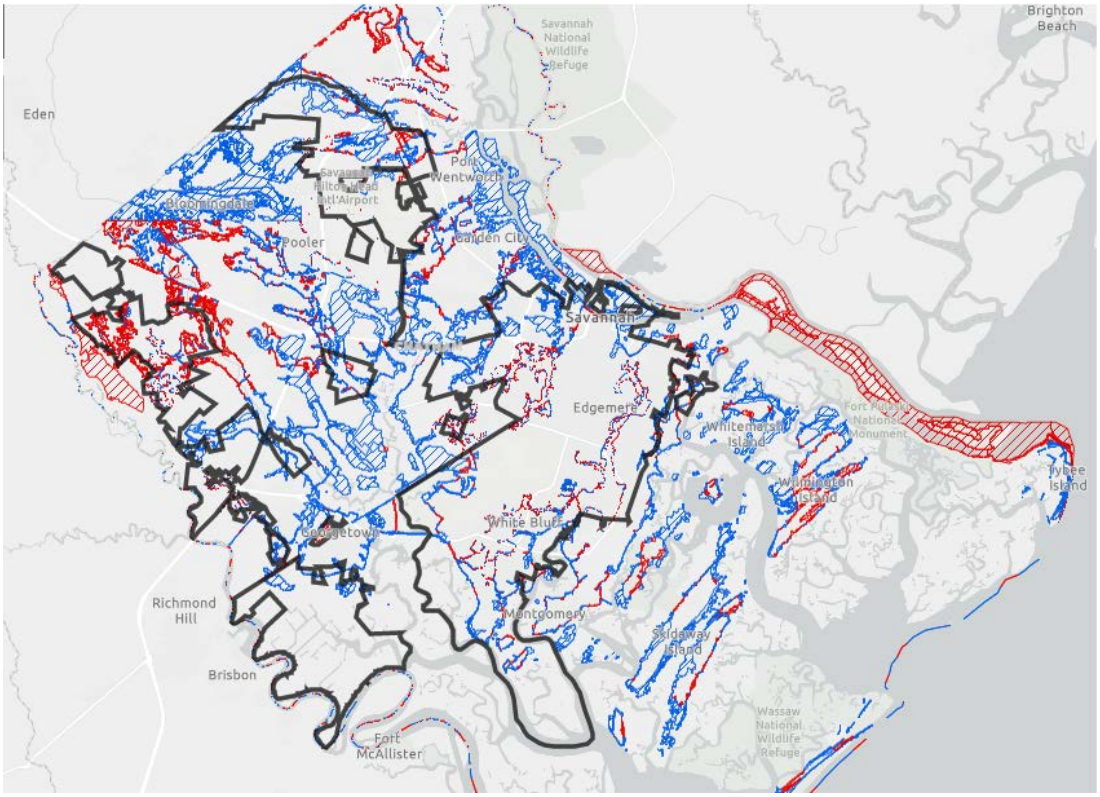

Figure 17. *Need for Flood Zone Insurance, the Savannah City Boundary*

This map showcases the zones where Flood Insurance Needs decreased or increased.

Flood insurance protects owners from property loss due to flooding. The most recurrent problems for Savannah in recent years are minor flash floods caused by surface water runoff in locations of low elevation, particularly where storm drains are blocked by debris (City of Savannah, 2015). This layer was produced by the Chatham County government in collaboration with FEMA. It shows the likelihood of flooding in a given year from storm surges and outlines where there is a need for flood insurance. Properties falling within the red-lined boundary have an increase in need for flood insurance, while properties falling within the blue-lined boundary have a lessened need for flood insurance.

iii. Unempolyment Rate

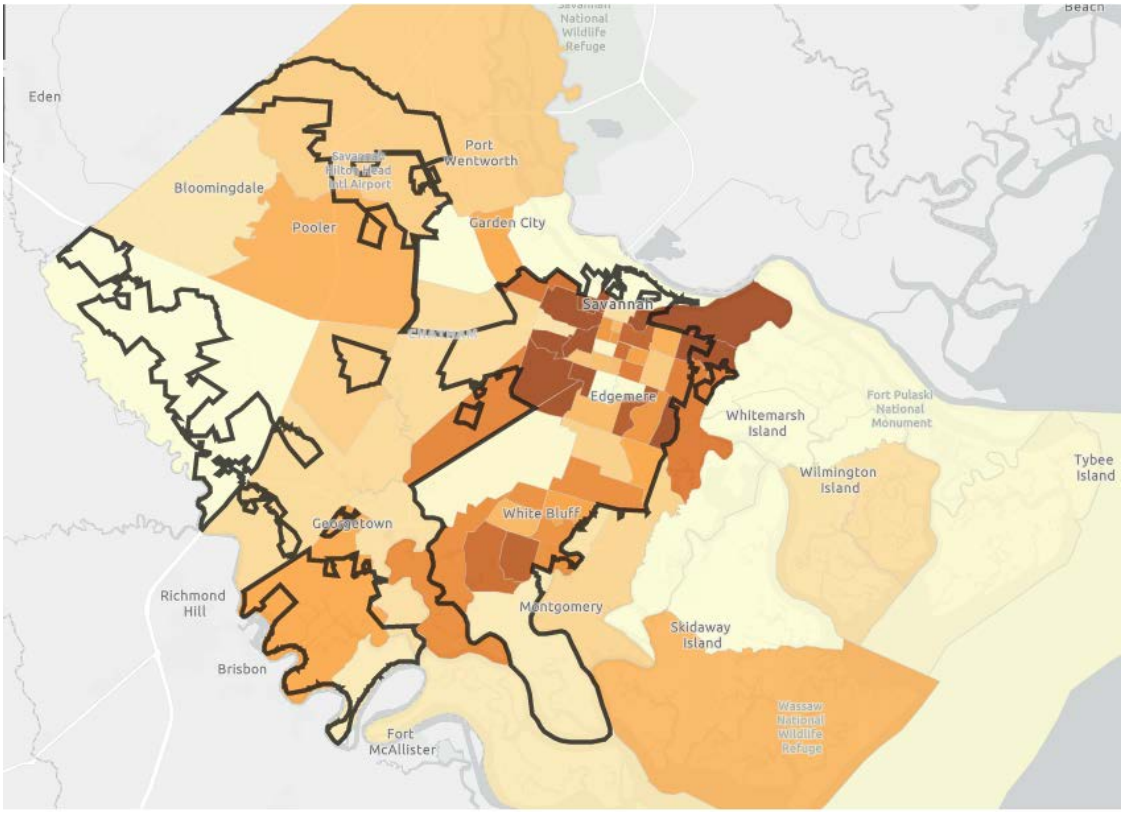

Figure 18. *Chatham Unemployment Rate, the Savannah City Boundary*

This map shows the unemployment rate by area within Chatham County. Unemployment rate is being used as a proxy for the economic vulnerability of an area.

The unemployment rate variable represents the percent of Chatham County residents that are jobless despite them actively seeking work. This gives us an indication of the economic vulnerability of an area. Lighter colors represent lower unemployment rates which exhibit a stronger economic base within the area, while darker colors exhibit higher unemployment rates which convey an underlying economic vulnerability for that area. As costs of living rise due to climate change going into the future, economically vulnerable areas will be less able to compensate.

iv. Household Energy Burden by Census Tract

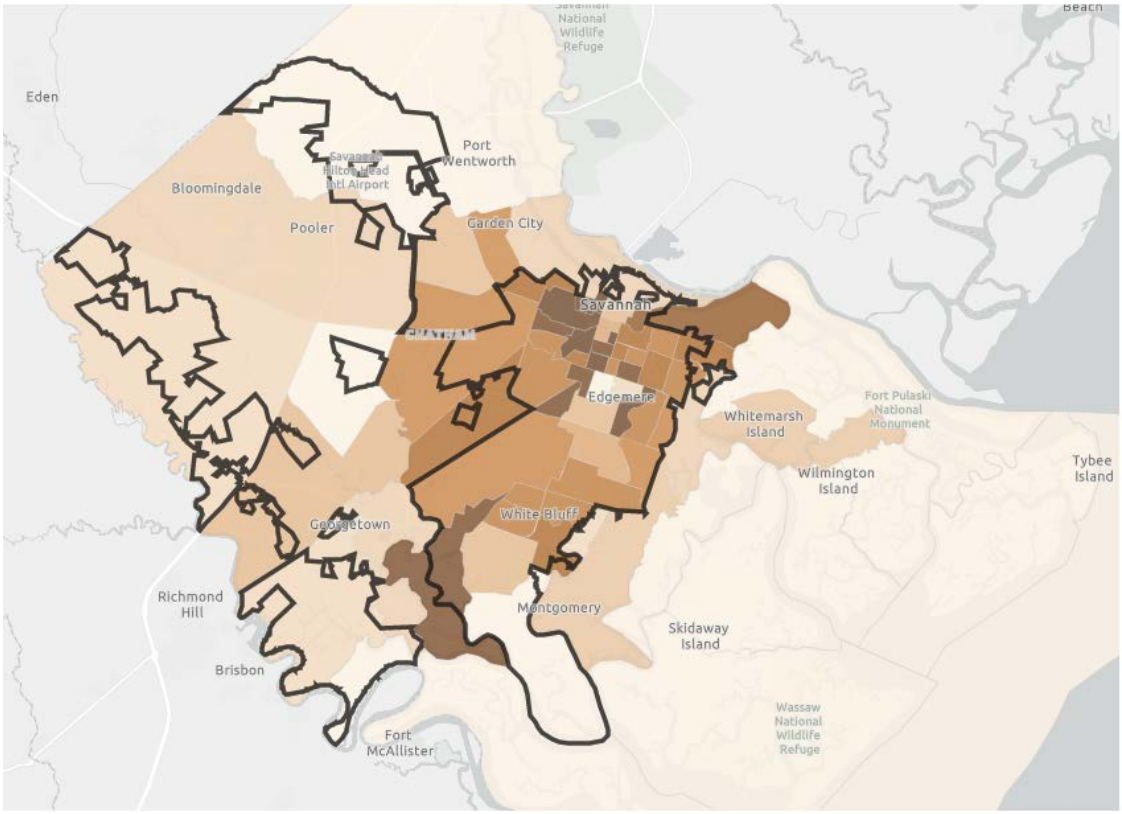

Figure 19. *Household Energy Burden, the Savannah City Boundary*

This map shows the energy burden by census tract in Bryan, Chatham, and Effingham counties (Greenlink, 2020). The energy burden is calculated by the amount of electricity and gas consumed compared to the household median income.

Household energy burden is defined as a large portion of the house income that is spent in home energy bills, including electricity, gas, and other heating fuels (US Department of Energy, 2018). Low-income households suffer a disproportionate energy burden - the national average energy burden for low-income households is 0.086 (8,6%), which is three (3) times higher than for non-low-income households (US Department of Energy, n.d.). Low-income Georgians face high energy burden despite having some of the lowest energy rates in the United States (ACEE, n.d.).

v. Electricity Consumption Normalized by Percent Population

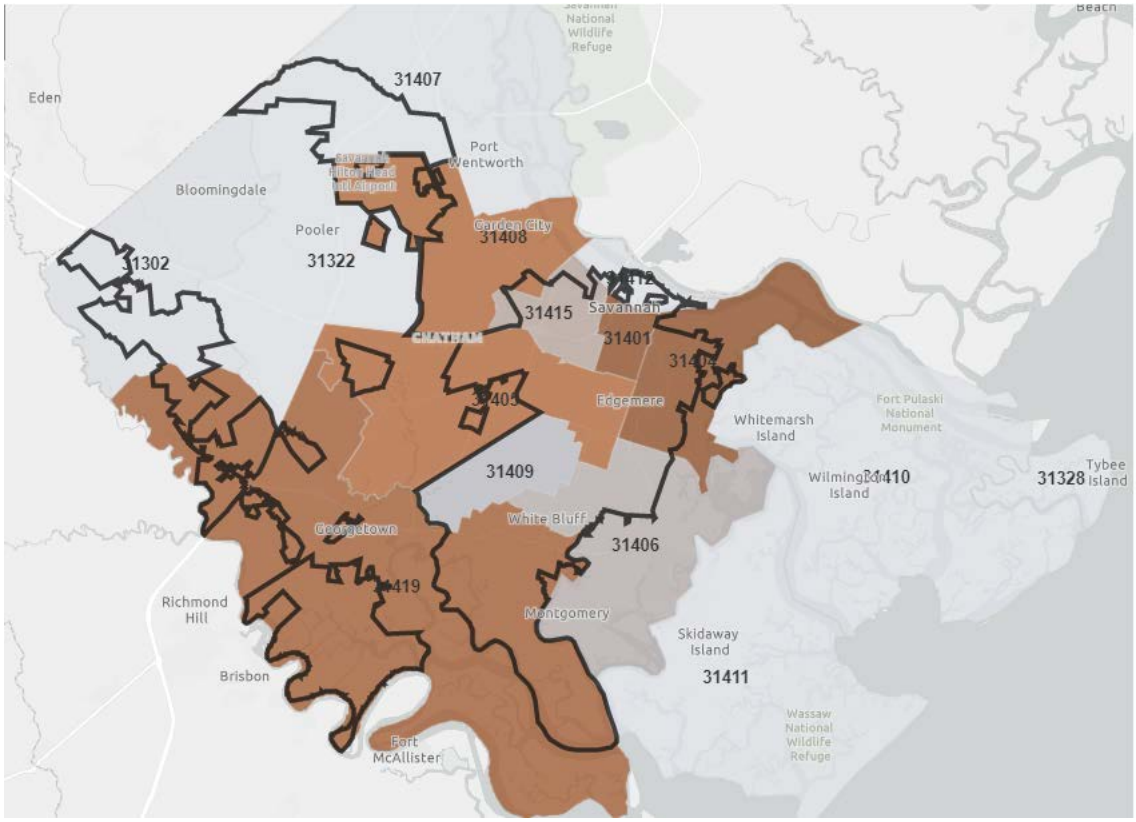

Figure 20. *Electricity Consumption (in kWh) by Zip Code, Normalized by Percent Population Living in Savannah*

This map shows the total electricity consumption (residential, commercial, and industrial) by zip codes normalized by percentage of the population living in the city of Savannah in kWh for the year 2019. Georgia Power, the local utility in Savannah, provided a consolidated data of electricity consumption in the residential, commercial, and industrial sectors by zip code (N. Deffley, personal communication, July 7, 2020). In order to determine the percentage of this electricity consumed exclusively within the city of Savanna limits, we used the percentage of the area of Savannah within those respective

vii. Electricity Consumption (in kWh) by Zipcode

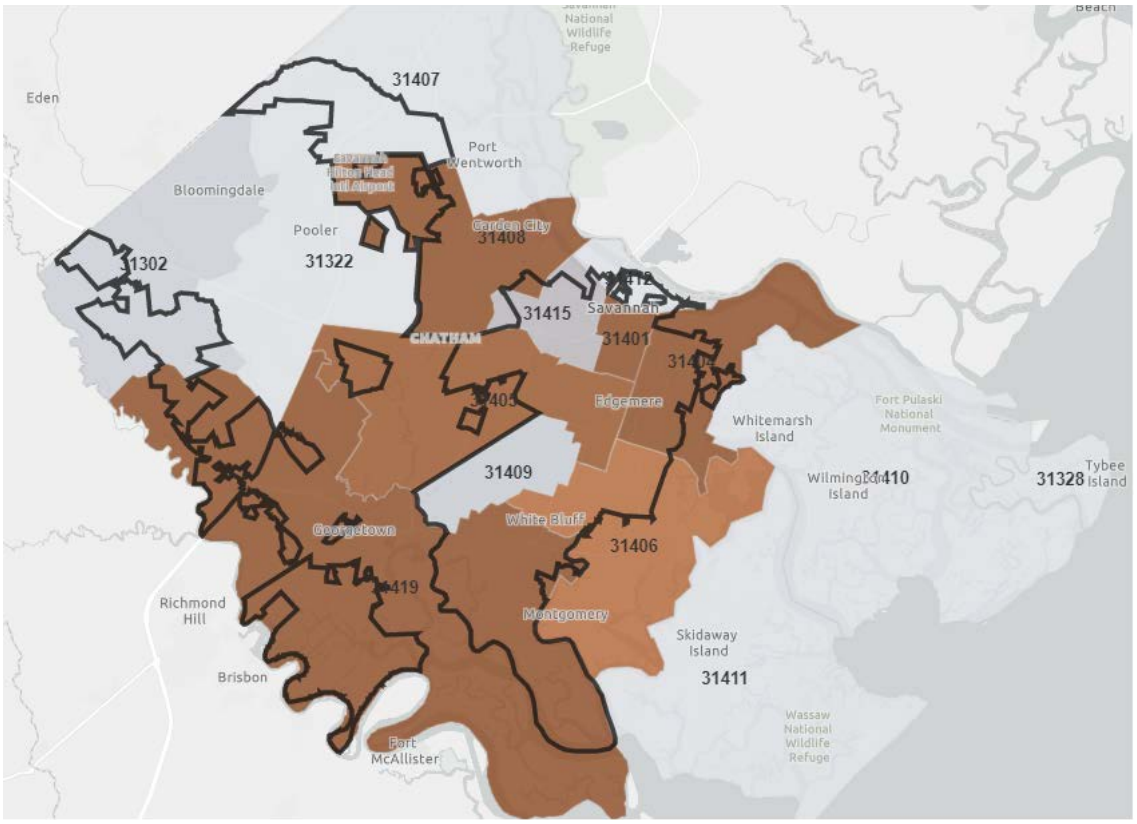

Figure 21. *Electricity Consumption, the Savannah City Boundary*

zip codes as a proxy (City-Data, 2020).

This map shows the total electricity consumption (residential, commercial, and industrial) by zip codes in kWh for the year 2019. Georgia Power, the local utility in Savannah, provided a consolidated data of electricity consumption in the residential, commercial, and industrial sectors by zip code

viii. Poverty

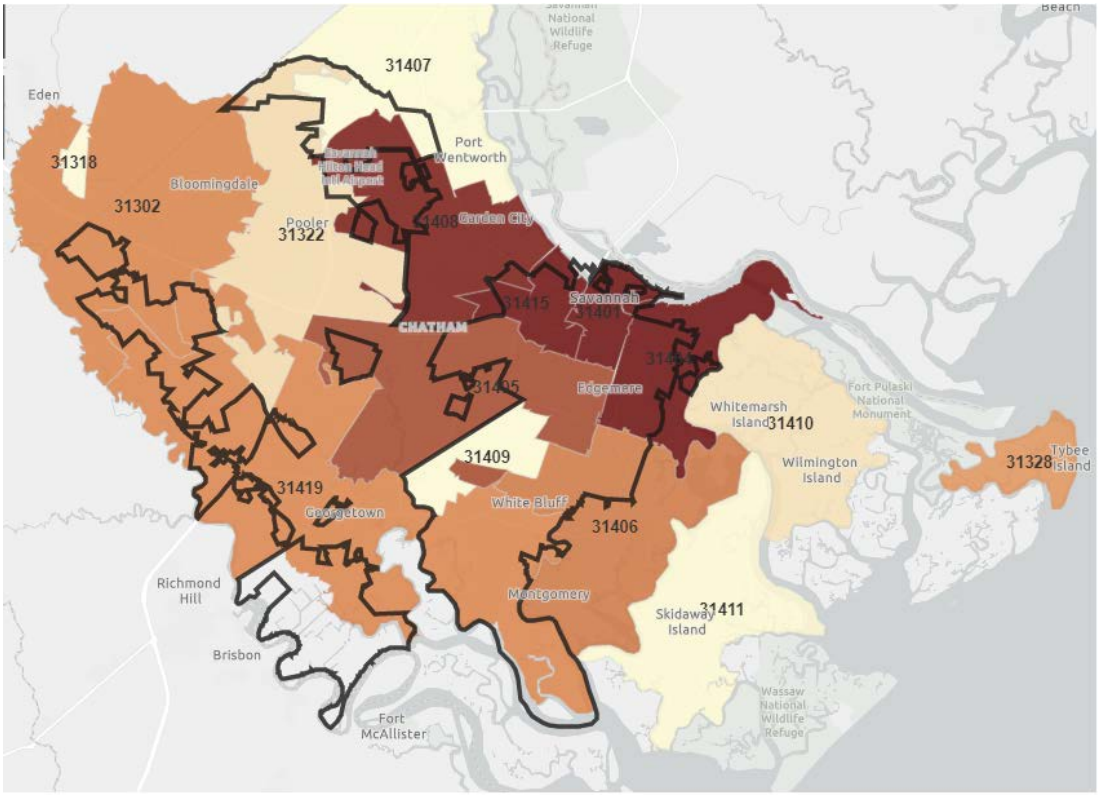

Figure 22. *Poverty by Zipcode, the Savannah City Boundary*

(N. Deffley, personal communication, July 7, 2020).

This map showcases poverty rates in Chatham County, organized by ZIP code boundaries. Poverty rate is a rather direct measure of the economic vitality, or vulnerability, of an area which in hand allows us to approximate which areas are and will be more prepared to combat the effects and future costs of climate change.

The poverty variable shows the percentage of the population that's at or above the poverty line in Savannah. Areas on the map with higher poverty rates indicate areas with an increased inability to combat climate change. The lighter colors closer to cream signify poverty rates at or below 4%. The closer to a darker brown that the map gets signifies poverty rates at or above 26%.

VII. FINDINGS

a. Environmental Team

i. Analysis

The environmental team has chosen to compare the Projected 5ft-above-high-tide Flooding map (ENV) with the Poverty by Zip Code and Percent of Population Black maps in order to analyze the overlay for spatial patterns. Figure 22 shows Poverty by Zip Code map overlaid with the Projected Flooding map, and Figure 23 shows the Percent of Population Black map overlaid with the Projected Flooding map. These three maps were selected because the marginalized communities are often impacted more by natural disasters due to their socio-economic status. We will describe what each of the maps represent and how they overlap to show different trends in vulnerabilities that exist in the city of Savannah.

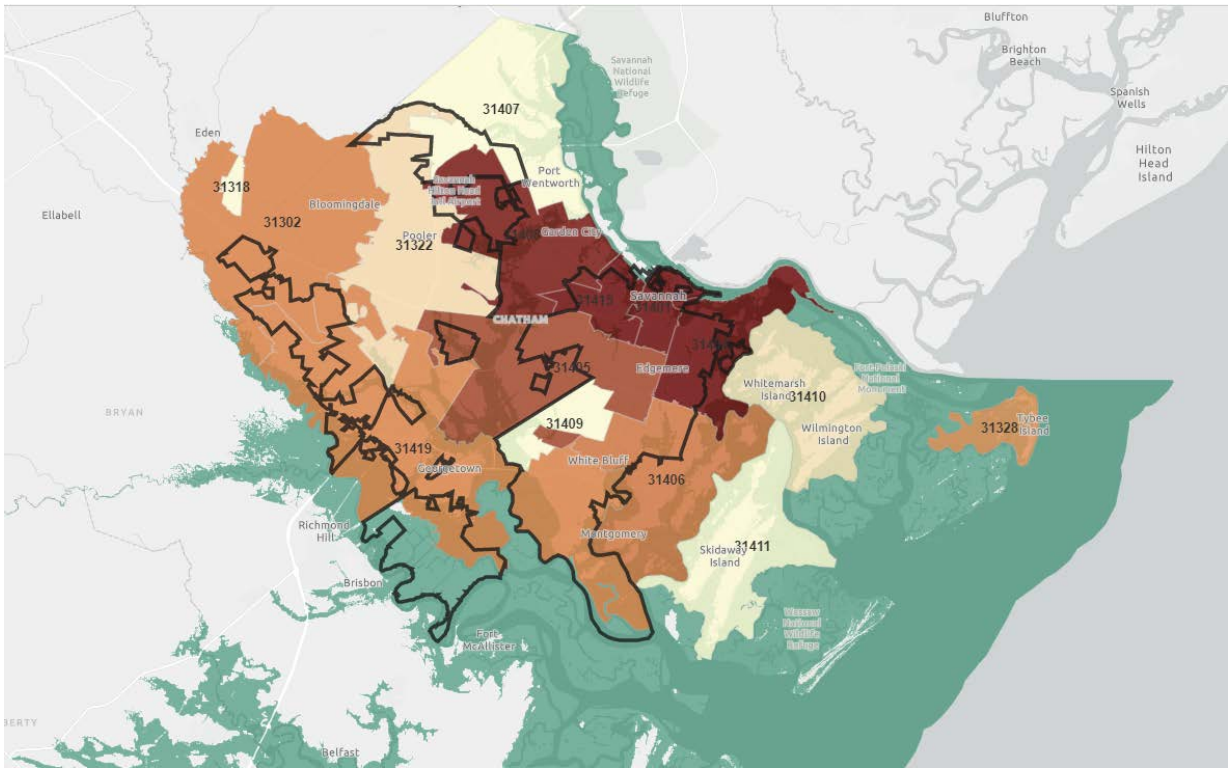

Figure 23. *Poverty by Zip Code map overlaid with 5ft Projected Flooding map*

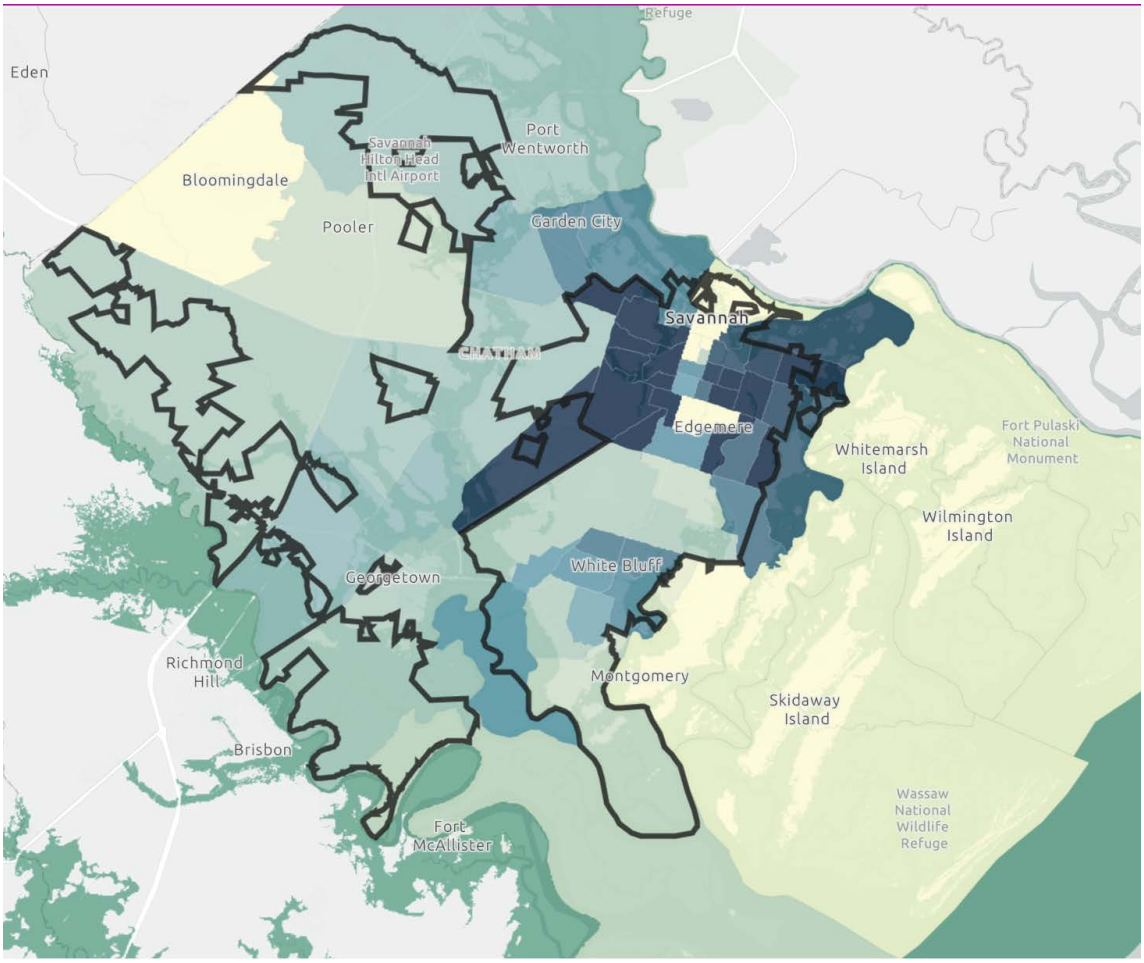

Figure 24. *Percent of Total Population Black by Census Tract map overlaid with 5ft Projected Flooding*

By comparing the poverty by zip code map from the economic team to the projected flood area map, seen in Figure 23, we notice that the poorer areas of the city are more drastically affected by rising sea level. In the projected flooding map, we can notice that along the Savannah River and the Ogeechee River there is a greater risk of flooding; cross-referencing that to the poverty by zip code map, we can see that many of Savannah's poorest communities live along these two rivers. The Clearview, Carver Village and Florida Junction, shown in Figure 24, are areas located on the Savannah River that have a poverty rate of around 26%. With the elevated risk of flooding in the areas adjacent to the river, we see that these particular communities are examples of the regions in the highest risk; since a large portion of people in this neighborhood live in poverty, they will be unable to protect themselves and their household in the event of a severe flood.

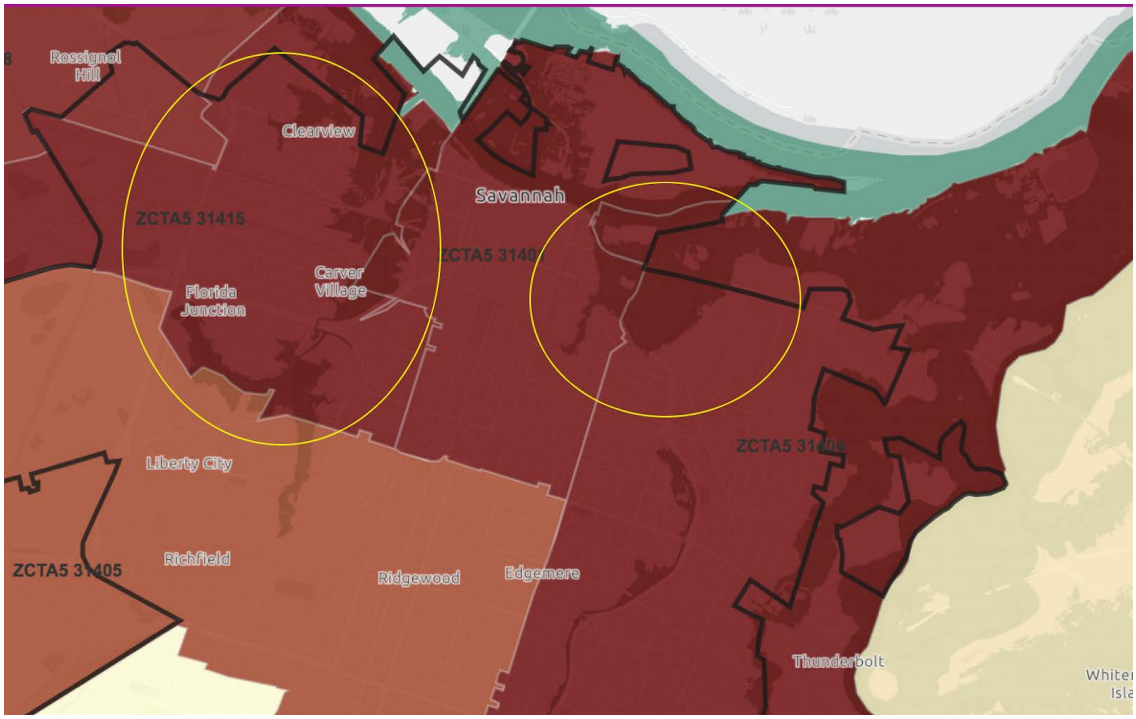

Figure 25. *Close-up on Figure 22 along the Savannah River*

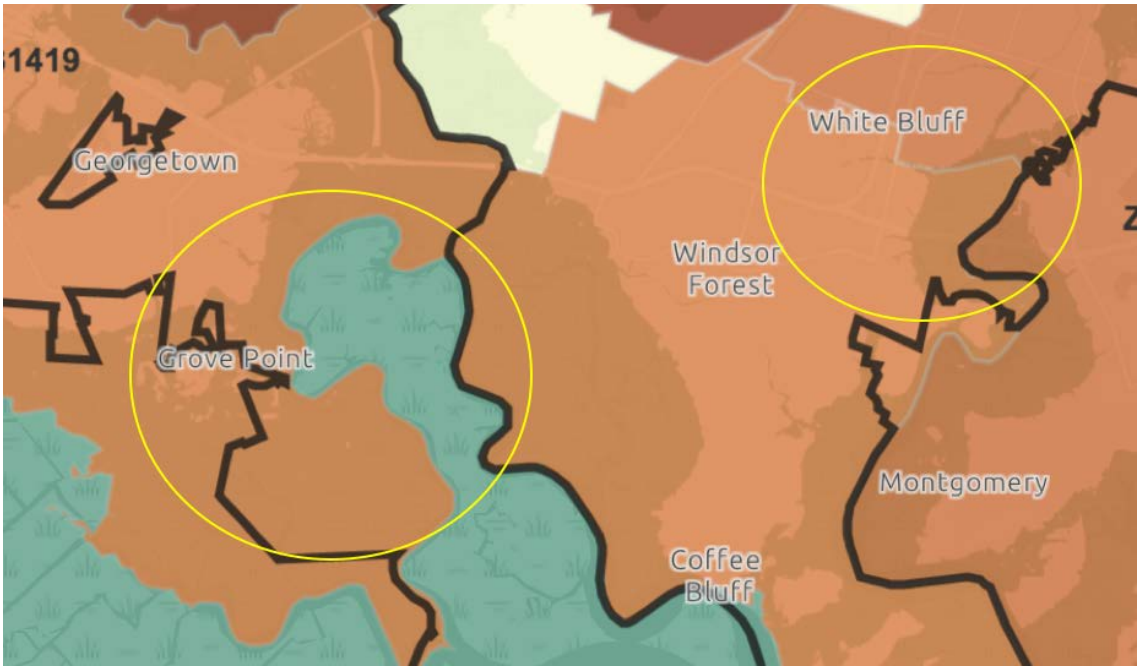

Figure 26. *Close-up of Figure 22 on the Ogeechee River*

The same scenario occurs in neighborhoods such as Grove Point, Whitebluff, and others that are located by the Ogeechee River, shown in Figure 26. This area consists of swamps and marshlands, resulting in a higher risk of flooding. This zip code area has around 14% of its population living in poverty. While the poverty is not as drastic as areas near the Savannah River, the flooding is much more significant. Flooding in these neighborhoods will exacerbate poverty levels as people's property is destroyed, their homes may be made unlivable, and they are forcibly displaced.

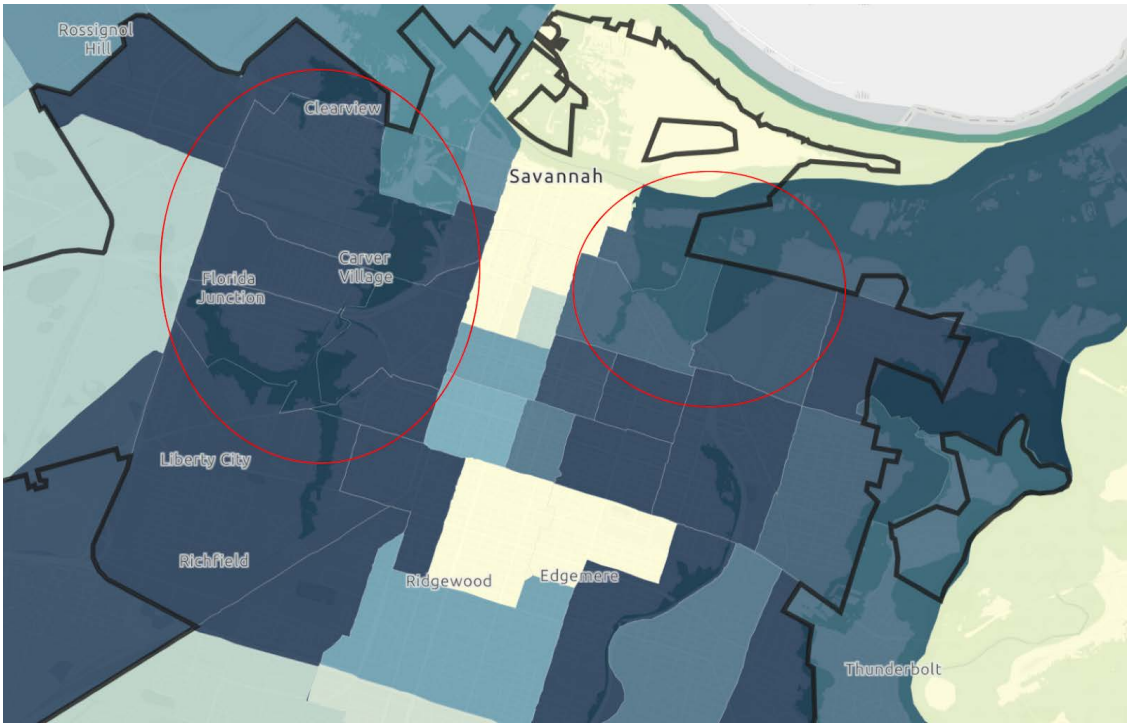

Figure 27. *Close-up of Figure 23 along the Savannah River*

There is also a notable correlation between projected flood areas and tracts having a higher percentage of Black residents, particularly in areas within Downtown Savannah closest to the Savannah River. As seen in Figure 27. Clearview, Carver Village, and Florida Junction on the west, along with communities close to Lepageville on the east show overlap between high percentage Black population and areas susceptible to 5 foot flooding. Between 65% to 75% of residents in these locations are Black according to 2010 census data. Areas near Grove Point and Whitebluff, shown in Figure 27, are affected heavily by flooding as well due to their proximity to the Ogeechee River. Between 45% to 55% of residents in these areas are Black according to 2010 census data. As noted before, neighborhoods closer to the Savannah River and Ogeechee River are subject to greater risk of severe flooding due to the effects of climate change. This makes the Black individuals of Savannah more vulnerable to the effects of climate change, as compared to other racial demographics in Savannah.

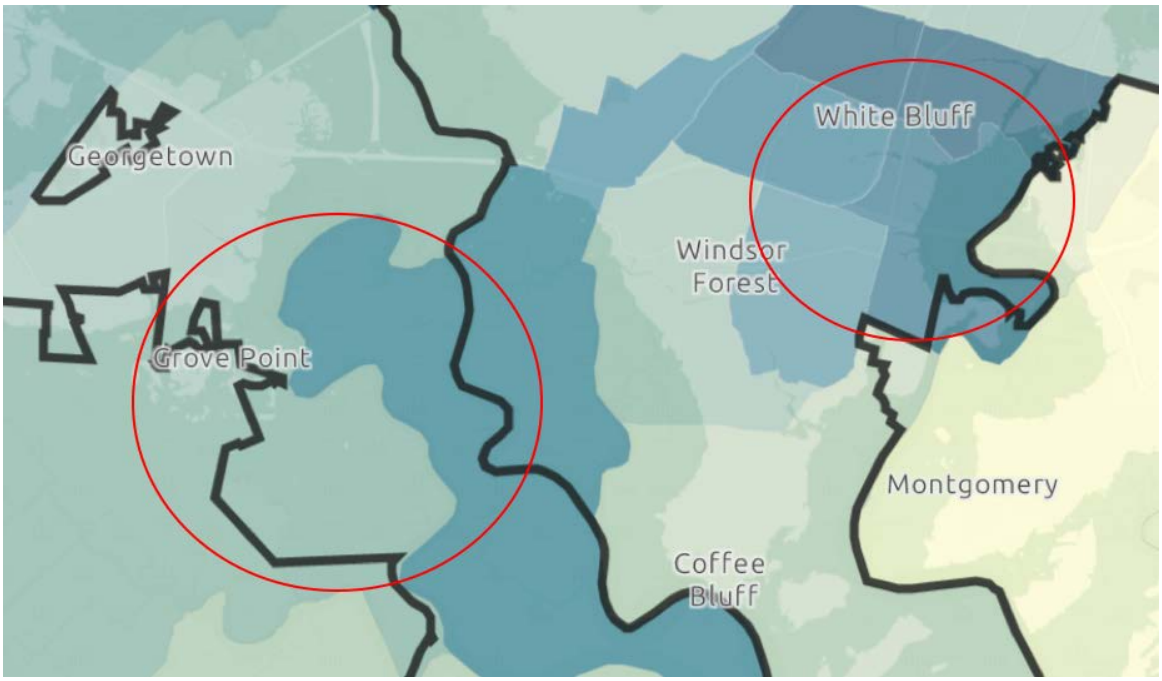

Figure 28. *Close-up of Figure 23 along the Ogeechee River*

In comparing the Poverty by zip code and percent Black population maps, we see a clear correlation between mostly Black neighborhoods and those with a greater proportion of their residence living in poverty. This is likely due to the history of systemic racism and generational poverty prevalent in our country. The correlation between impoverished Black communities in Savannah being located in higher risk flood areas also makes sense from a historical standpoint. Historically, segregation forced Black populations to live in the most undesirable parts of a city. In Savannah's case this could align with areas surrounding the historically polluted Savannah River (Gayer, 2014). Redlining practices from the 1930's onward also perpetuated the cycle of poverty in these areas, as mostly Black neighborhoods were discriminately denied access to housing loans, one of the main engines of wealth generation in the 20th century, for decades in Savannah (Murphy S.E., 2019).

ii. Problems Identified

The overlaid maps reveal issues regarding poverty and the lasting effects of segregation and racist policies within the limits of Savannah. The Poverty Rate by Zip Code map and the Percent of Population Black or African American map demonstrates that marginalized communities are disproportionately located in areas more susceptible to flooding. Neighborhoods bordering the Savannah River and the Ogeechee River that are likely to experience high levels of flooding have higher rates of poverty and a higher percentage Black population than other flood-risk areas of Savannah. Across the globe, marginalized communities face increased vulnerability to the effects of climate change and sea level rise, due to their inability to participate in environmental policies that have great impacts on their lives (Rayner and Malone, 2003). In conversation with Dr. Mildred McClain, co-founder and Executive Director of the Harambee House, we learned that the

residents in these neighborhoods are often disregarded from conversations that directly affect them (M. McClain, 2020). By including these communities in the conversation, we would be able to better understand the needs of the community.

While examining the Projected 5-ft Flooding map with the Percent of Population Black or African American map, it becomes very clear that majority Black communities will be more severely impacted by flooding. This is an example of patterns of behavior known as environmental racism. Environmental racism refers to the injustice that occurs in communities of color with regard to their environmental health and security. Near the bank of both the Savannah River and the Ogeechee River, Black populations are more severely affected by climate change and resulting sea level rise. The map reveals that higher percentage white neighborhoods are located farther inland than the most flood-vulnerable neighborhoods, and often have lower rates of poverty. This shows how city limits, institutional racism, and individual bias have caused the, in general, poorer African American populations to live in areas closer to the river, placing them at higher risk for flood hazards.

Similarly, the maps demonstrate that the areas with higher poverty by zip code are also highly vulnerable to floods and sea level rise. As flooding events become more frequent, the neighborhoods around the Savannah and Ogeechee Rivers will be unable to afford repairs for their homes, and those that rent their homes may be forced out. According to the 2019 Georgia census, 56.1% of households in Savannah are renters, which makes them become more susceptible to eviction if flooding occurs (Census Bureau, 2019). After natural disasters, like flooding, occurs, landlords are sometimes reluctant to readmit renters. This is due to a number of reasons; fear of lawsuits for unsafe conditions, a lack of capital to repair housing units, wanting to break leases or to re-rent apartments at higher rates, or wanting to demolish damaged properties and rebuild alternative housing (Elliot and Pais, 2006). Renters' job security is also greatly affected by flooding, as poor residents are unable to provide temporary housing for themselves or afford to live in the city. When Hurricane Katrina flooded 80% of New Orleans in 2005, surveys showed that renters were 1.9 times more likely to have lost their jobs in the aftermath of the storm than home-owners (Elliot and Pais, 2006).

Finally another issue that arises during flooding is evacuation. The Chatham Emergency Management Agency (CEMA) manages flood warnings in Savannah. Once CEMA receives word that there are potential dangers, they will activate a siren, however this siren may give as little as a fifteen minute warning (Chatham County Emergency Management., n.d.). In our discussion with Dr. McClain, she explained to us that many residents are not aware that this siren exists so when it does ring they do not take appropriate actions to protect themselves (M. McClain, 2020). In addition to limited communication regarding flood hazards, 8% of Savannah residents are completely vulnerable to flooding as they have no vehicles available to them in their household and thus cannot evacuate (Chatham County Department of Engineering, 2018). These issues continue to grow and develop as cities are segregating across class lines and subjected poorer residents to unequal treatment when natural disasters and changing climates occur.

iii. Actions Taken by City of Savannah

The city of Savannah, in 2012, created a Flood Mitigation Plan that addresses mostly flash flooding and not sea level rise. However, the Flood Mitigation Plan establishes different measures to prevent flooding such as regulating construction ordinances, developing stormwater conveyance systems and maintaining drainage systems that all prove beneficial for any water surge event, whether it be unexpected flash flooding or the more systemic sea level rise. The Plan lists 26 unique actions the city was to undertake in order to bolster their flood mitigation system, which are all grouped into 6 overarching goals: "establish measures to prevent flooding," "implement property protection activities," "ensure natural resource protection," "enhance emergency services," "construct structural projects," and "perform public information activities." These 26 activities were then ranked from highest to lowest priority by the 8 Planning Committee members at the time. The highest priority projects from each of the six goals were action 1.8, "maintain drainage system," action 2.3, "encourage purchase of flood insurance," action 3.5, " Regulate development within Chatham County's coastal barrier areas," action 4.1, "Merge the FMP with the Emergency Operation Plan," action 5.1, "Implement channel modification improvements", and action 6.2, "provide technical assistance"(Chatham County Department of Engineering, 2012).

These six actions represent the more important actions used by Savannah for flood mitigation, yet still fall flat of a complete flood mitigation system. Of the six, the drainage system, coastal construction regulation, and channel improvements help with the built infrastructure of the city, while the flood insurance, emergency system collaboration, and technical assistance are focused more towards the improvement of the flood information network to help and inform citizens about the flood risks of Savannah.

Action 1.6 uses Hazard Mitigation Assistance Grants as well as local funds with the aim was to "properly design stormwater conveyance systems [that are] effective in preventing erosion and can channel stormwater runoff." The second of the six actions, to "encourage the purchase of flood insurance," allows flood victims to be reimbursed for building losses up to $250,000, along with content and business coverage also being available. The third and sixth actions, to "regulate development within Chatham County's coastal barrier areas" and "implement channel modification improvements," are akin to the first action in that they aim to ensure adequate built environments for mitigating damage in the event of a flood. The fourth and sixth actions, "Merge the FMP with the Emergency Operation Plan" and "Provide technical assistance" respectively, utilize local funds to bolster the flood information network, in order to assure proper community education and preparedness for flooding events.

While these actions are put in place to assist both the built flood infrastructure as well as the flood information network, we believe much more can be done in both of these areas. This can be seen throughout the world, where similarly flood-prone urban areas are being more proactive and less reactive in their flood responses.

iv. Actions Taken by Other Cities - Rotterdam, Netherlands

Hundreds of coastal cities in the US and around the world are facing increased flooding just like Savannah, and some like Rotterdam, the largest port in Europe with a history of calamities related to flooding, are leading the world in hard-engineering techniques that embrace living with water. These techniques include constructing sea walls, water pumps, flood gates, and overflow chambers, which work together to directionally control the flow of water in the city and prevent excess water from entering the city from the sea (Muggah, 2019). A famous example involves Rotterdam's Maeslantkering, which translates to "Maeslant barrier" in Dutch. The Maeslantkering is a storm surge barrier consisting of two large barrier gates as large as the Eiffel Tower that protects the city's main waterway from storm surges when closed (Kimmelman & Haner, 2017). On a smaller scale, Rotterdam has also constructed "water squares" in underserved neighborhoods, shown in Figure 7. These operate as urban retention ponds that relieve pressures on drainage systems and in urban areas where natural retention ponds could not exist while also acting as public spaces for citizens to gather (C40 Cities, 2014).

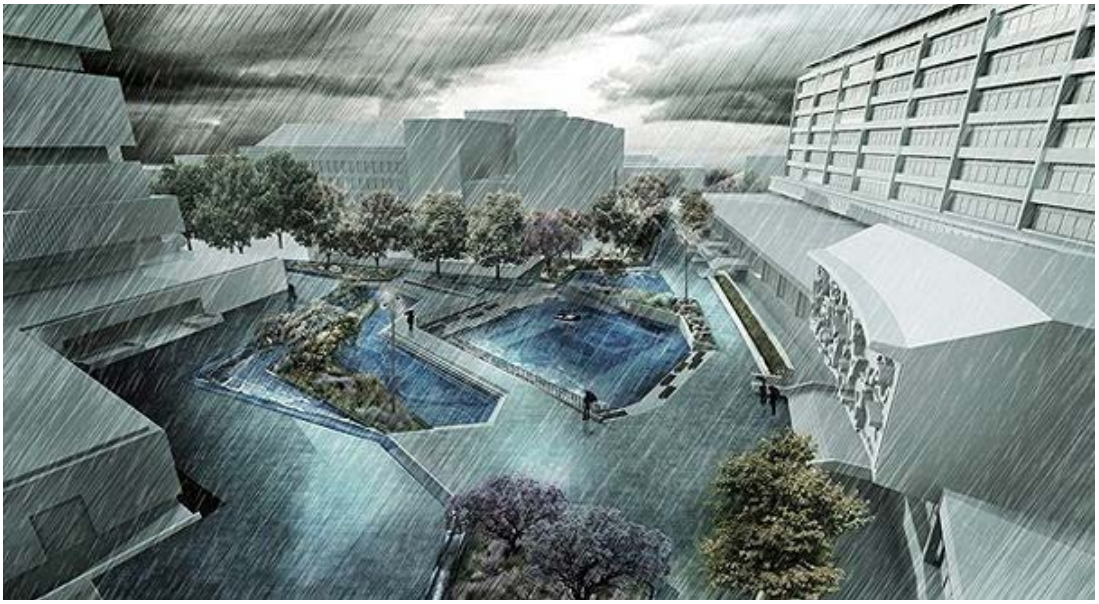

Figure 29. *Rendering of Water Squares retaining water during flooding in an urban park in Rotterdam, Netherlands (Keeton, 2014)*

Additionally, Rotterdam specifically has taken the initiative to educate its citizens on the effects of climate change, as a result "[putting] climate adaptation high on the public agenda" (Kimmelman & Haner, 2017). Rather than viewing climate change as a threat, the citizens of Rotterdam believe there is an "opportunity to make the city more resilient, more attractive, and economically stronger" (Muggah, 2019). A few examples of Rotterdam's public outreach campaigns can be found in the third and fourth steps of their four-step adaptation strategy, which are "working together and linking in with other projects in the city" and "added value for the environment, society, economy, and ecology" (Connecting Delta Cities, n.d.). Such programs include hosting public workshops in their sustainable floating pavilions, as well as the municipality substantiating the growth of climate adaptation-linked job training and offering "scope for pilot programs and

innovations within climate adaptation measures". The city of Savannah could explore similar engineering and educational solutions to prevent and address future flooding in the city as a whole. These solutions must be compliant with the three pillars of sustainability to ensure long-lasting growth in Savannah, while prioritizing the needs of vulnerable communities in the city.

b. Social Equity Team

i. Analysis

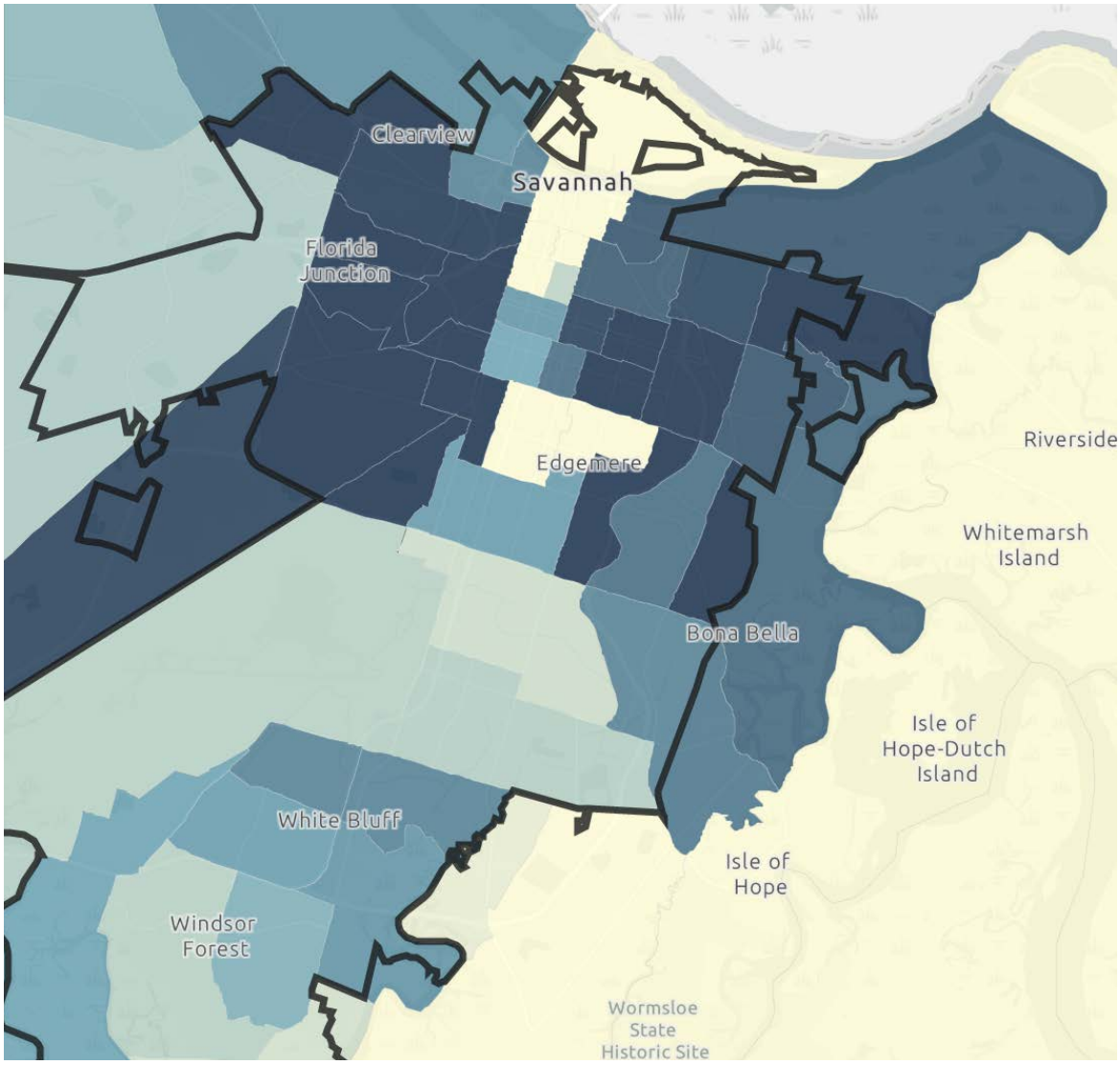

Figure 30. *Percentage Black*

The "Percentage Black" map shows the percentage of Black residents of each census tract in Chatham County. A darker blue represents an area with a higher concentration of Black residents (ARC, 2019). This data comes from the Atlanta Regional Commission.

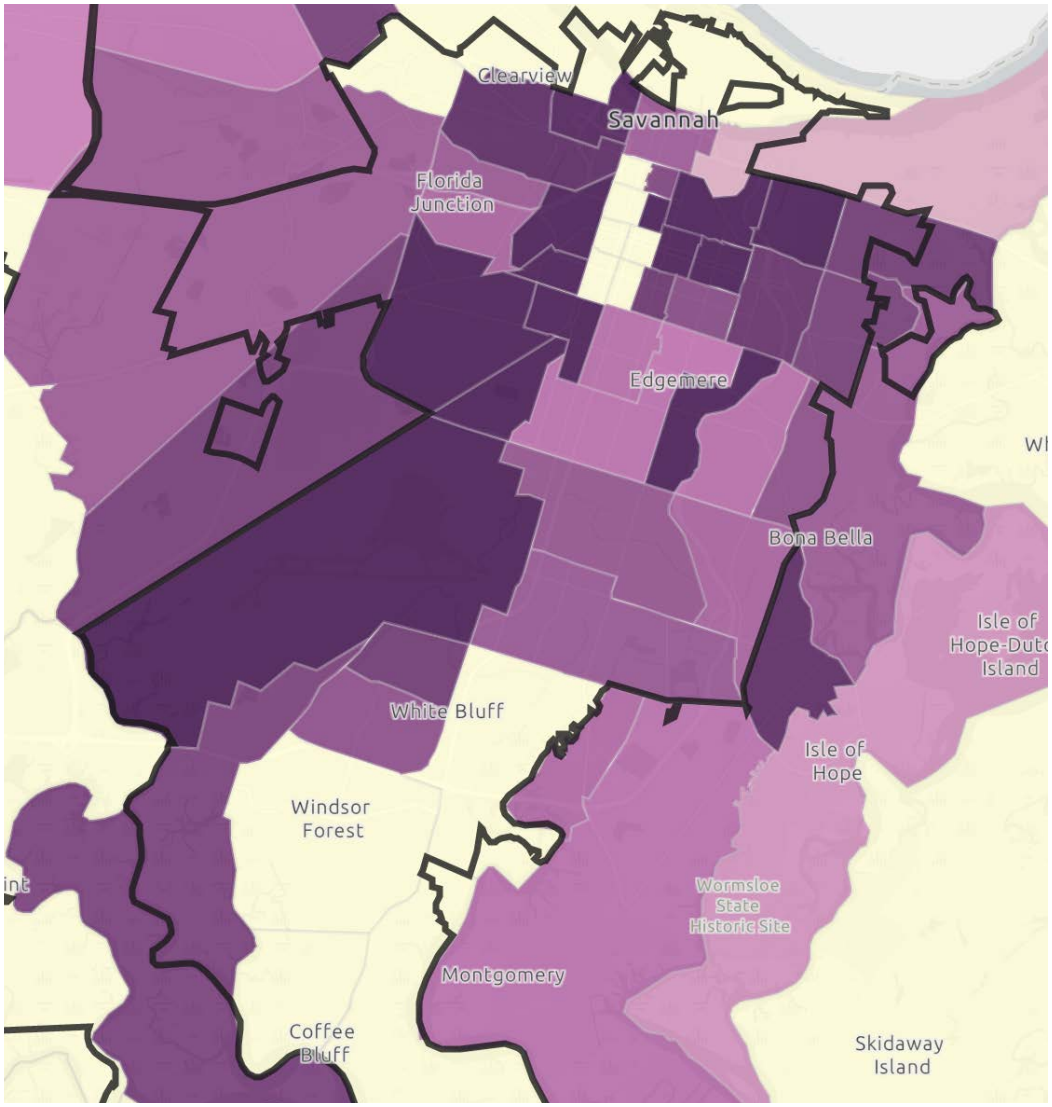

Figure 31. *Housing Burden*

The "Housing Burden" Map shows the percentage of households in each census tract that are burdened with housing problems. A darker purple represents an area with a higher percentage of burdened households (HUD, 2019). This data comes from the United States Department of Housing and Urban Development with the help of Mosaic Community Planning.

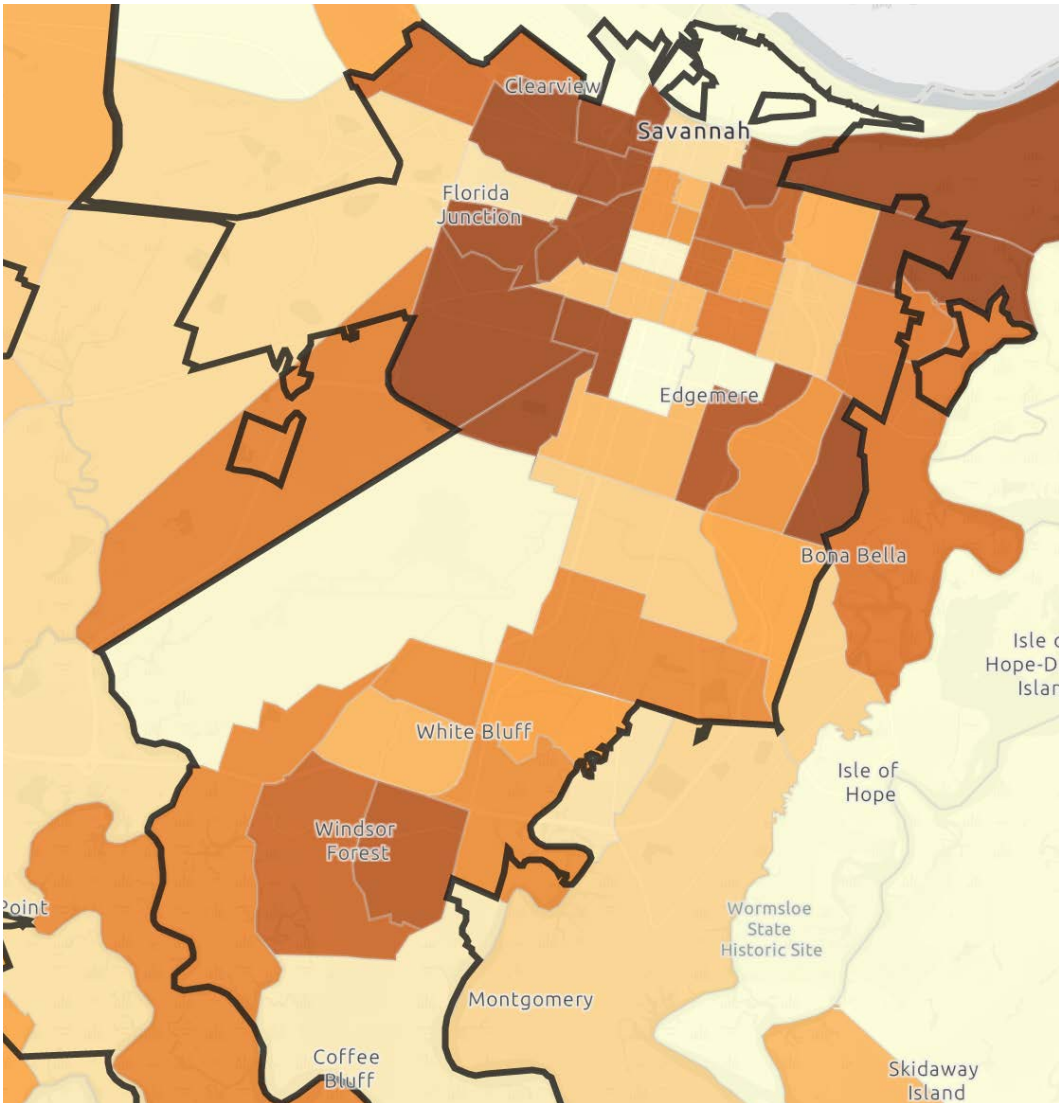

Figure 32. *Unemployment Rate*

The "Unemployment Rate" Map comes from the Economic team and shows the unemployment rate by area within Chatham County. The unemployment rate variable represents the percent of Chatham County residents that are jobless despite them actively seeking work. Lighter colors represent lower unemployment rates which exhibit a stronger economic base within the area, while darker colors exhibit higher unemployment rates which convey an underlying economic vulnerability for that area (ARC, 2017). This data comes from the Atlanta Regional Commission.

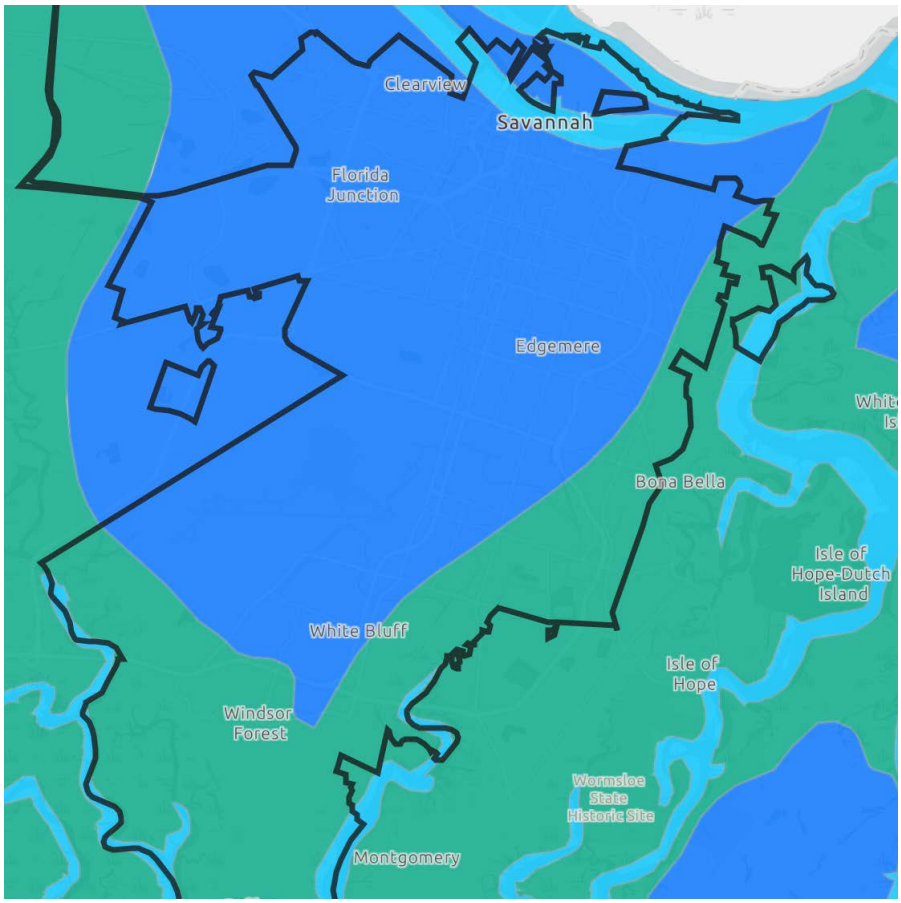

Figure 33. *Ground Water Pollution*

The "Groundwater Pollution" Map comes from the Environmental team, and it shows which areas of the city are more likely to be affected by pollution trickling down into this underground layer (SAGIS, 2019). The city of Savannah sources its water from either the Savannah River or the Floridan aquifer, which is an underground layer of water (Water Supply And Treatment - Water Quality., n.d.). This data comes from the Savannah Area Geographic Information System.

We chose to highlight the historic downtown area of the city of Savannah in order to show where the most financially burdened individuals reside in this area. Those with many financial stressors such as those experiencing housing burdens or unemployment are more likely to struggle to combat environmental challenges such as groundwater contamination (Winkel & Nazrul Islam, 2017). Climate change directly correlates with groundwater supply for two reasons, quantity and quality. As climate change causes more extreme weather, there will be longer periods of droughts and floods, which "directly affects availability and dependency on groundwater" (International Groundwater Resource Assessment Center, n.d.). Additionally, climate change causes sea level rise which can cause salt to infiltrate the groundwater and consequently contaminate the drinking water. As climate change intensifies in the coming years, downtown Savannah is projected to have contamination in their groundwater which will disproportionately affect people of color.

ii. Problems Identified

We found correlation between higher housing burden rates, higher unemployment rates, and greater percentages of Black residents in the downtown Savannah area. Additionally, there was a correlation between census tracts with less housing burden, lower unemployment rates, and a greater percentage White population. These correlations can be seen in the following maps:

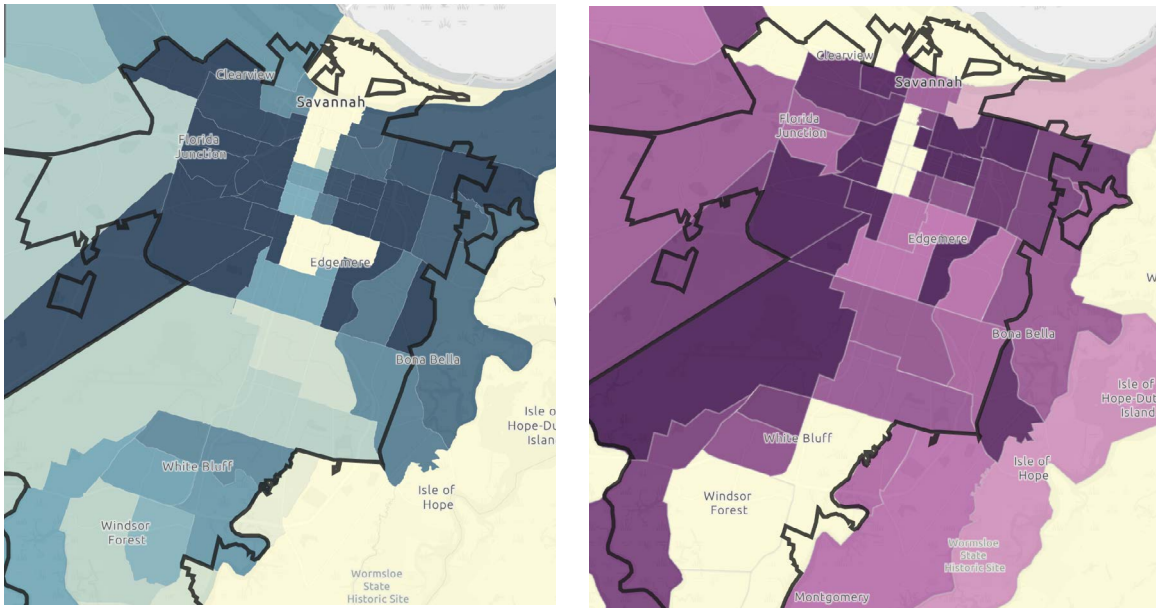

Figure 34. *Figure 30 vs Figure 31- Correlation Between Housing Burden and Race*

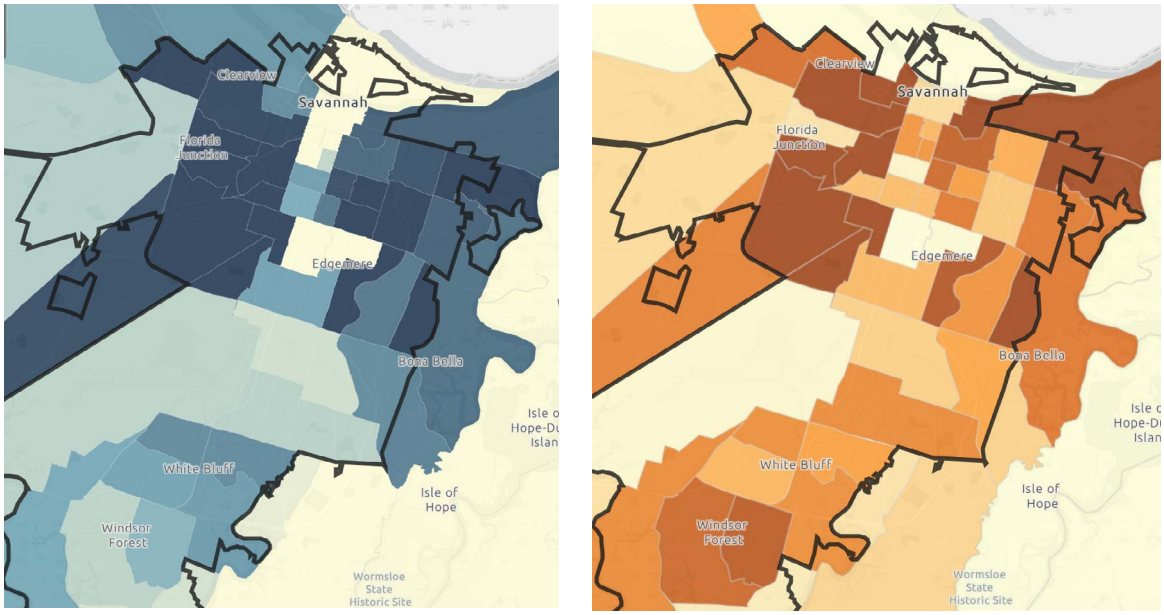

Figure 35. *Figure 30 vs Figure 32 - Correlation Between Housing Burden and Race*

The intersection of greater housing burden and higher unemployment rates indicates greater financial burden and stress. While risk of groundwater pollution affects all households in the downtown area, the population with a greater financial stress may be less able to adapt to the effects of groundwater pollution such as water borne illnesses (Arcadia, 2017).

This area of Savannah clearly demonstrates a sharp geographic divide in socioeconomic status and how it directly correlates with race. The areas on the map that are at least 85% White never experienced the worst cases of housing burden (greater than 53%) or unemployment rates (greater than 15%).

iii. Actions Taken by the City of Savannah

Savannah has taken significant steps as a city to address the issue of housing burden. Established in 2011, the Savannah Affordable Housing Fund (SAHF) helps fund the construction and rehabilitation of affordable housing units, as well as financially assisting homebuyers, renters, landlords, developers with loans and downpayments for low-income individuals (Savannah Affordable Housing Fund, 2020). SAHF has contributed over $18 million in investments and has been involved in over 300 projects (Savannah Affordable Housing Fund, 2020). The following are specific initiatives recorded in the city of Savannah Assessment of Fair Housing in 2017:

+ Partner with the Housing Authority of Savannah to hold an annual informational forum for landlords and property managers on the benefits of the HCV program and the obligations and responsibilities of tenants, landlords and the public housing authority under the voucher program (Annually, Q2 beginning 2018) (Mosaic Community Planning, 2017)

+ Conduct fair housing education workshops (Quarterly, beginning Q1, 2018) (Mosaic Community Planning, 2017)

+ Fund fair housing enforcement services (Annually, January); OR Establish a portal on the city's website for registration of fair housing discrimination complaints (Q3, 2017) (Mosaic Community Planning, 2017)

+ Establish a neighborhood revitalization program: 50 dwellings repaired/ constructed, $5 M in housing investment (Private, CDBG, HOME), $250K in city-financed infrastructure improvements (Begin 2018, end 2020) (Mosaic Community Planning, 2017)

+ Partner with the State of Georgia ADA Coordinator's Office to deliver a training session on fair housing accessibility issues to local code enforcement officials, design professionals and property owners (Q4, 2018) (Mosaic Community Planning, 2017)

Policy implementation towards groundwater contamination, unemployment, and racial inequity are not as robust as housing affordability, but still exist in the city. Savannah currently uses external tools and programs to address unemployment. Employ Georgia by the Department of Labor (DOL) is an online tool to help job seekers get matched with a

job that they are qualified for (GDOL, n.d.). Savannah River Site Groundwater Management Program (SRS, 2016) purpose is to protect, monitor, remediate, and use groundwater. This program does the following: ensures future groundwater contamination does not occur, monitors groundwater to identify areas of contamination, remediates groundwater contamination as needed, snd conserves groundwater.During a Black Lives Matter protest, Mayor Johnson announced a task force that would be dedicated to racial bias and inequities and work on solving those issues within the city (Jones, 2020), however there is no information about this task force on the city's website.

iv. Actions Taken by Other Cities

To address the issues identified by the social equity analysis, we can refer to policy action of other cities as case studies towards recommending solutions for the city of Savannah.

Austin, Texas, St. Paul, Minnesota, and Anaheim, California all have put forward programs to alleviate housing burden in low-income communities. In Austin, local governments give voters the ability to vote on how funds are allocated in their city. Voters said yes to a $250 million affordable housing bond which supports rental assistance, affordable home ownership, and home repair programs (Sukumaran, 2019). The funding will be put toward the Austin Housing Finance Corporation, which will use it to buy land and build houses for low-income residents (Sukumaran, 2019). St. Paul gives a property tax break of 40% if landlords keep at least a fifth of the building's units affordable for low-income tenants (Walsh, 2019). Anaheim has a program similar to St. Louis. The city gives a vacant lot to a developer as a part of an agreement to build an affordable housing complex with 20% of the units being for homeless households (Sukumaran, 2019).

A possible solution towards unemployment could be found in the same state. Atlanta, Georgia's Westside Works program, located in the historical Westside neighborhood, "is a long-term neighborhood program focused on creating employment opportunities and job training for residents of the Westside community" (Westside Works, n.d., p. 1). The program consists of four steps including an initial assessment, development, placement, and support services. Westside Works placed 701 residents into full time employment by January of 2019 (Westside Works, n.d.).

In the 1990s, the residents of Waupaca, Wisconsin found elevated levels of nitrates in the groundwater which was their major source of drinking water. The city government, technical experts, and citizens developed a wellhead protection plan that included nitrate level tracking. The data received from this was used in land use decision making and the commission provided educational crop consulting services to farmers about nitrate reduction. By 2009, the city reported average nitrate concentrations below the EPA's max contaminant level (EPA, nd).

b. Economic Development Team

i. Analysis

To further analyze this dynamic in Savannah, we chose the three following maps: Percentage of All Businesses by Neighborhood, which will serve as a proxy for small businesses, with darker gray areas having a denser concentration; Projected Flooding 5ft Above High Tide, projected to happen at least once by the year 2080 assuming a medium rise in sea levels due to the effects of climate change(Surging Seas, 2016), and represented by seagreen colored areas; Increased/Decreased Need for Flood Insurance, which will also highlight areas where flood insurance will be needed and businesses may be vulnerable, represented by red/blue areas respectively. We chose these with the objective to uncover potential climate-related flood vulnerabilities in Savannah that would have a major negative impact on the vitality of local businesses.

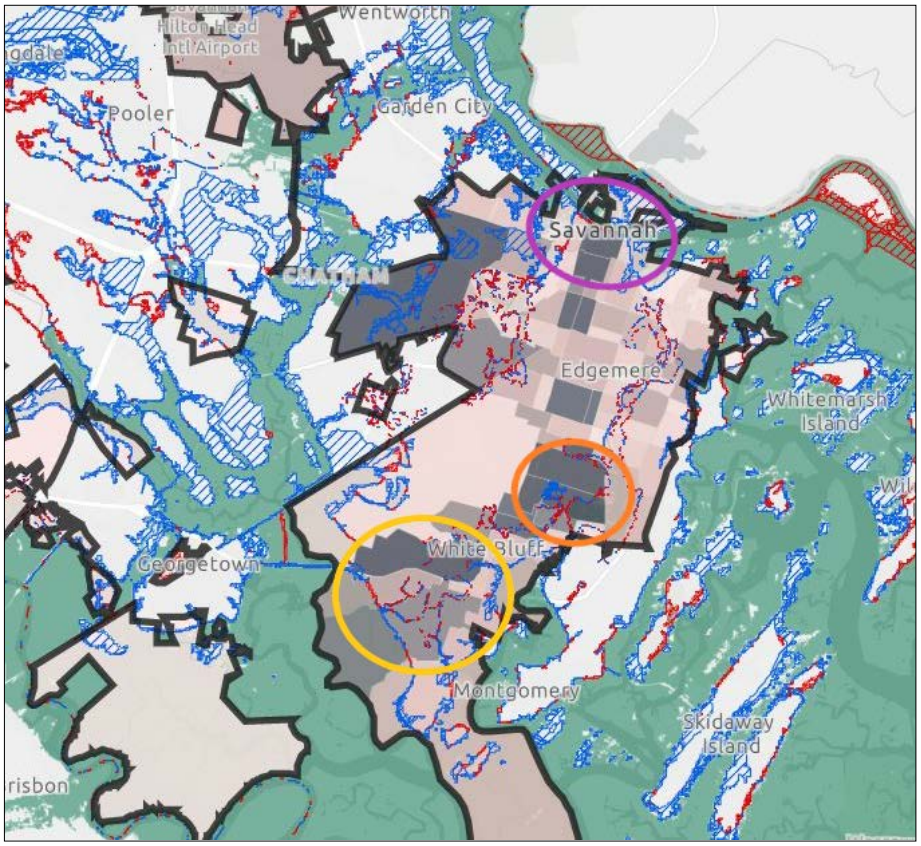

Figure 36. *Map of the City of Savannah with highlighted areas of analysis.*

The map above exhibits the overlap between the locations of business (the dark grey areas have over 2.5% of the businesses of Savannah within their area), the areas vulnerable to flooding five feet above high tide (indicated by seagreen), and the decreased (blue) or increased (red) trend in need for flood insurance on a year by year basis.

Areas of dark grey, overlapped with the seagreen indicate an area where businesses will face a projected 5 foot rise in sea level. The presence of veneers of red and blue areas within these same dark grey areas indicates whether these businesses will have an

increased or decreased flood insurance need, respectively. A focus on the red areas and seagreen areas within the dark grey areas where businesses agglomerate, will serve as an aid to identify this vulnerability. A detailed analysis of each area, along with their identified issues, can be found in the following section.

ii. Problems Identified

Taking into account the issues highlighted by the selected maps and their relationships, areas of high business density within the city of Savannah are experiencing varying degrees of flooding risk. We'll be analyzing each area, highlighted by a distinctly colored circle in Figure 36, to identify the sources of their vulnerabilities.

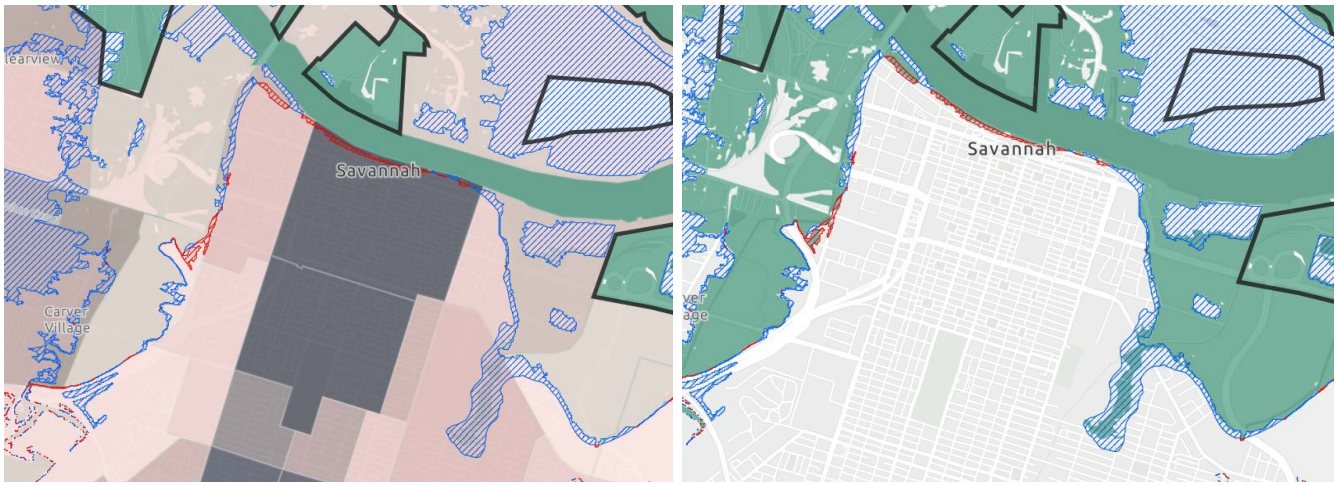

Figure 37 *Historic District Neighborhood Area (with & without business percentages)*

Figure 37 showcases our first area of analysis, the neighborhoods in the Historic District (purple circle in Figure 35), with a distinct strip of red by the areas close to the Savannah River. This indicates an increasing need for flood insurance for businesses close to the river, putting those businesses without proper insurance in a vulnerable position for flood related issues. It is important to also note the compounded effect of rising sea levels and fluvial(river) flooding as an added risk, a factor often unaccounted for in flood hazard assessments(Moftakhari, 2017). The resulting impact from both hazards interacting will result in an aggravated risk area impacting businesses in the river's vicinity.

Our second area of analysis are the neighborhoods of Oakdale, Avalon/Oglethorpe, Highland Park, Chippewa, and Oakhurst; all of them shown in Figure 37 and circled in orange in Figure 35. We can identify a significant overlap of the dark grey areas of business agglomeration with the seagreen of projected 5ft rise to the right side of the Highland Park neighborhood, while also presenting strips of red for increased flood insurance need. Oakhurst, Oglethorpe, and upper Oakdale also exhibit noteworthy red areas while having seagreen areas in their immediate vicinity. In contrast with the first area, which has fluvial flooding as the main problem, this area will have to deal with compounded pluvial(rainfall) flooding issues. Rising sea levels, storm surges, and heavy precipitation as a result of climate change will exacerbate pluvial flooding issues present in the area(Bevacqua, 2019). Businesses within the mentioned areas will have to take precautions against these flooding scenarios.

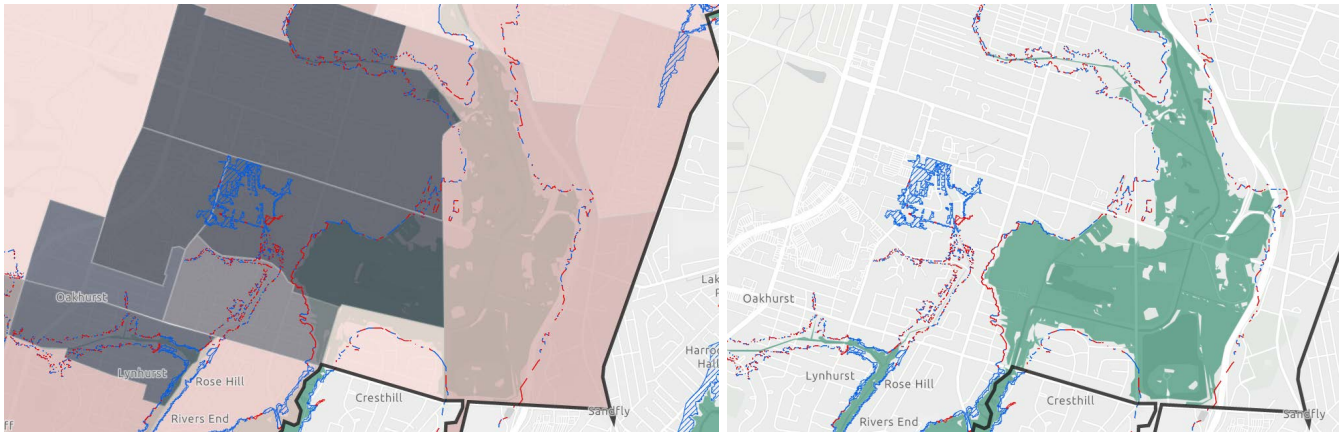

Figure 38. *Oakdale, Avalon/Oglethorpe, Highland Park, Chippewa, Oakhurst Neighborhoods Area (with & without business percentages).*

The last area of analysis are the Wilshire and Windsor Forest neighborhoods. We can identify Wilshire as having the highest agglomeration of businesses in this area, with few red areas within and no seagreen areas overlapped, indicating a low immediate flooding risk. However, it is important to note a substantial amount of those areas in the immediate vicinity present significant seagreen and red area overlaps. With rising sea levels exacerbating floodplains and reducing drainage efficiency, as described in a Southeast China study, there is a risk of these neighbouring issues extending into the area with high business concentrations (Griffiths, 2019).

Figure 39. *Wilshire and Windsor Forest Neighborhoods Area (with & without business percentages).*

iii. Actions Taken by the City of Savannah

Anticipating the effects of climate change, such as rising seas, the city of Savannah has implemented an array of policies, projects, and chapters of government to help the community prosper through future change. For starters, the Savannah chapter known as SCORE describes themselves as "Counselors to America's Small Business". They offer free business mentoring and counseling to the small business community (Seigal, 2018).

In relation to flooding, property owners in flood-prone areas of Savannah receive a 25 percent discount on their federal flood insurance though FEMA's Community Rating System, which

rewards efforts by local governments to improve their floodplain management (Landers, 2018) Furthermore, The Chatham County–Savannah Metropolitan Planning Commission has proposed retrofitting bridges with deeper foundations in Savannah and, in the long term, to elevate new bridges and dig deeper foundations for infrastructure and buildings so that it may better withstand flooding (U., 2016).

In combination with these measures, the Smart Sea Level project is working to monitor the water levels across Chatham County, the project's stated goal is to "provide real-time information about water levels across Chatham County to aid in emergency planning and response during episodes of flooding associated with storms, king tides, and other environmental events. The sea level data also provide a unique and important dataset to aid scientists, engineers, and regional planners in quantifying the short- and long-term risks associated with continued sea level rise" (Smart Sea Level Sensors, 2019).

Additionally, the city of Savannah has the ongoing "Green Infrastructure to Green Jobs'" Initiative, a program that forms an advisory committee of community leaders to create three urban tree nurseries on over 350 underutilized flood-prone FEMA lots (Kenworthy, 2018). The initiative will provide unemployed and underemployed Savannah residents with comprehensive classroom and hands-on landscape training apprenticeships, with the goal for them to become a Georgia Certified Landscape Professional, a certification held by only ~400 people in the state. With coastal Georgia experiencing extreme weathers, as well as Savannah's tree canopy having withstood significant damage from recent hurricanes, this green infrastructure project will serve to improve the city's resilience while allowing community members to engage in initiatives that benefit them and allow them to take ownership of their communities (Russell, 2019).

iv. Actions Taken by Other Cities

Other coastal cities can be used as a blueprint on how to work with climate change. New York City, for example, has successfully developed and begun to implement multiple flood resilience plans to strengthen its coastal protection against rising sea levels. The BIG U proposal was created to secure and protect Lower Manhattan from the impacts of changing climate such as increased floodwater and storms. The first phases of the project are being implemented as the East Coastal Resiliency (ESCR) Project and the Lower Manhattan Coastal Resiliency (LMCR) projects. East River Park is being developed under the ESCR Project while the LMCR project is being implemented in two separate parts from Montgomery Street to the Battery (Chester, A., Sasson, I., Ovink, H., Klinenberg, E., & Lawton, J. , 2019).

The East Side Coastal Resiliency (ESCR) Project was approved in November of 2019, and consists of $1.45 billion to raise East River Park 8 to 10 feet above sea level. Apart from potentially life-saving protection from flooding, it will also offer increased pedestrian connections across and around the East River on grade bridges. The LMCR Project will consist of an area that spans the Lower Manhattan coast, working to increase resilience to flooding while at the same time preserving access to the water and providing ample public space. Through this overarching BIG U plan, New York City is working to safeguard critical infrastructure and services, bolster the protection of neighbourhoods, and upgrade buildings to better withstand flooding and hurricanes (C4 Cities, 2019).

New Orleans has created a Coastal Master Plan that includes 124 projects that are building or maintaining over 800 square miles of land. These projects are expected to reduce damage by $8.3 billion annually by year 50, which pays for itself three times over, equaling to more than $150 billion saved over the next 50 years (Baker et. al., 2017). New Orleans is appointing a "chief resilience officer" to help integrate the decision making of state agencies with the state's coastal Master Plan (Schleifsten, 2020). Further, it was announced recently that the state will put $115 million from expected state surplus and $120 million from federal offshore oil and gas revenue into the coastal trust fund. This money will be used towards coastal restoration and flood protection. Levee and flood control improvements will be implemented in four key places along the coastline (Schleifsten, 2020).

Rising sea levels is a global issue that the city of Savannah cannot solve itself, but there are a number of measures that we propose Savannah take to limit the impact of rising sea levels on its vulnerable population. Savannah's first priority should be properly educating their impoverished citizens through outreach programs on the effects of flooding, how to recognize the signs and early warnings of incoming floods, and how climate change and global warming will increase the severity and frequency of floods. These education measures would be focused on closing the environmental knowledge gap in its communities, who can then do their part to offer environmental solutions that would have the greatest impact on their own communities. As Dr. McClain pointed out, many people in the community do not even know the sound of the flood-warning sirens (McClain 2020).

VIII. RECOMMENDATIONS

a. Environmental Team

Savannah could invest in more flood prevention infrastructure such as sea walls, flood gates, retention ponds, water pumps and water squares. New water management infrastructure would protect the city from increasingly severe floods and storms. These measures would be most effective if built along the Savannah and Ogeechee rivers, as that is where the most likely flooding will occur, and in that way would protect the identified vulnerable communities that live closest to the rivers. The construction of such projects would also provide jobs for the area, further benefiting the impoverished communities that live close to the rivers. Retention ponds and water squares would be less expensive and complex than entire sea walls or flood gates and pump systems, however those more expensive and complex solutions would yield a greater impact on flood prevention. The decision would be up to Savannah which they would rather invest in. Whatever the city may choose, like the prominent coastal cities that have developed better flood management techniques, Savannah would benefit from learning to "live with water in their city" (Muggah, 2019).

In addition to investing in flood-prevention infrastructure, Savannah could implement programs that assist impoverished neighborhoods in flood-prevention and flood-recovery, for when floods damage does occur. 34.3% of Savannah's impoverished population live in homes that were built before 1950, and are likely in desperate need of flood-proofing renovations ("Savannah, Georgia (GA) Poverty Rate Data", 2017). To help mitigate the effects of flooding on impoverished communities, the city of Savannah could start a program for low-income residents that teaches

how to and subsidizes the cost of flood-proofing homes. Savannah could also expand flood insurance coverage for low-income residents, as a loss in home equity due to flooding would only perpetuate the cycle of generational poverty. These programs can be equitable, environmental, and economical, as home value is closely tied to personal equity. Helping low-income residents recover from environmental disasters can lead to them increasing their contribution to the city's economy. Whatever solution the city chooses to pursue, it is imperative that they include the voices of those living in these marginalized communities in the decision making process. As discussed with Dr. McClain, a proper solution can only come from cooperation with a community, and not an outside force looking in.

b. Social Equity Team

After studying the problems the city of Savannah faces and researching how other cities have dealt with similar issues, the team developed recommended solutions that we hope can help Savannah overcome the issues of high unemployment rates and housing burden that overwhelmingly affect Black communities. Our solutions address housing, groundwater contamination, unemployment, and racial equity, respectively.

In a similar manner to programs St. Paul, MN, we recommend the city of Savannah adopt tax break incentives for landlords who provide a certain percentage of affordable units. The specific numbers could differ from St. Paul's as Savannah sees fit.
Additionally, we recommend the strategies presented in Pathways to Stable Homes, a study from Massachusetts, which outlines three policies to be both "feasible and effective" to "ensure families have enough resources to afford housing without forgoing other basic needs" (Children's Healthwatch, 2019, p.2). We believe the following two policies could be helpful to the city of Savannah:

1. Ensuring access to childcare subsidy and reducing child care subsidy co-payments,
This plan specifically suggests capping childcare payments at 7% of income. Essentially the goal is to close the gap between income and the major expenses households typically face - rent and childcare (Children's Healthwatch, 2019, p.2).

2. Providing eviction-prevention assistance to families with rental arrearages.
This policy provides a safety net for families when unforeseen circumstances occur.

Although the city of Savannah is not currently suffering from groundwater contamination, the region is susceptible to being polluted, which would cause devastating issues for the residents relying on the aquifer. Therefore, it is crucial for Savannah to continue to ensure clean groundwater in the prevention of contamination and to also be prepared to respond in the event of a problem. We would like to encourage the city to continue to regularly monitor the contaminant levels, use groundwater in the most efficient and sustainable manner for urban water-supply, have an emergency plan in the event of contamination as well as alternative water sources, and to maintain an adaptive management strategy as the groundwater system and urban environment changes over time (Howard et al., 2015).

Towards unemployment, we first recommend that Savannah adopt a similar program to Atlanta's Westside Works. Our maps highlight areas that are in need of these employment programs. Westside Works partners with major corporations and provides job training in several career areas to give the most opportunity possible. This program has a range of career-building opportunities that range from culinary to information technology to construction. There are six different options that are listed on the website. The program walks individuals through the entire process beginning with an initial assessment, followed by skill training and development, then job placement, and finally the program will individualized support services for interviews and screenings among others (Westside Works, n.d.).

We also recommend doing further research into the theory of "spatial mismatch" which is the theory that poor and minority neighborhoods experience higher rates of unemployment because there are simply not very many jobs in these neighborhoods (Neumark, 2018, p. 8). The Hamilton Project provides a summary of the issue stating "The segregation of disadvantaged groups into areas with fewer jobs, in addition to inadequate transportation to jobs in other places, implies that wages, minus any commuting costs, are more likely to be below the wages at which individuals would be willing to work" (Neumark, 2018, p. 8).

In a speech by mayor Van Johnson during a Black Lives Matter protest, the mayor stated that he would like to implement a task force that identifies racial disparities and then quantifies them (Dikes, 2020). Our presumption is that this task force is in the works, and we would like to suggest some recommendations for this task force. Similar to the task force dedicated to LGBTQ+ rights, Proud Savannah, it is crucial that the task force include minority community members, local allies and activists (such as members from the Harambee House), nonprofit leaders, city staff, and elected officials (savannahga, 2020). These members are necessary to gauge how the community feels and what they experience while being able to make real change through elected city officials. Mostly, the city must give a platform to community members of color and simply listen and learn (Bowden et al, 2020). After listening, asking questions, and learning, action must be taken by the city to help the Black community combat systemic racism.

c. Economic Development Team

The city should consider providing incentives to small/medium size businesses to work together to implement risk-reduction measures (Lowlander, 2017). Investing in tailored Green Infrastructure projects to supplement existing gray and green infrastructure initiatives will help mitigate high-business density areas' vulnerabilities by slowing and reducing stormwater discharges in areas of high pluvial flooding risk with strained drainage systems, while adding environmental, social and economic benefits to the area (EPA, 2020). This concept could be implemented in a similar fashion to the Green Infrastructure to Green Jobs Initiative, or in conjunction with it. By allowing small business owners to take part in a community-led green infrastructure initiative, the city could employ this opportunity to inform them of the current flood risks their business and area are facing, while giving them a tool to combat the source of the risk and empowering the concept of community ownership.

Savannah should take a more active role in supporting small/medium sized business resilience by providing information in usable and easily accessible formats. Much like the businesses in the report, many Savannah businesses have taken steps to protect their properties and businesses. However, they are lacking in the knowledge of low-cost adaptation measures that can be taken towards climate change (Lowlander, 2017). The Georgia Department of Natural Resources (GADNR) prepared a Flood Response Toolkit to help communities prepare, respond, and recover from flood related emergencies. A similar Flood Response Toolkit, tailored to the needs and flood risk of Savannah could help to prepare, assess, and provide resources for flooding (Landers, 2018). This could become a useful tool to supplement the aforementioned community-led green infrastructure initiative, as it would provide a succinct and standardized source of knowledge for community members to refer to in case of flood-related emergencies, while adding insight to their flood mitigation efforts.

We also recommend that, in high business districts, a gradual subsidization of flood insurance costs should occur depending on factors such as the flood risk and the size of a business. This will help mitigate some of the negative effects increasing environmental related costs will have on businesses in Savannah. Small businesses with smaller margins will be particularly helped by such a policy, because they would likely be the first to struggle if operating costs were to start to increase, 25% of small businesses never reopen after a climate disaster (Williams, 2018).
Additionally, Savannah could help businesses implement measures taken in residential housing to adapt to climate change. This won't apply to every business, but due to the size of small businesses and their properties, many of them could benefit from the same protection measures as residential housing. This help could be given in the form of how-to guides and case study workshops provided by the city (Lowlander, 2017).

Lastly, a thorough benefit-cost analysis (BCA) should be conducted before any flood or other hazard mitigation project is funded. If the BCR is 1.0 or greater then the benefits of proposed legislation outweigh the costs, and the project should be commenced . It is imperative, however, that in this BCA, society as a whole is given appropriate standing within the analysis (Landers, 2018).

d. Recommendations Toward Future Studies

+ COVID imposed multitude limitations to this project. The class had to be delivered virtually due to the social distancing required. The class had to be asynchronous as well, as such, we experienced many days in which we didn't have the full participation of the teams. Our class was not able to visit Savannah either, and had to learn about its details and nuances through extraneous sources.

+ The pandemic caused chaos in every aspect of everyone's lives and has made seeing others in person dangerous and not possible. We were hoping to travel as a group to Savannah in order to get a first hand glimpse of the city we are working so hard to help; however this was made impossible by the growing implications of the virus.

+ As we talked about with Dr. Mclain and Michael MacMiller, it is important that we involve the community in this analysis. One way to do this is by holding more meetings with members of the community in order to learn from each other.

+ Projects of this type require more time than the assigned to this class. We recommend to outline a schedule at the beginning of the semester which takes into account the availability of community partners.

+ It would be beneficial to spend less time on developing maps and more time on developing solutions.

+ Upgrading this class to a 4 hour class may allow to include a fourth class session in the week (during the summer), or the encouragement to work on smaller portions of the project outside of our scheduled meeting times.

+ Not being able to interact with people has made it difficult to get a visual on the project at hand and get real time feedback from affected residents. One recommendation could be to approach businesses that haze zoom or other web conference capabilities so that one can still get real time input from those employers.

+ Virtual working relies on many variables for everyone to successfully attend the class and participate (e.g., internet access or time differences). It is difficult to ensure all of these variables line up so that the team can fully work together on the project each day.

+ Since this class took place in an online setting, in-person breakout sessions were not possible, forcing the students into an online format that is more unknown to us than classic in-person collaboration. This likely had an effect on our efficiency and collaborative abilities.

+ Virtual meetings, while helpful, are not as productive as in person classes. The groups can not see each other while in virtual calls and it is therefore much harder to interact in between groups fluidly. People are seemingly much more likely to remain quiet or turn off their camera compared to if they were in person as well.

+ Similar studies conducted in the future, whenever possible, would benefit from in-person collaboration.

+ Because this data analysis was done in early-mid 2020, we were unable to use updated 2020 census data. Much of the data that we collected was from the census, which was completed a decade ago. For example, the "Percent of Total Population Black or African American by Census Tract," was collected nearly a decade ago. As Savannah is a highly dynamic city, the population and demographics are sure to shift; however, the general trend will be similar, allowing us to draw patterns from the data without reliance on the minutiae of the situation.

+ Much of the data found for the study was organized based on zip code or census tracts in Chatham county. These spatial organization units cross over the city limits of Savannah in several instances, making it difficult to draw direct conclusions about purely populations within the city of Savannah.

+ Given more time, perhaps more spatially precise data could have been found, or extrapolated out from larger aggregate data sources.

+ In the next few years, the 2020 census data will be highly accurate for analysis. For years where the data is outdated, the usage of general population patterns as well as third party population data in lieu of the census data will prove to be useful.

+ Our correlations were based on visual analysis; however, it is necessary a statistical correlation analysis for more accuracy with the results.

+ We would like to visit Savannah post-pandemic to meet with city officials and the communities highlighted in this study to further discuss our results and recommendations

IX. CONCLUSION

Through this Climate Vulnerability Assessment, we aim to provide a succinct yet thorough identification and analysis of the environmental, social, and economic vulnerabilities which high risk communities face. By applying the three dimensions of sustainability and approaching each vulnerability through the framework of the United Nations Sustainable Development Goals, we were able to identify, analyze, and recommend solutions toward addressing policy areas most pertinent to at-risk communities in Savannah.

Due to the disproportionate impact environmental disasters such as flooding have on marginalized communities, our environmental spatial analysis focused on the relation between projected flooding areas with impoverished and Black communities. The analysis showed a strong correlation between marginalized communities that live along the two rivers that border the city of Savannah, the Savannah river to the north and Ogeechee River to the south, and their proximity to areas likely to experience high levels of flooding in the coming decades. After researching what other coastal cities around the world have done to address similar problems, we proposed solutions to the city of Savannah that focused on three different approaches to addressing the problem; educating marginalized communities to close the environmental-risk knowledge gap, investing in more comprehensive flood mitigation infrastructure, and implementing local social/financial programs aimed at flood-proofing communities and providing flood-recovery assistance.

The Social Team identified that Black and low-income communities were the most at-risk for negative climate effects in housing affordability, unemployment, groundwater contamination, and racial equity. To address issues of housing affordability, our recommendations include incentivizing the construction or conversion of affordable housing units as well as subsidizing childcare costs for low-income families. We also recommend addressing the "spatial mismatch" of jobs in low-income areas to alleviate the burden of unemployment through funding programs which emphasize sustained job creation or provision in these communities. The health of at-risk communities must also be improved. Proper monitoring and treatment of groundwater contamination levels at a city-wide scale would ensure that all communities in Savannah were guaranteed access to clean water for drinking and household needs. Ultimately, for marginalized communities to be properly represented, the city must give a platform to community members of color and simply listen and learn (Bowden et al, 2020).

After conducting the analysis in the three identified areas of high business density within the city of Savannah, the Economics Team identified varying existing degrees of flood hazard vulnerability, with pluvial flooding compounded by sea level rise being the common looming threat faced by all areas. From studying existing initiatives, as well as projects developed by coastal

cities with similar climate-related issues, we developed the following recommendations for the City of Savannah: developing a community-led green infrastructure initiative in areas of high small business flood vulnerability, aiming to particularly engage small business owners; developing a city of Savannah Flood Response Toolkit akin to the existing GADNR toolkit to supplement the green infrastructure initiative and better inform small business owners along with residents; consider providing gradual flood insurance aid to small businesses based on size and vulnerability; implementing existing residential housing protection to small businesses when appropriate.

While this Assessment represents the best efforts of the Sustainable Cities Studio teams, we recognize that the project faced several limitations. The COVID-19 pandemic has been a major barrier towards this project, as the studio course was conducted completely online for the first time. The team was unable to visit Savannah or convene in person, so meetings with our research and community partners were also virtual. Additionally, the team was unable to meet with community members and stakeholders beyond our community partners because of the pandemic, limited digital resources, and a compressed timeline. This Climate Vulnerability Assessment was conducted over a course of two and a half months, starting on May 11, 2020, and culminating July 21, 2020. The tight timeline also meant that data were not as robust as they could have been. The most up to date census data available at the time of this analysis were from 2010. Despite these limitations, we were able to produce a spatial analysis tool which was used to identify and assess vulnerabilities faced by at-risk populations in Savannah, and recommend steps towards implementing policy solutions. We hope that through this project we were able to provide a foundational analysis for the city of Savannah's Office of Sustainability, and hope that our interactive GIS tool can assist the community in achieving its sustainability goals.

You can visit the project's website to use the interactive GIS tool: https://cpcapstone2020.wixsite.com/mysite

X. REFERENCES

Aguirre, J. (2014, June 02). The Unlikely History of the Origins of Modern Maps. Retrieved July 20, 2020, from https://www.smithsonianmag.com/history/unlikely-history-origins-modern-maps-180951617/

AR5 Synthesis Report: Climate Change 2014. (2014). Retrieved July 20, 2020, from https://www.ipcc.ch/report/ar5/syr/

Associated Press. (2016, October 11). Savannah's signature tree canopy gets bushwhacked by Matthew. Retrieved July 17, 2020, from https://www.foxnews.com/us/savannahs-signature-tree-canopy-gets-bushwhacked-by-matthew

Atlanta Regional Commission Open Data. (2017). Demographics By Race. Retrieved from the ARC website https://opendata.atlantaregional.com/datasets/demographic-by-race-by-census-tract-2017

Atlanta Regional Commission. (2017). Poverty (by Zip Code) 2017. Retrieved from https://www.arcgis.com/home/item.html?id=31e0cf19dc344a2897abf0c6c57cfe3e

Atlanta Regional Commission. (2017). Unemployment (by Census Tract) 2017. Retrieved from https://opendata.atlantaregional.com/datasets/17b27625c46c40339e5f895ddfe856b3_237?geometry=-114.208%2C22.479%2C-58.705%2C35.860

Bettencourt, L. M., Lobo, J., Helbing, D., Kuhnert, C., & West, G. B. (2007). Growth, innovation, scaling, and the pace of life in cities. Proceedings of the National Academy of Sciences, 104(17), 7301-7306. doi:10.1073 pnas.0610172104

Bohr, J., & Mccreery, A. C. (2019). Do Energy Burdens Contribute to Economic Poverty in the United States? A Panel Analysis. Social Forces. doi:10.1093/sf/soz131

C40 Cities. (2014, August 27). Benthemplein Water Square: An innovative way to prevent urban flooding in Rotterdam. C40 Cities. https://www.c40.org/case_studies/benthemplein-water-square-an-innovative-way-to-prevent-urban-flooding-in-rotterdam

City-Data (2020). Zip Code (Savannah, GA), Detailed Profile. Retrieved July 9, 2020, from http://www.city-data.com/zips/31409.html

Chatham County Department of Engineering. (2012). Flood Mitigation Plan: Unincorporated Chatham County. Retrieved from http://engineering.chathamcounty.org/Portals/engineering/forms/floodZones/Flood%20Mitigation%20Plan.pdf

Chatham County Department of Engineering. (2018). Floodplain Management Plan: Chatham County. Retrieved from http://engineering.chathamcounty.org/Portals/Engineering/forms/Chatham%20County%20FMP%20Final.pdf

Chatham County Emergency Management. (n.d.). Flooding. Retrieved July 14, 2020, from https://www.chathamemergency.org/PrepareNow/Flooding

C. (n.d.). Flooding. Retrieved July 14, 2020, from https://www.chathamemergency.org/PrepareNow/Flooding

Chatham County Goverment (2018). FDPO - Preliminary Flood Zones. Retrieved from https://chathamcountyga.maps.arcgis.com/home/item.html?id=57fe36575d034a00af29fb4e02447a7b

City of Rotterdam. (2013). Rotterdam Climate Adaptation Strategy [Ebook] (p. 27). Retrieved 16 July 2020, from http://www.urbanisten.nl/wp/wp-content/uploads/UB_RAS_EN_lr.pdf.

City of Savannah (2016). A Sustainability Assessment. Retrieved from https://www.arcgis.com/home/item.html?id=0e468b75bca545ee8dc4b039cbb5aff6

Chatham Community Blueprint Status Report. Retrieved from https://www.coastalgaindicators.org/content/sites/uwce/Status_Report_2018_V14-1_Final_Draft.%5B1%5D.pdf

Cobb, K., Clark, R., Matthews, R., & Deffley, N. Smart Sea Level Sensors in Chatham County. Smart Sea Level Sensors in Chatham County. Retrieved 21 May 2020, from https://www.sealevelsensors.org/.

Cohen, B. (2006). Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. Technology in Society, 28(1-2), 63-80. doi:10.1016/j.techsoc.2005.10.005

COLLINS1, M., &, F., & RUSHMAN3, M. (2001, November 01). Land-Use Suitability Analysis in the United States: Historical Development and Promising Technological Achievements. Retrieved July 20, 2020, from https://link.springer com/article/10.1007/s002670010247

Connecting Delta Cities. (n.d.). Rotterdam CLimate Change Adaptation Strategy. Retrieved July 17, 2020, from http://deltacityofthefuture.com/cities/rotterdam/climate-change-adaptation

Dennis, W., Phillips, B., & Starr, E. (1994). Small Business Job Creation: The Findings and Their Critics. Business Economics,29(3), 23-30. Retrieved May 28, 2020, from www.jstor.org/stable/23485971

Dunkelberg, W. (2018, August 7). Small Business Powers The Economy Forward. Retrieved May 28, 2020, from https://www.forbes.com/sites/williamdunkelberg/2018/08/06/small-business-powers-the-economy-forward/#504c120114ed

Economic Research Service USDA. (2015). Food Access Research Atlas. Retrieved from https://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas.aspx

Economic Research Service, USDA. (2019). Supplemental Nutrition Assistance Program. Retrieved from https://www.ers.usda.gov/topics/food-nutrition-assistance/supplemental-nutrition-assistance-program-snap/

Elliott, J. R., & Pais, J. (2006). Race, Class, and Hurricane Katrina: Social Differences in Human Responses to Disaster. Social Science Research. Retrieved 2013, from https://ebookcentral.proquest.com/lib/gatech/reader.action?docID=1075388&ppg=1.

EPA. (2018) Greenhouse Gas Emissions from Large Facilities. FLIGHT. Retrieved June 25, 2020, from https://ghgdata.epa.gov/ghgp/main.do

Equitable Development and Environmental Justice. (2019, March 28). Retrieved July 07, 2020, from https://www.epa.gov/environmentaljustice/equitable-development-and-environmental-justice

Fragomeni, M. B. (2019). When Cities Plan For Heat: A Collaborative Framework to Integrate Planning and Climate [Unpublished doctoral dissertation]. The University of Georgia.

Food and Nutrition Service, USDA. (n.d.). Supplemental Nutrition Assistance Program (SNAP). Retrieved from https://www.fns.usda.gov/snap/supplemental-nutrition-assistance-program

Foreword [Foreword]. (2013). In T. Theis & J. Tomkin (Authors), Sustainability: A comprehensive foundation. Rice University, Houston, Texas: Connexions.

Gayer, J. (2014). 10 Million Pounds of Toxic Chemicals Dumped into Georgia's Waterways. Environmentgeorgia.org. Retrieved 14 July 2020, from https://environmentgeorgia.org/news/gae/10-million-pounds-toxic-chemicals-dumped-georgia%E2%80%99s-waterways.

Georgia School Reports. (2020, March 10). Retrieved from https://schoolgrades.georgia.gov/chatham-county

Housing and Urban Development. (2010). Housing Problems. Retrieved from https://egis.hud.gov/affht/

Greenlink (2020): Household Energy Burden by Census Track. https://greenlink.org

Intro to SLS. (n.d.). Retrieved July 20, 2020, from https://serve-learn-sustain.gatech.edu/intro-sls

Klosterman, R. (1997, September 1). Planning Support Systems: A New Perspective on Computer-Aided Planning - Richard E Klosterman, 1997. Retrieved July 20, 2020, from https://journals.sagepub.com/doi/10.1177/0739456X9701700105

Keeton, R. (2014, January 27). A Storm-Water Drainage System Cleverly Disguised as a Park. Next City: The Future of Resilience. https://nextcity.org/daily/entry/a-storm-water-drainage-system-cleverly-disguised-as-a-park

Kimmelman, M., & Haner, J. (2017). The Dutch Have Solutions to Rising Seas. The World Is Watching.. Nytimes.com. Retrieved 14 July 2020, from https://www.nytimes.com/interactive/2017/06/15/world/europe/climate-change-rotterdam.html.

Latu, S. (2017, December 05). Sustainable Development: The Role of GIS and Visualisation. Retrieved July 20, 2020, from https://onlinelibrary.wiley.com/doi/pdf/10.1002/j.1681-4835.2009.tb00268.x

McClain M. (2020, June). Video Conference.

Mosaic Community Planning. (2017). City of Savannah Assessment of Fair Housing. Retrieved from https://www.savannahga.gov/DocumentCenter/View/10596/City-of-Savannah-Assessment-of-Fair-Housing?bidId=

Muggah, R. (2019, January 16). The world's coastal cities are going under. Here's how some are fighting back. World Economic Forum. https://www.weforum.org/agenda/2019/01/the-world-s-coastal-cities-are-going-under-here-is-how-some-are-fighting-back/

Murphy, S. E. (2019, July 3). Home Ownership and Zoning: Redlining, Then and Now. Savannah Morning News. https://www.savannahnow.com/news/20190703/home-ownership-and-zoning-redlining-then-and-now#:~:text=The%20U.S.%20government%20itself%20was%20the%20origin%20of%20redlining.&text=According%20to%20official%20documentation%20she,Americans%20as%20a%20detrimental%20factor.

NOAA. Sea Level Rise Data. https://coast.noaa.gov/slrdata/. Accessed Jul. 7, 2020. Online. https://www.arcgis.com/home/item.html?id=32c888eac6bd41b5b17f51d9d8175969

Nuisance Flood Areas. Retrieved from https://irp-cdn.multiscreensite.com/a7a94d2a/files/uploaded/Flood%20Zone%20Map.pdf

Office of Policy and Development Research (n.d.) CHAS: Background. Retrieved from https://www.huduser.gov/portal/datasets/cp/CHAS/bg_chas.html

Rayner, S., & Malone, E. L. (2003). Climate change, poverty and intragenerational equity: The national level. International Journal of Global Environmental Issues, 1(2). doi:http://www.inderscience.com/offer.php?id=977

Savannah Area GIS Open Data. (2017). Grocery Stores. Retrieved from the SAGIS website: https://data-sagis.opendata.arcgis.com/datasets/grocery-stores

Savannah Area GIS Open Data. (2020). Libraries. Retrieved from the SAGIS website https://data-sagis.opendata.arcgis.com/datasets/libraries

Savannah Police. (2020, June). Weekly Crime Reports. Retrieved from the Savannah Police website: http://savannahpd.org/

Surging Seas: Risk Zone Map. (2016). Retrieved from https://ss2.climatecentral.org/#11/32.0212/-81.0976?show=property&projections=0-K14_RCP85-SLR&level=1&unit=feet&pois=hide

Sustainable Cities Capstone (2019). Climate vulnerability assessment: Downtown ATL. Retrieved from https://cpcapstone2019.wixsite.com/mysite/class-info The Trust for Public Land. (2020, May 13). Urban heat island severity for U.S. cities.

Thomson, D. A. (2016). SMALL BUSINESS, EDUCATION, AND MANAGEMENT: The life and times of john bolton. (1st Ed.) New York, NY: Rouledge.

Trent, V. P. (1992). Groundwater Pollution Susceptibility Map of Georgia. Hydrologic Atlas 20. doi:http://www.georgiaplanning.com/documents/EnvironmentalPlanning/Groundwater Method1992.pdf

United Nations Millennium Development Goals. (n.d.). Retrieved July 20, 2020, from https://www.un.org/millenniumgoals/

USGS. (2019). What is a geographic information system (GIS)? Retrieved July 20, 2020, from https://www.usgs.gov/faqs/what-a-geographic-information-system-gis?qt-news_science_product=0

U.S. Census Bureau Savannah, Georgia. (2019). Retrieved July 14, 2020, from https://www.census.gov/quickfacts/fact/map/savannahcitygeorgia/PST045219

U.S. Department of Energy. (2016). Low-Income Energy Affordability Tool. Retrieved from https://www.energy.gov/eere/slsc/maps/lead-tool

U.S. Forest Service. (2019, December 6). USFS Cartography 2016 Tree Canopy Cover CONUS. ArcGIS Online. https://www.arcgis.com/home/item.html?id=32c888eac6bd41b5b17f51d9d8175969

U.S. Global Change Research Program. (2016). Populations of Concern. https://health2016.globalchange.gov/populations-concern

Vaughan, E. (2018, July 31). Federal Programs for Energy and Housing. Retrieved July 07, 2020, from https://www.eesi.org/briefings/view/073118housing

Yeh, A. G., & Li, X. (1998). Sustainable land development model for rapid growth areas using GIS. International Journal of Geographical Information Science, 12(2), 169-189. doi:10.1080/136588198241941