

# Exploring Tax Base Implications of Sea Level Rise in Westport, WA

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**Abstract**

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Global climate change has led to an accelerating trend of mean sea level rise, putting coastal communities around the world at risk from flooding, more intense storm surges, saltwater intrusion, and increased erosion. The coastal city of Westport, WA is vulnerable to sea level rise due to its low elevation, and even today experiences flooding during king tide events. This area will also be affected by any Cascadia Subduction Zone earthquakes and subsequent tsunamis in the future, and is predicted to be almost entirely inundated in a medium to large magnitude scenario except for a few narrow dune ridges with greater elevation. Due to these acute and longer-term risks, the city needs to explore adaptation solutions to safeguard human lives, infrastructure and capital investments, and the continuity of its governmental solvency. The uncertainty of sea level rise predictions and the infrequent and unpredictable nature of CSZ ruptures can lead to a lack of urgency in the planning response. In the long run, retreat to higher ground is the only adaptation solution that will reduce most hazard risk for Westport. Retreat is a controversial topic globally and in the local community that has cascading effects across all dimensions of the human experience. There are factors that “push” a community to relocate,

and factors that “pull” those people to resettle in a safer area. Successful models of managed retreat have used DAPP to make a plan that adapts as various thresholds are reached throughout the process. These thresholds can be incorporated into a community’s plan to signal when a push or pull factor reaches a critical point, and the next phase of the plan should be implemented.

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# Chapter 1: Introduction

## Problem Statement & Research Questions

People have lived in coastal areas for as long as we have been on earth, but our settlements have increasingly included capital-intensive infrastructure that is fixed in place. Prior to the arrival of white settlers, the Washington coast was home to indigenous peoples who thrived due to the natural abundance of food resources found there. These tribes tended to have more nomadic lifestyles that included moving locations seasonally to obtain resources. Moves could also occur due to environmental hazards; tribal groups have been adapting to their natural environments since prehistoric times.<sup>1</sup> Today, coastal cities have permanent infrastructure like roads, water and sewer systems, electric grids, and buildings. This infrastructure is expensive to install and maintain, and nearly impossible to relocate.<sup>2</sup> As sea levels rise, some of this infrastructure could be damaged by flooding and salt water intrusion or completely cut off from land, rendering it unusable. Incorporated cities along the coast have a duty to their residents to provide these public services, and will see a conflict with that commitment as the costs to do so become increasingly prohibitive. This problem will be exacerbated by the loss of property, and corresponding tax base contributions, when parcels become inundated or property owners choose to abandon at-risk areas for higher ground.

The professional and scientific community increasingly is coming to believe that some coastal communities will inevitably have to retreat from their current locations in order to remain safe and viable. The topic of managed retreat is daunting and often receives substantial pushback from residents when the topic is brought up. However, planning for an orderly retreat rather than a collection of uncoordinated community actions can help maintain social cohesion,

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<sup>1</sup> John Carey, "Core Concept: Managed Retreat Increasingly Seen as Necessary in Response to Climate Change's Fury," *Proceedings of the National Academy of Sciences* 117, no. 24 (June 16, 2020): 13182–85, <https://doi.org/10.1073/pnas.2008198117>.

<sup>2</sup> Judy Lawrence et al., "Implementing Pre-Emptive Managed Retreat: Constraints and Novel Insights," *Current Climate Change Reports* 6, no. 3 (September 1, 2020): 66–80, <https://doi.org/10.1007/s40641-020-00161-z>, 67.

make more efficient use of funds, and better prepare newly settled areas to adequately and equitably serve new residents. My interest in the topic stems from the notion that over the long run, many communities will need to implement retreat to some extent, and that there are many unanswered questions surrounding the economic implications on our current system before, during, and after retreat occurs.

Migration of populations broadly includes “push” factors and “pull” factors, associated with characteristics of the current place of residence and the receiving community, respectively. Retreat can be thought of as having both push and pull factors that impact a community and can become more or less urgent depending on environmental changes, the decisions of other cities and individuals, economic conditions, etc. These factors all combine to help calculate risk for an individual, household, or broader community, and can be weighted differently based on the person or group’s own values, circumstances and ideologies, and their willingness to tolerate risk.

In this thesis, I explore one push factor that has been modeled several times in academic studies:<sup>3</sup> the impacts of an increase in mean high water of the ocean on coastal properties, and its implications for property values and property taxes. I look specifically at the municipality of Westport, Washington. Local governments may be pushed into action based on their ability, or inability, to remain financially solvent over time. In order to continue providing services into the future, coastal municipalities will likely need to spend increasingly large sums of money to protect and maintain infrastructure and assets at risk of inundation.<sup>4</sup> These cities often generate a portion of their funds through property taxation of residents, often benefitting from the higher assessed values of coastal properties. However, as these properties become

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<sup>3</sup> Linda Shi and Andrew M. Varuzzo, “Surging Seas, Rising Fiscal Stress: Exploring Municipal Fiscal Vulnerability to Climate Change,” *Cities* 100 (May 1, 2020): 102658, <https://doi.org/10.1016/j.cities.2020.102658>; “When Rising Seas Hit Home | Union of Concerned Scientists,” accessed June 2, 2021, <https://www.ucsusa.org/resources/when-rising-seas-hit-home>.

<sup>4</sup> Kim S. Alexander, Anthony Ryan, and Thomas G. Measham, “Managed Retreat of Coastal Communities: Understanding Responses to Projected Sea Level Rise,” *Journal of Environmental Planning and Management* 55, no. 4 (May 1, 2012): 409–33, <https://doi.org/10.1080/09640568.2011.604193>.

inundated or at risk of inundation, these values may decrease the tax base.<sup>5</sup> If the properties are determined to be a total loss and need to be abandoned, or perhaps purchased through a buyout program aimed at victims of natural hazards generally funded by the federal government and left vacant, then the city will have completely lost that contributor to the tax base. Property tax revenues currently account for 18% of Westport's current expenses, per the 2021 Budget.<sup>6</sup>

Then I explore an area of suitable high-ground near Westport that has some key infrastructure already in place and which could make for an attractive site for relocation. This site has many "pull" factors that make it a contender for a planned managed retreat settlement, including several proposed uses generated in our College of Built Environments Winter 2021 studio course. I synthesize our existing analysis and design work to more fully imagine what this area could be for the citizens of Westport and the surrounding South Beach area if and when they choose to implement a managed retreat strategy.

This thesis aims to answer the following research questions:

- How will each increment of sea level rise from one foot up to nine feet affect properties in Westport, WA? Where are they located and to what extent will they be inundated?
- What are the impacts on the local tax base from inundation as sea levels rise? What do these impacts mean in terms of the city's current budgetary structure?
- What might a new community on higher ground look like and provide for current and future South Beach residents?

My findings from these research questions are meant to be used by Westport and its residents in discussions about adaptation and resilience options, up to and including retreat. I assert that a Dynamic Adaptive Pathway Planning (DAPP) model could be beneficial as they

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<sup>5</sup> Linda Shi and Andrew M. Varuzzo, "Surging Seas, Rising Fiscal Stress: Exploring Municipal Fiscal Vulnerability to Climate Change," *Cities* 100 (May 1, 2020): 102658, <https://doi.org/10.1016/j.cities.2020.102658>, 1.

<sup>6</sup> "CITY OF WESTPORT, WA," accessed June 2, 2021, <https://www.ci.westport.wa.us/departments/finance.php#outer-193>.

plan for an uncertain future with multiple hazards. I do not and can not recommend the exact time frames or actions that should be taken by Westport during their planning process, because these features of resilience planning should ideally be community-generated. I hope that my findings can be helpful to them in their planning process, perhaps to identify potential trigger points in a DAPP scheme, and help provide some direction and clarity during a complex and challenging process for the community.

In this chapter, I introduce the basic context of Westport and the concept of managed retreat. Chapter 2 provides a literature review covering the science of sea level rise, the various dynamics of coastal property values and management decisions, managed retreat as a resilience measure for communities, planning strategies for retreat including DAPP, the local planning context, and precedent studies that looked at property tax base impacts from sea level rise. Chapter 3 includes my methodology for my GIS analysis of Westport's taxable properties. Chapter 4 presents my findings and discusses what the implications are for each interval of sea level rise included. Chapter 5 is an analysis and case study of a predetermined uphill area centrally located in the South Beach region that could be used for managed retreat if and when that option is implemented by Westport. Chapter 6 summarizes my concluding thoughts and recommendations based on my knowledge gained through the research and writing of this thesis.

## Westport, WA Context

### Geographic Setting

Westport, Washington was the focus of the College of Built Environments 2021 winter studio co-taught by Professors Dan Abramson and Ken Oshima. Three groups of students focused on interventions in different geographic areas in and around Westport, aiming to increase the city's resilience in the face of environmental hazards due to its coastal position

along the Pacific Ring of Fire. I chose to use Westport as the case study location for my thesis to build upon the work our class did and to provide more information to relevant stakeholders with whom we had built a relationship.

Westport is a city on the Washington coast located in Grays Harbor County. It is an incorporated city of approximately 2,000 full time residents.<sup>7</sup> It is located on a peninsula that forms the south end of the mouth of Grays Harbor. This peninsula is partly natural, and partly constructed through human intervention. Jetties at the north and south entrances of the harbor have allowed for extensive accretion of sand, increasing the size of the point.

Due to its position with three surrounding edges of water, Westport is especially prone to climate change induced sea-level rise. Multiple predictions have emerged in recent years giving projections for time scales and depths of inundation along coastlines globally. Much of Westport is low-lying apart from several dune ridges that provide some higher ground. Further inland, there are bluffs that rise from about 40 feet of elevation up to around 400 feet in height. Westport could benefit from expanding the footprint and collective identity of their community to higher ground due to their current location's vulnerability to natural hazards, including sea level rise.

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<sup>7</sup> "Census - Geography Profile," accessed June 2, 2021, <https://data.census.gov/cedsci/profile?q=1600000US5377630>.

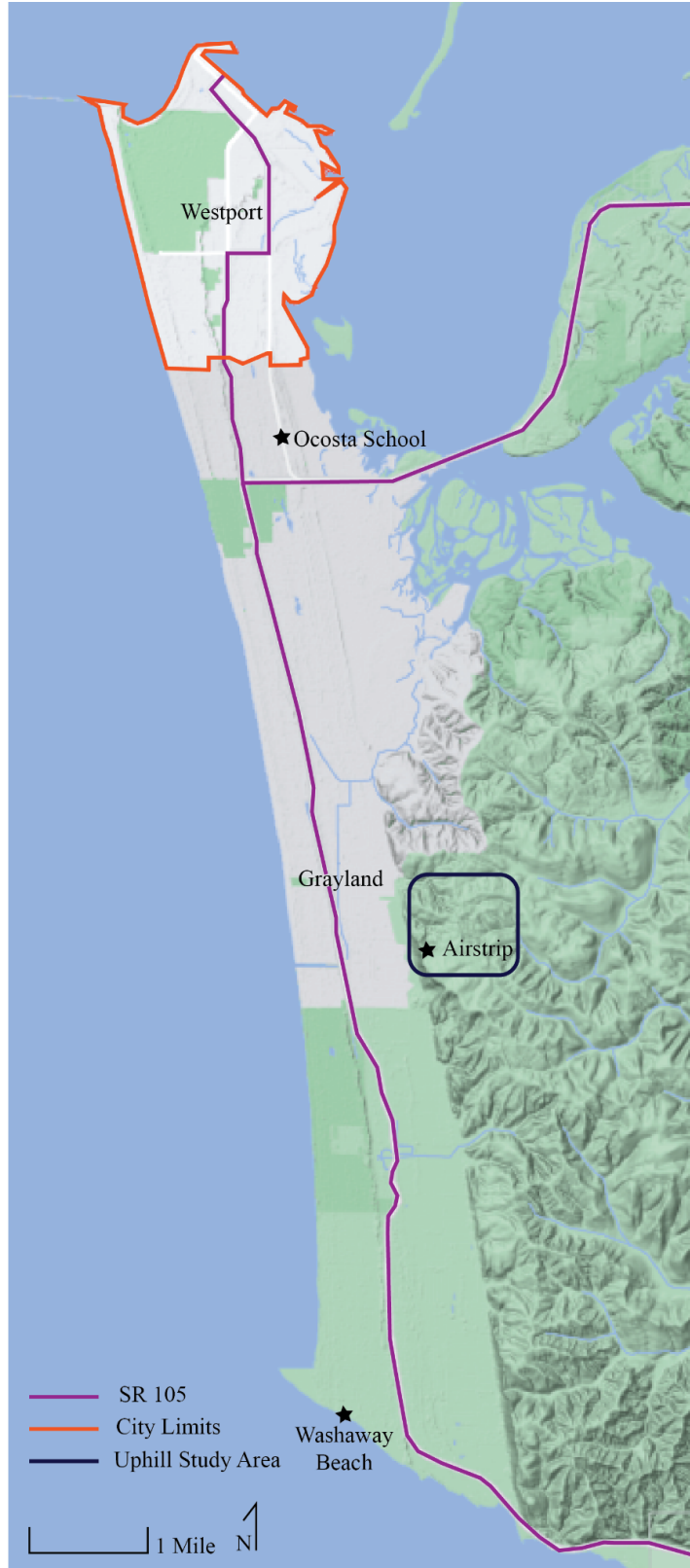


Figure 1: Context map of Westport and South Beach showing topography. Source: Google Maps.

## Hazards Overview

Besides the threat of sea level rise that is shared by coastal communities around the world, this area has some specific hazards that also can be motivating factors for relocating to higher ground. Westport and the coastline extending from British Columbia down to Northern California is prone to fault line earthquakes along the Cascadia Subduction Zone (CSZ).<sup>8</sup> These earthquakes are due to pressure building up as the North American tectonic plate slides over and pushes down the Juan de Fuca plate.<sup>9</sup> The slow movement over time has added elevation to the ground height of the area, and release through a fault slip will lead to land subsidence. This may be quite significant, potentially losing instantly as much as six feet of elevation in some locations, with some models even predicting subsidence of 9.8 feet.<sup>10,11</sup> The projected rise in mean global sea level therefore becomes compounded by the possibility of a significant loss of baseline elevation in this area. The CSZ has ruptured approximately 7 times in the last 3,500 years, giving an average recurrence period of 300-500 years.<sup>12</sup> The last known rupture occurred in 1700, detected through documentation of an “orphan” tsunami that was reported in Japan without being preceded by any discernible earthquake there, and that was corroborated by indigenous oral histories of the event on the North American coast, and evidence from forests of dead trees that seemed to have been suddenly thrust into salt water along the Washington

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<sup>8</sup> Bridgeview Consulting, “Grays Harbor County 2018 Multi-Jurisdiction Hazard Mitigation Plan Update Volume 1: Planning-Area-Wide Elements,” July 2018, 7-6.

<sup>9</sup> Bridgeview Consulting, 7-8.

<sup>10</sup> Bridgeview Consulting, 12-20.

<sup>11</sup> Bridgeview Consulting, 12-22.

<sup>12</sup> Bridgeview Consulting, 7-18.

coast.<sup>13</sup> We are therefore within the window of another rupture likely occurring; most experts agree it is not a matter of if it will happen again, but when, and how severely.<sup>14</sup>

Besides land subsidence in this area, there are other risks that come from the CSZ. The earthquake itself is likely to be quite large in magnitude, anywhere from 8.0-9.0 in most scenarios used for planning purposes.<sup>15</sup> This will cause intense shaking, damage to buildings and infrastructure, and may trigger liquefaction and landslides throughout the area. However, the most dangerous element comes after the shaking has stopped. The CSZ has the power to generate very large tsunami waves that can reach Westport within 25-40 minutes after the earthquake is felt.<sup>16</sup> Inundation depths at Westport from CSZ tsunamis of various magnitudes have been modeled by scientists, and while there is a great deal of uncertainty as to how severe an event is possible, the “maximum considered” event for which the Washington State Department of Natural Resources and Emergency Management Division are planning evacuation routes would inundate the great majority of the Westport peninsula,<sup>17</sup> and also flood the rest of South Beach’s relatively flat beach and bogland up to the base of the high-ground bluffs.<sup>18</sup> The tsunami will likely last for multiple hours and will consist of multiple waves of water coming inland and returning to sea.

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<sup>13</sup> Brian F. Atwater et al, “The orphan tsunami of 1700 — Japanese clues to a parent earthquake in North America,” Professional Paper 1707, U.S. Geological Survey, 2015, <https://pubs.usgs.gov/pp/pp1707/pp1707.pdf>.

<sup>14</sup> “Getting Ready for the next Great Cascadia Subduction Zone Earthquake,” Pacific Northwest Seismic Network, accessed June 22, 2021, <https://pnsn.org/blog/2020/01/27/getting-ready-for-the-next-great-cascadia-subduction-zone-earthquake>.

<sup>15</sup> Bridgeview Consulting, 7-21.

<sup>16</sup> Bridgeview Consulting, 12-22.

<sup>17</sup> Cara Donovan, “A Proposal for Using Geonarratives in Hazard-Adaptive Planning: Coastline Change in South Beach, Washington” (Seattle, WA, University of Washington, 2021).

<sup>18</sup> D. W. Eungard et al, 2018, “Tsunami hazard maps of southwest Washington—Model results from a ~2,500-year Cascadia subduction zone earthquake scenario,” Washington Geological Survey Map Series 2018-01, 4 sheets, scale 1:48,000, 11 p. text. [http://www.dnr.wa.gov/publications/ger\\_ms2018-01\\_tsunami\\_hazard\\_southwest\\_washington.zip](http://www.dnr.wa.gov/publications/ger_ms2018-01_tsunami_hazard_southwest_washington.zip).

## Community Response to Hazards

The community is aware of the risks from a CSZ rupture, and have signs throughout the area indicating tsunami evacuation routes to the higher bluffs. There is also a system of tsunami warning sirens that can be heard throughout South Beach if a tsunami is imminent. The Ocosta School was rebuilt through a local initiative to include a tsunami vertical evacuation structure (VES). The community worked together to create the first VES in the country without funding from higher levels of government, signaling their willingness to prepare for natural hazards. Due to the extreme risk of Westport becoming inundated by SLR, and future inability to provide services to residents, one adaptation measure that was discussed in the 2018 comprehensive plan update is managed retreat. Retreat is a hot-button issue that has been seeing increased attention in recent years, and is becoming widely accepted as inevitable in some locations.<sup>19</sup> The residents proposed exploring the possibility of annexing land on higher ground, but have not made significant movement towards planning actual retreat of the community. Some of this higher ground lies outside the city limits near the Ocosta School.

## Economic Context

Westport's economy and livelihoods are centered around the sea. There is not a way to provide resilience as well as adaptation to hazards through simply cutting off the connection between the two. Westport has a sizable marina on its northern point that is part of the larger Port of Grays Harbor, which also includes deep water shipping terminals, an airport, and rail infrastructure for moving freight in Aberdeen. The marina itself supports commercial fishing, charter boats for visitors, and pleasure boating. Commercial fishing provides a sizable economic impact on the area, itself generating around 1,000 jobs.<sup>20</sup> The charter boat sector is smaller but

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<sup>19</sup> A. R. Siders, "Managed Retreat in the United States," *One Earth* 1, no. 2 (October 25, 2019): 216–25, <https://doi.org/10.1016/j.oneear.2019.09.008>.

<sup>20</sup> Martin Associates, "The 2013 Economic Impact of the Port of Grays Harbor," October 2014, <https://www.aberdeenwa.gov/DocumentCenter/View/699/Appendix-F-Port-Economic-Impact-Report-pdf>.

still employs around 200 people directly to carry out.<sup>21</sup> Additionally, the area around the marina hosts warehouses and cold storage meant for storing and processing the catch of fishermen and preparing it for distribution. A shipyard also works on building ships, both luxury yachts and boats available for commercial uses. Besides attracting avid fishermen, Westport also hosts some of the best surfing along the Washington coast, and has become increasingly popular with visitors from nearby cities. During the COVID-19 pandemic particularly, many Seattle area residents have been taking mini-vacations to the area to escape the city or get a change of scenery while they work remotely.

Other key economic activities include the production of cranberries, and oyster and clam fisheries. Both of these industries are threatened by SLR in similar ways. Oysters and clams also require specialized environments to grow, consisting of shallow beds along the shore. The increased erosion due to increased storm activity and higher and more intense wave action threatens the habitats of razor clams that are key for their survival. The sea isn't only disrupting industry on the beach though. This area is a very large producer of cranberries nationwide, working as part of the Ocean Spray corporation. Cranberries grow in inland bogs, many of which are east of SR 105, relatively far from the beach. Saltwater intrusion into the water table is increasingly causing problems for the cranberry bog owners. The cranberries need a lot of fresh water during the harvesting process, and salt water can ruin the crop.

Due to the nature of the agricultural and food producing industries, and the seasonality of enjoyable weather, the economy in Westport has cyclical aspects. During the summer and fall months general tourism is higher than other times, but some of the best surfing comes in the winter. There are also different types of seafood that are fished for throughout the year, with crabbing being the most robust industry that sustains the area through the winter months.

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<sup>21</sup> Martin Associates, "The 2013 Economic Impact of the Port."



Figure 2: Photo of Westport's fishing activities by season in the Marina District. Photo by Trajan Smith.

## Chapter 2: Literature Review

### Sea Level Rise

There is near-unanimous consensus among the scientific community that human activity has influenced the global climate. This trend has numerous implications that will alter how ecosystems function in the future. One such trend is the rising and accelerating level of global mean sea level (GMSL). The Intergovernmental Panel on Climate Change (IPCC) released their Fifth Assessment Report titled *Climate Change 2014*, which discussed historic sea level rise rates compared to modern rates. The mean rate of global averaged sea level rise was very likely to be 1.7 mm/year between 1901 and 2010, and 3.2 mm/year between 1993 and 2010,

indicating a net increase in sea level rise which is accelerating over time.<sup>22</sup> This increase is attributable to thermal expansion of the sea water, where warming waters expand to occupy more space, the loss of ice sheets, sea ice, and glaciers, and a decrease in land water storage.

The IPCC developed four Representative Concentration Pathways (RCPs) which predict climate change outcomes based on varying amounts of greenhouse gas emissions globally depending on the global policy pathways chosen. The RCP 2.6, or low scenario, is representative of strict environmental monitoring measures to drastically decrease global emissions and keep warming below 2°C. RCP 4.5 and 6.0 are intermediate scenarios, and RCP 8.5 is assuming continued high greenhouse gas emissions.<sup>23</sup> The “business-as-usual” path of continuing current trends lies somewhere between RCP 6.0 and RCP 8.5. The Climate Impacts Group at the University of Washington College of the Environment created data visualizations of the findings from Miller et al. (2018), which shows the probabilities of various levels of SLR under different RCPs by a given year. Potential SLR given by 2100 for the area near Westport ranges from less than zero feet (in the event of continued uplift by tectonic action) to nearly 8 feet.<sup>24</sup>

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<sup>22</sup> R. K. Pachauri, Leo Mayer, and Intergovernmental Panel on Climate Change, eds., *Climate Change 2014: Synthesis Report* (Geneva, Switzerland: Intergovernmental Panel on Climate Change, 2015).

<sup>23</sup> Pachauri, Mayer, and Intergovernmental Panel on Climate Change, *Climate Change 2014*, 57.

<sup>24</sup> Ian Miller, H. Morgan, G. Mauger, T. Newton, R. Weldon, D. Schmidt, M. Welch, and E. Grossman, “Projected Sea Level Rise for Washington State - A 2018 Assessment,” prepared for the Washington Coastal Resilience Project, 2019  
<https://cig.uw.edu/resources/special-reports/sea-level-rise-in-washington-state-a-2018-assessment/>.

## VISUALIZATION #1: Projected sea level change by year

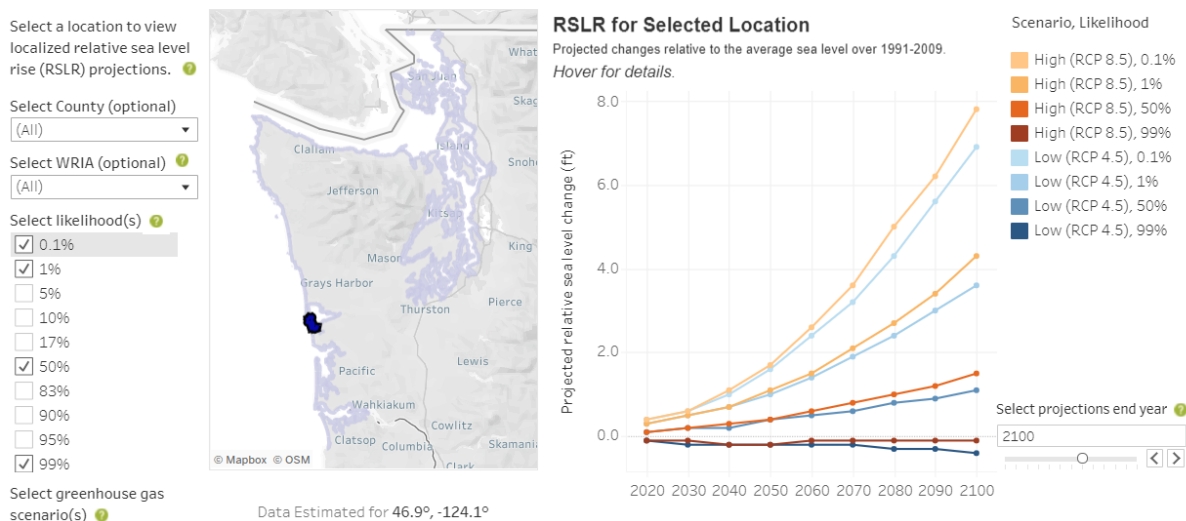


Figure 3: Projected sea level change by year for the area near Westport, WA.<sup>25</sup> Visualization from University of Washington Climate Impacts Group.

Scientific experts at the IPCC released a Special Report on the Ocean and Cryosphere in a Changing Climate that included chapter 4: “Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities” in which they discussed the risks associated with coastal communities due to the rise in sea level. While sea level has been higher in past geologic periods, we are now experiencing the effects of increased mean high water on human settlements whose design and construction is incapable of accommodating this change. An important observation made in the chapter is that many decisions affecting the coast between the next few decades to a century are ones that are made today, such as the siting of critical infrastructure, urban planning and development policies, financing schemes, and adaptation choices.<sup>26</sup> Logically, this makes sense due to the enduring nature of built structures and the multi-decade financing schemes needed to pay for them.

Rising sea level can be harmful to coastal communities in a myriad of ways: permanent inundation of mean water level or mean high tide levels; increasingly frequent or intense

<sup>25</sup> Miller, “Projected Sea Level Rise,” <https://cig.uw.edu/our-work/applied-research/wcrp/sea-level-rise-data-visualization/>.

<sup>26</sup> Pachauri, Mayer, and Intergovernmental Panel on Climate Change, *Climate Change 2014*, 327.

flooding; enhanced erosion; migration, loss, or imbalances of ecosystems; salt water intrusion to ground and surface waters; and decreased drainage capacity.<sup>27</sup> Of particular concern to Westport is the potential negative impacts climate change may have on their fisheries industry, however these are more directly related to ocean acidification and warming than sea level rise.<sup>28</sup> Sea level rise may have a more detrimental effect on their tourism activities such as surfing and beach-combing.

Adaptation solutions generally include protection via sea walls or wetland habitats, accommodation through raising structures, or retreat of key infrastructure and uses to higher and safer ground. The report notes that hard protection can be a costly investment that is better suited to high-density, wealthier communities, whereas retreat is more viable in sparsely-populated, lower-income areas. A consequence of doubling down on hard protection is that it can support path dependency in which development behind the protection intensifies due to the perception of safety.<sup>29</sup> This in turn increases the amount of capital at risk if the protection is breached or fails in another way.<sup>30</sup> This cycle increases the demand for hardened protection further into the future even as it becomes increasingly less effective against rising seas.

## Coastal Property Value & Adaptation Dynamics

Homes in coastal areas benefit from the natural amenities and recreational opportunities that the ocean and beaches provide. This adds value to the home, causing it to be more expensive to purchase than it would be if it were located elsewhere, even just a few parcels inland from the beach. This benefit sometimes needs to be balanced by potential buyers with the risk of inundation during a flood or storm event, and in the future will also be a concern due to climate-change induced sea level rise.

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<sup>27</sup> Pachauri, Mayer, and Intergovernmental Panel on Climate Change, *Climate Change 2014*, 375.

<sup>28</sup> Pachauri, Mayer, and Intergovernmental Panel on Climate Change, *Climate Change 2014*, 381.

<sup>29</sup> Lawrence et al., "Implementing Pre-Emptive Managed Retreat."

<sup>30</sup> Pachauri, Mayer, and Intergovernmental Panel on Climate Change, *Climate Change 2014*, 389.

For many homes currently at risk of flood damage, they are located on or adjacent to a federally-designated floodplain and may be eligible for highly discounted flood insurance rates through the National Flood Insurance Program (NFIP). Floodplain maps showing potential inundation under floods of varying magnitudes and likelihood can help homebuyers incorporate risk into their decision making. As has been demonstrated and discussed at length by economists, humans are not perfectly-informed rational decision makers and they may not incorporate risk adequately or effectively into their purchasing choices.<sup>31</sup> This can especially be true when tax dollars are subsidizing flood insurance that would otherwise be prohibitively costly at the true market price.

While some people may consider FEMA flood maps in their buying decisions, others may determine the amount of risk of a given property based on direct observation of flooding events. Researchers Atreya and Ferreira (2015) investigated the price discount, or the implicit flood risk premiums, on homes in Albany, Georgia that were affected by severe flooding in 1994 and found that properties that were inundated were discounted substantially more than comparable properties located within the mapped floodplain that were not inundated in the flood event.<sup>32</sup> Their explanation for this phenomenon was that, in addition to a regular “information effect” on home prices from knowing their location is in the floodplain, buyers were also reacting to seeing for themselves the damage and risk possible on homes that were not eligible for insurance. This can be categorized as the “availability heuristic,” where individuals assess the probability of an event’s occurrence based on the ease with which they can recall examples of that incident occurring in their own experience.<sup>33</sup> Predictably, the discounting of at-risk properties only lasted for a few years immediately following the flood as it faded from the collective

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<sup>31</sup> Asaf Bernstein, Matthew T. Gustafson, and Ryan Lewis, “Disaster on the Horizon: The Price Effect of Sea Level Rise,” *Journal of Financial Economics* 134, no. 2 (November 1, 2019): 253–72, <https://doi.org/10.1016/j.jfineco.2019.03.013>, 254.

<sup>32</sup> Ajita Atreya and Susana Ferreira, “Seeing Is Believing? Evidence from Property Prices in Inundated Areas,” *Risk Analysis* 35, no. 5 (2015): 828–48, <https://doi.org/10.1111/risa.12307>.

<sup>33</sup> Atreya and Ferreira, “Seeing Is Believing?”

memory of potential buyers. For this and other reasons, the authors concluded that portraying flood risk using the typical probability measures “may not be sufficient for the individuals never directly affected by flooding to prompt them to behave proactively to protect against flood risk.”<sup>34</sup>

One option to reduce the risk of flooding, particularly in densely populated, wealthy communities, is building hardened protection such as sea walls to hold back water. These may be implemented by a governing body, or put in place by property owners on their own beach to protect their investment. Sea walls can be problematic for neighboring properties, however, due to the way they change the natural wave breaks along the coast, leading to more erosion of sand on adjacent properties. A 2019 study by the Center for Climate Integrity estimated the costs that would be incurred by the year 2040 for sea walls needed to protect the public infrastructure of coastal communities across the country in a moderate sea level rise scenario (RCP 4.5). Their main goal is to show the extensive costs of hard protection and to hold major polluters accountable for their share of the costs. They estimate that Westport would need to build six miles of seawalls at a cost of \$171.9 million in order to mitigate risks from sea level rise, with a per capita cost of \$83,587. This is the 14th most costly of all cities in Washington.<sup>35</sup>

Another prominent adaptation strategy is beach nourishment, where sand is added to the beach to maintain its width. This is often paid for or subsidized by various levels of governments. The beach can be considered an impure public good<sup>36</sup> with recreational benefits, but beach nourishment can also provide an outsized benefit to property owners who live on the coast. Numerous studies have been conducted that look at the practice of beach nourishment.

Parsons and Powell (2001) estimated the cost over the subsequent 50 years of beach nourishment in Delaware compared to the costs of retreating from the beach as it migrates

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<sup>34</sup> Atreya and Ferreira, “Seeing Is Believing?” 847.

<sup>35</sup> “Climate Costs in 2040,” accessed June 2, 2021, <https://www.climatecosts2040.org/how-will-you-pay/washington-westport>.

<sup>36</sup> Megan Mullin, Martin D. Smith, and Dylan E. McNamara, “Paying to Save the Beach: Effects of Local Finance Decisions on Coastal Management,” *Climatic Change* 152, no. 2 (January 1, 2019): 275–89, <https://doi.org/10.1007/s10584-018-2191-5>.

inland. For this study, they relied on historic rates of erosion observed in Delaware. The anticipated costs of retreat were grouped into four categories: land, capital, proximity, and transition. Land costs were defined as the difference in value between the land with and without beach migration being allowed to take place. This land that would be lost due to beach migration is technically the loss of inland acreage and not beachfront acreage, as the beachfront land will still exist, it will just shift inward eliminating usable non-beachfront land. Therefore, the “amenity” value of coast proximity is not counted as a cost because it is simply transferred to the next inland property as the beach migrates over time. The capital costs include the loss of beachfront structures and infrastructure, and the changes in use and maintenance of them in the years prior to removal or inundation. The proximity costs describe the “welfare loss” that new structures would have had if the beach were stable.<sup>37</sup> The transition costs include the labor, capital, and raw materials that are required in order to remove structures from shoreline.

They note that the optimal strategy for each coastal community will be unique to them based on local conditions. For some, the removal of structures may even be the most cost-effective option. Taken together, the authors determined that the cost of beach nourishment makes more sense financially than retreat for the time period studied. The cost of beach nourishment was between \$15-20 million (2000\$) per decade, and the cost of retreat ranged from \$33 million at one foot of annual erosion up to \$622 million at 8 feet of annual erosion. At historical erosion levels, by 2050 retreat of Delaware’s coast was estimated to cost \$291 million. Most of these costs were incurred in the second decade of the study time period due to discounting and development patterns. The authors noted that “if the market adjusts for the impending future loss, the actual losses will be somewhat lower,”<sup>38</sup> because homeowners may opt to forgo improvements on their properties and local jurisdictions may opt to stop maintaining

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<sup>37</sup> Michael Powell and George R. Parsons, “Measuring the Cost of Beach Retreat,” *Coastal Management* 29, no. 2 (April 1, 2001): 91–103, <https://doi.org/10.1080/089207501750069597>, 94.

<sup>38</sup> Powell and Parsons, “Measuring the Cost of Beach Retreat,” 96.

infrastructure, resulting in lower property values along the coast; this consequently also leads to a lower quality housing stock in the case of retreat versus that of continued beach nourishment.

If paying to continue beach nourishment, often by the federal and state-level governments, is the most cost-effective way in the immediate future to preserve coastal capital and infrastructure, what might be the outcome if and when this is no longer the case and beach nourishment is stopped? McNamara et al. (2015) looked at beach nourishment along the coast of North Carolina in order to determine what might happen if there was a sudden removal of the federal subsidy, and they found that it could potentially trigger “a dramatic downward adjustment in coastal real estate, analogous to the bursting of a bubble.”<sup>39</sup> Historically, the federal government has paid for about  $\frac{2}{3}$  of the cost of beach nourishment, spending \$787 million between 1995 and 2002 alone.<sup>40</sup> The amount of sand needed to maintain beach width depends on how often storm events and natural erosion wash away the sand. Sand is also expected to increase over time as it becomes increasingly scarce. Both of these factors contribute to uncertainty of the long-term cost of beach nourishment. McNamara et al. note that beach nourishment as an adaptation measure is decided on a local basis, generally to provide maximum recreational value and storm-protection along the coast; this action can lead to a path dependency where real estate markets and future decisions about coastal management depend on continued investment in beach nourishment to protect valuable tax base properties and to satisfy political will to maintain the status quo.

For their study, the authors compared the property values of coastal properties with and without the added subsidy of beach nourishment. The difference between the two values, the traded value and the underlying value, are classified as a ‘wedge’ in percentages. This wedge was determined to be between 9% and 34% in most models, essentially saying that up to  $\frac{1}{3}$  of a coastal property’s value was due to federal subsidy of ongoing beach nourishment. If the federal

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<sup>39</sup> Dylan E. McNamara et al., “Climate Adaptation and Policy-Induced Inflation of Coastal Property Value,” *PLOS ONE* 10, no. 3 (March 25, 2015): e0121278, <https://doi.org/10.1371/journal.pone.0121278>, 1.

<sup>40</sup> McNamara et al., “Climate Adaptation and Policy-Induced Inflation of Coastal Property Value.”

government chose to stop paying for beach nourishment, the value of coastal properties would immediately decline by the percentage of this wedge. In the worst case scenario from their study, the authors found that a low value property subjected to high rates of erosion and hurricane recurrence would see a 95% reduction in property value due to subsidy removal.<sup>41</sup> This drastic result is partially due to the fact that this wedge percentage is higher for low-value properties because the subsidy makes up a larger share of the total value. Maintaining the status quo of beach nourishment over time would lead to the expectation of these property value reductions happening slowly over decades as climate change influences natural systems. Instead, if this practice were stopped abruptly it could lead to a coastal property value crash and subsequent decrease in property tax revenues for municipalities that are needed for critical infrastructure. The authors note that if the federal government does opt to reduce spending on beach nourishment, potentially after a time period where it no longer is the most economically feasible option, it should be done in a gradual, phased-out approach rather than a sudden cessation. They also question whether beach nourishment and its effects of reducing the demand for emergency disaster relief is the most efficient use of federal dollars compared to other subsidized programs.

The choices that we make regarding development policy along the coasts can have lasting impacts, because property assets are large, lumpy investments that have an expected lifespan of decades, if not longer. “Vulnerability of many coastal towns is not only attributable to exogenous shocks in the form of damage from large storm events, which garner much of society’s attention, but also reflects the intertwined nature of coastal property value, coastline behavior, and coastal management policy.”<sup>42</sup> As will be discussed later in this literature review, management choices can be a larger variable for potential future outcomes than the inherent unknowns associated with climate change.

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<sup>41</sup> McNamara et al., “Climate Adaptation and Policy-Induced Inflation of Coastal Property Value.”

<sup>42</sup> McNamara et al., “Climate Adaptation and Policy-Induced Inflation of Coastal Property Value,” 10.

In their 2019 study, Mullin, Smith, & McNamara investigated the coastal management outcomes of different local financing structures in regards to beach nourishment. The authors discussed that a wider beach as an outcome of beach nourishment is an impure public good because wealthier property owners who live on the beach benefit more than people who do not live on the beach, but it is still a public recreational amenity. The properties right on the beach have both the benefit of utilizing the recreational space and also increased protection of their own private investment from erosion and storm damages and a boost in their property value from a wider beach.

Beach nourishment is too costly of an adaptation option for individual property owners to undergo themselves. Typically, any private investment in adaptation would lead to a raising of structures or hardened barriers, neither of which contribute to a public amenity like a wider beach. In fact, raising structures may interrupt a viewshed and hardened barriers can restrict the size of the public beach further, both resulting in negative community outcomes. However, public financing of public goods for climate resilience can be challenging due to the fact that the benefits of many of them are in the future and not immediately apparent to taxpayers, and therefore are hard to justify an increased tax burden for today.

In the study, it was found that placing a higher tax burden on those property owners who benefited most from an increased beach width actually resulted in a wider beach equilibrium than in the case of a flat tax rate across all residents.<sup>43</sup> This scheme is an arguably more equitable distribution of the costs because it charges more to those with a higher ability to pay, who are also the group that benefits disproportionately. In this way differential property tax fees are similar to user fees charged by a municipality, because those with the highest demand pay more in an attempt to capture some of the added value of the “product” to those properties. This structure is used in communities on the east coast of the United States, and in practice beachfront property owners might pay rates as much as 10-15% higher than non-beachfront

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<sup>43</sup> Mullin, Smith, and McNamara, “Paying to Save the Beach.”

property owners.<sup>44</sup> Willingness of property owners to agree to this structure may also depend on the built form of the community. A “thin” community with a larger number of beachfront properties may be more amenable to this differential tax rate than a “thick” community with relatively fewer beachfront properties compared to inland properties, likely due to an increased level of sharing of the cost burden.<sup>45</sup>

Choices by municipalities in terms of which adaptation measures to pursue and ways in which they are financed influence the long-term coastal management of their beaches. Sometimes this can lead to path dependency of certain adaptation measures, particularly because they can protect residents while also allowing the community to retain its beach amenities which can be drivers for tourism. The authors note that the price of coastal real estate is tied to the “hedonic price of beach width (which reflects the value of storm protection and beach amenities capitalized into real estate prices and implicitly reflects future expectations about erosion.)”<sup>46</sup> Future expectations about continued protection from hazards is a common theme throughout many coastal communities.

Shi and Varuzzo (2020) had some important insights into the relationship between the value of individual properties and their impact on municipal budgets and land use decisions. Due to a substantial reliance on property tax revenues, cities can be negatively impacted by sea level rise as high-value properties are inundated. The authors note that “within the existing governance framework, low-lying cities therefore will need to compensate for tax base losses (whether due to federal buyouts, property devaluation, or disasters) by lobbying for more state aid, squeezing more money out of remaining areas, or risk losing revenues, residents, and service quality.”<sup>47</sup> In some places, the out-migration of people has already happened after disasters or flooding incidents. If there is not a competitive market in the area looking to buy

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<sup>44</sup> Mullin, Smith, and McNamara, “Paying to Save the Beach.”

<sup>45</sup> Mullin, Smith, and McNamara, “Paying to Save the Beach.”

<sup>46</sup> Mullin, Smith, and McNamara, “Paying to Save the Beach,” 280.

<sup>47</sup> Shi and Varuzzo, “Surging Seas, Rising Fiscal Stress,” 10.

properties, and especially if there are increasing flood insurance premiums for homes, people may choose to abandon their properties when they can't sell them. This phenomenon has the potential to create "climate slums"<sup>48</sup> consisting of abandoned properties falling into disrepair, which could compound fiscal stress on municipalities. Another factor that could harm the ability of coastal municipalities to finance regular functions and climate adaptation measures is the fact that major credit rating companies like Standard & Poor and Moody's are beginning to include climate hazard risks into their municipal bond ratings.<sup>49</sup> Shi and Varuzzo succinctly sum up the complex interplay of market forces, legislative and fiscal paradigms, and climate hazards by saying: "market corrections that realign property values with actual flood risks and insurance needs would accelerate the devaluation of coastal real estate, reducing property tax rolls for coastal cities and residential suburbs, and exacerbating fiscal stress in the most climate-exposed municipalities."<sup>50</sup>

Kousky voices the notion that seems logical: "retreat could be left to the market. As inundation occurs, property values should decrease, and people should move inland regardless of government policy."<sup>51</sup> However, she then proceeds to list key reasons why the market is not the optimal means of carrying out retreat. First, rising seas may motivate certain homeowners to invest in hard protective measures on their own properties, which can be problematic for adjacent properties. These seawalls also decrease the land available for public access through their construction and later through not allowing natural inland migration of the beach. This can pose questions about legality and equity as it takes away from the public amenity. A related issue is the idea that coastal ecosystems provide "public goods" to a community through storm surge mitigation, water quality improvements, recreational opportunities, and aesthetic

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<sup>48</sup> "My Drowning City Is a Harbinger of Climate Slums to Come | The Nation," accessed June 3, 2021, <https://www.thenation.com/article/archive/low-water-mark/>.

<sup>49</sup> Shi and Varuzzo, "Surging Seas, Rising Fiscal Stress," 10.

<sup>50</sup> Shi and Varuzzo, "Surging Seas, Rising Fiscal Stress," 10.

<sup>51</sup> Carolyn Kousky, "Managing Shoreline Retreat: A US Perspective," *Climatic Change* 124, no. 1 (May 1, 2014): 9–20, <https://doi.org/10.1007/s10584-014-1106-3>, 9.

enhancements. These natural habitats will also not be able to migrate inland where seawalls exist, and the public good will be under-provided by the market. Kousky notes that these goods possess a higher value in densely populated areas because there are more people benefiting from these ecosystem services and a lack of appropriate substitutes for them. Some areas of highly valuable ecosystems where land can be more cheaply put into conservation would be ideal candidates for limited development. Due to the abundance of high quality habitats around the Westport and South Beach areas, these shorelines would be ideal candidates for increased conservation, particularly in the event of retreat.

Another reason why the market may not stimulate retreat is because property owners are not always going to make the most optimal choices with their personal investments if they are not responsible for the full costs of their actions. Public taxpayer dollars subsidize coastal development through infrastructure investments and disaster aid. When rising seas may signal that a property owner should divest from their coastal property, their expectation about how the government will respond to flood damage may counteract that signal. Economic actors can carry assumptions about current land value trends, private property rights being upheld, financial stimulus from the government in the wake of disasters, and continued insurance coverage at discounted rates. Kousky also notes that “homeowners and developers may be interested in risks over only the next few decades, even though many buildings and infrastructure have a much longer life,”<sup>52</sup> likely due in part to the standard 30-year mortgage cycle and their perception of being able to sell the property before any serious issues arise.

People might also not have complete information about the risks, or they may have personal beliefs that bias them from fully considering and understanding risks. Kousky also cites Kahneman et al. (1982) saying that people are generally poor at evaluating risks because they often use “heuristics”, or rules of thumb, “that can bias them in predictable ways.”<sup>53</sup> Additionally,

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<sup>52</sup> Kousky, “Managing Shoreline Retreat,” 12.

<sup>53</sup> Kahneman et al., “Judgment Under Uncertainty: Heuristics and Biases,” Cambridge University Press, New York, (1982) quoted in Kousky, “Managing Shoreline Retreat,” 12.

personal values and beliefs can influence an individual's "perception of scientific consensus and their evaluation of whether someone is a 'knowledgeable and trustworthy expert.'"<sup>54</sup>

## Managed Retreat

Managed retreat is often defined as the intentional movement of people and assets away from an area at risk from one or more hazards in a pre-emptive, planned way. When thinking about managed retreat conceptually, there are a lot of unanswered questions and literature gaps, such as who decides to make the move, when it is appropriate, who pays for the costs, and the logistics of retreating from expensive fixed infrastructure that is characteristic of modern human settlements. Legal issues include private property rights and eminent domain issues. Community cohesion, livelihoods, and personal and collective identity are also important factors to be cognizant of. And even after the logistics of relocating are addressed, the question becomes about where people will go and how they will influence their new communities, be it an existing nearby city or a new town built from the ground up. While there are several examples of planning for retreat, from local to national and even international contexts, the processes and logistics of each are varied and complex.

According to flood risk expert Nicholas Pinter, the first documented instance of retreat of a community in the US took place in 1881 in Niobrara, MO when residents relocated after a major flood. They used livestock to pull their buildings to higher ground located a mile and a half away.<sup>55</sup> Since then, a few dozen domestic communities have made the choice to move to safer areas and approximately 1.3 million people have been part of a managed retreat globally over the last thirty years.<sup>56</sup>

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<sup>54</sup> Kahan et al., "Cultural Cognition of Scientific Consensus," *J Risk Res* 14, (2010):147–174, quoted in Kousky, "Managing Shoreline Retreat," 12.

<sup>55</sup> Carey, "Core Concept."

<sup>56</sup> Miyuki Hino, Christopher B. Field, and Katharine J. Mach, "Managed Retreat as a Response to Natural Hazard Risk," *Nature Climate Change* 7, no. 5 (May 2017): 364–70, <https://doi.org/10.1038/nclimate3252>, 364.

Native American communities are some of the most proactive groups in implementing managed retreat, enabled by their sovereign governmental status and more communal land ownership practices. The concentration of decision-making power in local hands excludes some bureaucracy that would otherwise be present. Numerous Alaska and Pacific Northwest Native tribes are working towards managed retreat as sea level rise, flooding, and other climate change processes affect their villages, with some receiving modest government funding or land grants.<sup>57</sup>

In Washington, about 30 miles north of Westport, the Quinault Indian Nation produced a full Village Relocation Master Plan for their community of Taholah, which is also at risk from tsunami and sea level rise inundation. The plan identifies facilities and infrastructure at risk and provides a master plan to locate their necessary services in the new relocation area on higher ground. The plan also includes a chapter summarizing economic opportunities and potential grant programs to help finance the project.<sup>58</sup>

The Isle de Jean Charles, LA relocation project is the most extensive ongoing relocation which was funded through a \$48.3 million Community Development Block Grant from the Department of Housing and Urban Development.<sup>59</sup> The process began with public outreach and information gathering in 2016, and had multiple iterations of determining needs and finding suitable relocation sites. The stakeholders being relocated ultimately got to vote between the final options of relocation site that met all the necessary criteria.<sup>60</sup> Construction began on the infrastructure of “The New Isle” in 2020.

President Obama instituted an inter-agency working group to try to tackle the concept of managed retreat and develop a national strategy during his last weeks in office. This working

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<sup>57</sup> Alan Parker and Zoltan Grossman, *Asserting Native Resilience: Pacific Rim Indigenous Nations Face the Climate Change* (Corvallis: Oregon State University Press, 2012), <https://muse.jhu.edu/book/19352>.

<sup>58</sup> “Taholah Village Relocation Master Plan,” accessed June 2, 2021, <http://www.quinaultindiannation.com/planning/projectinfo.html>.

<sup>59</sup> “Isle de Jean Charles,” accessed June 2, 2021, <http://isledejeancharles.la.gov/>.

<sup>60</sup> Pat Forbes, “Resilience in Vulnerable Communities: When Climate Change Forces Relocation,” (webinar hosted by the American Planning Association), attended January 29, 2021, <https://web.archive.org/web/20210602170012/https://www.youtube.com/watch?v=g1AtxDzVaBo>.

group was disbanded by his successor, so we still do not have a large-scale plan in place to address the vulnerability of our nation's coasts.<sup>61</sup> Other nations have done considerably more to prepare themselves for managed retreat. The Federated States of Micronesia have updated their development regulations to direct new development inland.<sup>62</sup> Kiribati, another island nation, has purchased land in Fiji in anticipation of the need to migrate in the future.<sup>63</sup> The Maldives have turned to creating land by pumping sand from the seafloor to protect their residents, the majority of whom live 3 feet or less above sea level.<sup>64</sup> The United Kingdom has embraced the idea of managed realignment, which allows the sea to reclaim and advance natural ecosystems representative of a healthy coastline as it overtops existing hard protective infrastructure.<sup>65</sup>

Overall, this topic is rapidly coming to the forefront of many discussions worldwide as it is increasingly being seen as a future inevitability for more communities. In 2019 the Climate Adaptation Initiative at Columbia University's Earth Institute organized the first conference focused on managed retreat that brought together scholars, scientists, and experts in various fields to discuss the topic.<sup>66</sup> The 2021 conference is scheduled for June 22-25. The Georgetown Climate Center at the Georgetown University Law Center released their Managed Retreat Toolkit in July 2020 which seeks to inform state and federal policy.<sup>67</sup> The City of Boston held a design competition to reimagine what their at-risk coastline could look like while accommodating for changing conditions into the future.<sup>68</sup>

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<sup>61</sup> "Obama's Final Push to Adapt to Climate Change - Bloomberg," accessed June 2, 2021, <https://www.bloomberg.com/opinion/articles/2016-12-16/obama-s-final-push-to-adapt-to-climate-change>.

<sup>62</sup> Hino, Field, and Mach, "Managed Retreat as a Response to Natural Hazard Risk," 368.

<sup>63</sup> Carey, "Core Concept," 13183.

<sup>64</sup> Norman Miller, "A New Island of Hope Rising from the Indian Ocean," accessed June 14, 2021, <https://www.bbc.com/travel/story/20200909-a-new-island-of-hope-rising-from-the-indian-ocean>.

<sup>65</sup> "U.K. Examples of Managed Retreat," Student Materials, accessed June 14, 2021, [https://serc.carleton.edu/integrate/teaching\\_materials/coastlines/student\\_materials/1001](https://serc.carleton.edu/integrate/teaching_materials/coastlines/student_materials/1001).

<sup>66</sup> "At What Point Managed Retreat? Resilience Building in the Coastal Zone | Climate Adaptation Initiative," accessed June 2, 2021, <https://adaptation.ei.columbia.edu/content/what-point-managed-retreat-resilience-building-coastal-zone>.

<sup>67</sup> "Managed Retreat Toolkit » Introduction - Georgetown Climate Center," [georgetownclimatecenter.org](https://www.georgetownclimate.org/adaptation/toolkits/managed-retreat-toolkit/introduction.html), accessed June 16, 2021, <https://www.georgetownclimate.org/adaptation/toolkits/managed-retreat-toolkit/introduction.html>.

<sup>68</sup> "Our Story," *Boston Living With Water* (blog), accessed June 2, 2021, <http://www.bostonlivingwithwater.org/about>.

## Managed Retreat as Resilience

The decision to retreat is not one that communities, neighborhoods, or individuals come to easily. Besides the logistical challenges and unanswered questions about the process, there is an emotional factor involved that can be hard to overcome. Connection to place, particularly for residents who have spent a significant portion of their lives in a given area, makes the idea of moving quite daunting. There is also little guarantee that key social connections and quality of life will be maintained in a new place, even with extensive planning. In order to be accepted by a community, retreat needs to be framed as an opportunity to expand the identity of a place, and to build a place that addresses and improves on any shortcomings of the original settlement.

A.R. Siders argues that retreat should be realized at a large scale, rather than by each individual household over time, in order to see the largest potential leap in policies and actions that benefit all people. She notes that “large-scale managed retreat [...] would provide an opportunity and incentive to redesign underlying norms and infrastructure. It would require institutional and legal reforms and behavioral changes. Difficult decisions about who pays and who receives support would inspire difficult conversations about past injustices and current inequalities.”<sup>69</sup> Addressing institutional inequities at a community-wide or national level could improve the outcomes for the most vulnerable people during the retreat process. This group would include renters, who are often in a gray area for the purposes of retreat. They tend to receive relocation assistance when a managed retreat strategy is being implemented, but it can be difficult to classify them in instances where they own a structure but lease the land as is the case in many mobile home communities.<sup>70</sup> Siders succinctly poses a huge question regarding equity: “is the goal to move anyone who is at risk (including millionaires and new arrivals) or to help those who do not have the resources to relocate on their own?”<sup>71</sup>

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<sup>69</sup> Siders, “Managed Retreat in the United States,” 216.

<sup>70</sup> Siders, “Managed Retreat in the United States,” 220.

<sup>71</sup> Siders, “Managed Retreat in the United States,” 221.

Forsyth and Peiser researched retreat in the context of moving to a fully built-out new settlement, in the vein of new towns built by governments or corporations, and how that could help reduce climate sprawl. They argue that having settlements with a range of services and housing types could help a community move as a unit to this place rather than scattering to various outskirts of existing urban areas, or displacing other households through climate gentrification. Moving communities as groups also aims to maintain key social connections that have been built over time that would disappear if people became scattered. They note that one effective way to maintain these ties is to relocate to an area close enough to the original settlement so that people can still commute to their jobs. This could be part of an argument for Westport to relocate to an area on the high-ground bluffs because it still allows for the high levels of employment found along the coast.

Forsyth and Peiser conclude that retreat will likely be a matter of where and when to move, not if one should move, and that a robust planning process can enhance resiliency for the community. Planning ahead can also help alleviate extreme fiscal burdens: “the cost of planned retreat is obviously paid by someone but in unplanned dispersal it is spread across a wide area, over time, and is often not clearly visible. Planned communities may be more efficient but need resources up front.”<sup>72</sup> Essentially, the costs will exist regardless of planning or not, and seeing them listed up front in a plan can be daunting but may actually be the better route than unplanned reactionary movement after a disaster or gradual sea level rise. Preparedness helps a community maintain resilience.

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<sup>72</sup> Ann Forsyth and Richard Peiser, “Lessons from Planned Resettlement and New Town Experiences for Avoiding Climate Sprawl,” *Landscape and Urban Planning* 205 (January 1, 2021): 103957, <https://doi.org/10.1016/j.landurbplan.2020.103957>, 8.

## Planning for Retreat

Because there is little doubt that some communities will inevitably have to retreat, it is important to start planning now for this eventuality. Lawrence et al. (2020) sought to articulate the myriad challenges inherent to pre-emptive managed retreat in order to help visualize the obstacles in the way of successful implementation. The authors define managed retreat as “removing people and their assets away from hazards preemptively and permanently.”<sup>73</sup> The opposite of managed retreat is unmanaged retreat where people gradually abandon their properties along the coast and there is voluntary movement as the hazards grow more bothersome, leading to a natural decline of the previous community. Some obvious issues that communities face with planning for retreat involve governance structures and current planning paradigms, legal and property rights issues, place-attachment and cultural considerations, finding and securing adequate new land, and funding.

One large question of managed retreat is that of responsibility regarding planning and implementing the actual steps needed to ensure successful retreat. For example, many people would logically assume that the government is responsible for facilitating this process, or at the very least would be there in the aftermath to assist citizens who needed financial or other kinds of support. The authors, however, ask the question of “the nature of the ‘social contract’ between citizens and the state in the context of climate change adaptation.”<sup>74</sup> Should the government be solely responsible for funding and facilitating retreat? How can public funding --taxpayer dollars from various levels of government--be organized and administered to coastal communities in a way that avoids moral hazard? A contentious area of moral hazard in the public discourse has long been that of federal flood insurance that allows people to reside and rebuild in risky areas at very low additional costs rather than the full cost it would truly be to rebuild structures on their own or with private insurance. This subsidized insurance is paid by

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<sup>73</sup> Lawrence et al., “Implementing Pre-Emptive Managed Retreat,” 67.

<sup>74</sup> Lawrence et al., “Implementing Pre-Emptive Managed Retreat,” 67.

taxpayers across the country, including land-locked states, but mainly benefits people living in coastal areas or low-lying floodplains along major rivers. In the US context, FEMA bears the majority of costs related to post-event beach nourishments and property buyouts. The authors note that many buyouts take the shape of owners receiving fair market value pre-disaster for their properties, but sometimes can look like an offer of replacement housing in a similar neighborhood that is not at risk from hazards. Governmental assistance will likely not look the same in other countries, however. In their article, Lawrence et. al phrase it as such: “in many countries, the main burden will fall on tax-payers. However, not all countries have the fiscal resources to socialize private losses associated with managed retreat.”<sup>75</sup>

In terms of buyouts, how is the risk due to sea level rise included in the fair market value being paid by the government? Is it included at all? Is the government paying more for a property because of its benefits derived from being on the coast in the efforts to remove people from the risk presented by that same coastal proximity?

Another major consideration includes determining the various levels of government that could or should be involved in retreat, and who has the power to ultimately make decisions. Intergovernmental cooperation is often time-consuming and restricted to inefficient solutions due to bureaucratic red tape. This is also a key issue with sharing costs for critical infrastructure necessary to facilitate retreat. The authors note that sub-national governments may have a harder time raising funds due to their more limited taxation options. New levies proposed at local levels often require a vote by the residents and therefore require public support and buy in order to pass. Support for an increase in public expenditure can be unpopular for property owners that may not directly benefit; covering private property damage or loss with public dollars is a controversial issue. Another complication includes raising money today to address future problems that often are not at the forefront of people’s minds. The nature of human’s perception of risk makes slow-moving hazards like sea level rise feel less pressing and

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<sup>75</sup> Lawrence et al., “Implementing Pre-Emptive Managed Retreat,” 76.

therefore not an efficient cause to direct money to when other issues feel more urgent. The authors propose that some dedicated funding mechanisms put in place to cover future costs of adaptation options would be an important step towards enhancing resiliency. Allowing the funding of managed retreat strategies to be paid for over multiple generations with pre-funding arrangements can help ensure intergenerational equity. It is also worth researching flexible design options for infrastructure constructed today that will allow assets to adapt more easily in the future, and to consider the role of nature-based approaches to resilience.

In her (2014) article *Managing Shoreline Retreat: A US Perspective*, Carolyn Kousky proposes a three-part strategy for the retreat of communities: first, reduce new development in areas deemed to be at risk. The next step is to adopt policies that allow for removal of development over time in a phased manner. Both of these steps can largely be achieved through changes to land use policies and zoning regulations, and stricter requirements when rebuilding or repairing after storm events. These changes can also apply to municipal and other governmental actions in regards to their own infrastructure. Jurisdictions could include education about their services and any tipping points beyond which repair or maintenance will be discontinued. The final part of Kousky's suggestions include taking advantage of any disaster scenarios to implement retreat. This could be a major factor in any decision made by Westport and the larger South Beach region. The risk of severe damage and land subsidence from a Cascadia Subduction Zone earthquake and tsunami present an opportunity to seek a fresh start post-disaster, or to accelerate any retreat efforts already underway at that point in time. The uncertainty of when this event may occur in the future poses questions about starting immediately or waiting for the hazard to act as a catalyst for change.

Limiting development in areas that appear to be suitable today could prove to be a tricky project. Kousky suggests identifying high-risk zones as a way to easily identify areas that should not be further developed. However, this poses the issue of creating a theoretical line beyond which people will consider safe. This can be problematic because future projections of sea level

rise are constantly being updated, and may manifest in certain areas differently than expected due to other environmental changes over time. The risky areas would have to adapt as new information was incorporated into sea level rise projections, but this may not be feasible if people have already invested in infrastructure beyond the first “safe” line. On the other hand, including such a large area in the high-risk zone to ensure protection from any future threat may end up eliminating options that would otherwise be safe for the natural lifespan of its intended use or never be impacted by the hazard at all.

Despite some questions about where the line should be drawn, this method could be used to help inform property owners and any prospective buyers during the purchase process of the risk to the land and structures due to future sea level rise. Kousky notes that “designated high-risk areas could also be used to more closely align the benefits and costs of coastal development to promote more economically efficient decision-making. Many costs of coastal development are borne by the government; subsidies for coastal development, such as public funding of roads, water, and sewerage, could be eliminated in the highest-risk areas. The federal government could adopt a policy of not funding major infrastructure or building in these areas. The Coastal Barrier Resources System (CBRS) offers precedent: federal funds are not available for coastal barrier lands designated by Congress. Development in these areas is allowed but not at taxpayer expense. CBRS does not restrict state funds, however.”<sup>76</sup> Some states have shifted towards similar policies, including Maine, Florida, and Massachusetts.<sup>77</sup> Policies like this put the onus of a reasonable response to costs versus benefits of coastal development on to the property owners as they make their decision on where to live. She continues by saying that “another possible justification for restrictions on development in high-risk areas is that development is a lump investment and can be difficult to undo.”<sup>78</sup> One proposed way to realize limited development along the coast is a National Seashore, which

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<sup>76</sup> Kousky, “Managing Shoreline Retreat,” 12.

<sup>77</sup> Kousky, “Managing Shoreline Retreat.”

<sup>78</sup> Kousky, “Managing Shoreline Retreat,” 11.

would essentially create public lands along all coasts in the U.S. as a public amenity for recreation and storm-buffering benefits, but would also allow for ports and other types of working shores.<sup>79</sup>

Another suggestion posed by Kousky to facilitate retreat is rolling easements. Essentially, as sea levels rise, the inundated area becomes part of a public easement and would depreciate the value of the shrinking property over time. Property owners may opt in this case to discontinue improvements on their properties as they get smaller over time, thus letting the value decline to zero. She notes “rolling easements effectively deal with uncertainty, harnessing the market to incorporate new information.”<sup>80</sup> A different alternative could be that the government purchases properties along the coast and then leases them back to tenants until they are deemed unsafe. This idea has large upfront costs of acquiring property, but does allow for some money to be regained through leasing rather than a simple buyout upon inundation.

## Dynamic Adaptation Pathway Planning (DAPP)

One promising strategy communities can use to plan for climate change impacts to their communities under conditions of uncertainty is Dynamic Adaptive Pathway Planning (DAPP). This strategy has been implemented when infrastructure investment and policy decisions need to be made in the near-term, but will have lingering implications in the long-term. This method seeks to include various scenarios like scenario planning does, and includes key tipping points which steer communities to an alternative adaptation pathway. Plans will specify actions to be taken now that leaves open options for adaptation in the future. The various pathways included in the model are often based on the levels of risk a community is comfortable with, and the types of solutions that fit with their unique circumstances.

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<sup>79</sup> Siders, “Managed Retreat in the United States,” 222.

<sup>80</sup> Kousky, “Managing Shoreline Retreat,” 14.

DAPP was developed by researchers in the Netherlands by combining two well-known frameworks for decision-making under conditions of uncertainty.<sup>81</sup> The first method that they incorporated is known as “adaptation pathways” which describes the “sequencing of actions over time, potential lock-ins, and path dependencies.”<sup>82</sup> The other method that DAPP was built on is known as “adaptive policymaking,” which provides contingency actions to help adapt to changing and new information. Both of these methods use similar signaling measures to help policymakers adapt their planning. Adaptation pathways use tipping points where “a particular action is no longer adequate for meeting the plan’s objectives,” and adaptive policymaking includes triggers, which “specifies the conditions under which a prespecified action to change the plan is to be taken.”<sup>83</sup>

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<sup>81</sup> Marjolijn Haasnoot et al., “Dynamic Adaptive Policy Pathways: A Method for Crafting Robust Decisions for a Deeply Uncertain World,” *Global Environmental Change* 23, no. 2 (April 1, 2013): 485–98, <https://doi.org/10.1016/j.gloenvcha.2012.12.006>.

<sup>82</sup> Haasnoot et al., “Dynamic Adaptive Policy Pathways,” 486.

<sup>83</sup> Haasnoot et al., “Dynamic Adaptive Policy Pathways,” 486.



Figure 4: An example of a DAPP map from a case study in the Rhine Delta of the Netherlands.<sup>84</sup>

DAPP was proposed in the managed retreat of stormwater and wastewater infrastructure in New Zealand, as documented by Kool et al. (2020) The article highlights that the main concern for the agencies in charge of such infrastructure is maintaining the balance of continued levels of service over time as the challenges from a changing climate get progressively worse. For this case study, the main questions were whether or not these infrastructures could be adapted over time to withstand environmental change, or if they would inevitably have to retreat, and if they did retreat, at what point or performance level does it become necessary to do so?

<sup>84</sup> Haasnoot et al., "Dynamic Adaptive Policy Pathways," 493.

Retreat is most likely to occur in a phased approach over a time scale of decades, particularly for costly infrastructure.

The Kool et al. article developed a DAPP prototype for retreat of wastewater and stormwater infrastructure near Wellington, New Zealand. To create this prototype, they had conversations with key local stakeholders “to identify thresholds for stormwater and wastewater services and retreat options, and for developing a comprehensive and area-specific retreat strategy comprising pathway portfolios, retreat phases, potential land use changes, and for exploring pathway conflicts and synergies.”<sup>85</sup> The adaptation thresholds that are a result of the process are the objectives of any given strategy within the scheme; when it is determined that the current pathway will fail to meet these goals, a pathway shift occurs. A key feature of the DAPP methodology is the inclusion of signals (warning signs of an imminent change in the current retreat stage) and triggers (decision points that mark the start of retreat phases). The failure to adapt to an alternative portfolio before an adaptation threshold is reached can lead to increased costs and system disruptions.

A key feature of DAPP that can alleviate some concerns with long-term investments in property and infrastructure in an uncertain future is that of defined triggers when the next adaptation pathway will be adopted. Transparency in these matters can potentially avoid conflict when an expectation of a certain level of service might exceed the capacity of the system to continue providing that service. Essentially, “signalling planning and land use changes could create more certainty for the community and relevant stakeholders, enabling them to anticipate changes in retreat phase and consequently infrastructure service levels.”<sup>86</sup> Being able to anticipate when policies may shift can protect developers and property owners who otherwise

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<sup>85</sup> Rick Kool et al., “Preparing for Sea-Level Rise through Adaptive Managed Retreat of a New Zealand Stormwater and Wastewater Network,” *Infrastructures* 5, no. 11 (November 2020): 92, <https://doi.org/10.3390/infrastructures5110092>, 1.

<sup>86</sup> Lawrence et al., “Implementing Pre-Emptive Managed Retreat,” 73.

would continue operating under the status quo, and could be surprised by plans to limit development or infrastructure maintenance in a given area.

Siders (2019) also brings up the idea of defining threshold conditions and tipping points for retreat. She gives one example of how DAPP could be thought of within a community: “a community could decide this year that when nuisance flooding occurs more than ten times in a month, they will relocate Main Street to a predesignated site at higher elevation.”<sup>87</sup> Setting these types of conditions also helps the members of the community plan accordingly and removes ambiguity from decisions made by a jurisdiction.

## Planning for Retreat in Westport

The City of Westport is covered under the Grays Harbor County Hazard Mitigation Plan, which has a supplemental section that is specific to the concerns of city residents. However, in the 500+ page plan, there is no mention of “retreat” as a means for increasing community-wide resilience. In fact, the only mention to be found of this idea came from the community engagement efforts of a 2018 University of Washington studio group assisting Westport update its Comprehensive Plan.<sup>88</sup> Consequently, the update to the Comprehensive Plan has numerous mentions of considering higher ground both within and outside the city limits as potential areas to site key infrastructure and vulnerable development in the future. There are also mentions of tsunami risk and sea level rise as potential drivers for a need to relocate in the future.<sup>89</sup> These updates signal increased acceptance of retreat as a potential pathway for Westport and the outlying communities to consider in the future. However, community sentiment is still very much

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<sup>87</sup> Siders, “Managed Retreat in the United States,” 223.

<sup>88</sup> Daniel Abramson, Catharina Depari, Charlotte Dohrn, Frank Gonzalez, Katherine Idziorek, Pegah Jalali, Lauren Keber, et al., “Localizing Hazard Mitigation: Recommendations for Westport’s Comprehensive Plan Update,” Seattle: University of Washington Institute for Hazards Mitigation Planning and Research, 2018, <http://mitigate.be.uw.edu/research-and-practice-2/research-and-practice/>; Helen Stanton, “Integrating Hazard Mitigation Strategies into the City of Westport’s Comprehensive Plan Update,” Thesis (M. Urban Plan.), University of Washington, 2019. <http://hdl.handle.net/1773/45278>.

<sup>89</sup> Stanton, “Integrating Hazard Mitigation Strategies into the City of Westport’s Comprehensive Plan Update,” 26.

rooted in rebuilding and protecting the current site of Westport, even as some comments signal the challenges inherent with doing so. The biggest challenge will be how the city and county move forward with planning efforts that still take into account the best interests of the residents and also include current information to make the best choices for the future.

Another venture, the Grays Harbor County Coastal Futures Project, was conducted by a team of researchers at Oregon State University led by Peter Ruggiero. The purpose was to quantify various resilience and economic measures for Grays Harbor County based on a suite of potential “futures.” In addition to refining sub-regional estimates of shoreline elevation changes in coastal Washington, the team engaged with numerous stakeholders in order to define the “alternate futures” for the County that combine climate data, anticipated population growth and associated development, and stakeholder-derived management policies for coastal development. The goal was to quantify and showcase the various outcomes of alternative management strategies on numerous community indicators. The alternative futures generated from the stakeholder input were categorized based on their approach to managing the shoreline in the future, and were separated into four categories: Baseline (continuation of present-day policies), Realign (relocation of infrastructure and/or people), Protect (building or strengthening shoreline armour), and Restore (prioritize habitat protection and conservation). Figure 5 shows the four categories.

## Grays Harbor County Policy Scenario Narratives

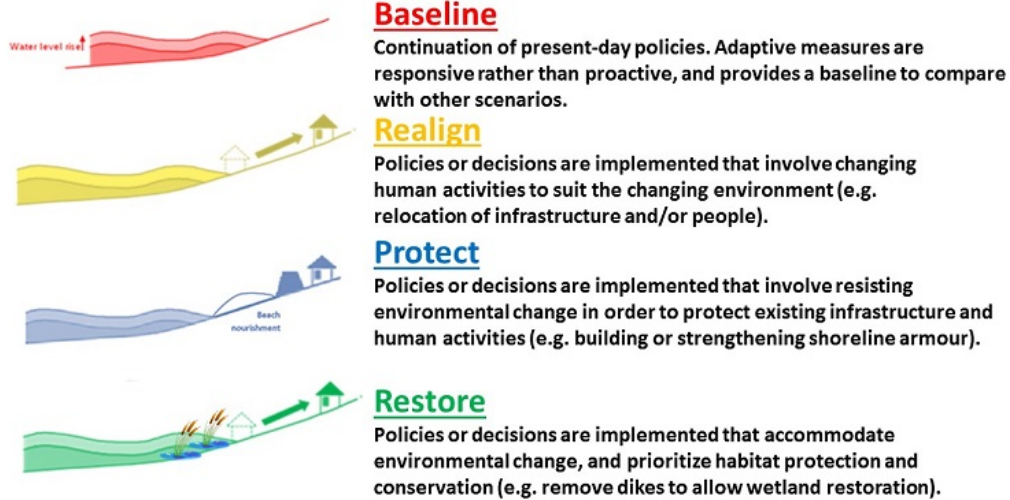


Figure 5: Policy scenario narratives from the Grays Harbor County Coastal Futures Project.

Management strategies included for discussion were methods of Beach Protective Structures (BPS) like riprap walls, Soft Protective Structures (SPS) as in beach nourishment through adding sand volume to dunes, proactive methods such as removing buildings from a hazard zone or building on the safest portion of a lot, raising infrastructure to avoid inundation, and relocating buildings and infrastructure. Table 1 shows the strategies used by each policy scenario.

*Table 1: The management strategies included within each policy scenario examined in the Grays Harbor County Coastal Futures Project.*

	<b>Baseline</b>	<b>Protect</b>	<b>Realign</b>	<b>Restore</b>
<b>BPS Construction</b>		X		
<b>BPS Maintenance</b>	X	X		X
<b>BPS Nourishment</b>	X	X		
<b>SPS Construction</b>				X
<b>SPS Maintenance</b>				X
<b>SPS Nourishment</b>				X
<b>Remove Buildings From Hazard Zone</b>			X	
<b>Remove Infrastructure From Hazard Zone</b>			X	
<b>Raise/Relocate to Safest Site</b>		X	X	
<b>Raise Infrastructure</b>		X		

A sophisticated software analysis allowed the researchers to play out the various scenarios and track things like the number of flooded buildings, the extent of erosion, the impacts to public beach access, and the costs for each strategy under low, medium, and high climate change scenarios through the end of the century. Figure 6 is a graph from the project website showing the number of buildings that they determined would experience flooding under each policy pathway and climate scenario. The graph clearly shows the large gap between the worst case scenarios (dotted lines) for the Baseline, Protect, and Restore pathways compared to the Realign pathway, with drastically fewer buildings being flooded later in the century when relocation to safer areas of buildings and infrastructure is implemented.

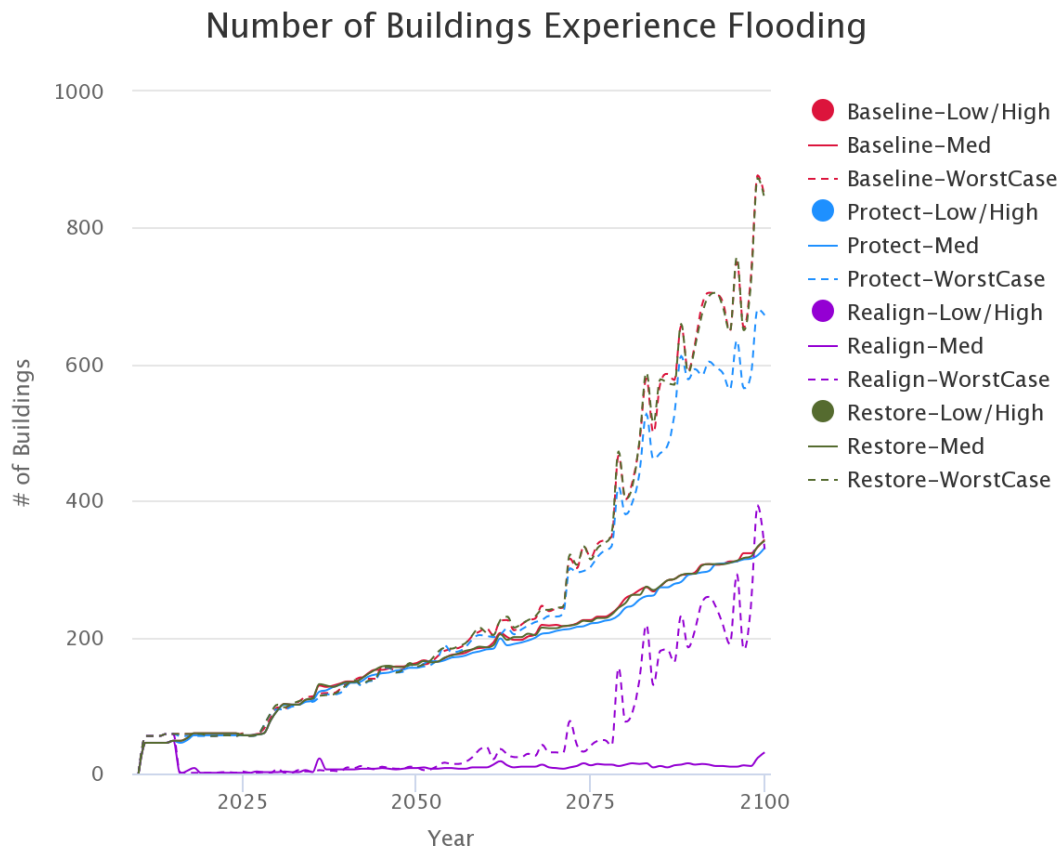


Figure 6: Graph from the Coastal Futures Project website showing the number of buildings experiencing flooding under each scenario.

Figure 7 is a graph that provides annual costs for each adaptation pathway in the various climate scenarios. Through discussion with lead researcher Peter Ruggiero, I learned that the exact cost figures should be treated more like comparative reference points rather than set in stone. The costs are difficult to predict and incorporate into the modeling, but the takeaway from the team's estimates should be the relative costs and required spending patterns of one pathway versus the others. Figure 8 shows the costs for each pathway just under the high (RCP 8.5) climate change scenario, and is easier to read. There are very noticeable differences in costs for the four policy scenarios. Both the Protect and Restore scenarios have large spikes early on, which could be due to the need to construct either BPS or SPS infrastructure rather than just maintaining existing infrastructure.

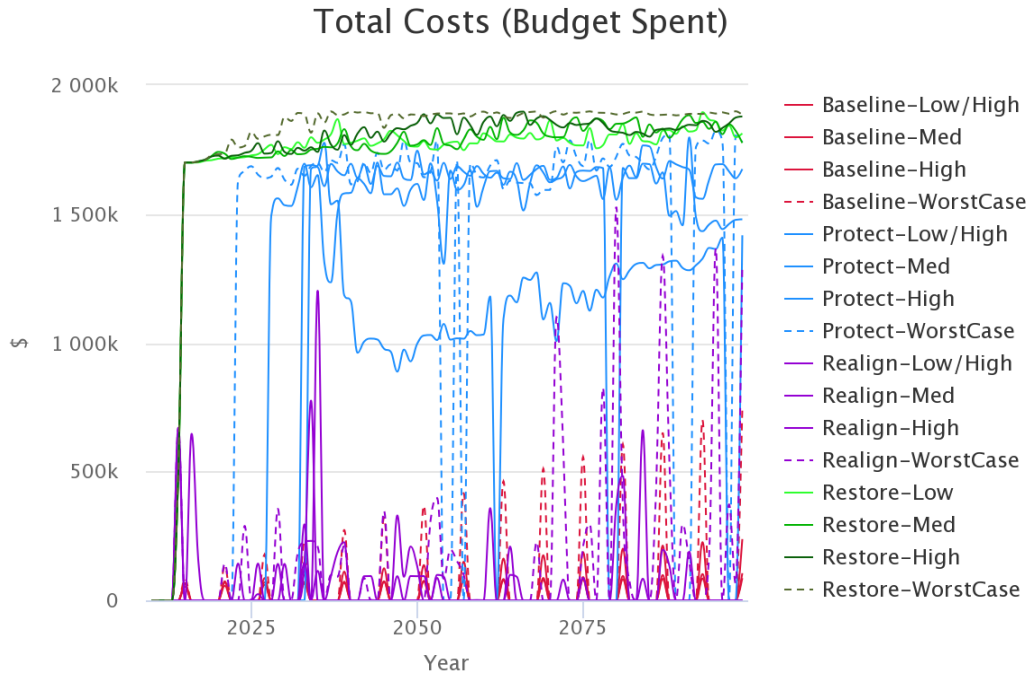


Figure 7: Graph from the Coastal Futures Project website showing the Total Costs (Budget Spent) for each climate change and management scenario combination.

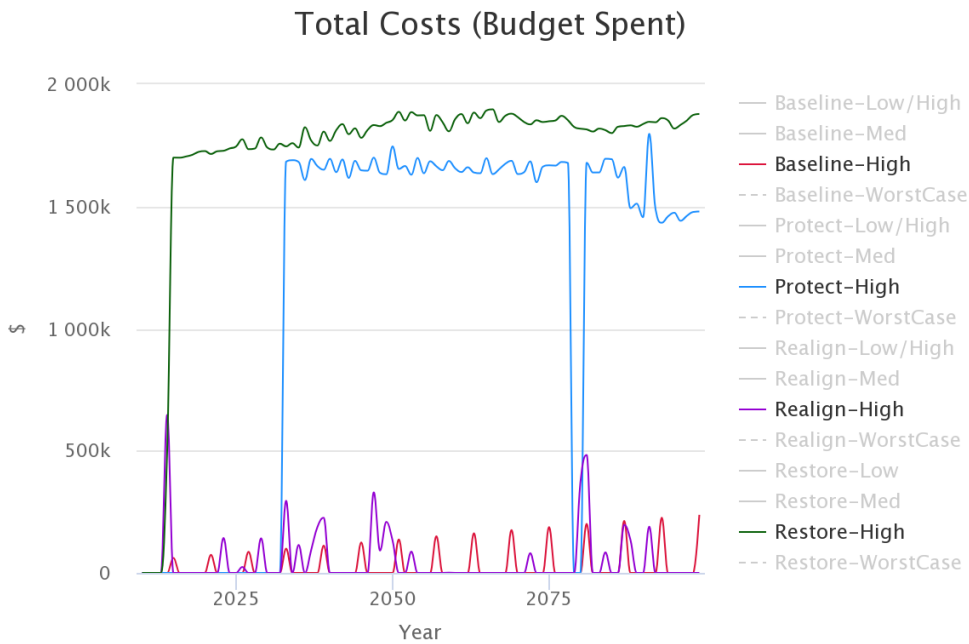


Figure 8: Graph from the Coastal Futures Project website showing the Total Costs (Budget Spent) for each management pathway in the High climate change scenario.

Figure 9 is a graph showing the unmet demand for spending for each scenario. All combinations are relatively close in this category aside from the costs of the Protect pathway

under the worst case scenario of climate change. This unmet demand is drastically higher than any other, diverging around the middle of the century. The costs of protecting the community increase as sea levels keep rising, making the necessary sea walls taller and taller.

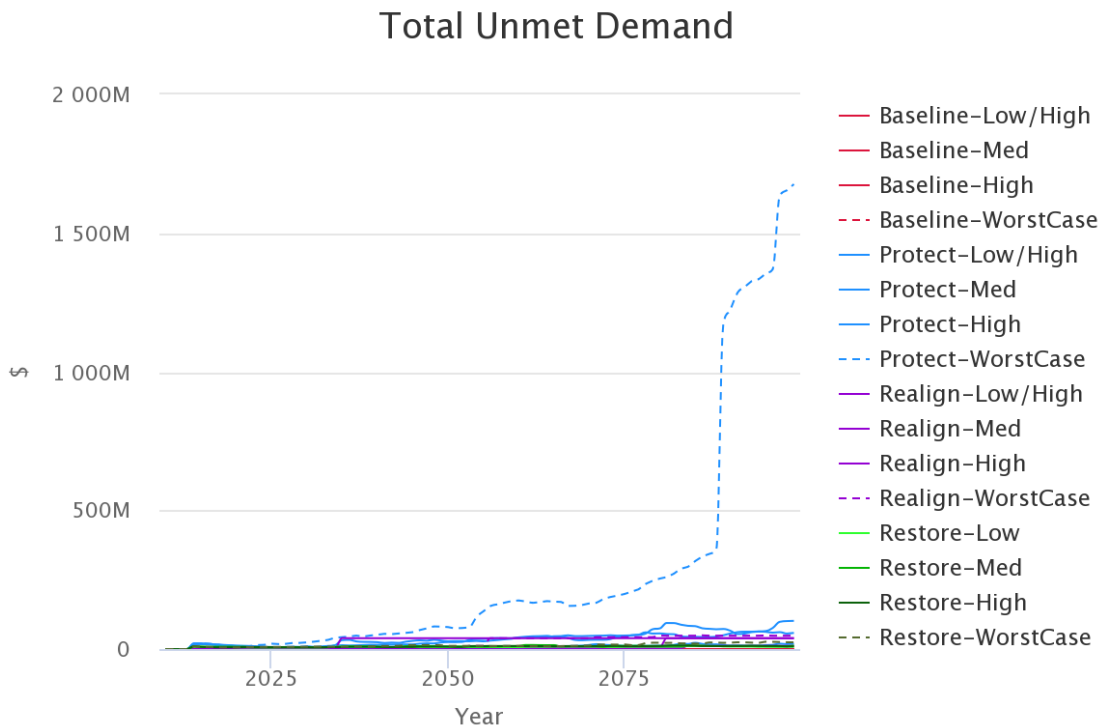


Figure 9: Graph from the Coastal Futures Project website showing total unmet demand for all scenarios.

The Coastal Futures team also worked with Tillamook County, Oregon. The scenario pathways were named differently in that iteration of the project, but the research team used the knowledge gained from both to reach an important conclusion about coastal management and planning for climate uncertainty. They found that “in general, model results suggest that human decisions can introduce greater variability to the impacts to the landscape by coastal hazards than climate change uncertainty.”<sup>90</sup> Figure 10 shows a graph of buildings that will be affected by

<sup>90</sup> Peter Ruggiero, John Bolte, Janan Evans-Wilent, Kai Parker, Cynthia Schwartz, Katherine Serafin, and John Stevenson, "ENVISIONING COASTAL FUTURES: EXPLORING ALTERNATIVE SCENARIOS FOR THE US PACIFIC NORTHWEST COASTLINE," Proceedings of Conference on Coastal Engineering, no. 36 (2018): 11.

flooding in Tillamook County over time under each of their scenarios. There are also arrows showing the range of climate variability and the range between scenarios based on the management decisions made. This shows that the range of possibilities is larger between different management options versus the different possible scenarios of climate change.

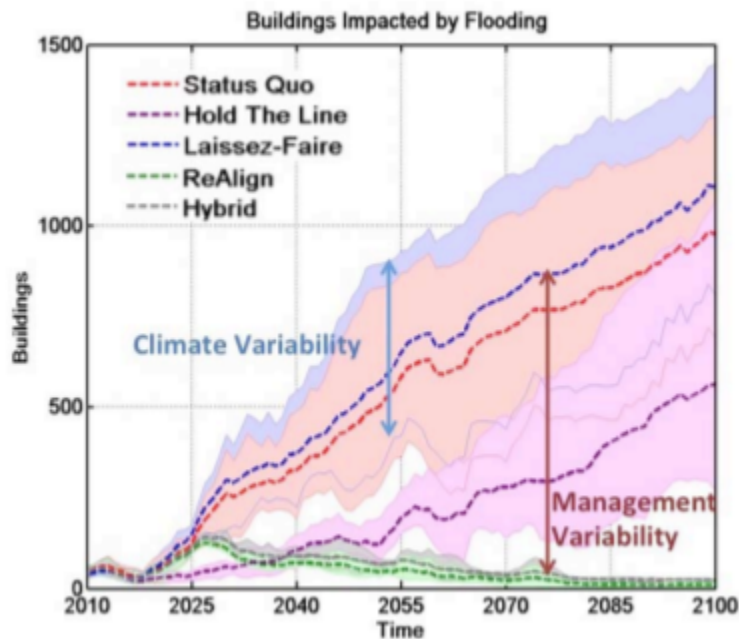


Figure 10: Graph showing the range in variability due to climate change and management policies on the number of buildings impacted by flooding in Tillamook County, OR.<sup>91</sup>

## Precedent Studies

Researchers Shi and Varuzzo (2020) conducted a study in Massachusetts looking at coastal cities and their varying vulnerability from sea level rise on municipal revenues. They found that some cities were more vulnerable than others based on their land use patterns, even as most cities continue to permit development in flood-prone areas because the resulting property taxes can help them reach their present day budgetary needs.<sup>92</sup> The authors note that many cities used land- or growth-based financing mechanisms in order to fund their operations,

<sup>91</sup> Ruggiero et al., "ENVISIONING COASTAL FUTURES," 11.

<sup>92</sup> Shi and Varuzzo, "Surging Seas, Rising Fiscal Stress," 1.

and these revenue streams not only incentivize development in hazardous areas, but also face increased vulnerability due to sea level rise. Impacts to municipalities are not likely to be uniform along any coast and may exacerbate existing inequalities, particularly if some communities have very limited alternative sources of generating revenue. And while the authors only studied the effects of sea level rise on property taxes, they note that “the full fiscal impact of climate change is likely much greater when accounting for multiple hazards, broader economic impacts, and rising local service and expenditure needs.”<sup>93</sup>

For their study, Shi and Varuzzo created a GIS model of sea level rise data from NOAA overlaid on parcel-specific data for coastal communities. This allowed them to determine which parcels and buildings would be affected at each level of sea level rise from 1 to 6 feet and calculate the amount of tax revenue that would be lost. Municipalities were then categorized by the amount of municipal revenue at risk as a percentage of the total municipal budget and mapped. More densely populated urban areas, that also tend to be more land-constrained, generally had higher levels of fiscal exposure due to sea level rise than less urbanized communities. One explanation for this trend could be that land-constrained communities often have fewer options for growth to expand the value of their tax base, and therefore may support high-end redevelopment of vulnerable coastal properties to boost their revenues.

This study looked at the value of the property separately from the value of the buildings located on each parcel. If the property is partially inundated, they didn’t necessarily assume that the whole value of the property would be lost. However, if the water touched any part of a building on the lot it was assumed to lose its value. This study also looked at permanent, year-round inundation rather than a threshold amount of flooding beyond which a property would be deemed unusable. This varies from a set of similar studies conducted by the Union of Concerned Scientists (UCS) in 2017 and 2018.

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<sup>93</sup> Shi and Varuzzo, “Surging Seas, Rising Fiscal Stress,” 1.

Their first report, *When Rising Seas Hit Home*, determines which coastal communities will be chronically inundated by rising sea level and approximates the timeframe in which it might happen. They emphasize that even prior to complete inundation, rising seas will cause increased nuisance flooding that makes conducting normal day-to-day routines challenging or impossible. At a certain recurrence threshold, this flooding is likely to be so bothersome that people will begin considering retreat from their homes. The UCS classifies “chronic inundation” as flooding that occurs 26 times or more within one year, and a “chronically inundated” community as one that has this frequency of flooding over 10% or more of its land area, excluding wetlands.<sup>94</sup> To put this measure in perspective, 26 times per year would average out to about two flood events per month; much of this flooding is also likely to occur during normal tidal processes.

The UCS determined their thresholds of inundation through prior literature on the subject, as well as consultation with experts in the field. However, the amount of flooding that is tolerable will vary for each community and each member within them. The authors pose some important questions: “a point will be reached when residents of many neighborhoods will have to think about living elsewhere as their lawns and yards and first floors become unusable, as their businesses remain shuttered and inaccessible, as land where generations of people have lived and died is overwhelmed by seawater. What is the measure of loss for a city becoming chronically inundated? For locals, it could feel incalculable. How much would they be willing, or able, to invest to delay these losses?”<sup>95</sup> There is a wide range of inundated communities between the lowest and the highest sea level rise prediction scenarios, however the authors determined that Westport would not reach the level of chronic inundation in any scenario. This is likely partly because of the topography along the western shore of Westport, with the dune ridges acting as natural barriers. Additionally, they used the US Census Bureau’s county

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<sup>94</sup> “When Rising Seas Hit Home | Union of Concerned Scientists,” accessed June 2, 2021, <https://www.ucsusa.org/resources/when-rising-seas-hit-home>, 1.

<sup>95</sup> “When Rising Seas Hit Home | Union of Concerned Scientists,” 16.

subdivisions to define the boundaries of each community. The additional land south of the Westport city limits that is generally safer from inundation likely made the community fall below the 10% threshold for chronic inundation. Wetland areas were also not counted as usable land.

Importantly, nearby Aberdeen-Hoquiam will become chronically inundated by 2100 under the high sea level rise scenario of 6.6 feet by the end of the century, falling right at the 10% threshold to be considered chronically inundated.<sup>96</sup> The report also mentions Chinook, WA, located south of Westport near the border with Oregon. Chinook, “by the end of the century in the intermediate scenario, [...] would become an island every other week, and about one-third of its homes would flood.”<sup>97</sup> This community is near Naselle, WA, which is at high risk of inundation under all sea level rise scenarios, becoming chronically inundated by the end of the century with low sea level rise and as early as 2045 with high sea level rise.<sup>98</sup>

The 2018 UCS study, *Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate*, built upon this knowledge and sought to quantify the impending losses of property in coastal communities due to sea level rise. Again, the researchers looked at a low, intermediate, and high sea level rise scenario to determine how many properties are at risk, their current value, and their contribution to local tax bases. Their findings are staggering; the analysis determined that by the end of this century, 2.5 million residential and commercial properties along the coasts will be at risk of chronic flooding. The current value of these properties is \$1.07 trillion.<sup>99</sup> Aside from the value of these properties, flooding will also cause damage to roads, bridges, ports, energy infrastructure, and so much more that is not included in this UCS report. Not only are these costly assets to build and maintain, they are also crucial for conducting daily life and commerce. Economic losses due to the inundation of property and infrastructure will actually be much greater than the simple assessed value.

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<sup>96</sup> “When Rising Seas Hit Home | Union of Concerned Scientists.”

<sup>97</sup> “When Rising Seas Hit Home | Union of Concerned Scientists,” 29.

<sup>98</sup> “When Rising Seas Hit Home | Union of Concerned Scientists.”

<sup>99</sup> “Underwater | Union of Concerned Scientists,” accessed June 2, 2021, <https://www.ucsusa.org/resources/underwater>, 2.

The importance of this research is summed up well by the authors here: “there are many stakeholders in the coastal real estate market, from individual homeowners and business owners, to lenders, taxpayers, developers, insurers, and investors. Whether a property market crashes, or property values steadily decline in response to worsening flooding, these stakeholders are poised to sustain large collective losses. Many coastal residents, whether they own homes or not, will be affected as shrinking property tax bases prevent cities and towns from fully funding schools, emergency services, and infrastructure repairs, or as property tax rates rise for all residents to compensate for those properties devalued by flood risks.”<sup>100</sup> The authors also note that they used the high sea level rise scenario for many of the numbers quoted in the paper, because they felt that people would have a low risk tolerance in regards to their homes because it is often the largest household asset.

The report classified communities by their zip codes. Westport is within the 98595 zip code, but this area also includes properties south of the city limits up to where State Route 105 turns east. This report also used the Zillow Transaction and Assessment Database (ZTRAX). Their results for the 98595 zip code can be found in the table below. The authors did mention that Washington was one of 8 states where chronic inundation would have disproportionate impacts on low- to moderate-income households. In these states, “60 percent or more of the homes at risk of chronic inundation within the next 30 years are valued below the state median.”<sup>101</sup>

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<sup>100</sup> “Underwater | Union of Concerned Scientists,” 3.

<sup>101</sup> “Underwater | Union of Concerned Scientists,” 10.

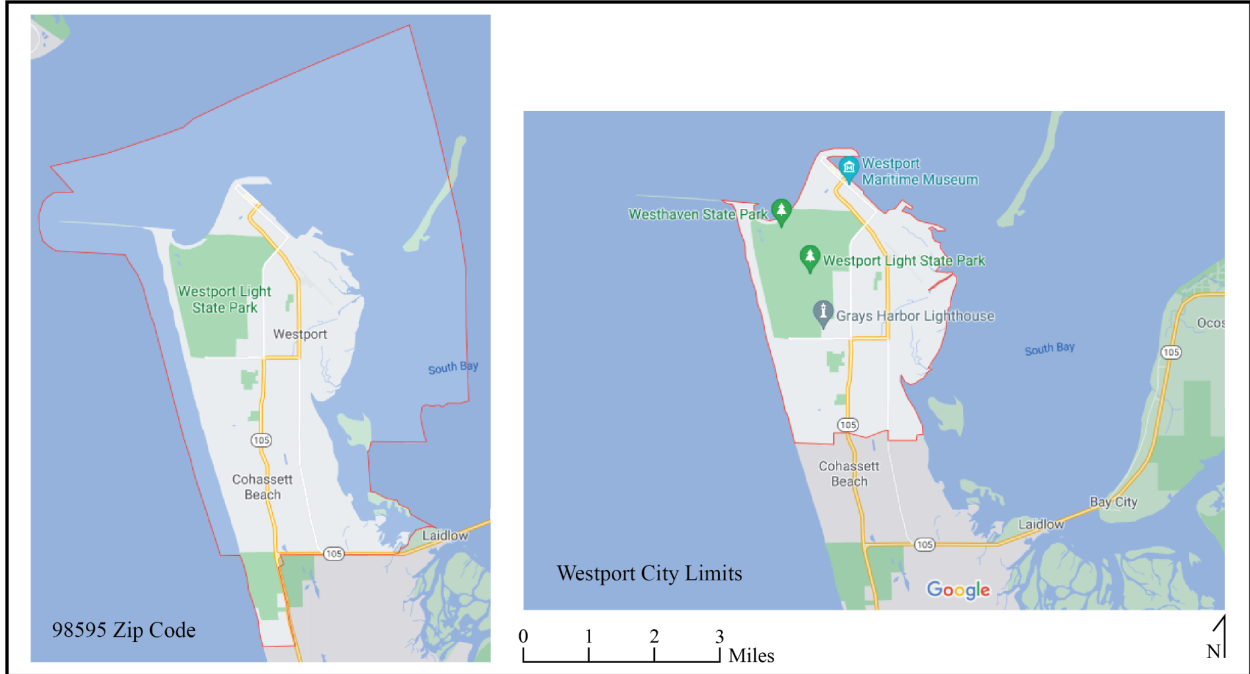


Figure 11: Map comparison of 98595 zip code and Westport City Limits. Images from Google Maps.

Table 2: UCS Underwater Data for 58595<sup>102</sup>; Property Tax at Risk includes contributions to all relevant taxing districts, not just those collected by the City of Westport.

Total Homes	Total Value	Total Property Tax	Emissions Scenario	Year	Homes at Risk	Value at Risk	Property Tax at Risk
3,024	\$386,260,598	\$3,908,859	High	2045	47	\$4,336,584	\$49,831
				2060	86	\$7,809,086	\$85,176
				2080	178	\$16,678,503	\$185,118
				2100	433	\$44,154,357	\$524,184
			Med	2060	47	\$4,336,584	\$49,831
				2080	86	\$7,953,116	\$86,909
				2100	137	\$12,313,573	\$133,741
Low	2100	43	\$3,864,799	\$43,505			

<sup>102</sup> "Underwater | Union of Concerned Scientists."

## Chapter 3: Methods

In order to analyze how different increments of sea level rise will impact Westport, I used GIS to map the new mean high water level at each point. Using these maps, I can see where and to what extent a parcel is expected to be inundated with water in the future. The majority of the GIS data was sourced from the Grays Harbor County online GIS portal which provides data to the public to use. The sea level rise layers were sourced from NOAA.<sup>103</sup> By overlaying each increment of sea level rise data, I can find parcels that are inundated partially and fully and determine at which foot of SLR each one is at risk.

There are limitations to this type of analysis, particularly in this area. Land uplift and subsidence can affect land elevation and subsequent height compared to mean high water as it rises. Additionally, mean high water is not a static metric due to the cycle of high and low tides, seasonal fluctuations like king tides, and wave action. Calculating heights of waves is a very localized exercise and depends on wind, beach dynamics, storm events, local water temperature, etc. This type of analysis is therefore not suitable to be used for exact predictions of SLR, but rather as a general guide for at-risk properties and infrastructure.

Other similar studies have used Zillow's ZTRAX data which includes recent sales records combined with assessor appraised value.<sup>104</sup> This data is not accessible generally for master's research projects, but it would be an interesting comparison to conduct the same study with both sets of data and note any differences in results.

The parcel data layer contained crucial information such as assessed building and land values from the most recent appraisal for 2020 property tax calculations. In order to only include parcels within the Westport city limits, I created a new layer that only included parcels with the tax code WE172 H2. This code refers to parcels that are required to pay property taxes to the City of Westport along with other important entities like the Ocosta School District, the Hospital

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<sup>103</sup> "Sea Level Rise Data Download," accessed June 3, 2021, <https://coast.noaa.gov/slrdata/>.

<sup>104</sup> Shi and Varuzzo, "Surging Seas, Rising Fiscal Stress."

District #2, and E.M.S. and Fire Districts. Table X shows the various levy rates for each entity within the WE172 H2 tax district.

*Table 3: Levy rates for each applicable category within the WE172 H2 taxing district for 2021.*

<b>Tax District WE172 H2</b>	
<b>Levy Name</b>	<b>Levy Rate</b>
City Basic	0.9149732
State School #1	1.9277413
State School #2	1.019795
County Current	1.4233377
Veterans Relief	0.0049379
Port	0.3462286
Library	0.323658
Hospital #2	0.6010684
E.M.S.	0.439606
Fire District	1.3181979
Fire Bond	0.8185601
School Bonds	1.678052
School Enrichment	1.7789674
<b>Total</b>	<b>12.5951235</b>

The Grays Harbor County Assessor’s Office is responsible for determining the market value of real property for the purposes of calculating property tax. The assessed property value is not raised in order to increase budgets for various taxing districts. Rather, taxing districts determine their budgets internally and then have them approved by the legislative authority that oversees them. As the cost of providing public goods increases, these budgets increase as well. Taxes are also collected to cover the cost of levies that have been approved by the voters for specific purposes. The Assessor then uses the final budgets to determine the necessary tax rates in order to generate the required revenues. The assessed value of real property is then multiplied by that tax rate per each thousand dollars of assessed value to find the tax amount a property owner will pay. For my analysis I used the City Basic levy rate to determine which taxes

were going directly to the City, and the total combined rate of all levies to calculate total property tax contributions of each property.<sup>105</sup>

Per the City of Westport's 2021 Budget, property tax revenues feed into the Current Expense Revenues, which is the largest value by subcategory within Governmental Funds. Other subcategories within this group include the General Reserve Fund, various GO bonds, an Unemployment Fund, and a Real Estate Excise Taxes (REET) Fund. The other major category within the budget is Enterprise Funds which include services like garbage, water, and sewer. The budgeted amount for Current Expenses in 2021 is \$2,679,768, and the total for Governmental Funds is \$4,974,580.<sup>106</sup> This makes up a little less than half of the total city budget for 2021 of \$10,498,790, the majority of which is generated by enterprise funds. Property taxes are one contributing source of revenue for the Current Expense category, and are budgeted to generate \$221,500 in 2021. Property taxes are just one of the various forms of taxes that make up the revenues for this fund; overall, 71% of the Current Expense category comes from taxes. Of those taxes, property taxes account for 18%; this is slightly more than the 16% from water and sewer utility taxes and slightly less than the 19% from the state sales tax.<sup>107</sup> The full budget can be viewed on the city's website. Overall, property taxes are not the biggest piece of Westport's budget, but the amount generated from them annually can be enough to cover one or more city departments. The only two areas with budgets larger than the revenues from property taxes alone include Police and Non-Department/IT. A loss of property tax revenue would, all else being equal, decrease the city budget, but would likely not cause a drastic decline in revenue. However, there are many other tax revenues that also depend on residents using or purchasing services and products which may decline if population decreases due to

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<sup>105</sup> GHC Assessor's office

<sup>106</sup> City of Westport, 2021 Budget, <https://cms8.revize.com/revize/westportwa/2021%20Budget.pdf>, sourced from <https://www.ci.westport.wa.us/departments/finance.php>, accessed June 3, 2021, 4.

<sup>107</sup> City of Westport, 2021 Budget, 9.

sea level rise. Sales tax revenues will likely decline with fewer people living in Westport, and utility taxes will also likely decline if overall profits of utility entities decrease.

For my GIS analysis, I created a layer showing only parcels within the tax district that are not tax exempt. Exemptions could be granted for seniors or people with disabilities, or for publicly owned land. Therefore, the actual number of parcels, area inundated, and potential value at risk in Westport are higher than the totals in my results, but I chose to focus on properties that would directly affect the property tax revenues for the City. This analysis also does not include any public right-of-way square footage. These limitations will not truly show how much land area will be inundated by sea level rise, and could be refined in a future study to more accurately determine true assets at risk.

The first part of the analysis included looking at how many parcels would be affected, with any percentage of inundation, at each sea level rise interval in feet. This included parcels that were almost completely submerged or parcels that had a small corner covered by the new mean high high water level. I found the number of parcels affected at each additional foot of sea level rise, and created layers for all taxable properties not affected as well. The next portion of the analysis included the tabulate intersection tool, which gave me the square footage as well as the percentage of each parcel that would be inundated at each level of sea level rise. This was a cumulative measure, so that a parcel that was minorly submerged at one foot of sea level rise was then recounted with higher inundation at two feet of sea level rise, for example.

This analysis has numerous limitations both with the datasets available and the uncertain nature of how factors will change in the future. First, the GIS data layers from Grays Harbor County have different extents than the sea level rise layers from NOAA, and therefore the exact point where they overlap can not be used as a definitive measure. Next, this GIS model only takes a snapshot of one year's appraised property values and tax rates. In the future the prices of property could appreciate, as real estate markets often tend to do, or could depreciate as climate change or a Cascadia Subduction Zone event impact the area. Tax rates

also are determined based on the needs of the entities receiving funds from them, and this will likely increase in the future as the costs of maintenance and personnel go up. Additionally, new regional districts with taxing authorities could be put into place that would add to the tax burden. Conversely, some project-specific funding like GO bonds will expire after a set period of time, but new ones may be passed by the voters. Lastly, this analysis does not account for population change in the future or redevelopment of properties within the city. Essentially, this data is most useful as a baseline to help understand how much of today's tax base is at risk at each level of sea level rise if it were to happen in the near future.

## Chapter 4: Results & Discussion

My analysis of sea level rise and its impacts on Westport's properties and property tax base revealed the number and location of properties impacted at each 1-foot interval between 1 foot and 9 feet of sea level rise, as well as their current assessed value and tax contributions to all applicable taxing districts and Westport alone. It also allowed me to quantify how many parcels at each interval will be minorly or majorly inundated classified as percent of a property predicted to be underwater at the new mean high water level. Table X is a summary table of the findings, followed by a more in depth discussion of each sea level rise interval.

*Table 4: Summary of GIS analysis results.*

Inundation Level	Number of New Properties Inundated	Total Area (SF)	Assessed Value	Total Tax Revenue	City-Only Tax Revenue
1 Foot	94	9,063,668	\$21,781,742	\$274,343	\$19,929
2 Feet	13	419,703	\$2,700,535	\$34,013	\$2,471
3 Feet	141	3,205,521	\$23,722,326	\$298,785	\$21,705
4 Feet	177	2,728,911	\$22,744,476	\$286,469	\$20,810
5 Feet	120	5,945,787	\$26,658,453	\$335,766	\$24,391
6 Feet	271	4,349,546	\$46,841,637	\$589,976	\$42,858
7 Feet	128	1,501,180	\$25,409,297	\$320,033	\$23,248
8 Feet	375	4,204,369	\$42,862,881	\$539,863	\$39,218
9 Feet	70	886,909	\$8,592,542	\$108,224	\$7,861
Total	1,389	32,305,594	\$221,313,889	\$2,787,472	\$202,491
Remaining Properties	577	9,149,635	\$76,138,116	\$958,968	\$69,664

Within the WE172 H2 tax district, there are 2,098 parcels. Of those, there are 1,966 parcels that are not tax exempt. This is the group that I included in my analysis, so numbers of parcels affected and those not affected will sum to this number. My calculation of tax revenue specifically for the City of Westport based on these properties for 2021 was \$272,160.61. The figure used in the city's budget document is \$221,500. This difference could be due to rounding errors within my GIS analysis. It is also possible that Westport chose to under-budget their expected tax revenues because of uncertainties in that process or experience with nonpayment or late payments in the past.

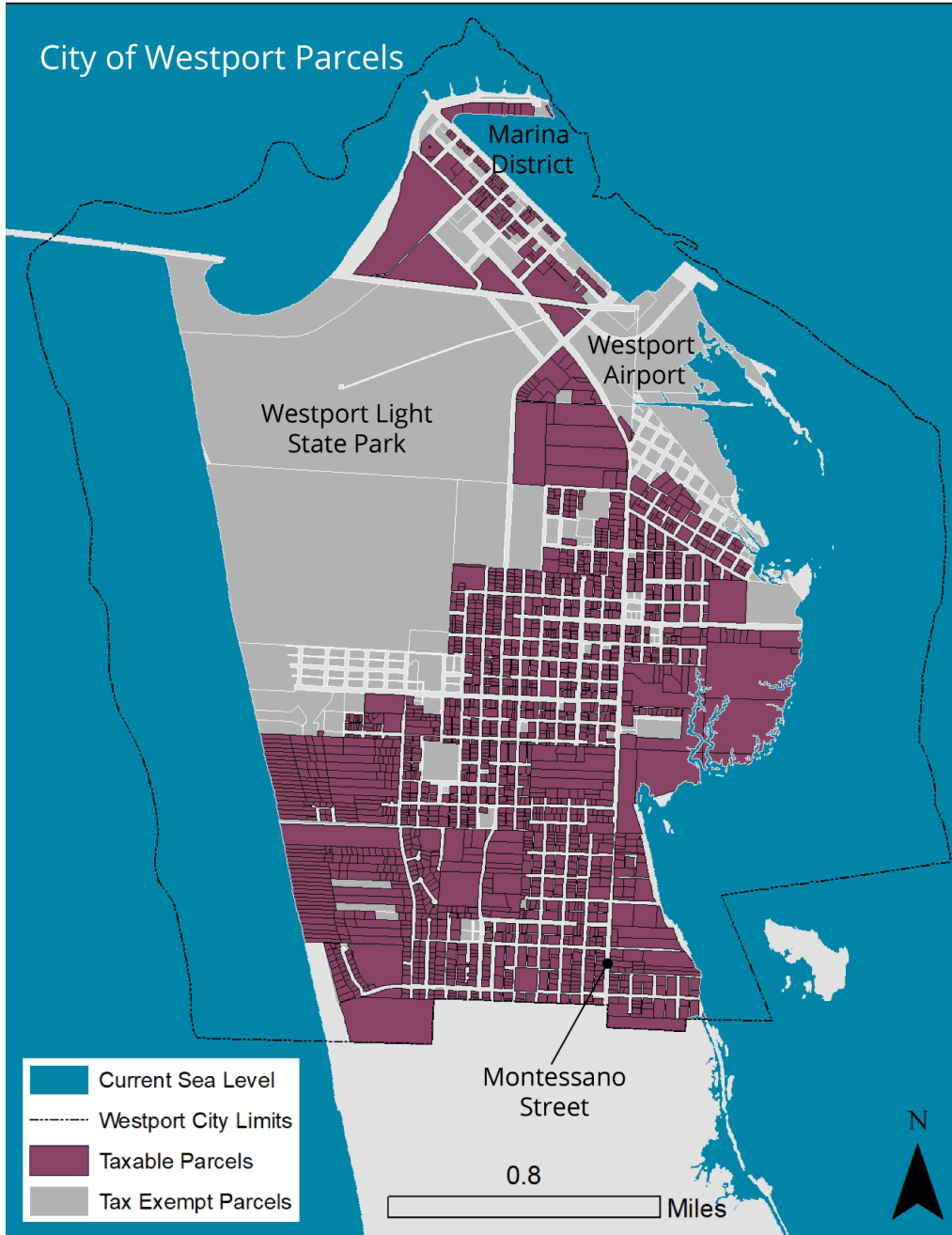
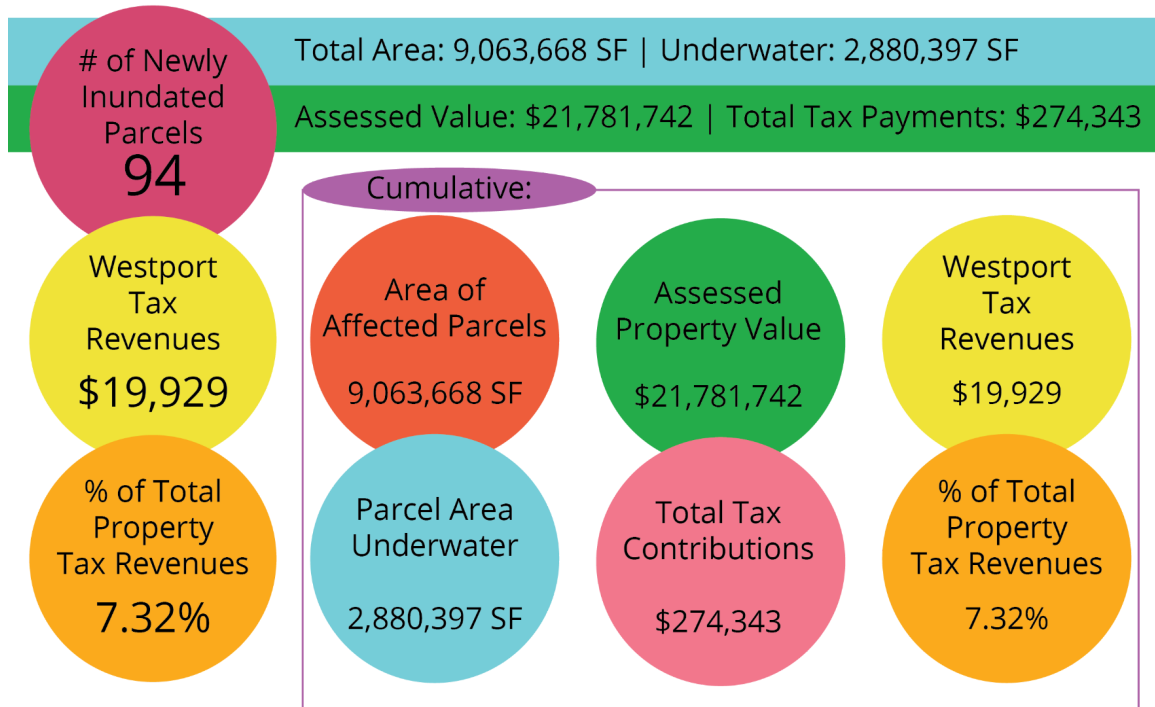


Figure 12: Map of Westport parcels.

At one foot of sea level rise, 94 parcels totaling 9,063,668 square feet will be impacted to varying degrees. These properties have a cumulative appraised value of \$21,781,742 and contribute \$274,343 in property tax revenue to the applicable tax districts, \$19,929 of which goes to the City. About 60% of these parcels are only mildly impacted, with 10% or less of their land area inundated at this level. Only one parcel is almost entirely inundated with one foot of

sea level rise. The impacted parcels are along both the west and east shores, but mainly concentrated to the south. At this level of inundation, there does not appear to be major interference with existing road networks, but there are a few parcels in the marina district impacted that could interfere with the movement of people and goods. There is also water encroaching on the city airport, which is not included as taxable property, but may have to cease operations due to inundation.

# Sea Level Rise Interval: 1 Foot



		Newly Inundated Parcels (94)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	57	60.6	57	2.9
	10-20%	12	12.8	12	.6
	20-30%	6	6.4	6	.3
	30-40%	4	4.3	4	.2
	40-50%	3	3.2	3	.2
	50-60%	4	4.3	4	.2
	60-70%	2	2.1	2	.1
	70-80%	1	1.1	1	.1
	80-90%	4	4.3	4	.2
	90-100%	1	1.1	1	.1
Percent of Total Taxable Parcels Affected					4.8

Figure 13: Infographic of results for 1 foot of sea level rise.

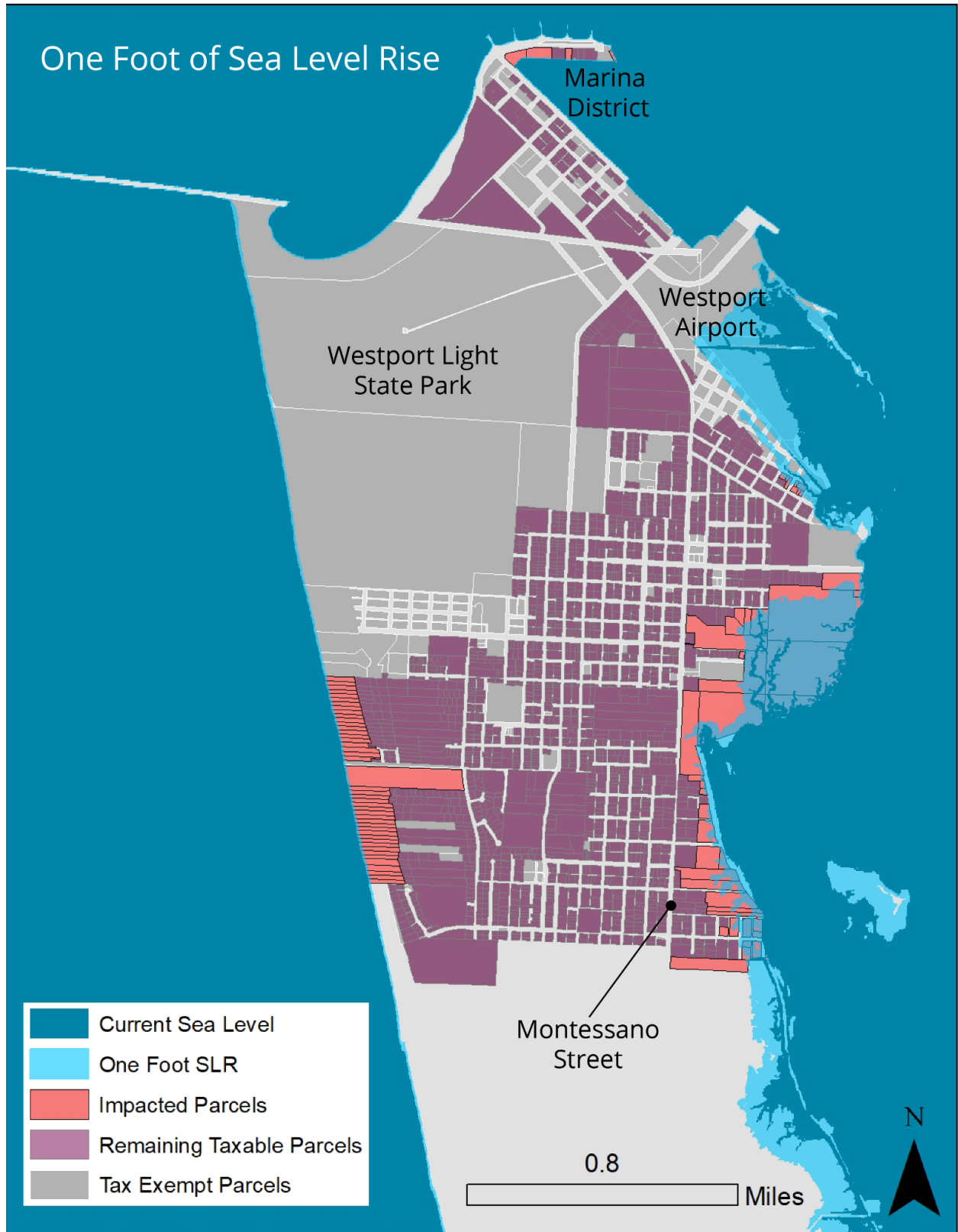
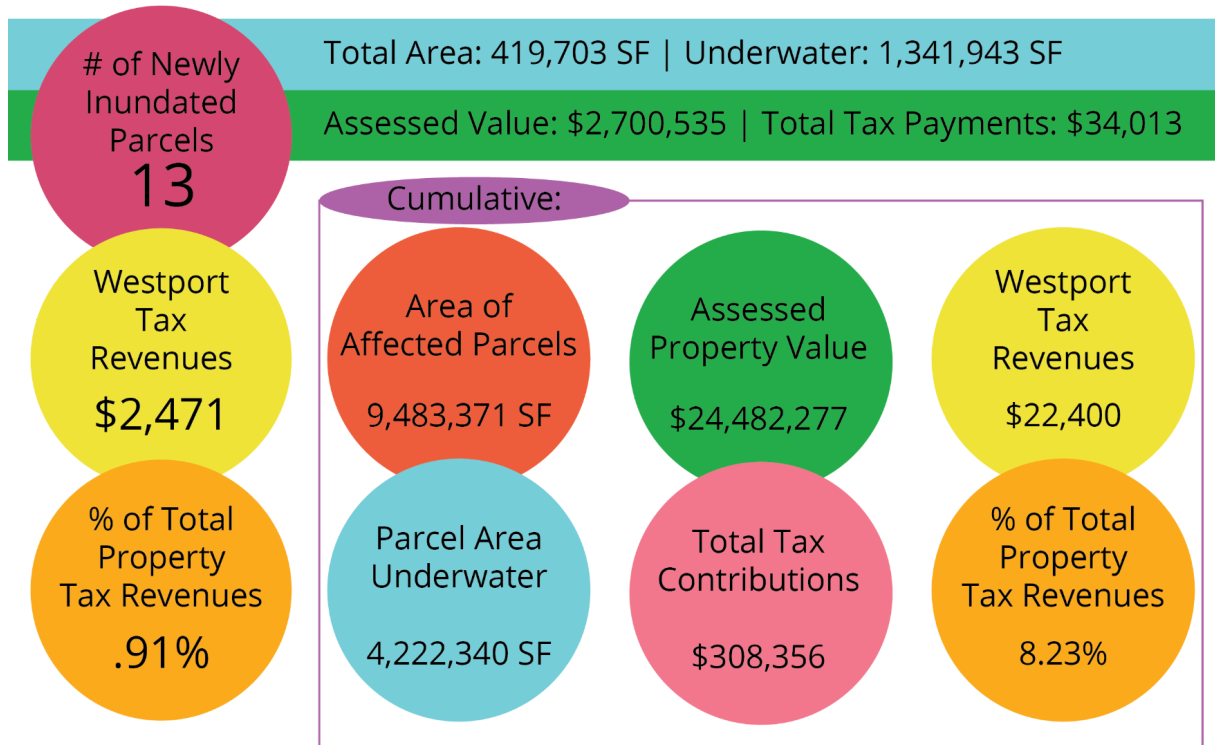


Figure 14: Map of 1 foot of sea level rise inundation.

At two feet of sea level rise, 13 additional parcels become impacted by sea level rise. These parcels total 419,703 square feet and have a cumulative appraised value of \$2,700,535. They contribute \$34,013 to the total tax base, and \$2,471 to the City. The tax revenue losses are relatively small and not likely to have a major impact on the City's budget. At this interval, more than half of the impacted parcels are still only mildly affected by sea level rise, but there are now 7 parcels that are 90+% flooded. This interval of sea level rise has a modest impact on Westport compared to that of the first foot of sea level rise, and may provide an optimal window in which to respond through adaptation or retreat after witnessing the impacts thus far. There may be increased motivation to respond to sea level rise at this point partially due to the fact that the road leading from the south end of town up to the marina district, Montesano Street, is now adjacent to inundated parcels at two places. This may cause this route to be cut off during high tides or storm surge events. As an important transportation corridor, increased nuisance flooding may make retreat a more attractive adaptation option for some citizens.

# Sea Level Rise Interval: 2 Feet



		All Inundated Parcels (107)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	61	57	61	3.1
	10-20%	2	1.9	2	.1
	20-30%	6	5.6	6	.3
	30-40%	4	3.7	4	.2
	40-50%	6	5.6	6	.3
	50-60%	5	4.7	5	.3
	60-70%	5	4.7	5	.3
	70-80%	6	5.6	6	.3
	80-90%	5	4.7	5	.3
	90-100%	7	6.5	7	.4
Percent of Total Taxable Parcels Affected					5.4

Figure 15: Infographic of results for 2 feet of sea level rise.

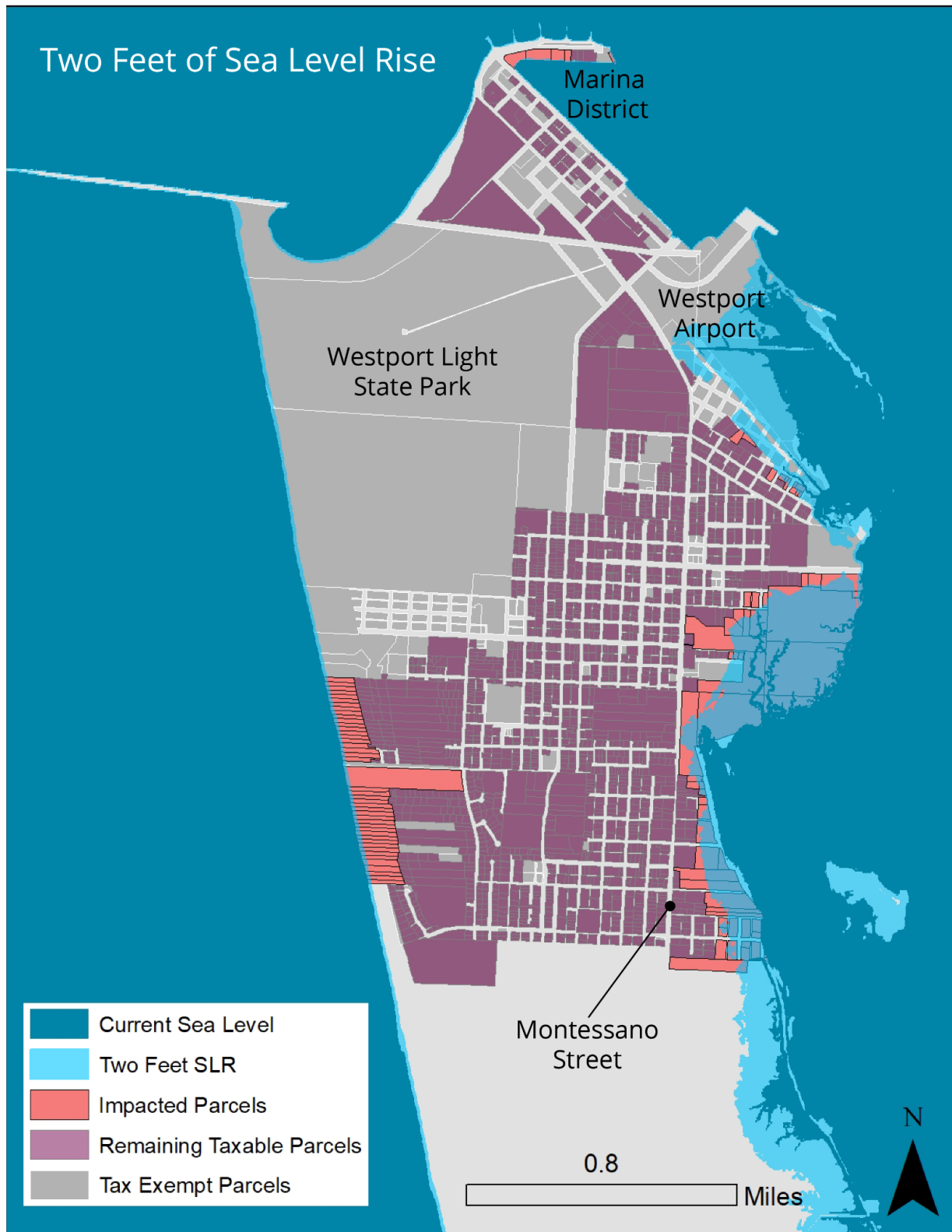


Figure 16: Map of 2 feet of sea level rise inundation.

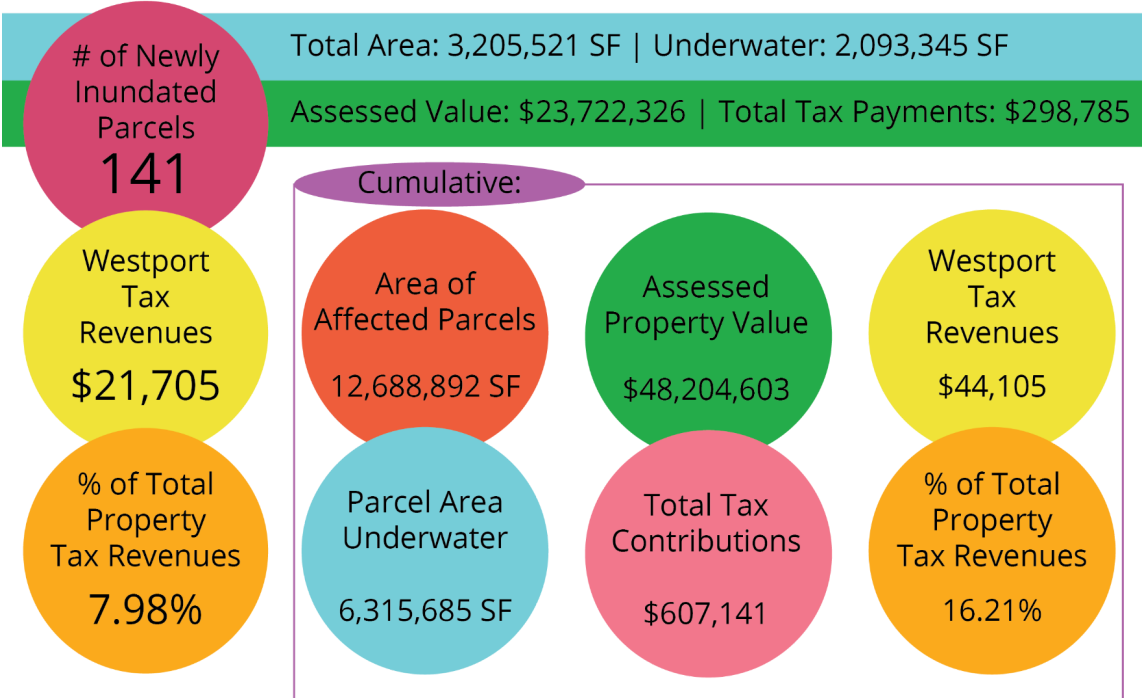
At three feet of sea level rise, another 141 parcels become inundated in Westport. These newly impacted parcels have a total area of 3,205,521 square feet, but account for the largest assessed value impacted thus far at \$23,722,326. These properties add \$298,785 to the county tax base with \$21,705 of that total going to the City. A little more than a third of affected properties are only mildly flooded here, but 27% of properties are 90+% flooded. This sea level rise interval is often quoted as a top-end estimate by the end of this century.<sup>108</sup> At this point a cumulative 16.21% of Westport's property tax revenue is at risk from inundation. While some parcels with mild flooding may still be actively retaining their property values and paying their taxes, 44% of all inundated parcels are more than half submerged at mean high water. During king tides or storm surge events, this water height will reach even higher, damaging any buildings that may be located on the dry parts of the properties. There are also now four points along Montesano Street adjacent to inundated parcels, increasing the likelihood for nuisance flooding.

Sea level rise along the outer coast is relatively modest compared to the inundation along the shore adjacent to the harbor. Several reasons for this could include elevation barriers from natural and engineered sand dunes that hold back the rising seas, as well as hardened protection measures. The shore in the harbor is lined with sensitive wetland areas, which can help buffer the effects of wave action and erosion. However, these areas don't have a way to hold back rising seas. Ultimately, this analysis is imperfect due to the lack of ground-truthed data that could help refine the local context to conduct this type of analysis. A highly accurate survey along with documentation of riprap walls and other forms of protection measures would be better for determining how sea level rise will truly affect Westport. This analysis is valuable for showing the properties most at risk of being inundated with sea water, and the general order in which parcels will become flooded.

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<sup>108</sup> "AR5 Climate Change 2013: The Physical Science Basis — IPCC," accessed June 3, 2021, <https://www.ipcc.ch/report/ar5/wg1/>, 1180.

# Sea Level Rise Interval: 3 Feet



		All Inundated Parcels (248)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	90	36.3	90	4.6
	10-20%	13	5.2	13	.7
	20-30%	15	6.1	15	.8
	30-40%	10	4	10	.5
	40-50%	11	4.4	11	.6
	50-60%	6	2.4	6	.3
	60-70%	13	5.2	13	.7
	70-80%	16	6.5	16	.8
	80-90%	7	2.8	7	.4
	90-100%	67	27	67	3.4
Percent of Total Taxable Parcels Affected					12.6

Figure 17: Infographic of results for 3 feet of sea level rise.

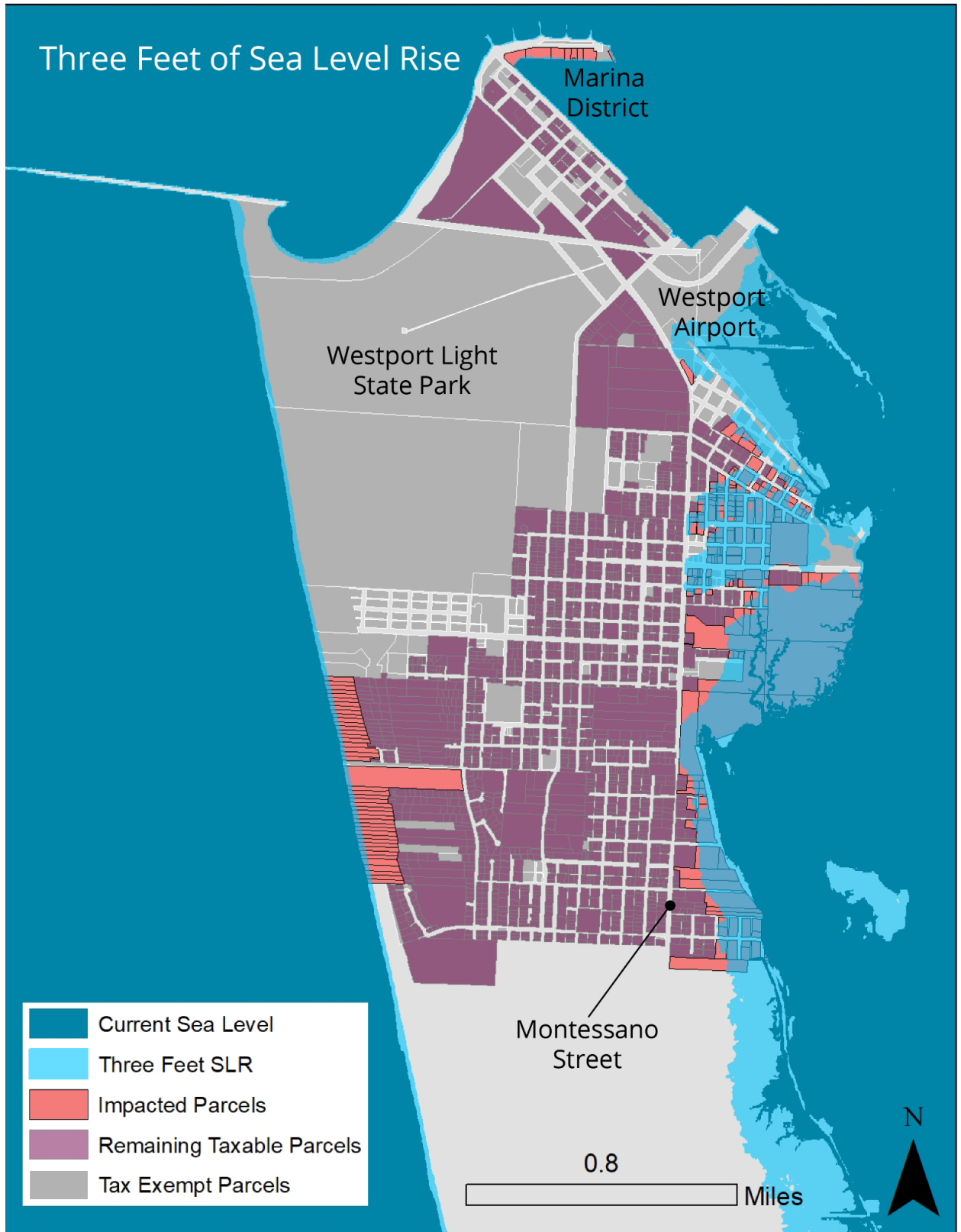


Figure 18: Map of 3 feet of sea level rise inundation.

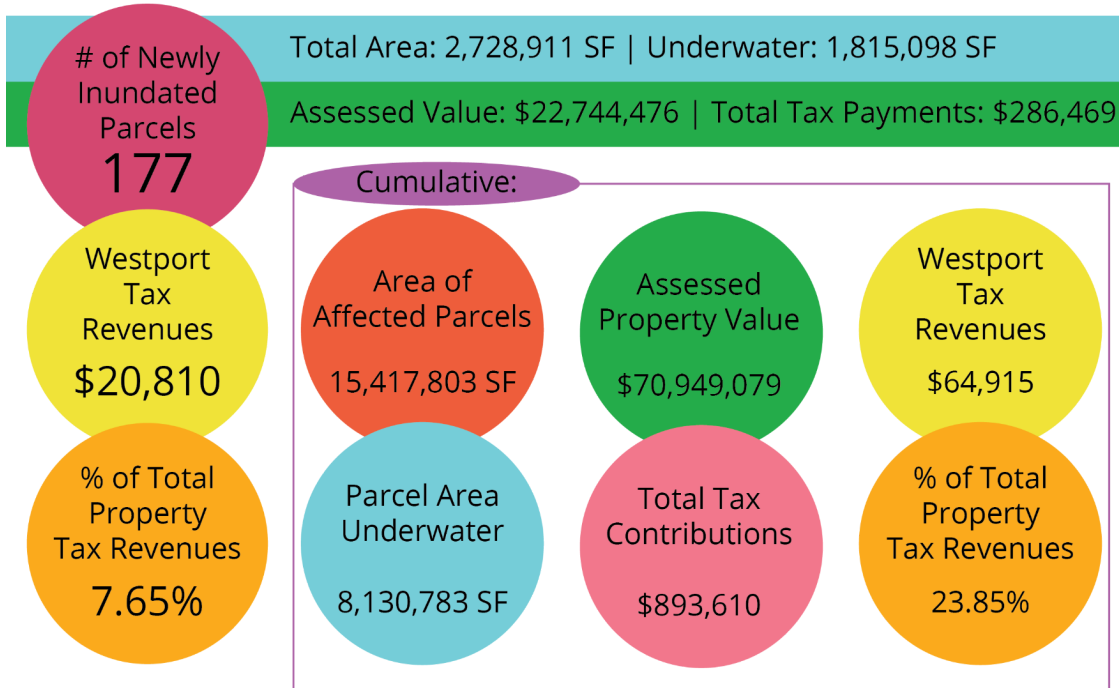
At four feet of sea level rise, 177 more properties will be inundated at the mean high water level. These parcels include 2,728,911 square feet and are valued at \$22,744,476. The total tax contribution of these parcels is \$286,469 and the City contribution is \$20,810. At this interval, nearly 40% of parcels are severely inundated (90+% underwater). Four feet of sea level rise will impact to some extent the properties comprising almost one quarter of all property tax revenues for Westport. Of all taxable parcels in the city, more than one in five of them are at least partially flooded with four feet of sea level rise. This increment of sea level rise is generally not expected until after the end of this century, but there has been discussion in the scientific community recently about new information regarding the stability of the ice caps that could drastically speed up SLR.<sup>109</sup> In this case, four feet may become a reality sooner rather than later.

This increment has a major surge of inundated parcels west of Montesano Street and into the center of Westport. Many of these properties are single family homes or small businesses. In terms of functionality of the community, this increment of inundation appears to be detrimental enough to warrant retreat. With many people now without a home and businesses being forced to close, it is likely that people would begin moving away on their own by this point, fracturing the community's sense of self, economic viability, and ability to generate and support tourism. The inner third of the peninsula remains relatively untouched at this point, but may not be able to support the rest of the community within the built environment currently in place.

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<sup>109</sup> Jonathan L. Bamber et al., "Ice Sheet Contributions to Future Sea-Level Rise from Structured Expert Judgment," *Proceedings of the National Academy of Sciences* 116, no. 23 (June 4, 2019): 11195–200, <https://doi.org/10.1073/pnas.1817205116>.

# Sea Level Rise Interval: 4 Feet



		All Inundated Parcels (425)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	77	18.1	77	4
	10-20%	53	12.5	53	2.7
	20-30%	18	4.2	18	.9
	30-40%	11	2.6	11	.6
	40-50%	14	3.3	14	.7
	50-60%	22	5.2	22	1.1
	60-70%	17	4	17	.9
	70-80%	20	4.7	20	1
	80-90%	24	5.7	24	1.2
	90-100%	169	39.8	169	8.6
Percent of Total Taxable Parcels Affected					21.6

Figure 19: Infographic of results for 4 feet of sea level rise.

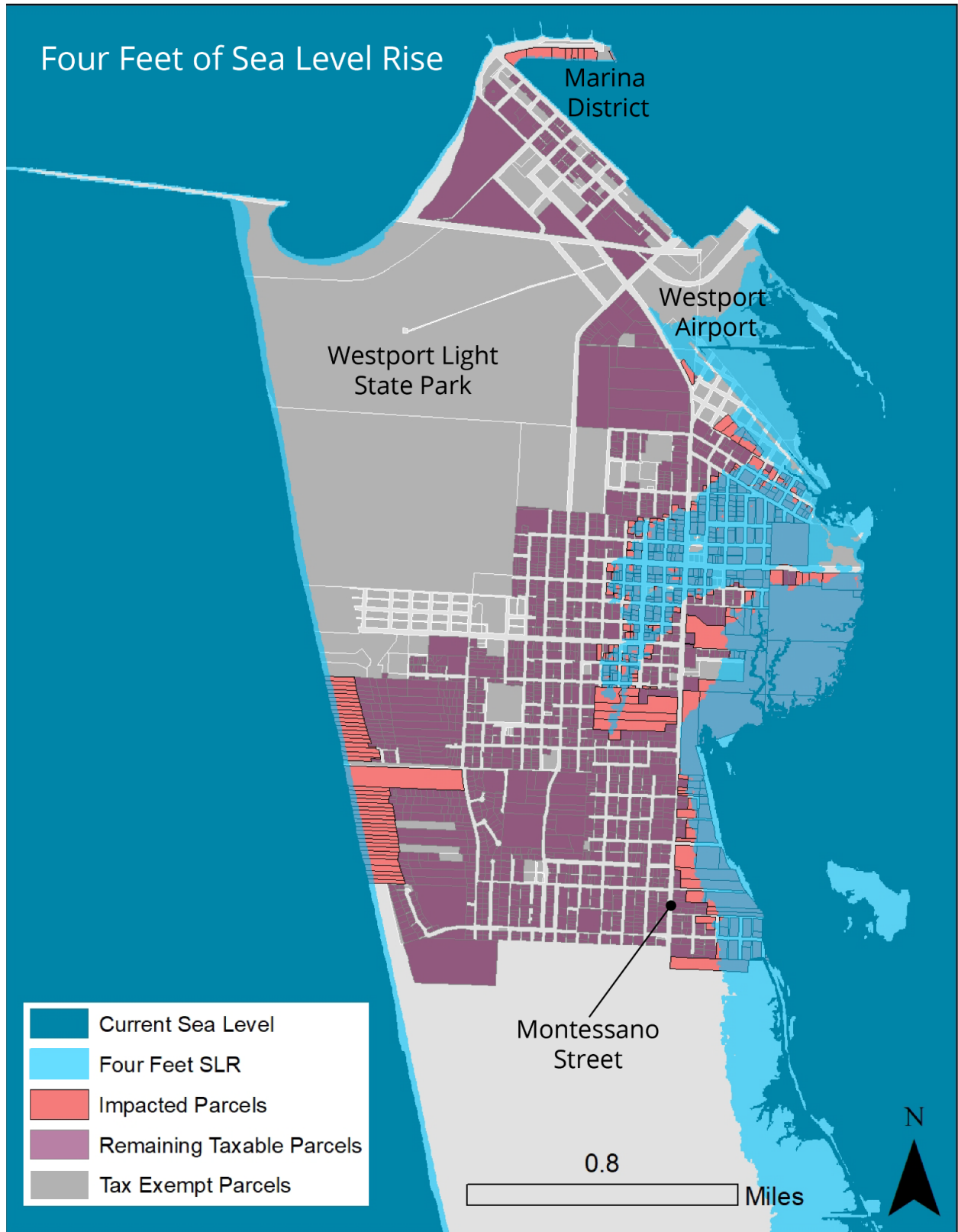
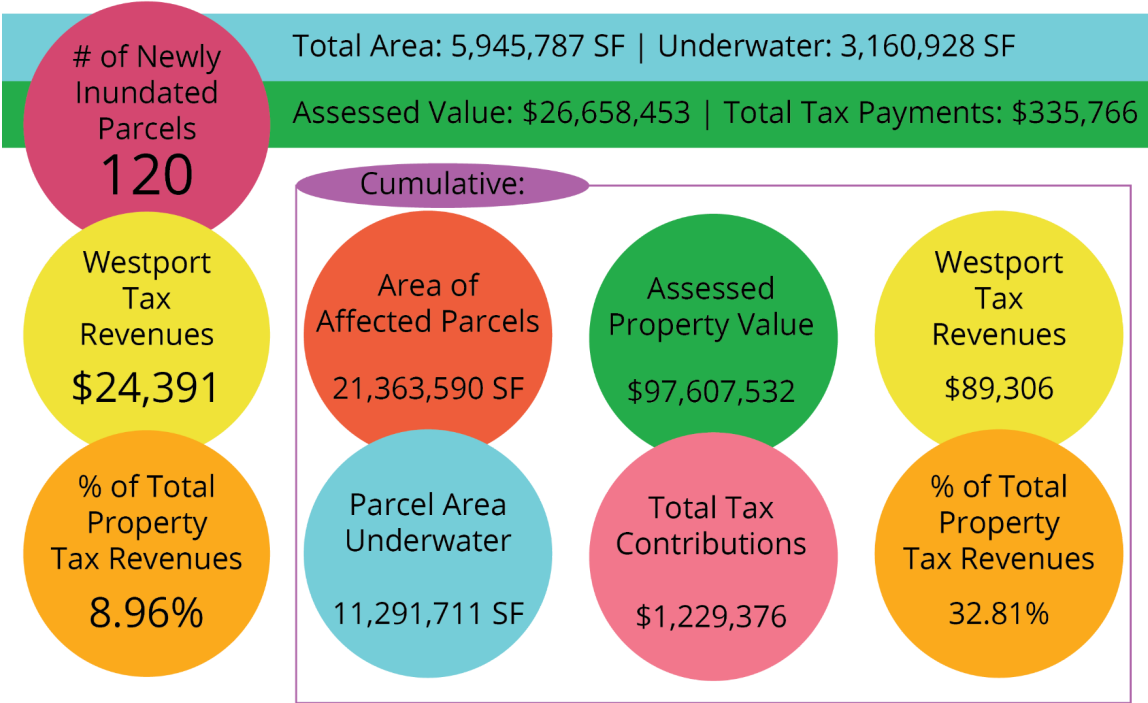


Figure 20: Map of 4 feet of sea level rise inundation.

Five feet of sea level rise adds 120 newly affected properties that cover 5,945,787 square feet. These parcels are valued at \$26,658,453, the largest value for a newly inundated section up to this point. The tax contribution for all taxing districts is \$335,766 and for the City is \$24,391. The most significant finding at this inundation level is that essentially half of all affected parcels are 90+% flooded at mean high water. Additionally, one-third of the City's entire property tax revenue is now at risk and almost \$100 million worth of property is flooded to some degree. Very large portions of government-owned lands are now flooded on a daily basis. The most viable place for people to live and work is now in the south-central portion of Westport.

The marina district, which is the main driver of the local economy, now exists essentially as an island. Some type of floating bridge would be required to reach where the existing infrastructure is, and that infrastructure itself would need to be made to float or otherwise raised to combat inundation. Assuming that fisheries and boating remain a dominant sector of employment, the Port of Grays Harbor may seek to relocate its infrastructure. The other areas of the Port located in Aberdeen will also be feeling the impacts of sea level rise. The deepwater shipping terminals may be harder to relocate depending on how deep they need to be, but it would be likely that any other docks for commercial fishing or charter fishing could be moved to another point within the harbor that will have more permanent access, and perhaps greater natural sheltering from tsunami waves.

# Sea Level Rise Interval: 5 Feet



		All Inundated Parcels (545)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	75	13.8	75	3.8
	10-20%	69	12.7	69	3.5
	20-30%	23	4.2	23	1.2
	30-40%	23	4.2	23	1.2
	40-50%	15	2.8	15	.8
	50-60%	14	2.6	14	.7
	60-70%	13	2.4	13	.7
	70-80%	23	4.2	23	1.2
	80-90%	21	3.9	21	1
	90-100%	269	49.36	269	13.7
Percent of Total Taxable Parcels Affected					27.7

Figure 21: Infographic of results for 5 feet of sea level rise.

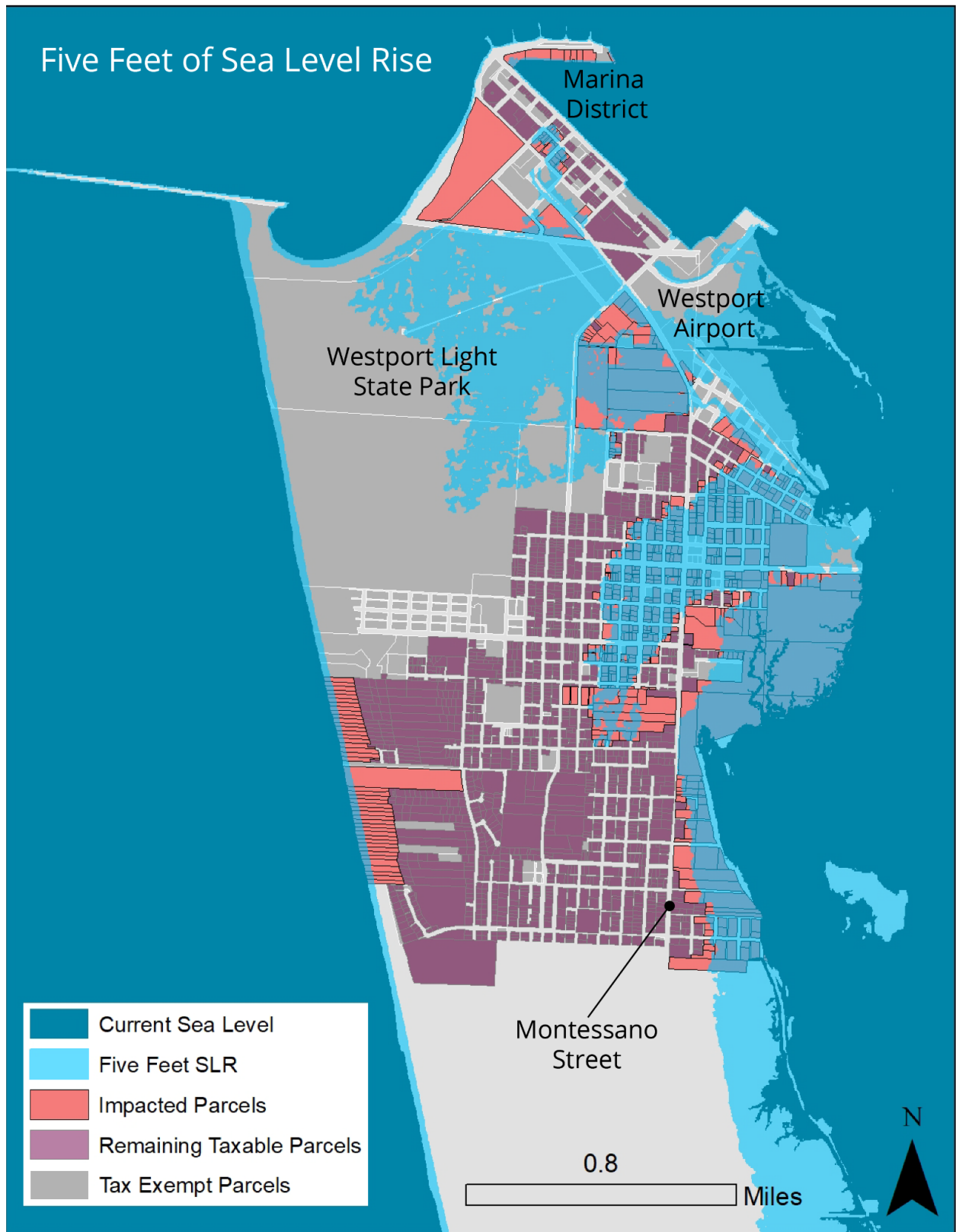
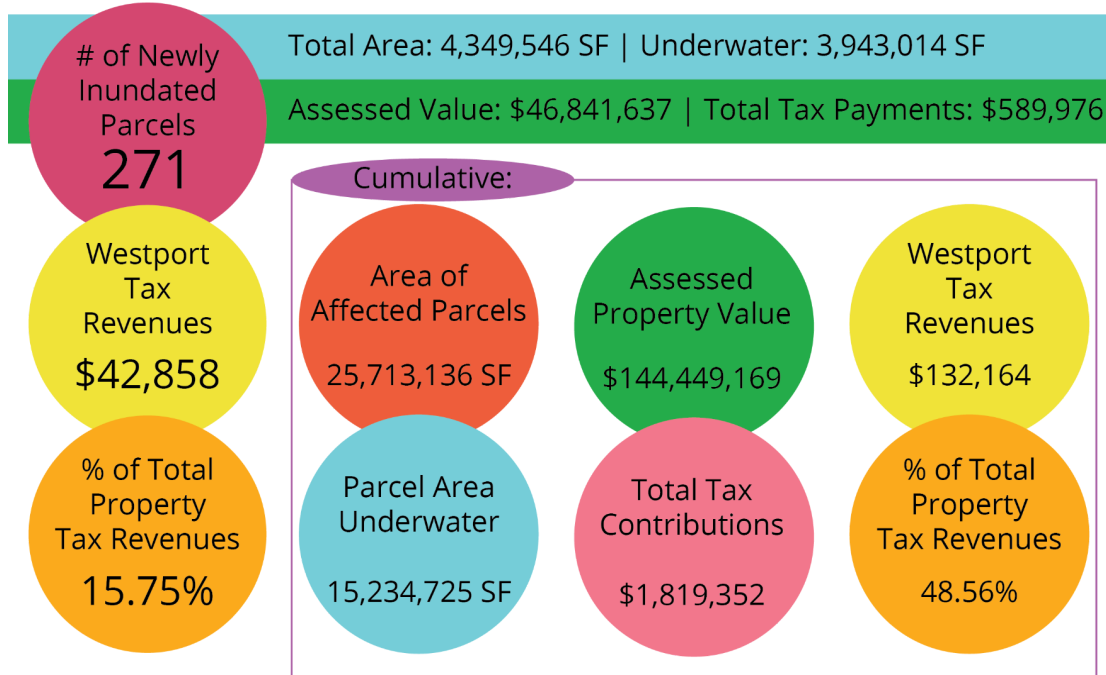


Figure 22: Map of 5 feet of sea level rise inundation.

At six feet of sea level rise, slightly less than 2 meters, 271 new parcels are inundated. This is the largest single increase in the number of affected parcels up to this point. The land area of the new parcels totals 4,349,546 square feet and has a combined value of \$46,841,637. These parcels account for \$589,976 for the various taxing authorities, including \$42,858 that goes to Westport. Again, at this interval about half of all affected parcels are 90+% flooded. Nearly half of all revenue that Westport collects from property taxes is now at risk, likely making future private investment in the area too risky. Small pockets of dry parcels still exist, but there are very limited existing transportation routes to access them.

# Sea Level Rise Interval: 6 Feet



		All Inundated Parcels (816)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	87	10.7	87	4.4
	10-20%	70	8.6	70	3.6
	20-30%	34	4.2	34	1.8
	30-40%	29	3.6	29	1.5
	40-50%	29	3.6	29	1.5
	50-60%	34	4.2	34	1.7
	60-70%	33	4	33	1.7
	70-80%	42	5.2	42	2.1
	80-90%	46	5.6	46	2.3
	90-100%	412	50.5	412	21
Percent of Total Taxable Parcels Affected				41.5	

Figure 23: Infographic of results for 6 feet of sea level rise.

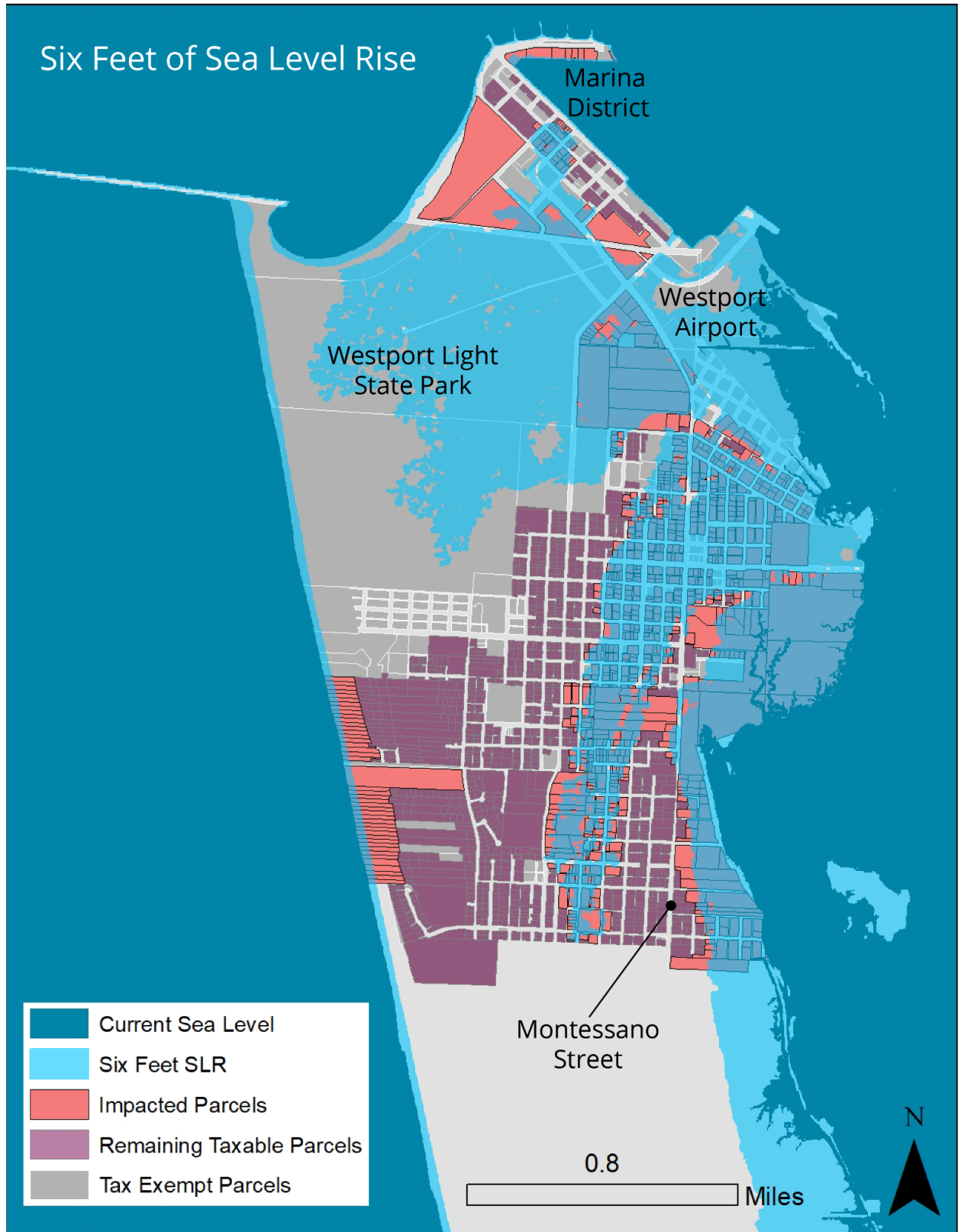


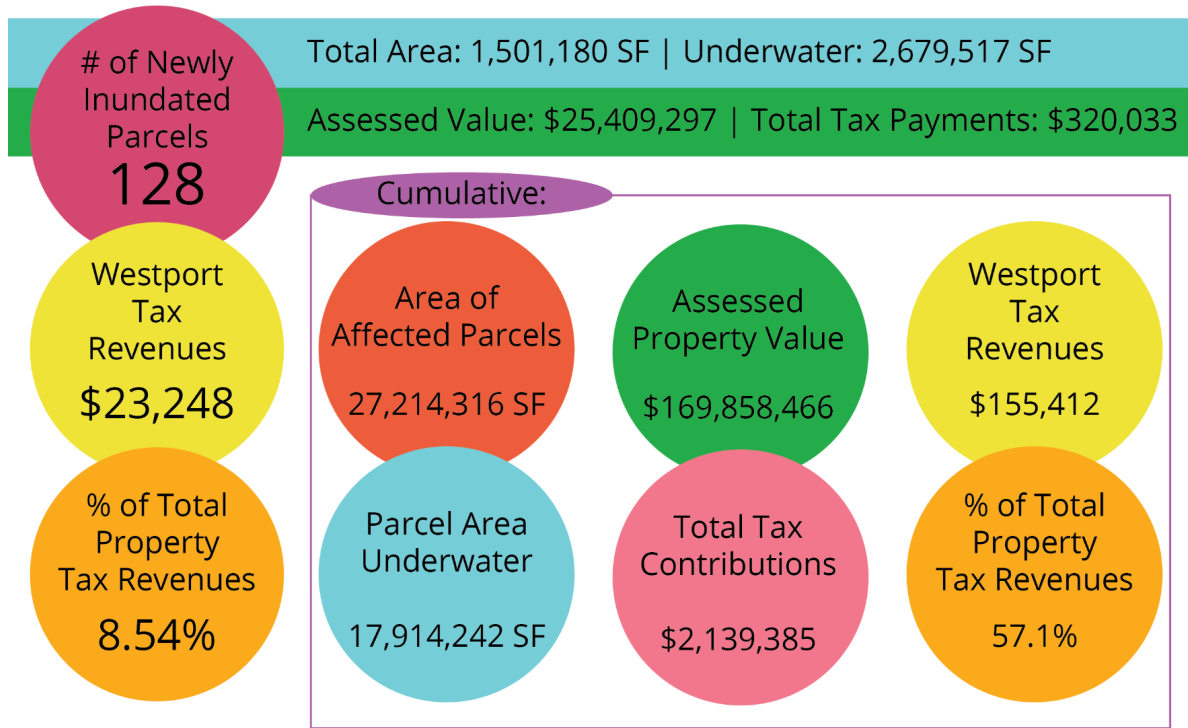
Figure 24: Map of 6 feet of sea level rise inundation.

Seven feet of sea level rise newly inundates 128 properties that cover 1,501,180 square feet of land, excluding streets. These properties are valued at \$25,409,297 and contribute \$320,033 to the local taxing districts and \$23,248 to Westport. This level of inundation severely floods (90+%) 62% of affected parcels. It also effectively floods the Westport Light State Park, the future site of a proposed golf course currently undergoing the public outreach and planning processes.<sup>110</sup> While the proposal does call for supporting uses, such as a medium-sized inn and a golf shop, a golf course is not necessarily risky development to put in an area that is likely to become flooded. Depending on the absolute amount of sea level rise, it's possible this area will only experience flooding during storm surge events. Because a golf course does not require much in terms of tangible, built assets, it may be a good investment choice for the near-term. Depending on the financing details, there may be less for the property owner to lose if and when this area floods.

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<sup>110</sup> "Westport Light Recreation Concession Area | Washington State Parks and Recreation Commission," accessed June 2, 2021, <https://www.parks.state.wa.us/1161/Westport-Light-Recreation-Concession-Are>.

# Sea Level Rise Interval: 7 Feet



		All Inundated Parcels (944)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	61	6.5	61	3.1
	10-20%	64	6.8	64	3.3
	20-30%	36	3.8	36	1.8
	30-40%	26	2.8	26	1.3
	40-50%	17	1.8	17	.9
	50-60%	35	3.8	35	1.8
	60-70%	37	4	37	1.9
	70-80%	35	3.8	35	1.8
	80-90%	42	4.5	42	2.1
	90-100%	591	62.6	591	30
Percent of Total Taxable Parcels Affected					48

Figure 25: Infographic of results for 7 feet of sea level rise.

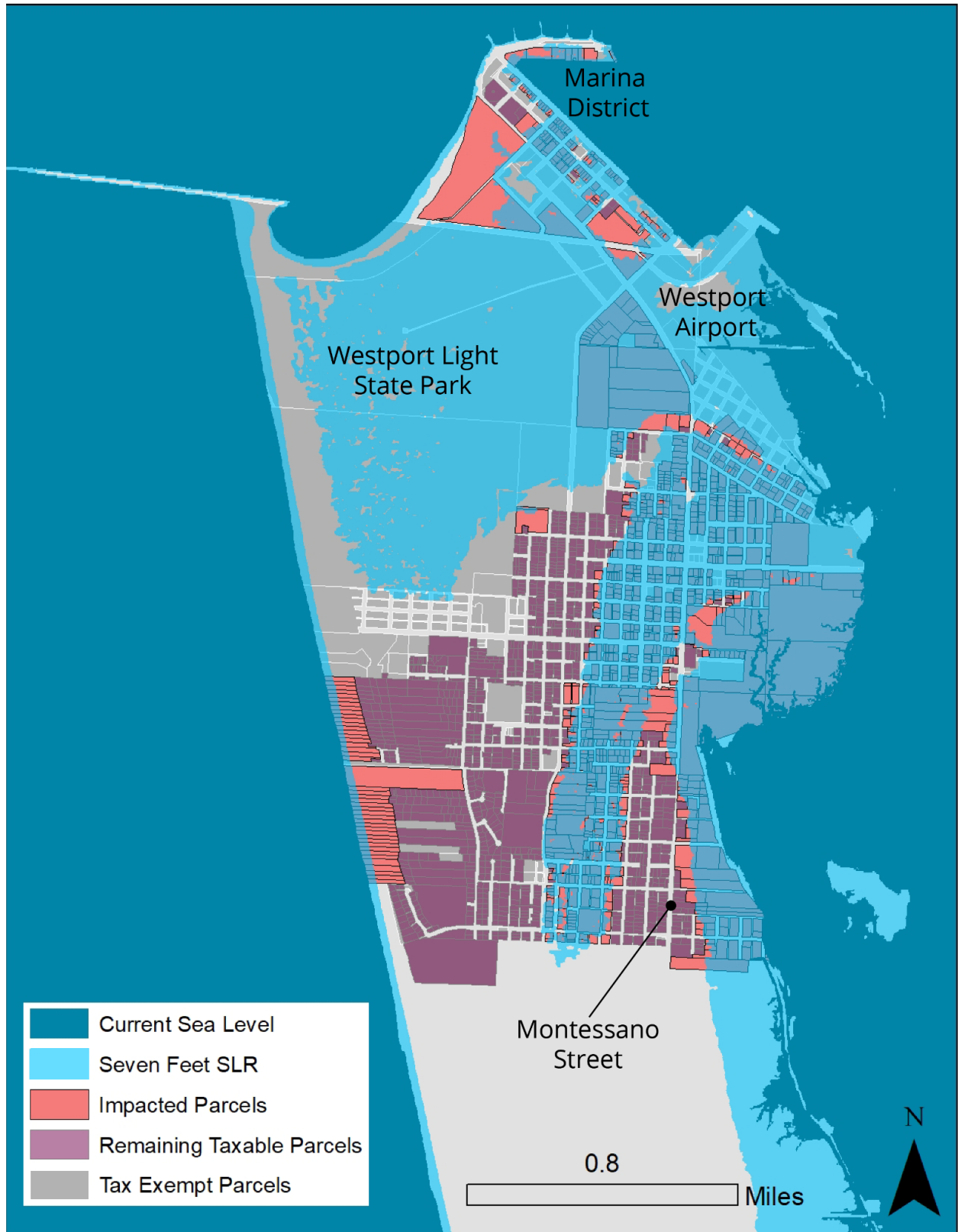
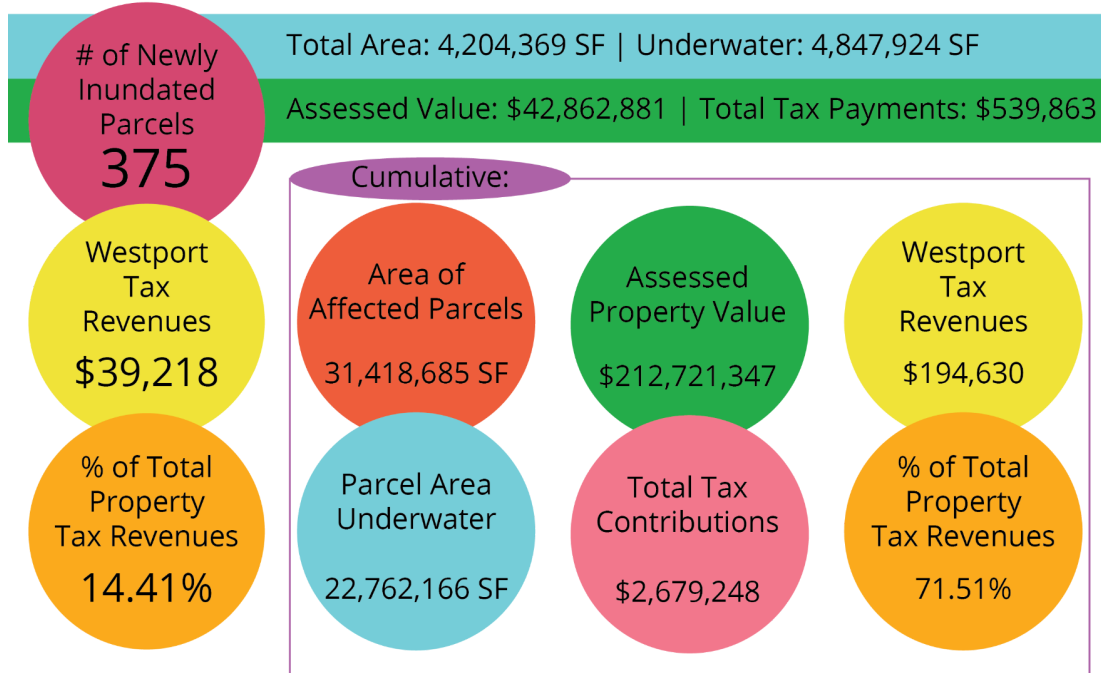


Figure 26: Map of 7 feet of sea level rise inundation.

At eight feet of sea level rise, the largest single jump in affected parcels takes place. At this increment 375 parcels will be newly inundated. These properties cover 4,204,369 square feet of land and are valued at \$42,862,881. These properties add a significant \$539,863 to the tax base, \$39,218 of which goes to Westport. Nearly three quarters of all impacted properties are severely flooded (90+%) at this interval, and almost half of all taxable parcels within Westport are severely flooded. Over 70% of all property tax revenue collected by Westport is now at risk, putting a large dent in their budget. Over \$200 million worth of property is now essentially worthless or at risk from flood damage.

# Sea Level Rise Interval: 8 Feet



		All Inundated Parcels (1,319)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	57	4.3	57	2.9
	10-20%	85	6.4	85	4.3
	20-30%	26	2	26	1.3
	30-40%	23	1.7	23	1.2
	40-50%	25	1.9	25	1.3
	50-60%	19	1.4	19	1
	60-70%	31	2.4	31	1.6
	70-80%	35	2.7	35	1.8
	80-90%	54	4.1	54	2.8
	90-100%	964	73.1	964	49
Percent of Total Taxable Parcels Affected					67.1

Figure 27: Infographic of results for 8 feet of sea level rise.

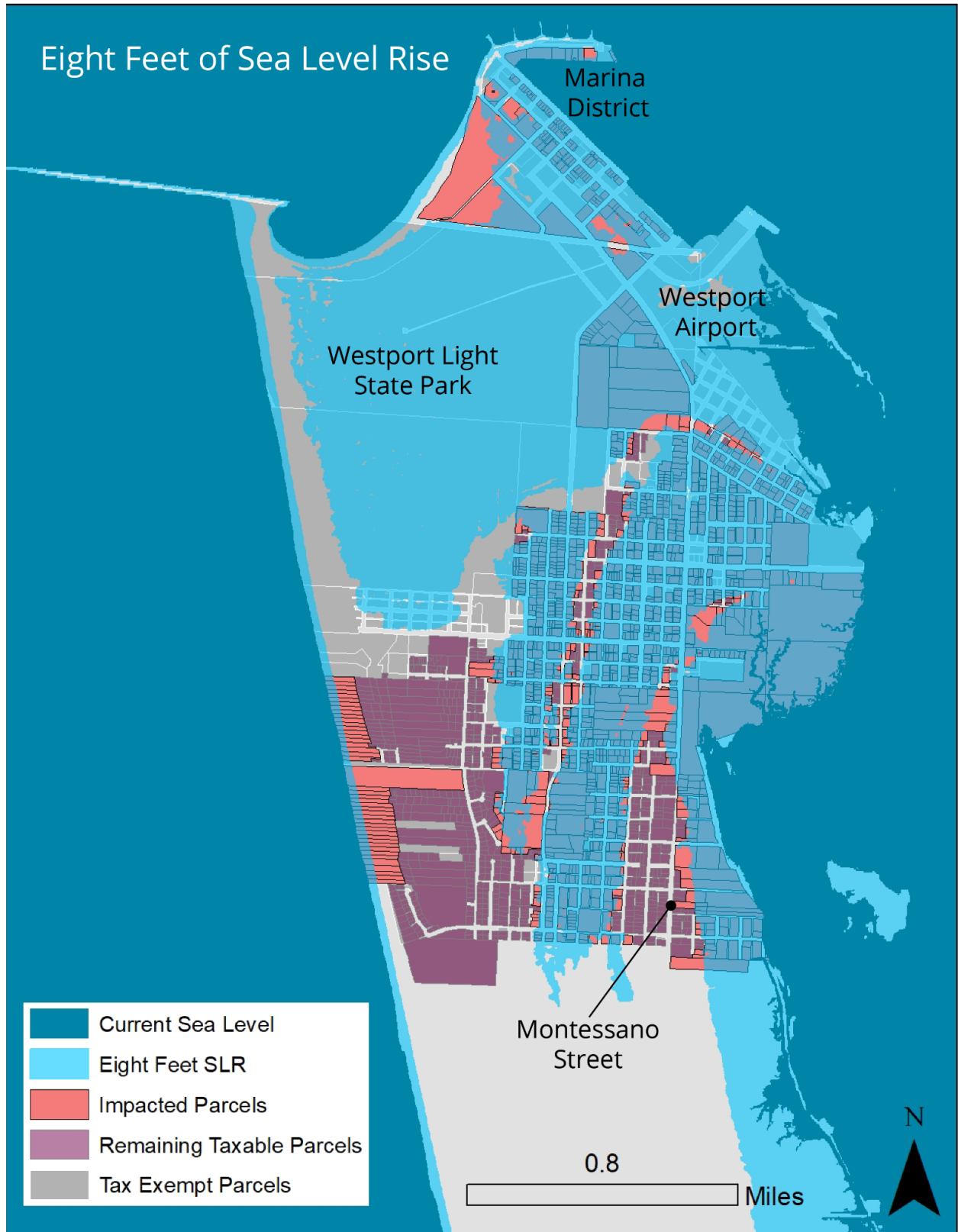
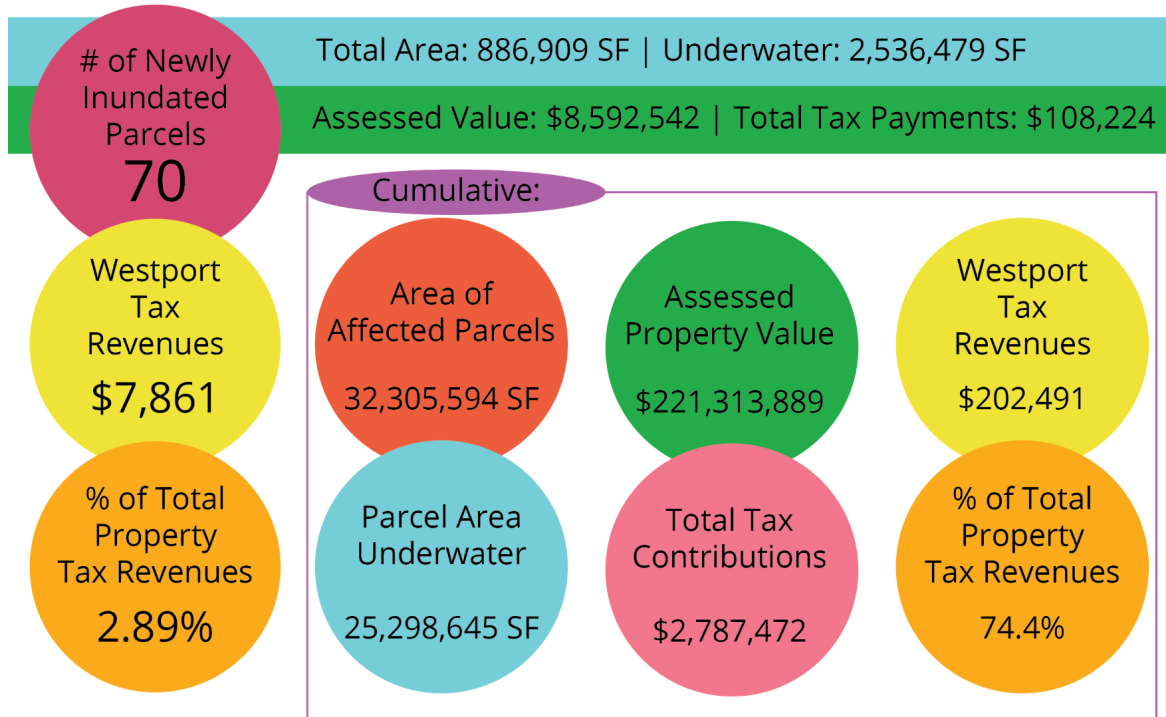


Figure 28: Map of 8 feet of sea level rise inundation.

Nine feet of sea level rise will add a modest 70 properties to the list of affected parcels, which consist of 886,909 square feet. The total value of these properties is assessed at \$8,592,542 and they contribute \$108,224 total in property tax and \$7,861 to Westport. Over 75% of all flooded parcels are severely inundated (90+%), and almost 55% of all taxable parcels within Westport are severely flooded. The City has now lost or is at risk of losing three-quarters of its property tax revenues, and 70% of all of their taxable parcels are flooded to some degree. Nine feet of sea level rise is not likely to occur within a timeframe that would still have Westport existing as a functioning city in its current location. This level of flooding may be more likely to be seen if a magnitude 9+ CSZ earthquake were to happen and cause the land to subside. While this amount is within the predicted range of possible subsidence, it is at the very high end. If this hazard did occur, relocation may be required anyway due to damage from the earthquake and subsequent tsunami that would hit Westport. It is possible in that scenario that there would be very little undamaged property anyway that would be contributing to the tax base.

The last area of Westport to be above water is the dune ridge in the southwest corner of the city. This area has largely single-family homes, some of which are high-value vacation properties not lived in year-round. With nine feet of sea level rise, a total of 1,389 taxable parcels are flooded. This leaves only 577 taxable parcels unaffected, with a total value of \$76,138,116. These properties currently contribute \$958,968 in property taxes overall and \$69,664 to Westport.

# Sea Level Rise Interval: 9 Feet



		All Inundated Parcels (1,389)		Total Taxable Parcels (1,966)	
		# Inundated	% Inundated	# Inundated	% Inundated
Percent of Parcel Underwater	0-10%	54	3.9	54	2.8
	10-20%	55	4	55	2.8
	20-30%	27	2	27	1.4
	30-40%	22	1.6	22	1.1
	40-50%	20	1.4	20	1
	50-60%	20	1.4	20	1
	60-70%	21	1.5	21	1.1
	70-80%	57	4.1	57	2.9
	80-90%	40	2.9	40	2
	90-100%	1,073	77.3	1,073	54.5
Percent of Total Taxable Parcels Affected					70.7

Figure 29: Infographic of results for 9 feet of sea level rise.

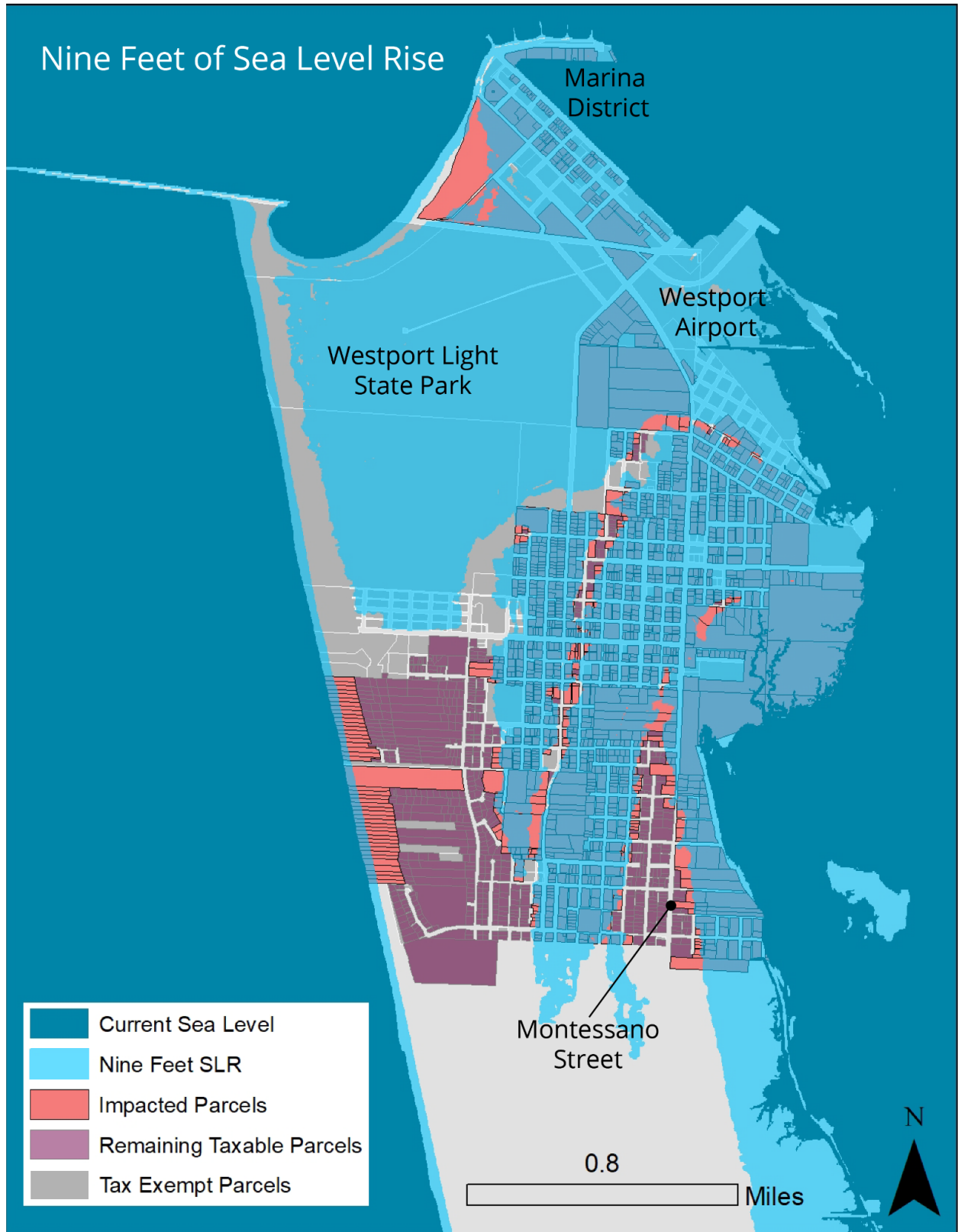


Figure 30: Map of 9 feet of sea level rise inundation.

While some of these increments of sea level rise seem highly unlikely in the foreseeable future, it is also important to consider the impacts of the subsidence that is possible after a Cascadia Subduction Zone event. Per the findings of tsunami modelers,<sup>111</sup> an L1 event could cause anywhere from 4.9 to 9 feet of land subsidence. A 5 foot drop in land elevation combined with 2 feet of sea level rise, for example, would have impacts similar to 7 feet of sea level rise without subsidence, *ceteris paribus*. Obviously there would be confounding factors due to earthquake and tsunami damage, so these scenarios can not be directly compared.

The Union of Concerned Scientists used the metric of 10% or more of usable land area flooded to determine “chronically inundated” in their report.<sup>112</sup> They did not find Westport to be chronically inundated by their definition. A key reason this may not be the case is because of the large area of wetlands along the harbor, which are not counted as usable land area for their analysis. However, from my calculations using taxable parcel land area, Westport will reach the point of chronically inundated at 2 feet of sea level rise. The total land area of taxable parcels is 41,455,232 square feet, and there will be 4,222,340 square feet of that underwater at 2 feet of inundation. The map for 2 feet of inundation does not look like I would expect for a community defined chronically inundated, however, so a different percentage may be more meaningful for that calculation.

Based on my findings and the background research I have conducted on retreat, I would recommend that Westport plan to act prior to the end of the century, or before seas rise more than three feet. It is unknown which of these circumstances will come first, but a DAPP strategy can help work within the uncertainties of climate change. Aside from just the property taxes at risk from rising seas, critical infrastructure and transportation routes will be disrupted. These will require more funds to maintain or protect from inundation even as the tax base shrinks. Additionally, other forms of taxes that are generated through people spending money in

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<sup>111</sup> Cara Donovan, “A Proposal for Using Geonarratives in Hazard-Adaptive Planning: Coastline Change in South Beach, Washington” (Seattle, WA, University of Washington, 2021).

<sup>112</sup> “When Rising Seas Hit Home | Union of Concerned Scientists,” 1.

Westport are likely to decline; tourists will be less likely to choose Westport as their destination if they need to contend with extensive nuisance flooding.

## Chapter 5: Managed Retreat Case Study

When considering a managed retreat from Westport and the greater South Beach region, the forested bluffs to the southeast make logical sense. These areas will be safe from sea level rise as well as tsunami inundation in the event of a CSZ earthquake. These lands are largely owned by various levels of government and private logging corporations. There are existing primitive logging roads that connect to various communities, but very little other development. Near the bluff edge uphill from Grayland lies a spattering of homes and an airstrip for small private airplanes, but otherwise the area is largely undeveloped. The landowner with the airstrip also owns considerable acreage adjacent in both Grays Harbor and Pacific Counties, for an estimated total of 1,075 acres.

This property was volunteered to the studio to be used as a case study site. The landowner has also considered the possibility of building an uphill community to enhance the resilience of the region from natural hazards. This land has several key pull factors that make it desirable as a relocation site. Location-wise, it is located about halfway between Westport to the north and Washaway Beach area to the south, making it central to the entirety of South Beach. The main access road stems from the center of Grayland. There are three wind turbines located on the south end of the property, providing adequate electric power. This wind farm was created through sponsorship of the Coastal Community Action Program, a non-profit organization that supports low-income households in Grays Harbor and Pacific counties.<sup>113</sup> Fiber-optic internet cable also services the property. The old logging roads provide access to nearby communities,

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<sup>113</sup> LaFranchi, Kim, "Coastal Energy Project Impact Report Grayland, WA" (Los Angeles, CA: Strategic Development Solutions, June 2011), [https://www.craft3.org/docs/default-source/case-studies/coastal-energy-project-060111.pdf?sfvrsn=215b8d71\\_2](https://www.craft3.org/docs/default-source/case-studies/coastal-energy-project-060111.pdf?sfvrsn=215b8d71_2).

and could become crucial connections if the sole bridge on SR 105 towards Aberdeen becomes inundated or damaged. The airstrip could be used in the event of an emergency to bring in supplies or help people evacuate.

Due to the inevitability of a CSZ earthquake and subsequent tsunami, at the very least it makes sense to consider this area as a safe place to evacuate to, and as a base during the recovery and rebuilding process. However, there is also an opportunity to generate tourist dollars and provide longer-term uses in this safe location to better prepare for the future. From these goals, our studio team imagined what type of uses could be beneficial to the community in the short term, while also encouraging them to consider what the potential could be in the future.

## Studio Work

The College of Built Environments 2021 Winter Studio focused on the resilience of Westport and sought to produce adaptation options for them, while also considering their position along the Pacific Ring of Fire and learning from other communities that are vulnerable to seismic activity and tsunamis. My team included myself, MUP student Courtney Ross, landscape architecture student Tammy Kuo, and architectural design students Amanda Hosmer, Parker McKean, and Yifan Lin. Together we developed proposed land uses on the property that would serve as income generators in the short term and features of a permanent settlement in the long term which could also be repurposed as a base post-disaster at any point in time.

The projects that we chose to work on included a vertical evacuation structure (VES) in Grayland with a gondola that would bring people to a terminal on the uphill property, an environmentally-conscious resort, and a community wellness center. We also wanted to explore the idea of becoming more food-independent through incorporating agriculture as both an attraction and an asset. This was partly due to the efforts of the nearby Shoalwater Bay Tribe to enhance their food sovereignty, due to being located in a food desert, and their tribal traditions

of living off of the land.<sup>114</sup> We also wanted to provide opportunities for low-income residents of South Beach to pursue homeownership by implementing incremental building.

## Cedar Retreat

The Cedar Retreat is an ecologically-conscious resort that features camping platforms placed in circular formations, all connected by boardwalks. This method was used to avoid having to clear cut the land and disturb large amounts of soil like would be necessary with traditional foundations. The layout of the platforms was chosen in order to be similar to the existing Grayland Beach State Park Campground. These platforms could be built to include some walls or a roof structure, and then in the future could be the basis for incremental homes. Likely these homes would be used as vacation homes or rental properties for tourists in the medium-term, with people actually moving to them full-time later as they are further built out or their homes in South Beach were affected by hazards.



*Figure 31: Proposed layout (left) and design (right) of the camping platforms at Cedar Retreat.*  
Source: Amanda Hosmer

## Therme Grayland

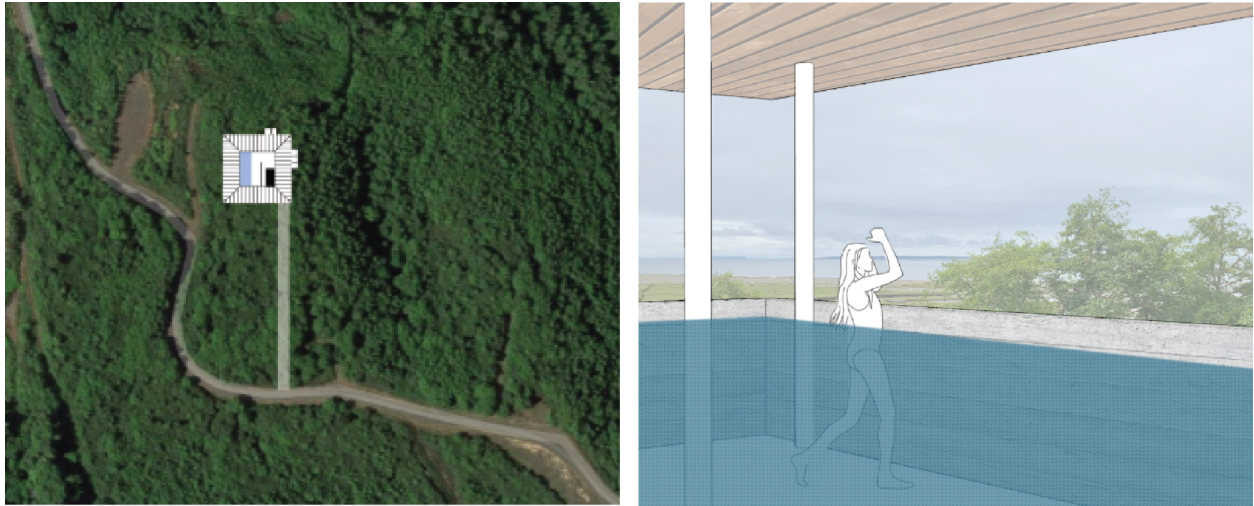
Therme Grayland is a wellness retreat that can be visited by both local residents as well as tourists and will include spa amenities. This project was inspired in part by the desire of the

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<sup>114</sup> “American Roundtable: Dynamic Landscapes, South Beach, Washington,” The Architectural League of New York, accessed June 16, 2021, <https://archleague.org/event/dynamic-landscapes-south-beach-washington/>, 106.

area residents to build a community pool facility, as well as extend the existing trail network.<sup>115</sup>

The building incorporates sliding glass doors which open to allow a more intimate connection to the surrounding natural environment.



*Figure 32: A site plan (left) and conceptual rendering (right) of Therme Grayland. Source: Parker McKean*

## The Oculus VES

The Oculus vertical evacuation structure is located in Grayland across from the existing community center. The structure can be used for events and day-to-day activities, but also will provide safe high ground during a tsunami. The proposal also includes a rooftop gondola terminal that will connect to another terminal near the airstrip on the property. This gondola line could be set up for use after a disaster to help move people to higher ground, but in regular situations will be a great attraction as it flies over the nearby cranberry bogs.

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<sup>115</sup> City of Westport, "COMPREHENSIVE PARK & RECREATION PLAN 2018-2023," Accessed June 2, 2021, [http://www.ghcog.org/Planning/Westport\\_ParkPlan2018.pdf](http://www.ghcog.org/Planning/Westport_ParkPlan2018.pdf).

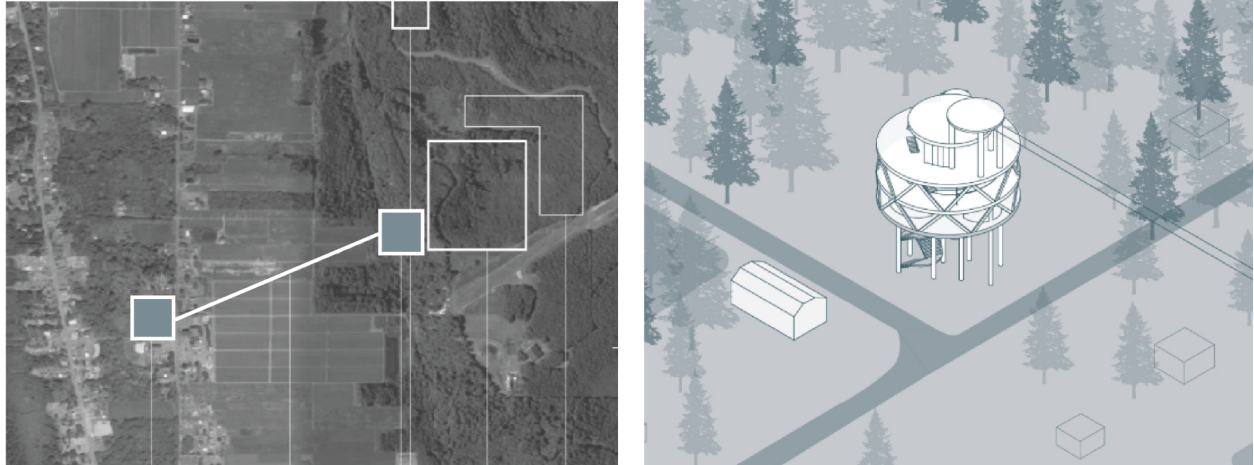


Figure 33: Site plan (left) and a conceptual rendering (right) of the Oculus VES. Source: Yifan Lin

### Regenerative Forest

The Regenerative Forest concept includes agricultural zones as well as gathering places like campfire stations and an outdoor classroom. Trails and boardwalks will be weaved throughout the site to allow for self-guided tours and recreation. An additional benefit of incorporating these agricultural sites in the overall scheme is that they can be strategically placed in areas otherwise unsuitable for development. The property has some significant slopes that cannot be built on, but are prime areas for trails and agriculture to be located.



Figure 34: Site plan (left) and conceptual rendering of an outdoor classroom (right) in the Regenerative Forest. Source: Tammy Kuo

## Site Plan

Based on the uses developed within our team, I generated a potential site plan of the property. This plan shows the locations of the previous projects and lays out potential future land uses. In deciding where each type of use should go, I imagined the timeline of development, with much of it likely beginning along the western edge near the airstrip and main access road. This is the most logical progression of construction, especially due to the community's desire to not clear cut large areas of timber. The timeline of development here is an important question that would have to take into account the community's willingness to plan for retreat. Ideally, the community would be able to come together and determine what they would like to see in this new settlement.

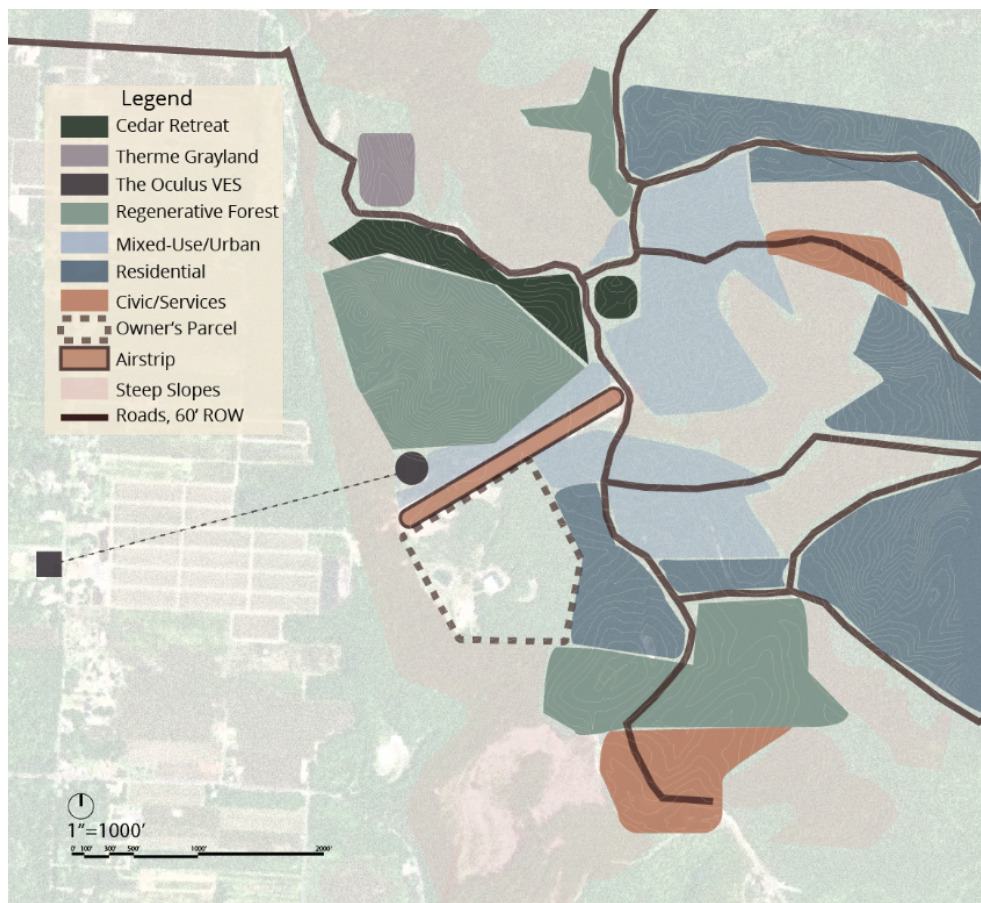


Figure 35: Site plan of proposed interventions and future land uses on uphill property.

## Expanding the Community

In order to “pull” South Beach residents to the uphill property, there need to be occasions that encourage them to spend time there and feel comfortable in that space. The proposed uses from our studio course would help provide these occasions, and show people that some key infrastructure exists already. After work is done to provide the rest, it is largely a blank slate that they can make their mark on, bringing the best elements from Westport and South Beach while addressing less than perfect elements through creative planning. The new settlement would need to take into account the total population expected to reside there once it is built out, although the large swaths of government lands surrounding the property would allow for future expansion, if needed. In fact, the government land could be classified as another pull factor. Since the government will often be looked at to provide financial and logistical assistance for retreat, it may be beneficial for them to turn over ownership of this land to the City of Westport in lieu of some cash funding.

The uphill settlement is geographically close to where South Beach residents currently live, work, and play. Being able to relocate where they live to a nearby spot that allows for continued employment in the largest industries here is a huge motivating factor, and one that some communities who will have to relocate won't be able to maintain. By moving vulnerable infrastructure and people to a safe area, any mitigation and adaptation dollars spent can focus on protecting the important marina, and ensuring a healthy coastal ecosystem remains intact for recreation. Providing an incentive to revamp the forest roads in the bluffs is also a smart idea ahead of any natural disasters because of the current vulnerability of the sole bridge to Aberdeen.

Opting to relocate the residents and functions of the City of Westport, and surrounding South Beach area, can enhance long-term resilience for the community. Besides the fact that the bluffs are high enough to be unaffected after a CSZ-trigger tsunami, they are also resilient to

climate-change induced sea level rise. Economic activities can expand into new uses while still having easy access to the parts of the community that are current economic drivers. Planning in a community-oriented way can help address any current shortfalls of the area, and create the vision of the residents. A land swap for low-land parcels and properties in the uphill settlement can help provide opportunities for maintaining the shared culture and avoiding extreme financial hardships by residents or the City. Westport has shown initiative in forward-thinking strategies to protect the community from hazards. By designing an uphill settlement focusing on environmentally-conscious uses that can generate income, provide an evacuation staging area, and become a long-term home for everyone can be another step towards becoming one of the most progressive communities in terms of hazard mitigation. This designation could also be leveraged to generate tourism and show residents and experts from other communities what is possible when a community comes together to plan for their lasting resilience.

## Chapter 6: Conclusion

In conclusion, generally people, corporations, and governments are not fully incorporating the risks of sea level rise into their planning and policy decisions. This leaves individual households and entire communities vulnerable to financial losses that can have a domino effect on markets at large. Mass default on mortgages, or a dire insolvency of jurisdictions who usually foot the bill after disaster scenarios can lead to a national or even global economic downturn similar to 2008. All forms of adaptation strategies require funding, and many of them are too costly for an individual to pursue alone. Jurisdictions will likely see increasing pressure to generate and implement community-wide adaptation strategies for SLR and other environmental hazards.

Acting sooner rather than later gives the City of Westport the largest tax base from which to draw to finance the adaptation measures that the community decides to pursue. DAPP

planning can help the community tackle current issues while also leaving open potential options in the future, and provide signals for when a shift in policy needs to be made. If retreat from Westport occurs, the outcomes are likely to be better financially and in terms of maintaining social connections if a coordinated, large-scale strategy is implemented rather than piecemeal retreat by individuals after their properties become unlivable. Being prepared will also produce better outcomes than reactionary planning in the wake of a CSZ earthquake and tsunami, although this inevitable natural hazard could be implemented into a DAPP scheme as a tipping point.

The property in the bluffs south of Westport was chosen as a case study because of the interest from the property owner, but it also provides some key elements, or pull factors, that make it a strong contender for a community relocation area.

My research used a method of analysis used by other groups to examine the fiscal vulnerability of municipalities in the face of climate change induced sea level rise. The findings are most meaningful for the residents and leaders of the Westport/South Beach area, though the method is reproducible to other coastal communities. Hopefully, the knowledge gained about where vulnerable parcels are located and their overall contribution to the tax base of Westport can be used to help the community in their hazard adaptation planning efforts. Quantifying increments of sea level rise in terms of property value and tax base loss may help some residents more fully understand the implications of rising seas, not only to their property, but also to their broader community. My findings may also cause other levels of government and various special districts to consider the impacts of SLR on them and begin to plan for the future.

Limitations of this research included various aspects of GIS data as described in the methods section, as well as the general uncertainty surrounding SLR and CSZ events. Due to the COVID-19 pandemic, I had very limited engagement with Westport stakeholders, and do not have personal experience visiting the community.

Future research could explore numerous paths based on this thesis. First, to better refine the tax base findings there could be a process to determine a threshold when an individual parcel would lose all of its market value. This could include separating the assessed land value from the assessed building value and then devaluing them separately as water began to inundate them. A feasibility analysis could be conducted of the property on the bluffs to determine if it would support the goal population and what the costs of infrastructure and construction might be. The community could also expand by holding workshops to develop a DAPP plan, and maybe look into the possibility of a new regional entity with taxing authority to carry out the retreat process.

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