Coastal Virginia Communities and Their Response to Increased Flooding

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Floods are one of the most common natural disasters and are affecting a growing number of US communities, both coastal and inland, and climate change is mainly to blame. Sea level rise, increased coastal flooding, subsidence, and climate-fueled storms are especially impacting communities across Virginia, specifically the eastern shore and surrounding islands. Tangier Island in Chesapeake Bay for example has lost 67 percent of its landmass since 1850, and most of its remaining landmass is likely to be fully submerged within the next 50 years, forcing residents to abandon their homes (Belt, 2019). In some areas of Virginia, tidal flooding has increased by 132 percent since 2000 (SLR, n.d.). Along regions of the Northeast Atlantic (Virginia coast and northward), rise in sea level is projected to be greater than the global average for nearly every future scenario. Mitchell et al. (2013) estimate a 4.5 to 7-foot rise in sea level on the Eastern Shore of the United States by 2100, four times the global average.

Continuous sea level rise as a result of global climate change presents clear and highly consequential risks to the US over the coming decades. Floods are responsible for more than 100 U.S. fatalities per year and cause mass property damage. Repairing impaired infrastructure across the nation cost FEMA an estimated $48.6 billion between 1998 and 2014. On Virginia's coast, the Norfolk-Virginia Beach MSA ranks 10th globally in value of assets exposed to increased flooding from sea level rise. Exposed assets include Naval Station Norfolk, which would require up to $460 million to replace aged piers already affected by sea level rise and millions more to protect ocean-bordering infrastructure crucial to the base's training, logistics missions, and maintenance. Over 45,000 properties in Chesapeake, Norfolk, Virginia Beach,

Portsmouth, and other nearby cities are already exposed to repeated tidal flooding, and that number is only expected to increase. Beyond property damage, floodwaters can also carry disease and contamination through leaked toxic chemicals, raw sewage, and other hazardous substances. Defiled floodwater can pollute drinking water and cause infections and respiratory illnesses. Floods lead to economic loss, contribute to mental health problems, and can destroy entire communities. Though flooding affects people of all backgrounds, it disproportionally affects people of lower-income, minority communities, and the elderly.

In response to flooding, humans have the option to alter their homes and fortify their environment. With flooding becoming a growing threat to Virginia's coastal communities, activists want to see more funding – and greater action – for programs aimed at mitigating the effects of climate change. In 2016, the General Assembly passed a bill creating the Virginia Shoreline Resiliency Fund to provide localities with low-interest loans to aid businesses and residents with flood mitigation expenses; however, the fund hasn't received any money since its creation, and there will be another attempt at restructuring the bill later this year. The Virginia Conservation Network (VCN) is asking for an annual $50 million to be allocated to the fund (VCU, 2020). Once the Shoreline Resiliency Fund gains traction, Virginia can begin to adapt to the impeding sea level rise.

Hampton recently received $11 million from the state and federal government to help with elevating homes at risk of flooding. This program is available to homeowners who meet a cost-to-benefit ratio set by FEMA; however, the program is flawed. The cost of raising a home is approximately $250,000, and most homeowners are responsible for up to 25 percent of the total cost as well as the cost of temporary relocation (VCU, 2020). Norfolk, on the other hand, devised a plan known as Vision 2100, which addresses sea level rise in commercial and residential areas

of the city. Vision 2100 divides neighborhoods into low and high-risk areas based on sea level rise projections, and it creates plans dependent on the expected composition and risk of each neighborhood. By executing this plan, Norfolk hopes to become a model for resilience by improving transportation, expanding the flood mitigation system, and building infrastructure expected to last a century. Virginia Beach has also started blocking development in locations where sea level rise is projected to increase flooding in the near future (VCU, 2020).

Virginia was recently awarded a $120.5 million grant from the U.S. Department of Housing and Urban Development to fight sea level rise in Hampton Roads. These funds support a nonprofit called RISE, which aims to "accelerate innovation in resilience-building solutions and demonstrate how adaptation to the impacts of climate change can be turned into an economic growth and job creation engine for coastal regions" (RISE, n.d.). RISE recently awarded between $160,000 and $310,000 each to six entrepreneurs with promising resilience-building proposals to protect communities. For example, InfraSGA is piloting innovative urban retrofit bio-retention systems to relieve flooding at reduced cost of operation, maintenance, design, and construction. Another group, GROW Oyster Reefs, LLC, is building an organic seawall to improve the water quality in the Chesapeake Bay and mitigate flooding (RISE, n.d.).

Also fighting flooding is the Chesapeake Climate Action Network, a nonprofit targeting the effects of global warming in Maryland, Virginia, and Washington, D.C. (CCAN, n.d.). Sea Level Rise strives to "enlighten and enable elected officials to implement widespread solutions to sea level rise" and stresses that Hampton Roads is "second only to New Orleans as the largest population center at risk from sea level rise in the country" (SLR, n.d.). Corresponsingly, the Chesapeake Bay Foundation "highlights natural solutions for adapting to sea level rise in Virginia that can both protect cities and suburbs and improve local water quality" (CBF, n.d.).

To combat the growing threat of flooding, Virginia must increase funding of and further pursue flood-mitigation projects, and efforts to reduce greenhouse gas emissions and limit the effects of global climate change must accelerate.

Review of Research

The frequency of daily tidal flooding is accelerating in over 25 Atlantic and Gulf Coast cities, the rate of sea level rise on the east coast of the US exceeds the global average, and heavy rainfall is increasing in intensity and frequency across the nation. Global climate change is mainly to blame. Recent years have been the warmest years ever recorded in human history (Wuebbels et al., 2017). Global atmospheric concentration of carbon dioxide recently surpassed 400 parts per million (ppm), a level last reached approximately 3 million years ago when both sea level and global average temperature were much higher (Wuebbels et al., 2017). The Chinese Academy of Sciences reports that "the rate of heat introduced to the planet's oceans over the last 25 years is equivalent to the energy produced by 3.6 billion atomic bombs" (Wood, 2020). By absorbing approximately 93 percent of the excess heat produced by greenhouse gas emissions since 1950, the world's oceans have warmed by about 1.3 degrees Fahrenheit and have risen at a rate greater than during any preceding century in at least 2,800 years (Wuebbels et al., 2017). As a result, the frequency of nuisance floods has increased nearly 10-fold in several US coastal cities (Wood, 2020).

Hood contends that climate change and sea level rise are currently on track to wipe out 50 percent of the world's sandy beaches by 2100 (Hood, 2020). These beaches make up more than a third of the global coastline, often in densely populated areas. Sea level rise, storm surge, new construction, and reduced sediment from dammed rivers are all depleting these shorelines. Even

if humanity greatly decreases the pollution that drives global warming, more than a third of the earth's shorelines could still disappear by the end of the century, crippling coastal tourism in countries big and small (Hood, 2020). More importantly, beaches serve as the first line of defense from coastal storms and flooding, and without them the effects of extreme weather events will be significantly higher. Some countries such as the US are already planning extensive defense solutions, but large-scale engineering schemes are unaffordable and unfeasible in most nations.

Virginia is in the process of implementing new adaptation strategies to reduce the impact of flooding events. Among the on-going efforts previously discussed, the Virginia Institute of Marine Science recommends a number of solutions including management/retreat options that consist of zoning and planning actions. This strategy avoids development in flood-prone areas while simultaneously protecting the environment. The Institute suggests accommodation options as well, such as elevating roads and buildings, implementing warning and response systems, constructing shelters and floatable/floodable development, and restoring floodplains. The Institute also recommends constructing shore protection structures, floodgates, tidal and storm surge barriers, and sea walls (Virginia Institute, 2013).

Flood Mitigation in Coastal Virginia Communities

Virginia needs to implement both non-structural and hybrid methods to reduce flood risk in coastal areas. In non-structural methods, natural buffers are improved; hybrid methods integrate soft and nature-based efforts with harder materials for increased structure and stability. Regarding non-structural strategies, Virginia must execute beach nourishment, wetland restoration/creation, and oyster restoration. Turning to hybrid methods, the state must construct

living breakwaters and marsh sills. Virginia also needs to raise infrastructure along the coast and halt development in flood-prone areas.

Beach nourishment is a defensive technique that consists of pumping sand onto an existing beach to increase beach width and increase its elevation. Adding to a beach's area acts as a buffer for coastal flooding and allows for more dissipation of wave energy during storm events; however, a nourished beach can erode two to three times faster than a natural beach. With sea level rise already projected to erode 1 meter of east coast shoreline per year, periodic nourishment will be required to maintain the desired level of fortification (Greene, 2002). An estimated $201-$798 million of sand replenishment will be needed to protect Virginia's coast from 50-200cm of sea level rise by the end of the century (Beach Replenishment, n.d.). Beach nourishment is the preferred course of action to combat shoreline erosion in the United States, Australia, and Europe (Greene, 2002)

Wetlands are low-lying ecosystems that host a variety of vegetation types adapted to frequent flooding. Wetlands provide flood and erosion control, water purification, and food and habitat for wildlife. The grasses within the wetlands present vegetation-induced resistance, which alleviate erosion, dissolve wave energy, delay storm surge intrusion, and guard against tidal flooding. Though Virginia's Nontidal Wetlands Permit program has slowed the elimination of wetlands since the start of the century, urban and industrial development, agriculture, dredging, damming, and diking destroyed approximately 42 percent of Virginia's wetlands between 1780 and 1980 (Augustine, 2004). Fortunately, degraded wetlands can be restored. Upland areas with low banks can be excavated to develop new tidal marshes, and sand fill can be used to raise the elevation. Under a 2010 agreement, Virginia committed to restoring 10,000 new acres of

wetlands in and around the Chesapeake Bay area (Department, n.d.). Moving forward, the state must address all threats to wetlands and commit to a net resource gain of the ecosystem.

Living breakwaters are offshore structures designed to limit wave energy by creating a barrier between open water and shoreline. They can be designed to float or can be attached to a bottom substrate, and they are built at emergent elevation in offshore shallow areas. Beyond attenuating wave energy, living breakwaters allow for new vegetation growth and the establishment of a new beach. In response to the devastation caused by Hurricane Sandy back in 2012, New York donated $60 million to implement living breakwaters along its coast. The project will be complete by 2021 and will consist of 3,200 linear feet of breakwater reinforcement (Griffin, 2018). Virginia needs to follow New York's lead and install living breakwaters on its own coast to improve flood mitigation and incorporate beneficial ecological components.

Marsh sills are very common and one of the most traditional types of hybrid living shoreline techniques, and they have proven to better withstand coastal storms than hardened structures. Along North Carolina's coast in 2012, the UNC-Chapel Hill Institute of Marine Sciences found that "over a third of bulkheads were damaged after a storm, while no damage was observed in marsh sills" (Still, 2018). Marsh sills are typically low-profile stone structures built in the water parallel to the shore. They are used to armor or widen an existing marsh, and they cause waves to break offshore, establishing a protected area that allows for sediment to accumulate between the structure and the coastline. With time, marsh platforms increase in width and elevation. Concrete blocks that contain 30 percent oyster shells, known as oyster castle blocks, are one version of sill structure that will both mitigate flooding and help with oyster restoration in Virginia (Moss, 2019).

Oyster reefs are semi-emergent aquatic habitats that function in a way similar to constructed marsh sills and breakwaters. Oysters filter sediment and remove pollutants from the water, and their reefs reduce shoreline erosion and provide feeding grounds for many important species. These shellfish are iconic to Virginia's coast, but overharvest, pollution, and disease have depleted oyster populations over the last hundred years. Virginia needs to restore the oyster population by building organic reefs along the coast. This will benefit both the oysters and the shoreline. Alongside Grow Oyster Reefs, LLC (GROW), the Nature Conservancy and its partners are working to restore oyster reefs in 10 Chesapeake Bay Tributaries by 2025 (Oyster Restoration, 2018). Once established, these reefs will weaken storm waves and help decelerate erosion along marsh edges. As they grow, the reefs will accrete towards the surface at pace with sea level rise. The reefs will have an adaptive capacity for storm protection and a cleaner, healthier bay will result.

Virginia must raise its coastal infrastructure and implement stricter zoning regulations. Over 5 million people (more than 60 percent of Virginia's residents) live on tidewater land (Gordon, 2019). If no proactive action is taken, Virginia Beach could incur expenses totaling $330 million per year in its battle against sea level rise over the next century (Coutu, 2020). Elevating structures and roads above base flood level will reduce flood damages. This is a reasonable strategy in areas with low development density; however, FEMA and Virginia need to work together to provide a more affordable program to homeowners along the coast. Vertical zoning ordinances can also be used to require new structures to be built at an elevation above a set contour. Virginia needs to elevate roads to ensure access to properties and safe evacuation routes. Elevated roads will act as levees, protecting both themselves and the properties behind them from flooding. Raising roads will be cheaper in rural areas but more complicated and

expensive in developed areas where interconnected storm sewer systems become a factor (Virginia Institute, 2013).

Virginia must halt development along flood-prone shoreline and establish rolling easements. Horizontal zoning ordinances can be used to require structures to be built a certain distance from the shoreline. Virginia receives approximately $2.8 million per year from the National Oceanic and Atmospheric Administration, and part of that funding is meant for coastal zone enhancement grants (Gordon, 2019). This is already a commonly accepted form of zoning and can allow for the use of rolling easements. Rolling easements facilitate the natural movement of the shoreline landward. As a regulation, it will allow for wetlands and beaches to migrate inland, preserving natural resources along the shoreline and reinforcing vegetational resistance at little to no cost. Complimentary to these methods, a buyout program will allow Virginia's coastal cities to purchase flooded or endangered houses, demolish them, and restrict future development on those properties. The corresponding areas could then be used for additional flood control projects. Beyond these measures, it would be smart for residents and businesses to begin moving farther inland and away from areas likely to flood.

Reduction of Greenhouse Gas Emissions

The tools and technology exist to effectively and affordably shift from fossil fuels to clean energy. Nearly 100 percent of the world's energy needs could be satisfied by renewable resources by mid-century, with the right public policies (7 Solutions, 2016). The Institute for Energy Economics and Financial Analysis claims that Coal-produced energy will be gone by 2030 mostly because the "price of producing power at natural gas plants and with wind and solar has declined dramatically" (Weise, 2019). Coal for example is officially more expensive than

solar power and other major electricity generation systems. Electricity generation is especially concerning because only one-third of the energy in the fuel used to produce electricity is actually converted to usable electric power. Munson reports that “nearly 70% of U.S. greenhouse emissions comes from generating electricity and heat, whereas only 19% comes from automobiles” (Munson, 2009). Though technical improvements for new vehicles could avoid approximately 1.4 gigatons of carbon dioxide annually by 2030, improving the efficiency of electric generation by incorporating renewable energy is the most essential and immediate solution for lowering greenhouse gas emissions (Weise, 2019). Utilizing the unused thermal energy produced in power plants and developing renewable energy plants will be the key to enhancing efficiency.

A system founded on output-based allocations of carbon emissions is the best way to implement and progress the efficiency of powerplants. Based on the previous year’s national average output of C02, producers of electricity and thermal energy will be given an initial allowance for carbon dioxide emissions per delivered megawatt-hour of electricity and Btu of thermal energy. Facilities that produce levels of carbon dioxide above this amount will have to purchase additional allowances from cleaner plants that successfully keep their emissions down. Allowance credits will be fully interchangeable between heat and power. Annual carbon allowances will be cut every year, allowing clean energy plants to improve their economic position by selling their spare allowances and forcing dirty power plants to adapt to greener methods (Munson, 2009). To save money and reduce carbon emissions in accordance with this policy, dirty plants can initially invest in technology that improves their efficiency. They can then begin to sell their wasted thermal energy to nearby thermal-using plants, factories, and commercial buildings. Dirty plants can use this extra source of money to invest in renewable

energy production such as wind farms. They can also hire the services of energy recycling plants to earn additional carbon allowances.

Consider the faults of other programs. A system of allowances per unit of input fuel, such as the Clean Air Act's approach toward pollution criteria, does not optimize energy productivity and does not reward efficiency. A carbon tax requires legislators to determine the precise price per ton of carbon dioxide emissions to achieve the desired level of fossil-fuel reduction. This tasks Congress with deciding how to spend the collected money, which creates an atmosphere ripe for mischief. A cap-and-trade system that distributes additional allowances to prominent emitters, as was done in 1990 with sulfur emissions, rewards pollution instead of clean energy, and it hinders efficiency.

Munson stresses that "we must reduce total carbon emissions by 70% or more over the next 50 years" (Munson, 2009). The recommended output system will allow for maximum flexibility for the market to lower fossil-fuel use and will encourage profitable greenhouse gas reduction. In the United States, establishing a system such as this one will be relatively simple and will stimulate an investment boom in clean energy productivity. Instead of collecting and distributing trillions of dollars, Congress will only have two tasks: set just rules for determining output allowances and establish the annual decline rate for allowances per unit of useful output. Once Virginia, and the United States, prove this system to be effective, other countries will have incentive to follow a similar process. Transitioning away from a carbon-intensive economy will inevitably harm some businesses, especially large polluters; however, this transition is necessary for the establishment and growth of renewable energy around the globe, and it is the first step the world must take in mitigating climate change and sea level rise.

Conclusion

The main concern with increased flooding is not so much about the approximate 8-inch increase in global average sea level since 1900. Rather, the main concern revolves around sea level projections for the 21st century as a direct impact of human-caused global warming. Regardless of the mitigation strategies Virginia ends up pursuing, the state must take immediate action. Flooding and sea level rise are only going to worsen with time; however, Virginia's coastal cities can reduce the consequences if politicians, independent organizations, and motivated individuals work together to devise a realistic, affordable, and prompt plan of defense moving forward. The same can be said for reducing greenhouse gas emissions both inside and outside of the United States. If Virginia and the rest of the world shift their current priorities in the direction of flood and climate mitigation, the 22nd century will be greener and sea level rise will be manageable.

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