# Climate Change in South and West Chatham

Gerry Stahl, October 2025

The Energy and Climate Action Committee (ECAC) in coordination with the Chatham Department of Natural Resources planned and oversaw a year-long scientific study in 2024 of the four major salt marshes of South and West Chatham: Forest Beach, Cockle Cove, Bucks Creek and Oyster Pond. The purpose of the study was to gather baseline data that could be useful for interventions to preserve these marshes into the future. The study was conducted by the Center for Coastal Studies (CCS) in Provincetown. The study produced very detailed maps of elevation, sampled marsh sedimentation and cataloged local vegetation. Using this data, the study predicted where marsh was likely to disappear in coming decades and analyzed areas surrounding the marshes to determine suitability for marsh migration. ECAC has initiated plans for a similar study to be conducted of the other nine salt marshes in Chatham during calendar year 2026.

The study by CCS found that the four marshes are generally quite healthy now, but are subject to a variety of threats from climate change. For findings from the study, including details on the calculation of areas most suitable for marsh migration at different levels of future sea level rise and other technical aspects, see the report by the Center for Coastal Studies at:
https://www.chatham-ma.gov/DocumentCenter/View/9072/Chatham_Marshes_Final_reduced and
https://www.chatham-ma.gov/DocumentCenter/View/9121/CCS_ChathamMarshes_Appendices_Final.

This ECAC report provides a supplement to the CCS report concerning elevation, vegetation and sedimentation data. This supplement incorporates information on housing and roads in Chatham, to envisage specific implications of climate change for Chatham residents.

Closely related to the concerns of the marsh study are the projections of flooding, storm surge and wave depth based on the recent Massachusetts Coast Flood Risk Model (MC-FRM). This model of threats to the Massachusetts coastline has important consequences for the marshes, floodplain, low-lying roads and homes near the shore or marsh in South and West Chatham. These are also discussed below, complementing the issues raised by the CCS study results. We begin this report with an overview of $CO_2$ emissions and global warming, which drive the sea level rise and storms.

Following the CCS marsh study, it remains for ECAC to use the data and analysis of the study to suggest Town actions to preserve the salt marshes and to mitigate anticipated consequences of climate change. This involves considering the outlook for sea level rise on the Chatham shoreline and situating the consultant's findings specifically within the local circumstances in Chatham, including the placement of residential properties, roads and beaches. It also involves presenting the likely outcomes of climate change generally in Chatham, and consequent recommendations to Town government and to the community. To begin this undertaking, this document addresses the following topics:


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## A. Global and local warming trends caused by greenhouse gas emissions

The percentage of carbon dioxide gas ($CO_2$) in the atmosphere is the major determinant of sea level rise, global warming and climate change in general. As documented in Figure 1 shown here, there has been an unprecedented increase in $CO_2$ and other greenhouse gases in the atmosphere, which has driven an historically exceptional rise in global temperatures and sea level

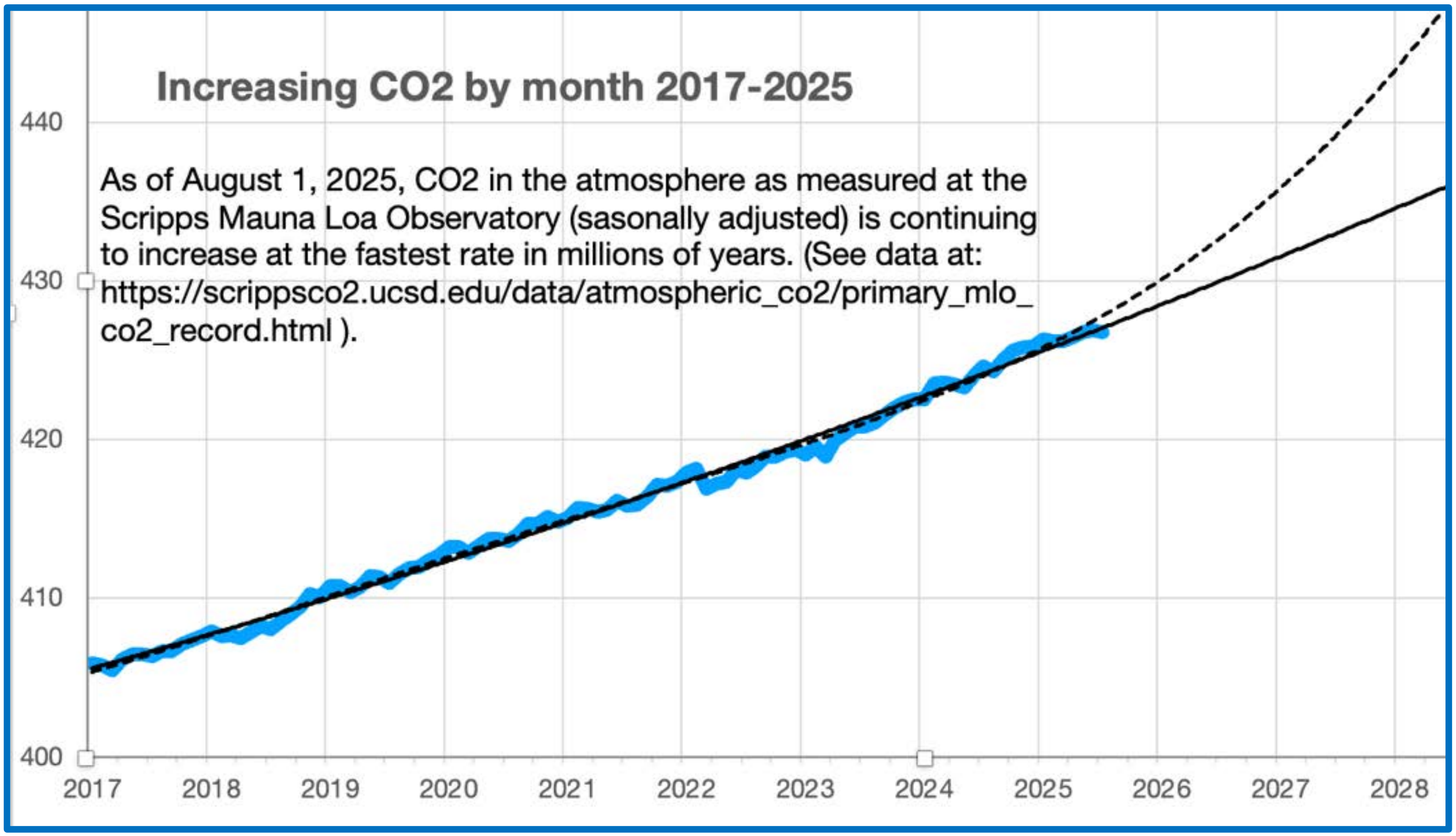



*Figure 1. Global $CO_2$ atmospheric content in parts per million. (Data from Scripps.)*

A gradual decrease of average global temperature in the 1800s was reversed by the $CO_2$ emissions released by industrialization, with its reliance on fossil fuels. The increase of $CO_2$ has subsequently followed an exponential trend of average global temperature in sea and air (see Figure 2).

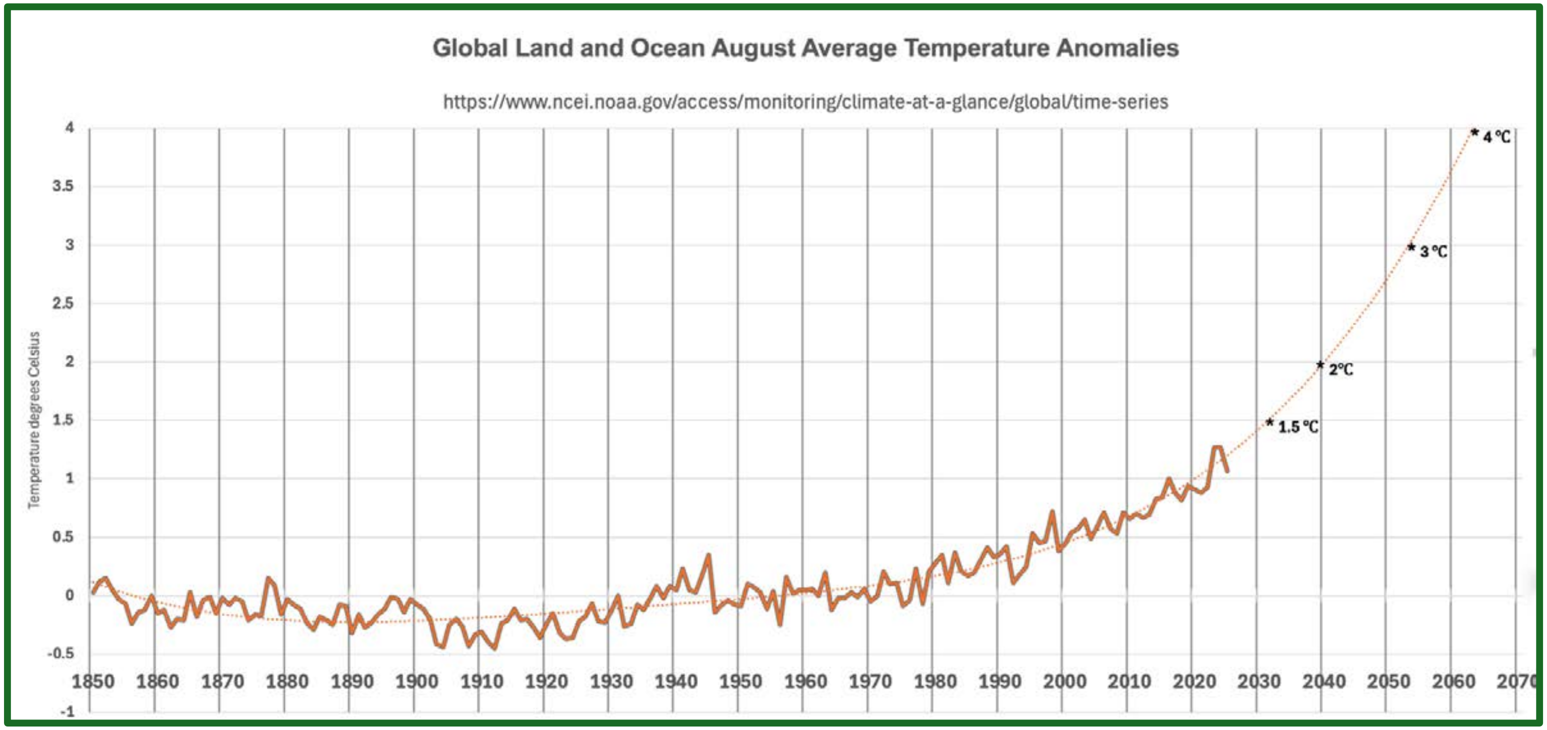



*Figure 2. Trend of average global temperature on land and ocean, in degrees Celsius compared to 1850. (Data from NOAA.)*

According to the NOAA website on "Climate change: global temperature" (https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature published May 29, 2025): "The amount of future warming the Earth will experience depends on how much carbon dioxide and other greenhouse gases we emit in coming decades. Today, our activities—burning fossil fuels and to a lesser extent clearing forests—add about 11 billion metric tons of carbon (equivalent to a little over 40 billion metric tons of carbon dioxide) to the atmosphere each year. Because that is more carbon than natural processes can remove, atmospheric carbon dioxide amounts increase each year."

On Cape Cod specifically, the average temperature (measured at its daily high) has been rising even faster than the global rate (see Figure 3).

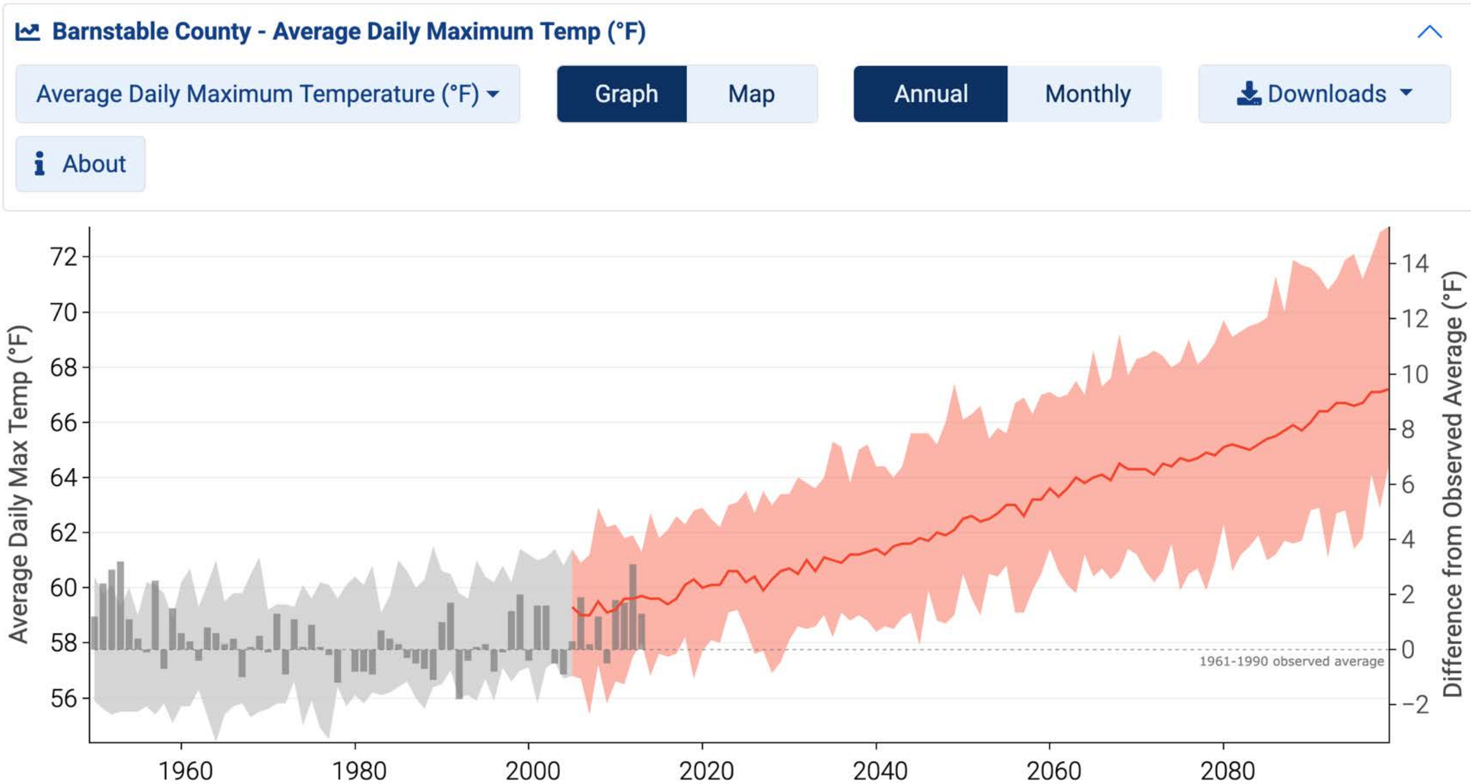



*Figure 3. Trend of average daily maximum temperature on land on Cape Cod, in degrees Fahrenheit.*

The increase in average global temperature tends to follow closely the rate of increase in global emission of carbon and other greenhouse gases. As shown on the left of Figure 4, scientists have charted alternative possible scenarios of carbon emissions for the next 75 years. Most scenarios projected there assume that emissions will be dramatically reduced, at least in line with the Paris Agreement. Only the "higher scenario" RCP8.5 assumes continuing high emissions – as suggested in Figure 1. The global temperature is then predicted on the right of Figure 4 for each of these emission scenarios (with uncertainty ranges for each scenario colored in).

According to the 2017 U.S. Climate Science Special Report, if yearly emissions continue to increase rapidly, as they have since 2000, models project that by the end of this century, global temperature will be at least 5.0°F (2.8°C) warmer than the 1901-1960 average, and possibly as much as 10.2°F (5.7°C) warmer (see the range colored in pink for the year 2101). If annual emissions had stopped increasing after 2017 and begun to decline significantly soon after, models project global temperatures would still be at least 2.4°F (1.3°C) warmer than the first half of the 20th century, and possibly up to 5.9°F (3.3°C) warmer.

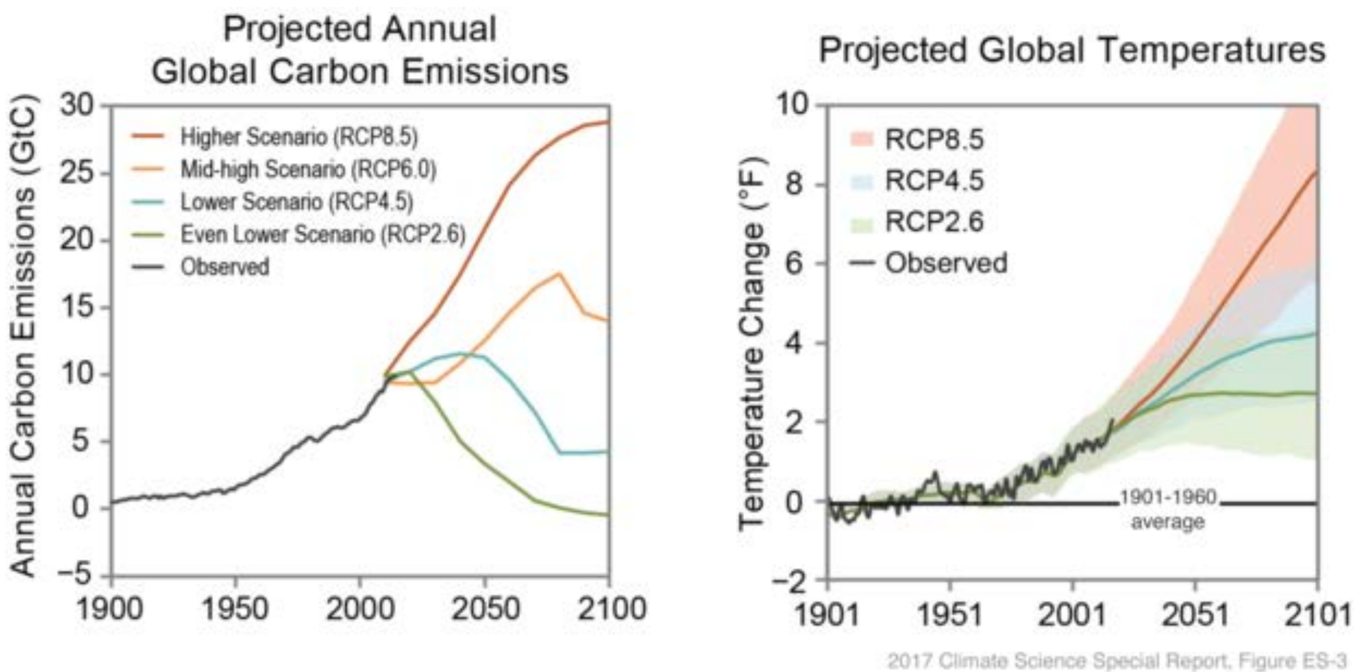



*Figure 4. (**left**) Hypothetical pathways of carbon emissions ("representative concentration pathways," or RCPs) throughout the twenty-first century based on different possible energy policies and economic growth patterns. (**right**) Projected temperature increase relative to the 1901-1960 average depending on which RCP we eventually follow. Image by Katharine Hayhoe, from the 2017 Climate Science Special Report by the U.S. Global Change Research Program.*

The UN Paris Agreement of 2015 aimed to "substantially reduce global greenhouse gas emissions to hold global temperature increase to well below 2.0°C above pre-industrial levels and pursue efforts to limit it to 1.5°C." The 1.5°C (2.7°F) goal was necessary to prevent low-lying islands and coastal areas from being submerged (see Figure 21). The 2.0°C (3.6°F) goal was to prevent disastrous storms, wildfires and sea level rise. We are already beginning to see the consequences of the 1.5°C increase. According to *Our Final Warning: Six Degrees of Climate Emergency* by Mark Lynas, an increase of 2.0°C (3.6°F) will stress human societies and destroy many natural ecosystems such as rainforests and coral reefs. At an increase of 3.0°C (5.4°F), the stability of human civilization will be seriously imperiled. An increase of 4.0°C (7.2°F) would probably bring a full-scale global collapse of human societies, accompanied by a mass extinction of the biosphere. By 5.0°C (9.0°F), most of the globe will be biologically uninhabitable, with humans reduced to a precarious existence in small refuges. At 6.0°C (10.8°F), we risk triggering a runaway warming process that destroys the capacity of the planet to support life.

Climate scientists have long warned that climate change can not be reversed as it passes these milestones because processes in nature like melting tundra, glacial collapse and warming ocean currents set into motion natural processes that drive further climate change regardless of human action. Technical solutions to remove $CO_2$ from the atmosphere by future generations are proving to be infeasible. Furthermore, as climate change worsens, social structures will deteriorate, making worldwide efforts even harder to negotiate. For instance, as major regions of the world become uninhabitable, masses of people will have to immigrate to survive – increasing global conflicts and competition for food and other resources.

## B. Current trends of local sea level rise (at Nantucket, Boston and Woods Hole)

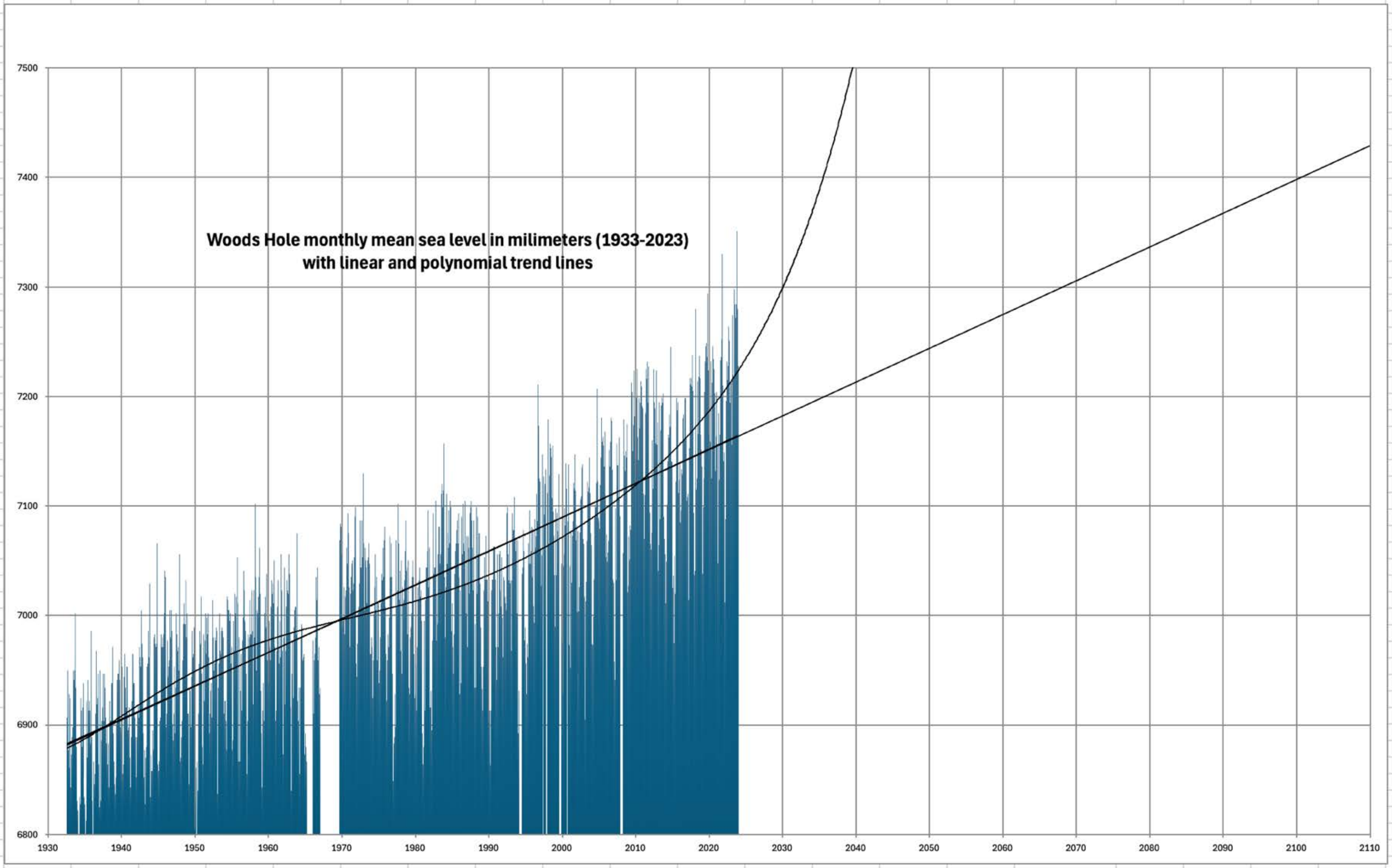
Climate change is a global issue, whose current impact is becoming visible in other parts of the world. What are the most immediate effects expected in Cape Cod and specifically in Chatham? Relevant new data are now available relevant to the likely loss of salt marsh in part of Chatham.

Estimates of sea level rise are critical to predicting future salt marsh extent, flooding and storm surge. Yet it is hard to estimate for the future, given seasonal effects, global warming, shifting currents, glacier melting and other tipping points. It varies considerably in different parts of the world, with recent and expected sea level rise along Chatham's coast higher than most places.

The State of MA, NOAA, the UN and local experts have adopted models of the likely sea level rise that can be expected over the next 75 years. It is hard to keep predictions up to date with current data. Many recent models assumed that countries would meet goals of the 2015 Paris Agreement, but that is not occurring.

Global $CO_2$ emissions continue to increase, despite the increased competitiveness of renewable energy. Greenhouse gas emissions trigger natural processes in glacier melting, ocean currents, tundra thawing, etc., which in turn release more carbon and methane. The result is seen in the continuing rising trend of $CO_2$ in the air as measured in Hawaii since 1958 (see Figure 1 of recent $CO_2$ data).

The CCS study of four marshes relied on predictions for Nantucket from the United Nation's 2021 Intergovernmental Panel on Climate Change (IPCC) 6th assessment report (AR6), which predicted 2.9 ft of sea level rise by 2100. However, this now seems to be a very conservative value. The Pleasant Bay *Climate Adaptation Action Plan* of 2024 adopts an estimate of 4.0 ft ("intermediate") or 8.0 ft ("high") by 2100 for different planning purposes. One can compare these predictions with graphs of historic sea levels at Woods Hole (Figure 5) and Boston (Figure 6) as well. Figure 7 compares the predictions from these sources (in feet) for 2030, 2050, 2070 and 2100:




| | 1980 | 2010 | 2030 | 2050 | 2070 | 2100 |
|---|---|---|---|---|---|---|
| linear trendline predictions (mm) | 7040 | **7103** | **7180** | **7240** | **7310** | **7400** |
| polynomial trendline predictions (mm) | 7020 | **7103** | **7280** | **7500** | | |

| | 1980 | 2010 | 2030 | 2050 | 2070 | 2100 |
|---|---|---|---|---|---|---|
| linear trendline predictions (ft) | **23.1** | **23.3** | **23.6** | **23.8** | **24.0** | **24.3** |
| polynomial trendline predictions (ft) | **23.0** | **23.3** | **23.9** | **24.6** | | |

| | 1980 | 2010 | 2030 | 2050 | 2070 | 2100 |
|---|---|---|---|---|---|---|
| linear increase since 1980 (ft) | **0.0** | **0.2** | **0.5** | **0.7** | **0.9** | **1.2** |
| polynomial increase since 1980(ft) | **0.0** | **0.3** | **0.9** | **1.6** | | |

*Figure 5. Sea level rise measured at Woods Hole. (Data from NOAA at https://psmsl.org/data/obtaining/stations/367.php .)*

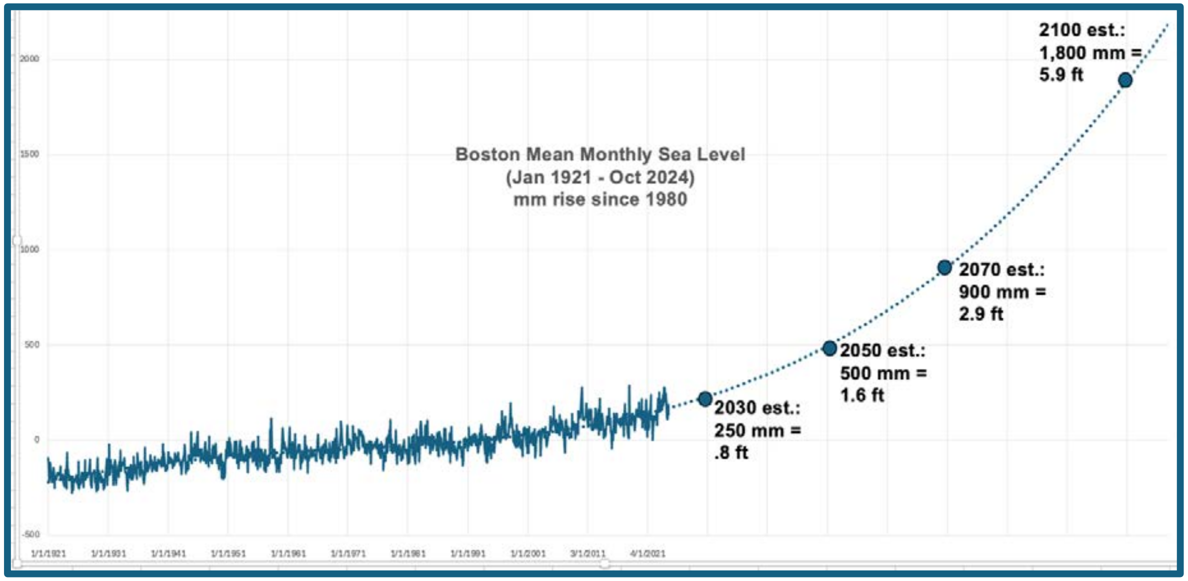



*Figure 6. Sea level rise measured at Boston. (Data from NOAA at [https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8443970](https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8443970) .)*

| sea level rise (feet) | 2030 | 2050 | 2070 | 2100 |
|---|---|---|---|---|
| CCS study | | 1.15 | 1.8 | 2.95 |
| Woods Hole | 0.9 | 1.9 | 3.2 | 5.8 |
| Boston | 0.8 | 1.6 | 2.9 | 5.9 |
| Nantucket - interm. | 0.7 | 1.5 | 2.4 | 4.2 |
| intermediate-high | 0.9 | 1.8 | 3 | 5.2 |
| high | 1.2 | 2.5 | 4.3 | 7.9 |
| extreme | 1.4 | 3.1 | 5.5 | 10.5 |

*Figure 7. Comparison of predictions of sea level rise in the next 75 years.*

Based on this comparison, it may be that the CCS study predictions for 2100 will likely occur as soon as 2070 and the CCS study predictions for 2070 may occur nearer to 2050. For planning purposes, Chatham should be prepared for flooding by 2100 based on sea level rise of from 5 to 10 feet along Chatham's coast. A series of maps showing the effects of these higher sea level rise values (Nantucket "high" figures in the above comparison) will be shown in later sections below. It is important to plan decades ahead, as it can take several years to propose, approve, fund, permit and construct projects; and, of course, the projects should continue to be viable for many years once implemented.

## C. Loss of salt marsh in Chatham by 2050, 2070 and 2100 (based on the CCS study)

Salt marshes are a major natural resource of Chatham. They provide much of the scenic charm of the town. They protect surrounding properties from the worst threats of storm surge and provide a wealth of ecological services to the flora, fauna, sea life and water quality. The ECAC has determined that Chatham's salt marshes face the greatest peril and represent the most important asset to protect as Chatham confronts rising sea levels. The purpose of the CCS study was to generate information on the current condition of four Chatham marshes in order to predict their future trends and to recommend possible interventions. The goal is to preserve these marshes as much as possible in the face of sea-level rise and climate change, to support the ecology of the marshes, to prevent loss of habitat and natural resources, and to protect neighboring residences.

Figure 8 and Figure 9 predict potential migration of salt marsh to suitable upland. Suitability is based on land elevation and slope, tide heights and adjacency to other marsh areas. The CCS study does not take into account existing human infrastructure – that will be addressed in a later section of this report.

Figure 8 shows the areas around Cockle Cove and Bucks Creek marshes projected to the year 2100, with 3 feet of sea level rise. All the current marsh areas have been flooded, even during low tide, so they do not support marsh grass. Only the uplands areas shown in red are suitable for marsh. The marsh may be able to migrate there if not blocked by residences, roads, walls, etc.

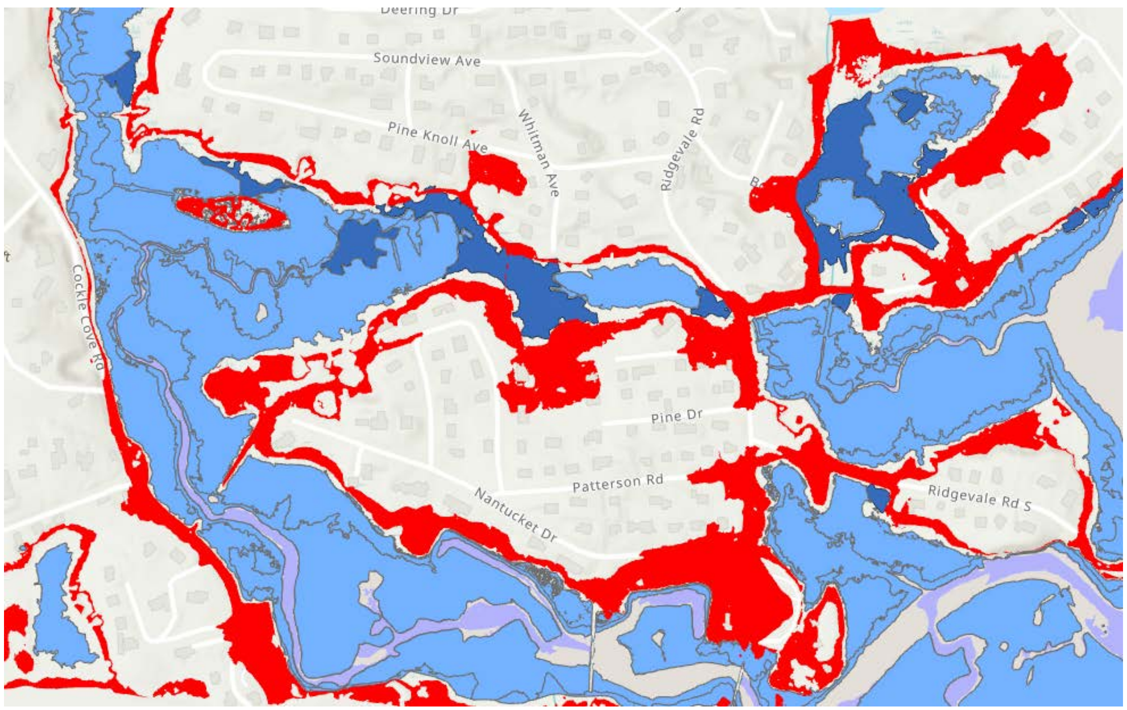



*Figure 8. Detail of area of Chatham around Cockle Cove and Bucks Creek marshes in 2100, with 3 ft of SLR.*


*Color coding for Figure 8 and Figure 9.*

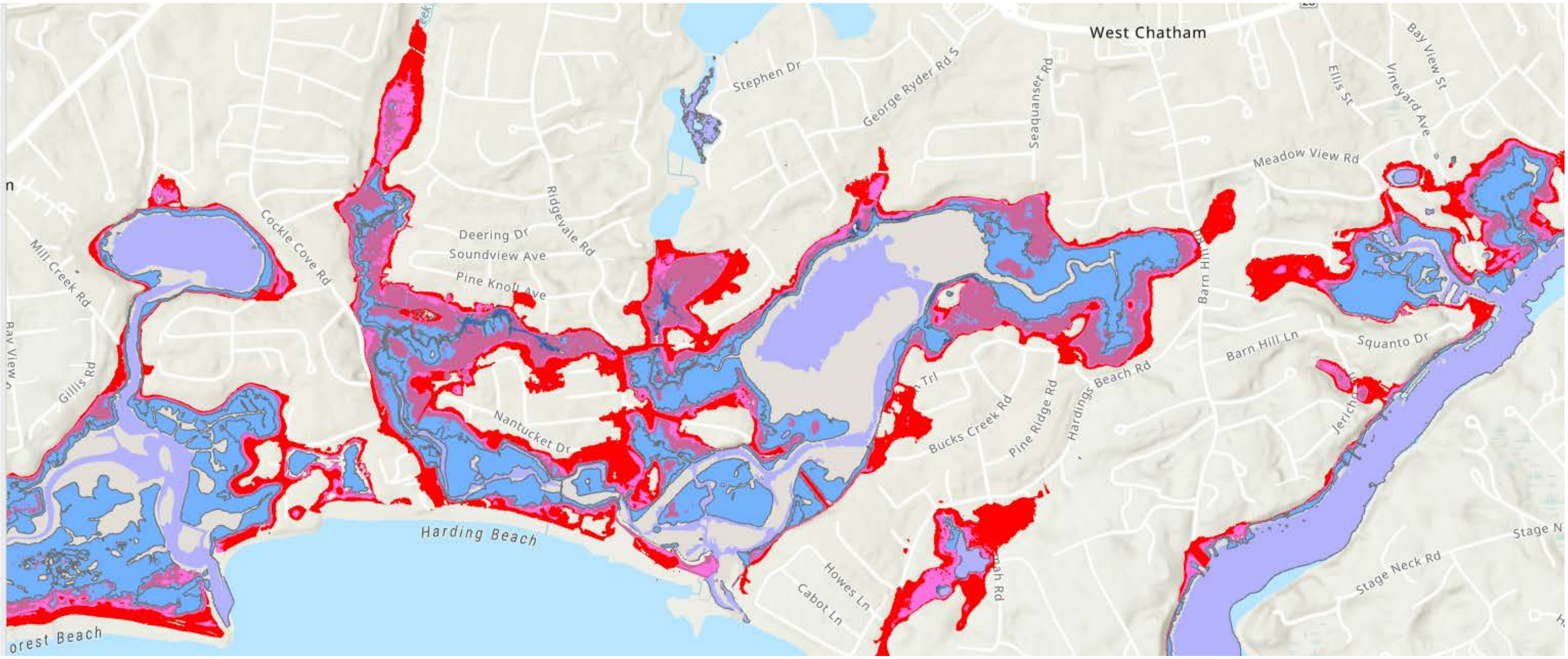



*Figure 9. Marshes projected to 2050, 2070 and 2100, with 1.15, 1.8 and 3 ft of SLR, indicated in purple, pink and red respectively. Successive layers overlap and obscure earlier ones.*

Figure 10 is a chart from the CCS study final report showing how the amount of land available for marsh is shrinking with sea level rise. It shows a reduction from the present to 2100 from 205.5 acres to 78.5 acres – a loss of over half (62%) the marsh land in the study area of South and West Chatham. This is based on the study's assumptions of sea level rise, so it may occur by 2070. This also does not take into account private property ownership, which will limit marsh migration. Further analysis of this is presented in the next section.

| | | Loss from previous | | Loss from 2025 | |
|---|---|---|---|---|---|
| Year | Acres | Acres | % | Acres | % |
| 2025 | 205.5 | - | - | - | - |
| 2050 | 124.2 | 81.3 | 40% | 81.3 | 40% |
| 2070 | 83.4 | 40.8 | 33% | 122.1 | 59% |
| 2100 | 78.5 | 4.9 | 6% | 127.0 | 62% |

*Figure 10. Loss of marsh extent in the four marshes.(See CCS final report.)*


*Figure 11. Photograph of a purple marsh crab. (Photo from Wikipedia.)*

A surprising – and disturbing – discovery in the study of the four marshes was the abundance of purple marsh crabs (*Sesarma reticulatum*, shown in Figure 11). While native to New England, they are thought to be responsible for considerable recent salt marsh loss in many areas throughout the Cape Cod region. Their population explosion in areas of the Cape may be due to climate change, pushing ecosystems northward and reducing natural predators of these crabs. Unlike fiddler crabs and other local varieties, purple marsh crabs are nocturnal and eat salt grasses, thereby destroying the marsh. There is no known practical solution to the over-population of these crabs.

## D. Chatham parcels most suitable for future marsh migration (based on the CCS study)

If our marshes are gradually being submerged by sea level rise, what can be done to preserve them? Salt marshes do have mechanisms to extend their lives. Sedimentation (accumulation of sand brought in by the tides and organic material from old marsh grass) will prolong the viability of existing marsh, preventing marsh grasses from drowning. Also, with rising tide levels, marshes can migrate into adjacent land that is slightly higher than the high-marsh border – if not too steeply sloped. However, houses, roads, stone walls and other man-made structures can prevent such marsh migration. The study produced fine-grained elevation contours around the existing marshes and sampled sedimentation rates over time. But the consultant study could not take into account the locations of residences, roads and other barriers to marsh migration – that is addressed in this report.

Figure 12 and Figure 13 indicate locations in South and West Chatham rated as most suitable for marsh migration, based on the CCS study, assuming sea level rise of 1.15 ft, 1.80 ft and 2.95 ft by 2050, 2070 and 2100, shown in purple, pink and red, respectively. They also take into account sedimentation rates (which vary considerably across each marsh) and slope of the land (which must be under 20% for marsh migration). Residential parcels (not including parcels owned by the Town or the local land trust) that include area considered suitable for marsh migration are highlighted in tan.

A closer look would be needed to see which of these 418 highlighted residential properties, valued at a total of $571 million, contain significant areas for marsh migration, where homes are located on the property, and how much new marsh could be established there. Most of the properties highlighted just overlap the potential marsh areas along thin strips, at a distance from any building. Many of these areas may already be protected by wetlands bylaws. However, about 40 houses actually overlap or abut the potential marsh area. In some cases, it might be desirable to subdivide a property and to donate the wetland part to the Town or the local land trust. Alternatively, a conservation restriction on the subdivided section might suffice. Where a substantial part of a property including the residential building is threatened by flooding, the Town might want to offer a “managed retreat” plan. Such options would, of course, require careful investigation of individual properties and extensive community discussion in the coming years – including prioritizing compared to properties around the nine other marshes to be studied in 2026.

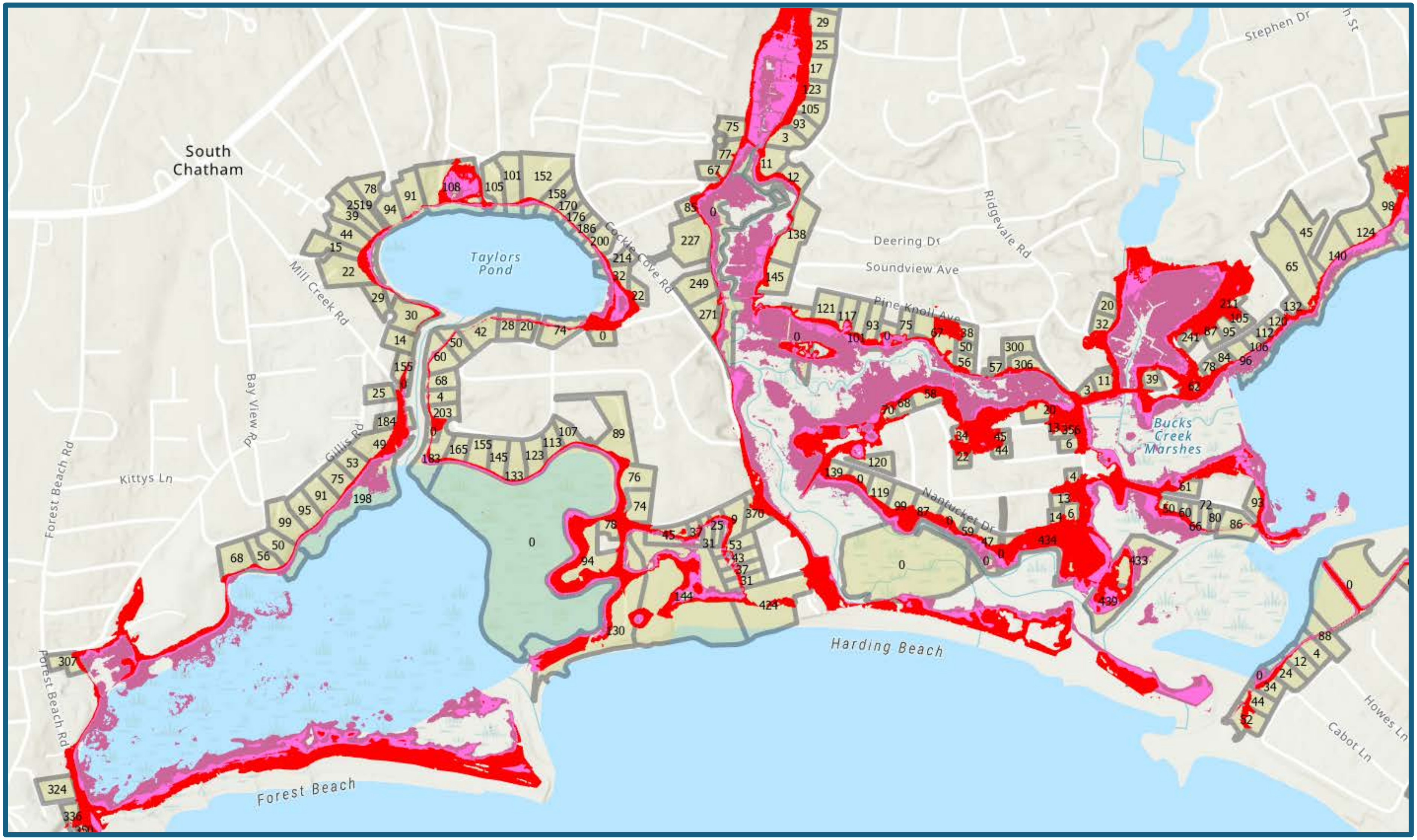



*Figure 12. Map of parcels in South Chatham that include potential marsh migration areas, given 3 ft of sea level rise. Numbers on properties are their street numbers. (All maps generated by G. Stahl.)*

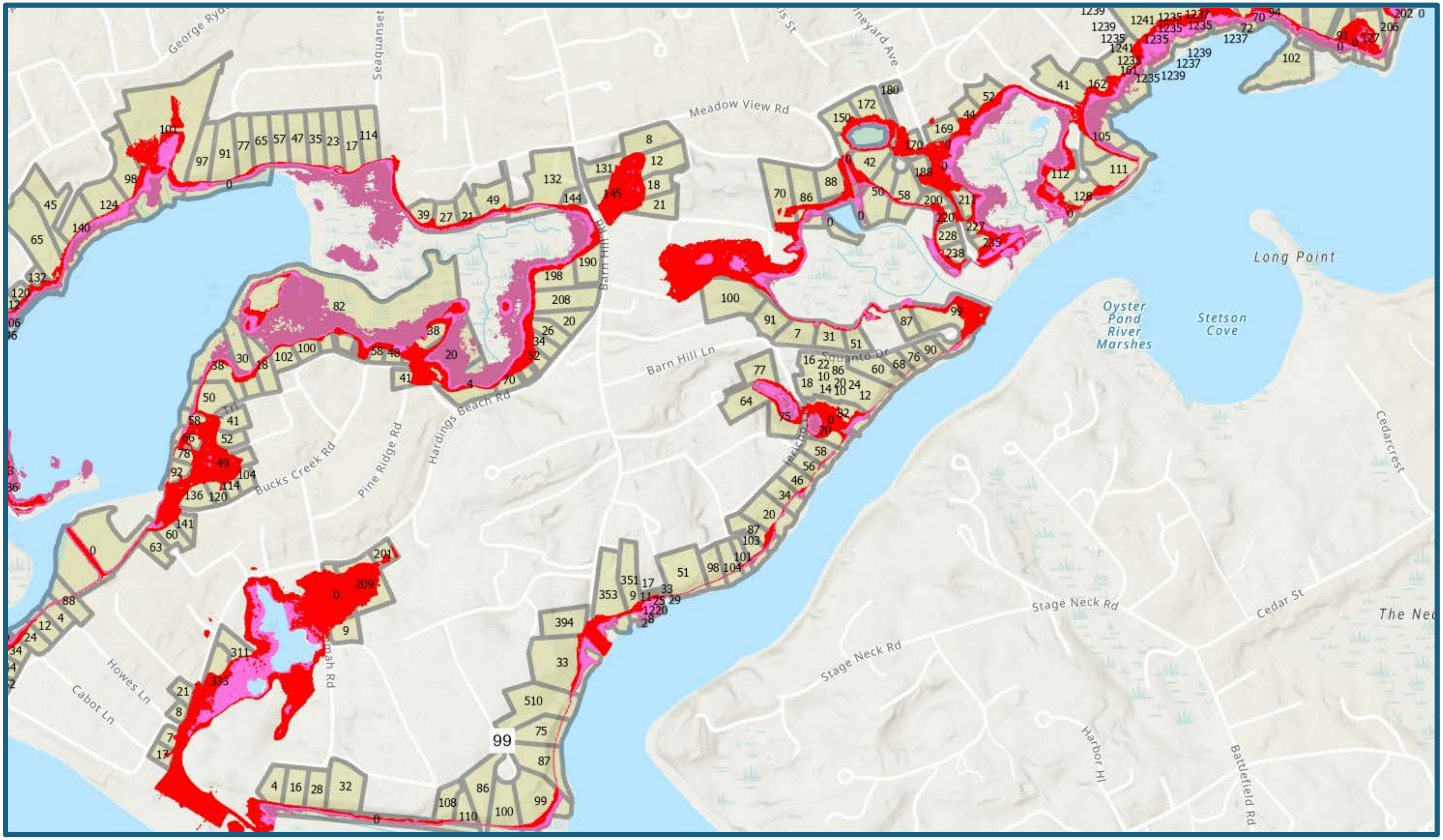



*Figure 13. Map of parcels in West Chatham that include potential marsh migration areas, given 3 ft of sea level rise.*

## E. Flooding and wave surge for residences (based on MC-FRM)

The CCS study was focused on the salt marshes, not on homes. The threat to residences is best analyzed through use of the new model of tides and waves along the Massachusetts coast, recently developed by the state. The Massachusetts Coast Flood Risk Model (MC-FRM) for 2030, 2050, and 2070 simulates sea level rise and coastal storms to predict the consequences of climate change events in Chatham. This probabilistic model uses the "Nantucket high" predictions of sea level rise (1.2, 2.5 and 4.3 feet), in accordance with official state predictions (https://www.mass.gov/info-details/massachusetts-sea-level-rise-and-coastal-flooding-viewer ). The remainder of this report concerns predictions of this model for the floodplain in South and West Chatham, to complement the findings of the CCS marsh study. Figure 14, Figure 15 and Figure 16 map predictions for flooding, storm surge and wave effects along Chatham's southern coast in 2070 during a major ("hundred-year") storm event, assuming 4.3 ft of sea level rise, high tide and additional storm surge.

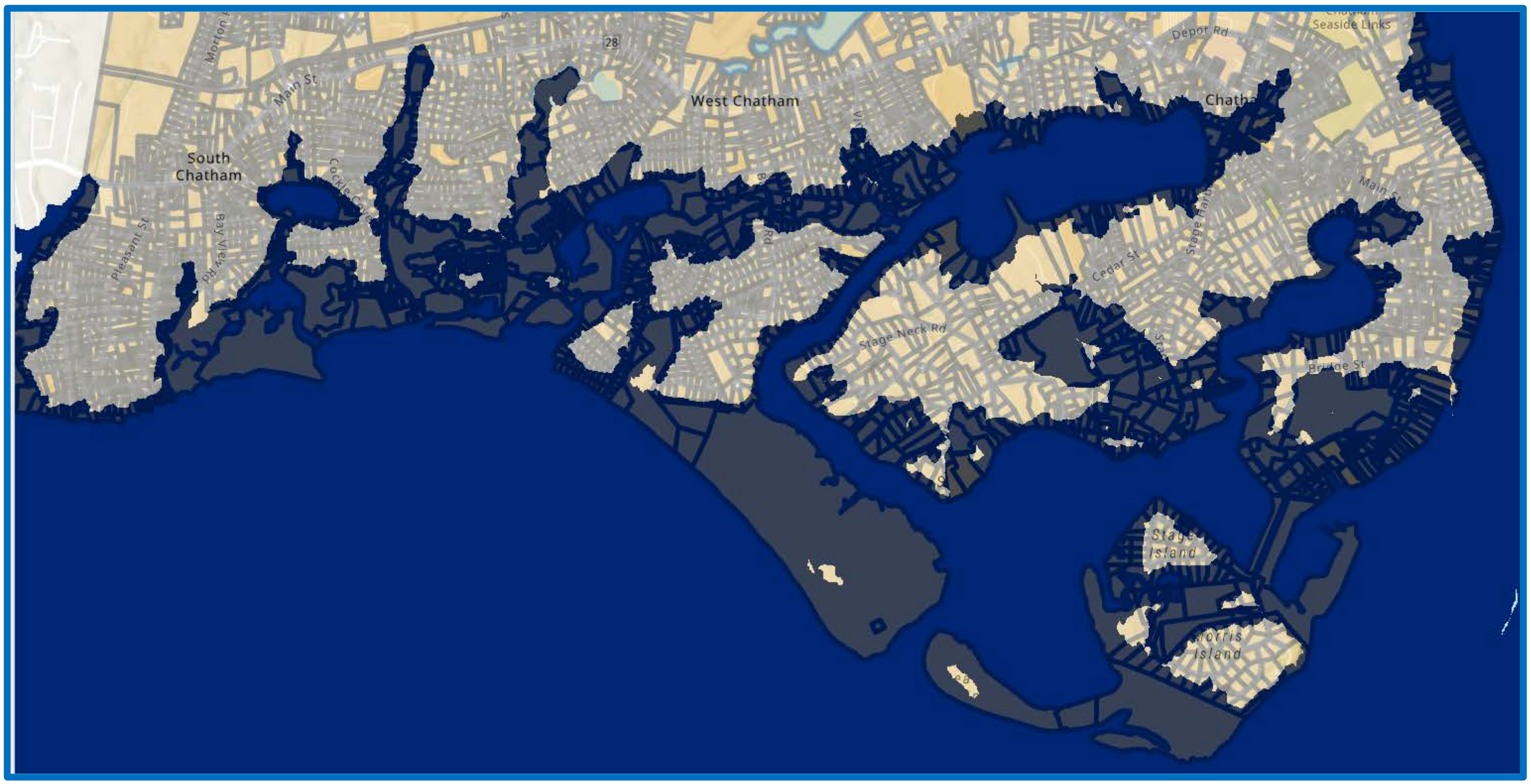



*Figure 14. Map of flooding (black areas) predicted by MC-FRM in 2070 at a 1% probability (hundred-year flood).*

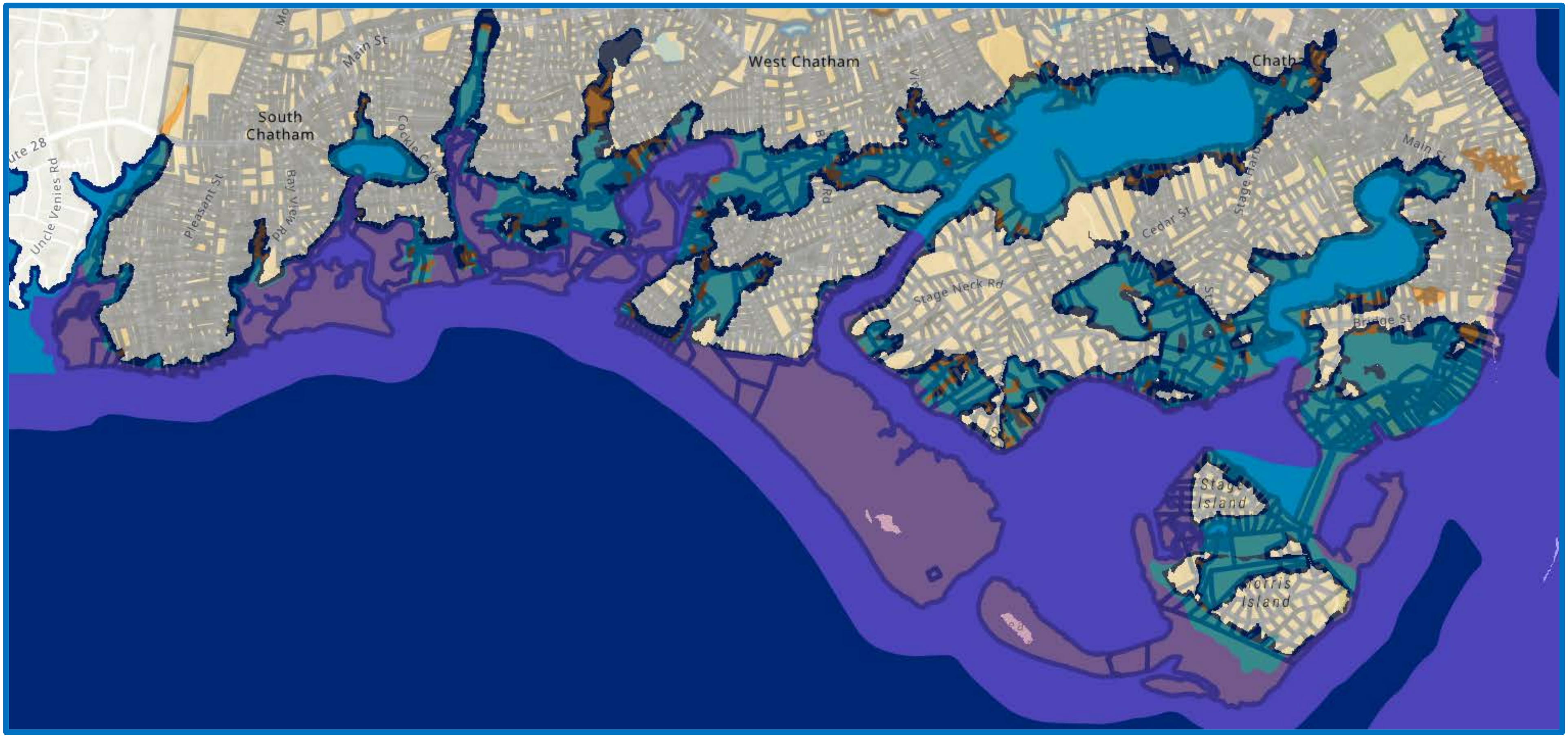



*Figure 15. Map of flooding predicted by MC-FRM for 2070 with 1% probability (a hundred-year flood), overlain with the FEMA 2014 floodplain. The projected flooding extends out beyond the floodplain in the black areas. The FEMA 2014 floodplain (with colors showing flood depths) is currently used for the wetland bylaws regulated by Chatham's Conservation Commission, as well as for flood insurance regulations.*

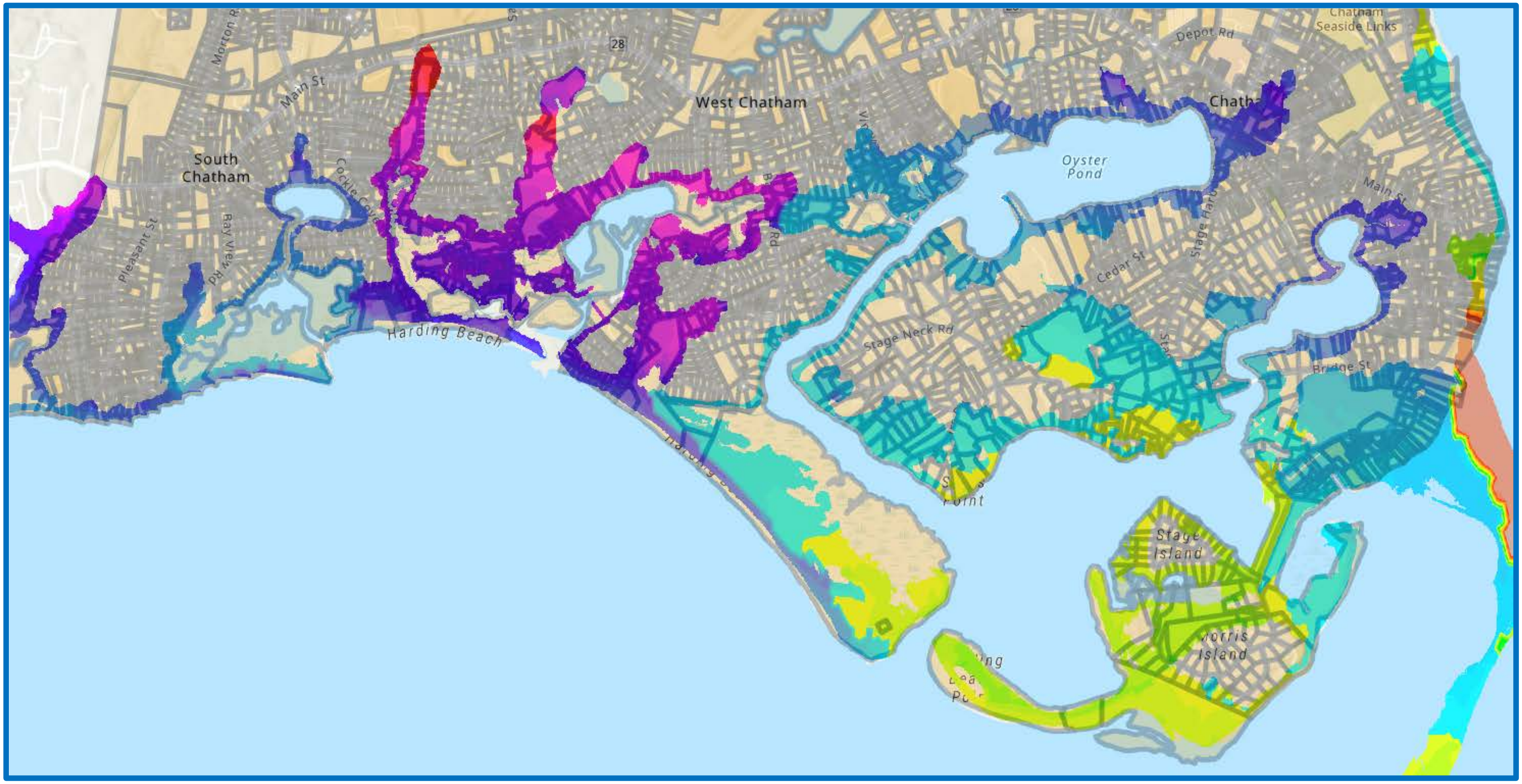
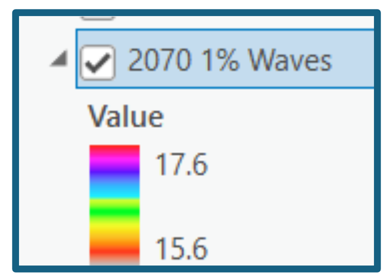



*Figure 16. Map of wave depth (in feet) predicted by MC-FRM for 2070 with a 1% probability hundred-year wave surge.*



## F. Low-lying roads and isolated neighborhoods (based on MC-FRM)

Due to the topology of marshes dividing up the residential land near the shore along South and West Chatham, many neighborhoods have only a single road connecting them to the Route 28 highway. Flooding events can isolate these neighborhoods, cutting off access and escape by residents as well as by emergency responders. As most of the isolated residences are in the floodplain, they are likely to be in need of assistance during severe weather events.

Many low-lying roads lie between areas of marsh that will expand toward each other over time. Interventions to maintain the viability of these roads should be careful not to increase tidal restriction. It may be helpful to install culverts under these roads to facilitate the drainage of water through the marsh systems and to increase water circulation through increased connectivity within these systems.

Figure 17 is a map of flooding predicted by MC-FRM for 2070 with 1% probability (a hundred-year flood), assuming 4.3 ft of sea level rise, with potential locations of low-lying roads (in red) and possible new or existing culverts connecting marsh areas (in light brown):

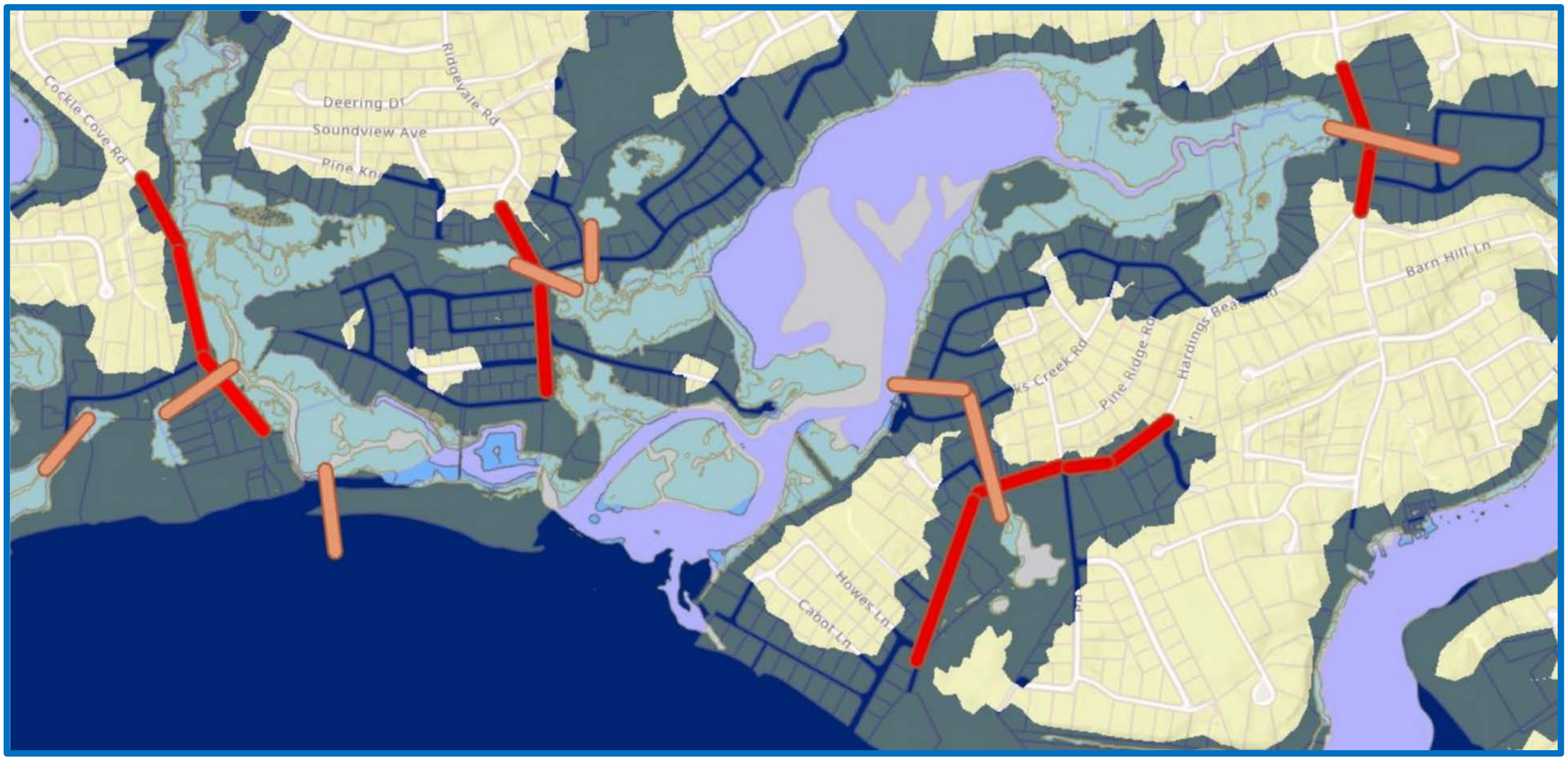



*Figure 17. Low lying roads: Cockle Cove Road, Ridgevale Road, Hardings Beach Road during a 2070 hundred-year flood.*

Figure 18 Figure 19 and Figure 20 are close-up maps of neighborhoods that will be affected by the flooding of major roads in South and West Chatham during the 2070 hundred-year flood depicted in Figure 17.


*Figure 18. Properties isolated by a flooded Cockle Cove Road. Approximately 92 homes, assessed at over $122 million. (Numbers on properties are their street numbers.)*

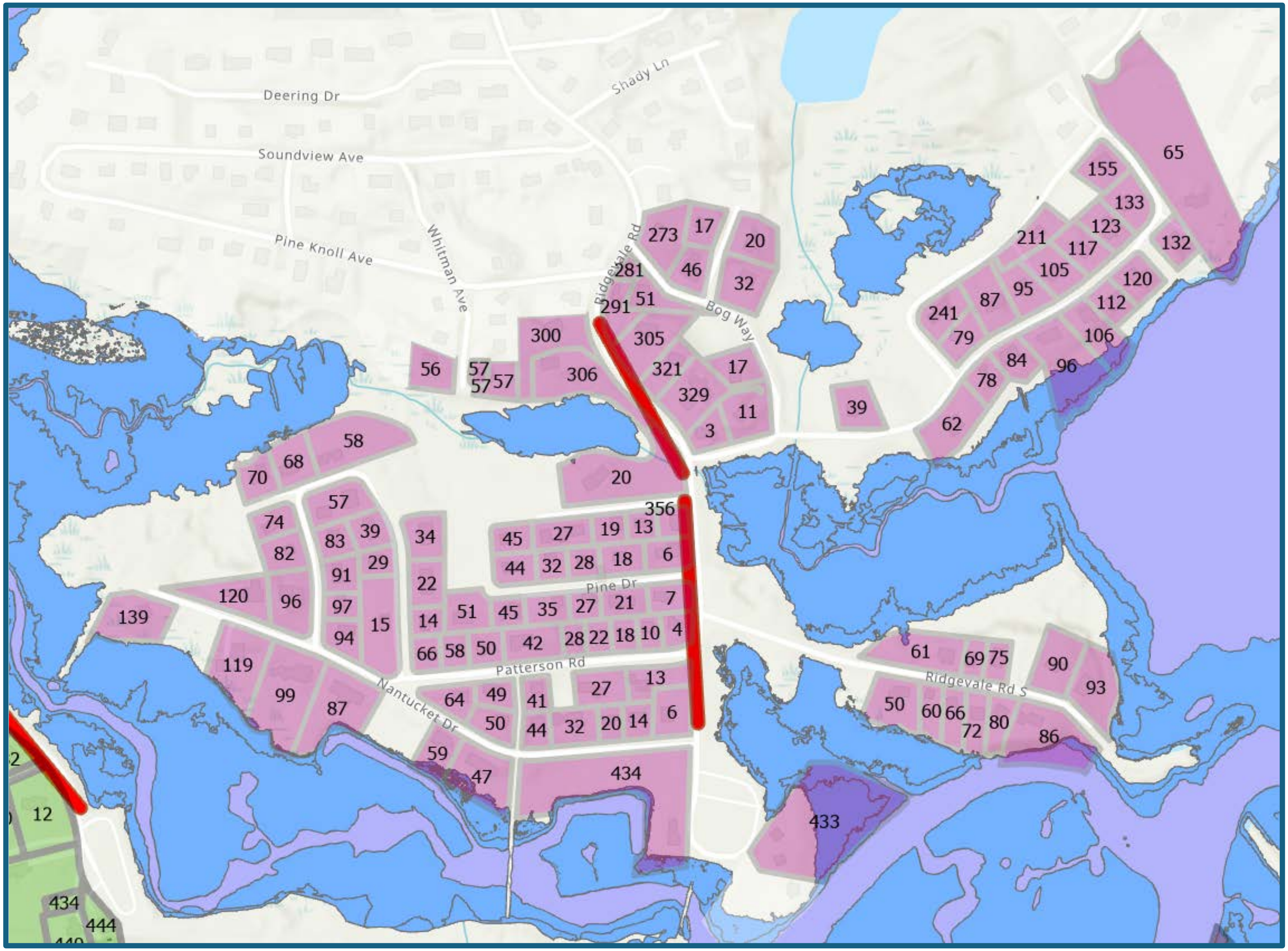



*Figure 19. Properties isolated by a flooded Ridgevale Road. Approximately 114 homes, assessed at over $115 million.*

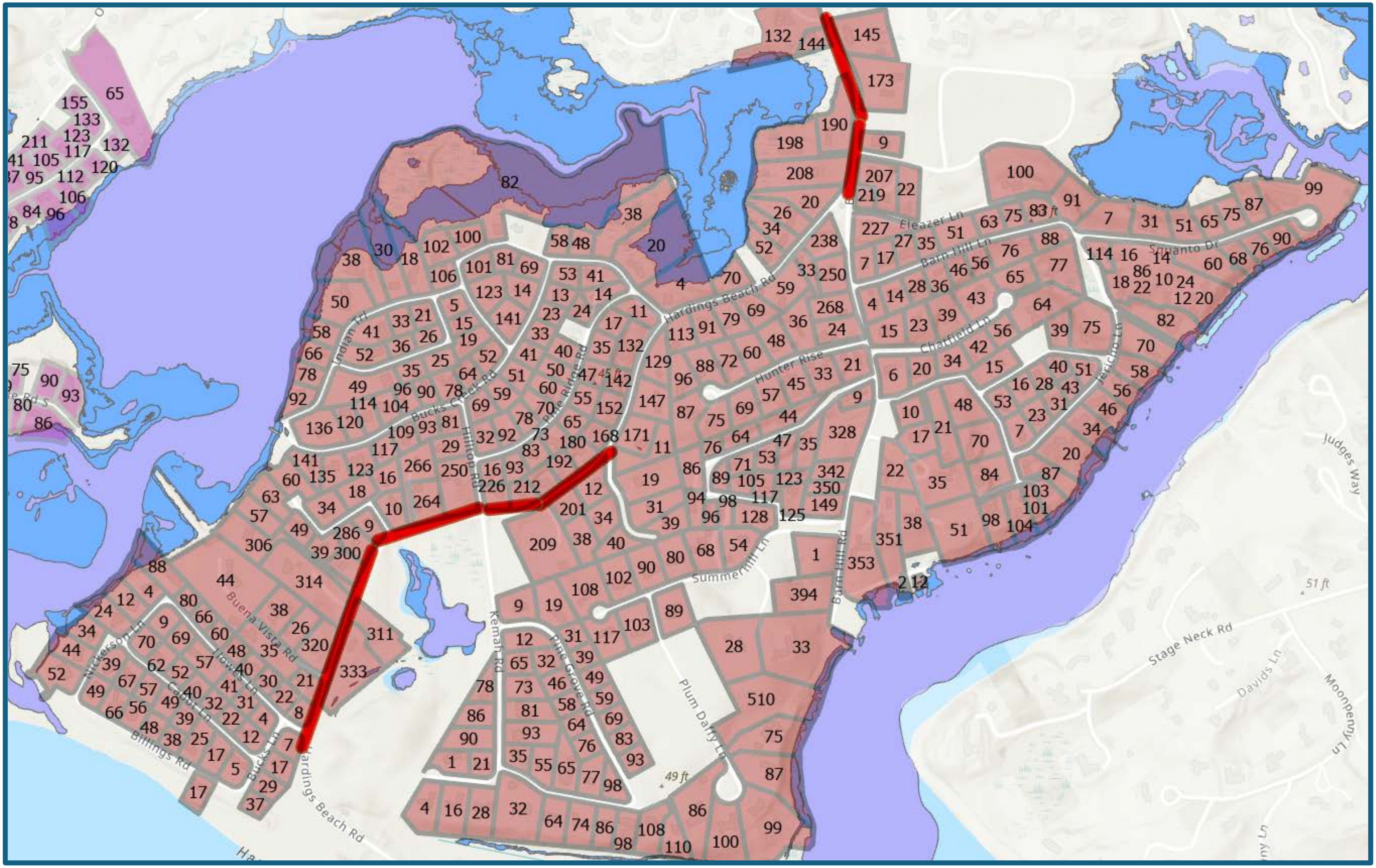



*Figure 20. Properties isolated by a flooded Hardings Beach Road. Approximately 382 homes, assessed at over $578 million.*

The critically endangered neighborhoods served by these three low-lying roads include almost 600 homes worth over $800 million,* with no alternative access. This presents a potentially serious threat to residents during increasingly frequent and severe future storm events. It raises challenges for Town departments charged with ensuring safety.

There are about 1,650 properties with buildings in Chatham's overall floodplain defined by FEMA – about 22% of the total number of homes in Chatham. These properties will virtually all be threatened by flooding during high tides and major storms in the coming decades. Properties in the floodplain cannot be further developed; following floods, they will probably have decreasing market value and increasing difficulty securing flood insurance and reasonable mortgages. The Town could consider forms of "managed retreat" to help residents transition out of these areas, as some other coastal towns have done. Public ownership or strict conservation restrictions of properties in the floodplain may be important for implementing interventions to preserve the marshes and to otherwise respond to climate change.

MC-FRM predictions for the beaches (shown in the preceding maps, which do not assume sand replenishment or other interventions, or even reflect natural sedimentation or rain runoff) show major beach areas completely swallowed up by the ocean. In addition, parking lots and roads to beaches are increasingly flooding. Some beaches of Chatham are already topped over by high tides each year and require substantial sand replenishment annually. As the sea level rises, it will become harder (and more costly) to maintain these beaches, which are Chatham's major tourist attraction and prized recreational areas.

This report has focused on the probable effects of climate change on the salt marshes of South and West Chatham, based on the recent CCS study of those marshes. The marshes are key resources for Chatham, defining its environment, drawing tourists and protecting properties from storm surge. Next year, ECAC will be looking similarly at the other nine major marshes of Chatham. There are also additional likely impacts of climate change upon Chatham that have not been considered in this report, such as violent storms, wildfires and scarcity of drinking water. Just when habitable land area in Chatham will be decreasing from erosion and flooding, population pressure will skyrocket with migration from increasingly uninhabitable regions of the world. Long-term planning should assess these varied threats and design a balanced response.

*Figure 21. At some point, putting houses on stilts, raising roads and using boats is not sustainable. Villages in the South Pacific have already had to retreat (displace or migrate) due to climate change and sea level rise. (Photo from The Atlantic, 9/22/2025.)*

* This analysis was done using Chatham assessor's data from 2022. Since 2022, some wetland properties may have been acquired by the Town or by the local land trust; property values have increased.