Impacts of Sea Level Rise and Flooding on Low-Income Communities in Hampton Roads, Virginia

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Andrew Bowman

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Rider W. Foley, Department of Engineering and Society

INTRODUCTION

Recently, flooding has become more frequent and damaging as a result of climate change, even in areas far from the coast. As the air in Earth's atmosphere becomes warmer, its water-holding capacity increases, meaning some areas of the world will see increased precipitation (Hausfather, 2018). Furthermore, precipitation will become more intense. The state of Virginia is projected to see an 8% increase in heavy precipitation for every degree Celsius the Earth warms, or a 24% increase by the end of the century (Hausfather, 2018). More frequent heavy precipitation and severe flooding will result in more property damages. Annual flood losses in the U.S. are projected to rise by over 25% to $40.6 billion by 2050 (Wing et al., 2022). The city of Hampton, Virginia currently has over 16,000 properties that are at risk of being severely affected by flooding over the next 30 years (Risk Factor, 2022). Norfolk, Virginia has over 17,000 properties at risk of severe flooding over the next 30 years (Risk Factor, 2022). This number represents roughly half of the properties in each city. As heavy precipitation events become more frequent and sea level continues to rise, the Hampton Roads area will become more susceptible to dangerous and damaging floods.

The technical section of this paper will address the three main categories of flood adaptation technology: structural, non-structural, and nature-based. The Science, Technology, and Society (STS) section of this paper will utilize Langdon Winner's theory of technical arrangements as forms of order to analyze the disproportionate effects flooding has on low-income residents in Hampton Roads, Virginia. If not constructed with low-income neighborhoods in mind, flood adaptation technologies being implemented in Hampton Roads could compound the already disproportionate effects low-income residents are facing with more frequent flooding.

CASE CONTEXT: IMPACTS OF FLOODING ON LOW-INCOME RESIDENTS

Affordable housing in Virginia is among the most vulnerable to flooding in the country. Between five and ten percent of homes sold by the Department of Housing and Urban Development in Virginia are in flood zones, compared to 0.1 percent of all other homes (Jingnan et al., 2021). The state ranks fourth with nearly 1,500 low-income housing units that will be at risk of flooding by 2050 (Turken, 2020). Some of these housing units are already exposed to as many as four flood events per year (Buchanan et al., 2020). Much of this housing is in Hampton Roads, which can be seen in Figure 1. In fact, 700 of the estimated 1,500 units are in the city of Norfolk alone (Sauer, 2022).

Figure 1. Map of Hampton Roads, Virginia (Hampton Roads Chamber of Commerce, 2019).

Virginia's Hampton Roads is facing the highest rates of sea level rise along the Atlantic seaboard and is second only to New Orleans as the largest U.S. population center at risk (NOAA, 2022). Rates of sea level rise continue to accelerate, with recent projections estimating a rise of 1.7 feet by 2050 (Coutu, 2020). That number is projected to increase to 3 feet by 2080 and at

least 4.5 feet by 2100. (Coutu, 2020). Furthermore, the acceleration at the majority of tide stations suggests that Hampton Roads may end up facing the higher end of sea level projections in the coming decades (Coutu, 2020). Three feet of sea level rise would impact between 59,000 and 176,000 people and cause between 162 to 877 miles of road to be inundated, either permanently or regularly (NOAA, 2022).

The increasing threat of flooding for residents of affordable housing and low-income communities has damaging effects. First, as affordable housing units are exposed to flooding more frequently, property damages will rise. These damages will likely be multiplied because of the lack of financial resources available to low-income residents (Foudi et al., 2017). Second, flooding can have a negative effect on the mental health of individuals who are frequently exposed to flooding (Foudi et al., 2017). As low-income neighborhoods in Hampton Roads experience worse flooding because of sea level rise, mental health problems are likely to become worse. Finally, flooding increases microbial and chemical loads in surface waters, which can lead to a serious health risk for residents (Yard et al., 2014). Surface water collected during flood events can contain higher level of pathogens like *E.coli* and enterococci (Yard et al., 2014). Increased flooding in low-income communities means residents will likely be more exposed to pathogens.

As sea level continues to rise and flooding becomes more frequent, coastal municipalities will be tasked with implementing substantial adaptation technologies and techniques to protect their communities. Flood adaptation technologies are engineered innovations aimed at protecting people and infrastructure from flooding. They are generally categorized into three categories: structural, non-structural, and nature-based.

Structural flood adaptation technologies include physical structures such as dikes, levees, and seawalls. They are generally cost-effective in areas with high populations and asset concentrations, such as coastal cities, but can still require immense capital investments (Jongman, 2018). Dikes and levees are embankments typically made of rock or concrete that are built along rivers or coastlines. The main purpose of dikes and levees are to withstand the pressure of rising water levels (Bralower, 2022). Seawalls are similar to dikes and levees in that they are sloped embankments made of concrete or stone, but are designed to protect coastal communities from flooding caused by storm surges or high tides (Bralower, 2022).

Non-structural flood adaptation technologies include measures that are not reliant on physical structures. They are generally more accepted and less expensive than structural technologies, but may provide lower protection against flooding (Kundzewicz, 2009). One example is early warning systems, which use sensors connected to the Internet of Things (IoT) and communicate with monitoring stations to provide alerts when a flood is imminent. With flood sensor networks, emergency response teams can view when and where roads are flooded, how deep the water is, and the changing conditions of the flood in real-time (Semtech, 2021).

Nature-based flood adaptation technologies use natural systems to mitigate the impacts of flooding. Often, nature-based technologies are more cost-effective than structural solutions and enhance the overall health of ecosystems (The Nature Conservancy, 2020). Coastal wetlands provide storm protection valued at $23.2 billion every year in the United States (The Nature Conservancy, 2020). Wetlands are areas where land is covered by water, and they provide natural protection to the inland by their ability to store large amounts of water. Restoring wetlands reduces the risk of flooding by having a more effective natural barrier between the water and communities.

STS THEORY: TECHNOPOLITICS

A major concern with regards to increasing flood adaptation technologies in Hampton Roads is the decisions surrounding which socioeconomic neighborhoods the technologies will be concentrated in. Langdon Winner discusses the theory of technopolitics and the idea of technical arrangements as forms of order in "Do Artifacts Have Politics?" (1980). Winner discusses how the very process of technical development is so thoroughly biased that it regularly produces outcomes counted as breakthroughs by some and setbacks by others (Winner, 1980). He continues by explaining how agents of power who have geographic and temporal reach can shape society through technology. It is important to identify the agents of power, the subjects of the power, and how the power is being used. Winner argues that agents often use their power, either consciously or subconsciously, for political reasons that cause harm to underrepresented groups.

Hampton Roads is composed of many localities, the largest being the cities of Norfolk, Hampton, Newport News, Virginia Beach, and Chesapeake. The local government of each of these cities has a City Council which, with the help of other committees, writes a comprehensive plan for their city. The comprehensive plan is the policy document that dictates the long-term actions of the city. Applying this to Winner's theory of technopolitics, it can be seen that the agents of power—the City Councils—have long-term temporal reach over their respective geographic regions. The decisions the City Councils make in their comprehensive plans, such as where to concentrate development or which flood adaptation techniques to implement, could potentially harm specific residents for many years. This can be seen in flood-susceptible communities around the United States. Martinich et al. (2012) found that socially vulnerable populations are more likely to experience disproportionate impacts of sea level rise and bear

disproportionate costs of adaptation. Areas at risk of sea level rise but low levels of social vulnerability are more likely to have their shores fortified (Martinich et al., 2012). Nearly all the land was abandoned in the highest social vulnerability category, while almost all the land was armored in the lowest social vulnerability category (Martinich et al., 2012). So, while localities are investing in adaptation techniques for areas prone to flooding, these areas are generally not where socially vulnerable residents live.

In Hampton Roads, expensive oceanfront properties have been fortified while low-income residents have been ignored as sea levels rise in their neighborhoods (Sauer, 2022). Similar technopolitics could occur with the introduction of other flood adaptation technologies. For example, local governments may choose to zone affordable housing in flood-prone areas, or restore wetlands that protect wealthy neighborhoods. Social conflicts generally occur with the implementation of adaptation technologies when there is an uneven distribution of public money (Hinkel et al., 2018). Wealthier residents of localities generally have a louder public voice which can influence governments away from aiding low-income residents (Hinkel et al., 2018). Furthermore, low-income residents often have less resources when it comes to participating in local government. Localities in Hampton Roads must ensure that the flood adaptation technologies are deployed in low-income communities to aid residents who are the most socially and economically vulnerable.

RESEARCH QUESTION AND METHODS

The research question explored in this paper is: Are localities in Hampton Roads doing enough to combat the flooding-related disproportionalities that low-income residents face? This question is important because it targets the root of the problem. It is known that localities in

coastal Virginia have promoted building and investment in infrastructure in areas that will not be viable in 50 years (Belt, 2019). It is also known that low-income residents are facing disproportionate effects from flooding, so it is essential to know why they are put into vulnerable positions in the first place. The question is answered through a content analysis of policy documents from localities in Hampton Roads including comprehensive plans, hazard mitigation plans, floodplain maps, and affordable housing plans. The various documents were analyzed to discover the correlation between general housing, affordable housing, and flooding. This was done by determining how many times housing is mentioned versus affordable housing, and then how many times each are mentioned with relation to flooding, sea level rise, and resilience. Specifically, “flood”, “sea level rise”, and “resilien” were searched for in the comprehensive plans to ensure variations of the words were also included. Furthermore, the documents were analyzed to discover if there are specific statements or plans that address affordable housing and flooding impacts. The analysis is assessed ethically to discover if the plans of localities in Hampton Roads are equitable and consider the consequences of flooding and sea level rise in low-income areas.

RESULTS

The comprehensive plans of Hampton, Newport News, and Chesapeake do not mention flooding or sea level rise in relation to affordable housing. Of the five cities analyzed, only Norfolk and Virginia Beach mention flooding in their respective comprehensive plan sections on housing. Norfolk is the only city that emphasizes flooding with relation to affordable housing. The City of Hampton does not emphasize affordable housing in their comprehensive plan, as it is only mentioned 19 times compared to 354 mentions of general housing. The other four cities

have similar mentions of affordable housing when compared to general housing, with Chesapeake having the best ratio. Key terms mentioned in each city's comprehensive plan can be seen in Table 1.

Table 1. Number of mentions in each city's comprehensive plan (Bowman, 2023).

		Amount of Mentions								
		Housing	Affordable Housing	Ratio	Flooding	Flooding & Housing	Sea Level Rise (SLR)	SLR & Housing	Resilience	Resilience & Housing
Municipality	Norfolk	203	36	0.18	84	10	19	0	36	0
	Hampton	354	19	0.05	35	0	11	0	23	0
	Newport News	181	33	0.18	50	0	18	0	68	1
	Virginia Beach	269	64	0.24	121	14	56	6	17	0
	Chesapeake	172	44	0.26	47	0	7	0	4	0

The City of Norfolk's comprehensive plan, PlaNorfolk2030, is one of two comprehensive plans that mentions flooding in its section on housing. An anytical and ethical assessment of PlaNorfolk2030 reveals that the City of Norfolk is concerned with the impacts flooding and sea level rise have on low-income residents and is implementing plans to protect affordable housing from these impacts. One of the vision statements of the plan is, "A variety of well-maintained housing options that are affordable and accessible to all residents" (City of Norfolk, 2013, 1-3). Furthermore, affordable housing is one of the main focues of an entire chapter, which is titled "Ensuring Housing Choices For All" (City of Norfolk, 2013, 7-1). Flooding is mentioned 10 times in this chapter. One of the outcomes listed in the chapter is "Reduced threats of property loss due to flooding" (City of Norfolk, 2013, 7-6). Actions the City of Norfolk plans to implement to accomplish this outcome include improving the city's rating in the National Flood Insurance Program's Community Rating System, ensuring that all new development in flood-

prone areas comply with the city's flood protection regulations, ensuing that residents in flood prone areas are notified of the threat, and pursuing funding to raise or acquire homes that have experienced repetitive loses due to flooding (City of Norfolk, 2013, 7-7). In an addition to PlaNorfolk2030, the city has a long-term policy document specifically focused on flooding challenges due to sea level rise called Vision2100, which divides the city into four zones based on assets and risks, as seen in Figure 2 (City of Norfolk, 2016). Yellow zones are neighborhoods that experience frequent flooding and need to adapt to the rising waters. Purple zones are neighborhoods at less-risk of flooding and should be improved so that they continue to thrive. One of the action items of Vision2100 is create tool and incentive to develop a more resilient housing market (City of Norfolk, 2016, 24). This includes zoning and incentive programs to encourage development in low-risk areas and developments that deconcentrate poverty resulting in mixed-income neighborhoods (ibid). Inclusionary zoning, which gives a share of all new construction projects to affordable housing, is encouraged (City of Norfolk, 2016, 25). PlaNorfolk2030 and Vision2100 demonstrate that the City of Norfolk is aware of the threat flooding has on affordable housing and is working to solve the issue.

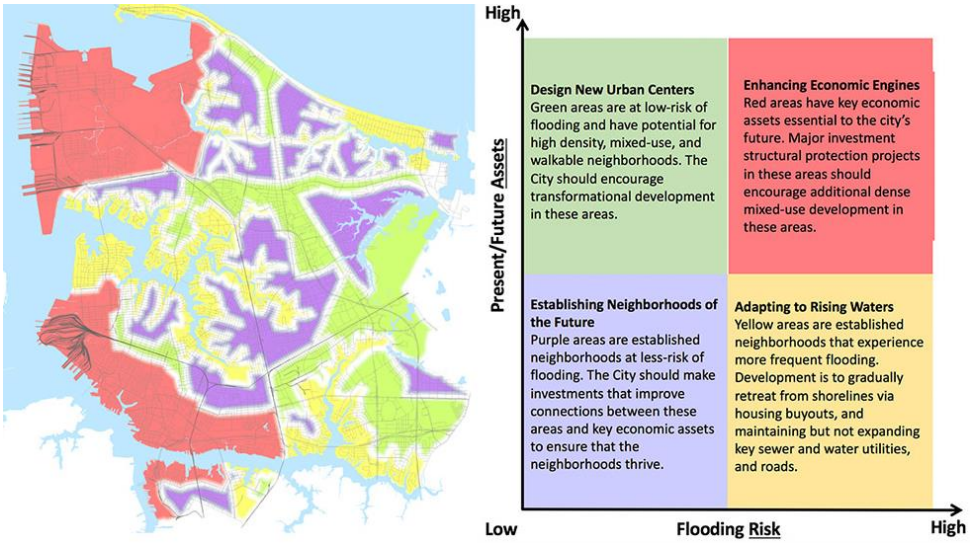

Figure 3. Norfolk Vision2100 map of zones and descriptions (City of Norfolk, 2016).

The City of Virginia Beach Comprehensive Plan mentions flooding 14 times and sea level rise 6 times in its section on housing. However, there are no direct mentions of affordable housing with relation to flooding or sea level rise. One of the guiding principles mentioned in the comprehensive plan is a diverse housing stock, where it is stated that "a decent, affordable home should be a right, regardless of income" (City of Virginia Beach, 2018, 1-9). The vision of the section on housing states, "Virginia Beach will be a City with vibrant, well-maintained neighborhoods where all residents have the opportunity to obtain desirable, safe, and affordable housing" (City of Virginia Beach, 2018, 2-65). This suggests that the city envisions affordable housing being safe from flooding, but it is not specified. The chapter does recommend policies related to sea level rise and flooding with relation to general housing. These policies include concentrating new development at higher elevations outside of flood zones and in the development approval process, avoiding development inside floodplains and low-lying areas (City of Virginia Beach, 2018, 2-72). Recommended policies for housing affordability include facilitating the development of affordable housing that is well-designed and constructed and supporting the location of housing to be within areas that afford residents with easy access to useful services and facilities (City of Virginia Beach, 2018, 2-74). Both of these policies suggest well-constructed affordable housing that is safe from flooding. Incentives related to affordable housing mentioned include reasonable density increases, development fee waivers, and expediated reviews (City of Virginia Beach, 2018, 2-73). These are good incentives, however, it is important that expediated reviews of affordable housing developments do not overlook sea level rise and flooding.

Although not directly mentioned in the housing chapter, flooding is recognized as a significant concern for residents in the Chesapeake 2035 Comprehensive Plan. In the chapter

titled “Responsible Growth”, one of the objectives is: Development and redevelopment will be designed in such a way as to mitigate the potential impacts from flooding and sea level rise (City of Chesapeake, 2014, 66). Strategies for this objective include exploring flood mitigation techniques such as removing structures and preserving properties subject to repetitive losses due to flooding and directing new development and redevelopment toward higher ground (City of Chesapeake, 2014, 67). In the section on housing, affordability is a major emphasis. The overarching goal of the section is to “foster the development and maintenance of a diverse, safe, and quality housing stock that is accessible and affordable to all people who live or work in the City” (City of Chesapeake, 2014, 82). Strategies to attain this goal include redeveloping old, existing housing into affordable housing, adapting non-residential buildings for residential use, and protecting existing neighborhoods from decline (City of Chesapeake, 2014, 83). Furthermore, the section states that Chesapeake will “support the development of housing funded through the Low-Income Housing Tax Credit Program, to the extent that such developments are compatible with the City’s land use policies” (City of Chesapeake, 2014, 84). This ensures that city-supported affordable housing complies with the flood-conscience land use policies.

Both Newport News’ and Hampton’s comprehensive plans contain general statements about affordable housing, with no mention of flooding or sea level rise. For example, Newport News’ Comprehensive Plan 2040 states, “permanent affordable housing solutions and support services are needed to reduce the homeless population” (Newport News Planning, 2018, 38). However, flooding is not as large of an issue in Newport News as it is in the other cities, as less than 2 percent of the city’s land area is within 2 feet of current sea level (Newport News Planning, 2018, 55). Still, there is no mention of housing in sections on flooding and sea level rise. In the Hampton Community Plan, there is a small section dedicated to the existing

conditions of affordable housing in which it is stated that there remains an unmet need for affordable housing units at the very low income level (City of Hampton, 2006). One of the adopted policies is to support housing programs that encourage mixed income neighborhoods and discourage the isolation of low income households. (City of Hampton, 2006, HN-21). This could help protect low income residents from flooding as their housing would be in the same neighborhoods as more advantaged residents. However, there is no direct mention of flooding and housing. The only specific statement about flooding in the comprehensive plan is related to the relocation or elevation of city facilities in flood prone locations (City of Hampton, 2006, CF-29). Based on these results, it can be concluded that the City of Hampton is not concerned with the disproportionate effects flooding has on low-income residents.

DISCUSSION

Applying the theory of technopolitics (Winner, 1980) to the analysis of the comprehensive plans of the five cities reveals how policy documents can show implicit bias. The agents of power in this case are the comprehensive plan writers which include members of city council and the planning commission. The writers have geographic power over city residents since they decide what and who to prioritize. They also have temporal power since comprehensive plans are long-term policy documents and generally do not change significantly over the years they cover. Therefore, comprehensive plans can favor some residents and regions while ignoring others. Implicitly, the comprehensive plans of Hampton, Newport News, and Chesapeake do not prioritize flood-related issues that impact housing by the simple failure to mention the words “flooding” and “sea level rise” in sections on housing. The city of Hampton shows implicit bias against affordable housing by only mentioning it at 5 percent the rate of

general housing. Furthermore, all of the cities besides Norfolk do not specifically mention affordable housing when discussing flooding, which suggests they are ignoring an important issue that impacts vulnerable residents the most (Martinich et al., 2012). The motivation of why writers of comprehensive plans fail to mention impacts flooding has on affordable housing cannot be determined through a policy analysis. Still, the failure to address the issue shows an implicit bias against low-income residents.

One limitation of this analysis is that only comprehensive plans were analyzed. Although a comprehensive plan is a broad, long-range policy document that represents a city's goals, there could be other policy documents that cities write and follow, such as hazard mitigation plans and flood maps. A caveat to only analyzing comprehensive plans is that affordable housing and flooding may be mentioned in one of the city's other policy documents. However, an analysis of a comprensive plan is a standardized approach to discovering priorities since most locality's have some version of one. A second limitation is that some of the comprehensive plans were not written within the last five years. The most egregious example is the Hampton Community Plan, which was written in 2006 and last updated in 2011. The city's new comprehensive plan, Hampton 2040, has not been published. Plans from over five years ago may be outdated as a city's priorities can shift dramatically, especially in Hampton Roads with relation to climate change.

As future comprehensive plans are released by the five cities, they should be analyzed in a similar manner, looking for connections between housing, affordability, flooding, and sea level rise. The new plans could also be compared to previous plans to discover if any priorities changed with relation to affordable housing and flooding. If the cities have any, an analysis could be done on other policy documents related to flooding, sea level rise, and housing, which

would give more insight into specific actions the cities are undertaking. Local government leaders could also be contacted to get similar information. Gaining insight into where affordable housing is located in each city would be beneficial. If the city itself does not disclose this information, local nonprofit organizations focused on affordable housing could be contacted. A comparison of the locations of affordable housing and the city's flood map would show where the city should focus mitigation efforts. Finally, similar studies could be conducted in other coastal areas susceptible flooding such as New Orleans, which is facing the highest rate of sea level rise in the country (NOAA, 2022).

As an engineering major and public policy minor, Langdon Winner's theory of technopolitics is particularly interesting. Winner's theory and the results of analyzing the comprehensive plans of cities in Hampton Roads shows how implicit biases imbedded into policies can impact not only residents, but also engineering decisions. For example, a comprehensive plan may direct development in areas prone to flooding, which would present an ethical dilemma for developers and engineers. It is therefore important for engineers to do their own due diligence when working for the public sector. After graduation, I will be working for a private company that works almost exclusively with municipalities. This research has made me more aware of the implicit bias and technopolitics that can exist within a municipality's policy documents, and I will ensure that I am conscience of that when I enter the workforce.

CONCLUSION

Climate change has and will have the most significant impact on the most socially vulnerable populations. This, coupled with the fact that Hampton Roads is facing the highest rate of sea level rise on the east coast, can lead to devastating outcomes for low-income residents.

Therefore, it is essential that local policies work to protect vulnerable populations from the impacts of climate change. In Hampton Roads, flooding and sea level rise will continue to have damaging effects on residents of affordable housing, especially given that they are largely ignored in comprehensive plans. The fact that affordable housing and flooding are not directly mentioned in four of the five comprehensive plans is reflective of a nation that ignores its most vulnerable populations. Cities in Hampton Roads must prioritize vulnerable populations in their comprehensive plans and protect them from flooding and sea level rise. Norfolk's Vision2100 should be used as a model for other cities and localities, which should create their own zones based on assets and risk. By focusing new affordable housing development in low-risk parts of Hampton Roads and gradually buying out homes or relocating residents from high-risk areas, cities can combat the disproportionate effects climate change is having on low-income residents.

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