Town of Plymouth Open Space and Recreation Plan

Addendum

Climate Change Resiliency

Plymouth Open Space Committee

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Town of Plymouth Open Space and Recreation Plan Addendum
Climate Change Resiliency

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Town of Plymouth Open Space and Recreation Plan Addendum Climate Change Resiliency

EXPLANATION OF NEED FOR ADDENDUM

The Plymouth Open Space Committee completed an update to the Open Space and Recreation Plan, which was approved on March 5, 2018, as required by the Massachusetts Executive Office of Energy and Environmental Affairs Division of Conservation Services. This update will be in effect until July 2024, ensuring Plymouth's eligibility for grants and other support from the Commonwealth.

During this process, the Open Space Committee recognized the need to address the potential impacts of climate change in an addendum to the Open Space and Recreation Plan before the next required deadline in 2024. This addendum to Plymouth's Open Space and Recreation Plan seeks to identify the potential impacts of climate change and offer recommendations for strengthening the resilience and adaptability of the Town of Plymouth in the face of climate change.

EXECUTIVE SUMMARY

Climate change poses increasing challenges for Plymouth, particularly within its coastal areas. Sea level rise, storm surge and high winds from more frequent and intense coastal storms, extreme heat, drought, and freshwater flooding are a sample of climate change related hazards that Plymouth is experiencing. These may lead to property and infrastructure damage, interruption of vital services (i.e., energy, food, water, emergency response) and loss of cultural resources. Plymouth could reduce its vulnerability through appropriate planning.

In this document, the effects and impacts of climate change in Plymouth are presented, along with the introduction of a matrix, which is a tool developed by the OSC to examine the relationships between open space objectives in climate change resiliency and the strategies to fulfil them. The recommendations presented here are based on findings from the matrix.

RECOMMENDATIONS AND FINDINGS

Based on the matrix and the scores generated, the top six recommendations are presented below.

1) Create a strong education and outreach initiative to encourage specific actions for all projects designed to meet resiliency objectives.

Education, encouraging one or more specific actions, was shown to be an important strategy in all but one of the objectives. The high score for education led the OSC to conclude that every project and climate action initiative would benefit by increased educational outreach messaging.

2) Acquire and protect land, prioritizing land acquisition in the following order:

- Parcels within aquifer protection zones;
- Parcels with coastal features; and,
- Forested parcels and freshwater wetlands.

Acquiring land of various types helps mitigate high temperatures, contributes to good air quality, protects fresh water supplies, ensures equal access to open space for all residents, provides outdoor recreation opportunities, reduces burning of fossil fuel for transportation and maintains local and regional biodiversity. This strategy also contributes to reaching at least 10 other objectives.

3) Encourage Conservation Restrictions (CRs) for proposed developments.

A conservation restriction is a legal agreement between a landowner and a government agency or land trust that permanently protects open space by limiting future uses of the land, usually including the amount and type of development that can take place. Landowners maintain ownership, management, and the right to sell their land or pass it on to heirs.

4) Encourage smart residential development on previously disturbed or under-utilized lands.

Residential growth should be managed to minimize environmental and climate change impacts. Focus redevelopment of previously disturbed or obsolete properties, thereby reducing traffic congestion, fossil fuel consumption, help maintain scenic views, mitigate the heat island effect and contribute to reaching 13 other climate adaption objectives.

5) Acquire/protect lands for sustainable initiatives

Acquiring lands for sustainable initiatives, such as food and energy production, increases local, sustainable food supply, reduces the use of fossil fuels and contributes to cleaner water and greater recreational opportunities.

6) Limit clear-cutting for development

Limiting clear-cutting in new developments helps to mitigate the heat island effect, reduce and help control freshwater flooding, maintains water quality in waterbodies such as streams, ponds, and the bay (i.e., surface water), increases carbon sequestration and adds to the scenic beauty and sense of well-being important to mental health.

These recommendations indicate where Plymouth can most effectively focus immediate efforts to achieve the greatest potential adaption to climate change.

DEFINITIONS

Climate Change Adaptation: The ability of a system (or town) to adjust to climate change effects - including climate variability and extremes - in order to moderate potential damage, take advantage of opportunities, or cope with the consequences.

Climate Change Mitigation: Action to limit the magnitude or rate of global warming and its related effects. This generally involves reduction in human emissions of greenhouse gases and increasing the extent or capacity of carbon *sinks*, such as forests.

Climate Resilience: The capacity of a system (or town) to withstand or recover from hazards associated with climate change.

Environmental Justice: The equal protection and meaningful involvement of all people with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies and the equitable distribution of environmental benefits.

Managed Retreat: The application of management and mitigation tools designed to move existing and planned development out of the path of both short-term and long-term hazards (e.g., storm events, sea level rise).

Nonpoint Source Pollution: Pollutants from diffuse sources, such as land runoff, atmospheric deposition, drainage, seepage, rainfall and snowmelt.

Point Source Pollution: Pollutants from a specific identifiable source, such as a discharge pipe. These are regulated by federal and state agencies.

Repetitive Loss Property: Any insurable building for which two or more claims of more than $1,000 were paid by the National Flood Insurance Program (NFIP) within any rolling ten-year period since 1978.

Social Disruption: The alteration or breakdown of social life, often in a community setting.

Storm surge: An unusual, often destructive rise in sea level above normal high-tide level, caused by a combination of low atmospheric pressure and strong onshore winds during a storm.

Vector-borne Disease: A disease transmitted by one species of animal (often an insect) to another (including humans).

INTRODUCTION

Open Space can provide nature-based solutions to issues arising from climate change and make a community more resilient to the anticipated hazards associated with sea level rise, rising temperatures and an increase in extreme weather events. Open Space areas provide many benefits and services to towns, such as recreational opportunities, wildlife habitat, increased property values, and scenic views. Along with these, depending on ecosystem type, natural Open Space can filter water, decrease erosion, act as a carbon sink, combat the heat island effect of developed areas, mitigate flooding, protect infrastructure from storms, and more. This addendum to the Open Space and Recreation Plan incorporates the benefits of Open Space into recommendations that, if applied, will strengthen Plymouth's resilience and adaptation to climate change.

EFFECTS OF CLIMATE CHANGE IN PLYMOUTH

Climate change has already caused shifts in temperature, precipitation, storm intensity and sea level in Plymouth and across the globe. Except where noted as otherwise, the data in this section are based on projections for the South Coastal Basin (which includes the eastern half of Plymouth) and the Buzzard's Bay Basin (which includes the western half of Plymouth) from the Northeast Climate Science Center at the University of Massachusetts Amherst.[1] We report the range of change expected rather than absolute numbers, because the amount of change depends on the emissions scenario the world follows, which might range from a significant reduction of carbon emissions to an increase in emissions.

Average temperatures are increasing, as are periods of extreme temperatures, both high and low. The average temperature in Massachusetts increased by almost 3°F from 1900 to 2016.[2] In Plymouth, by 2100, temperatures will likely warm 3° to 10°F from the present baseline (1971-2000) average. Every season is experiencing warming. During winter, this means more of the precipitation falling as rain rather than snow, and a decreasing number of days with snow cover. In spring, the growing season will begin earlier and in fall it will extend later. Summers will be hotter with extended periods of drought.

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1 *Massachusetts Climate Change Projections*. https://www.mass.gov/files/ma-statewide-and-majorbasins-climate-projections-final.pdf.

2 *Massachusetts State Climate Summary*. NOAA Technical Report NESDIS 149-MA. Runkle, J., Kunkel K., Frankson R., Easterling D., DeGaetano, A.T., Stewart, B., and W. Sweet. 2017.

Temperature extremes, both high and low are increasing. The number of hot days (over 90°F) per year is increasing. The baseline (1971-2000) average is just over 4 days; by the end of the century, this will increase to 12 to 62 days. Additionally, due to fluctuations in the jet stream, there likely will be more periods of extreme low temperatures.

Precipitation, too, will be affected in several ways, predominantly in terms of amount of precipitation and intensity and number of heavy precipitation events. In Plymouth, the observed baseline (1971-2000) average for annual precipitation is 47-48 inches. By 2100, this will range from no change to an additional 7 inches of precipitation per year, with winter and spring experiencing the greatest increases. This fluctuates year to year. For instance, the Blue Hill Observatory, located less than 30 miles northwest of Plymouth, documented 2018 as the third wettest year on record with precipitation totaling over 67 inches.[3]

Along with an increase in total precipitation, the amount of precipitation falling in heavy rainfall events and the number of these events have increased. In the Northeast U.S., between 1958 and 2012, the amount of precipitation falling in *heavy* storm events increased by 70%.[4] Heavier rainfall often leads to increases in erosion, nonpoint source pollution and risk of flooding. On an annual basis, presently Plymouth experiences 8-9 days with precipitation greater than 1 inch, 1 day with greater than 2 inches and 0.045 days with greater than 4 inches of precipitation. By the 2090s, this is modeled to increase to 9 to 13 days, 1.2 to 2 days, and -0.035 to 0.175 days, respectively.

Due to changes in global temperature, storms are becoming more intense and are generating larger waves, greater storm surge, higher winds, and heavier precipitation. These are likely to cause major coastal flooding and destruction in the velocity (wave) zones on low elevation beaches, collapse of unarmored coastal bluffs, and destruction of sea walls. High winds will continue to topple trees and power lines blocking roads and emergency vehicle access and leaving homes and businesses without power, often during periods of low temperature.

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3 Blue Hill Observatory & Science Center. 2019. http://bluehill.org/observatory/2018/02/2018-precipitation.

4 *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II.* U.S. Global Change Research Program, 2018: [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)].

Mean sea level (measured in Boston) increased 11 inches between 1900 and 2019. Relative to mean sea level in 2000, by 2050, there is a 66% probability that sea level will rise 0.8 to 1.5 feet, although it is possible it could rise as much as 4 feet. By 2100, relative to mean sea level in 2000, there is a 66% probability that sea level will rise 1.5 to 4 feet, while it is possible that it could rise as much as 9.7 feet. The actual rise is dependent on mitigation measures undertaken by this generation and future ones, that is, how much greenhouse gas is emitted and how much carbon is sequestered.

IMPACTS OF CLIMATE CHANGE IN PLYMOUTH

The impacts of climate change in Plymouth relevant to open space are divided into three categories for discussion in this section – *Health and Safety*, *Quality of Life* and E*conomic Security*.

Health and Safety

Ten of the health and safety topics below were informed by the Centers for Disease Control and Prevention's (CDC's) climate change and health website.[5] The Open Space Committee included two additional topics of specific importance to the Town of Plymouth.

1. Air pollution

Climate change will cause ground-level ozone to increase. Airborne particulate matter may also increase, especially during wildfires and windstorms. Increased hospitalizations and deaths from respiratory ailments such as asthma are expected.

2. Allergens

Allergenic plant species are expected to increase in number, range, and pollen production as seasonal temperatures and number of frost-free days increase. The pollen season will get longer. Indoor allergens, such as mold and fungi, may also increase as temperatures rise.

3. Wildfires

Increased temperatures, in combination with longer periods of drought, will increase the likelihood of wildfire. Fire itself directly endangers people, pets, wildlife and structures. Additionally, the smoke can

[5] https://www.cdc.gov/climateandhealth/effects/default.htm.

drift for many miles, harming those in its path. In the aftermath of wildfire, there likely will be decreases, at least in the short term, in human recreation, wildlife diversity, and ecosystem services (such as erosion control) in natural areas.

4. Temperature Extremes

Extreme heat events (i.e., heat waves) will increase, endangering those who work outdoors, the elderly, the homeless, those with chronic health conditions, and people who cannot afford air conditioning. Outdoor activities may need to be limited to prevent heat stroke, heat exhaustion or dehydration for people and their pets. Periods of extreme or unusual cold temperatures may increase the incidence of hypothermia and frostbite.

5. Increased Precipitation

New England is experiencing heavier rainfall events due to climate change; this trend is modelled to increase. This, along with greater total amounts of precipitation, will likely lead to increased freshwater flooding, endangering those in flood-prone areas, and to more soil erosion, damaging natural areas and putting more sediment into water bodies, which will lower water quality. Heavy snowfall events or freeze/thaw periods can damage structures and topple trees that take out power lines and block roads.

6. Increasing Storm Intensity

Storms, including coastal storms (i.e., hurricanes and nor'easters), are characterized by high winds, large amounts of precipitation, and strong waves, which can cause power outages, salt and freshwater flooding, and erosion. Additionally, if storm surge occurs during a normal high tide, extreme coastal flooding may occur. As climate change causes storms to intensify, all of these impacts are expected to increase.

7. Water Quality

Climate change affects both surface and groundwater, including drinking water. Increased precipitation, especially heavy events, will increase polluted stormwater runoff containing suspended solids, which will end up in waterbodies. This will decrease water quality, affecting drinking water, shellfish and fish populations, outdoor recreation, wildlife and pets, and more.

8. Mental Health and Stress-related Disorders

Climate-related disasters, such as destructive hurricanes or wildfires, increase mental health problems both in those with prior issues and in those previously healthy. Also, there is increasing evidence that there are mental health implications, such as anxiety, distress and despair, from the knowledge that climate change is occurring and causing environmental degradation. On the other hand, natural areas and parks are associated with mental well-being, stress-relief, and better mental concentration.

9. Sea Level Rise

The rising sea is eroding or destroying public access infrastructure, such as paths, stairways, boat launches, and parking areas, and, in some cases, a beach or park itself. And, because increasing sea level will cause a corresponding rise in groundwater levels, septic systems and cesspools near the coast may flood, which would decrease water quality of nearby surface water and groundwater.

10. Vector-borne Disease

Insects such as mosquitoes and ticks harbor diseases such as Eastern equine encephalitis and Lyme disease that are transmittable to humans. As average temperature rises, the active season for insects is getting longer increasing the risk of vector-borne disease.

Two additional topics, *radioactive waste* and *Superfund site,* while not entirely unique to Plymouth, are not addressed in the CDC website. However, they are important concerns relevant to open space, especially with the added stressor of climate change.

11. Radioactive Waste

Radioactive waste from the Pilgrim Nuclear Power Plant that is being decommissioned is stored in Plymouth. Sea level rise combined with storm surge and other extreme weather events could cause the containment infrastructure to fail and release radioactive waste into the environment.

12. Superfund Site

The Plymouth Superfund site located along the Harbor at Cordage Park, has been identified by the Environmental Protection Agency (EPA) as one of 945 climate-vulnerable locations in the country due to its potential vulnerability to a minimum intensity (Category 1) hurricane. This site is categorized as "highest flood hazard" and noted for "flooding at high tide with no additional sea level rise." The EPA recognizes that climate change may impact certain Superfund sites during extreme precipitation as well as coastal flooding events and recommends that additional measures be considered in these high-risk areas to prevent toxic chemicals from escaping into the environment.[6]

Quality of Life

Climate change will affect Plymouth residents' quality of life in these areas relevant to open space: *Health and Safety* (addressed in the previous section) and *Outdoor Recreation*, *Natural Environment*, and *Living Environment,* which are addressed below.

Many Plymouth residents identify outdoor recreation as an important reason why they enjoy living here. Ample opportunities, such as: Hiking, biking, birding, fishing, hunting, boating, swimming, shell-fishing, winter sports, nature photography and nature exploration exist within the 134 square miles of the Town's boundaries. Climate change will affect these locations and alter how people can engage with them. For instance, coastal erosion from sea level rise and stronger storms may degrade or destroy beach access areas. Higher temperatures may shorten the time safely spent outdoors and preclude midday activities, ocean acidification may decrease shellfish numbers, and viewable wildlife may suffer from range shifts or disease outbreaks. More frequent cyanobacteria outbreaks in ponds may make any form of recreation on or in them potentially dangerous.

Beyond affecting recreational areas for humans, damage to the natural environment may decrease quality of life by affecting plants and wildlife. Plymouth residents enjoy pleasing scenery of natural or rural landscapes, water views, greenery, and flowering plants. Many enjoy observing turkeys, deer, butterflies, birds and other wildlife. Researchers have linked time in nature to better mental health, lower stress levels, and better concentration. However, higher temperatures may increase outbreaks of insect pests that kill trees, cause shifts in the ranges of plants and animals, and benefit invasive plants (for example, *Phragmites*, which outcompetes native wetland plants often creating a monoculture). Wildfire may destroy scenic views and pollute the air. Drought may impact wildlife, especially aquatic species.

All living things require clean air and water, food, and a tolerable climate to survive. Air and water quality will degrade with climate change. Increased pollen, dust and even ozone will make its way into homes

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[6] *Superfund Sites and Climate Change.* Report to Congressional Requesters. October 2019. https://www.gao.gov/multimedia/GAO-20-73/interactive/s.

and businesses affecting indoor air quality. Water piped into homes without treatment will be the same quality as its source.

Agricultural lands are designated as open space. They contribute to the quality of life within the Town of Plymouth, including its economy, while providing a sense of community and aesthetic pleasure. Rising atmospheric CO_2 through climate change will directly impact crops via effects on pests and disease. Warmer weather patterns will promote destructive insect propagation and support longer periods of infestation. Mean sea level rise can be expected to promote the loss of agricultural land through permanent inundation. Protection from the elements may be necessary along with increased watering during drought.

Economic Security

Climate change is considered one of the biggest threats to economic stability worldwide. Economic impacts from climate change may be categorized as **direct**, as in damage or destruction to infrastructure from coastal storms and water shortages due to drought, or **indirect**, as warming water decreasing the capacity of marine waters to support shellfish aquaculture and flooding causing contaminants to enter the water supply.

A. Direct Effects of Climate Change on Economic Security

Plymouth is already experiencing direct economic impacts of climate change. For instance, a list of expenditures provided by Plymouth's Department of Marine and Environmental Affairs shows that repairs necessary due to flooding to Plymouth Long Beach and neighboring Warrens Cove from 2009 to 2019 cost nearly $4 million. The 2020 seawall reconstruction at Plymouth Beach and Warrens Cove, designed to protect infrastructure in the area from storm surges, cost over $8 million (Appendix A: Plymouth Long Beach Shore Protection Costs). Climate Central, an independent nonprofit organization researching climate impacts, predicts a likelihood of 52 to 90% that Plymouth will experience coastal flooding in excess of 4 feet above the current high tide level by 2030, and a likelihood of 93 to 100% of a flooding event above 4 feet by 2050 (Appendix B: *Coastal Risks for Plymouth*, Climate Central). A sea level rise prediction map created by NOAA indicates that a 4-foot rise in sea level will divide Plymouth Long Beach into several small islands.[7] Since 2002, fourteen single-family homes have required relocation, either due to structural damage attributed by coastal storm erosion and/or flooding (Appendix C).

Plymouth's other beaches and waterfront properties, including an estimated 700 homes, are at risk for coastal flooding during a Category 4 hurricane. These homes may be damaged or destroyed unless they are relocated or raised above the storm surge level (Appendix E: *Plymouth Storm Surge Map*). With the high cost of repairing and arming beachfront property, Plymouth might consider alternative solutions such as coastal adaptation and managed retreat.

Extreme rainfall events, expected to increase in frequency and intensity as temperatures rise, are proving costly for Plymouth. For example, an unnamed storm on July 12, 2019, which lasted only a few hours, delivered over 5 inches of rain—overwhelming stormwater drainage capacity, flooding homes and parking lots, collapsing roads, and damaging vehicles. Plymouth does not track the costs associated with extreme rainfall events, but these costs are expected to escalate as climate change progresses.

Along with extreme rainfall events Plymouth is now experiencing longer periods of drought. In the summer of 2020, the region experienced over four months of below normal rainfall, causing the Massachusetts Department of Energy and Environmental Affairs to declare a Level 3 Extreme Drought in the Town of Plymouth.[8] Drought impacts include diminished quantity and quality of streamflow, groundwater, and surface water; degraded aquatic life and habitat; increased fire danger; decline in the health of forests; reduced water supply, which may lead to diminished pressure for firefighting; and increased fire risk for people and infrastructure, especially for those living near forests.[9] Second only to hurricanes in costs across the nation,[10] repeated drought poses a new set of significant threats to Plymouth's economy.

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[7] *Sea Level Rise Viewer*. NOAA. Digital Coast. https://coast.noaa.gov/slr/#/layer/slr/4/7863404.68547663/5153347.388420918/15/satellite/none/0.8/2050/interHigh/midAccretion.

[8] *Current Drought Status*. Massachusetts Drought Management Task Force. Oct. 2020. https://www.mass.gov/service-details/current-drought-status.

[9] *Massachusetts Drought Management Plan*. Massachusetts Executive Office of Energy and Environmental Affairs. Sept. 2019. P. 9. https://www.mass.gov/doc/massachusetts-drought-management-plan/download.

[10] *The High Cost of Drought*. National Integrated Drought Information System. January 23, 2020. https://www.drought.gov/drought/news/high-cost-drought.

The Plymouth-Carver aquifer, the sole source of drinking water for Plymouth, is bounded by a freshwater-saltwater interface. All of the water that enters the aquifer eventually discharges into Cape Cod Bay. The flow of water seaward usually prevents saltwater from encroaching into coastal freshwater aquifers. However, extended periods of drought and excessive groundwater pumping can cause the encroachment of seawater into coastal groundwater systems.[11] If this happens, the cost of saltwater intrusion into Plymouth's groundwater supply will be determined by the extent of the intrusion and the numbers of wells affected. Any of the remedies to saltwater contamination, such as creating barriers to saltwater incursion, extending existing water delivery systems, drilling new or deeper wells, building salinization plants, or abandoning properties, would result in substantial costs to the Town.

The Plymouth Water Division (PWD) supplies water to 69% of the homes and businesses in Plymouth. The PWD monitors and tests the municipal water supply regularly to assure an adequate supply of safe drinking water to those it serves. However, the remaining 31% of Plymouth's residents rely on private wells for fresh water and must assume responsibility for the safe and careful use of the water resources shared by all.[12] The Massachusetts Department of Environmental Protection recommends that residents outside of municipal water systems test their wells once every year for bacteria and nitrates and to repeat testing if they see a water quality change after a heavy rain or extended drought. In 2019, the PWD drafted a Water System Master Plan (WSMP) with its first goal being "to assure that high quality drinking water is provided to all homes and businesses." The cost of frequent water testing is beyond what many well owners can afford. The Town may want to consider aggregate testing or area sampling of wells or find a way to provide financial assistance for residents whose wells may be at greatest risk of contamination after flooding events or prolonged periods of drought, which are expected to occur more frequently as the climate warms.

Municipal water suppliers are required by law to include an Emergency Response Plan (ERP) in the WSMP. The ERP updated in 2018 states, "In order to decrease the vulnerability of the water system, the PWD should consider implementing the following: …Implement climate adaptation program and integrate risk

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11 *Saltwater Intrusion.* USGS. https://www.usgs.gov/mission-areas/water-resources/science/saltwater-intrusion?qt-science_center_objects=0#qt-science_center_objects.

12 *Draft Water System Master Plan*, Plymouth Water Division, November 2019, p. ES-1.

assessment into planned capital improvements."[13] The WSMP budget recommends spending over $57 million over the next 15 years for improvements to the municipal water system, but it does not include funding for a climate adaptation program that could potentially benefit all Plymouth residents. Funding a climate adaptation program would significantly increase the PWD budget. Without such a program Plymouth is in danger of ignoring the threats that climate change poses for the economy and the real costs of delivering safe drinking water to the Town.

B. Indirect Effects of Climate Change on Economic Security

The indirect effects of climate change are difficult to assess. The following is a brief analysis of how climate change may affect fresh and sea water resources, agriculture, fishing and aquaculture industries, food security, tourism, housing prices and insurance rates and intangibles such as biodiversity.

1. Fresh Water Resources

Increased stormwater runoff due to heavy rainfall events creates a problem that may affect Plymouth more than any other town in the Commonwealth. Plymouth is known for having a pond for every day of the year, when in fact Plymouth has 450 ponds within its boundaries. The town also contains five brownfield sites[14] and myriad nonpoint source pollution sites, such as lawns, trails, roadways, parking lots and construction areas, all of which are known contaminators of Plymouth's ponds. Currently, the Town regularly tests about 39 ponds. Yet, with more than 5,000 acres of ponds scattered throughout the town, Plymouth is facing a real financial challenge in preventing further contamination of ponds and improving the water quality of the ponds known to contain pollutants.

2. Agriculture

Southeastern Massachusetts supports nearly 400 cranberry growing families who cultivate over 14,000 acres of cranberry bogs, making cranberries the number one food crop in Massachusetts.[15] Possible climate impacts expected to affect cranberry farming include:

- Increased frost damage due to warm periods in late winter and early spring followed by colder temperatures,

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13 DRAFT Water System Master Plan, Plymouth Water Division, November 2019, P. 150.

[14] *Massachusetts Brownfield Tracking Spreadsheet*, Massachusetts Department of Environmental Protection. December 2018. https://www.mass.gov/doc/brownfields-list/download.

[15] *The Cranberry*, Massachusetts Cranberry Growers. https://www.cranberries.org/how-cranberries-grow.

- Scald due to heat stress injury,
- Rot due to increased stress associated with scald and changing precipitation patterns making plants vulnerable to fungal infections,
- Insect infestations as insect ranges expand northward as temperatures warm.

Cranberry farmers may be facing these challenges, yet scientists note that with the longer growing season expected because of climate change, cranberry production could remain lucrative if these stressors can be successfully managed. [16]

3. Fishing and Aquaculture

Plymouth's resident fishing fleet includes four commercial fishing boats and 40 lobster boats. In addition, the Town grants over 30 aquaculture licenses for oyster cultivation. Of these industries, lobster fishing and oyster harvesting are most at risk due to temperature extremes and ocean acidification that accompany climate change. Warmer water lowers lobsters' resistance to disease and inhibits reproduction and development. With the rise in ocean temperatures, the lobster population is expected to move northward, potentially ending commercial lobster fishing in Plymouth. This is seen already as lobster harvests in New York, Connecticut and Massachusetts have declined, while Maine's lobster catch has been steadily increasing.

Warmer air temperatures lead to more carbon dioxide entering the oceans, acidifying the water, which prevents oysters from forming a hard shell and disrupts the development of their larvae. Warm water fosters diseases that kill oysters. Increased storms with strong winds and waves destroy equipment. Over the past 20 years Massachusetts has developed a shellfish industry that in 2018 resulted in harvests of over $45 million.[17] Plymouth is a major contributor to this industry but will require investment in storm protection and water quality to remain a viable economic resource.

4. Food Security

In 2015, the Massachusetts Food Council published the *Massachusetts Local Food Action Plan.* The Plan envisions: "a strong, abundant and resilient food system that is rooted in communities, provides quality

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[16] *Climate Change and Cranberry Agriculture*. Manomet, Inc.. Eric Walberg. March 2017. https://www.cranberries.org/sites/default/files/uploads/pdf/Meeting_files/Climate_Change_Walberg_March_2017.pdf.

[17] *Climate change challenging Massachusetts oyster fishery*, Daily Hampshire Gazette. Sarah Garcia. Nov. 2019. https://www.gazettenet.com/Oysters-and-climate-change-30437343.

jobs, contributes to a vibrant economy, utilizes, enriches and sustainably manages our State's Natural Resources; supplies healthy, affordable and accessible food for all residents of the Commonwealth."[18]

Plymouth has a growing local food scene, and local food production can be a viable economic engine for the community. Rooftop farms and apiaries, urban farming on front or back yards, vacant lots, parks, open spaces and underutilized warehouse spaces are among the potential locations for farming. Plymouth has several commercial farms in the Downtown Village Area, including hayfields, the Plymouth County Farm and Plimoth Patuxet.

Plymouth's residents would benefit from the protection and improvement of soil and water quality needed to produce food, maximize environmental benefits from agriculture and reduce hunger and food insecurity. Given the challenges we face—rapid sea level rise, droughts and floods and infrastructure failures—it would be extremely beneficial to the Town to protect existing farmland and create opportunities for more people to farm and produce food locally, leading to a more resilient economy.

5. Tourism

Contaminated water impacts fisheries, recreational water activities, and the sense of beauty and well-being important to Plymouth's tourism industry. Tourism generates over 4,000 jobs and forms a large part of Plymouth's economy.[19] In 2018, for example, domestic travelers alone spent an estimated $671 million in Plymouth County.[20] The County does not track tourism income in the Town of Plymouth specifically, but with its many tourist attractions, hotels, and restaurants, it is evident that a large share of the County's tourism dollars is transacted in Plymouth. Further decline in the water quality of coastal waters, ponds and streams could severely impact tourism in Plymouth.

6. Property Values

Another indirect effect of climate change can be seen in the decreasing value of vulnerable coastal properties and the increasing rates for coastal property insurance as property owners and potential

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[18] *Massachusetts Local Food Action Plan.* Massachusetts Food Policy Council. Dec. 2015. P. 11. https://mafoodsystem.org/static/plan/pdfs/MLFSPFull.pdf.

[19] *The Economic Impact of Travel on Massachusetts Counties 2018*, https://www.massvacation.com/wp-content/uploads/2020/01/MA-2018-Report-Oct.-30-2019-002.pdf, p.39.

[20] Ibid. p.33.

buyers become aware of the increased risks of coastal living. A 2018 study by the International Union of Concerned Scientists warns that as sea level rises an estimated 7,000 homes in Massachusetts, worth more than $4 billion, will be subject to chronic flooding by 2045.[21]

6. Insurance Rates

Since 2006, insurance companies have used Flood Insurance Rate Maps to set home and business insurance costs. Property owners are asked to provide an elevation certificate and a copy of a flood map if they wish to dispute the higher rates. While some major insurers have withdrawn coverage from thousands of homeowners in coastal areas, others have added clauses that require homeowners to pay higher deductibles for damages resulting from named storm events. Although the criteria for naming storms is highly contested, the result is that homeowners are largely responsible for losses resulting from a hurricane or named storm up to a designated percentage before the insurance company covers the damage. What effect the devaluing of coastal homes will have in Plymouth is yet to be determined.

7. Biodiversity

Located in the heart of the Massachusetts Coastal Pine Barrens—a globally rare ecosystem—Plymouth is home to over 70 plants and animals listed by the Commonwealth as Endangered, Threatened or A Species of Concern (Appendix D: Mass NHESP State Listed Species - Plymouth). Rising temperatures could harm migratory bird species like the red knot, which is famous for its annual migrations from Chile to the Arctic. Every spring, red knots stop to replenish their fat reserves to provide fuel for the remainder of their journey north by feeding on horseshoe crab eggs on tidal flats and beaches in Plymouth, Kingston and Duxbury Bays. Because horseshoe crabs spawning is based on ocean temperature, they will likely spawn earlier in the spring. The longest distance migrants, such as red knots, most likely initiate migration based on changes in day length. Thus, there may be a mismatch in red knot arrival time and horseshoe crab egg laying, resulting in species decline.

Warmer winter temperatures have allowed the migration of the Southern Pine Beetle, found recently in several locations in Massachusetts. Scientists expect that the Southern Pine Beetle will destroy large swaths of pitch pine (as has already happened in the New Jersey and Long Island Pine Barrens) and

[21] *New Study Finds 89,000 Massachusetts Homes Worth $63 Billion will be at Risk from Tidal Flooding,* Union of Concerned Scientists, Jun. 2019, https://www.ucsusa.org/about/news/89000-massachusetts-homes-worth-63-billion-will-be-risk-tidal-flooding.

contribute to a shift in the types of trees that dominate Plymouth's forested lands. What the further decline of biodiversity means for Plymouth's economy is uncertain; however, the environmental benefits of biodiversity include capturing and storing energy, pollination supporting food production, cycling water and nutrients, erosion control, pest control, disease control and climate regulation, among others. Evidence shows that habitat conservation generates more economic benefits than does habitat conversion. The overall benefit/cost ratio of the conservation of remaining wild nature is estimated to be at least 100:1.[22] This is why ecologists recommend conserving at least 50% of natural lands in open space as a way to protect biological diversity and maintain ecological processes.[23]

THE MATRIX: OBJECTIVES FOR CLIMATE CHANGE RESILIENCY AND STRATEGIES TO ACHIEVE THEM

As illustrated in this document, climate change poses considerable challenges for Plymouth. Addressing these challenges will require careful planning to ensure that the actions undertaken by the community to adapt to climate change are effective and affordable. To identify and prioritize climate action recommendations, the OSC identified 24 climate-action objectives within the categories of:

- Health and Human Safety
- Economic Impacts
- Quality of Life
- Climate Change Mitigation

and identified 32 feasible strategies to fulfill them under the general categories of:

- Property Acquisition and Protection
- Management
- Regulation
- Other

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[22] *Economic Benefits of Biodiversity.* We Conserve PA. https://conservationtools.org/guides/95-Economic-Benefits-of-Biodiversity.

[23] *Why Half?* Half-Earth Project. www.half-earth.org.

Using a matrix (See Table 1., P. 18) with *objectives* as row headings and *strategies* as column headings, the OSC created a tool to assess how well each strategy addresses each objective and which of the strategies provides the greatest opportunity to advance multiple climate objectives. Each strategy received a score for its ability to address each of the 24 objectives. A score of zero means the strategy has little or no impact in fulfilling the objective. A score of one or two means the strategy can help achieve the objective *adequately* or *substantially*, respectively. Each column yielded a total score for the strategy, which were compared. A higher score means the strategy has greater ability to address climate change resilience in terms of the open space objectives.

While all of the strategies included in the matrix are useful and valuable in building climate change resiliency, the OSC recommends giving the highest priority to those strategies shown by the matrix to be the most effective in reducing the effects of climate change in Plymouth.

Matrix Table

			Acquisition/Protection										Management									Regulation								Other					
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	
		OBJECTIVE	**Acquire/protect forested parcels**	**Acquire/protect parcels with *coastal features* (e.g., barrier beaches, dunes)**	**Acquire/protect freshwater wetlands**	Acquire/protect property with public access to waterbodies	**Acquire/protect parcels within aquifer protection zones**	Acquire/protect lands for sustainable initiatives, e.g., food production, renewable energy production	Acquire coastal parcels with at-risk buildings	Acquire/protect parcels identified in BioMap2 or NHESP	**Encourage CRs for proposed developments**	Ensure open space access within 1 mile for all residents	Plant native trees or shrubs	Manage for healthy ecosystems (e.g., thin forest, control invasive plants, decrease fuel loads)	Construct/maintain trails	Remove hard structures on coastal parcels	Facilitate managed retreat	Conserve water	Manage for sustainable initiatives (such as Civic Agriculture, organic farms and renewable energy)	Construct handicapped access/trails/infrastructure	Construct living shoreline	**Encourage smart residential development**	Cap/reduce impervious surface	Amend rules & regs to reduce and Incentivize replacement of traditional lawns with native vegetation trees, shrubs	**Limit clear-cutting for development**	Require Low Impact Development	Change zoning to prohibit building in FEMA flood hazard zones	Incentivize food gardens and landscaping in subdivisions	Override homeowners' rules that prohibit installation of roof-mounted solar panels or clotheslines	Increase public transportation opportunities (e.g., routes, frequency)	**Conduct outreach and education to encourage specific actions**	Construct sidewalks and bike lanes Complete Streets Initiative	Support efforts to replace aging septic systems	Ecologically manage utility easements	**Total**
Human Health and Safety	1	Maintain good air quality	2	1	1	1	1	1		1	1	1	2	1					1		1	2		1	1	1		1	2	2	2	1		1	**23**
	2	Reduce wildfire												2																	2				**2**
	3	Mitigate heat island effect	2	1	1		1	1		1	1	2	2	1		1			1		1	2	2	2	2	2		1		1	2	1		1	**23**
	4	Reduce or control freshwater flooding	2		2		2	2		2	2		2	1					1			1	2	1	2	2	2				1			1	**17**
	5	Prevent loss of life or human endangerment from storms		2	1				2							2	2				2		1			1	2				2				**10**
	6	Maintain surface water quality	2	2	2		2	2	1	2	2		1	2		2	2		1		1	1	2	2	2	2	2				2		2	1	**23**
	7	Support mental health through scenery	2	2	2	2	2	1		2	1	2	2	1	2	1				2	1	1	1	1	2			1			1	2		1	**23**
	8	Protect drinking water (aquifer) quality and quantity	2		2		2	1		1	1		1					2	1			2	2	1	2	2					2	1			**16**
	9	Support physical and mental health through outdoor exercise	2	2	2	2	1	1		1	1	2			2					2								2		1	2	2			**15**
	10	Reduce transmission of tick and mosquito-borne disease												1																	2				**2**
Economic	11	Reduce building and infrastructure damage from storm impacts	1	2	2		1		2		1		1	1		2	2				2	2	2	1	2	2	2				1		1	1	**20**
	12	Prevent repetitive loss	1	1	1				2				1			2	2				1	1	1	1	1		2				2				**14**
	13	Maintain property values	1	1	1	2	1	1		1	1	2	1	1	1					1	1	1					2			1	1	1			**19**
	14	Provide new job opportunities						1					1	1	1	1	1	1	1	1	1					1			1	1	1	1		1	**16**
	15	Support eco-tourism	1	1	1	2	1	1	1	1	1	1	1	2	2	1	1	1	1	2	2	1	1	2	2	1	1	1		2	2	2		1	**30**
	16	Maintain local and regional biodiversity	2	2	2		1	1	1	2	2		2	2		1	1	2	1		2	2	1	2	2	2					2		1	2	**23**
	17	Create a local, sustainable food supply				1		2			1	1						1	2					1				2		1	1	1			**11**
Quality of Life	18	Maintain scenic views	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	1		2	2	2	2	2	2	1	2	1			1			2	**27**
	19	Increase public recreational water access		2	2	2			1		1	1			1	1				2		1								1		1			**12**
	20	Prevent traffic congestion	2	2		1	1	1	1	1	2	1			1					1		2								2	2	2			**15**
	21	Ensure equal access to open space for all residents	2	2	2	2	2	1	2	2	2	2			2					2		1						2		2	2	2			**17**
	22	Provide outdoor recreation opportunities	2	2	2	2	2	2	2	2	2	2		1	2	1		2		2	1				1	1		2		2	2	2		1	**23**
Mitig-ation	23	Increase carbon sequestration	2	1	2	1	2	1	1	2	2	1	2	2		1	1		1		2	2	2	2	2	1	1	1			2			2	**25**
	24	Reduce use of fossil fuel						2				2			1				2			2	1					1	2	2	2	2			**11**
		TOTAL	**30**	**28**	**30**	**20**	**24**	**23**	**17**	**23**	**26**	**22**	**21**	**21**	**17**	**18**	**14**	**10**	**13**	**17**	**20**	**26**	**20**	**19**	**23**	**19**	**16**	**15**	**5**	**18**	**39**	**21**	**4**	**15**	

CONCLUSION

Climate change poses many challenges to Plymouth. This document, an addendum to the Town of Plymouth's Open Space and Recreation Plan, describes how climate change will affect temperature, precipitation, storm intensity and sea level in Plymouth and how this, in turn, may impact people's interaction with open space and the nature-based services provided by open space. The impacts are addressed under three category headings: health and safety, quality of life and economic security. Finally, this document presents a tool, in the form of a matrix, to prioritize strategies for achieving climate change resiliency objectives for open space. Based on the tool, recommendations for priority actions pertaining to open space are presented that will increase Plymouth's resiliency to climate change and help to ensure a healthy and safe future for Plymouth's residents.

APPENDICES

Appendix A: Town of Plymouth Revetment Repairs, Long Beach/Warrens Cove

Town of Plymouth Seawall Revetment Repairs — Long Beach/Warrens Cove

Year	Project	Total Cost	Grant Funds	
Warrens Cove/Plymouth Beach Seawall				
2003?	Warrens Cove Revetment Repairs/Reconstruction	?		
2009	Emergency Seawall Repairs	$37,499.00		
2010	Seawall & Revetment Repairs	$121,600.00		
2012	Seawall & Revetment Repairs	$264,788.14		
2014	Warrens Cove Feasibility Study	$85,798.72	$63,351.29	
2015	Revetment Repairs			DPW staff & equipment
2016	Seawall Stabilization	$2,000.00		DPW staff & equipment
2017	Seawall & Revetment Reconstruction Design & Permitting	$124,751.00	$93,563.00	
2017	Seawall Stabilization	$1,000.00		DPW staff & equipment
2017	Warrens Cove Nourishment Design & Permitting	$94,462.50	$70,012.50	
2018	Warrens Cove Revetment Reconstruction	$975,615.03	$731,711.27	
Long Beach				
2014	Day Parking/Ryder Way Repairs	$2,475.00		DPW staff & equipment
2015	Day Parking/Ryder Way Repairs	$5,850.00		DPW staff & equipment
2016	Long Beach Cobble Nourishment (overwash areas)	$441,755.54	$279,080.00	DPW staff & equipment
2018	Rebuild Day Parking & Portion of Ryder Way	$116,752.60		DPW staff & equipment
Long Beach Stone Dike (Army Corps of Engineers Structure)				
2013	Stone Dike Maintenance/Repairs			DPW staff & equipment
2016	Stone Dike Maintenance/Repairs	$700,000.00	$700,000.00	(Army Corps Funds)
Total		$2,974,347.53	$1,937,718.06	
Estimated Costs for Future Projects:				
	Plymouth Beach Seawall Reconstruction	$4,030,000.00		
	Warrens Cove Nourishment	$4,000,000.00		

Appendix B: *Coastal Risks for Plymouth*, Climate Central, p.1.

COASTAL RISKS FOR PLYMOUTH, MA

Selected water level: 4 feet. May occur from sea level rise, coastal flooding, or both.

What's at risk on land below 4 feet?[1,2]

- Population: 12
- Property value: $21 Million

4 feet in historical context[3,4]

- Highest observed area flood: 8.6 feet in 1938
- Statistical 1-in-100 year flood height: 4.3 feet

Unnatural Coastal Floods[5]

Since 1950, a tide station at Boston has recorded 149 days exceeding local National Weather Service flood thresholds. Without climate-driven sea level rise, the count would be 56. The station is 34 miles from Plymouth.

Rising seas = more floods[4]

- Plymouth, MA has already experienced about 7 inches of sea level rise over the last 55 years of records. Climate change is projected to drive much more rise this century.
- This raises the starting point for storm surges and high tides, making coastal floods more severe and more frequent.

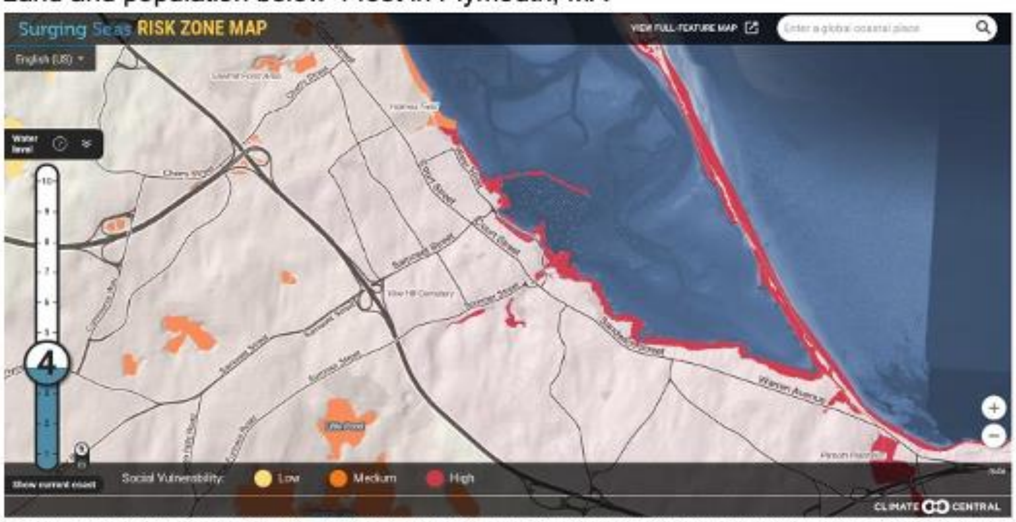
When could a 4-foot flood happen?[3,4,6]

- Likelihood by 2030: 52% – 90%
- Likelihood by 2050: 93% – 100%
- Likelihood by 2100: 100% – 100%

The ranges shown derive from the intermediate low vs. intermediate high global sea-level scenarios from a 2017 NOAA technical report for use in the U.S. National Climate Assessment, which point to projected local rises of 2.1 vs. 6.8 feet by 2100. The more heat-trapping pollution emitted, the higher that sea-level rise is likely to be.

Find more places, water levels and downloads at riskfinder.org

Land and population below 4 feet in Plymouth, MA



Social vulnerability (e.g. from low income) compounds coastal risk. Land below 4 feet is colored according to the legend. Surging Seas uses high-accuracy lidar elevation data supplied by NOAA. Map reflects a uniform sea level and/or flood height. Individual storm surge, tidal or rainfall events cause more complex and uneven water surfaces.

Email sealevel@climatecentral.org to ask about tailored analysis

1 Floods and sea level rise are relative to local high tide lines circa 1992 (mean higher high water across 1983-2001).
2 Values exclude sub-4-ft areas potentially protected by levees, natural ridges, and other features.
3 Climate Central estimates risk by combining local sea level rise projections with flood height risk statistics based on historic data.
4 Flood risk projections and history are based on records from the NOAA water level station at Woods Hole - Buzzards Bay, 30 miles from Plymouth, from 1958 to 2013.
5 Strauss, B. H., Kopp, R. E., Sweet, W. V. and Bittermann, K., 2016. Unnatural Coastal Floods. Climate Central Research Report.
6 Sea level projections are localized, and local flood risks projected, based on methods from Tebaldi et al. 2012 (Environmental Research Letters).

Surging Seas
Sea Level Rise Tools & Analysis by
CLIMATE CENTRAL

For more methods, limitations, full citations, see source: riskfinder.org

Citation: Coastal Risks for Plymouth, MA, Climate Central, 7/30/2020

Appendix B: *Coastal Risks for Plymouth*, Climate Central, p 2.

SEA LEVEL RISE AND COASTAL FLOODING FAQS

What causes sea level to rise?

- **A warming ocean:** Thermometer and satellite measurements show that the ocean has been warming for more than a century. Water expands as it warms, and the only way the ocean can go is up and out.
- **Shrinking ice:** Warmer air and water temperatures are causing global glaciers and ice sheets on Greenland and Antarctica to melt or to break off into the ocean. Adding water or ice from land to the ocean raises sea level, and is by far the biggest future threat.
- **Sinking land:** In some places, coastal land is sinking, due to a variety of slow, long-term processes not linked to current climate change, or due to pump extraction of water or fossil fuels from underground formations.

What causes climate change?

- The main activity causing climate change is the burning of fossil fuels, which emits heat-trapping pollution.
- Leading scientific bodies agree: *Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research concludes that the greenhouse gases emitted by human activities are the primary driver.*[7]

Can sea level rise be slowed?

- Major cuts in heat-trapping pollution through measures such as a swift global transition to a clean energy economy, climate-friendly agriculture, and protecting forests would reduce future sea level rise.

Does sea level rise affect flooding?

- Sea level rise raises the starting point for waves, tides, and storm surge, making coastal floods more severe and more frequent.
- A February 2016 Climate Central analysis found that about two-thirds of U.S. coastal flood days since 1950 would not have met the National Weather Service's local definition of flooding without the few inches so far of human-caused, climate-driven global sea level rise.

What does the future hold?

- Some future sea level rise is inevitable due to pollution already in the atmosphere, forcing some adaptation.
- Rapid cuts in emissions of heat-trapping pollution would increase the chances of limiting global sea level rise to near 2 feet this century, but continuing unchecked pollution could lead to a rise of more than 6 feet.[8]
- A 2-foot rise would mean widespread, dramatic increases in flooding, and submergence of the very lowest coastal places. A 6-foot rise would pose severe and in cases existential threats to major coastal cities worldwide.
- Many places will be able to reduce sea level rise impacts by establishing defenses, accommodating floods, or relocating some development, at uncertain cost.
- Pollution this century will lock in sea level rise for hundreds of years to come – likely far more than 6 feet on the current path. The final amount will depend on how rapidly the world community can reduce and then stop heat-trapping pollution.

REDUCING YOUR RISK

Preparing yourself and your community

- Actions to curb heat-trapping pollution will reduce sea level rise, but some rise is unavoidable.
- Learn more about the actions you can take yourself at sealevel.climatecentral.org/flood-preparation
- Make sure leaders in your community know your area's risks by sharing this fact sheet and riskfinder.org
- Surging Seas can help your community participate in FEMA's Community Rating System. Contact us to learn more.
- Climate Central offers tailored mapping, projections and analysis to meet the specific needs of cities, counties, states and businesses, using scenarios and data you can choose: contact sealevel@climatecentral.org to learn more.

Resources available for Massachusetts

- Mass.Gov: Climate Change:
  http:/ www.mass.gov/eea/air-water-climate-change/climate-change/
- EPA's Resilience and Adaptation in New England (RAINE):
  https:/ www.epa.gov/raine
- Massachusetts Ocean Resource Information System (MORIS):
  http:/ www.mass.gov/eea/agencies/czm/program-areas/mapping-and-data-management/moris/
- For a longer list see: sealevel.climatecentral.org/responses/plans

In the News

Our sea level research has been covered in USA Today, Time, the major networks, CNN, PBS, NPR, AP, Bloomberg, the Washington Post, the New York Times, and hundreds more outlets.

Climate Central

Climate Central is an independent nonprofit, nonadvocacy organization that researches climate impacts. Our web tools are based on peer-reviewed science and are included as resources on national portals such as NOAA's Digital Coast and the U.S. Climate Resilience Toolkit.

Get more analysis at riskfinder.org

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7 Statement on climate change from 31 scientific associations (2016). http://www.aaas.org/sites/default/files/06282016.pdf (Accessed July 7, 2016). Learn more at http://climate.nasa.gov/scientific-consensus/

8 Based on local sea level projections from Kopp et al. 2014 (Earth's Future) and more recent Antarctic research in DeConto and Pollard 2016 (Nature). For full citations and methods visit riskfinder.org

Appendix C: Single-Family Homes Relocated Due to Coastal Storm Damage and/or Flooding

Parcel ID	Address	Year
046-000-026-000	241 Manomet Avenue	2015
047-000-024B-000	108 Sandwich Road	2016
048-049-030-000	21 Manomet Avenue	2013
052-000-037C-000	315 Center Hill Road	2002
054-000-003-029	37 Oak Bluff Circle	2015
054-005-001A-002	46 Nameloc Road	2002
054-005-005-004A	32 Nameloc Road	2010
095-000-052-000	21 West Ridge Trail	2010
098-000-069A-000	164 Black Cat Road	2013
124-000-001-165	29 Lake View Boulevard	2012
132-000B-006-000, 132-000B-126-000	Saquish Beach	2013
132-000B-072-000Z	Saquish Beach	2005
132-000B-259-000, 132-000B-260-000	Saquish Beach	2018
046-000-026-000	241 Manomet Avenue	2015

Appendix D: Mass NHESP State Listed Species – Plymouth

Town	Taxonomic Group	Scientific Name	Common Name	MESA Status	Federal Status	Most Recent Observation
PLYMOUTH	Butterfly/Moth	*Abagrotis nefascia*	Coastal Heathland Cutworm	SC		1991
PLYMOUTH	Butterfly/Moth	*Acronicta albarufa*	Barrens Dagger Moth	T		2003
PLYMOUTH	Mussel	*Alasmidonta heterodon*	Dwarf Wedgemussel	E	E	Historic
PLYMOUTH	Bird	*Ammodramus savannarum*	Grasshopper Sparrow	T		2014
PLYMOUTH	Butterfly/Moth	*Apamea inebriata*	Drunk Apamea Moth	SC		2002
PLYMOUTH	Bird	*Bartramia longicauda*	Upland Sandpiper	E		2014
PLYMOUTH	Vascular Plant	*Calamagrostis pickeringii*	Reed Bentgrass	E		2016
PLYMOUTH	Butterfly/Moth	*Callophrys irus*	Frosted Elfin	SC		2018
PLYMOUTH	Bird	*Caprimulgus vociferus*	Eastern Whip-poor-will	SC		2018
PLYMOUTH	Vascular Plant	*Carex striata*	Walter's Sedge	E		2017

PLYMOUTH	Butterfly/Moth	*Catocala herodias gerhardi*	Gerhard's Underwing	SC		2012
PLYMOUTH	Butterfly/Moth	*Catocala pretiosa pretiosa*	Precious Underwing	E		2011
PLYMOUTH	Butterfly/Moth	*Chaetaglaea cerata*	Waxed Sallow Moth	SC		1983
PLYMOUTH	Bird	*Charadrius melodus*	Piping Plover	T	T	2018

PLYMOUTH	Beetle	*Cicindela purpurea*	Cow Path Tiger Beetle	SC		2004
PLYMOUTH	Butterfly/Moth	*Cicinnus melsheimeri*	Melsheimer's Sack Bearer	T		2012
PLYMOUTH	Butterfly/Moth	*Cingilia catenaria*	Chain Dot Geometer	SC		1946
PLYMOUTH	Vascular Plant	*Dichanthelium wrightianum*	Wright's Panic-grass	SC		1990
PLYMOUTH	Dragonfly/Damselfly	*Enallagma daeckii*	Attenuated Bluet	T		1994
PLYMOUTH	Dragonfly/Damselfly	*Enallagma pictum*	Scarlet Bluet	T		2018
PLYMOUTH	Dragonfly/Damselfly	*Enallagma recurvatum*	Pine Barrens Bluet	T		2018
PLYMOUTH	Mammal	*Eubalaena glacialis*	Northern Right Whale	E	E	2010
PLYMOUTH	Vascular Plant	*Eupatorium novae-angliae*	New England Boneset	E		2018
PLYMOUTH	Bird	*Gavia immer*	Common Loon	SC		1815
PLYMOUTH	Bird	*Haliaeetus leucocephalus*	Bald Eagle	T		2018
PLYMOUTH	Butterfly/Moth	*Hemaris gracilis*	Slender Clearwing Sphinx	SC		2010
PLYMOUTH	Butterfly/Moth	*Hemileuca maia*	Barrens Buckmoth	SC		2013
PLYMOUTH	Butterfly/Moth	*Hypomecis buchholzaria*	Buchholz's Gray	E		2010
PLYMOUTH	Vascular Plant	*Isoetes acadiensis*	Acadian Quillwort	E		2015
PLYMOUTH	Bird	*Ixobrychus exilis*	Least Bittern	E		1977

PLYMOUTH	Vascular Plant	*Lachnanthes caroliana*	Redroot	SC		2012
PLYMOUTH	Mussel	*Leptodea ochracea*	Tidewater Mucket	SC		2013
PLYMOUTH	Vascular Plant	*Liatris scariosa var. novae-angliae*	New England Blazing Star	SC		2018
PLYMOUTH	Mussel	*Ligumia nasuta*	Eastern Pondmussel	SC		2012
PLYMOUTH	Vascular Plant	*Lipocarpha micrantha*	Dwarf Bulrush	T		2018
PLYMOUTH	Butterfly/Moth	*Lithophane viridipallens*	Pale Green Pinion Moth	SC		2005
PLYMOUTH	Vascular Plant	*Mertensia maritima*	Oysterleaf	E		1857
PLYMOUTH	Butterfly/Moth	*Metarranthis pilosaria*	Coastal Swamp Metarranthis	SC		2017
PLYMOUTH	Vascular Plant	*Myriophyllum pinnatum*	Pinnate Water-milfoil	SC		1910
PLYMOUTH	Fish	*Notropis bifrenatus*	Bridle Shiner	SC		2011
PLYMOUTH	Vascular Plant	*Ophioglossum pusillum*	Adder's-tongue Fern	T		1983
PLYMOUTH	Butterfly/Moth	*Papaipema sulphurata*	Water-willow Borer Moth	T		2015
PLYMOUTH	Bird	*Parula americana*	Northern Parula	T		1892
PLYMOUTH	Vascular Plant	*Persicaria puritanorum*	Pondshore Knotweed	SC		2018
PLYMOUTH	Bird	*Pooecetes gramineus*	Vesper Sparrow	T		2014

PLYMOUTH	Vascular Plant	*Potamogeton confervoides*	Algae-like Pondweed	T		1974
PLYMOUTH	Butterfly/Moth	*Psectraglaea carnosa*	Pink Sallow Moth	SC		2005
PLYMOUTH	Reptile	*Pseudemys rubriventris pop. 1*	Northern Red-bellied Cooter	E	E	2019
PLYMOUTH	Vascular Plant	*Rhynchospora inundata*	Inundated Horned-sedge	T		2018
PLYMOUTH	Vascular Plant	*Rhynchospora nitens*	Short-beaked Bald-sedge	T		2016
PLYMOUTH	Vascular Plant	*Rhynchospora scirpoides*	Long-beaked Bald-sedge	SC		2017
PLYMOUTH	Vascular Plant	*Rhynchospora torreyana*	Torrey's Beak-sedge	E		1989
PLYMOUTH	Vascular Plant	*Sabatia kennedyana*	Plymouth Gentian	SC		2018
PLYMOUTH	Vascular Plant	*Sagittaria teres*	Terete Arrowhead	SC		2018
PLYMOUTH	Vascular Plant	*Scleria pauciflora*	Papillose Nut Sedge	E		2014
PLYMOUTH	Vascular Plant	*Spartina cynosuroides*	Salt Reedgrass	T		1929
PLYMOUTH	Butterfly/Moth	*Speranza exonerata*	Pine Barrens Speranza	SC		2017
PLYMOUTH	Vascular Plant	*Sphenopholis pensylvanica*	Swamp Oats	T		2000
PLYMOUTH	Bird	*Sterna dougallii*	Roseate Tern	E	E	2012
PLYMOUTH	Bird	*Sterna hirundo*	Common Tern	SC		2015
PLYMOUTH	Bird	*Sterna paradisaea*	Arctic Tern	SC		2010
PLYMOUTH	Bird	*Sternula antillarum*	Least Tern	SC		2015

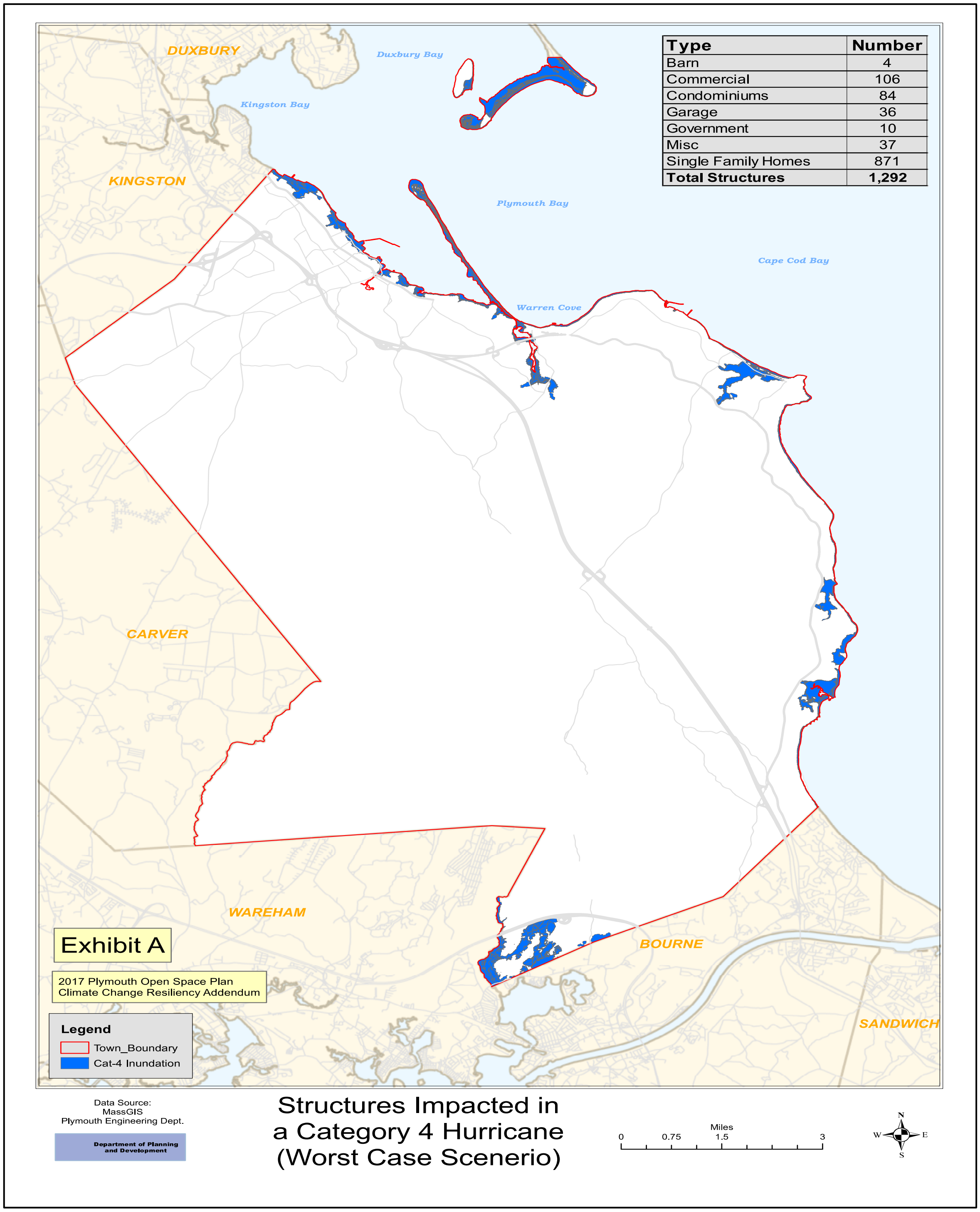
PLYMOUTH	Mussel	*Strophitus undulatus*	Creeper	SC		2007
PLYMOUTH	Mammal	*Synaptomys cooperi*	Southern Bog Lemming	SC		1894
PLYMOUTH	Reptile	*Terrapene carolina*	Eastern Box Turtle	SC		2017
PLYMOUTH	Bird	*Tyto alba*	Barn Owl	SC		1980
PLYMOUTH	Vascular Plant	*Utricularia resupinata*	Resupinate Bladderwort	T		2016
PLYMOUTH	Vascular Plant	*Utricularia subulata*	Subulate Bladderwort	SC		2018
PLYMOUTH	Butterfly/Moth	*Zale lunifera*	Pine Barrens Zale	SC		2013
PLYMOUTH	Butterfly/Moth	*Zanclognatha martha*	Pine Barrens Zanclognatha	SC		2011

SC – Special Concern

T – Threatened

E - Endangered

Appendix E. Plymouth Storm Surge Maps



Type	Number
Barn	4
Commercial	106
Condominiums	84
Garage	36
Government	10
Misc	37
Single Family Homes	871
Total Structures	**1,292**

Exhibit 1: Cat. 4 Storm Impacts – Plymouth

Exhibit 2: Cat. 4 Storm Impacts – Saquish/Clarks Island

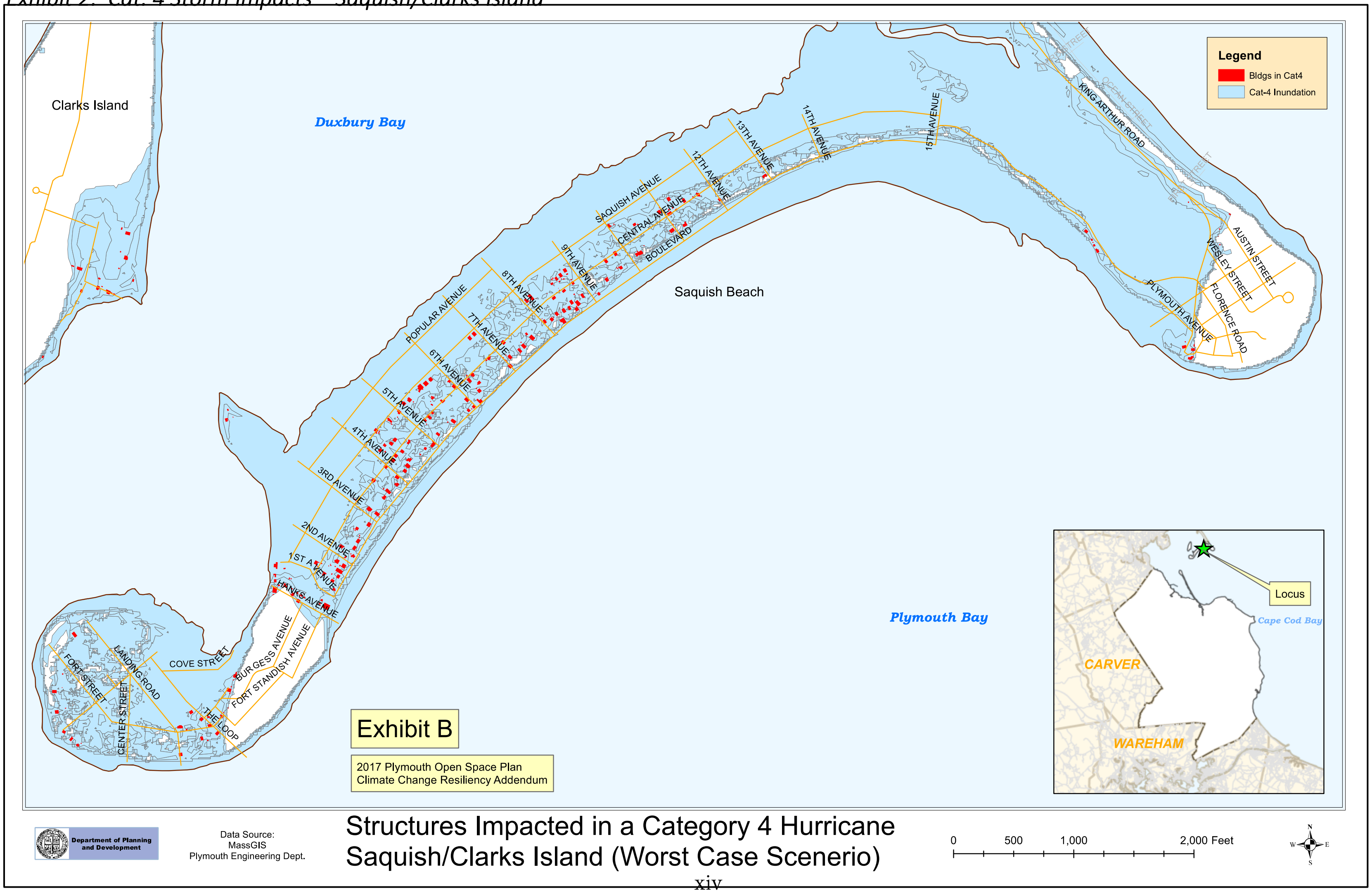
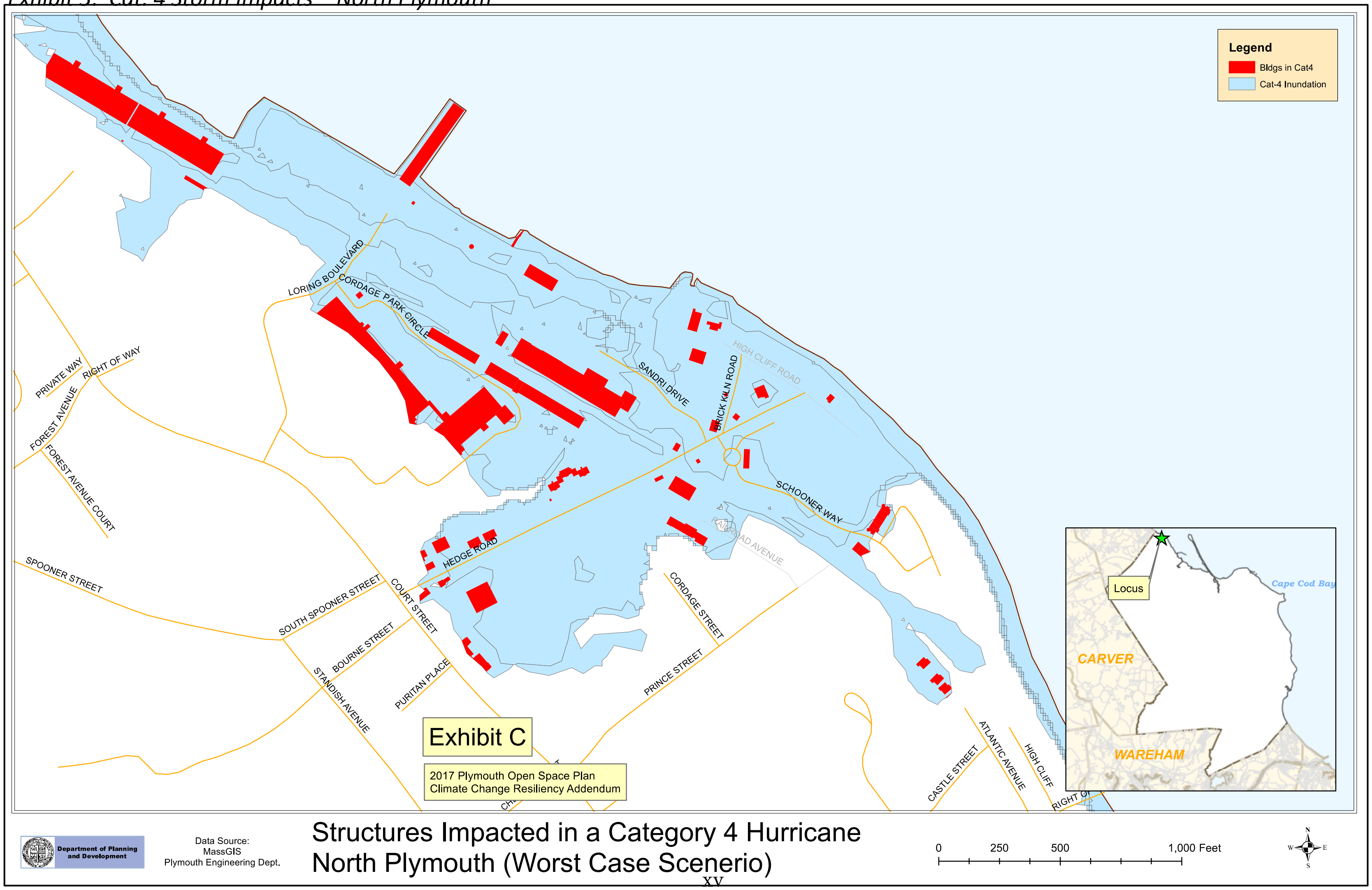


Exhibit 3: Cat. 4 Storm Impacts – North Plymouth



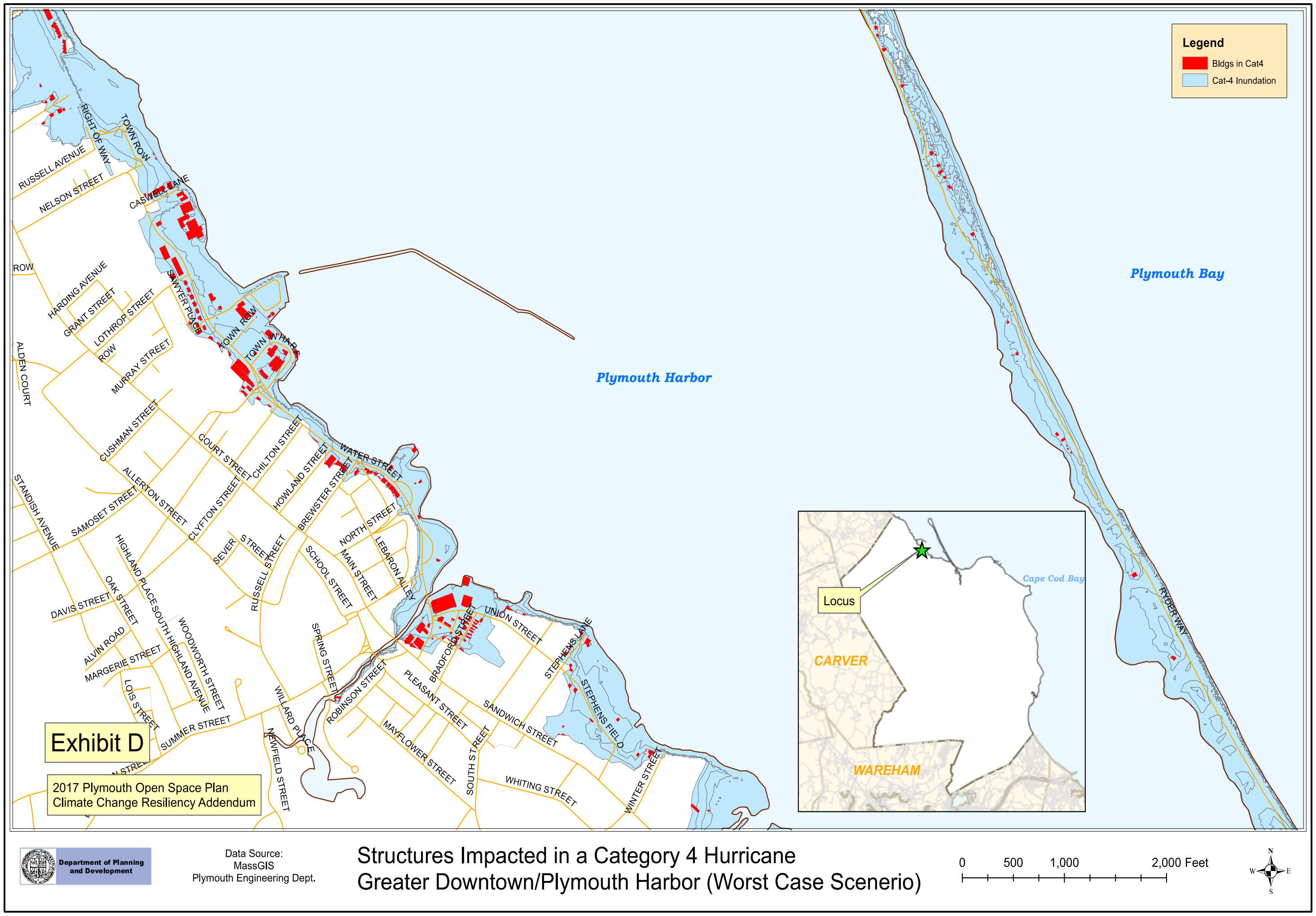


Exhibit 4: Cat. 4 Storm Impacts Greater Downtown/Plymouth Harbor

Exhibit E: Cat. 4 Storm Impacts – Whitehorse Beach

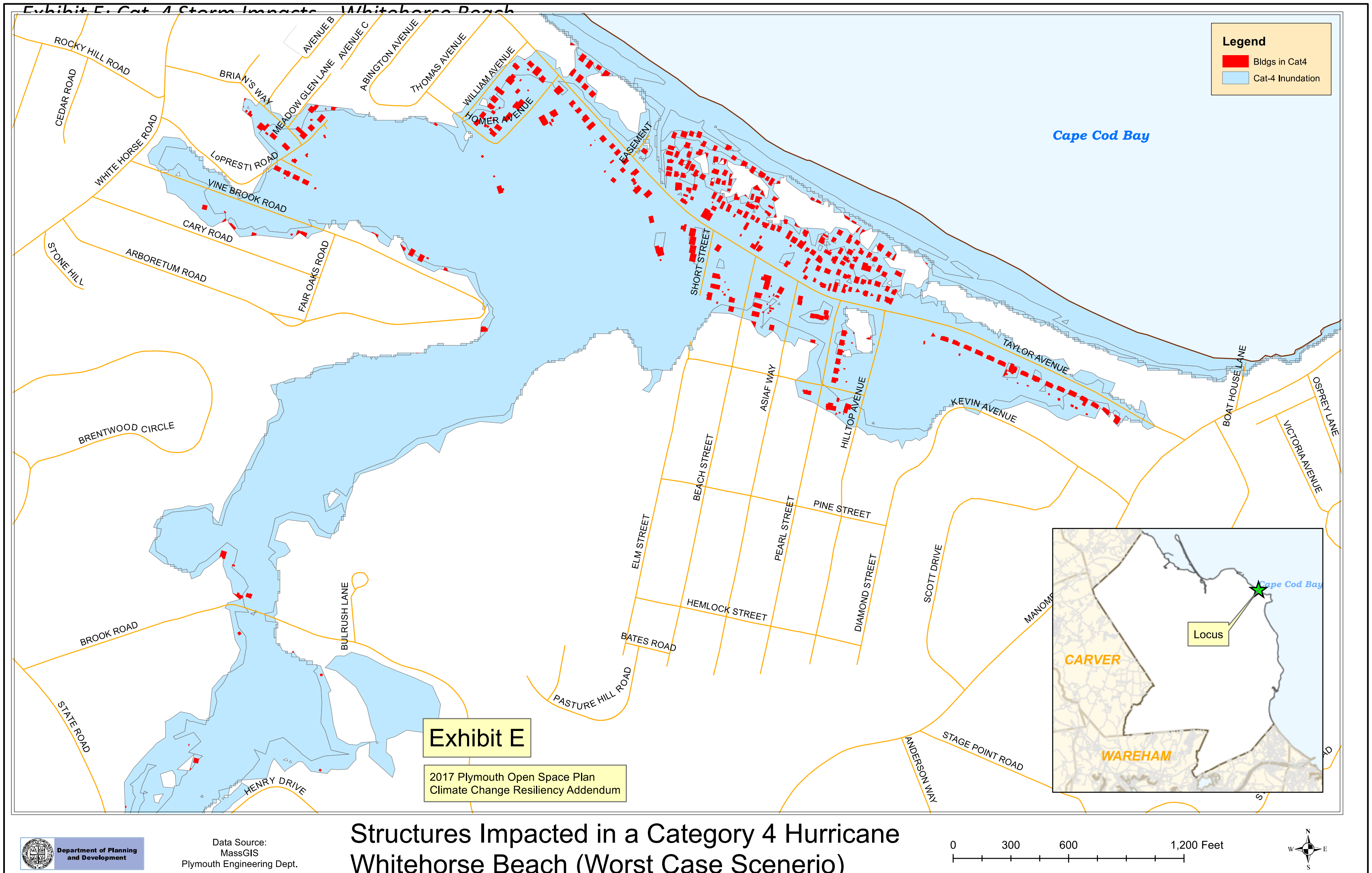


Exhibit 6: Cat. 4 Storm Impacts – Fisherman's Lane

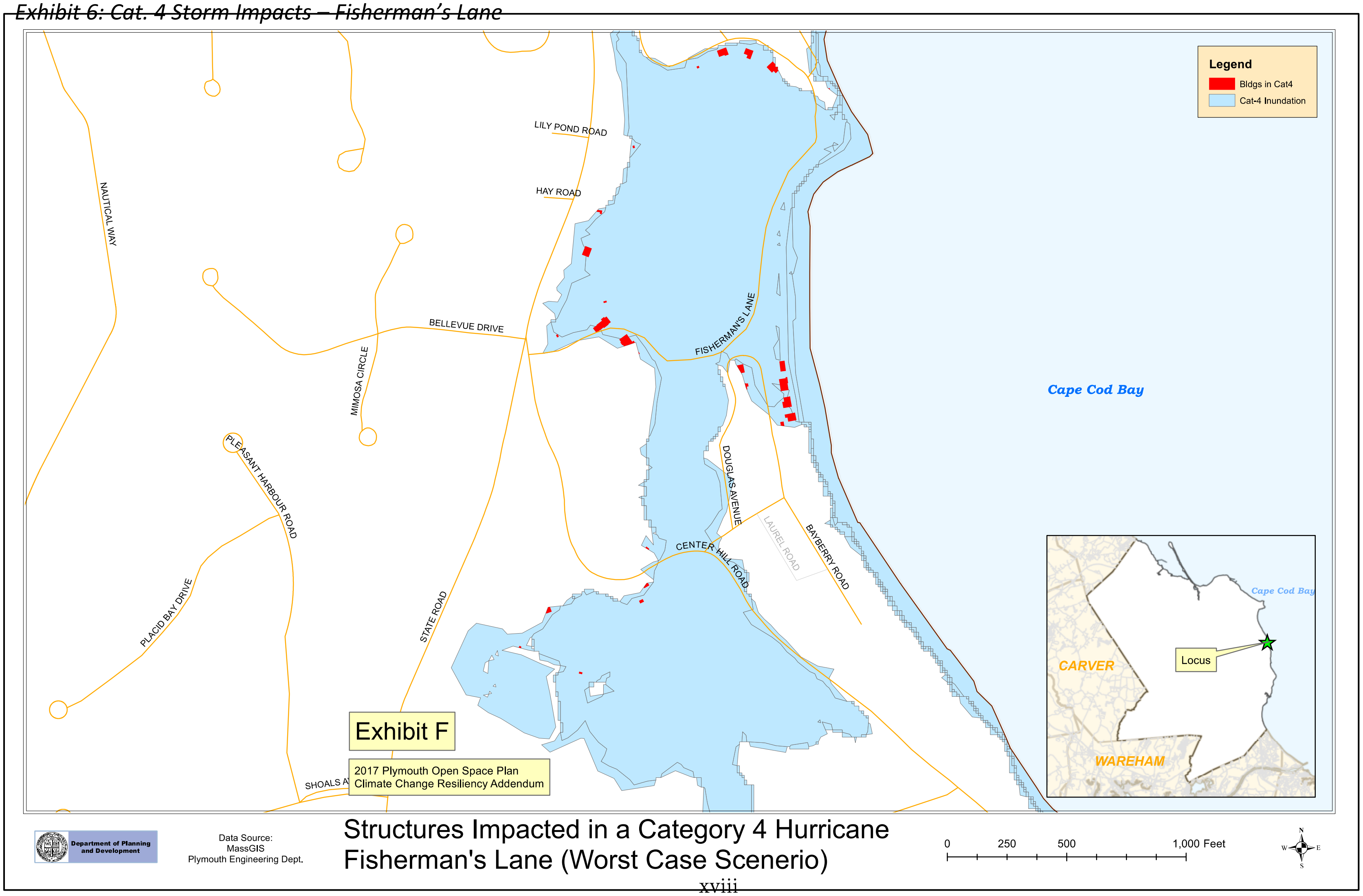


Exhibit 7: Cat. 4 Storm Impacts – Center Hill Road

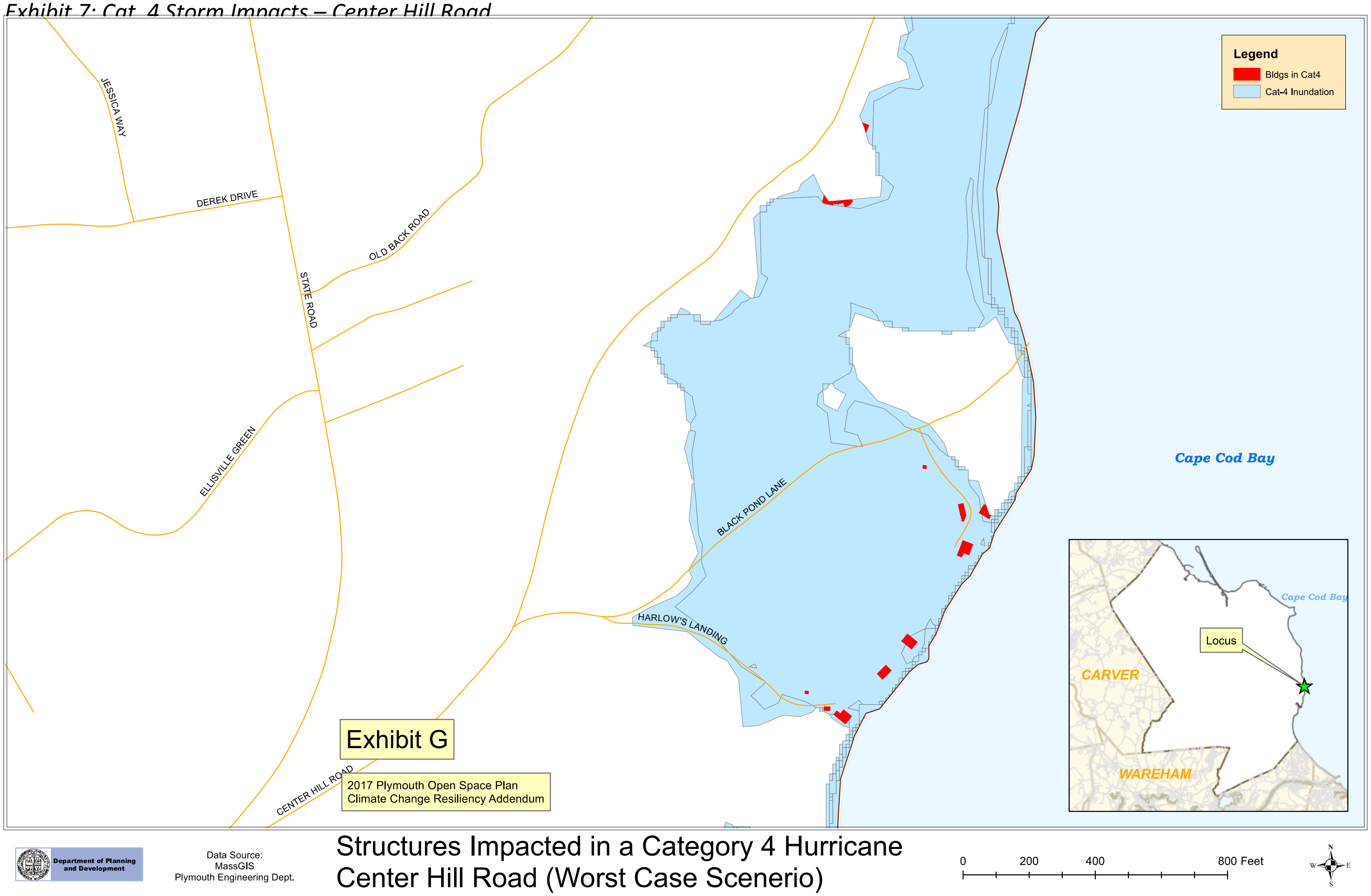


Exhibit 8: Cat. 4 Storm Impacts – Ellisville

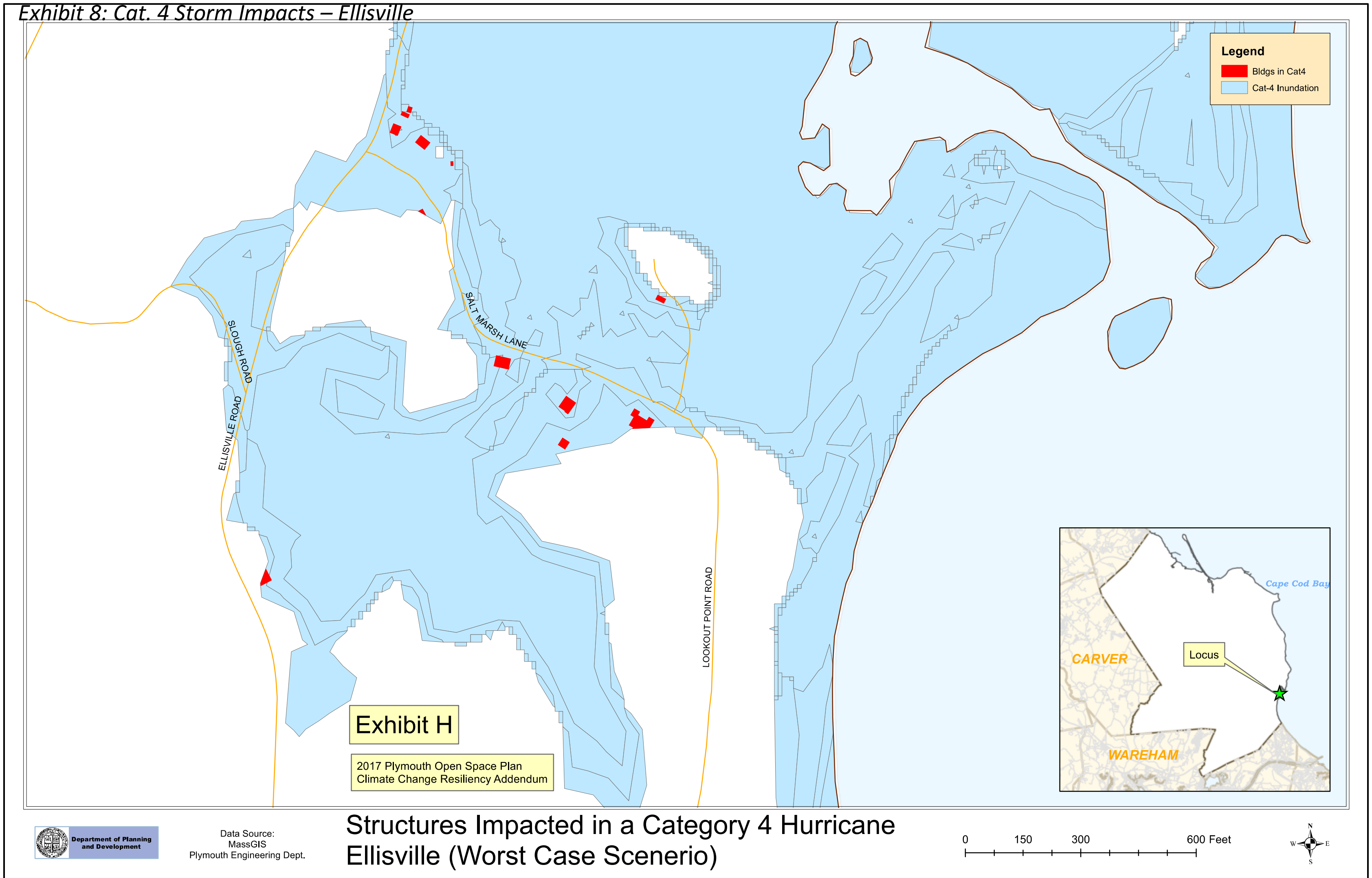
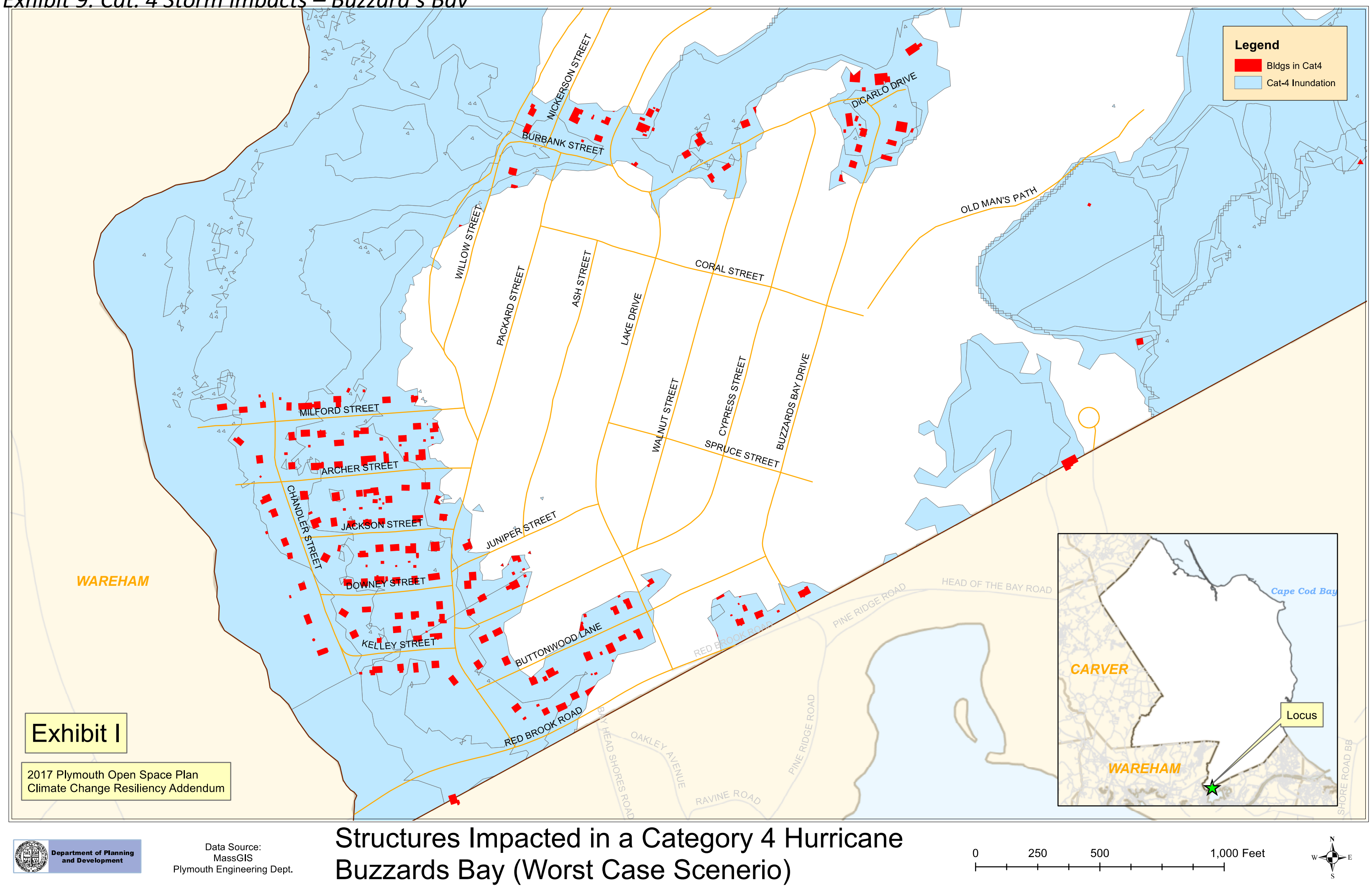


Exhibit 9: Cat. 4 Storm Impacts – Buzzard's Bay



Structures Impacted in a Category 4 Hurricane
Buzzards Bay (Worst Case Scenerio)

Appendix F: Matrix Guide and Further Details

The primary focus of this Addendum is the identification of the specific climate changes challenges facing Plymouth related to open space and potential solutions that promote climate change resiliency. To this end, the team created a matrix (See Table 1, Page 18), first identifying 24 climate change resiliency objectives in these categories:

1. Human health and safety
2. Economic Security
3. Quality of life
4. Mitigation

The team subsequently identified 32 obtainable (i.e., feasible) strategies for the Town of Plymouth to reach the 24 objectives in the following categories:

1. Acquisition/Protection
2. Management
3. Regulation
4. Other

In the matrix, note that the 24 objectives are listed as row headings on the left side. At the top of the table, heading up the columns, are 32 strategies. In the cells where a strategy and an objective meet, no entry (blank space) means that the strategy does not address the objective (or, in other words, the objective cannot be reached by the strategy). Where the strategy would be effective or highly effective in fulfilling an objective, a “1” or a “2” respectively, was placed. Each column’s entries are summed at the bottom of the matrix and range from 4 to 30 out of a possible 48. For each row, *hits* (the number of columns that have either a “1” or a “2” in them) was tallied to demonstrate how many of the 32 strategies address each objective. The scores for *hits* ranged from 2 to 30 of a possible 32.

In the *Acquisition/Protection* category, 10 strategies are listed with scores (totals) ranging from 17 to 30. The highest score (30) was received by **Acquire/protect forested parcels and Acquire/protect freshwater wetlands. Acquire/protect coastal parcels and Encourage conservation restrictions (CRs) for proposed developments** received scores of 28 and 26, respectively.

In the *Management* category, the nine strategies have scores (totals) ranging from 10 to 21. The three highest scores were received by **Plants native trees and shrubs** and **Manage for healthy ecosystems** (21), **Construct living shoreline** (20), and **Remove hard structures on coastal parcels** (18).

In the *Regulation* category, the eight strategies received scores (totals) ranging from 5 to 26. The three highest scores were received by **Minimize number of residential units** (26), **Limit clear-cutting for development** (23), and **Cap/reduce impervious surface** (20).

In the *Other* category, the five strategies have scores (totals) ranging from 5 to 39. The three highest scores were received by **Conduct outreach and education to encourage specific actions** (39), **Construct sidewalks and bike lanes** (21), and **Increase public transportation opportunities (e.g., routes, frequency)** (18)**.**

To analyze the feasibility of reaching each objective, the team examined the number of strategies that addressed each objective, that is, received a score of “1” or “2”. These were called *hits*. For instance, in the *Economic* Security category, the objective **Support ecotourism** received the highest score (30) because it is addressed by 30 of the 32 strategies. This means that there are numerous methods to help meet the objective, and if several of the strategies are put into play, the town may have a greater ability to achieve it. Other objectives, such as **Reduce transmission of tick and mosquito-borne disease**, are supported by far fewer strategies, in which case, if the objective is considered important, more effort might be put into the few viable strategies.