ABSTRACT

Title of Thesis: SINK OR SWIM: A CONVERSATION ON LIFE IN AN INUNDATED CHESAPEAKE BAY WATERSHED

Deane Lowell Townsend, Master of Architecture, 2020

Thesis Directed By: Ronit Eisenbach, and School of Architecture, Planning and Preservation

Historic Chestertown, Maryland, is one of the oldest existing communities in the state of Maryland. Strategically situated along the Chester River, this town—like many others on the Delmarva Peninsula—is at risk to external forces of climate change and sea level rise which threaten to inundate and displace the town. Facing an uncertain future due to climate change and other socio-economic factors, Chestertown possesses the opportunity of challenging the status quo and raises the question can the concept of community be reimagined to address the severity of climate change and sea level rise while fostering a positive relationship to the environment? Observations to historic patterns of settlement, resilient design strategies, and building construction methodologies have been analyzed and applied to help protect the historic town while fostering an environmentally conscious community model. This model serves as a critique to previous settlements and current development proposals for the town, challenging the need to prioritize natural ecology over the built environment.

SINK OR SWIM:
A CONVERSATION ON LIFE IN AN INUNDATED CHESAPEAKE BAY WATERSHED

by

Deane Lowell Townsend

Thesis submitted to the Faculty of the Graduate School of the
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Advisory Committee:
Professor Ronit Eisenbach, Chair
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GMSL	Global Mean Sea Level
RCP	Represented Concentration Pathway
FEMA	Federal Emergency Management Agency

Chapter 1: The Chesapeake Bay as Home

The Bay as Home

The Chesapeake Bay is more than just a body of water, it is a sense of identity and place. Communities lining the bay have become places for recreation and tourism destinations during the warmers months of the year, yet is home to local residents and complex migratory species of animals alike. Considering the history and economic exploitations of the Bay, the region is a prime example of how people and places are interconnected, and more specifically how humans have always manipulated the land to provide for their needs.[1]

Figure 1 Families play on the beach at Sandy Point State Park in Anne Arundel County, MD.

Source: courtesy Steve Droter, Chesapeake Bay Program. https://www.chesapeakebay.net/

[1] National Parks Service. *History.* August 1, 2019.

That interconnection to the Chesapeake Bay watershed is by extension of its vastness and interconnectedness throughout the Mid-Atlantic region. Though the main body of water constituting the Chesapeake Bay is bounded by both the states of Maryland and Virginia, vast networks of tributaries and streams that feeds the bay additional extends into the neighboring states of Delaware, New York, Pennsylvania, and West Virginia. Encompassing this region, the area of the watershed accounts for a region that occupies 64,000 square miles,[2] within this region another 11,684 miles constitutes for the profile of shorelines and the body of water constituting the Chesapeake proper accounts for 4,480 square miles, at an average length of 200 miles.[3] Of those 4,480 square miles of water and with an average depth of 21 feet and depth upwards of 170 feet in select locations, the bay retains nearly 18-trillion gallons.[4] This water, mixing freshwater from the tributaries and saltwater from the Atlantic Ocean, creates the ideal brackish conditions necessary to support estuarine conditions and consequently makes the Chesapeake Bay the largest estuary in the nation.[5] Under these conditions, the bay supports nearly 3,600 species plants and animals, representing about 348 different species of finfish, 173 species of shellfish, over 2,700 plant species, 29 species of migratory waterfowl, and over 16 species of underwater grasses.[6]

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[2] National Aquarium. *Chesapeake Bay*. 2019.
[3] Maryland Sea Grant. *Chesapeake Bay Facts and Figures.* June 2013.
[4] Ibid.
[5] Ibid.
[6] Ibid.

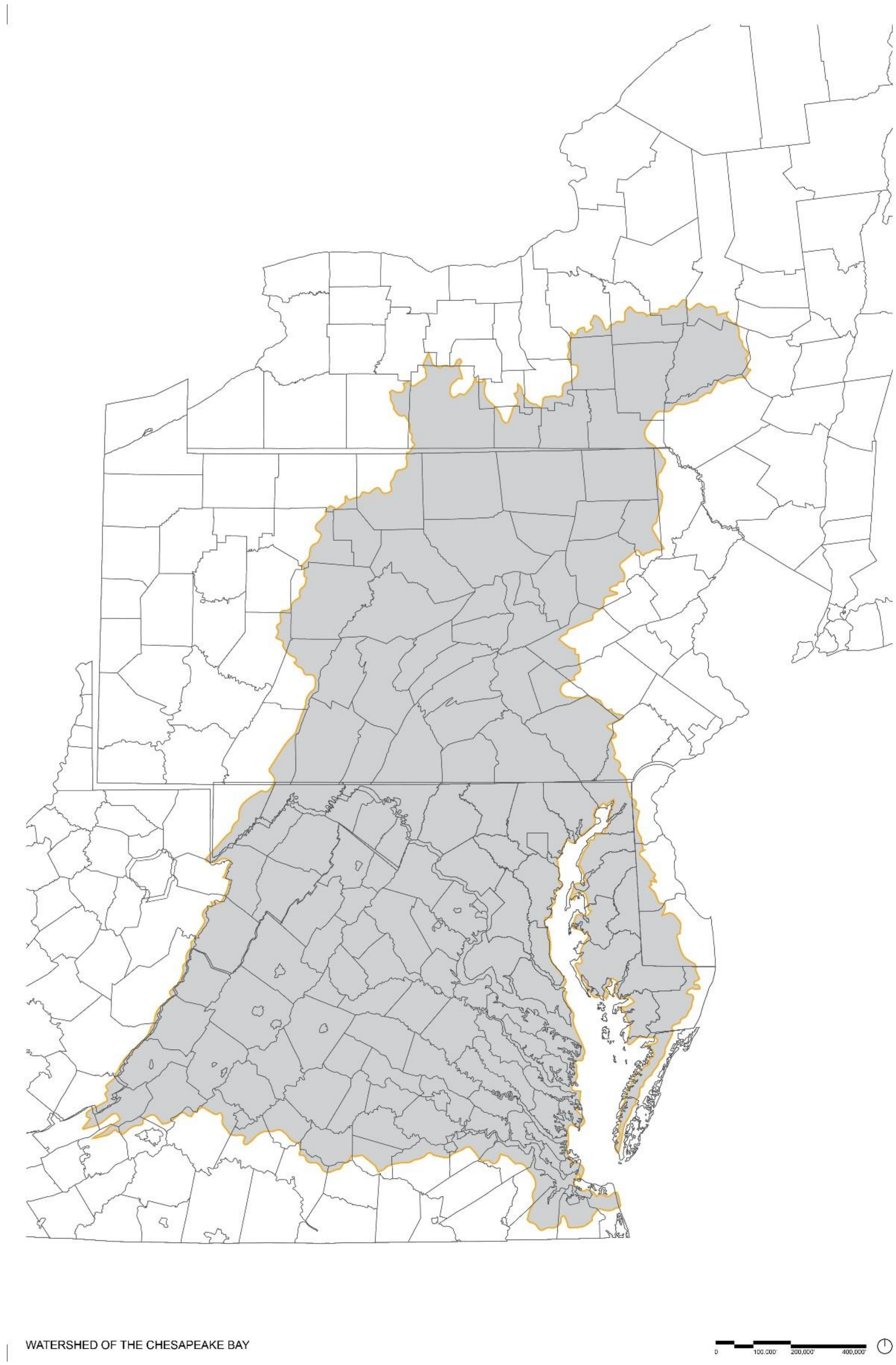

Figure 2 Watershed of the Chesapeake Bay

Source: Author, data derived from USGS

Given the abundant estuarine conditions of the Chesapeake watershed, the region has also attracted the large concentrations of human populations. In 2017, a report was conducted throughout the Chesapeake Bay watershed to better understand the population and residents of the watershed. Derived from reported county census data, it is estimated that approximately 18.2 million people live in the Chesapeake Bay watershed as of 2017,[7] of those approximately 550,000 people reside on the Delmarva peninsula. The total number of residents in the Chesapeake Bay watershed is anticipated to increase by another 2 million residents by 2030 and another 2.5 million by 2050 in total. Of that growth, the Delmarva Peninsula is expected to grow by another 143,900 residents by 2050.

COUNTY	1950	1960	1970	1980	1990	2000	2010	2017	PROJ 2020	PROJ 2030	PROJ 2040	PROJ 2050
KENT, DE	3,978	6,897	8,603	10,318	11,660	13,310	17,051	18,576	19,005	20,279	21,298	22,089
NEW CASTLE, DE	5,981	8,402	10,544	10,879	12,077	13,671	14,715	15,298	15,654	16,278	16,497	16,432
SUSSEX, DE	20,879	24,916	27,354	33,361	38,544	53,320	67,109	76,701	78,116	84,696	88,083	90,333
CAROLINE, MD	18,234	19,462	19,781	23,143	27,035	29,772	33,066	33,193	34,050	38,450	42,950	45,801
CECIL, MD	30,703	44,557	49,052	55,623	65,672	79,114	93,065	94,573	96,279	110,040	124,675	132,989
DORCHESTER, MD	27,815	29,666	29,405	30,623	30,236	30,674	32,618	32,162	34,300	37,350	39,500	42,309
KENT, MD	13,677	15,481	16,146	16,695	17,842	19,197	20,197	19,384	20,900	22,100	23,000	24,190
QUEEN ANNE'S, MD	14,579	16,569	18,422	25,508	33,953	40,563	47,798	49,770	50,750	55,750	61,050	65,131
SOMERSET, MD	20,745	19,623	18,924	19,188	23,440	24,747	26,470	25,918	26,750	28,450	29,550	31,010
TALBOT, MD	19,428	21,578	23,682	25,604	30,549	33,812	37,782	37,103	38,850	40,900	42,000	43,855
WICOMICO, MD	39,641	49,050	54,236	64,540	74,339	84,644	98,733	102,923	106,200	118,200	126,650	136,746
WORCESTER, MD	6,336	6,496	6,690	8,454	9,587	12,739	14,083	14,148	14,534	15,861	16,860	17,925
ACCOMACK VA	17,700	16,027	15,174	16,358	16,586	20,040	17,350	17,027	17,670	15,888	13,924	13,206
NORTHAMPTON, VA	11,901	11,672	9,935	10,061	8,985	9,007	8,523	8,149	8,231	7,756	7,184	6,807
TOTAL	**251597**	**290395**	**307948**	**350357**	**400505**	**464610**	**528561**	**544924**	**561289**	**611999**	**653221**	**688824**

Table 1 - Evaluation of Current and Projected Population Growth on the Delmarva Peninsula.
Source: table by author, data derived from the Chesapeake Bay Program & United States Census Bureau

[7] *Population | Chesapeake Bay Program.* 2019.

Figure 3 Projected Population Intensity by 2050

Source: Author, data derived from the Chesapeake Bay Program & United States Census Bureau

With that anticipated population growth in the area, also comes the realization of deteriorating health of the Chesapeake Bay. For each person living in the Chesapeake Bay watershed, the region is physically altered as forested land is cleared for residential development and agricultural needs, and implemented infrastructure creates impervious surfaces that attributes to environmental degradation and increased pollution.[8] However, what is not anticipated or yet fully understood from census data alone and projected population growth in the area, are the impending effects of climate change and sea level rise to the area. The next chapter—Chapter 2: Climate Change and Sea Level Rise—will elaborate further upon the anticipated impacts in the region and what that means for present and future residents in the watershed.

—End of Chapter—

[8] *Population Growth | Chesapeake Bay Program.* 2019.

Chapter 2: Climate Change and Sea Level Rise

An obstacle to continued population growth in the Chesapeake Bay watershed, is the impending threat of climate change and subsequent sea level rise that will inundate the region. In the last decade, advancements in scientific technology, documentation, and data networking have broadened availability of important information about climate change. With the increased propagation of climate change data and resources, climatologists have shed new insight towards the dire situation and projection that sea level rise will have on the future of the planet. This chapter will bring awareness to the factors that have contributed to climate change and sea level rise, assess current projections for sea level rise, review the effects of sea level rise, and succinctly convey the challenges that the Chesapeake Bay watershed and Mid-Atlantic region will have to address in the years to come.

Contributions to Sea Level Rise

Fundamental to the basis of sea level rise, is the understanding of the conditions that contribute to the propagation of climate change. At its core, sea level rise has been driven by the rising concentrations of atmospheric pollutants, which has subsequently warmed the atmosphere by natural phenomena referred to as the greenhouse effect. The greenhouse effect is the natural process and byproduct of Earth’s atmosphere, whereby suspended particulate and gas absorb, trap, and reflect incoming solar radiation and heat waves within the atmosphere. Under these conditions, the trapped or absorbed solar radiation acts as incubator for Earth’s surface, warming not only the atmosphere but subsequently geographic and aquatic features of the planet. Exacerbating this problem, according to the Earth Science Communications Team from NASA, dependancy on industrialization in the past 150 years has resulted in growth of atmospheric carbon dioxide concentration from 280 parts-per-million to 400 parts-per-million.[9] Consequently, nearly doubling the concentration of greenhouse gases which includes carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), synthetic halocarbons (HC), and water vapor (H_20), the Intergovernmental Panel on Climate Change has found in their report made in 2013 that the average temperature of Earth had increased by more than one degree Farenheight just within the 20th century alone.[10] While some greenhouse gases, such as methane, have a relatively shorter life expectancy of a couple decades, other greenhouse gases such as carbon dioxide could persist in the atmosphere for periods as long as a couple centuries upwards to a milenia.[11]

With rising atmospheric temperature brought about by greenhouse gases, it is important to acknowledge the immediate and long-term consequences brought about by that warming. With the warming of atmospheric temperatures, a considerable portion of rising global mean sea level elevation in the past one hundred years can be attributed to the slow and gradual loss of glaciers or polar ice sheets. Though most of that glacial melt has been attributed to the loss of land-based glaciers, the increase in sea level rise will emerge from melting of Artic and Antarctic ice sheets. In a study

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[9] National Aeronautics and Space Administration. The Causes of Climate Change. Earth Science Communications Team. September 30, 2019. https://climate.nasa.gov/causes/

[10] Strauss, B., et al. Maryland and the Surging Sea: A vulnerability assessment with projections for sea level rise and coastal flood risk. Climate Central Research Report, 2014, 10

[11] Zickfeld, Kirsten. Solomon, Susan. Gilford, Daniel M. Centuries of thermal sea-level rise due to anthropogenic emissions of short-lived greenhouse gases. Proceedings of the National Academy of Sciences of the United States of America, 2017, 657-662.

conducted by Dr. Andrea Dutton, "Sea-Level Rise Due to Polar Ice-Sheet Mass Loss during Past Warm Periods," past episodes of increased atmospheric concentration of greenhouse gases and subsequently an increased atmospheric temperature, had contributed to higher sea levels by melting Antarctic and Artic ice sheets. Alarmingly, in this report, findings suggested that the present (2014) concentration of atmospheric carbon dioxide gas are similar to that of the Pliocene period, whose atmospheric temperature was 2-3 degrees Celsius greater than present with a sea level over 130 feet higher than present.[12]

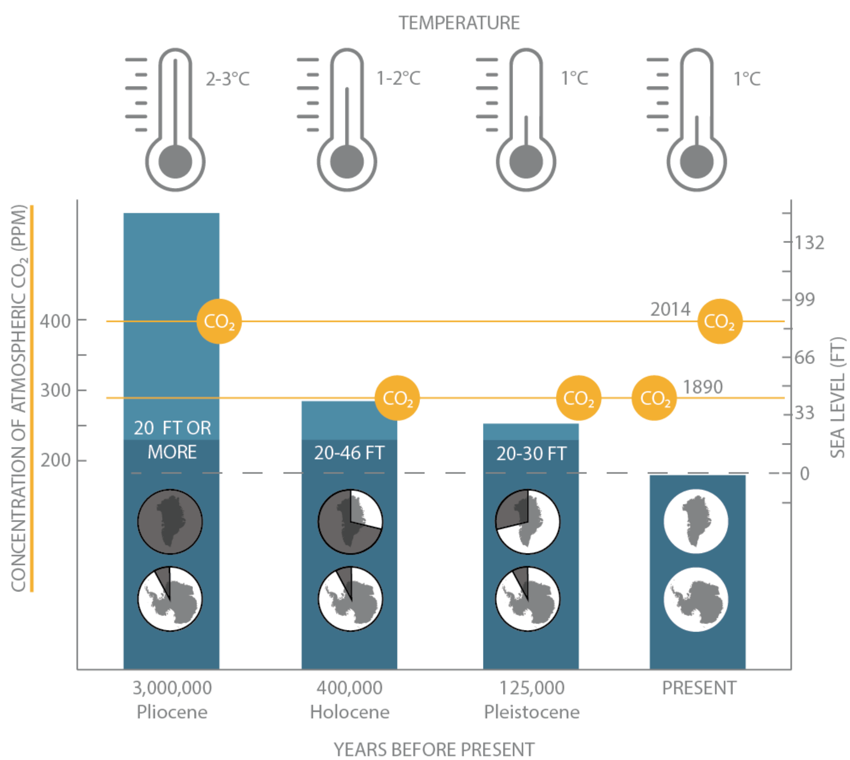

Figure 4 Peak global mean temperature, atmospheric carbon dioxide, maximum global mean sea level (GMSL), and source(s) of meltwater

Source: diagram courtesy of Dr. Andrea Dutton, "Sea-Level Rise Due to Polar Ice-Sheet Mass Loss during Past Warm Periods."

[12] Dutton, A., A. E. Carlson, A. J. Long, G. A. Milne, P. U. Clark, R. DeConto, B. P. Horton, S. Rahmstorf, and M. E. Raymo. "Sea-Level Rise Due to Polar Ice-Sheet Mass Loss during Past Warm Periods." *Science*, no. 349 (2015).

With the concerns of growing atmospheric carbon dioxide, though Antarctica has maintained its integrity for the time being there are still concerns about its longevity. In recent studies of glacial retreat and rebound of the Antarctic continent, climatologist and glacialogist have taken note of the massive continental ice sheet which is about seven times larger than Greenland itself, resting on the edges of a submerged, deep-sea basin. The growing concern is not so much that Antarctica will melt away as one piece—a scenario that would probably take a thousand years to realize—but the concern that the ice shelves supporting the ice sheet will weaken, collapse, plumment into the basin below. [13] This would subsequently trigger a runaway polar ice sheet melt scenario, whereby the polar ice would fragment and melt more rapidly than anticipated.

Under these conditions, the severity and impact to sea level rise has been given considerable catastrophic concern, but how soon those impacts can be experienced has been debated. Presuming that Greenland and Antacrtica will melt at a more regular rate, some conservative estimates have suggested that sea-level rise could achieve 6.5 feet by the year 2100 and 20 feet by 2200.[14] In more severe projections as it relates to the possible runaway conditions of Antarctica, firgures have estimated that it could potentially raise the sea-level upwards to 200 feet.[15]

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[13] Boesch, D.F., W.C. Boicourt, R.I. Cullather, T. Ezer, G.E. Galloway, Jr., Z.P. Johnson, K.H. Kilbourne, M.L. Kirwan, R.E. Kopp, S. Land, M. Li, W. Nardin, C.K. Sommerfield, W.V. Sweet. Sea-level Rise: Projections for Maryland. Cambridge, MD: University of Maryland Center for Environmental Science, 2018. 7

[14] DeConto, RM, Pollard, D. "Contribution of Antarctica to past and future sea-level rise." *Nature*, no. 531 (2016)

[15] National Snow and Ice Data Center. Quick Facts on Ice Sheets. 2019. https://nsidc.org/cryosphere/quickfacts/icesheets.html (accessed October 2019).

With the deterioration of polar glaciers, other secondary side effects on the geologic processes come into consideration. Dissapearance of polar ice sheet mass will weaken the existing gravitational pull on tides towards the poles, and resulting in redistribution of water away from north and south pole thus resulting in higher sea levels then previously predicted.[16] Loss of glaciers and rising water temperatures could destabilze and slow the convective current of the gulf stream,[17] which pulls waters off the Atlantic coast. With reduced gulf stream efficiency by an increasing homogenous warm water temperature, the impact has been projected to contribute an additional average of 0.17 meters (0.55 feet) of sea level rise by the year 2100 in the Mid-Atlantic region.[18] Additionally, with the disapearance of glacial ice sheets and rising sea levels, vertical land movement or subsidence will become another issue. In the Mid-Atlantic region and within the state of Maryland alone, the anticipation of overdrawing of groundwater sources will contribute towards land subsidence in low-lying regions around the Chesapeake Bay. Alarmingly, in locations such as Norfolk, Virginia, where the soil composition is similar throughout the majority of the Delmarva peninnsula, current projections suggest a subsidence of 10 centimeters (0.33 feet) by 2100.[19]

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[16] Boesch, D.F., W.C. Boicourt, R.I. Cullather, T. Ezer, G.E. Galloway, Jr., Z.P. Johnson, K.H. Kilbourne, M.L. Kirwan, R.E. Kopp, S. Land, M. Li, W. Nardin, C.K. Sommerfield, W.V. Sweet. Sea-level Rise: Projections for Maryland. Cambridge, MD: University of Maryland Center for Environmental Science, 2018. 7

[17] Ezer, T., Atkinson, L.P., Corlett, W.B., Blanco, J.L. "Gulf Stream's induced sea level rise and variability along the U.S. mid-Atlantic coast." Journal of Geophysical Research - Oceans, no. 118 (2013): 685-697.

[18] Yin, J., Schlesinger, M.E., Stouffer, R.J. "Model projections of rapid sea-level rise on the northeast coast of the United States." Nature Geoscience, 2009.

[19] Boesch, D.F., W.C. Boicourt, R.I. Cullather, T. Ezer, G.E. Galloway, Jr., Z.P. Johnson, K.H. Kilbourne, M.L. Kirwan, R.E. Kopp, S. Land, M. Li, W. Nardin, C.K. Sommerfield, W.V. Sweet. Sea-level Rise: Projections for Maryland. Cambridge, MD: University of Maryland Center for Environmental Science, 2018. 13

Projections of Sea Level Rise

With all these variables contributing towards increase in climate change and sea level rise, it is important to understand what does this mean and what are the projections for sea level rise, and how soon could it impact us? Observations of sea level rise have been progressively developed upon from observations overtime, and some of the longest records of sea level monitoring stem from eighteenth century Europe, with documentation occurring as early as 1700 C.E. in Amsterdam, 1768 C.E. in Liverpool, and 1774 C.E. in Stockholm.[20] These recordings were made with the assistance of tidal gauges, critical for those communities to better understand tidal fluctuations for maritime trade. The global networking of tidal gauges would expand in the mid-twentieth century, and by the early 1990s tidal monitoring and recording had been expanded upon and supplemented through the use of satellite altimetry. In the past twenty-five years, the combination of tidal-gauge readings and satellite altimetry has broadened the understanding of sea level rise. In the time period from 1993-2018, collective recordings have found that the global mean sea level (GMSL) has rose by 0.084 millimeters per year (0.394 inches per year).[21] At this rate, if sea levels were to continue to rise it is anticipated that the GMSL would be 0.67 meters (2.2 feet) higher than mean sea level height based off the elevation from 2000.[22] However, it is important to note that this method only follows trending patterns in

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[20] Ekman, M. "The world's longest continuous series of sea level observations." (Pure Appl. Geophys), no. 127 (1988): 73-77.
[21] Nerem RS, Beckley BD, Fasullo JT, Hamlington BD, Masters D, Mitchum GT. "Climate-change–driven accelerated sea-level rise." proceedings of the National Academy of Sciences of the United States of America, 2018.
[22] Nerem RS, Beckley BD, Fasullo JT, Hamlington BD, Masters D, Mitchum GT. "Climate-change-driven accelerated sea-level rise detected in the altimeter

sea-level rise and does not account for additional forcing pathways such as increased growing or stabilized levels of greenhouse gases, glacial melt, changing ocean dynamics, or vertical land movement.

To account for the unknown variables in association to projections of future sea level rise, climatologist have expanded projections using Represented Concentration Pathway (RCP) modelling to compile and compare various sea level rise projections. Under this framework, RCP's serve as the benchmarks for climatic conditions that dictates sea level rise, and are categorized into the following scenarios: 1) RCP2.6 which is the low emissions pathway complying with the Paris Agreement's goal of net-zero greenhouse gas emission by or before 2050, 2) RCP4.5 which is the moderate emission pathway that has stabilized emissions but suffers from residual after effects, and 3) RCP8.5 which is worse-case scenario of high-emission pathway based upon continued growth of greenhouse gas emission with little to no means of reduction.[23]

Provided with the uncertainties about controlling the amount of greenhouses emitted into the atmosphere and the accelerated rate of glacial melt to sea level rise, the state of Maryland established the Maryland Commission on Climate Change in 2015 to help better interpret the sea level rise scenarios in the region. Under this commission, sea level projections were inferred by the 2014 Intergovernmental Panel on Climate Change's report. In a recent report issued by the Maryland Commission on Climate Change in 2018, "Sea-Level Rise – Projections for Maryland," the

[23] Horton BP, Kopp RE, Garner AJ, Hay CC, Kahn NS, Roy K, Shaw T. "Mapping sea-level change in time, space, and probability." Annual Review of Environment and Resources, no. 43 (2018): 481-521.

findings suggested that because greenhouse gas emissions have not been reduced, and are still approaching the rate of the growing emissions pathway, Represented Concentration Pathway 8.5. Unless considerable efforts are made and implemented to halt greenhouse emissions, current projections indicate that there is a 66% probability of RCP 8.5 occurring in the future. Based off this emissions pathway, the following sea level projections should be observed with strong consideration:

Sea level rise by the year 2050: 0.1–0.5 meters (0.3–1.6 feet).

Sea level rise by the year 2100: 0.4–2.4 meters (1.3–7.9 feet).

Sea level rise by the year 2150: 0.8–6.0 meters (2.6–19.7 feet).

Sea level rise by the year 2300: 1.0–15.5 meters (3.2–50.8 feet).

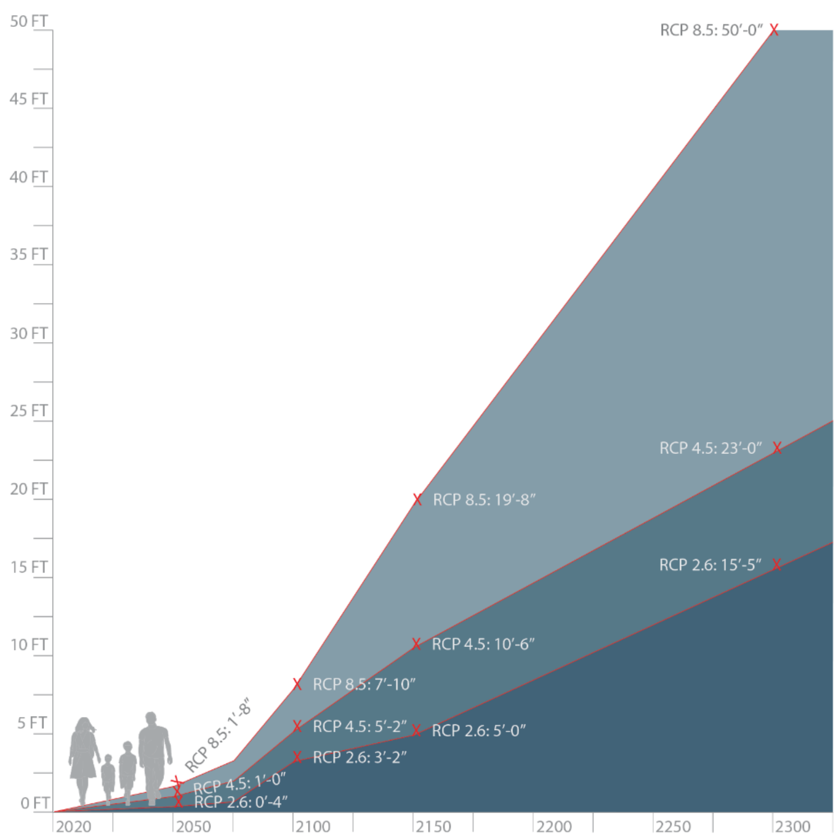

Figure 5 Represented Concentration Pathway Projections

Source: Author

Under this scenario, widening ranges in sea level elevations come into play with the uncertainty of accelerated glacial melt and its impacts on sea level rise.

Figure 6 Progression of Sea Level Rise overtime on the Delmarva Peninsula

Source: Author; data derived from Climate Central, climatecentral.org

Effects of Sea Level Rise Experienced in the Region

Important to the discussion of sea level rise and not secondary to the problem at hand, are the effects associated with rising sea levels. Aside from inundation in low lying areas, rising seas will contribute towards accelerated shoreline erosion, increased storm surge, increased frequency of nuisance flooding, and saltwater intrusion. Of these impacts imposed by sea level rise, storm surge would immediately have the most damaging impact in a shorter period of time. As it has been estimated, just an increase in the global mean sea level by 1 meter (3.2 feet) could result in 5% increase in storm surge elevation near the mouth of the Chesapeake Bay which would be equivalent to 0.05 meters or 0.16 feet, but could be significantly higher at the head of the bay with an estimated 20% increase, equivalent to 0.2 meters or 0.66 feet.[24] Coupled with increasing levels of global atmospheric temperature, it is fair to presume that the frequency and intensity of significant coastal storms--hurricanes, nor'easters, or tropical depression—would impact the Atlantic coast more regularly in the coming years. It is important to consider how future communities and developments develop and implement strategies in these growing hostile conditions.

What does this mean for the future of the Chesapeake Bay

Even if the global mean temperature is stabilized and the amount of greenhouse emissions into the atmosphere is significantly reduced by the end of this

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[24] Zhong, L., M. Li and M.G. Foreman. "Resonance and sea level variability in Chesapeake Bay." Continental Shelf Research, no. 28 (2008): 2565-2573.

century, sea levels will continue to rise for generations to come. Oceans will continue to absorb heat and expand,[25] accelerating the process of glacial melt and sea level rise. Provided that greenhouse gases emissions are still on track with the growing emissions pathway (RCP8.5),[26] it is imperative that strategic planning and response towards sea level rise addresses or—at the very least—acknowledges the end of life cycle driven by rising sea levels, following the current projections benchmarks of global mean sea level for the following years:

Sea level rise by the year 2050:	0.1–0.5 meters (0.3–1.6 feet).
Sea level rise by the year 2100:	0.4–2.4 meters (1.3–7.9 feet).
Sea level rise by the year 2150:	0.8–6.0 meters (2.6–19.7 feet).
Sea level rise by the year 2300:	1.0–15.5 meters (3.2–50.8 feet).

Uncertainties still persist in the timeframe of sea level rise, both for the unknown factors of greenhouse emission concentrations as well as accelerated degradation of polar ice sheets. Having conducted this research, new findings have recently been published suggesting that sea level rise might worse than initially anticipated, finding that previous land elevations were higher than what they were accounted for and that sea level rise might be three times more impactful than initially thought.[27] However, best efforts shall be employed to compensate, mitigate, and reduce the overall impacts of sea level rise in the coming generations.

[25] Boesch, D.F., W.C. Boicourt, R.I. Cullather, T. Ezer, G.E. Galloway, Jr., Z.P. Johnson, K.H. Kilbourne, M.L. Kirwan, R.E. Kopp, S. Land, M. Li, W. Nardin, C.K. Sommerfield, W.V. Sweet. Sea-level Rise: Projections for Maryland. Cambridge, MD: University of Maryland Center for Environmental Science, 2018.
[26] Ibid. 23
[27] Editorial Board. "Opinion | Rising Seas Are a Much Bigger Danger than Experts Thought." *Washington Times.* October 2019.

Anticipating the Worst

Under these projected conditions, it is best to presume the worse-case scenario for this condition and plan accordingly. In the previous chapter, Chapter 1 – The Chesapeake Bay as A Home - it was outlined that of the population of residents in the Chesapeake watershed region was on the projected path of growing towards a population of 22.5 million people by 2050. Of those, approximately 694,000 people will reside on the Delmarva Peninsula. Following the trends of the Represented Concentration Pathway 8.5, the following trends can be observed for residents in the state of Maryland living within near proximity to the Chesapeake Bay. In the worst-case scenario of sea level rise achieving an increased height of 2 feet by 2050, a total of 14,965 people living around the Chesapeake Bay and Atlantic Ocean will be negatively impacted by inundation.[28]

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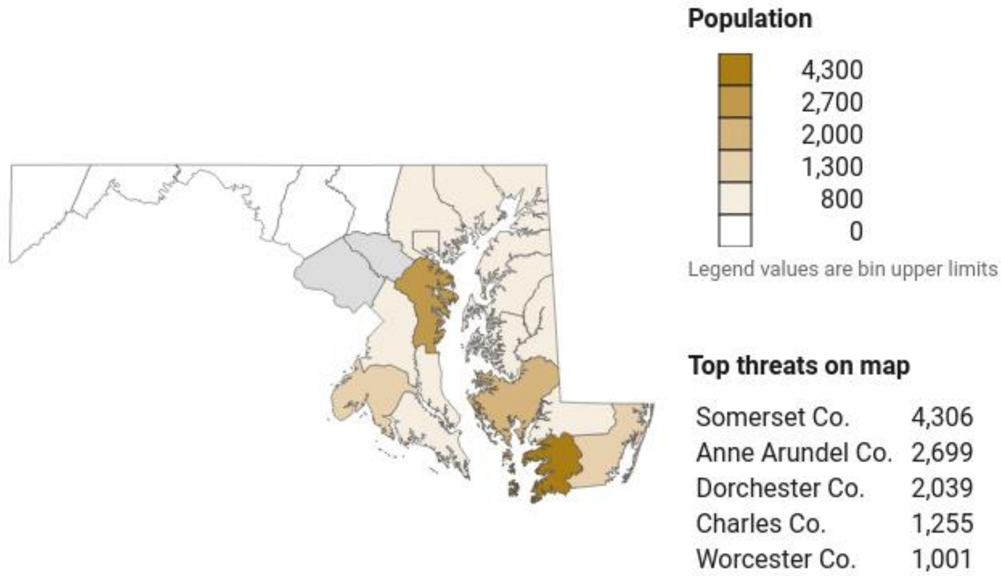

Figure 7: Total Population below 2 FT in Maryland by County

Source: diagram courtesy by Climate Central, climatecentral.org; Surging Seas Risk Finder

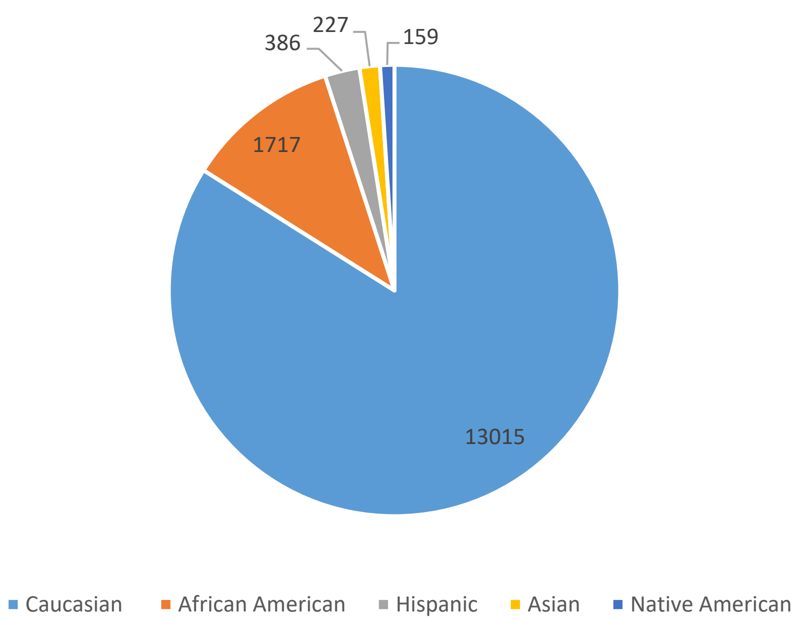

Figure 8 - Demographic Distribution of Residents in Maryland Impacted by Sea Level Rise by 2050 – Population by Ethnicity

Source: diagram courtesy by Climate Central, climatecentral.org; Surging Seas Risk Finder

Of the nearly 15,000 anticipated impacted residents in the Chesapeake watershed by 2050, about 9,561 homes will be damaged or lost to flooding or sea level rise, estimating a total of $4.4 billion dollars in property damage and approximately 190 square miles of land will be inundated.[29] The greater concentration of property loss and damage will occur along the coastal shoreline of the Delmarva peninsula during this time period, with greater impact on the lower southeast counties with Dorchester, Somerset, and Worcester counties bearing the greatest impact of immediate sea level rise.

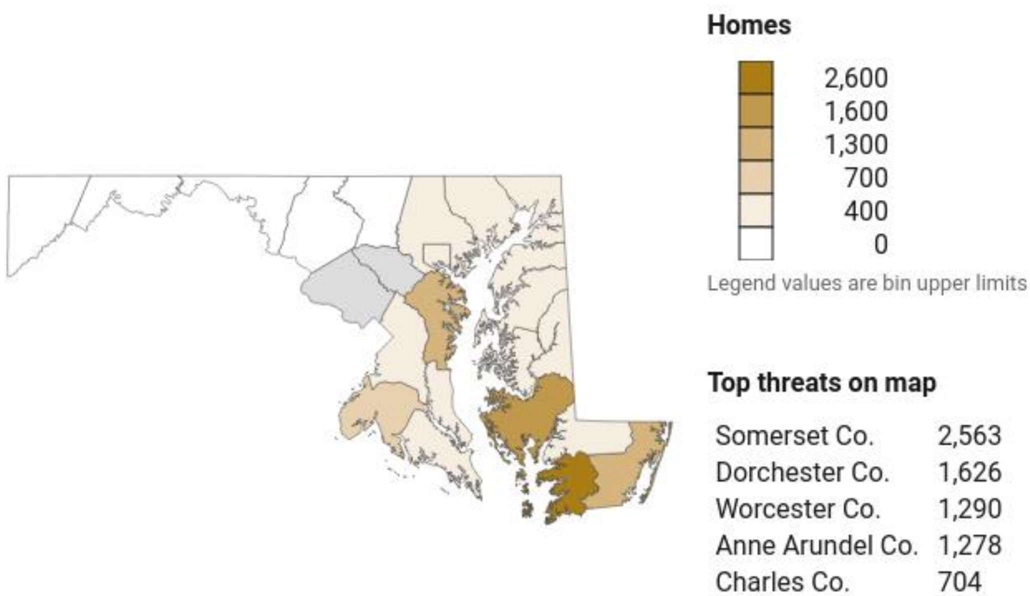

Figure 9 Total Buildings below 2 FT in Maryland by County

Source: diagram courtesy by Climate Central, climatecentral.org; Surging Seas Risk Finder

[29] Climate Central. *See Your Local Sea Level and Coastal Flood Risk.* 2019.

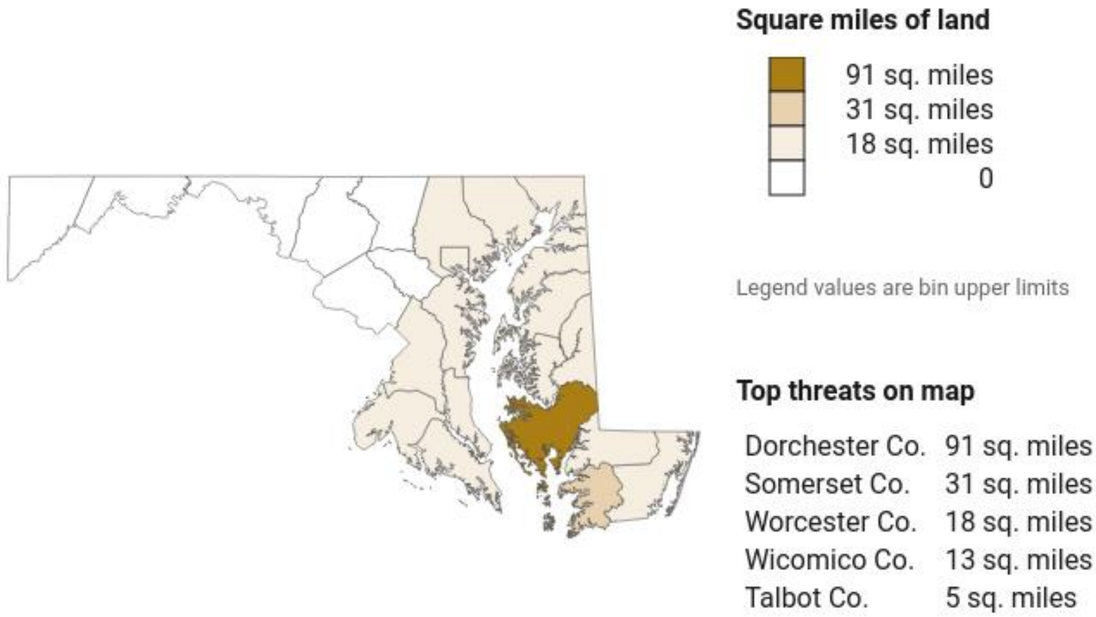

Figure 10 Total Land below 2 FT in Maryland by County

Source: diagram courtesy by Climate Central, climatecentral.org; Surging Seas Risk Finder

Beyond 2050 and into 2100, it is anticipated that under the worse-case scenario of the Represented Concentration Pathway 8.5, that sea level rise will approach an elevation of 8 feet higher than current mean sea level conditions. Under these conditions, it is estimated that the number of impacted Maryland residents will reach and exceed 110,000 people. Under these conditions a considerable amount of sea level rise will be felt along the shoreline of the western bank of the Chesapeake Bay, but will ultimately continue to plague the Delmarva Peninsula.

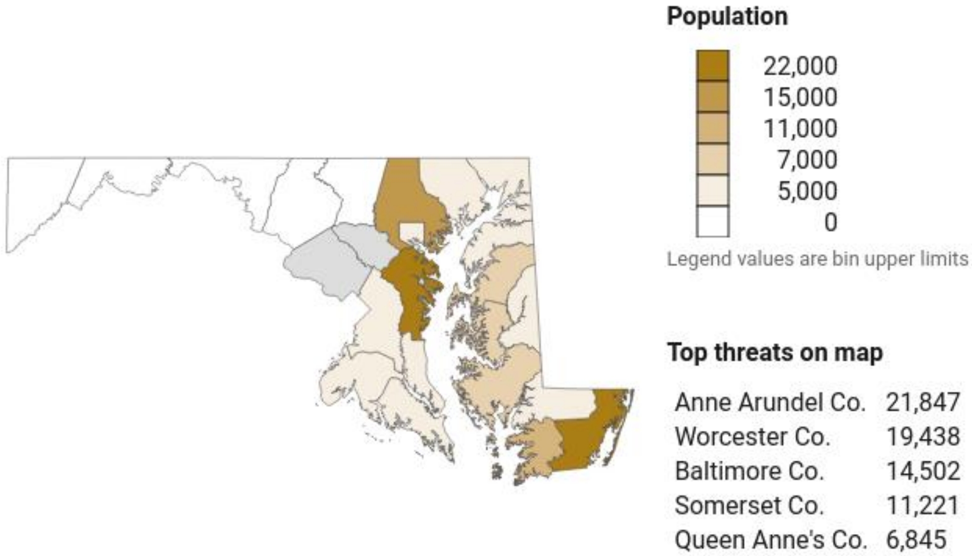

Figure 11 Total Population below 8 FT in Maryland by County

Source: diagram courtesy by Climate Central, climatecentral.org; Surging Seas Risk Finder

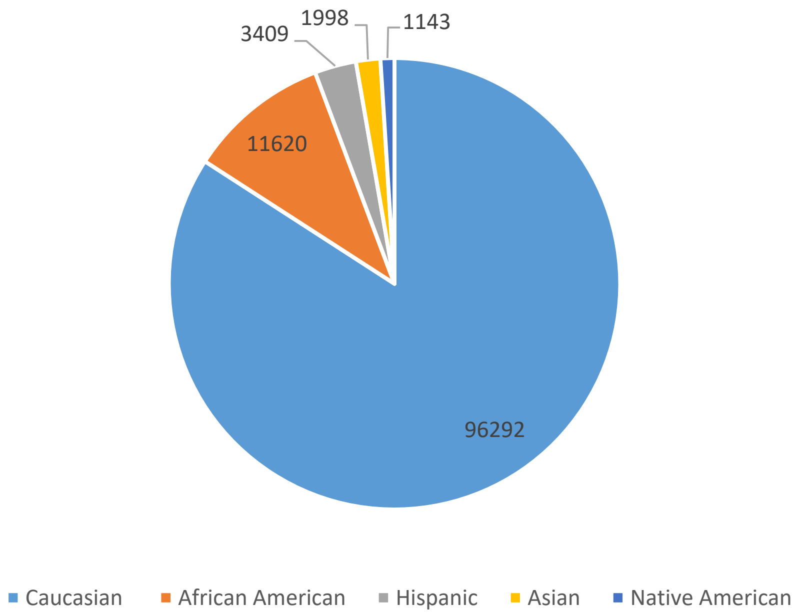

Figure 12 Demographic Distribution of Maryland Residents Impacted by Sea Level Rise by 2100 – Population by Ethnicity

Source: diagram courtesy by Climate Central, climatecentral.org; Surging Seas Risk Finder

Of the nearly 110,000 anticipated impacted residents in the Chesapeake watershed by 2100, an estimated total of 81,163 homes will be damaged or lost due to flooding or sea level rise, with an estimated $37.1 billion dollars in property damage and a loss of approximately 630 square miles of land.[30] The greatest concentration of property loss and damage will occur along the coastal shoreline with the greatest impact experienced in Worcester county bordering the Atlantic Ocean. Despite Worcester County enduring the brunt of property damage, attributed to the loss of oceanfront property in Ocean City, MD, the greatest amount of land loss to be expected from this region will occur in Dorchester County.

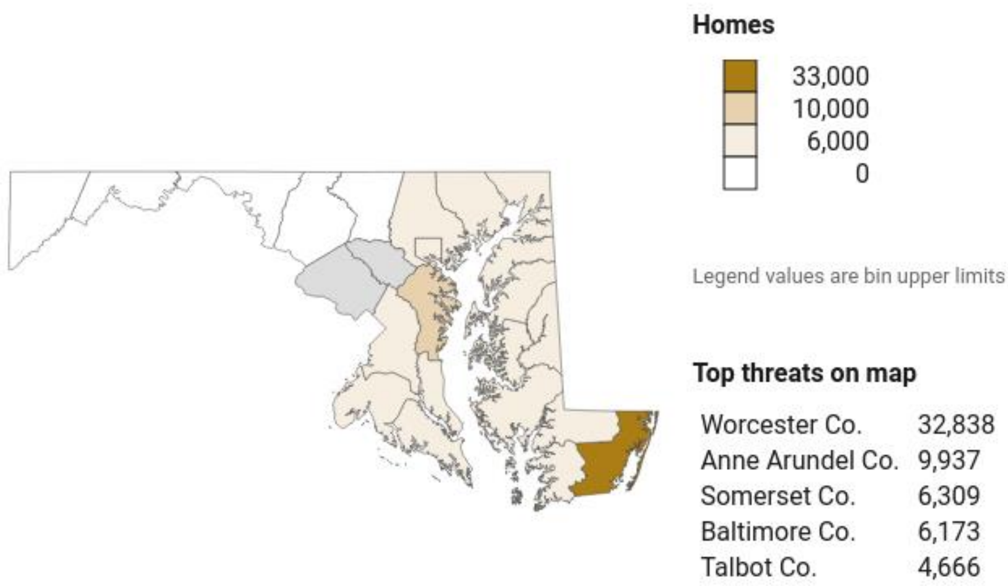

Figure 13 Total Buildings below 2 FT in Maryland by County

Source: diagram courtesy by Climate Central, climatecentral.org; Surging Seas Risk Finder

[30] Climate Central. *See Your Local Sea Level and Coastal Flood Risk.* 2019.

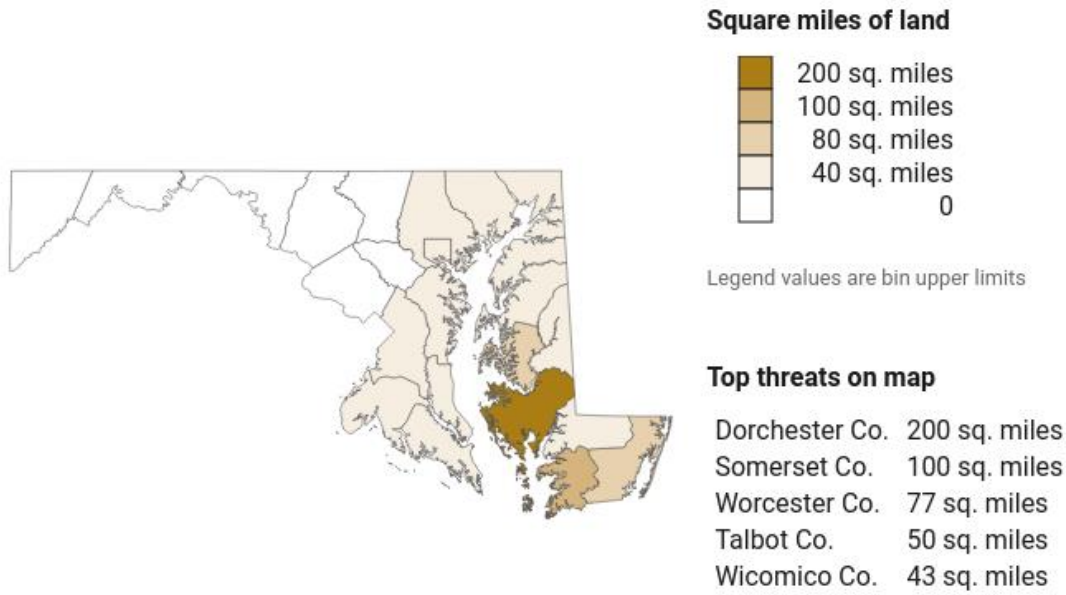

Figure 14 Total Land below 2 FT in Maryland by County

Source: diagram courtesy by Climate Central, climatecentral.org; Surging Seas Risk Finder

—End of Chapter—

Chapter 3: The Human Aspect, Influence of Culture and Beliefs

One of the greatest challenges for communities responding to sea level rise, will derive from how residents of susceptible communities will rationalize decisions towards the environment based on belief and values. This chapter will evaluate the beliefs and values of stakeholders in the Chesapeake watershed, assess how to bring these members to a common ground for discussion about what is the appropriate response, and shed light on the probable outcome as reflected in recent responses to sea level impact felt regionally and locally.

Accommodating the Human Need and Interest

When engaging local communities, residents, and stakeholders about the significance and impact of sea level rise it is important to understand and appreciate the values held by all members of the community. Anthropologist, Dr. Michael Paolisso's work on the complex societal interactions and values of different social groups in the Chesapeake watershed, will be illuminated to gain insight into the delicate relationship of community members on the Eastern Shore.

Considering the broad range of human interaction and beliefs held throughout communities along the Chesapeake Bay, it is important to note that the common element which connects all stakeholders is the idea of the bay. Which as Paolisso has come to identify through his experience has been the idea that people are connected to a sense of environmentalism derived from the uniqueness and natural beauty of the Chesapeake Bay, that has developed and been reinforced through historical, economic, and cultural connections to this region.[31] With this connection to the region, stakeholders have been compartmentalized into the general groups as environmentalists, scientists, resource managers, and harvesters (farmers and watermen). Each group has their own perception of the bay and how the ecology of the bay should be utilized as well as protected, and this perception ranges from returning the bay to a pristine condition untouched by human interaction to an outlook that view the bay as a resource to support their livelihood.[32] With the varied outlooks and perspectives towards the watershed, it is important note how these groups of people view themselves as "stewards, guardians, and / or protectors" of the Bay.[33] It is through this self-identification and relation that one has with the ecology of the bay, which drives the interests, conflicts, and connections of these social groups to uniqueness of the environmental conditions of the Chesapeake Bay watershed.

With these strong and deep-rooted feelings of attachment to the bay, the conversation of what next for the bay has been obstructed by strong opinions and feelings for this region. As underscored by Dr. Paolisso's work, the explicit or implied linkage to place – community, location, or region bounded geographically – and by a perceived limit in space and time, practice, beliefs, and values, has set the parameters for how stakeholders perceive the region of the Chesapeake Bay.[34] In doing so, the idea of place has limited the understanding on how beliefs, values, and

[31] Paolisso, Michael Jeffrey. *Chesapeake Environmentalism : Rethinking Culture to Strengthen Restoration and Resource Management. Chesapeake Perspectives.* College Park, MD: Maryland Sea Grant, 2006. Paragraph 10
[32] Ibid. Paragraph 6
[33] Ibid. Paragraph 9
[34] Ibid. Paragraph 23

practices are exchanged across social groups, prioritized the documentation of disappearing rural communities, culture as a static entity, and the perception of cultures as objects in space and time.[35]

Regional Response

When considering how local communities will respond to the challenges of sea level rise and how those communities will make informed decisions about the quality of life they wish to have, it is important to look at how other communities in the region are handling the issues of sea level rise. Of recent occurrence is the displacement of nearly 1,000 inhabitants from Ocracoke Island, North Carolina, where Hurricane Dorian—reduced to a category 1 hurricane by landfall—drove a wall of storm surge nearly seven feet tall island. In its aftermath, the community is faced with the dilemma of what to do next? Raised immediately in the report by the Washington Post, “Amid Flooding and Rising Sea Levels, Residents of One Barrier Island Wonder If It’s Time to Retreat,” local residents are faced with the dire question: can this island—with and elevation of 3 feet—survive future threats of sea level rise and extreme weather, and if not then why rebuild? [36] In the article by The Washington Post, author Frances Sellers outlines the different perspectives from stakeholders throughout the community:

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[35] Paolisso, Michael Jeffrey. *Chesapeake Environmentalism : Rethinking Culture to Strengthen Restoration and Resource Management. Chesapeake Perspectives.* College Park, MD: Maryland Sea Grant, 2006. Paragraph 24

[36] Seller, Frances. "Amid Flooding and Rising Sea Levels, Residents of One Barrier Island Wonder If It's Time to Retreat." *The Washington post.* November 11, 2019.

- Patricia Piland, middle school teacher: believes that [Ocracoke] can plan for sea level rise but doing so will require working with nature rather than human forces.
- Tom Pahl, county commissioner: Uncertain of the timeline left of the island and how soon sea level rise will claim it, and believes the best course of action is resiliency then retreat.
- Janet Spencer, hardware store owner: admits that long-term residents will hold out because it is the only thing they know, and is their way of life.

These documented responses to a natural disaster imposed by Hurricane Dorian, reflect the various beliefs and hopes that these community members hold and represents the future uncertainty for other communities around the region and globe. Yet, in spite of the beliefs and hopes that residents hold in preserving a community, as Tom Pahl began to infer about the uncertainty of the timeline, there will reach a point where the severity of sea level rise will outweigh the feasibility of continuing living in vulnerable locations. Already impacting this community has been the Federal Emergency Management Agency's response to deny residents individual assistance. Though FEMA's decision hinged on the assessment of the state as a whole to rectify this incident since strained resources were limited to an isolated area. However, as professor for the Study of Developed Shorelines at Western Carolina University, Rob Young, suggests that the lack of clarity on the nation's policies for shoreline protection or threshold of when the public sector will not be able to or want to afford the risk of investing resources into the these vulnerable communities has raised concerns about the futures of these locations.[37] Raising the question about what is the best course of action and preparation for communities living in vulnerable regions.

Local Response

In a similar occurrence to Ocracoke, the University of Maryland has been working with the residents of Deal Island, Maryland, under the Deal Island Peninsula Project. This project spearheaded by Dr. Michael Paolisso, seeks to bring together local community members in open conversation with one another about how to respond to sea level rise to express their beliefs and views on the matter.[38] From the study, many residents have expressed views that they do not wish to leave, they do not want the government to tell them when to leave, and that they want to maintain their way of life for as long as possible.[39] With this comes the realization that most of the residents tend to live an independent lifestyle and are typically more self-sufficient, and coercion into communal and group efforts will become a challenge in the coming decades.

—End of Chapter—

[37] Seller, Frances. "Amid Flooding and Rising Sea Levels, Residents of One Barrier Island Wonder If It's Time to Retreat." *The Washington post.* November 11, 2019.
[38] Ortiz, Erik. "How to Save a Sinking Island." NBCNews.com. November 13, 2017. Accessed November 15, 2019.
[39] Ibid.

Chapter 4: Chesapeake Bay – A Pattern of Settlement

“The longer you can look back, the farther you can look forward.”[40]

-Winston Churchill, March 1944

Responding to the issues of climate change and sea level rise is not an unprecedented issue, as historic communities have dealt with similar circumstances. However, what has changed has been human attachment and investment to place, resulting in susceptible communities to climate change. To better understand how communities can respond to climate change in the region, it is important to look into settlements of the past to help predict the settlements of the future.

Patterns of Settlement

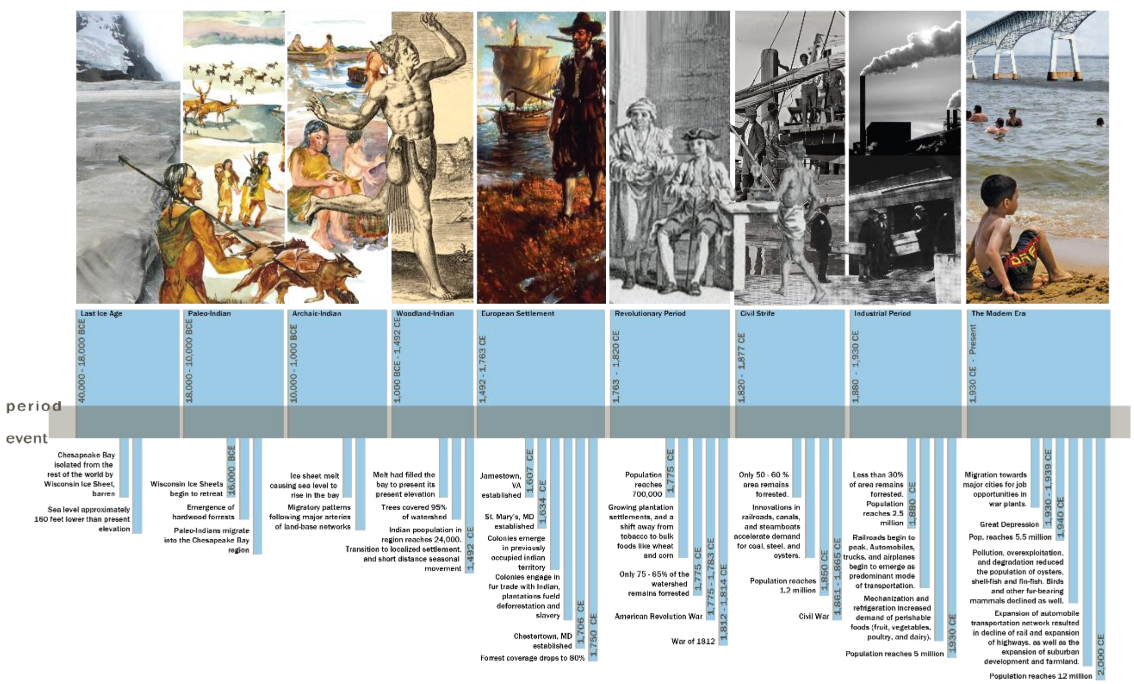

Figure 15 : Timeline of the Chesapeake Bay

Source: Author

[40] Ratcliffe, Susan. Oxford Essential Quotations. Oxford: Oxford University Press, 2016.

The history of the Chesapeake Bay watershed predates European exploration and settlement, and extends as far back as the last ice age before the first known contact of the human settlers arrives to this region. Following the last ice age which ended around 20,000 years ago, the landscape of the Chesapeake watershed was far different from current conditions. Water that presently fills the bay was land-locked and frozen in glaciers, keeping the elevation of sea level substantially lower than present levels. In comparison, the sea level was approximately 160 feet lower than the current mean sea level.[41] Under these conditions, the Chesapeake Bay did not exist and the only resemblance to the bay was the ancient Susquehanna River. This region, landlocked and exposed by the Wisconsin ice-sheets,[42] would later become a vegetated oasis but was largely barren during this period.

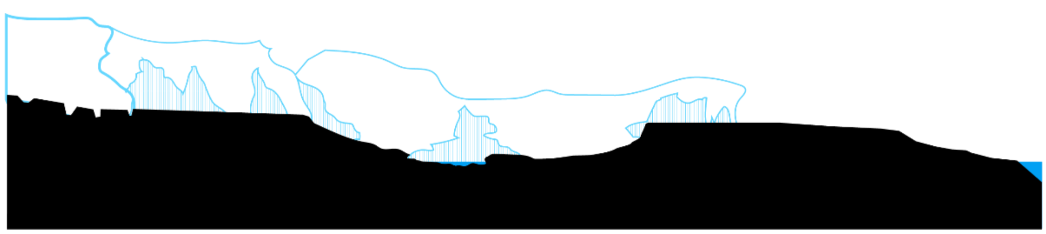

Figure 16 : Section through the Chesapeake Bay – The Last Ice Age (40,000 BCE – 18,000 BCE)

Source: Author

[41] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000.
[42] Ibid. 19

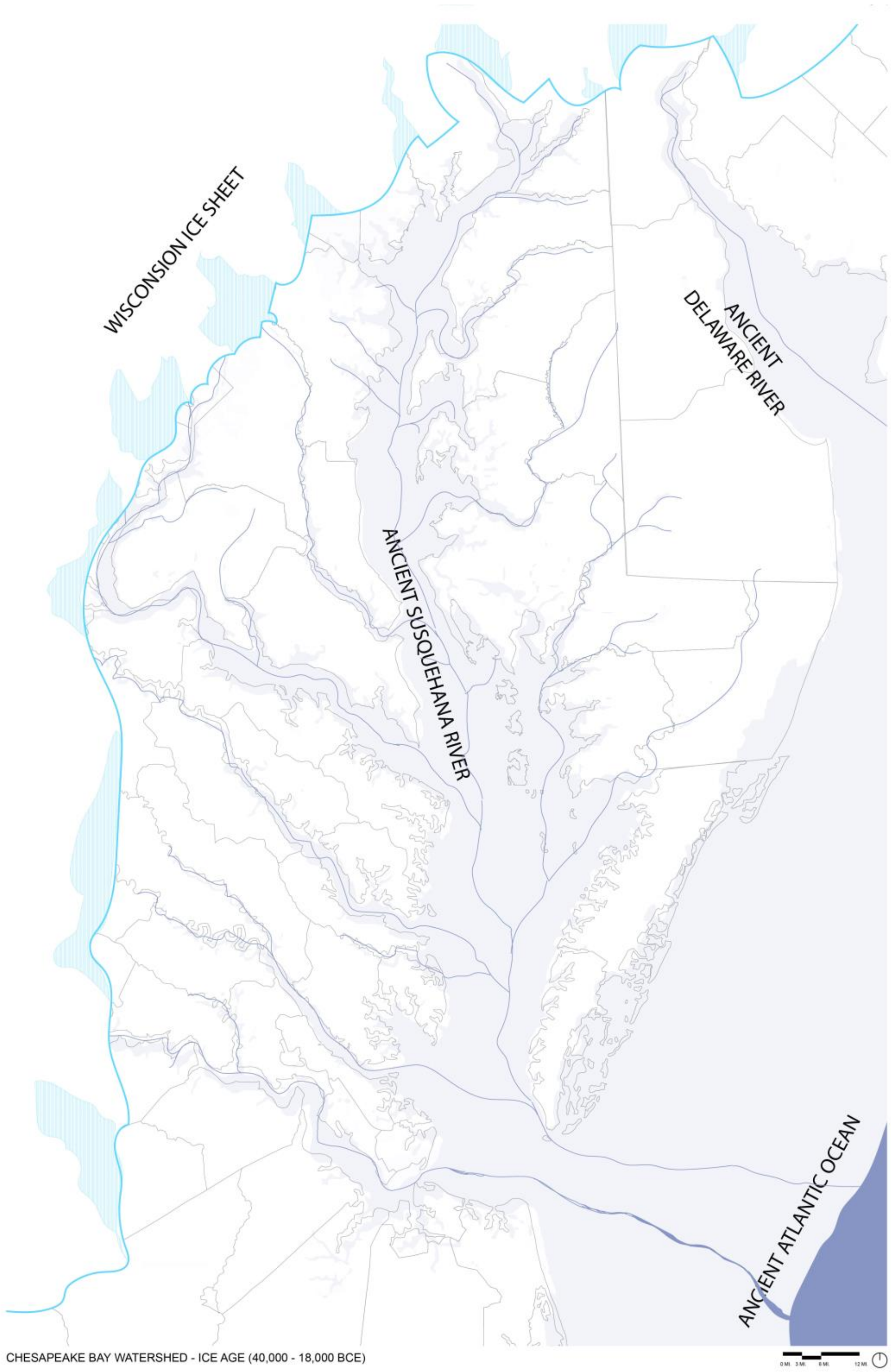

Figure 17 : Patterns of Settlement in the Chesapeake Bay - The Last Ice Age (40,000 BCE – 18,000 BCE)

Source: Author

Around 18,000-15,000 BCE as the Wisconsin ice-sheets began to retreat, water from glacial melt began to fill the watershed turning a once desolate landscape into an oasis of streams, grasslands, and forests. As the region became vegetated, colonies of white-tailed deer, black bear, turkey, and other species of wildlife migrated into the region, and shortly thereafter Paleo-Indians migrated through newly formed passageways carved by glacial melt in pursuit of resources. These Paleo-Indians are considered the first indigenous people to the region, and thrived from 18,000-9,000 BCE. Little is known about Paleo-Indian settlements, but what archaeologists can infer from deposits of scrap rock and broken Clovis-point tools indicates that Paleo-Indians were largely nomadic. They would establish temporary camps to harvest local resources, and once those resources were exhausted Paleo-Indians would abandon the camp and move to the next site with abundant resources.[43] Of the identified Paleo-Indian sites, most have been found strategically situated on flat, open, and elevated areas that would offered commanding views of the surrounding terrain and typically within close proximity to reliable sources of water and resources—particularly stone—if and when available.[44] In the case of settlement along the Delmarva peninsula, the absence of vast lithic resources—the dominant Paleo-Indian tool resource—resulted in the theory of elliptical migration patterns around the peninsula. Given the scale of this journey, completion of a full loop would not feasible within a regularly daily interval, and it is suggested that temporary camps were established to facilitate migration of Paleo-Indians. Following the distribution of

[43] "History & Culture." National Parks Service. Accessed November 14, 2019.
[44] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 23

Paleo-Indian sites littering the peninsula, this theory suggests a pattern migration where indigenous people would travel north to harvest lithic materials used for their tools. Returning from this quarry, the native populations would traverse along the Delaware River wetlands before trekking along the Pocomoke, Wicomico, or Nanticoke River sheds before reaching the drainage basin at the mouths of these rivers. Along the way, they would harvest the invaluable food resources before reaching Paw Paw Cove, speculated hub for most Paleo-Indian populations in the area.[45]

Figure 18 Section through the Chesapeake Bay – Paleolithic Indians (18,000 BCE – 10,000 BCE)

Source: Author

[45] Lowery, Darrin. "The Paw Paw Cove Paleoindian Site Complex, Talbot County, Maryland." *Archaeology of Eastern North America, Vol. 17* , 1989: Eastern States Archeological Federation. 161

Figure 19 : Patterns of Settlement in the Chesapeake Bay – Paleo-Indian (18,000 BCE – 10,000 BCE)

Source: Author

Around the time of 10,000 – 1,000 BCE, as the glacial ice sheets continued to melt and rivers feeding into the ancient Susquehanna River (now the present day Chesapeake Bay) began to rise and widen, the Paleo-Indians transitioned into Archaic-Indians. As the water rose, former migratory pathways trekked by Paleo-Indians became inundated and obstructed by larger bodies of water, and the overly exhausted lithic resources in northern Delaware impeded traditional migratory patterns. Submersion of former routes did not impede the Archaic-Indians. Instead, archeological findings suggest that the Native-Indians of this time were part of an elaborate trade network throughout the American continent. Evidence of pottery, adzes, and banner stones—items not indigenous to the region—suggests trade occurred with other Archaic-Indians to the south and west, and as far south as Mexico.[46] Provided by the presence of adzes and concentration of camps near bodies of water, Archaic-Indians transferred towards maritime network, utilizing adzes to fashion canoes and tributaries as major transportation corridors. Unfortunately, similar to the Paleo-Indian populations, it is believed that more Archaic-Indians sites exist but have been lost to rising sea level and human development.

Figure 20; Section through the Chesapeake Bay – Archaic Indians (10,000 BCE – 1,000 BCE)

Source: Author

[46] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 37

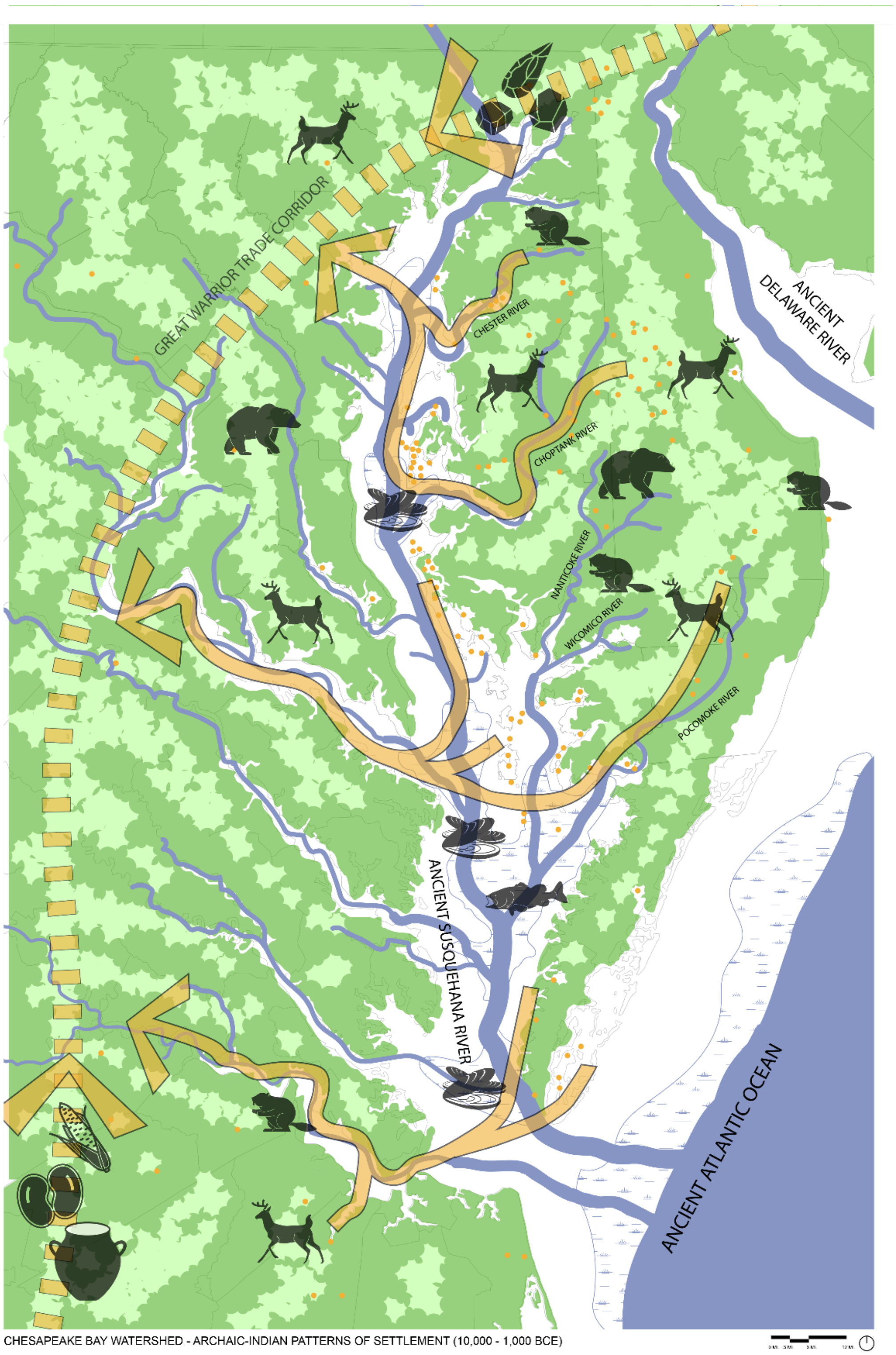

Figure 21: Patterns of Settlement in the Chesapeake Bay – Archaic-Indian (10,000 BCE – 1,000 BCE)

Source: Author

Around 1,000 BCE, Woodland Indians would supplant Archaic-Indians, and continue to flourish in the region beyond 1,492 CE. By 1,000 BCE, land-based ice sheets had nearly disappeared, and the volume of glacial melt increased sea levels to present elevations. The abundance of water increased soil fertility, and forest coverage expanded to account for nearly 95% of the land use.[47] In a vast sea of woodlands, Woodland Indians carved out communities from small clearings, and shifted away from nomadic lifestyles to domestic settlements. As these communities grew, the demand for more cultivated resources such as squash, beans, tobacco, and corn required more farmland. Razing forests was the most efficient method for creating arable land, however, Woodland Indians would discover that their villages were temporary as the average duration for each town would last for ten to twenty years before natural resources were exhausted.[48] To offset this, tribes developed a practice of burning fields to return nutrients to the soils, but this would only extend effectiveness for two to three years.[49] Under these conditions, tribes developed a pattern of living lightly on the land,[50] migrating between seasonal camps established along a tributary corridor to minimize over exhaustion of natural resources.

Figure 22 : Section through the Chesapeake Bay – Woodland Indians (1,000 BCE – 1,492 CE)

Source: Author

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[47] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 64
[48] National Parks Service. *History.* August 1, 2019.
[49] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 44
[50] National Parks Service. *History.* August 1, 2019.

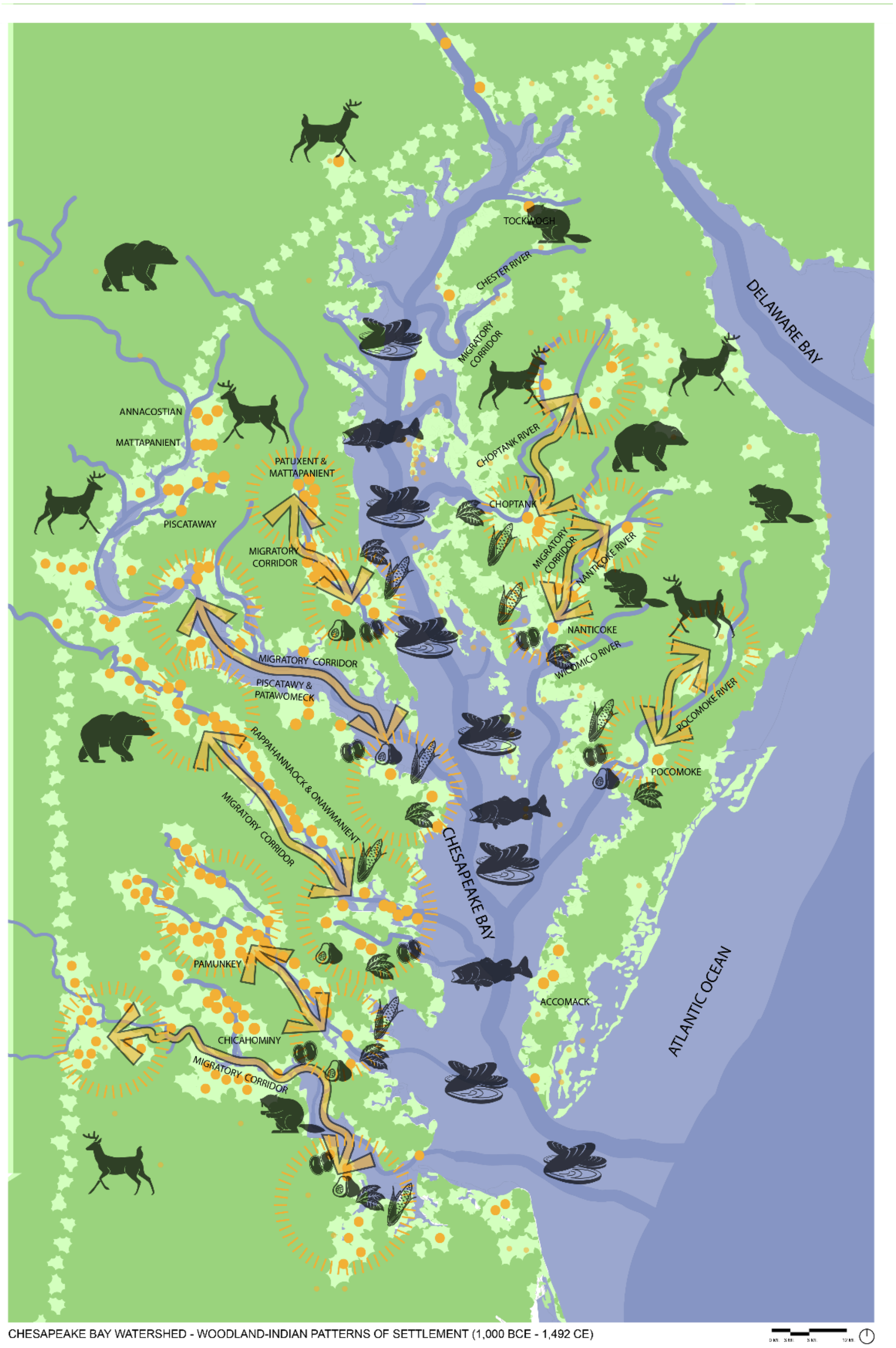

Figure 23 Patterns of Settlement in the Chesapeake Bay – Woodland-Indian (1,000 BCE – 1,492 CE)

Source: Author

From 1,492 - 1,763 CE the advent of European exploration saw the establishment of European colonies throughout the Chesapeake Region, signaling the decline in Native Indian populations and environmental conditions. The first permanent English colony of Jamestown, Virginia, was settled in 1607 by the Virginia Company of London, whose ultimate motivation for the "Bay of Chespioc" expedition was the exploitation of gold, silver, and passage through North American to the Far East.[51] Though this colony would not succeed in finding luxuries of gold and silver, its pattern of manipulating and exploiting the land would persist into other colonial settlements throughout the region. From initial contact with settlers, Native Indian populations declined from an estimated 24,000 inhabitants to less than 2,400 between 1,500 – 1,650 CE, a 90% population reduction.[52] In the absence of former Native Indian communities, European colonists established their own settlements, homesteads, and plantations in lots and clearings once occupied by the Native Indians. These sites were prime for European settlement, as the cleared land facilitated quick building development and cultivation of farmland for newly arriving settlers. Similarly, the concentration of these sites along navigable tributaries enabled colonist quick access to settlements by boat,[53] the primary mode of transportation through where dense vegetation would impede land routes, otherwise. It is important to note that during this period in time, a singular land-based route was established from present Rock Hall, MD, through Chestertown, MD, and north towards

[51] National Parks Service. *History.* August 1, 2019.
[52] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project,* 2000. 66
[53] Ibid. 57

Philadelphia, PA, to connect the tidewater colonies of the Chesapeake Bay with New England, which was faster than navigating around the Delmarva Peninsula.

As European colonies grew, external factors such as the transatlantic trade would impose increasing demand for colonial exports—in particular tobacco—and would require larger tracts of arable land to maximize productivity. Keeping up with economic demands, colonists began clearing larger tracts of land to make more room for farmland, and it is estimated that forest coverage dropped from pre-1500 estimates of 95% coverage in the Chesapeake Bay watershed, to an estimated 65-75% coverage by 1750.[54] As forested area dwindled, destabilized sediment and runoff began to clog harbors and rivers to the point of becoming unnavigable. Consequently, colonists would abandon former settlements, relocate, and repeat the process elsewhere. However, the clearing of forested land was not the only casualty during the period of colonial settlement. In order to keep up with production, populations of Africans were enslaved, shipped, and sold to the American colonies as a commodity. By 1700, it is estimated 40% of the colonial population consisted of enslaved Africans, and that half of the region's workforce was comprised of slaves.[55]

Figure 24: Section through the Chesapeake Bay – European Settlement (1,492 CE – 1,763 CE)

Source: Author

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[54] "History." Chesapeake Bay Program. Accessed November 14, 2019.
[55] Ibid.

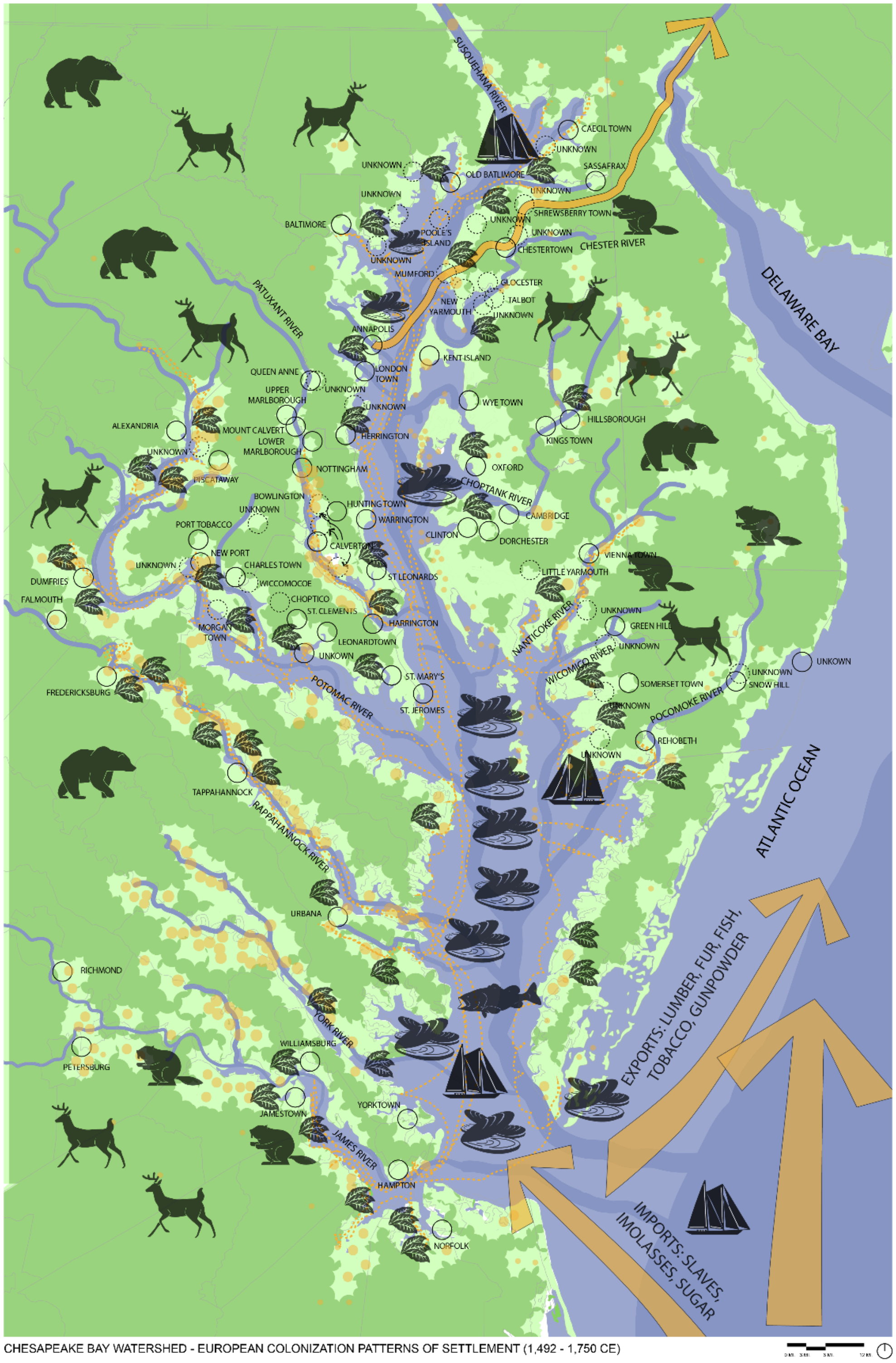

Figure 25 Patterns of Settlement in the Chesapeake Bay – Woodland-Indian (1,000 CE – 1,492 CE)

Source: Author

Following the Treaty of Paris which ended the Seven Years' War and French and Indian War in 1763, the American Colonies in the Chesapeake watershed would transition into the Revolutionary Period spanning between 1763 and roughly 1820 CE. Settlement growth would concentrate in established cities such as Annapolis, Baltimore, Norfolk, and Chestertown, reaching a regional population of 700,000 people by 1775.[56] As agricultural persisted to be the primary resource in the region, the practice of clearing woodlands for farmland continued and the timber harvested would supply the growing shipbuilding industry.[57] Maintaining economic demands, plantations grew into large businesses that would require more land and slaves, and with larger volumes of agricultural production soils would be exhausted much faster. To mitigate soil exhaustion, primary crops such as tobacco would be replaced by less exhaustive bulk food crops such as corn or wheat,[58] and as a result, Chestertown would emerge as the largest wheat and shipping port along the Delmarva Peninsula.[59]

Figure 26: Section through the Chesapeake Bay – Revolutionary Period (1,763 CE – 1,820 CE)

Source: Author

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[56] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 85
[57] National Parks Service. *History.* August 1, 2019.
[58] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 82
[59] Ibid. 85

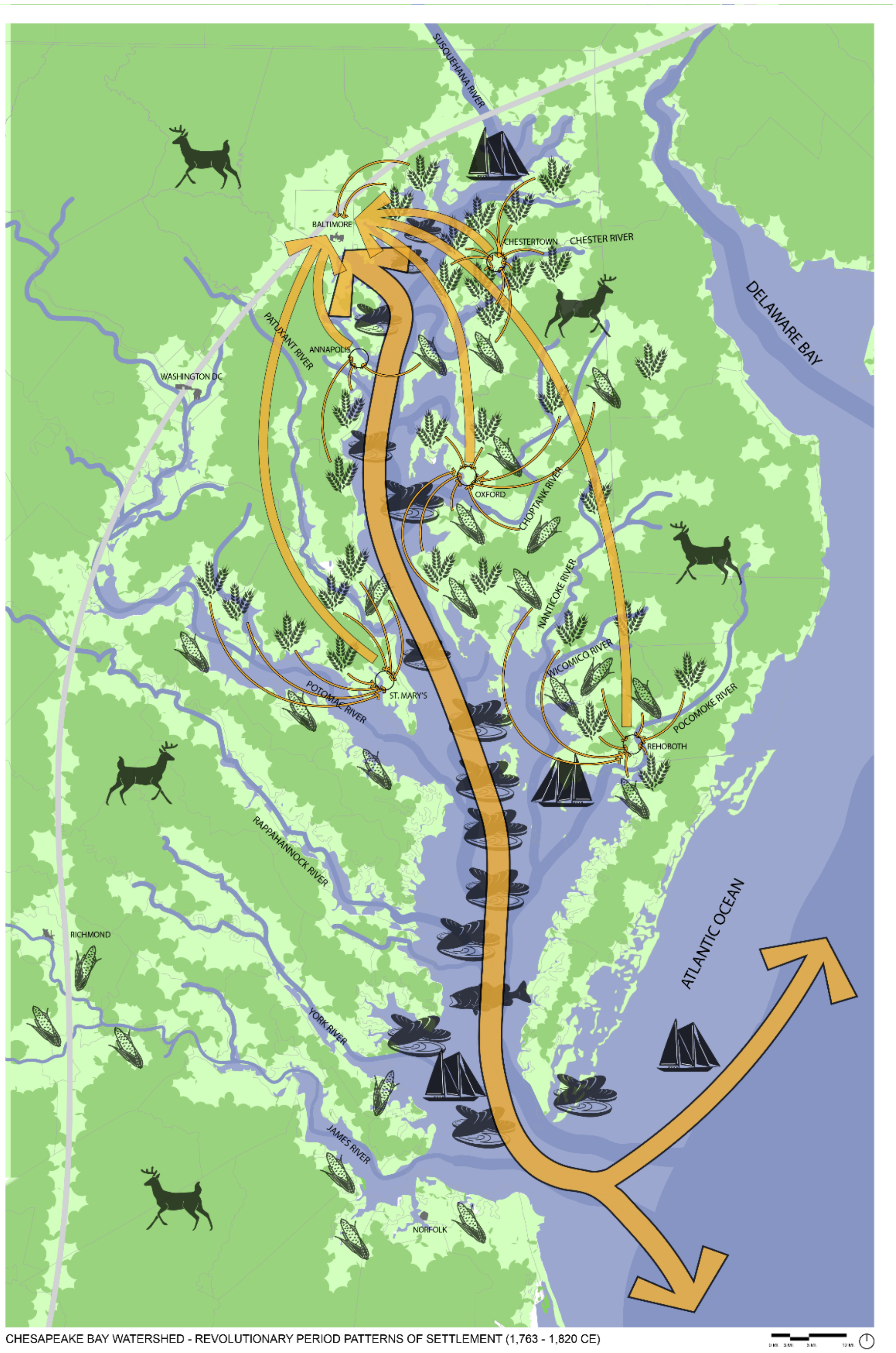

Figure 27 Patterns of Settlement in the Chesapeake Bay – Revolutionary Period (1,763 CE – 1,820 CE)

Source: Author

The conclusion to the War of 1,812 signaled the transition towards the period of Civil Strife from 1,820 to 1,877 CE. Emerging out of this conflict, successive waves of European immigration, emerging industrialization, and urban consolidation saw explosive population growth in the region. By 1,820, the regional population had nearly doubled to 1.3 million people from the initial 700,000 people as estimated in 1,775,[60] and those Baltimore accounted for nearly 62,000 people making it the third largest city in the nation at the time.[61] With this growth, Baltimore emerged as the regions' principal maritime port, eclipsing all rival ports like Chestertown and served as the hub for Maryland, Virginia, and potions of Pennsylvania feeding into the Susquehanna Valley. Fueling Baltimore's growth, the once heavily forested region had been reduced to 40 – 50 % coverage in the region,[62] for the use of building construction timber, heat, and provision of additional farmland. With growing deforestation, land routes became more accessible and the emergence of locomotive transportation solidified Baltimore's dominance of both land and water in the region. Despite the emergence of railroads, water was still relied upon for economic transportation of goods, and the development of steamboats helped facilitate faster water-based transportation. Chestertown still operated as the regional port for Kent, Queen Anne's, and portions of Cecil County during this period of time, however, the absence of railroad connection to Chestertown until the late 1800's would stifle progress, growth, and industrial development during this period in time.

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[60] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 85
[61] Ibid. 82
[62] Ibid. 103

Leading up to the Civil War from 1,861 to 1,865 CE, the dominant plantation model of the Chesapeake watershed resulted in strife in the region. The prohibition of overseas slave imports fueled the market for internal slave trade, and plantations exploited slaves like livestock at auctions.[63] Tension mounted between plantation owners and abolitionists, and in communities like Chestertown Frederick G. Usilton, owner and editor of *Kent News,* recounts "[that] before the actual breaking out of the Civil War, and when our noble commonwealth was in the throes of uncertainty as to whether her fortunes would be cast with the South or with the Union."[64] At the conclusion of the Civil War, the organization of plantations gradually dissolved as large estates became incapable of maintaining themselves without slavery. Yet, the region still prospered as people turned to the water for profit. Oysters were targeted for their vast abundance and were considered navigational hazards for their density. With the assistance of railroad and refrigeration, seafood markets expanded throughout the nation and the number of oysters processed in Baltimore increased from 1.6 million bushels in 1857 to 10 million by 1870,[65] and with that oyster populations began to decline.

Figure 28: Section through the Chesapeake Bay – Period of Civil Strife (1,820 CE – 1,877 CE)

Source: Author

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[63] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 99
[64] Usilton, Fred G. History of Kent County, Maryland, 1630-1916. 1916. 134
[65] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 105

Figure 29 Patterns of Settlement in the Chesapeake Bay – Period of Civil Strife (1,820 CE – 1,877 CE)

Source: Author

Following the Civil War, industrialization flourished and drastically altered the landscape of the Chesapeake watershed during the Industrial Period from 1,880 to 1,930 CE. During this time, the region's population continued to grow reaching 2.5 million people by 1,880 CE and 5 million people by 1,930 CE.[66] The majority of this growth had occurred around the major urban centers of Norfolk, Richmond, Washington D.C., and Baltimore, while rural communities began to stagnate and shrink. With this growth, the land continued to be cleared for development, and by 1,900 only 30% of forested area remained,[67] and the practice of draining wetlands and infilling swamps or marshes began to emerge to reclaim land for additional development. Around 1,910 CE, locomotive transportation began to peak, and the emergence of automobiles and airplanes accelerated the decline of rail. However, with the assistance of automobiles, refrigeration, and industrial canning; farmers turned from bulk crop items such as corn and wheat to more perishable food items such as fruits, vegetables, poultry, and dairy based products which were in high demand in urban centers.[68]

Figure 30: Section through the Chesapeake Bay – Industrial Period (1,880 CE – 1,930 CE)

Source: Author

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[66] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 119
[67] Ibid., 129
[68] Ibid. 123

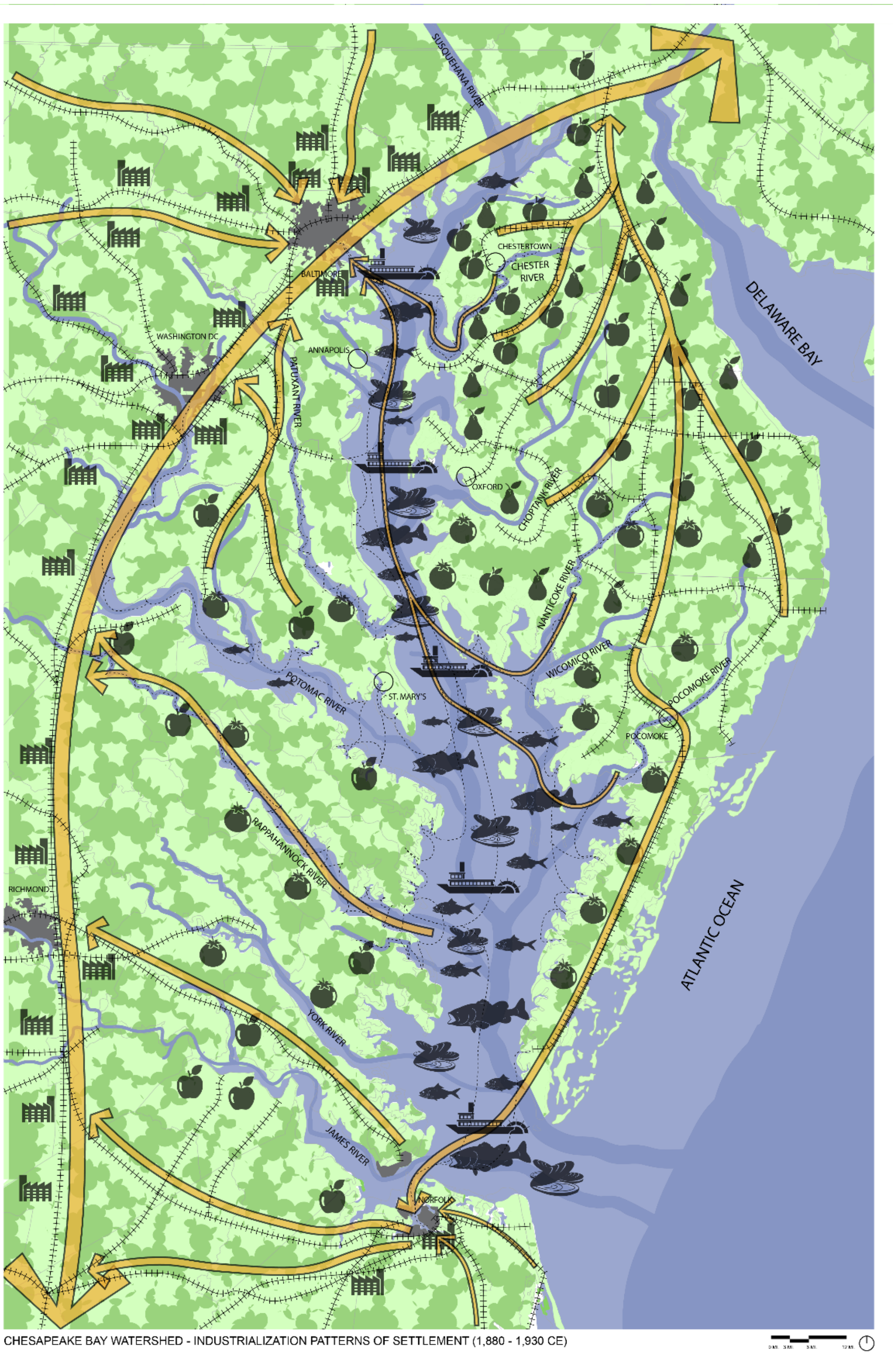

Figure 31 Patterns of Settlement in the Chesapeake Bay – Industrial Period (1,880 CE – 1,930 CE)

Source: Author

Following the industrial period, life in the Chesapeake transitioned into the Modern Era spanning from the 1,930's to the present. The beginning of this period was marked by the Great Depression, which witnessed mass migration of people to urban centers in search of work predominantly in war plants during World War II. During this time, rural communities stagnated and declined. With the increase in urban population and continued growth of industrialization, the first half of the Modern Era was marked with considerable over pollution and environmental degradation. Wetlands continued to be infilled, and old growth forests had been replaced by human settlement, highways, or farms. Yet, as wood become economically less important and agricultural production declined, forested areas gradually began to rebound throughout the region.[69] During this time, locomotive transportation continued its decline into inexistence as coal became less abundant while trucking, with the assistance U.S. Routes established during the 1930s, emerged as the dominant land-based transportation method.[70] With increasing automobile transportation and industrialization, bodies of water became poisoned and overharvesting would continue to dwindle the populations of maritime species.

Figure 32: Section through the Chesapeake Bay – The Modern Era (1930 CE – Present)

Source: Author

[69] Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000. 158
[70] Ibid. 146

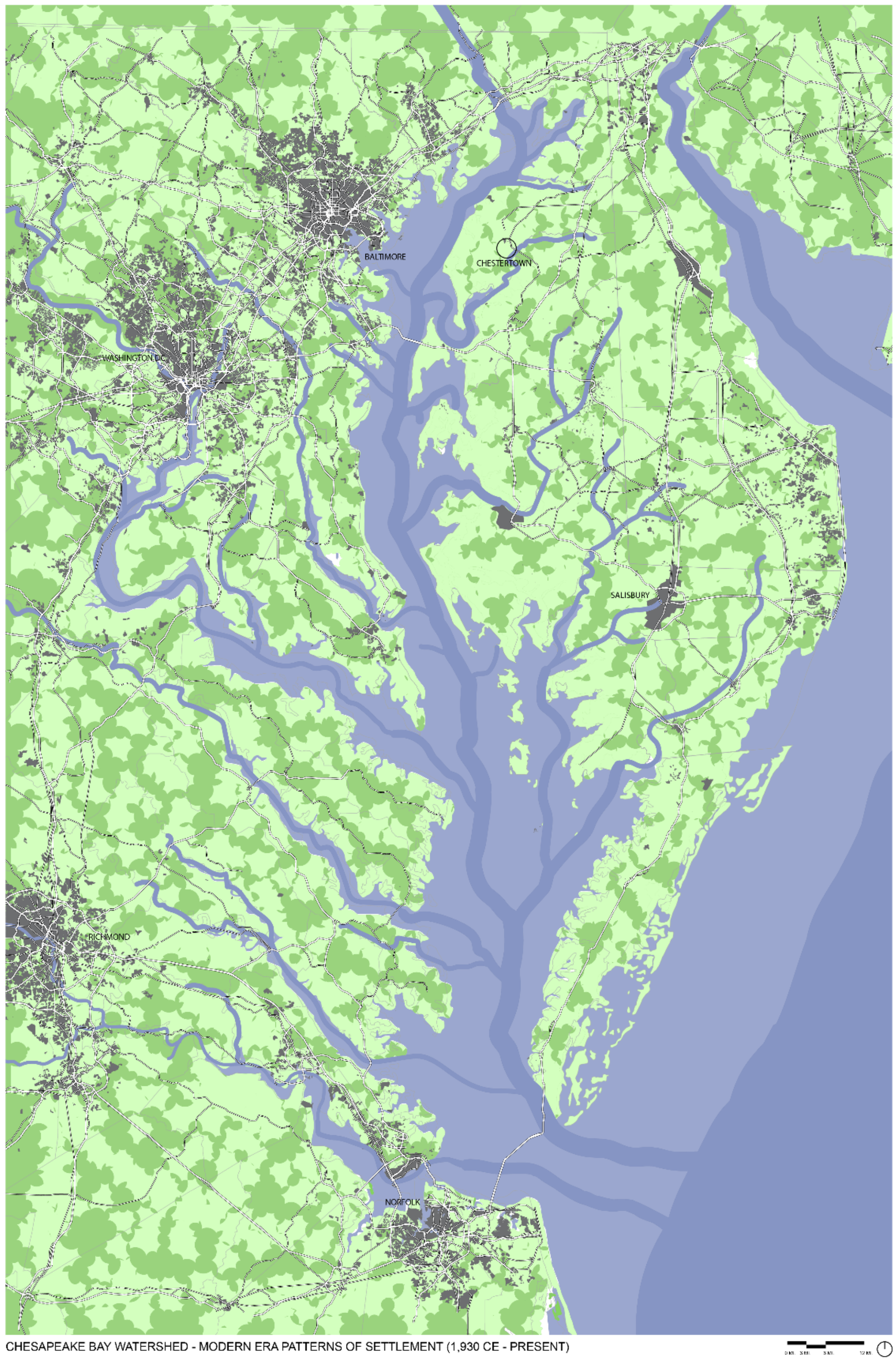

Figure 33 Patterns of Settlement in the Chesapeake Bay – The Modern Era (1930 CE – Present)

Source: Author

In summary, the original inhabitants of the Chesapeake Bay watershed were the most suited to respond to climate change and sea level rise. The belief of living lightly on the land, by harvesting only the resources they needed and relocating for replenished resources, created a system that not only fostered a positive relationship with the environment but would result in a resilient community model that could respond to environmental fluctuations. Unfortunately, the ideals of European settlement—implementation of fixed dwellings and exploiting the land for natural resources—has persisted as part of the fabric of American communities, and has consequently contributed towards environmental degradation. However, if communities make gradual shifts back to former patterns of settlement—living lightly off the land, harvesting only resources needed, and returning the worked landscape back to its native ecology—then communities might have the chance of minimizing and slowing the impacts of climate change, sea level rise, and environmental degradation.

—End of Chapter—

Chapter 5: Resiliency in the Chesapeake Bay

Strategies for Mitigating Hazards Imposed by Sea Level Rise

With the growing threat of inundation by sea level rise in the coming decades, waterborne communities will need to implement strategies to help prepare and protect communities and their way of life. Throughout the world, more than 600 million people live within 10 meters (33 feet) to bodies of water, and in the United States alone nearly 40% of the human population (approximately 131,800,000 people) live near the coast of other coastal tributaries,[71] and more alarmingly the majority of these settlements are in low-lying areas that are at or near sea level. As explored with the patterns of settlement throughout the Chesapeake Bay watershed, human settlements have historically and continuously develop along sources of water provided by their ease of access by water transportation, and their abundance and accessibility of water and natural resources. Yet, as climate change deteriorates and sea levels continue to rise, the World Bank estimates that over one trillion dollars of assets will be at risk every year due to sea level rise by 2050.[72] In response to growing concerns of sea level rise, mitigation—though crucial to continue every effort to reduce production of greenhouse gases—will not be sufficient alone as effects of climate change have begun and could potentially be irreversible. The next strategy of adapting to new environmental conditions and making our communities resilient or capable of rebounding from natural disaster, will become the next great challenge. Four

[71] Scott, Michon. Lindsey, Rebecca. *2017 State of the climate: Sea Level.* August 2018.
[72] Hallegatte, Stepahne. et al. "Future flood losses in major coastal cities." *Nature Climate Change 3(9),* 2013: 802-806.

approaches have been analyzed to stymie the effects of sea level rise, and are categorized into Hard Protection, Soft Protection, Floodable Protection, and Retreat strategies.

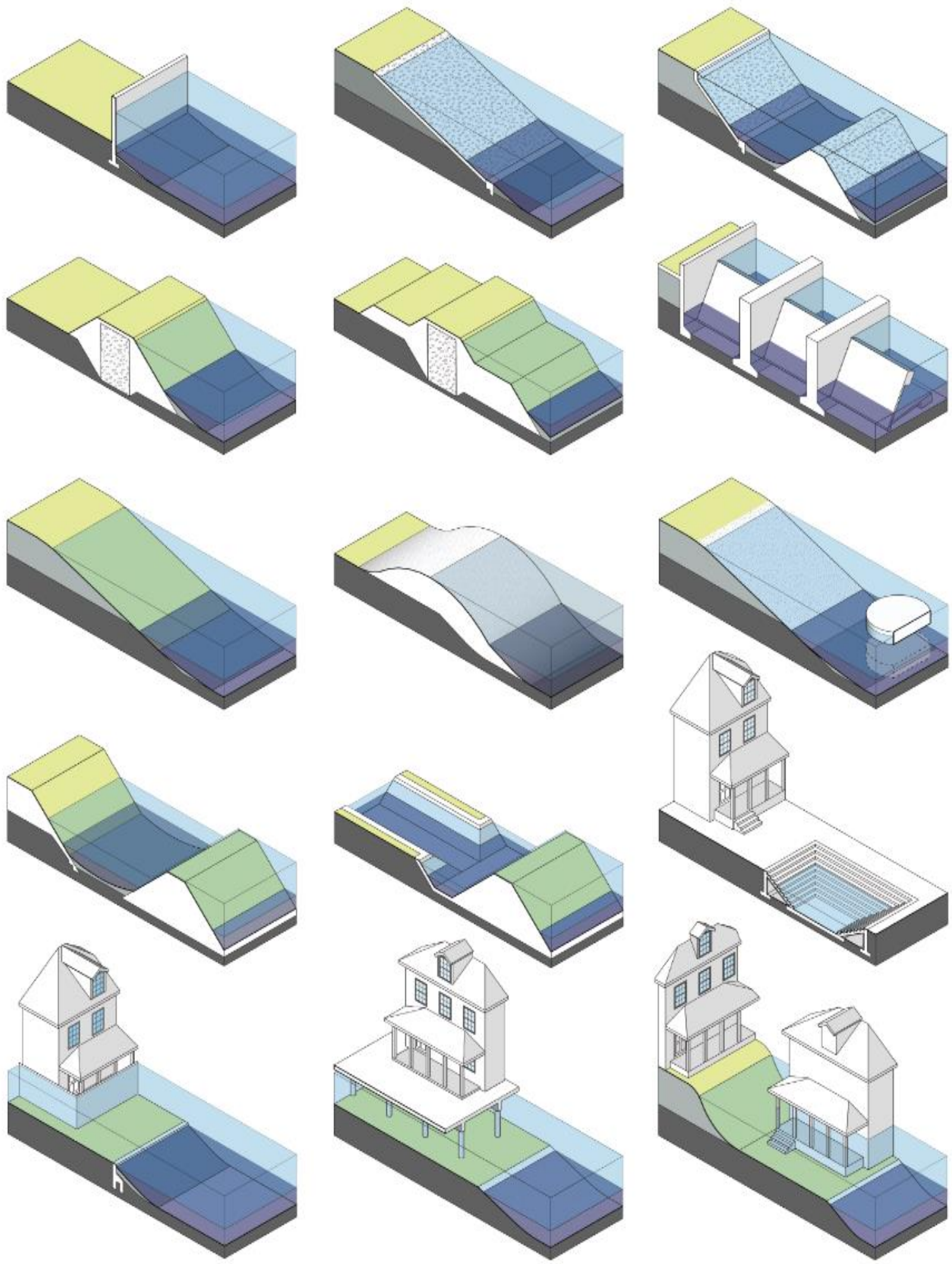

Figure 34 : Overview Transect of Resilient Strategies

Source: Author

Hard Protection Resilient Strategies

Hard protection strategies are the most typical form of resilient strategies implemented to resist inundation and rising waters. These engineered solutions provide a clear edge between town and water, and include typical configurations such as floodwalls, revetments, breakwaters, dikes (singular or multipurpose), and surge barriers. Careful planning is required to integrate these interventions throughout a community. Inserting hard protection strategies into an existing community can be disruptive and obstructive to the visual and physical connection that community has to water, which can further devalue the historic, cultural, and economic value of a community rendering it infeasible. Considerations of making hard protection interventions multi-functional by integrating programmable spaces such as nature trails, parks, plazas, or recreational fields as part of the barrier can help mitigate the disruption of the barrier and provide additional value.[73] However, it is important to note that the integration of outdoor spaces along the barrier will require more building area, in a location that might otherwise be limited by existing buildings. Additional programmed spaces will increase the overall cost of an expensive strategy category, which ranges from values as low as $100 per linear foot for simple floodwalls to several million dollar per linear foot for complex surge barriers. Given the great cost for hard strategies, it is important to note that these interventions are more viable in densely populated urban areas and are not economically suitable for rural communities.

[73] Al, Stefan. 2018. Adapting Cities to Sea Level Rise : Green and Gray Strategies. Washington, DC: Island Press. 14

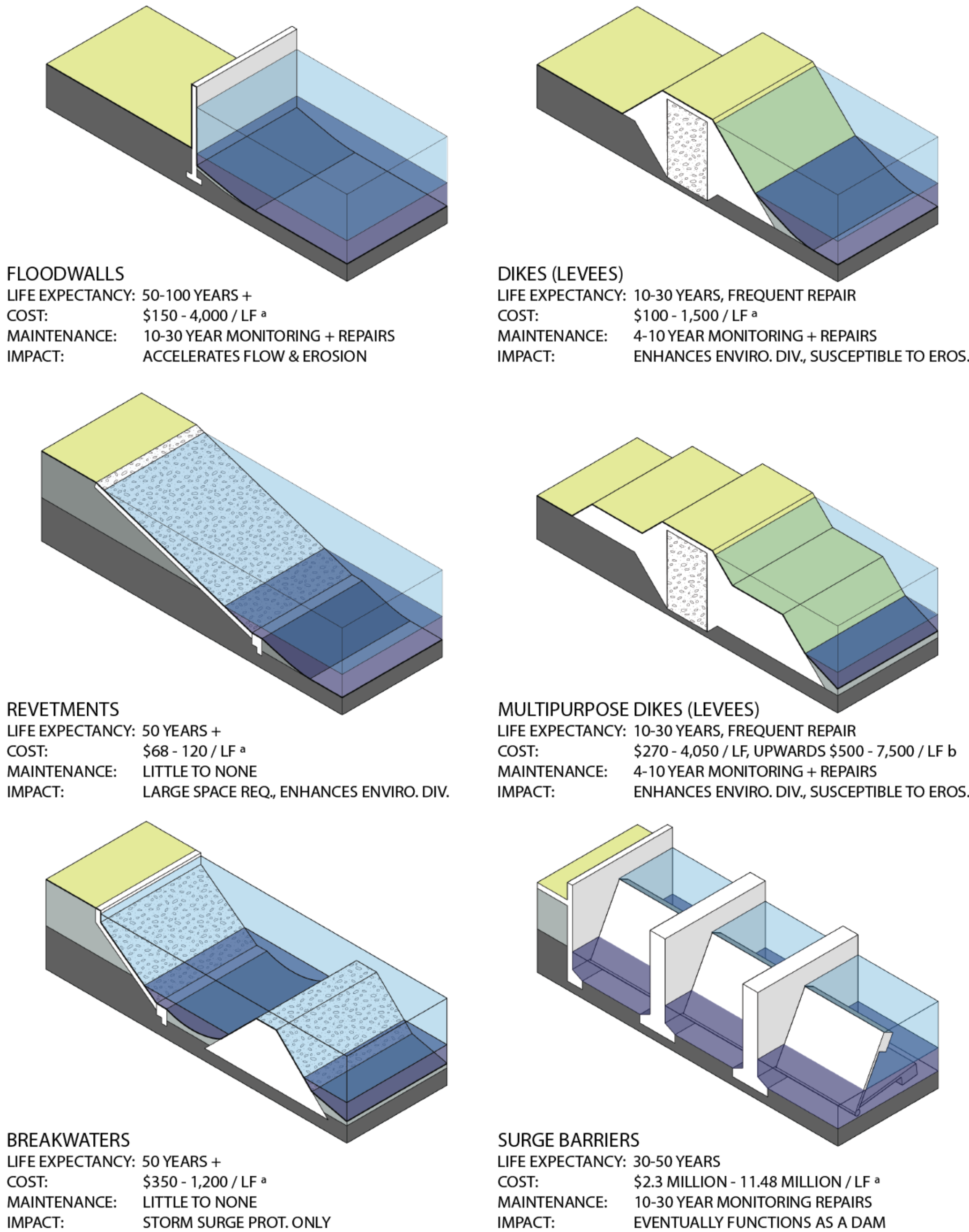

Figure 35 : Hard Protection Resilient Strategies

Source: Author

**Costs are derived from the following published reports and evaluated with current published building construction costs. An annual average cost factor of 2% was added for every year from initial estimates. Costs are subject to change due to prevailing economic factors and regional variances.

a. National Oceanic and Atmospheric Administration (NOAA). What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure. Eastern Research Group, 2013.

b. Aerts, Jeroen C.J.H. et. al. *Cost Estimates for Flood Resilience and Protection Strategies in New York City* . VU University Amsterdam, Institute for Environmental Studies, 2013.
c. Robert Snow Means Company. RSMEANS Building Construction Cost Data. Norwell, MA., 2018.

Soft Protection Resilient Strategies

Soft protection strategies are the least intrusive method to help make communities resilient to sea level rise. These strategies utilize plantings, sand, and other elements readily found in nature without requiring additional manufacturing to produce, to help absorb and buffer rising water. Types of soft protection strategies include living shorelines, dunes, and floating island, to create a "soft" shoreline edge blurring the boundary between dryland and water. Provided that these strategies utilize natural elements as a buffer between land and water, soft strategies create habitats for wildlife species promoting biodiversity while improving water quality and food resources.[74] The other added benefit of soft strategies is the relatively low cost in comparison to most other strategies. Simple methods of wetland restoration or construction can be as low as $3,500 to $35,000 per acre, and maintenance requirements of most soft strategies are little to none as most are left to run their course with nature. It is important to note with soft strategies, though they might be the least expensive alternative to other resilient strategies, they are incapable of stopping inundation of sea level rise, alone. As water rises, living shore lines will migrate inland to avoid being inundated themselves, and dunes will erode in time. Successful prevention of sea level rise requires the pairing of soft strategies with hard strategies. Using soft strategies as buffers for hard strategies, mitigating effects of

[74] Al, Stefan. 2018. Adapting Cities to Sea Level Rise : Green and Gray Strategies. Washington, DC: Island Press. 15

erosion or damage by wave impact, and to visually soften the hard edge that hard strategies impose between land and water.

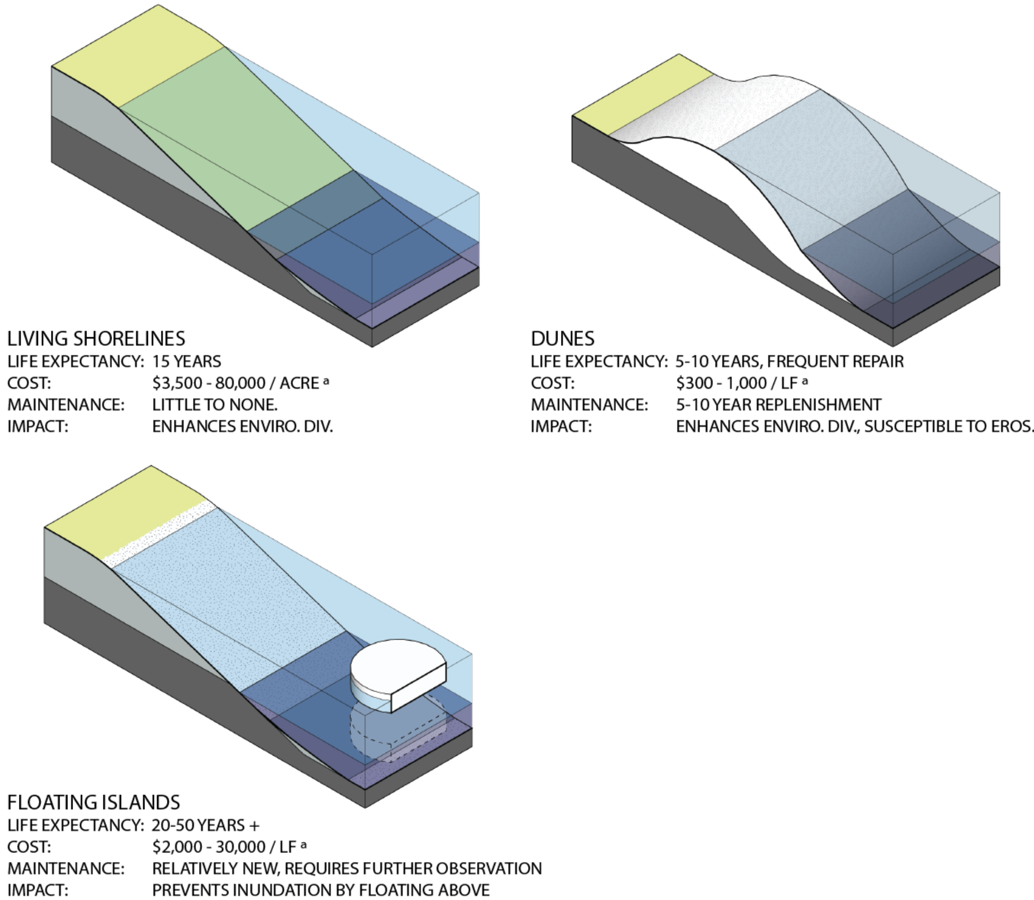

Figure 36 : Soft Protection Resilient Strategies

Source: Author
**Costs are derived from the following published reports and evaluated with current published building construction costs. An annual average cost factor of 2% was added for every year from initial estimates. Costs are subject to change due to prevailing economic factors and regional variances.

a. National Oceanic and Atmospheric Administration (NOAA). What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure. Eastern Research Group, 2013.
b. Aerts, Jeroen C.J.H. et. al. *Cost Estimates for Flood Resilience and Protection Strategies in New York City* . VU University Amsterdam, Institute for Environmental Studies, 2013.
c. Robert Snow Means Company. RSMEANS Building Construction Cost Data. Norwell, MA., 2018

Floodable Resilient Strategies

Floodable resilient strategies are another method of protection that a community can integrate into their urban fabric to make their city more resilient. These strategies are particularly helpful in locations that are prone to seasonal or tidal flooding, where a community is only under threat of inundation during peak rainfall or flooding conditions in otherwise normal circumstances. Floodable resilient strategies includes the use of floodable ponds or storm-water retention basins, polders, floodable squares, and pervious infiltrations areas such as impervious pavement or bio-swales. These strategies are also particularly helpful in largely developed areas where large expanses of impervious surfaces such as asphalt streets, concrete sidewalks, or buildings inhibit groundwater absorption and runoff overburdens storm-water infrastructure.[75] Integrating these strategies creates conditions that help store and gradually release water back into the environment, by creating pervious conditions that help facilitate groundwater absorption, or the creation of water catchment basins that delays the amount of water discharged and consequently flooding. These strategies have the potential of being considerably cost effective, where simple storm-water retention basins can collect and retain water. However, careful planning and consideration is required for integrating these methods into existing communities, as these methods typically require larger land areas for water storage and retention basins, an updated network of storm-water infrastructure, and the inevitability that these areas will become inundated with sea level rise.

[75] Al, Stefan. 2018. Adapting Cities to Sea Level Rise : Green and Gray Strategies. Washington, DC: Island Press. 15

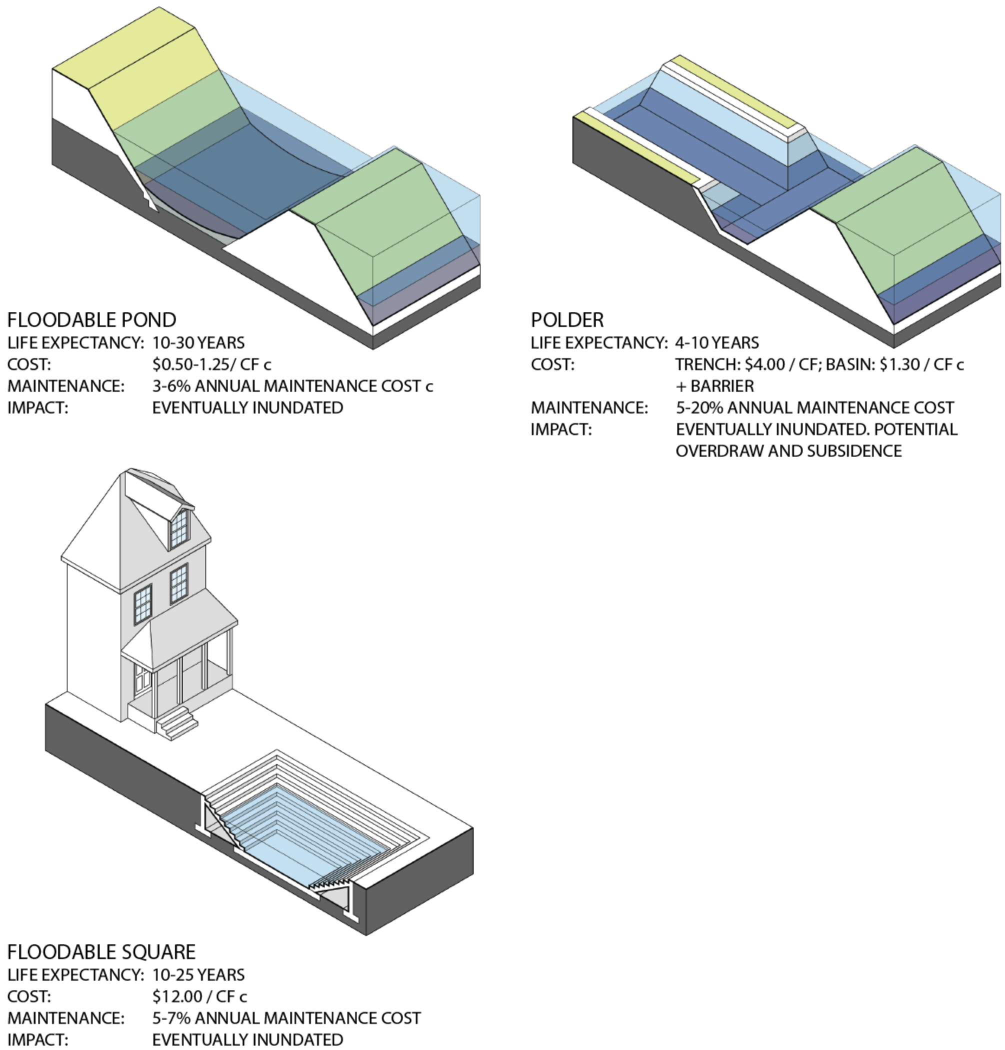

Figure 37 - Floodable Resilient Strategies

Source: Author
**Costs are derived from the following published reports and evaluated with current published building construction costs. An annual average cost factor of 2% was added for every year from initial estimates. Costs are subject to change due to prevailing economic factors and regional variances.

a. National Oceanic and Atmospheric Administration (NOAA). What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure. Eastern Research Group, 2013.
b. Aerts, Jeroen C.J.H. et. al. *Cost Estimates for Flood Resilience and Protection Strategies in New York City* . VU University Amsterdam, Institute for Environmental Studies, 2013.
c. Robert Snow Means Company. RSMEANS Building Construction Cost Data. Norwell, MA., 2018

Retreat Resilient Strategies

Retreat resilient strategies are flood protection methods that are implemented to manage the expectations of what impacts inundation will impose upon the community and individual property, and mitigate the liability of damage. Retreat strategies have been categorized as being planned or unplanned responses, whereby planned strategies implements preventative measures such as relocation to mitigate damage and expense from unforeseen natural disaster such as flooding while unplanned strategies are responses to natural disasters.[76] Under retreat strategies, three general protection methods have been identified to include elevating buildings and infrastructure, flood proofing, and strategic retreat of communities. Through the process of elevating and flood proofing buildings, these methods can be generally integrated into new construction with little expense to normal construction, but refitting existing structures with flood proof methods and elevated on piles can be considerably more costly and damaging to existing structure and function of a given structure. It is also import to note that both methods of elevating and flood-proofing structures largely places the burden upon the individual property owner to not only protect their building but to reintegrate utilities infrastructure. Of these methods that is implemented on a community wide scale, retreat has been presented as a solution whereby state or federal government authority intervenes and offers property buyouts to communities impeding natural disaster. Unfortunately, this method involves the

[76] Al, Stefan. 2018. Adapting Cities to Sea Level Rise : Green and Gray Strategies. Washington, DC: Island Press. 15

self-volition of members of the community to abandon their homes, businesses, and communities, resulting in ghost communities.

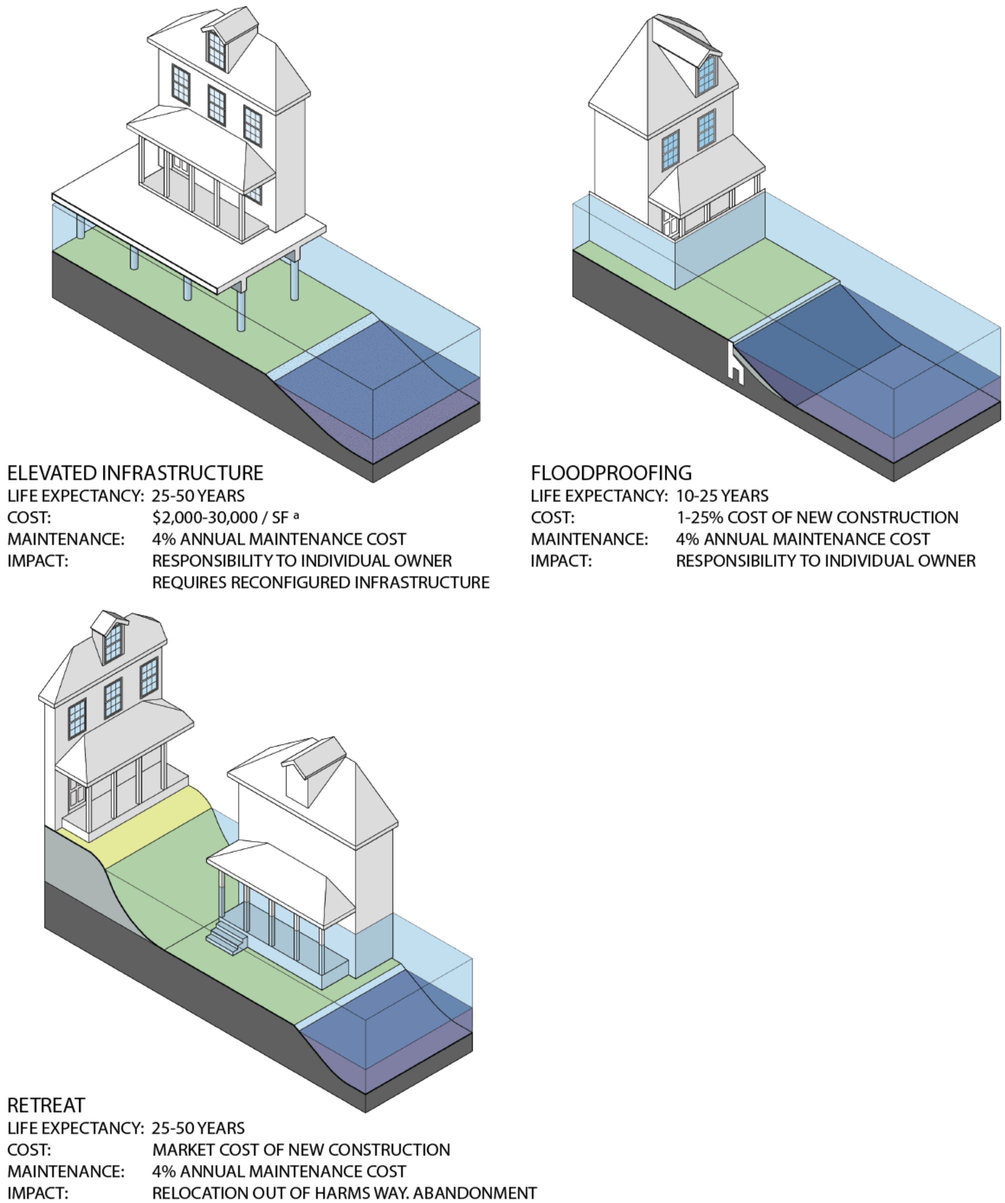

Figure 38 - Retreat Resilient Strategies

Source: Author
**Costs are derived from the following published reports and evaluated with current published building construction costs. An annual average cost factor of 2% was added for every year from initial estimates. Costs are subject to change due to prevailing economic factors and regional variances.

a. National Oceanic and Atmospheric Administration (NOAA). What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure. Eastern Research Group, 2013.
b. Aerts, Jeroen C.J.H. et. al. *Cost Estimates for Flood Resilience and Protection Strategies in New York City* . VU University Amsterdam, Institute for Environmental Studies, 2013.

c. Robert Snow Means Company. RSMEANS Building Construction Cost Data. Norwell, MA., 2018

Considerations for the Future of the Bay

With the anticipation of near or complete inundation of the Chesapeake Bay watershed within the next three hundred years under the current projections of the Represented Concentration Pathway 8.5, it is challenging to justify the resource and monetary investment into the region. With the consideration of these resilient strategies benefits and limitations, the reality is that not all communities can engineer and design their way out of the worst case sea level rise scenario. Hard protection strategies can only protect from so much rising water until overtopped and breached, soft and floodable protection strategies can only absorb so much water before completely inundated, and communities can only mitigate and redirect flooding until functionality is lost to sea level rise.

It is a misconception that most communities believe they can engineer their way out of the undesirable conditions of sea level rise. Some communities do possess the resources to engineer their way out of sea level rise, but the reality is that most communities do not possess the population density or economic resources to justify the implementation of these resilient strategies for the inevitability of inundation. As suggested by the Dean of Maryland's Henson School of Science and Technology at Salisbury University, Dr. Mike Scott, "there's nothing humans can do to stop the progression of water as it rises in the Chesapeake Bay and threatens to overtake islands and coastlines." [77] As addressed in the chapter regarding the impacts of sea

[77] Ortiz, Erik. "How to Save a Sinking Island." *NBCNews.com.* November 13, 2017.

level rise in the region, this will severely challenge residents planning to outlast the environmental conditions where the highest elevation along the mainland of the Delmarva peninsula is only 40 – 60 feet above sea level, at most.[78] Rather than ignoring the inevitable and creating a scenario of environmental refugees, Dr. Andrea Dutton, professor of geological sciences at the University of Florida, suggests that, "[communities need to have] more conversations about retreat. Relocate, develop along higher ground, and along corridors of retreat. With that opportunity would come jobs, economic growth, and saving lives." [79]

It is to the benefit and best interest of each community threatened by sea level rise and climate change to begin implementing zoning restrictions and policies that emphasize moving a town's core facilities and functionality away from the water's edge. However, by restoring the natural ecology along the waterfront, communities can slow the advance of sea level rise, buy the community time to move out of harm's way, and to improve the quality of life both on land and in the water.

—End of Chapter—

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[78] Ortiz, Erik. "How to Save a Sinking Island." *NBCNews.com.* November 13, 2017.
[79] Reframing Sea Level Rise. Directed by TEDx Talks. Performed by Dr. Andrea Dutton. 2017.

Chapter 6: An Overview of Chestertown

History of Chestertown and Character of Place

The town of Chestertown has a long history that predates the formation of the United States, serving as a colonial outpost for the fledgling Maryland colony. Dating as far back as 1668 and under the provisions of the Maryland New Towns Program initiated by Governor Charles Calvert, Chestertown had been designated as one of the eleven sites for the erection of “sea ports, harbors, creeks, & places for the discharging and unloading of goods and merchandises out of ships and boats and other vessels.” [80] Laid out on the northwestern banks of the Chester River, the orthogonal grid of the town follows the English tradition and philosophy for new town planning during the colonial English-American time period. As suggested by John Reps, most colonial tidewater planning and development may have derived from the publications of William Camden, *Britannica*, and John Speed, *Theatre of the Empire of Great Britain*, whose works illustrates the origin of English town planning from Roman Castrum and the establishment of cities as an essential part of a growing civilization.[81] Following the precedents of these works, it is highly probable that the layout of Chestertown—like other English settlements—followed these design principles. After subsequent revisions to the 1668 proclamation in 1669, 1671, and 1682; Chestertown had formally been established in 1706 under Maryland’s “Act for the Advancement of Trade and the Erection of Ports and Towns,” as part of a

[80] Rep, John Willim. *Tidewater Towns; City Planning in Colonial Virginia and Maryland.* Williamsburg, VA: Colonial Williamsburg Foundation, 1972. 92
[81] Ibid. 7-8

strategic effort by the Maryland government to organize legislative control, communications, and transportation network over the newly founded Maryland frontier.

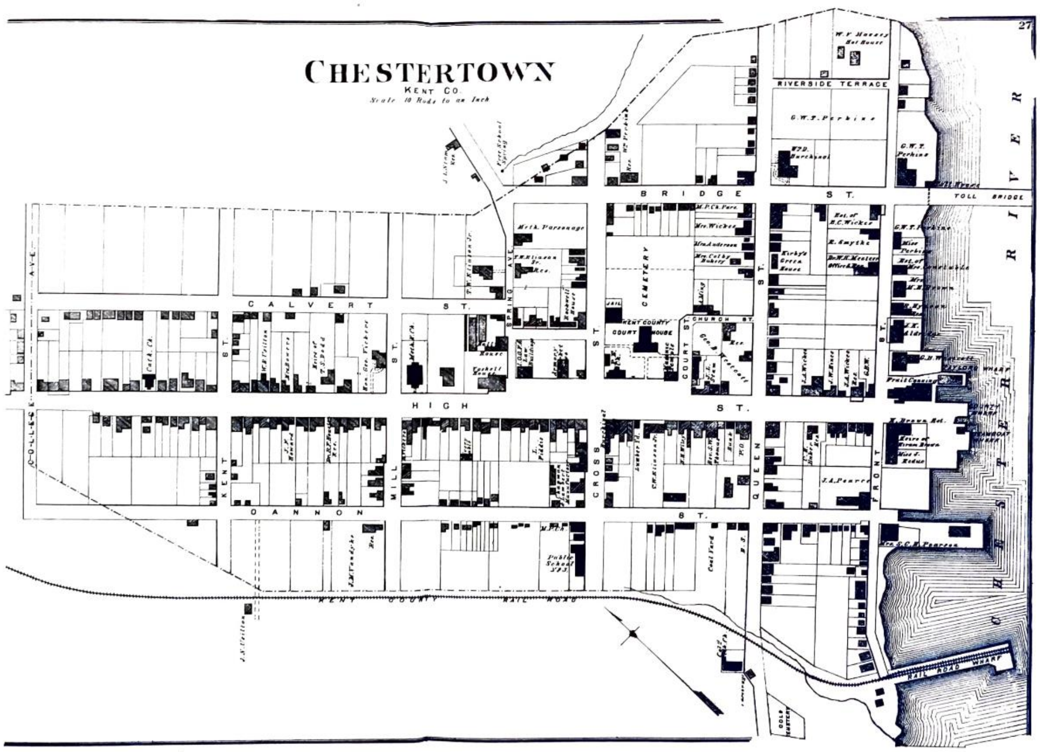

Figure 39 - Plan of Chestertown, Maryland: 1877

Source: Reps, John William. *Tidewater Towns: City Planning in Colonial Virginia and Maryland.* 79

In an effort to promote the newly established town and to attract settlers to this region, the 1706 act contained a clause to help stimulate growth. The clause exempted skilled craftsmen from taxes for a period of four years if they settled in this new town.[82] Attracting craftsmen to this region, Chestertown prospered. The waterfront became an active port, and maritime industry was the primary economic driver. At the water's edge, the dock at the end of High Street served as the principle port of

[82] Kent Conservation & Preservation Alliance. "Preliminary Cultural Landscape Assessment of Kent County, Maryland." 2019. 1.03

entry, where all goods were processed and travelers—some of notable and historic significance, such as President George Washington—were received in their journey along the fastest colonial route between the northern and southern colonies through the Chesapeake Bay watershed.

Figure 40 - Birds eye of Chestertown, Kent Co., Maryland.

Source: Fowler, T.M. and Fowler & Kelly. Retrieved form the Library of Congress
https://www.loc.gov/item/73693132/

Nicknamed the “Annapolis of the Eastern Shore,” nourished by the craft and trade during the period of colonialism in United States, a rich history of colonial architecture—and subsequent architectural styles—remains evident in the present fabric of Chestertown and contributes to the unique character of place. Within this town, a mixture of single-family, single and duplex dwellings front the streets with porches, brick cobbled sidewalks, and plantings to buffer the dwellings from streets while providing habitable street space. On main streets—Cross Street and High Street—mixed use buildings are utilized rather than single family dwellings, with retail occupying the street level and residential or additional office space above. Similar to the residential streets, the main street experience is enhanced through the provision of overhead projections such as porches, awnings, canopies, or trees to alleviate the continuity of the walled surface, while diffusing direct sunlight onto the street below making for a pleasing pedestrian space. Throughout the town, buildings of historical significance—such as the Custom's House and Hynson-Ringgold House to name a few—have been preserved and exist within their original context or next to a newer structure whose character conforms to the architectural history of the town. Yet, the most characteristic view of Chestertown is the one detached from it, the view from the Chester River onto the manor houses and porches fronting the river.

Figure 41 - View down Cannon Street, looking south

Source: Author

Figure 42 - View from Cross Street, looking north

Source: Author

Figure 43 - A view of Stam's Hall, Prince Theatre, The Imperial, and neighboring units from High Street, looking north.

Source: Author

Figure 44 - A view of the Custom's House and neighboring dwellings from the intersection of High Street and Water Street, looking south

Source: Author

Figure 45 - A view of the Hynson-Ringgold House from the intersection of Cannon Street and Water Street, looking north

Source: Author

Figure 46 - A panoramic view of Chestertown across the Chester River, between Chester River Association to Widehall; south half

Source: Author

Figure 47 – A panoramic view of Chestertown across the Chester River, between 103 N Water St and Chester River Bridge; north half

Source: Author

Challenges of Chestertown

Despite Chestertown's rich history, aesthetic beauty, and connection to the environment, the town is wrought with problems that threaten to undermine the prosperity of the town. As mentioned in the previous chapter covering the history and patterns of settlement throughout the region of the Chesapeake Bay watershed, the prosperity of Chestertown began its decline following the War of 1812 when maritime trade shifted and consolidated to the port of Baltimore. Following this transition, the collapse of plantation landholdings following the Civil War, a late introduction of locomotive transportation to the region, indirect connection to major bay-to-beach highway corridors, and general stagnation of rural communities over the years has hindered the prosperity of Chestertown. Having experienced slower growth over the years, data extracted from 2010 census reports and statistics published by Kent County has found that Chestertown makes up one of the wealthiest and poorest communities in the region. With a population of 5,254, Chestertown's poverty rate accounts for a staggering 26.6% as compared to the state's average of 9%, and the median income is $31,809 as compared to the state's average of $69,272.[83] Growth in Chestertown has been attributed to a growing population of retirees moving to from metropolitan vicinities of Baltimore, Washington DC, and Philadelphia,[84] which has increased demand on a limited housing supply while the town's youth are leaving in search of economic opportunity elsewhere.

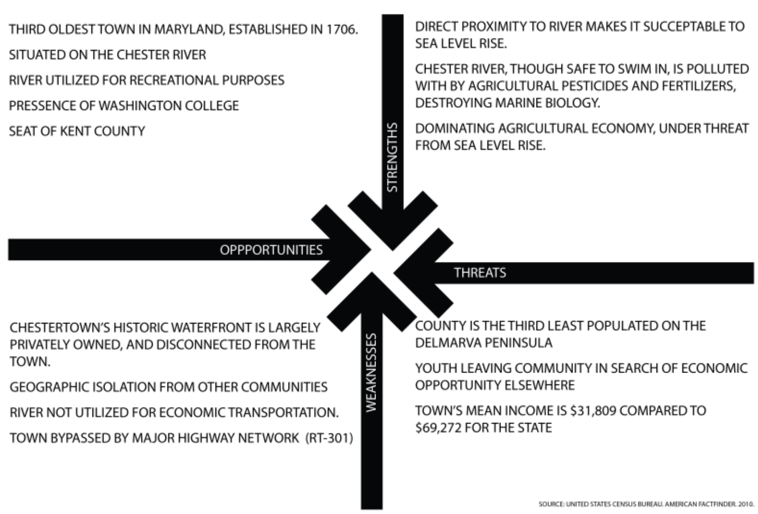

Figure 48 - Strengths, Weaknesses, Opportunities, and Threats Analysis

Source: Author. Data derived from United States Census Bureau – American Factfinder (quickfacts.census.gov) and Town of Chestertown. "Chestertown Sustainable Communities." Sustainable Communities Renewal Application. February 2019.

[83] Town of Chestertown. "Chestertown Sustainable Communities." Sustainable Communities Renewal Application. February 2019. 3
[84] Ibid. 5

Complicating the economic fragility of the town, Chestertown's proximity to the Chester River poses some unique challenges for handling sea level rise in the coming decades. Though the town and surrounding region along the Chester River watershed possesses some of the highest grade elevations on the Delmarva Peninsula, it too is subject to the impacts of sea level rise. Through the use of Geographic Information System mapping and elevation data derived from the United States Geological Survey, the impact of sea level rise has been mapped out over Chestertown and the Chester River watershed following the worst case flooding scenarios of the Represented Concentration Pathway 8.5.

The severity of sea level rise and climate change will not only have dire environmental impacts on Chestertown, but will negatively impact the Chester River watershed. Of the approximately 368 square miles (235,520 acres) of land comprising the Chester River watershed, agriculture accounts for 65% utilization of the Chester River watershed, approximately 239.2 square miles (153,088 acres) of land.[85] Without sea level rise, the dominant agricultural land use in the Chester River watershed has contributed to the deterioration of water quality as nitrogen and phosphorus runoff has resulted in algal blooms and reduced oxygen in the water. As climate change continues to elevate sea level rise, lands once formerly utilized for agricultural purposes will become inundated and unusable, their saturated soils will further pollute the river and towns adjacent to these rivers.

[85] Lee, Samuel, and Chloe Ng. Chester River Environmental Watershed Strategy (CREWS): A Comprehensive Management Plan. University of Delaware - Water Resources Center, 2016.

Figure 49 - Chester River Watershed Land Use
Source: Author

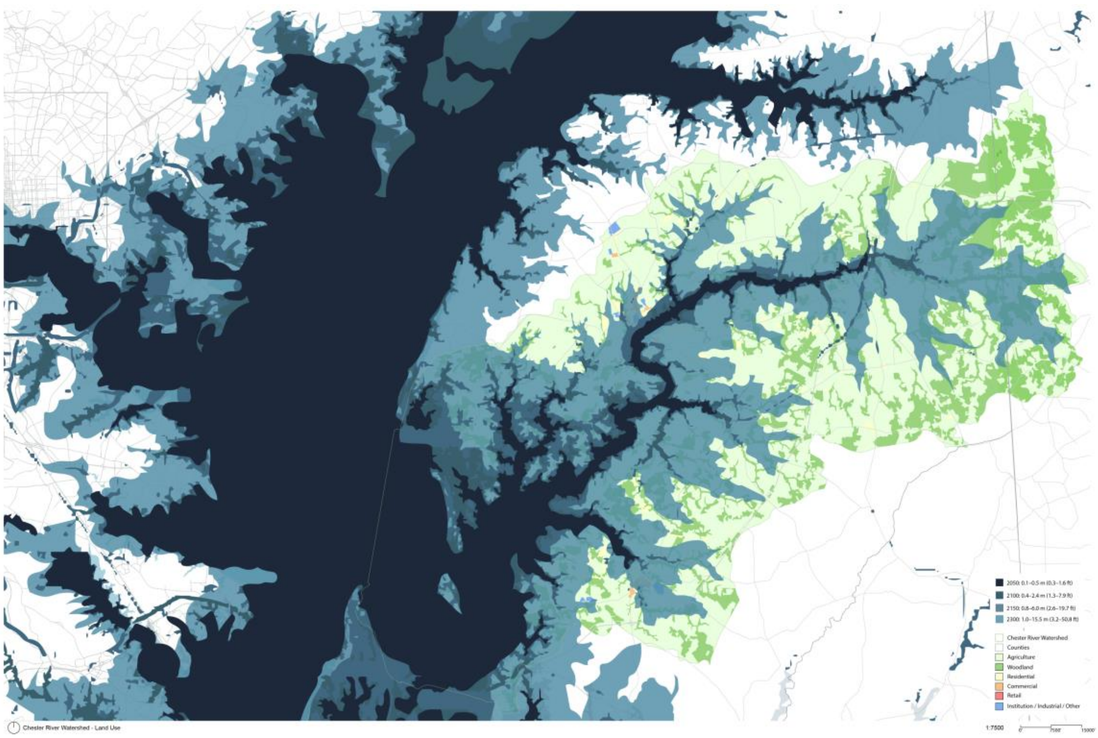

Figure 50 - Chester River Watershed Land Use - Projected Sea Level Rise Up to 2300 (50 FT)
Source: Author

Figure 51 - Site Plan of Chestertown – Existing Conditions
Source: Author

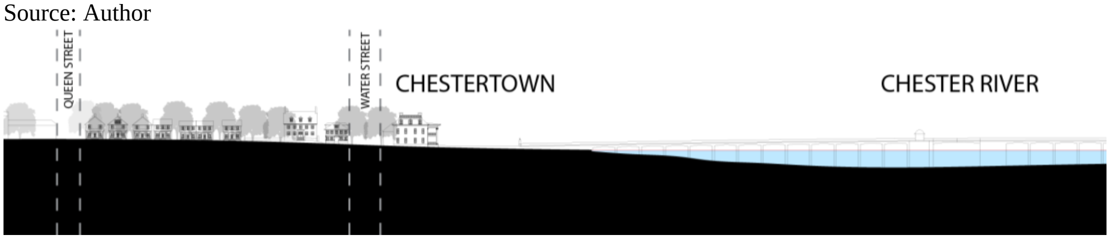

Figure 52 - Section through Chestertown at High Street - Existing Conditions
Source: Author

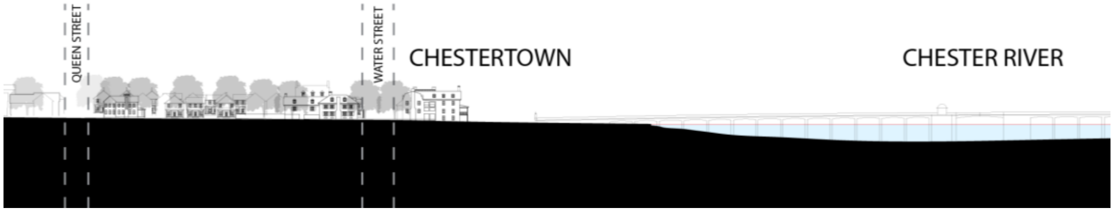

Figure 53- Section through Chestertown at Cannon Street - Existing Conditions
Source: Author

Figure 54 - Site Plan of Chestertown - Sea Level Rise by 2050 (2 FT)
Source: Author

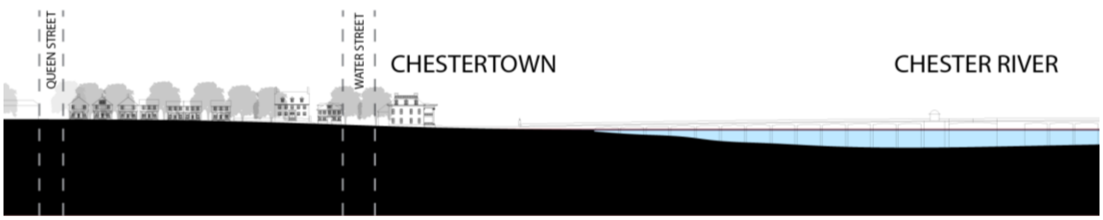

Figure 55 - Section through Chestertown at High Street – Sea Level Rise by 2050 (2 FT)
Source: Author

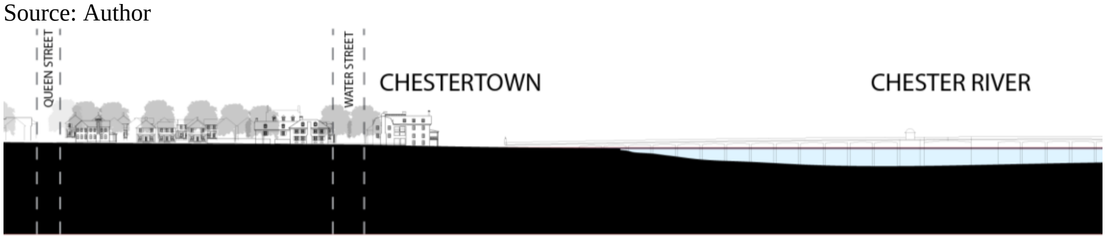

Figure 56- Section through Chestertown at Cannon Street - Sea Level Rise by 2050 (2 FT)
Source: Author

Figure 57 - Site Plan of Chestertown - Sea Level Rise by 2100 (8 FT)
Source: Author

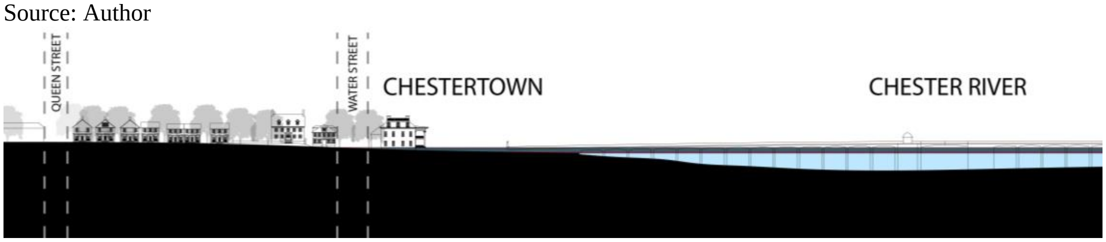

Figure 58 - Section through Chestertown at High Street – Sea Level Rise by 2100 (8 FT)
Source: Author

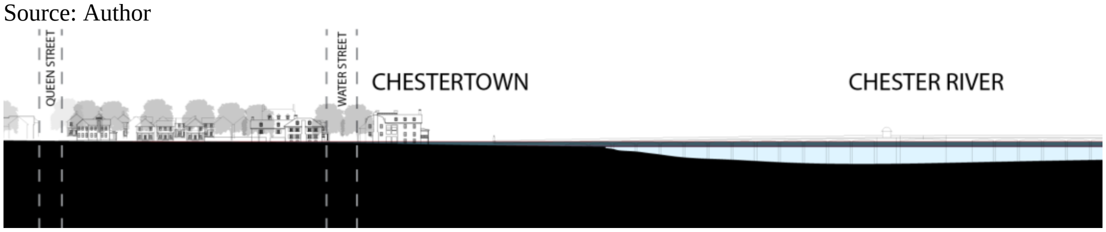

Figure 59- Section through Chestertown at Cannon Street - Sea Level Rise by 2100 (8 FT)
Source: Author

Figure 60 - Site Plan of Chestertown - Sea Level Rise by 2150 (20 FT)
Source: Author

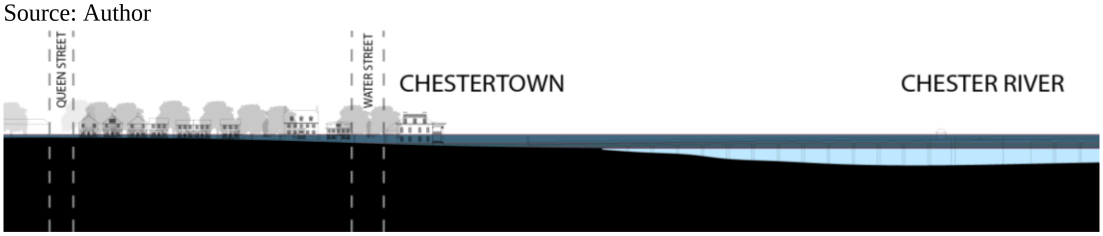

Figure 61 - Section through Chestertown at High Street – Sea Level Rise by 2150 (20 FT)
Source: Author

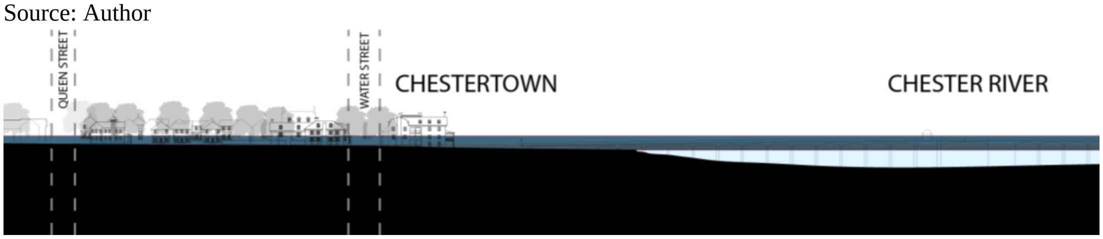

Figure 62- Section through Chestertown at Cannon Street - Sea Level Rise by 2150 (20 FT)
Source: Author

Figure 63 - Site Plan of Chestertown - Sea Level Rise by 2300 (50 FT)
Source: Author

—End of Chapter—

Chapter 7: Chestertown a Model of Resiliency

Protection of the Historic Town

Developing a protection strategy for Chestertown to offset climate change and sea level rise poses several unique challenges and obstacles. Several options were analyzed and tested, but not all were recommended due to their limitations in feasibility, practicality, or severe negative impact on the site or ecosystem. In all circumstances, the resilient strategies sought to address sea level rise up to 8 feet by 2100, as planning for resilient strategies to address sea level rise beyond 2100 became too unrealistic and the projected rate of growth of sea level rise becomes too severe to validate the purpose of investing and implementing resilient strategies in the region. The following resilient strategies explorations and proposals have been documented for hypothetical and educational purposes, suggesting possible outlooks on how Chestertown and surrounding region could respond to the impacts of climate change and sea level rise. Further consultation with civil engineers and disaster resilience & recover specialists are highly recommended before replicating the following strategies and scenarios into a real-life application.

Harden the Edge – Not Recommended Strategy

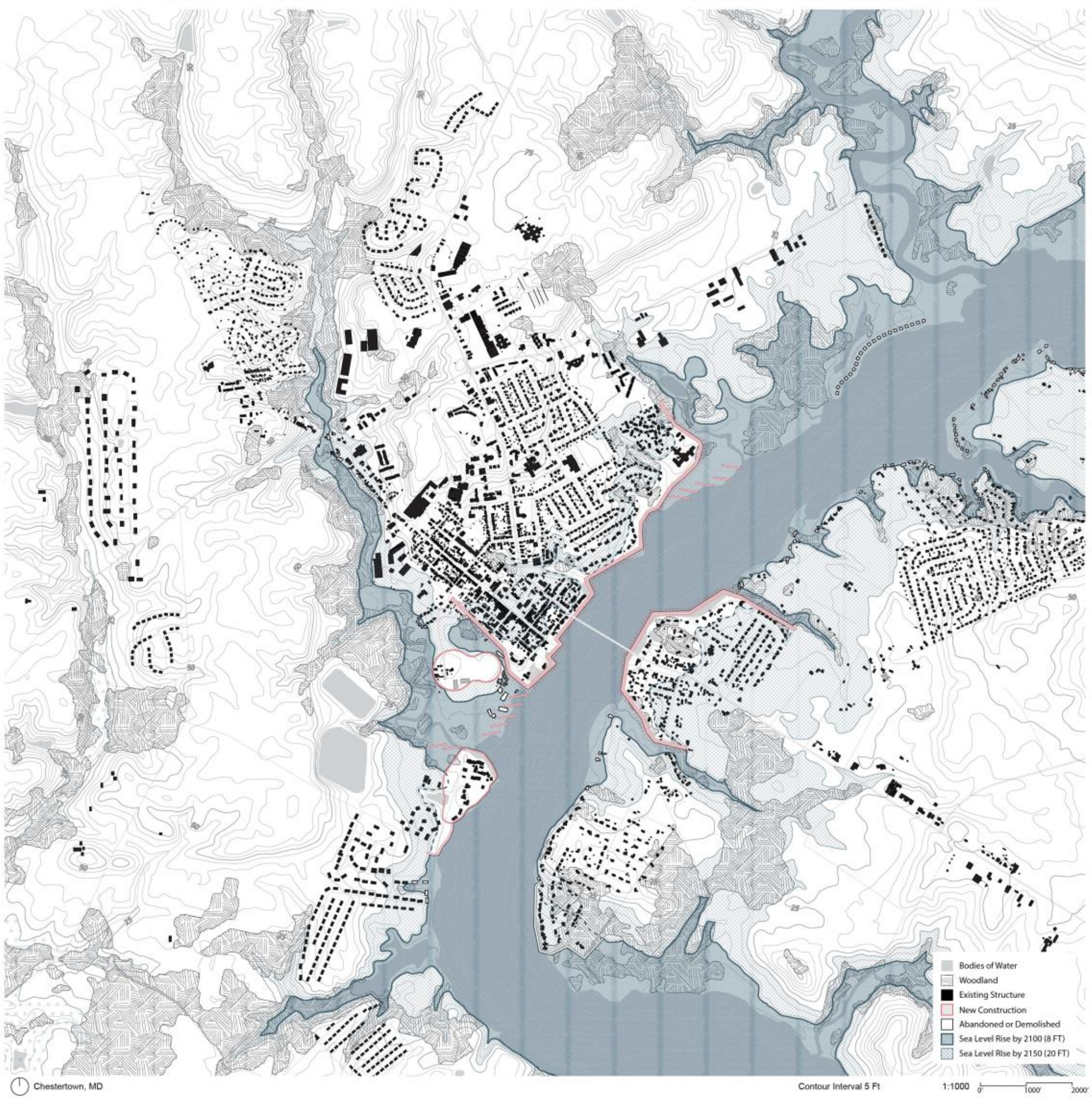

Figure 64 - Harden the Edge, Walling off the Town from 2100 Sea Level Rise
Source: Author

This strategy proposed to protect the town by walling off the historic town behind a system of engineered floodwalls or levees. The estimated cost of the scheme for approximately 18,000 linear feet of wall, was estimated to be around $82,080,000 for floodwalls or $30,780,000 for levees to protect both Chestertown and Kingstown. This proposal introduced a hard edge to protect the town, but would accelerate erosion downstream and would sacrifice connection to the waterfront.

Rail Trail – Not Recommended Strategy

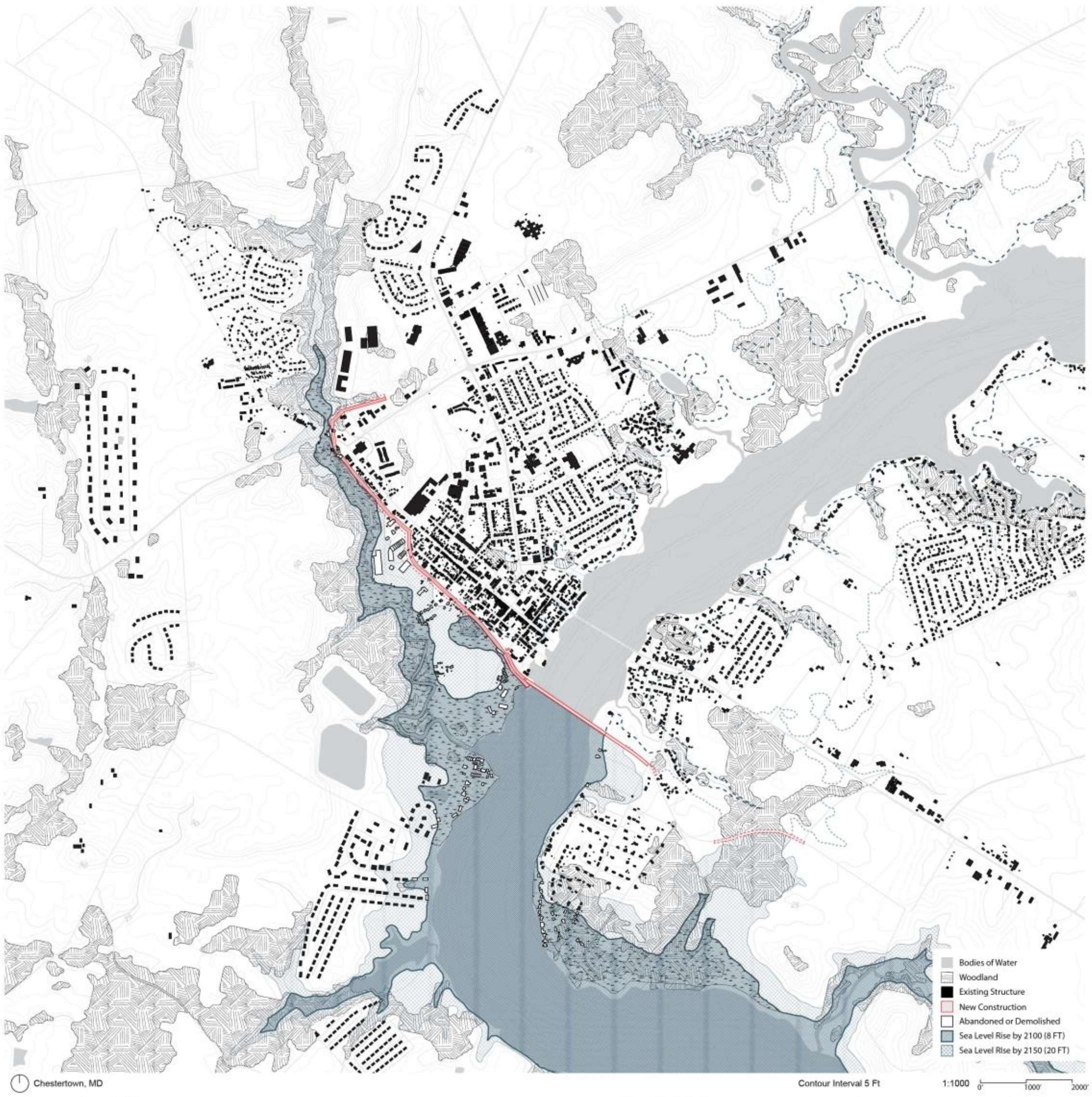

Figure 65 - Rail Trail, Utilizing a Surge Barrier to Protect from 2100 Sea Level Rise
Source: Author

This strategy proposed integrating a protective floodwall that would follow the path of the former Chestertown rail line running parallel to Radcliffe Creek, which would transition into a surge barrier spanning the Chester River. The surge barrier would function as a new bridge for the town, while floodgates or weirs would control the incoming flow of sea level rise. This scheme was not further pursued as it was too costly at an estimated cost of $109,350,000, excluding maintenance cost and the inevitable negative impact of essentially damming and flooding Chestertown.

Raise in Place – Not Recommended Strategy

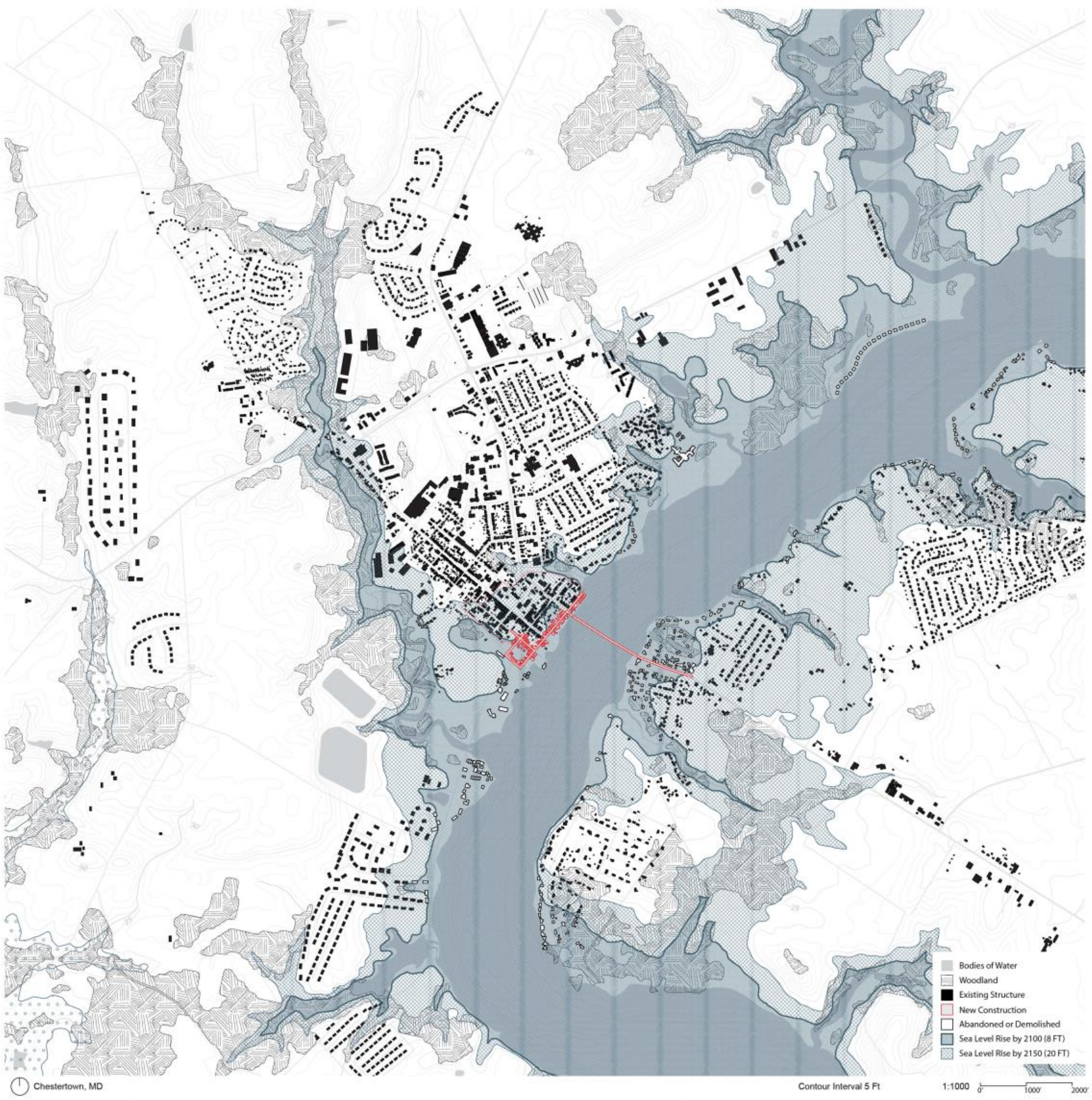

Figure 66 - Raise in Place, Elevating Existing Buildings and Infrastructure to Protect from 2100 Sea Level Rise
Source: Author

This exploration proposed the elevation of existing structures and infrastructure to portions limited to the historic town, while abandoning the rest. Unfortunately, the elevation of approximately 80 existing and historic buildings and infrastructure is a costly endeavor, with an estimated $30,000 per building and elevating approximately 7,000 linear feet of road and utility infrastructure, the estimated cost came out around $100,000,000; whose cost would be the burden of the individual homeowner.

South River Loop – Not Recommended Strategy

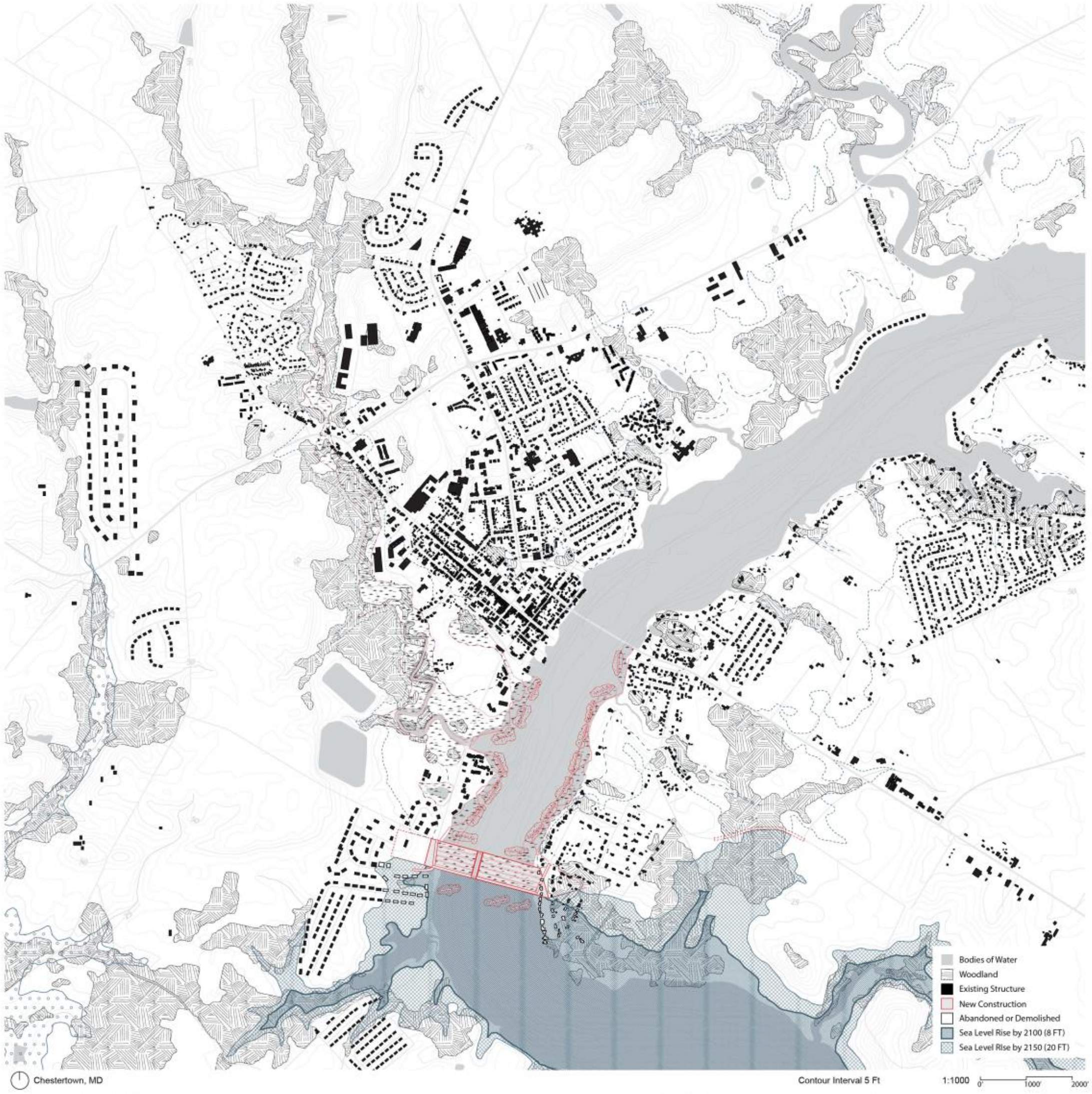

Figure 67 - South River Loop, Creation of Dam, Lock, and Wetlands to Protect from 2100 Sea Level Rise
Source: Author

This proposal was the starting point for the implementation of soft protection strategies as part of Chestertown's resiliency. The goal was to dam off rising sea level further downstream, while providing new and restored wetlands lining the Chester River to act as a drainage for storm runoff. This scheme was not further pursued as concerns for the creation of a dam would—at some point—result in the inevitable back-up and flooding of the Chester River at Chestertown rendering this strategy pointless, and concerns for impeding migratory species was of concern, too.

Oyster Reefs as a Solution

As an alternative to the previous strategies, a possible consideration is the utilization of oyster reefs to help mitigate and slow the advances of sea level rise. The Eastern Oyster is a native species of the Chesapeake Bay watershed, and possess the unique ability to grow and keep pace with sea level rise while filter feeding on water pollutants. Alone, a single oyster is capable of filtering up to two gallons of water per hour, but when part of a larger oyster reef colony whose densities average around 10 oysters per square yard these oysters are capable of filtering our nearly 6% of Nitrogen and 80% of Phosphorous contaminants in a body of water within a day.[86] The life expectancy of an oyster, if protected and left untouched from harvesting, experiences very quick juvenile growth to a relatively long life expectancy with considerably high reproduction values. Maturation from egg to juvenile oyster occurs within two-three weeks whereas the matured oyster can achieve a life expectancy around twenty years.[87] Around two-three years old oysters begins reproduction, and a single juvenile oyster is capable of producing around 7.61 million eggs per year whereas a mature oyster can produce around 58.3 million eggs per year.[88] With that many eggs produced within a year and estimating a 99% mortality, a single oyster can potentially add 20,000 to 450,000 new oysters to the oyster reef. With this growth, oyster reefs have the potential of keeping up with sea level rise, as studies conducted in the Wicomico river watershed have shown that oyster reefs have been capable of

[86] U.S. Army Corps of Engineers. "Chesapeake Bay Oyster Recovery: Native Oyster Restoration Master Plan - Maryland and Virginia." 2012. 202-203
[87] Ibid. 202
[88] Ibid. 106

growing around one to three inches per year.[89]

Figure 68 - Creation of an Oyster Barrier around Chestertown, Designed to Sea Level Rise up to 2100 (8 FT)

Source: Author

It is important to note, even though oysters are naturally occurring in the Chesapeake Bay watershed and are native to Chester River, special care and attention must be given to the implementation of oyster reefs. Alone, oyster reefs are incapable of preventing flooding from sea level rise and must be paired with other resilient strategies. For the sake this argument, this proposal suggest pairing oysters with an artificial dunes. Both oyster reefs and dunes are relatively inexpensive, with an estimated cost of around $150 per linear foot for new oyster reefs and $300 per linear foot of dunes, bringing the estimated proposal of approximately 9,590 linear feet of

[89] U.S. Army Corps of Engineers. "Chesapeake Bay Oyster Recovery: Native Oyster Restoration Master Plan - Maryland and Virginia." 2012. 231

Chestertown waterfront to a cost of around $4.32 million. It is important to note that the implementation of a dune and oyster barrier—and the other resilient edge conditions explored—is not a permanent solution to the issue of climate change and sea level rise, but will help the community bide time before the inevitable event of inundation.

A Critique on Current Proposals and a New Community Model

To help address the economic, social, and environmental issues of this community, the town of Chestertown had embarked on master planning endeavors to help stimulate the growth of the town. The most recent proposal and unrealized plan spearheaded by architecture firm Ziger/Snead Architects in 2014, and was the *Chestertown Public Arts Master Plan*. The goal of this proposal was to help stimulate Chestertown by creating a network of environmental trails and art installations that would connect the various historical sites throughout the town. The implementation of these networks through the town would enhance and contribute to the beauty of the town and environment, while providing a variety of public spaces that would foster community gathering and pedestrian connectivity throughout the community. To accommodate the shortfall of housing demands and to generate additional income for Washington College, the master plan proposed the conversion of the historic Stepne Manor plantation into a new housing development. Though the proposed development provided new pedestrian and vehicular paths that would circumnavigate and reconnect the site back to Chestertown, the environmental and historical connections of the site was underplayed by the need to subdivide the property into 266 residential properties.[90]

Figure 69 - A View of Chestertown

Source: courtesy by Kent County Historical Society, https://kentcountyhistory.org/

Figure 70 - Overlay of Ziger/Snead Architects Land Use Proposal onto Stepne Manor

Source: Author

[90] Heck, Peter. "Planers eye concept for Stepney development." My Eastern Shore MD, 2009.

Figure 71 - Overlay of Ziger/Snead Architects Land Use Proposal onto Stepne Manor

Source: Author

As a criticism to *Chestertown Public Arts Master Plan*, this thesis seeks to reimagine the proposed development for Stepne Manor conducted in 2014. As part of Chestertown's Sustainable Communities Action Plan, the town has outlined the goal of "seeking ways to increase tourism by capitalizing on history, culture and natural beauty; planful development pressure along its rural and river edges resulting from the influx of wealthy retirees; elevating and marking the African-American community's history; addressing river pollution from nitrogen and phosphorus runoff; and planning for anticipated effects of water rising coupled with land subsidence." [91]

[91] Town of Chestertown. "Chestertown Sustainable Communities." Sustainable Communities Renewal Application. February 2019.

Working with these goals, the following principles have been adopted to guide the new site proposal:

1) Return site to a natural ecolofy, resoting natural landscaoes, and utilizing soft protection strategies.
2) Maximize access to public, open space.
3) Maximize connectuve corridors between Chestertown and Stepne Manor, while minimizing the visual impact throughout the landscape.
4) Design with anticipation of sea level rise and climate change by 2100.

Working under these parameters, the goal has been to develop a site that is not a traditional residential development whose contributions have contributed to the effects of climate change and environmental degradation, but as a new model that is conscious of the environment. To achieve this goal, numerous layers of the site have been studied and applied, building upon one another for subsequent evolution of the site. Starting with the existing conditions of Stepne Manor, points of interest or nodes were called out from the site as future places or clearings.

Figure 72 - Existing Conditions at Stepne Manor

Source: Author

Figure 73 - Points of Interests, Nodes

Source: Author

Between these nodes, vegetation was added giving back to the natural ecology of the site, while paying careful attention to wind, sun, and views from each of the nodes. Prioritizing the environmental quality of the site over development, the realization was that not all residential clusters could obtain the same character or quality of views throughout the development, and consequently the placement of residential nodes had been distributed to maximize framed views throughout the landscape, while remaining hidden or obscured from direct view of the historic Stepne Manor yet creating select and visual connectivity from one cluster to the next.

Figure 74 - Revegetating Stepne Manor

Source: Author

Figure 75 - Prevailing Winds at Site
Source: Author

Figure 76 - Sun Path
Source: Author

Figure 77- Distribution of Clusters, Hidden from Sight of Stepne Manor
Source: Author

Figure 78 - Views from Clusters onto the Landscape
Source: Author

Connections were made back to Chestertown, with roads utilizing existing infrastructure on site or through new roads concealed throughout the landscape. Pedestrian bridge have been introduced to provide connection across the water and back to town, while trails meander throughout the newly forested strip of land or along the water's edge. Paying tribute to the African American history in Chestertown and throughout the region, the central trail has been dedicated as the Freedom Trail. The Freedom Trail is intended to recreate the experience of the Underground Railroad, as pedestrians are forced to meander between tree lines on either side of the forested area, gaining glimpses of clearings and Stepne Manor while dealing with the interplay of concealment and exposure along the path.

Figure 79 - Distribution of Roads

Source: Author

Figure 80 - Reconnection by Bridges

Source: Author

Figure 81 - Distribution of Trails

Source: Author

Figure 82 - Places and Building Use
Source: Author

Two cluster typologies have been distributed throughout the proposed development, and they are categorized as either ground clusters or water clusters as it relates with the corresponding geographic condition. Ground clusters consist of duplex units loosely arranged around a large central courtyard, which provides public gathering and recreational space at its core. Given the placement of these unit above the floodplain of the 2100 sea level rise, these units have been permitted to be built on the ground and their form is derived from the barn vernacular. The water clusters on the other hand, have been placed on or near the water’s edge. These clusters contrast to the ground cluster units, by elevated on stilts to avoid inundation thus constituting a tighter and denser footprint. These clusters can be accessed by bridge or boat, and their form is derived from the idea of a treehouse. In both configurations, a variety of unit types has been provided to foster social and economic diversity.

Figure 83 - Typical Cluster Overview, Ground and Water Type

Source: Author

Figure 84 - Typical Section through Cluster

Source: Author

Figure 85 - Typical Ground Cluster Configuration

Source: Author

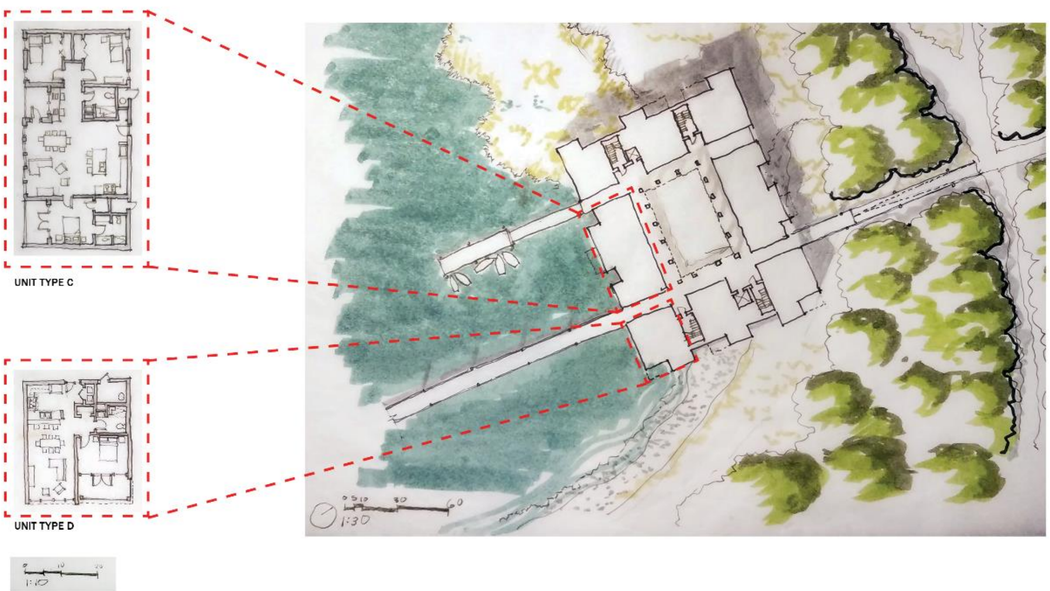

Figure 86 - Typical Water Cluster Configuration

Source: Author

Figure 87 - View towards Courtyard in Ground Cluster

Source: Author

Figure 88 - View towards Radcliffe Creek and Water Cluster

Source: Author

Figure 89 - View from Freedom Trail towards Stepne Manor

Figure 90 - View towards typical Ground Cluster

Source: Author

Conclusion

The implementation of resilient strategies—hard protection strategies, soft protection strategies, floodable protection strategies, and retreat strategies—to any given site in immediate or inevitable threat of sea level rise, shall be analyzed and carefully applied to each site on a case-by-case basis. Not all resilient strategies are appropriate for the protection of any given site, and must give careful consideration first and foremost to the health and well-being of the population of the impacted community, the immediate and long-term health of the environment, and the long-term availability of resources to help sustain the community and resilient strategies. In the interest of safety and well-being of communities susceptible to the effects of climate change and sea level rise, it is in the best interest of community leaders, planners, and developers to begin implementing zoning and development policies that phases community development and occupancy away from areas prone to flooding and sea level rise. However, all is not lost and communities can help buy time. By minimizing the consumption of non-renewable resources, reducing the expulsion of greenhouse gases into the atmosphere, and prioritizing natural ecology over developed land the effects of climate change can be mitigated. By gradually returning to a state of living lightly on the land, communities can minimize the effects of climate change and sea level while nurturing positive ecological communities.

—End of Chapter—

Bibliography

Aerts, Jeroen C.J.H. Botzen, W.J. Wouter. de Moel, Hans. Bowman, Malcom. *Cost Estimates for Flood Resilience and Protection Strategies in New York City* . VU University Amsterdam, Institute for Environmental Studies, 2013.

Al, Stefan. *Adapting Cities to Sea Level Rise: Green and Gray Strategies.* Washington, DC: Island Press, 2018.

Boesch, D.F., L.P. Atkinson, W.C. Boicourt, J.D., Boon, D.R. Cahoon, R.A. Dalrymple, T. Ezer, B.P., Horton, Z.P. Johnson, R.E. Kopp, M. Li, R.H. Moss, A. Parris, C.K. Sommerfield. *Updating Maryland's Sea-level Rise Projections. Special Report of the Scientific and Technical Working Group to the Maryland Climate Change Commission.* Cambridge, MD: University of Maryland Center for Environmental Science, 2013, 1-22.

Boesch, D.F., W.C. Boicourt, R.I. Cullather, T. Ezer, G.E. Galloway, Jr., Z.P. Johnson, K.H. Kilbourne, M.L. Kirwan, R.E. Kopp, S. Land, M. Li, W. Nardin, C.K. Sommerfield, W.V. Sweet. *Sea-level Rise: Projections for Maryland.* Cambridge, MD: University of Maryland Center for Environmental Science, 2018.

Cazenave A, Llovel W. "Contemporary sea level rise." *Annu. Rev. Mar. Sci.*, no. 2(1) (2010): 145–73.

Chesapeake Bay Program. *History.* 2019. https://www.chesapeakebay.net/discover/history# (accessed September 2019).

—. *Population | Chesapeake Bay Program.* 2019. https://www.chesapeakebay.net/state/population (accessed November 2019).

—. *Population Growth.* 2019. https://www.chesapeakebay.net/issues/population_growth (accessed December 2019).

Climate Central. *See Your Local Sea Level and Coastal Flood Risk.* 2019. https://riskfinder.climatecentral.org/ (accessed September 2019).

DeConto, RM, Pollard, D. "Contribution of Antarctica to past and future sea-level rise." *Nature*, no. 531 (2016): 591-597.

Dent, Richard J. *Chesapeake Prehistory : Old Traditions, New Directions.* . New York: Plenum Press, 1995.

Dutton, A., A. E. Carlson, A. J. Long, G. A. Milne, P. U. Clark, R. DeConto, B. P. Horton, S. Rahmstorf, and M. E. Raymo. "Sea-Level Rise Due to Polar Ice-Sheet Mass Loss during Past Warm Periods." *Science*, no. 349 (2015).

Reframing Sea Level Rise. Directed by TEDx Talks. Performed by Dr. Andrea Dutton. 2017.

Eastern Research Group. *What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure.* National Oceanic and Atmospheric Administration, 2013, Appendix A.

Editorial Board. "Opinion | Rising Seas Are a Much Bigger Danger than Experts Thought." *Washington Times.* October 2019. https://www.washingtonpost.com/opinions/rising-seas-are-a-much-bigger-danger-than-experts-thought/2019/10/31/e9d85976-fb3b-11e9-8190-6be4deb56e01_story.html (accessed November 2019).

Ekman, M. "The world's longest continuous series of sea level observations." (Pure Appl. Geophys), no. 127 (1988): 73-77.
Ezer, T., Atkinson, L.P., Corlett, W.B., Blanco, J.L. "Gulf Stream's induced sea level rise and variability along the U.S. mid-Atlantic coast." *Journal of Geophysical Research - Oceans*, no. 118 (2013): 685-697.
Grumet, Robert S. "Bay, Plain, and Piedmont: A Landscape History of the Chesapeake Heartland from 1.3 Billion Years Ago to 2000." *The Chesapeake Bay Heritage Context Project*, 2000.
Hallegatte, Stepahne. Green, Collin. Nichols, Robert J. Corfee-Morlot, Jan. "Future flood losses in major coastal cities." *Nature Climate Change 3(9)*, 2013: 802-806.
Heck, Peter. "Planers eye concept for Stepney development." *My Eastern Shore MD*, November 2009.
Horton BP, Kopp RE, Garner AJ, Hay CC, Kahn NS, Roy K, Shaw T. "Mapping sea-level change in time, space, and probability." *Annual Review of Environment and Resources*, no. 43 (2018): 481-521.
Jevrejeva S, Moore JC, Grinsted A, Woodworth PL. "Recent global sea level acceleration started over 200 years ago?" *Geophys. Res. Lett.*, 2008.
Kent Conservation & Preservation Alliance. "Preliminary Cultural Landscape Assessment of Kent County, Maryland." 2019.
Lee, Samuel, and Chloe Ng. *Chester River Environmental Watershed Strategy (CREWS): A Comprehensive Management Plan.* University of Delaware - Water Resources Center, 2016.
Li, M., Z. Wang and P. Jia. "Predicting and visualizing storm surges and coastal inundation: a case study from Maryland, U.S.A." *In Remote Sensing of Typhoon Impacts and Crisis Management.*, n.d.
Lowery, Darrin. "The Paw Paw Cove Paleoindian Site Complex, Talbot County, Maryland." *Archaeology of Eastern North America, Vol. 17* , 1989: Eastern States Archeological Federation.
Maryland Sea Grant. *Bay Culture.* July 24, 2013. http://www.mdsg.umd.edu/bay-culture (accessed October 2019).
—. *Chesapeake Bay Facts and Figures.* June 2013. https://www.mdsg.umd.edu/topics/ecosystems-restoration/chesapeake-bay-facts-and-figures (accessed November 2019).
Mitrovica, J.X., Gomex, N., Morrow, E., Hay, C., Latychev, K., Tamisiea, M.E.,. "On the robustness of predictions of sea level fingerprints." *Geophysical Journal International*, no. 187 (2011): 729-742.
Moon T, Ahlstrøm A, Goelzer H, Lipscomb W, Nowicki S. "Rising oceans guaranteed: Arctic land ice loss and sea level rise." *Current Climate Change Reports*, no. 4 (2018): 729-742.
National Aeronautics and Space Administration. *The Causes of Climate Change.* Earth Science Communications Team. September 30, 2019. https://climate.nasa.gov/causes/. (accessed October 2019).
National Aquarium. *Chesapeake Bay.* 2019. https://www.aqua.org/blog/2017/September/Chesapeake-Bay-Watershed (accessed November 2019).

National Oceanic and Atmospheric Administration (NOAA). *What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure.* Eastern Research Group, 2013.

National Parks Service. *History.* August 1, 2019. https://www.nps.gov/chba/learn/historyculture/index.htm (accessed October 2019).

National Snow and Ice Data Center. *Quick Facts on Ice Sheets.* 2019. https://nsidc.org/cryosphere/quickfacts/icesheets.html (accessed October 2019).

Nerem RS, Beckley BD, Fasullo JT, Hamlington BD, Masters D, Mitchum GT. "Climate-change– driven accelerated sea-level rise." *Proceedings of the National Academy of Sciences of the United States of America*, 2018.

Nerem RS, Beckley BD, Fasullo JT, Hamlington BD, Masters D, Mitchum GT. "Climate-change-driven accelerated sea-level rise detected in the altimeter era." *Proceedings of the National Academy of Sciences, U.S.A.*, no. 115 (2018): 2022-2025.

Ortiz, Erik. "How to Save a Sinking Island." *NBCNews.com.* November 13, 2017. https://www.nbcnews.com/specials/deal-island (accessed October 2019).

Paolisso, Michael Jeffrey. *Chesapeake Environmentalism : Rethinking Culture to Strengthen Restoration and Resource Management. Chesapeake Perspectives.* College Park, MD: Maryland Sea Grant, 2006.

Ratcliffe, Susan. *Oxford Essential Quotations.* Oxford: Oxford University Press, 2016.

Rep, John Willim. *Tidewater Towns; City Planning in Colonial Virginia and Maryland.* Williamsburg, VA: Colonial Williamsburg Foundation, 1972.

Robert Snow Means Company. *RSMEANS Building Construction Cost Data.* Norwell, MA., 2018.

Scott, Michon. Lindsey, Rebecca. *2017 State of the climate: Sea Level.* August 2018. https://www.climate.gov/news-features/featured-images/2017-state-climate-sea-level (accessed November 2019).

Seller, Frances. "Amid Flooding and Rising Sea Levels, Residents of One Barrier Island Wonder If It's Time to Retreat." *The Washington post.* November 11, 2019. https://www.washingtonpost.com/national/how-do-we-continue-to-have-life-here-amid-flooding-and-rising-sea-levels-residents-of-one-barrier-island-wonder-if-its-time-to-retreat/2019/11/09/dff076c0-fcab-11e9-ac8c-8eced29ca6ef_story.html (accessed November 2019).

Strauss, B., et al. *Maryland and the Surging Sea: A vulnerability assessment with projections for sea level rise and coastal flood risk.* Climate Central Research Report, 2014, 1-29.

Sweet WV, Kopp RE, Weaver CP, Obeysekera J, Horton RM, Thieler ER, Zervas C. *Global and Regional Sea Level Rise Scenarios for the United States.* NOAA Technical Report, Silver Spring, MD: National Oceanic and Atmospheric Administration, 2017.

Town of Chestertown. "Chestertown Sustainable Communities." *Sustainable Communities Renewal Application.* February 2019.

U.S. Army Corps of Engineers. "Chesapeake Bay Oyster Recovery: Native Oyster Restoration Master Plan - Maryland and Virginia." 2012. https://www.nab.usace.army.mil/Portals/63/docs/Environmental/Oysters/CB_OysterMasterPlan_Oct2012_FINAL.pdf.

Usilton, Fred G. *History of Kent County, Maryland, 1630-1916.* 1916.

Yin, J., Schlesinger, M.E., Stouffer, R.J. "Model projections of rapid sea-level rise on the northeast coast of the United States." *Nature Geoscience*, 2009.

Zhong, L., M. Li and M.G. Foreman. "Resonance and sea level variability in Chesapeake Bay." *Continental Shelf Research*, no. 28 (2008): 2565-2573.

Zickfeld, Kirsten. Solomon, Susan. Gilford, Daniel M. *Centuries of thermal sea-level rise due to anthropogenic emissions of short-lived greenhouse gases.* Proceedings of the National Academy of Sciences of the United States of America, 2017, 657-662.