Building Social Equity into Floodplain Buyouts

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1. Executive Summary

Floodplain buyouts are an effective tool to mitigate flood risk by moving people and properties out of harm’s way. This tool has received greater attention as flood events have increased in frequency and intensity in the United States due to hurricane storm surge, heavy precipitation, and sunny day flooding (US GCRP, 2018). In a buyout, the state or local government purchases frequently flooded properties from willing homeowners and converts the land into open space in perpetuity (Freudenberg et al., 2016). The main purpose of a buyout is to remove development from areas exposed to flood disasters.

While buyouts hold the promise of reducing flood risk by allowing the land to be used to store stormwater, they can also repeat inequitable practices of the past that have pushed vulnerable communities into less desirable areas. Low-income communities and communities of color are more likely to live in flood prone areas, in part because parcels in low-lying areas with fewer amenities are cheaper to purchase and as a result of past economic inequality and racially motivated legal tactics like redlining (Ueland & Warf, 2006). Federal funding for buyouts places a high priority on economic efficiency through the logic of benefit-cost analysis (Atoba et al., 2020). This economic logic encourages targeting acquisition of many cheaper properties over fewer expensive ones, which may damage strong community ties and reproduce the long legacy of displacement of vulnerable populations (Siders, 2019).

This study discusses the knowledge to date at the nexus between flood risk, social equity, and buyouts. Through a geospatial analysis, this study addresses these issues by developing a prioritization process to identify possible parcels for buyouts in a North Carolina town by focusing on the level of flood risk and proximity to natural areas. The resulting buyout scenarios are compared using a social vulnerability index and physical risk factors. This report includes a description of the methods for reproducing the prioritization process using geospatial tools. The prioritization process can be used to identify candidate parcels for buyouts in advance of the next major flood as a form of pre-disaster mitigation.

Incorporating social vulnerability information into buyout programs is valuable for identifying the most at-risk populations, prioritizing equity, and directing government funding to flood mitigation efforts that benefit the entire community. The study concludes with key recommendations to buyout program administrators at the state level.

Key Recommendations:
1. Create a statewide list of potential buyout properties using a prioritization process that includes not only flood risk attributes but also social vulnerability information.
2. Increase the state funding allocation for floodplain buyouts.
3. Create a robust program to provide counseling to buyout recipients for every step of the buyout process from first contact to relocation.

Keywords: Flooding, Flood Risk, Buyouts, Climate Adaptation, Resilience, Social Vulnerability
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1.2 Indigenous Land Acknowledgement

The land that New Bern occupies is the traditional ancestral lands of the Pamlico, Tuscarora, Neusiok, and Lumbee Native American peoples. The settlement of New Bern in 1710 displaced the Tuscarora village of Chattoka (Fenn et al., 2008). In a study of displacement from the land, it is especially urgent to reflect on the history of land dispossession experienced by Native American communities past and present.
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2. Introduction

Increasingly frequent flood events have generated greater attention to voluntary floodplain buyouts, a tool to mitigate flood hazards by permanently moving people and properties out of harm’s way (Zavar, 2015). Buyouts, also known as property acquisitions, reduce flood impacts by removing exposed buildings and infrastructure from flood-prone locations and converting the land to its prior undeveloped state, which can absorb and store floodwater (FEMA, 2011). When the government purchases a repeatedly flooded parcel as part of a buyout using federal funding, the land must be maintained as open space, prohibiting future construction except for the purpose of flood mitigation (Koslov, 2016). The parcel can be used as a stormwater wetland, water retention basin, or publicly accessible green space like a park, to name just a few uses. A buyout reduces future risk of structural damage, the economic costs of disaster recovery, and the threats from flooding faced by residents of the flood-prone property (Kihslinger et al., 2017).

Buyouts may increase community resiliency to flood impacts, but they may also have social inequity implications because of the way flood risk has historically been differentially spread across the landscape based on race and class (Siders, 2019). This study focuses on how buyouts may impact vulnerable communities. These communities have often been relegated to less desirable land, whether in the floodplain or in proximity to nuisance land uses because of the long history of social inequality in residential land use (Bullard, 2008; Freudenberg et al., 2016; Mileti, 1999). This increases their exposure to harmful flooding impacts (Cutter & Emrich, 2006). However, these communities have also experienced displacement because of urban renewal programs, historic marginalization, redlining, and forces of gentrification (Fullilove & Wallace, 2011). Case studies of buyouts have shown that the focus on economic efficiency of federal funding sources may replicate the effects of displacement on communities of color and low-income communities (Muñoz & Tate, 2016).

While buyouts are voluntary and property owners are compensated at the pre-flood fair market value of their homes, there are many other burdens participants must take on, like the monetary cost of relocating, loss of community identity, disruption of social relationships, and the years of waiting on bureaucratic procedures for the completion of the buyout (de Vries & Fraser, 2012; Elliott et al., 2020). Climate change has the potential to exacerbate these existing inequities in hazard exposure and vulnerability by worsening flooding because of wetter hurricanes and rising sea level, leading to more urban and rural flooding alike (Buchanan et al., 2020). If buyout programs are not done with social justice as a priority, they could feel more like involuntary displacement by powerful forces to many underserved residents rather than long-term flood mitigation.

2.1 Research Questions

To investigate the multifaceted issues created by buyout programs, this study used two analysis methods: a literature review of the nexus between flood risk, social equity, and buyouts; and a prioritization process of potential buyout locations using New Bern, North Carolina as the case study. New Bern, located in Eastern North Carolina, was devastated by several major hurricanes in recent years including Irene in 2011, Matthew in 2016, and most recently Florence in 2018 (Wetherington, 2017). The state of North Carolina was allocated FEMA and HUD funding to aid municipalities in recovering from the effects of major disasters. The North Carolina Office of Recovery and Resiliency (NCORR) manages
the funding, including the use of funds for buyouts. New Bern has created a list of potential properties to acquire so that the land can be converted to natural space to reduce flood hazards and will work with the state to begin the buyout process. The current study used this list of potential buyout properties for comparison with the prioritization process created by the analyst. The objective of the prioritization process was to answer the following questions:

1. What are the social vulnerability and risk attributes associated with the buyout locations that New Bern listed?
2. Where would a separate geospatial analysis that incorporates a measure of social vulnerability have prioritized buyouts?
3. What are the differences in risk from sea level rise and flooding, as well as social vulnerability of the buyouts between the scenarios created in this study and the buyout locations that New Bern listed?

These questions were chosen to address the recommendation from Siders (2019) to improve the buyout decision-making process by directly addressing long-term social inequality. The goal of the prioritization process is to incorporate social equity considerations by pulling in social vulnerability data in addition to physical risk information. Administrators of buyout programs using this prioritization process could target potential areas for buyouts that do not increase the disparate impacts of buyouts to socially vulnerable communities.

2.2 Study Area Context

New Bern is a small city with over 30,000 residents and historic significance in North Carolina. Figure 1 shows the location of New Bern within North Carolina for context, including major highways and rivers. New Bern’s history and culture are inextricably linked to its location where the Neuse River meets the Trent River. However, this riverine location exposes the city to flood hazards. The rivers can overflow and stormwater systems can back up after heavy precipitation and storm surge from hurricanes, causing urban flooding (Wetherington, 2020). Strong hurricanes have regularly disrupted life in North Carolina in recent years. Hurricane Florence was a powerful and relentless storm that was responsible for $100 million in property damages in New Bern due to the destructive storm surge, high wind, and extreme flooding (Bennett, 2018). Over 300 businesses and 4,000 homes were damaged or destroyed by Florence. With much of the town inundated, in some places with 10 feet of storm surge, over 800 people had to be rescued during and after the storm (City of New Bern, 2020a).
Figure 1: Location and boundaries of New Bern, North Carolina
3. Floodplain Management

3.1 Flooding and Floodplain Development

A floodplain is the land adjacent to a waterbody that can be flooded because of high water flow and rain events (Loos & Shader, 2016). On floodplain maps, these lands are also referred to as special flood hazard areas (SFHA), and are commonly referred to by their risk level using the term 100-year floodplain to denote that the land has a 1% chance of flooding in any given year (Pralle, 2019). Floodplains serve an extremely important role in the ecosystem, helping to move, filter, and store water. Society has used floodplains for centuries to develop communities and agricultural land because of the soil fertility and nearness to water for drinking, transportation, irrigation, and shipping. This has been made possible through a variety of flood control techniques like building levees and dams, channelizing rivers, and draining wetlands (Christin & Kline, 2017). For example, New Bern has 66 miles of drainage ditches, culverts, and pipes that make up the bulk of the city’s flood control system (Wetherington, 2020). Despite conservation programs, rules, and regulations that have attempted to protect floodplains and adjacent wetlands, and the inherent exposure to flood hazard, population density in US floodplains continues to grow (Wing et al., 2017).

Over the last three decades, flood costs have averaged $8.2 billion per year, and are increasing year over year in the United States (Wing et al., 2017). Floodplain development is the current driver of increasing flood costs, but climate change will aggravate the issue because of the increase in the frequency and intensity of hurricanes and flooding (IPCC, 2018; Klotzbach et al., 2018). Hurricanes and floods are natural phenomena and so the risk of damage comes because people build valuable property in vulnerable areas, exposed to flooding and storms (Pilkey et al., 2016). The 2020 North Carolina Climate Science Report states that it is virtually certain that storm surge flooding will increase in severity, that heavy precipitation accompanying hurricanes will very likely increase, and that sea level will continue to rise, impacting coastal regions (Kunkel et al., 2020). The projected increase in the severity of natural hazards will pose even more risk to the increasing population density in floodplains of North Carolina (Ntelekos et al., 2010).

3.2 Potential Responses to Threats

Climate change is accelerating the need for innovative responses to reduce flood risks from sea level rise and hurricanes (Pilkey et al., 2016). Detrimental flooding impacts in developed areas can be lessened through hazard mitigation measures. FEMA defines hazard mitigation as “any sustainable action that reduces or eliminates long-term risk to people and property from future disasters” (FEMA, 2020b). Flood impacts can be mitigated using policies and local, state, and federal government regulations, as well as physical changes to the environment, infrastructure, or property for flood protection. Hazard mitigation measures can reduce the burden on critical infrastructure and first responders during disastrous flood events (Kihlslinger et al., 2017).

Climate change adaptation and hazard mitigation researchers often break down measures to adapt to the effects of flooding into three broad categories, which are used to describe the potential responses to the threat of increase flooding: “protect,” “accommodate,” and “retreat” (Eichhorst et al., 2011). Figure 2 from Eichhorst et al. (2011) shows a simple graphic often used to describe these hazard mitigation measures.
Figure 2: Broad strategies for mitigating flood hazard in context of climate change

- **Accommodate**: Using measures that allow a building to remain undamaged during a flood, like raising the elevation of the building above the base flood elevation.
- **Protect**: Using engineering works to defend buildings against flood impacts. For example, engineers build seawalls and stabilized streambanks with boulders in order to create a physical barrier between a building and floodwater during storms.
- **Retreat**: Removing buildings from the flood zone and creating open space in its place so that built infrastructure is no longer exposed to the flood hazard.

These strategies are not rigid, but instead can be implemented over time based on the needs of the locale by utilizing the concept of adaptation pathways. This is the concept that hazard mitigation measures can be phased in based on a forward-looking planning process to review exposure to hazards and create adaptation plans that both anticipate change and have specified trigger points at which action must be taken to adapt to the environmental change (Haasnoot et al., 2013). For example, a town may identify a neighborhood that is perennially impacted by flooding, and town managers could decide to implement a rule to accommodate flooding by requiring that buildings in the area be raised above the 100-year flood elevation if they were substantially damaged during the next flood. This accommodation measure may eventually be inadequate, at which point the town managers may apply for state or federal assistance to protect a flood prone area using a seawall or a levee. The protective measure may eventually be overtopped by flooding, at which point the managers could decide it was necessary to retreat from the area by implementing strategic buyouts. The remainder of this study will focus on buyouts, the measure to retreat from flood hazard frequently used in the US context (Koslov, 2016).

4. **Strategic Floodplain Buyouts**

A buyout is a hazard mitigation measure where a property owner is offered funding to relocate from a building that has been damaged or destroyed by flooding (Conrad et al., 1998). The program provides eligible homeowners with the opportunity to sell their property at its pre-flood fair market value and move to a safer location.
value to the state based on a set of eligibility criteria, and these funds can be used by participants to relocate to a new home (NCORR, 2020). Buyouts funded by the federal government are always voluntary; no one is forced to relinquish their property to the government (de Vries & Fraser, 2017). Even if a city or state identifies a house that has been severely damaged multiple times, it is the decision of the property owner whether to stay and rebuild or to relocate using a buyout (Freudenberg et al., 2016). There have been over 40,000 buyouts of properties conducted in the US since 1989, mostly funded using federal aid after disasters (Peterson et al., 2020). The agencies that provide federal funds for buyouts are the Federal Emergency Management Agency (FEMA) and the Department of Housing and Urban Development (HUD) (Atoba et al., 2020).

Buyout programs are a way to remove development from at-risk areas (Martin, 2019). The house and other buildings and infrastructure on the property are demolished, and the property is restored to a pre-development open space state. The space can be used as a park, community garden, or stormwater wetland, but is sometimes left as a vacant lot depending on the size of the parcel and the capacity of the local government to maintain it (Salvesen et al., 2018). Zavar and Hagelman (2016) examined buyout locations from 1990 through 2010 and found that acquired land was converted to the following uses: about 7% as restored wetlands; about 40% as gardens, parks, playgrounds, and publicly accessible green spaces; and about 34% as vacant lots.

Buyouts benefit both participants and the surrounding community by permanently removing the possibility of future losses because people and infrastructure are no longer exposed to flood impacts in that location (FEMA, 2016). Creating open space for flood mitigation can increase long-term resilience to flooding and save communities money by reducing the cost of flood insurance, lessening property damage, and creating the indirect benefits of improved water quality, recreation opportunities, and increased property values (Brody & Highfield, 2013; Conrad et al., 1998). For example, being near a park or urban green space can increase property values for nearby houses (Crompton, 2011) and parks are beneficial for public physical health and mental wellbeing (Kabisch & van den Bosch, 2017). Buyouts are also cost effective from the national perspective because the empty lots are no longer in need of emergency aid and funding, recovery grants, and payouts for flood insurance claims (McDow, 2018). Buyouts have been conducted in North Carolina communities including Rocky Mount, Kinston, and Lumberton, as well as several others shown in Figure 3 from Salvesen et al. (2018).

Figure 3: Examples of past floodplain buyout programs in North Carolina
Researchers that surveyed households following Hurricane Sandy found that the primary reasons respondents would consider accepting a buyout were the cost of insurance, the cost of repairs after a disaster, and the possibility to protect the health and safety of oneself or one’s family (Bukvic & Owen, 2017). The individual seller forgoes their original home and usually their neighborhood, but hopefully gains a home that is not in a location as susceptible to flood damage. It is, however, not a guarantee that buyout participants will be able to afford a house in a safer location using their buyout funding (McGhee et al., 2020). This may be because the housing prices in areas with lower flood risk are higher than the pre-flood fair market value of the property, or because the housing stock in safer areas is low.

Buyouts can have negative effects on the community and on individual participants. For example, the town may lose some of its tax base and members of the community if the participants are not encouraged to relocate within the same municipality (BenDor et al., 2020). The detrimental impact to the local government’s tax base can be ameliorated by increasing participants’ funding if they relocate within the boundaries of the municipality (Freudenberg et al., 2016). Buyouts have more flood mitigation benefits if they are conducted strategically in clusters: a larger swath of open space made up of contiguous parcels can hold and convey more floodwater (Cusick, 2019). Absent this strategic focus on clustering, buyouts appear as a checkerboard pattern in which some lots are vacant, and some lots still have houses on the same street (Atoba et al., 2020). This creates a situation in which the local government must continue maintaining municipal infrastructure in an area that is less densely populated, which is less cost effective (BenDor et al., 2020). It also reduces property values and social cohesion because the neighborhood appears partially deserted (Cusick, 2019). However, participants have expressed feeling intense pressure to sell their property to the government, which may be a result of administrators seeking contiguous properties to avoid the checkerboard issue (Martin, 2019).

4.1 Buyout Funding and Selection Process

Following a presidentially declared disaster, impacted states and localities can request federal funding to aid in their recovery. States receive funding for buyouts from the federal government through several flood mitigation programs administered by FEMA and HUD. After a natural disaster like a hurricane or severe rainstorm, communities may determine if property owners are interested in participating in a buyout program (Carter et al., 2019). Funding for buyouts through FEMA usually comes from the Hazard Mitigation Grant Program (HMGP) which pays for 75% of program costs to administer buyouts, while the remaining 25% is expected to be matched by local agencies (FEMA, 2020b). FEMA evaluates proposals for buyouts from states to confirm that they follow rules including environmental efficacy and cost effectiveness (Kihslinger et al., 2017).

HUD provides funding to aid recovery and mitigation efforts through the Community Development Block Grant (CDBG) Mitigation and Disaster Recovery programs (Boyd, 2010). The principal goal of CDBG funding is to revitalize socioeconomically depressed areas (Tate et al., 2016). Communities only need to satisfy at least one of the CDBG national objectives: (1) to benefit low- and moderate-income (LMI) persons; (2) help eliminate and prevent urban blight; or (3) meet community development needs that pose a public threat (Tate et al., 2016). The first objective to benefit LMI persons, defined as individuals or families with an income no greater than 80% of the median income for the county, is the primary goal of the CDBG, but the third objective enables CDBG funding to be used for flood recovery
efforts like conducting buyouts (Boyd, 2010). State and local officials can use this funding more flexibly, like using it to meet FEMA’s 25% local match requirement (Boyd, 2010).

4.2 General Buyout Criteria

The criteria for buyout programs vary by funding source and disaster event but usually focus on the amount of damage the property suffered. Buyout program administrators have some discretion in where buyouts are conducted, especially when using HUD CDBG funds which are more flexible in their requirements (Freudenberg et al., 2016). The following list adapted from a floodplain buyout guide created by the Environmental Law Institute (Kihslinger et al., 2017) describes common criteria for determining if a property is eligible for a buyout gathered from case studies of programs:

- The property has suffered substantial damage.
- The property was flooded by the storm for which the agency has federal funding for buyouts.
- The property is in a flood prone area if funding is not attached to a specific event.
- The property buyout must be cost efficient, meaning it passes a benefit-cost analysis.\(^1\)
- The buyout program must be environmentally sound and improve public health, safety, and welfare for the surrounding area.
- The property is exposed to recurrent flooding.
- The property may be a severe repetitive loss property, which are NFIP-insured houses with at least four claim payments totaling over $20,000 (FEMA, 2006).
- The property is usually located within the floodplain.
- For some grant sources, the property must have flood insurance through the National Flood Insurance Program (NFIP).
- The property is adjacent to other buyout properties or open spaces.

4.3 Buyout Process in North Carolina

The North Carolina Office of Recovery and Resiliency (NCORR) was formed in the wake of Hurricane Florence in 2018 to manage rebuilding and resilience efforts in North Carolina (NCORR and NCDEQ, 2020). ReBuild NC is the program through which NCORR conducts long-term disaster recovery efforts. Through ReBuild NC, NCORR administers the Strategic Buyout Program to provide eligible landowners the opportunity to sell their property if it is located in a flood-prone area and relocate to a safer home (ReBuild NC, 2021). HUD awarded North Carolina $109 million in CDBG Mitigation funding allocated for the Strategic Buyout Program (Munger, 2020). The Strategic Buyout Program requires that properties are in a buyout zone, which are defined as areas with the greatest risk of damage from flooding (ReBuild NC, 2021). The state supplements the cost of buyouts and relocation through North Carolina’s State Acquisition and Relocation Fund, but this fund only fills the gap for buyout participants when grants from FEMA HMGP are insufficient for relocation (Georgetown Climate Center, 2020b).

\(^1\) Benefit-cost analysis is determined through calculating the ratio of the benefits (including future flood damage avoided) divided by the cost of the hazard mitigation measure (market value of the property and demolition cost). If the resulting ratio is greater than 1.0, the measure is cost efficient (FEMA, 2021).
State buyout programs often encourage participants to move within the area but outside the floodplain by supplying them with an extra financial incentive. For example, NCORR provides extra funding based on the participant’s financial need and where they choose to relocate. If participants relocate to an area with less flood risk, they can receive up to $50,000 on top of the pre-flood fair market value of the property which NCORR calls an Affordability Incentive (NCORR, 2020). If they move to an area with less flood risk within the same county as their original property, they can receive up to $10,000 extra as a Risk Reduction Incentive. The seller can receive up to $5,000 extra if they follow the same criteria but move elsewhere in North Carolina (NCORR, 2020).

New Bern has received a $328,500 grant from the state to develop and implement resiliency, recovery, and mitigation plans and projects (Wetherington, 2020). In New Bern, the buyout process is managed by the New Bern Community and Economic Development Division (Wetherington, 2019). New Bern has created a publicly accessible list of properties that may potentially participate in a future buyout program. City Manager Mark Stephens explained during a 2020 interview that “we are awaiting very clear, concise direction from the NC Office of Recovery and Resiliency through the CDBG program on exactly how to administer those programs. As soon as we get that information from the state, we will share that with the individuals who have been selected” for disaster recovery projects (Wetherington, 2020). Once the list of eligible applicants for buyouts is finalized, the city will submit an application to NCORR to review these potential local projects.

5. Unequal Exposure to Flood Risk

To have a full understanding of the nexus between floodplain development, social inequality, and flooding, it is important to understand the history of structural inequality, spatial discrimination, and the burdens of flooding on socially vulnerable communities. It is also an imperative to investigate why people live where they do, in a pattern which researchers have called “racialized topographies,” especially prevalent in Southern cities (Ueland & Warf, 2006). Structural inequality is the social stratification of unequal classes of people based on gender, ethnicity, race, and wealth which is perpetuated by society, economic and legal systems, and has produced enduring disparities in employment, health, wealth, and educational attainment (Hanks et al., 2018). Because of structural inequality in the US, low-income people and people of color have had worse access to high quality land and housing (Green & Hanna, 2018). The specific reasons are many, including segregation, displacement by urban development programs, and exclusionary practices sometimes codified in law, as in the case of redlining and mortgage discrimination (Fullilove & Wallace, 2011). Despite many of these practices being outlawed, the effects of this long history of disenfranchisement have reverberated for years. For example, Black families are generally less able to become homeowners at the same rate as White families, and even have less choice about where to purchase land. These inequalities in access to high quality land and housing has led to Black families disproportionately exposed to environmental health hazards, high rates of crime and violence, and poorer quality of life (Frederick, 2018).

Flood risk is not evenly dispersed in communities across socio-economic backgrounds. Environmental justice research examines the uneven distribution of the locations of environmental hazards compared to where low-income communities and communities of color live (Walker &
Burningham, 2011). Ueland and Warf (2006) found through geospatial and historical analysis that “residential housing, labor markets, and institutionalized racism conspired to relegate African Americans to the most low-lying, flood-prone, and amenity poor regions” of Southern cities. Communities of color are more vulnerable to hazards, and more exposed to weather disasters, which can be compounded by political and economic exploitation (Bullard & Wright, 2012). This has been confirmed in national case studies, which indicate that these communities are more prone to long-term impacts after a flood disaster, and have a harder time accessing federal funding meant for recovery (Muñoz & Tate, 2016).

5.1 Concept of Social Vulnerability

Social vulnerability is the concept that characteristics such as socioeconomic status, household composition, disability, minority status, language ability, housing type, and access to transportation influence the adaptive capacity of a community to tolerate environmental hazards (Tate et al., 2016). People with disabilities, elderly people, mobile home residents, renters, people without access to a private car, female-headed households, and non-English speakers are more likely to have more difficulties in preparing for a flood event by evacuating or maintaining emergency supplies, and are more likely to experience greater hardship (Hoffman, 2009). While physical exposure to hazards is an important component of risk, less socially vulnerable residents may experience less damage because they have more resources to prepare for and recover from hurricanes and floods, and they may be able to recover more quickly because they have funds to do so (Cutter & Emrich, 2006). The factors that make up social vulnerability do not fully explain all of what makes a person more at risk or more resilient to a given disastrous event, but disasters can magnify existing inequalities, so it is an important lens to understand the differential impacts of flooding.

Researchers have constructed several different indices to quantify social vulnerability to environmental hazards. Dr. Susan Cutter and fellow geographers were the first to conduct this type of analysis in 2003 when they created the Social Vulnerability Index called SoVI (Cutter et al., 2003). The Centers for Disease Control and Prevention (CDC) has created a similar model called the Social Vulnerability Index (SVI). The SVI is widely used to described vulnerability to diseases as well as natural hazards (CDC, 2016). The demographic components that make up the SVI using American Community Survey data are shown in Figure 4 (CDC, 2016).

Social vulnerability considerations are influencing policy decisions in North Carolina to ensure equitable distribution of recovery funds. The North Carolina Climate Risk Assessment and Resilience Plan addresses social vulnerability issues by discussing the problems of unequal exposure to risk based on demographic factors, and aiming to analyze these factors in project funding and implementation decisions (NCORR and NCDEQ, 2020).
5.2 Costs to Socially Vulnerable Communities

When buyouts are focused in socially vulnerable communities, there can be unforeseen inequitable consequences. Siders (2019) explained that the lack of transparency in the buyout process and the power that government officials hold creates a situation in which buyout program administrators could “purposefully target communities for retreat, whether maliciously, as an attempt to remove portions of the community; pragmatically, targeting affordable housing in order to purchase the most homes with limited funding; or beneficially, as an attempt to aid those at greatest risk.” While buyout programs have a race-neutral objective of reducing flood exposure, they are conducted in a subjective process in which racial bias, implicit or explicit, can have an impact on the process (Martin, 2019). In a geostatistical study of all North Carolina buyouts funded by FEMA HMGP from 1996 to 2010, Martin (2019) found that buyouts were clustered in African American neighborhoods within highly segregated counties. The buyout locations were not correlated with poverty or African American neighborhoods within flood zones, but solely with African American neighborhoods.

The overrepresentation of socially vulnerable populations in US buyout programs may dismantle a community’s social relationships, access to school, work opportunities, and place-based identity (de Vries & Fraser, 2012). If not administered with social equity as a priority, buyout programs may mimic policies of the past which instigated the displacement of communities of color. In a national study of over 40,000 flood-prone property buyouts, researchers found that bought-out properties were concentrated in poorer, more racially diverse areas within higher-income counties (Mach et al., 2019). In a study of eight buyout programs, benefit-cost analysis and political motivations were found to be the likely drivers of buyouts focused in low-income and minority neighborhoods (Siders, 2019). Benefit-cost analysis may seem agnostic to anything but the cost efficiency of an action, but studies show it tends to
favor protecting wealthier homeowners with grants to rebuild while buying out socially vulnerable people (Muñoz & Tate, 2016).

Buyout programs only acquire properties when the homeowner accepts the buyout voluntarily, yet buyout recipients tend to perceive the process as less than voluntary because they feel they are being pushed to accept the sale when they have few options right after experiencing a traumatic disaster (de Vries & Fraser, 2012). Research by McGhee (2017) showed that almost every single homeowner in a study of buyouts after Hurricane Sandy relocated to a neighborhood with higher social vulnerability than their previous neighborhood and many moved to homes that were still in the floodplain. This suggests that the buyout had a net negative outcome for the long-term resilience of participants. This is often because the money that homeowners are paid in exchange for the property acquisition may not be adequate to buy a home in a safer, less flood prone area or that there are not enough affordable housing units in safer areas (Muñoz & Tate, 2016).

While buyouts can be seen as a disruptive process of moving people with higher social vulnerability out of their original communities, it can also be seen as a beneficial mechanism to relocate the same people from disproportionate harm (Siders, 2019). There is a strong argument to be made that buyout programs in socially vulnerable communities help people recover from disasters by providing government assistance so they can move out of harm’s way (SAMHSA, 2017). Not aiding low-income communities and communities of color in relocating away from areas that are flood-prone can also perpetuate injustice (Siders, 2019). Incorporating social vulnerability information from the outset of a buyout process and making social equity an explicit goal using a transparent process could ensure existing inequalities in land use are not reinforced with government funding. The next section describes the methodology used for comparing potential buyout scenarios based on social equity.

6. Methods

6.1 Methods Overview

To attempt to tackle this issue of conflicting imperatives between flood resilience and social inequity and buyouts, a buyout prioritization process was conducted using geospatial analysis tools. The methods used for this analysis were based on a study by researchers at Texas A&M University, which created a multi-criteria spatial approach to select candidates for buyouts based on ecological values and other criteria (Atoba et al., 2020). Atoba et al. (2020) showed that ecological considerations can be added to existing requirements and still generate economically efficient buyout opportunities. Whereas the Texas A&M method bases candidate buyout selection criteria mostly on proximity data (e.g., the property is within 500 feet of parks), the current study bases candidate buyout selection criteria on overlay data (e.g., the property overlaps with a wetland with high potential for restoration.) The methods used are similar to the techniques of a composite land suitability analysis, in which sites are given a suitability rating based on how strongly they adhere to selected criteria (ESRI, 2020).

For the purposes of this study, New Bern was divided into the neighborhoods in the north, south, and east of the two main rivers. Viewing Figure 1, the Trent River is perpendicular to the larger Neuse River running from the northwest to the southeast. North of the Trent River and on the west side of the Neuse River, there are 11,500 residential parcels; the neighborhoods south of the Trent River and
west of the Neuse River have 2,627 residential parcels; and neighborhoods east of the Neuse River have 90 residential parcels. The region east of the Neuse River was called “eastern,” the region north of the Trent River was called “northern,” and the region south of the Trent River was called “southern” within this study. Railroad tracks bisect the northern region, visible as a straight grey line running northwest in Figure 1. The southern region contains a stream called Brice’s Creek that separates New Bern from the Croatan National Forest to the west, which is the large green area in Figure 1.

6.2 Data Collection and Preparation

The main data analysis programs used for this study were ArcGIS Pro version 2.7.1 and Jupyter Notebook version 6.1.4. Fourteen datasets were used for this analysis. Table 1 shows a description of the datasets, including the name, format, purpose for the analysis, and source. These data were chosen based on relevance to flood hazard analysis, wide use, similarity to datasets used by similar studies, ease of interpretation, and ease of preparation for analysis.

The 2019 parcel dataset for Craven County was downloaded from NC One Map. It was narrowed down to the boundary of New Bern only and from that set, only parcels which were listed as “Residential” or “Vacant Residential,” were chosen. The remaining parcels used for the analysis were reduced from the original amount of over 16,000 to 14,217 parcels.

New Bern’s Geographic Information Systems (GIS) Office made available a georeferenced list of properties potentially eligible for a buyout, based on damage during Hurricanes Florence and Irene, location in the floodplain, number of flood insurance claims, and first floor elevation, among other factors. In this report, the list will be referred to as “New Bern buyout list.” There were 269 properties in the list. All information identifying the property owner was removed from the table. The New Bern buyout list was connected to the parcel data set using the street address for each property, so that the properties which were potential buyout properties were noted in the parcel data. Some of the properties could not be attached to parcel data because of address errors, and so the final number of properties used for the analysis was 261 properties. A map of the New Bern buyout list is shown in Figure 11 of the Appendix.

The following indicators used in the analysis were raster data files, which are image files where every pixel has a value. The extent of flooding during Hurricane Florence in 2018 was downloaded from NC One Map. This data delineated flooded and non-flooded regions during the storm using satellite imagery (NC One Map, 2020). It is shown in Figure 12 in the Appendix. The extent of high tide flooding was downloaded from National Oceanic and Atmospheric Administration (NOAA). High tide flooding is the flooding that occurs during high tide and is also referred to as nuisance flooding (NOAA, 2020a). According to NOAA, high tide flooding will become more frequent as sea level rises, especially in low elevation areas, leading to more frequent road closures and overwhelmed stormwater systems (Sweet et al., 2017). High tide flooding is shown in the top left corner of the multi-panel map in Figure 13.

The extent of 6-feet of sea level rise (SLR) was downloaded from NOAA (NOAA, 2020b). The 6-foot SLR projection was chosen for several reasons over lower or higher projections of SLR. Researchers predict that the global SLR could exceed 2 meters, or about 6.5 feet, by 2100 because it is within the bounds of uncertainty for the high greenhouse gas emission scenario for the impacts of climate change (Bamber et al., 2019). A summary of a report on future SLR projections based on structured expert judgement explains that “for planning purposes, it would be prudent to use scenarios that anticipate 6.5
feet of SLR by the end of the 21st Century” (Shankman, 2019). Using this higher projection for SLR will make the buyout selection process relevant for long-term resilience planning (Bukvic, 2015). This dataset is shown in the bottom right map in Figure 13.

Five raster files were downloaded from the Natural and Working Lands in North Carolina datasets created by the Nicholas Institute for Environmental Policy Solutions (Warnell & Olander, 2020). These showed developed land in the active river area, unprotected forests and woody wetlands, forests and wetlands in the floodplain, forests in high flood risk watersheds, and high biodiversity habitats. Developed land in the active river area was a sign of hazard exposure, while the other four indicators were signs of restoration opportunities. Developed land in the active river area is shown in the top right corner of the multi-panel map in Figure 13. The four restoration opportunity indicators are shown in Figure 14. Detailed information about these datasets and how they were developed can be found in the Natural and Working Lands of North Carolina Data and Methods guide (Warnell, 2020).

The floodplain extent dataset was downloaded from the New Bern GIS Department (City of New Bern, 2020b). New Bern recently updated their floodplain extent as of the year 2020 to account for recent hurricanes and a new flood zone designation (New Bern GIS Department, 2020). This data shows the extent of the flood hazard area and is used for flood insurance designations in the National Flood Insurance Program (NFIP). This study only used the Special Flood Hazard Area (100-year floodplain). The extent of the floodplain, as well as the other designations for flood zones are shown in Figure 15.

The National Flood Insurance Program (NFIP) Claims dataset was downloaded from OpenFEMA (FEMA, 2020a). This dataset shows the number of NFIP claims that were made in each census tract between 1975 and 2019. NFIP claims are made by property owners after flood events damage their property. The claims suggest how much funding households in that area have received for flood disasters in the past. This dataset is aggregated at the census tract level. Figure 16 shows a map of the number of NFIP claims in New Bern at the census tract level.

The Hurricane Florence storm surge hindcast was downloaded from the Coastal Emergency Risks Assessment website, which provides visualization and data for storm surge based on the Advanced Circulation (ADCIRC) model (CERA, 2018). Storm surge is defined as the wind-driven waves that are pushed on shore during a coastal storm. In the case of Hurricane Florence, storm surge flooding reached heights of 10 feet in some areas, and greatly increased the amount of flooding the city experienced over flooding from precipitation and overwhelmed stormwater systems. This data included both whether the point was touched by storm surge but also how high the storm surge was at that point in US feet. The raw data had to be processed through a series of steps to be used in the study. The methodology section of the Appendix describes this process, and the methods are illustrated in Figure 17. The map of storm surge extent and depth is shown in Figure 18.

The Social Vulnerability Index (SVI) created by the Centers for Disease Control and Prevention is widely used to describe vulnerability to diseases as well as natural hazards (CDC, 2016). This model for social vulnerability was used for this study because it is frequently updated and easily downloadable for the census tract level of precision. The SVI uses 2012-2016 American Community Survey census data to create a composite score for each census tract with a score ranging from 0 to 1, where a higher score means higher vulnerability. The scoring is based on 15 demographic variables that describe socioeconomic status, household composition and disability, minority status and language, and housing type and transportation (CDC, 2016). The SVI scores for the census tracts are shown in Figure 19.
Although the parcel dataset included property value and land value information, these were not used as indicators because they were found to be unreliable because of missing data. Economic valuation was also specifically not part of this analysis, because one of the goals of the study was to see how buyouts could be conducted without focusing on cost. The methods of this study could easily be altered to include property value data to use as a metric for comparison.

Table 1: Description of datasets used for analysis

<table>
<thead>
<tr>
<th>Description</th>
<th>Format</th>
<th>Purpose</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Bern Parcels</td>
<td>Polygon Shapefile</td>
<td>Unit of division with detailed information for each parcel. Included for each parcel: street address, land use code (e.g., residential, industrial), area in square feet</td>
<td>New Bern GIS</td>
</tr>
<tr>
<td>Potential Buyout Properties</td>
<td>Point Shapefile</td>
<td>Properties in potential buyout with detailed information about vulnerability</td>
<td>New Bern GIS</td>
</tr>
<tr>
<td>Florence Flooding</td>
<td>Binary Raster</td>
<td>Spatial extent of flooding during Hurricane Florence</td>
<td>NC ONE Map</td>
</tr>
<tr>
<td>High Tide Flooding</td>
<td>Binary Raster</td>
<td>Spatial extent of flooding during a normal high tide</td>
<td>NOAA</td>
</tr>
<tr>
<td>Developed Active River Area</td>
<td>Binary Raster</td>
<td>Urbanized land within the active river area</td>
<td>Nicholas Institute</td>
</tr>
<tr>
<td>Forests and wetlands in the floodplain</td>
<td>Binary Raster</td>
<td>Unprotected forests and wetlands in the floodplain</td>
<td>Nicholas Institute</td>
</tr>
<tr>
<td>Unprotected forests</td>
<td>Binary Raster</td>
<td>All forests unprotected by state or federal designation</td>
<td>Nicholas Institute</td>
</tr>
<tr>
<td>Forests in high flood risk watersheds</td>
<td>Binary Raster</td>
<td>Unprotected forests in watersheds at high risk from flooding</td>
<td>Nicholas Institute</td>
</tr>
<tr>
<td>High biodiversity habitat</td>
<td>Binary Raster</td>
<td>Areas with a high score for the Natural Heritage Program’s Biodiversity and Wildlife Habitat Assessment</td>
<td>Nicholas Institute</td>
</tr>
<tr>
<td>6-foot Sea Level Rise</td>
<td>Polygon Shapefile</td>
<td>Impacts of predicted sea level rise of 6 feet as an indicator of future flood exposure</td>
<td>NOAA</td>
</tr>
<tr>
<td>Florence Storm Surge Hindcast</td>
<td>Continuous Raster</td>
<td>Spatial extent and level of storm surge in feet during Hurricane Florence</td>
<td>CERA</td>
</tr>
<tr>
<td>Social Vulnerability Index</td>
<td>Polygon Shapefile</td>
<td>Census tract level Social Vulnerability Index including demographic information</td>
<td>CDC</td>
</tr>
<tr>
<td>Floodplain</td>
<td>Polygon Shapefile</td>
<td>Extent of Special Flood Hazard Area (100-year floodplain)</td>
<td>New Bern GIS</td>
</tr>
<tr>
<td>Flood Insurance Claims</td>
<td>Polygon Shapefile</td>
<td>National Flood Insurance Program Claims by Census tract</td>
<td>OpenFEMA</td>
</tr>
</tbody>
</table>
6.3 Creating a Buyout Prioritization Process

All the indicator datasets were summarized within the parcel dataset using geospatial tools, such that each indicator became a new field in the parcel table. Within ArcGIS Pro, raster datasets were summarized within the parcels using the Zonal Statistics as Table tool. Shapefile datasets were summarized using the Summarize Within tool or Join Fields tool if the table had an identification field in common with the parcel dataset. Each parcel had a value for each of the indicators.

Eight of the twelve indicators shown in Table 2 were placed into two categories: whether they were indicative of exposure to flood hazard, or of restoration opportunities. These eight indicators were binary raster data, so that a parcel would have a value of “0” if no part of that indicator were within the parcel, and a “1” if any part of that indicator were within the parcel. The hazard exposure layers (flood extent of Hurricane Florence, the floodplain, the extent of high tide flooding, and the developed active river area) were collapsed into one number for easy processing by adding them together to create the hazard exposure score. Similarly, the restoration opportunity layers (forests and wetlands in the floodplain, unprotected forests, forests in high risk watersheds, and high biodiversity habitats) were collapsed into one number for easy processing by adding them together to create the restoration opportunity score.

Table 2: Indicators used to create flood hazard and restoration opportunities scores

<table>
<thead>
<tr>
<th>Hazard Exposure</th>
<th>Restoration Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florence flood extent</td>
<td>Forests and wetlands in the floodplain</td>
</tr>
<tr>
<td>Floodplain</td>
<td>Unprotected forests and woody wetlands</td>
</tr>
<tr>
<td>High tide flooding</td>
<td>Forests in high flood risk watersheds</td>
</tr>
<tr>
<td>Developed active river area</td>
<td>High biodiversity habitat</td>
</tr>
</tbody>
</table>

The justification for this method was as follows: if a parcel had flood hazard exposure layers within its borders, that would mean that if the residents of the buildings moved and the land was restored to an open space state, there would be no human assets exposed to the damaging impacts of the hazard. Basically, the hazard exposure would be reduced. If a parcel had restoration opportunity layers within its borders, that would mean that if residents of the buildings moved and the buildings were removed, this would create open space that could hold floodwaters and allow water to permeate the soil. It would also be beneficial to the environment by protecting and expanding the area of existing forests and wetlands in the floodplain, protecting any unprotected forests, restoring habitats, and protecting high biodiversity habitats.

These restoration opportunities and hazard exposure scores were added together to create a new indicator, the buyout benefit score. This was created to have a combined measure of risks avoided from moving people and property out of harm’s way with the reward of increasing open space to hold floodwater. These criteria were given equivalent weighting in the formula. The following formula was used to quantify this concept:

\[
\text{Buyout Benefit Score} = \text{Restoration Opportunities} + \text{Hazard Exposure}
\]
6.4 Producing Buyout Prioritization Scenarios

Buyout prioritization scenarios were created by establishing thresholds using the scores, SLR projection, and storm surge hindcast. Various scenarios were created by combining and changing the thresholds of the indicators and scores using a Jupyter Notebook, which also helped the analyst visualize the results of the filtering process as a geospatial map. These were decided on based on the combination of scores, exposure to flooding during Florence, level of storm surge during Florence, and projected inundation by SLR. During a buyout planning process, floodplain managers, government officials, and sometimes community members would be involved to decide on the indicators and thresholds used for each indicator.

6.5 Comparing Scenarios

The parcels that were chosen through the prioritization process for each buyout scenario were extracted from the residential parcels of New Bern into separate tables. Five statistics were used to compare the scenarios with the New Bern buyout list and with all residential parcels in New Bern used as a baseline. These statistics were: mean social vulnerability index score of the census tracts that the parcels occupied; mean depth of storm surge endured by parcels during Hurricane Florence; mean extent that Hurricane Florence flooded each parcel as a percent of the parcel; mean inundation attributed to projection of 6-foot SLR as a percent of the parcel; and mean count of NFIP flood insurance losses for the census tract. These statistics were also found for the parcels in the New Bern buyout list and the residential parcels of New Bern.

7. Results

The results of the study were a set of scenarios for potential buyout locations in New Bern based on hazard exposure, restoration opportunities, and the combination of the two, along with specific thresholds for sea level rise and storm surge depth above ground. Three scenarios were chosen out of the many iterations of scenarios produced for this analysis because they showed how the prioritization process could be used to target specific combinations of thresholds based on the analysts’ choices. The criteria used to create the scenarios are shown in Table 3. The locations of the potential buyout parcels produced by Scenarios 1, 2, and 3 are shown in Figures 20, 21, and 22, respectively. These three maps show the potential buyout locations with the residential parcels beneath them for context.

Scenario 1 was created by filtering out all parcels that did not have any restoration opportunities present but were exposed to at least 2 flood hazard indicators. This scenario produced 673 candidate buyout properties encompassing 708 acres restorable as open space. Scenario 2 was created by filtering out all parcels that were exposed to less than 2 flood hazard indicators and scored less than 3 for buyout benefits. This scenario produced 809 candidate buyout properties encompassing 623 acres restorable as open space. Scenario 3 was created by filtering out all parcels that were exposed to less than 2 flood hazard indicators and scored less than 3 for buyout benefits. Flooding from Hurricane Florence had to cover at least half of the parcel and SLR inundation had to cover at least 10% of the parcel. Storm surge from Hurricane Florence had to be at least 1 foot on average within the parcel. This scenario produced 757 candidate buyout parcels encompassing 560 acres restorable as open space.
### Table 3: Description of potential buyout scenarios

<table>
<thead>
<tr>
<th>Description</th>
<th>Filter</th>
<th>Count of Parcels</th>
<th>Area in Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Greater potential for restoration opportunities and reducing hazard exposure</td>
<td>Restoration opportunity &gt; 0 Hazard exposure &gt; 2</td>
<td>673</td>
<td>708.75</td>
</tr>
<tr>
<td>2 Greater buyout benefits. Potential for reducing hazard exposure. Parcel was flooded by Florence. Greater than 10% of the parcel would be inundated by 6-foot sea level rise</td>
<td>Hazard exposure &gt; 2 Buyout benefit &gt; 3 Sea level rise inundation &gt; 10%</td>
<td>809</td>
<td>623.08</td>
</tr>
<tr>
<td>3 Greater buyout benefits. Potential for reducing hazard exposure. More than 50% of the parcel was flooded by Florence. Greater than 10% of the parcel would be inundated by 6-foot sea level rise. Height of Florence storm surge was over 1 foot high.</td>
<td>Hazard exposure &gt; 2 Buyout benefit &gt; 3 Florence flooding &gt; 50% Sea level rise inundation &gt; 10% Storm surge &gt; 1 ft</td>
<td>757</td>
<td>560.58</td>
</tr>
</tbody>
</table>

### 7.1 Results by Indicator

Table 4 shows the descriptive statistics used to compare the scenarios with the New Bern buyout list and with all residential parcels in New Bern used as a baseline. Outcomes for New Bern’s residential parcels were used to contrast the scenarios with the New Bern buyout list. The following sections compare the scenarios to the New Bern buyout list and New Bern residential parcels based on five indicators: mean SVI score of the parcels based on the census tracts; mean height of storm surge endured by parcels during Hurricane Florence; mean extent that Hurricane Florence flooded each parcel as a percent of the parcel; mean inundation attributed to the 6-foot SLR projection as a percent of the parcel; and mean count of NFIP flood insurance losses of the parcels based on the census tracts.

### Table 4: Comparison of scenarios using descriptive statistics of the indicators

<table>
<thead>
<tr>
<th></th>
<th>Mean Social Vulnerability Score</th>
<th>Mean Florence Storm Surge (ft)</th>
<th>Mean Flood Extent by Parcel (%)</th>
<th>Mean SLR Inundation (%)</th>
<th>Mean Count of NFIP Claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB Residential</td>
<td>0.67</td>
<td>1.77</td>
<td>43.21</td>
<td>4.96</td>
<td>294</td>
</tr>
<tr>
<td>NB Buyouts</td>
<td>0.91</td>
<td>8.12</td>
<td>99.23</td>
<td>42.24</td>
<td>426</td>
</tr>
<tr>
<td>1</td>
<td>0.53</td>
<td>6.10</td>
<td>98.81</td>
<td>37.26</td>
<td>415</td>
</tr>
<tr>
<td>2</td>
<td>0.69</td>
<td>8.06</td>
<td>92.41</td>
<td>62.93</td>
<td>418</td>
</tr>
<tr>
<td>3</td>
<td>0.71</td>
<td>8.40</td>
<td>95.42</td>
<td>64.95</td>
<td>420</td>
</tr>
</tbody>
</table>
Social Vulnerability

The CDC breaks up the SVI score into four quartiles, with the value 0.0 representing the least vulnerable census tracts and the value 1.0 representing the most vulnerable census tracts. This is shown as a diagram in figure 5. New Bern’s residential parcels had a mean social vulnerability score of 0.67, which is in the third quartile and represents medium-high vulnerability. Parcels in New Bern’s buyout list had a mean social vulnerability score of 0.91, which is in the fourth quartile and represents high vulnerability. Parcels in the first scenario had a mean social vulnerability score of 0.53, which is in the third quartile and represents medium-high vulnerability. Parcels in the second scenario had a mean social vulnerability score of 0.69, which is in the third quartile and represents medium-high vulnerability. Similarly, parcels in the third scenario had a mean social vulnerability score of 0.71, which is in the third quartile and represents medium-high vulnerability.

![Figure 5: CDC Social Vulnerability Index score from lowest to highest in quartiles](image)

Figure 6 shows these values in a chart for comparison. The parcels in the New Bern buyout list are located in the census tracts with the highest social vulnerability of all these scenarios. This is 0.24 points higher than the average score in New Bern residential parcels. Scenario 1 had the lowest social vulnerability score, while scenarios 2 and 3 had very similar scores, which makes sense because they were constructed in a similar way, the only difference being the level of storm surge.

![Figure 6: Social Vulnerability Index scores for each scenario](image)
**Storm Surge**

A comparison of the average storm surge depth above ground for each set of parcels in US feet is shown in Figure 7. Parcels in the New Bern residential parcels exhibited lower average heights of storm surge flooding during Florence, experiencing on average 1.77 feet of storm surge, which makes sense because most parcels are not near the rivers and streams and experienced no storm surge at all. The New Bern buyout list experienced 8.12 feet of storm surge on average. Parcels in the first scenario had a mean storm surge depth of 6.1 feet, the second scenario had a mean storm surge depth of 8.06 feet, and the third scenario had a mean storm surge depth of 8.4 feet.

![Average Storm Surge during Florence (ft)](chart)

*Figure 7: Average storm surge depth during Hurricane Florence*

**Florence Flood Extent**

A comparison of the average extent covered by flooding from Hurricane Florence for each set of parcels in US feet is shown in Figure 8. The average extent covered by the flooding brought by Hurricane Florence in all residential parcels of New Bern was about 43.21%. This shows how extensive the flooding was during Hurricane Florence. In all the scenarios including New Bern’s potential buyout list, over 92.41% of each selected parcel was flooded by the extent of Hurricane Florence. This suggests that in each of the scenarios, the flooding covered nearly the entire set of parcels.
**Sea Level Rise**

A comparison of the average extent covered by flooding from 6-feet of SLR for each set of parcels in US feet is shown in Figure 9. The average extent covered by the flooding brought by SLR in all residential parcels of New Bern was about 5%. On average, the New Bern buyout list parcels would be 42% inundated by SLR. Parcels in the first scenario would be 37% inundated. Parcels in the second scenario would be 63% inundated. Parcels in the third scenario would be 65% inundated. This makes sense because scenarios 2 and 3 were targeting parcels at risk of SLR, while the first scenario contains parcels that are inland but still vulnerable to urban flooding.
National Flood Insurance Program Losses

A comparison of the average number of flood insurance claims for each set of parcels is shown in Figure 10. Flood insurance is required for properties within the floodplain. At least 94% of the properties identified by the scenarios were within the floodplain. The average number of flood insurance claims in all residential parcels of New Bern was about 294. In all the scenarios including New Bern’s potential buyout list, there were at least 415 flood insurance claims for the census tracts the parcels occupied, more than 40% greater than the average for all residential parcels. All of the scenarios were similar to the New Bern buyout list in this regard. This suggests the number of flood insurance claims were higher than that of the average New Bern residential parcels for each of the scenarios.

![Figure 10: Average number of NFIP flood insurance claims](image)

7.2 Answering Research Questions

The results of this study touch on the multiple indicators of overlapping risks and opportunities for resilience by reducing exposure to hazards and increasing space for ecological restoration. This section will use the results of the analysis to answer the research questions presented earlier and determine key findings of these analyses.

1. **What are the social vulnerability and risk attributes associated with the buyout locations that New Bern listed?**

   In general, the properties targeted for potential buyouts by New Bern were in lower income, more diverse census tracts with higher social vulnerability than the average for all New Bern residential properties. As shown in Table 5, there were 5.8% more people living below the poverty line, 5.2% more people without a high school diploma, and an 11.5% greater minority population when comparing census tracts of the New Bern buyout list to New Bern residential parcels. These findings follow the broader observation that buyouts across the nation occur in lower income, more racially diverse parts of
wealthier counties (Mach et al., 2019). This also supports the findings of Martin (2019) that North Carolina buyouts tend to be clustered in neighborhoods with more residents of color.

Almost all (92%) of the parcels in the New Bern buyout list were completely inundated by flooding from Florence. They were nearly all (95%) in the 100-year floodplain, which is another common requirement for federal funding. The New Bern buyout list targeted parcels that experienced on average 6-feet higher storm surge than the average New Bern residential parcel. This makes sense because these parcels would have experienced substantial damage from flooding and storm surge during the hurricane, and so would be eligible for buyout consideration. Federal and state requirements for buyouts mandate that a property is eligible if it was substantially damaged during the storm for which the state has received disaster aid.

New Bern’s buyout list table included information on the number of flood insurance claims the properties had experienced. The maximum number of claims was 9, the minimum was 1, and the average was 2.7 claims for the 262 parcels. The list also included that 46% of the properties experienced major damage, 33% experienced minor damage, and 15% were destroyed (a total loss of the value and usability of the home) during Hurricane Florence. Damage information is shown in Figure 11. This information was probably valuable for the decision-making process for the administrators of the buyout program in New Bern, but detailed information like this on all parcels in New Bern was not available to make comparisons.

Table 5: Comparison of SVI components for residential parcels and New Bern buyout list

<table>
<thead>
<tr>
<th>CDC Social Vulnerability Index Components</th>
<th>All New Bern Residential</th>
<th>New Bern Buyout List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socioeconomic Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Population below poverty line</td>
<td>18.1%</td>
<td>23.92%</td>
</tr>
<tr>
<td>% Unemployed population (age 16+)</td>
<td>8.66%</td>
<td>10.67%</td>
</tr>
<tr>
<td>Per capita income</td>
<td>$28,389.66</td>
<td>$22,376.24</td>
</tr>
<tr>
<td>% Population with no high school diploma (age 25+)</td>
<td>13.59%</td>
<td>18.77%</td>
</tr>
<tr>
<td>Household composition and disability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Population over 65</td>
<td>18.96%</td>
<td>18.2%</td>
</tr>
<tr>
<td>% Population under 17</td>
<td>22.16%</td>
<td>23.05%</td>
</tr>
<tr>
<td>% Population with a disability</td>
<td>15.49%</td>
<td>17.16</td>
</tr>
<tr>
<td>% Single parent families with children</td>
<td>9.64%</td>
<td>11.13%</td>
</tr>
<tr>
<td>Minority status and language</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Minority</td>
<td>44.9%</td>
<td>56.45%</td>
</tr>
<tr>
<td>% Persons with limited English proficiency</td>
<td>4.17%</td>
<td>6.44%</td>
</tr>
<tr>
<td>Housing &amp; transportation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of multi-unit structures (apartments)</td>
<td>9.38%</td>
<td>15.42%</td>
</tr>
<tr>
<td>Number of mobile homes</td>
<td>6.82%</td>
<td>7.33%</td>
</tr>
<tr>
<td>% Population in housing with more people than rooms (crowding)</td>
<td>2.87%</td>
<td>6.1%</td>
</tr>
<tr>
<td>% Population no vehicle</td>
<td>11.88%</td>
<td>14.28%</td>
</tr>
<tr>
<td>% Living in institutionalized group quarters</td>
<td>1.72%</td>
<td>2.06%</td>
</tr>
</tbody>
</table>
2. **Where would a separate geospatial analysis that incorporates a measure of social vulnerability have prioritized buyouts?**

The multi-scenario analysis shows that the spatial configuration of buyouts depends on the thresholds chosen for the combination of criteria, which can lead to different configurations of potential open space. Scenario 1 prioritized ecological restoration and so selected more parcels in or near forests and wetlands while Scenarios 2 and 3 prioritized hazard exposure reduction and so selected parcels near rivers and streams. The locations selected by Scenarios 1, 2, and 3 can be visualized in Figures 20, 21, and 22, respectively.

Scenario 1 selected 342 northern parcels, 283 southern parcels, and 48 eastern parcels. These encompassed 708 acres that would be converted to open space. The parcels selected by scenario 1 are located along the waterways but also inland, south of the railroad tracks and along some of the minor creeks in the northern region like Wilson Creek and Lawson Creek. Scenario 2 selected 578 northern parcels, 190 southern parcels, and 41 eastern parcels. These encompassed 623 acres that would be converted to open space. Scenario 3 selected 559 northern parcels, 160 southern parcels, and 38 eastern parcels. These encompassed 560 acres that would be converted to open space. The parcels selected by scenario 3 are identical to those in scenario 2 except with 52 removed. Scenario 3 is a version of 2 with a condition that storm surge inundation depth had to be greater than 1 foot on average. Scenarios 2 and 3 selected parcels along the waterways, including the historic downtown area.

There is some overlap between the three scenarios and the New Bern buyout list in the eastern and northern regions. Comparing Figure 11 to Figures 20, 21, and 22 shows that there is a noticeable absence of potential buyout parcels selected for the New Bern buyout list in the southern region of the town. New Bern selected 255 northern parcels and 6 eastern parcels. These include properties in the historic downtown district, closest to the water, and properties south of the railroad tracks. Scenarios 1, 2, and 3 have significant overlap in the southern region along Brice’s Creek.

3. **What are the differences in risk from sea level rise and flooding, as well as social vulnerability of the buyouts between the scenarios created in this study and the buyout locations that New Bern listed?**

Based on the results of the analysis using the five indicators, the New Bern buyout list and the three scenarios targeted parcels with heightened exposure to hazards over the average New Bern residential parcel. All scenarios created by the analyst selected parcels with similar attributes to the New Bern buyout list for average Hurricane Florence flood extent and the average number of flood insurance claims, as can be seen in Figures 8 and 10. While the analysis targeted similar locations in terms of flooding during Florence and past flood insurance claims, this was contrasted with New Bern’s residential parcels which had much lower values for flood extent and flood insurance claims, on average. This suggests that all scenarios and New Bern’s buyout list targeted parcels that were almost completely flooded by Florence, whether by storm surge or urban flooding or precipitation, and that these areas had experienced flooding in the past that required flood insurance claims for damages.

Storm surge during Hurricane Florence was a devastating source of floodwaters that damaged homes and buildings, flooded first floors and yards, carried away cars and statues, and stranded residents (Bennett, 2018). Because New Bern has built up along the riverfronts, it is threatened by storm surge. Scenarios 2 and 3 selected parcels which experienced very similar average heights for storm surge.
during Florence to one another and to the New Bern buyout list. Table 6 shows that parcels in scenarios 2 and 3 and the New Bern buyout list experienced more than four times the height in storm surge during Florence compared to all residential parcels in New Bern. This suggests that they were all targeting areas with high storm surge greater than 8 feet for buyouts.

Table 6: Difference between scenarios and New Bern buyout list compared to all residential parcels

<table>
<thead>
<tr>
<th></th>
<th>% Difference in SVI score</th>
<th>% Difference in storm surge depth</th>
<th>% Difference in SLR extent</th>
<th>% Difference in Florence flood</th>
<th>% Difference in NFIP claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB Buyouts</td>
<td>36%</td>
<td>358%</td>
<td>752%</td>
<td>130%</td>
<td>45%</td>
</tr>
<tr>
<td>1</td>
<td>-22%</td>
<td>244%</td>
<td>652%</td>
<td>129%</td>
<td>41%</td>
</tr>
<tr>
<td>2</td>
<td>1%</td>
<td>355%</td>
<td>1169%</td>
<td>114%</td>
<td>42%</td>
</tr>
<tr>
<td>3</td>
<td>6%</td>
<td>374%</td>
<td>1210%</td>
<td>121%</td>
<td>43%</td>
</tr>
</tbody>
</table>

A 6-foot increase in sea level would impact residents of New Bern even though the town is 60 miles from the nearest inlet to the Atlantic Ocean. Scenarios 2 and 3 were programmed to target parcels based on the average inundation extent of 6-feet of SLR over the parcels. Because of this, each contain parcels where over 60% of the area would be permanently inundated by 6-feet of SLR. This was why scenarios 2 and 3 exhibited SLR coverage over 10 times higher than the average New Bern residential parcel, as shown in Table 6. This was also why the locations of parcels in scenarios 2 and 3 are only along the riverfronts and near streams, whereas scenario 1 included land which is not threatened by SLR but is threatened by urban flooding. This suggests that there are a lot more properties that are at risk of permanent inundation in a future with higher sea levels. Many properties threatened by future SLR are currently within the list of New Bern buyouts, but there could be even more as in Scenarios 2 and 3. The high figure also suggests there are a lot of parcels not threatened by SLR inundation in New Bern in general, and there could be residential development opportunities outside of areas with overlapping risks of current and future flooding.

The parcels of the New Bern buyout list exhibited higher social vulnerability than the scenarios and all residential parcels in New Bern. The buyout list created by New Bern had a 36% higher SVI score than the average for residential parcels in New Bern. Scenario 1 had a 22% lower SVI score than the average for residential parcels. Scenarios 2 and 3 had a 1% higher and 6% higher SVI score than the average for residential parcels, respectively. This suggests that the New Bern buyout list was focused on areas with high social vulnerability even though, according to the results from the other scenarios, there are many more parcels in areas with lower social vulnerability that could be eligible for buyouts. Parcels in areas with lower social vulnerability that were flooded by Florence, experienced storm surge, and had more flood insurance claims were mostly in the southern region. The potential buyout properties in New Bern’s list were mostly concentrated in socially vulnerable census tracts. This may be related to the use of benefit-cost analysis calculations, as suggested in the study by Siders (2019), which is a requirement for federal grant funding. It may also be because the source of the hazard mitigation grant funding was HUD CDBG, which prioritizes revitalizing economically depressed areas. There may be other reasons for these findings which will be discussed within the study limitations section.
7.3 Study Limitations

There may be reasons why New Bern does not include any parcels in their potential buyout list in the southern region, besides cost and HUD CDBG requirements. These properties may have been chosen because the property owners reached out to the city to request a buyout. The northern region may have older neighborhoods which means that the buildings may have had more time to incur multiple flood events which might make the properties repetitive loss properties. The houses may have been built before floodplain building regulations were created, and so were not required to have higher first floor elevations as more recently built homes. Many of the parcels selected by the scenarios in the southern regions have forested backyards that buffer the properties from Brice’s Creek and Croatan National Forest to the west. These houses may have experienced a shorter period of flooding because there was more permeable surface to filter the water into the soil. The northern region, which has more urbanized area with more impervious surface coverage, may have created a higher flood peak that lasted longer, thus causing more damage to homes.

One point that may be noticed in these results was that the scenarios produced by the analyst targeted over 600 properties while the New Bern buyout list only had 269. Although the resulting scenarios encompassed over 5% of residential properties in the town of New Bern, this was by no means a recommendation to attempt to buy all these houses out in the short term. These are good candidates for buyouts because of their overlapping exposure to hazards and potential for restoration. The buyout prioritization process would need several more important steps outside of the scope of this project. One of those steps is to target properties based on spatial clustering. Targeting properties near one another to buy out would reduce a common problem in buyout programs: the checkerboard pattern. This problem has been described by other researchers (Atoba et al., 2020; Salvesen et al., 2018; Shepard et al., 2019) in which a few isolated houses are still on a street which is mostly depopulated, creating a checkerboard when viewed on a map. The adaptation pathway concept can also be used to solve for this problem, since some properties may be eligible for a possible buyout in the future, but program managers and the property owner may choose to defer a buyout until a damage threshold is reached.

Both the SVI and the flood insurance claims data provide information at a coarser spatial scale compared to other indicators in this analysis. Many assumptions are being made by using data at the census tract level, because this is a relatively large swath of area of varying sizes depending on the population. These datasets were used as a proxy for more granular data which was not available on household social vulnerability and flood insurance claims. Residents living in the parcels of interest may not conform to attributes of the census tract within which they are located. The SVI score and flood insurance claims data were used in relative terms, to make simple comparisons of scenarios, but data at the parcel level would make this analysis more robust.

Whereas this study was a desktop GIS exercise, buyout decision making usually occurs both through expert analysis and community and potential seller input. Assessors may go door to door to gauge potential interest of homeowners with flood-damaged properties, or neighborhoods may petition the state to consider buyouts (Binder & Greer, 2016). Buyout programs should ideally be community-driven and build trust and understanding for potential sellers so that the process can be fully voluntary and beneficial to the surrounding community. Community members need to be involved in the decision-making for such metamorphic changes to neighborhoods. The current study acts as an example of how a
buyout assessment could incorporate social vulnerability data using GIS tools, but engaging and empowering the community from the start is the best practice for state buyout programs.

8. Conclusions and Recommendations

All the scenarios and the New Bern buyout list had many commonalities in terms of indicators of hazard exposure. They all targeted properties that were exposed to severe flooding during Hurricane Florence as evidenced by the flood extent and storm surge. They all focused on properties within areas that had experienced major flood events from the past as evidenced through flood insurance claims. Many of the properties would also be partially inundated on a permanent basis if the threat of a 6-foot rise in sea level came to fruition. The most divergent aspect of these scenarios was that the buyout list created by New Bern was 36% more socially vulnerable than the average for properties in New Bern. Scenario 1 was 22% less socially vulnerable and scenarios 2 and 3 had about the same social vulnerability score as the average for properties in New Bern. This suggests that while there were many properties that were exposed to the same amount of flood hazard, the list made by the town targeted socially vulnerable neighborhoods with more minority and lower income residents.

The findings from this study and the literature on buyouts suggest that this municipality as well as many others may be disbursing federal funding for buyouts in a way that exacerbates social inequalities by encouraging the retreat of only some of the population in the poorest and most racially diverse areas. Although buyouts are always voluntary and can have considerable benefits to the former homeowners in terms of reducing future flood risk, they can also break up place-based ties and social relationships (de Vries & Fraser, 2017; Muñoz & Tate, 2016). Buyouts may be considered a form of displacement that forces the loss of neighborhood cohesion and disproportionately affects socially vulnerable areas that may have already been impacted by displacement in the past (Tate et al., 2016). The study by McGhee et al. found that Staten Island homeowners who participated in buyouts after Hurricane Sandy moved to places with greater social vulnerability and lower average income (2020). Does a buyout really benefit low- and moderate-income people by helping them move out of harm’s way? A large longitudinal study of buyout participants would be crucial to answer this important question, as the current study only scratches the surface (Martin, 2019).

This study did not include a cost efficiency analysis. This is because granular information on property values was not available for most of the parcels in New Bern. This would have made the comparison of the buyout selection process more realistic because benefit-cost analysis is one of the most important factors for funding requirements. Previous findings have shown that a buyout program is cost efficient when it includes primarily houses in the 100-year floodplain as well as severe repetitive loss properties (Conrad et al., 1998; Tate et al., 2016; Zavar, 2015). However, one of the purposes of this study was to determine how many properties are under threat from multiple layers of flood hazards, whether from a hurricane, a nuisance flood, or flooding in the future because of sea level rise. Many of the properties found in this analysis with high exposure to hazards may not have been targeted for buyouts by New Bern because they are not in economically depressed areas or did not meet the benefit-cost ratio requirements of the federal funders.
Strategic floodplain buyouts are an important tool that the federal, state, and local governments use for hazard mitigation and long-term resilience to future flooding. If buyouts are conducted by prioritizing only flood risk mitigation and cost efficiency without adequate understanding of the implications for marginalized communities, buyouts may perpetuate displacement of low-income communities and communities of color. Social inequity in buyout programs is a problem for long-term community resilience not only in New Bern but across the nation where towns and cities are grappling with the impacts of urban flooding and intensified storms.

Programs and funding sources that are only reactive to disasters are unsustainable for the amount of work that needs to be done to make a buyout program socially equitable and strategic for the purpose of increasing the value of this hazard mitigation technique (Schwartz, 2018). Single disastrous events catalyze action, but this focus on the disaster is often shortsighted because a buyout takes much longer than the attention of the media, public, and government officials (Greer & Binder, 2017). It would take even more time and effort to create a strategic buyout program that focuses on enhancing ecological functions to provide more flood protection and increase community resilience to hurricanes over the long term, while not disproportionately targeting socially vulnerable communities. By implementing the following recommendations, the State of North Carolina can develop the best tools, funding sources, and programs to have an ecologically sound and socially equitable strategic floodplain buyout process.

8.1 Recommendations

1. **Create a statewide list of potential buyout properties using a prioritization process that includes not only flood risk attributes but also social vulnerability information.**

   The first recommendation to state decisionmakers is to create a transparent process for prioritizing strategic buyouts. There could be a permanent program for community resilience created out of the North Carolina Office of Recovery and Resiliency (NCORR) to administer this prioritization process. NCORR has a technically skilled GIS office that would be capable of doing the advanced GIS analysis and stakeholder engagement process that this recommendation would entail. Administrators could create a geospatial data tool similar to that used in the current study to incorporate expert and public input not only on indicators of physical exposure to flood hazards but also social vulnerability. Public participation in the process and oversight would help ensure underserved property owners are neither underrepresented nor overrepresented in buyout plans.

   In addition to its use for recovery after a flood disaster, the tool could be used for pre-disaster mitigation to reach out to property owners about participating in a buyout. Homeowners that live in severe repetitive loss properties could be offered an anticipatory buyout before the next major flood event (McGhee, 2017). By being on this list, property owners could also be offered the pre-disaster fair market value for the house as soon as a major flood substantially damages the building, to reduce the lag time when homeowners often choose to rebuild instead (Moore & Weber, 2019).

2. **Increase the state funding allocation for floodplain buyouts.**

   The second recommendation is to increase the funding and flexibility of North Carolina’s State Acquisition and Relocation Fund. This would allow the state to fund buyouts and relocation, and not just supplement FEMA HMGP funding if it is insufficient (Georgetown Climate Center, 2020b). NCORR could use this funding outside of the federal requirements that buyouts must have higher benefits than costs or be located in areas approved for HUD funding, because this process can have too narrow of a focus
on lower-income communities. As an example, New Jersey funds buyouts through the Blue Acres Buyout Program within the Department of Environmental Protection. The funding from this program has been increased by state allocations in order to finance buyouts that were conducted after Hurricane Sandy (Georgetown Climate Center, 2020a). The buyout administrators are part of a permanent staff that can make more strategic decisions because of the separate funding that is not contingent on federal grants after a major disaster (Weber, 2019).

3. **Create a robust program to provide counseling to buyout recipients for every step of the buyout process from first contact to relocation to a safer area.**

   The third recommendation is for NCORR to create a large team of case workers to assist buyout participants in the process of relocating. Buyout participants would be supported in their relocation to a new home that is within their budget, within the town of origin to maintain social and work ties and is less exposed to future flood hazards. These case workers could provide support that reduces the feeling some residents who have been offered a buyout in other towns in North Carolina have expressed that they feel like they are being forced out (Phillips et al., 2012). These case workers would also update the buyout participants on the timeline for the process. A major criticism from several of the studies of buyouts is that the process takes an exorbitant amount of time and lacks transparency (Elliott et al., 2020; Greer & Binder, 2017; Jimenez-Magdaleno, 2017; Mach et al., 2019; Siders, 2019). Having case workers to advocate on behalf of the participants would make them feel more assured that the government officials are working in their best interest and helping them to relocate to a safer place.
9. References


10. Appendix

10.1 Data Preparation

The Hurricane Florence storm surge dataset used in this study was developed with the ADCIRC (Advanced Circulation) model. ADCIRC is a high-resolution coastal ocean circulation model that is used to simulate storm surge (Coastal Resilience Center, 2020). The ADCIRC model was chosen instead of the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model produced by the National Hurricane Center because of its precision and resolution (Kress et al., 2016). It was processed for use in a GIS program using Model Builder, a visual modeling tool. The storm surge (maximum inundation depth above ground) point shapefile for Hurricane Florence was downloaded from the Coastal Emergency Risks Assessment website (Coastal Emergency Risks Assessment, 2020). This web map service provides data from the ADCIRC Model Surge Guidance System. This data shows the inland extent of storm surge and the water depth above ground. The best hindcast of Hurricane Florence from the National Hurricane Center was chosen for the purposes of this study.

Within GIS, the Select by Location tool was used to pull data points only within the boundaries of an Eastern North Carolina counties shapefile. The workflow for converting the data from a point data file to its final raster form is shown in Figure 17. The storm surge maximum inundation depth shapefile for eastern North Carolina was re-calculated to change points with a null value to “0” so that they would represent “dry” points using the Recalculate Field tool. A triangulated irregular network (TIN) surface was created from this version of the point shapefile using the Create TIN tool. The TIN surface tool was used because it connects the points as nodes in a network of triangles, in which each node represents the depth of storm surge at that point. The TIN surface was converted to a raster, which is a square grid surface, because a raster surface is more suitable for certain calculations that were performed for this analysis.

After conversion to a raster, the image was manipulated to set a storm surge depth less than one foot as null to remove rivers and streams from the model. This was necessary because while the storm surge depths are meant to be above ground, the model used to create the file was created from a triangular network that included areas that should have resulted in no value. A digital elevation model (DEM) for Eastern North Carolina was downloaded from the US Geological Survey (USGS, 2019). Following this, the Raster Calculator tool was used to remove storm surge depth values that were less than the height of the DEM. This correction was done to the storm surge raster to remove irrational values. From there, the DEM was again used to subtract from the storm surge inundation depth above land raster. This was done so that the final storm surge inundation depth raster would take into account the actual height of the land surface. This process produced the visualization of storm surge depth and extent shown in Figure 18.
10.2 Maps and Figures

Figure 11: Potential buyout locations on New Bern buyout list showing damage from Florence
Figure 12: Extent of flooding during Hurricane Florence in 2018
Figure 13: Presence of potential exposure to flood hazards
Figure 14: Restoration opportunities components from the Natural and Working Lands dataset
Figure 15: Updated FEMA flood zones in New Bern
Figure 16: NFIP flood insurance claims made in each census tract between 1975 and 2019
Figure 17: Geoprocessing workflow to use ADCIRC storm surge model for analysis
Figure 18: Maximum storm surge extent and height during Hurricane Florence using ADCIRC model
Figure 19: CDC Social Vulnerability Index scores for each census tract
Figure 20: Locations of potential buyout parcels for Scenario 1
Figure 21: Locations of potential buyout parcels for Scenario 2

Legend:
- **Orange**: Scenario 2 potential buyout parcels
- **Green**: New Bern residential parcels
- **White**: New Bern Boundary

Base map credits: State of North Carolina DOT, Esri, HERE
Figure 22: Locations of potential buyout parcels for Scenario 3