Town of Madison Coastal Resilience Plan

DRAFT

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1 Introduction

Recent events such as Tropical Storm Irene and Hurricane Sandy have underscored the risks associated with occupying coastal areas, and highlighted the fact that property owners and municipalities bear a heavy financial burden to recover from these types of events.

This Coastal Resilience Plan has been developed as a toolbox to build coastal resilience in the coming years. As time passes and our collective understanding of sea level rise is refined, Madison will have the option to update this plan to more appropriately reflect evolving approaches to building resilience.

1.1 Project Goal

The overall goal of the "coastal resilience program" undertaken by Madison is to address the current and future social, economic and ecological resilience of the Town's shoreline to the impacts of sea level rise and anticipated increases in the frequency and severity of storm surge, coastal flooding, and erosion. The planning process was loosely based on the coastal resilience planning process established in 2011-2012 by The Nature Conservancy (TNC). The four steps of the coastal resilience process are:

1. Generate awareness of coastal risks
2. Assess coastal vulnerabilities, risks, and opportunities
3. Identify options or choices for addressing risks
4. Develop and implement an action plan to pursue selected options

In reality, this process began years ago with other planning efforts that involved the public, such as the Hazard Mitigation Plan. This specific planning process launched in September 2015 and was completed in May 2016. Public involvement included three informational meetings and an internet-based survey. Vulnerability and risk assessment was conducted from September 2015 through January 2016, and the adaptation/resilience options for Madison were reviewed and selected from January through April 2016.

This program is intended to highlight underserved, low-to-moderate income (LMI) populations and communities for additional consideration. Madison does not contain any LMI tracts[1], however the central part of the coast, from Surf Club Beach to Seaview Beach, is characterized by a relatively lower median income than the rest of the shoreline.

1.2 Project Funding

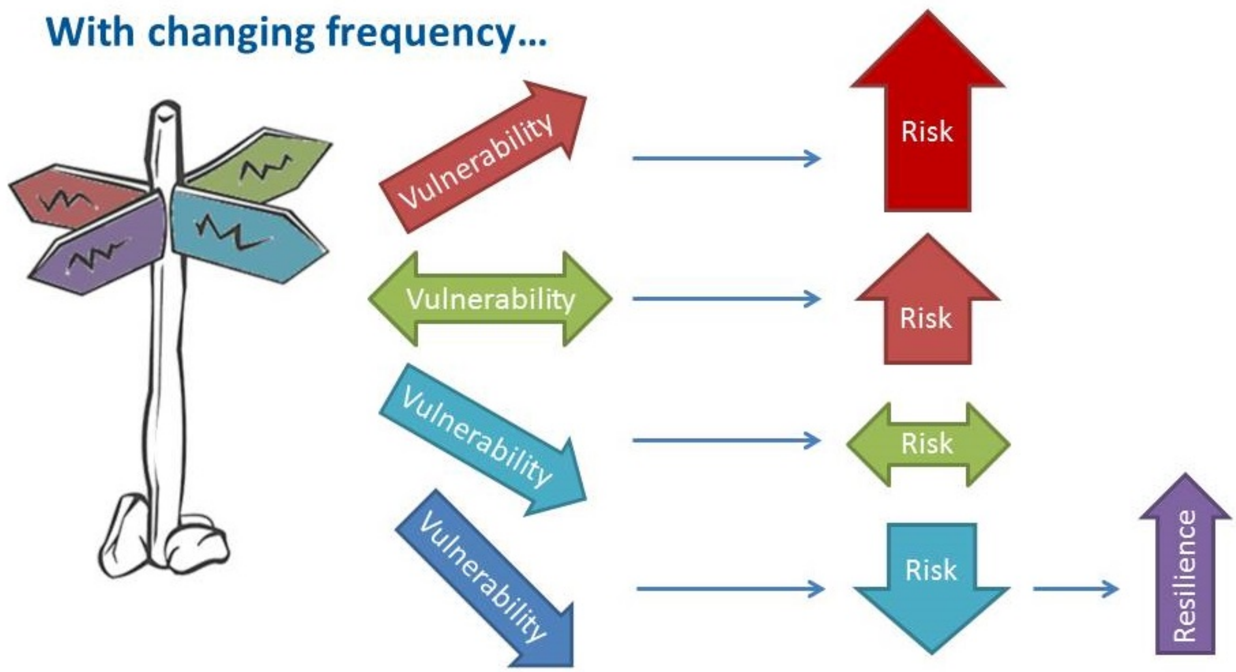
Preparation of this Community Coastal Resilience Plan was funded through the United States Department of Housing and Urban Development's (HUD) Community Development Block Grant Disaster Recovery Program (CDBG-DR). The money was allocated to HUD through the 2013 Disaster Relief Appropriations Act, which designated aid assistance for communities affected Hurricane Sandy.

[1] At the time of the CDBG-DR grant application in 2014, the LMI Census block groups were mapped based on estimates from the 2007-2011 American Community Survey (ACS) where the median income was 80% or lower of the Area Median Income (AMI). ACS estimates are based on a 5-year rolling average of a small sample size. LMI limits are revised annually. Current estimates available on the online CPD Maps viewer show that no Census block groups in Madison are currently HUD-designated LMI areas.

2 Vulnerability and Risk

2.1 Risk and Resilience Concepts

In the context of hazards, **risk** is the product or the sum of **vulnerability** and **frequency**. In the context of coastal hazards, risk depends on (1) the vulnerability of coastal communities and infrastructure, and (2) the frequency of flooding and storm events. Coastal storms are believed to be increasing in frequency, and flooding will increase in frequency as sea level continues to rise (refer to discussion below). Thus, even if coastal vulnerabilities remain static, risks will increase. If vulnerabilities increase as well, due to new development in hazard areas or failure to maintain existing protective structures, risks will increase dramatically. Alternatively, if vulnerabilities are reduced through adaptation, risk levels can be held steady into the future. If vulnerabilities can be reduced even further, then risks can be lowered in the face of rising sea level and increased coastal storms, leading to **increased resilience**.



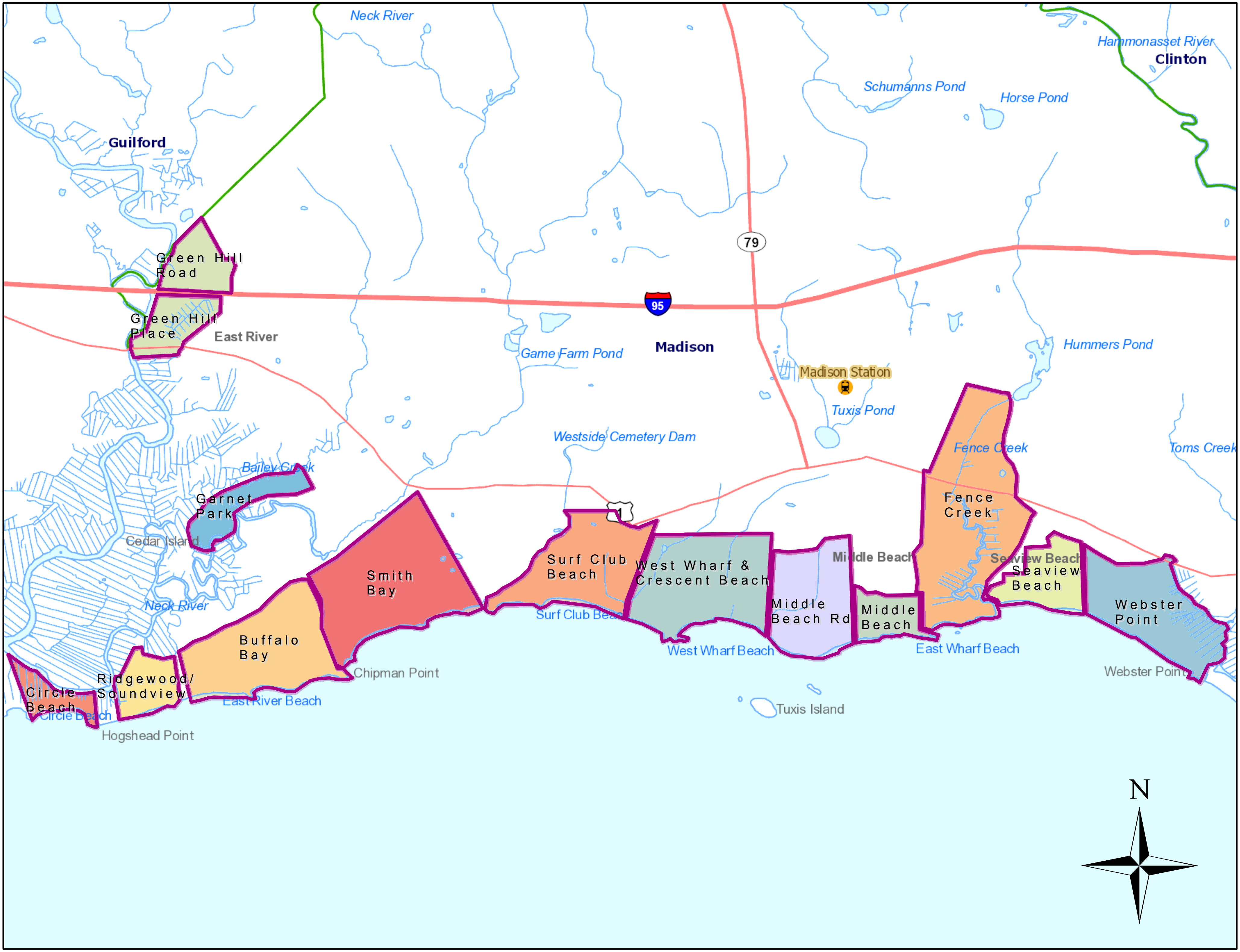
Resilience is the ability to resist, absorb, recover from, and adapt to disasters. **Coastal Resilience**, referring specifically to coastal hazards such as sea level rise, increased flooding, and more frequent and intense storm surges, can be achieved by decreasing coastal vulnerabilities through increased adaptation and planning.

2.2 Existing Conditions

2.2.1 Basic Town Info

Madison has approximately 18,259 residents living within 36.2 square miles of land. The Town has around six miles of coastline, not including the shore of Hammonasset Beach. Population density is relatively consistent along the Town's coastline, but higher density residential areas exist at the Soundview, Smith Bay, Middle Beach Road, and Seaview Beach neighborhoods along the coast. The less-developed areas along the coast are The Madison Surf Club Beach area toward the center of Town, and Hammonasset State Park at the eastern end of Town. For the purposes of this report, the Coastal neighborhoods of Madison are broken into the following:

- Green Hill Road: a dead-end road off of Wildwood Avenue north of Route 95 leads to five homes on the east bank of the East River.
- Green Hill Place: for the purposes of this project, this name refers to the mostly commercial area of Route 1, Green Hill Place, and Old Post Road at the western border of Madison south of Route 95. The area includes water-dependent businesses.
- Garnet Park: a strip of low-elevation residential properties jutting west off of Route 1, bounded by Bailey Creek to the north, Neck River to the south, and East River to the west.
- Circle Beach: about twenty homes constructed on a narrow, low elevation sand spit at the mouth of the East River, at the southwestern corner of Madison.
- Ridgewood/Soundview: the neighborhood east of Circle Beach around Ridgewood Avenue and Soundview Avenue, sometimes called "East River Beach."
- Buffalo Bay: for this project, this name refers to the beaches extending from Soundview Avenue to the Mercy by the Sea Retreat Center and Chipman Point.
- Smith Bay: this is the name for the finger roads south of Neck Road, from Pleasant View Avenue at the western edge to Shorelands Drive at the eastern edge. These private roads are relatively densely developed, and drop to very low elevations near the shoreline. The coast is characterized by alternating bulkheads and beaches.
- Surf Club Beach: the area from Garvan Point to the Madison Surf Club. This neighborhood has a large amount of open space.
- West Wharf & Crescent Beach: lower elevation neighborhood including Flower Avenue and Parker Avenue, and extending eastward along Middle Beach Road West. The West Wharf section has some beach fronting the homes. The Crescent Beach section, around Middle Beach Road West, does not consistently have a beach at high tide, and homes are protected by bulkheads.
- Middle Beach Road: this refers specifically to the section of road between Island Avenue and Park Avenue, where the road is immediately adjacent to the water and protected by riprap and seawalls.
- Middle Beach: This area has a narrow beach fronting a row of homes. Part of the coast has no beach at high tide. The western edge is at Park Avenue and the eastward edge is at East Wharf.
- Fence Creek: This includes the inland neighborhoods surrounding Fence Creek and its wetland, as well as the homes built at its mouth.
- Seaview Beach: Seaview Avenue is fronted by an undeveloped living shoreline, and backed by homes.
- Webster Point: in this document, Webster Point refers to the neighborhood from Seaview Avenue until Hammonasset State Park. This area is higher in elevation, and most homes are set back from the waterfront.


Neck River
Hammonasset River
Clinton
Schumanns Pond
Horse Pond
Guilford
79
95
Green Hill Road
Green Hill Place
East River
Game Farm Pond
Madison
Hummers Pond
Madison Station
Tuxis Pond
Westside Cemetery Dam
Fence Creek
Toms Creek
Bailey Creek
Garnet Park
Cedar Island
1
Smith Bay
Surf Club Beach
West Wharf & Crescent Beach
Middle Beach
Fence Creek
Seaview Beach
Seaview Beach
Neck River
Middle Beach Rd
Middle Beach
Webster Point
Surf Club Beach
Buffalo Bay
West Wharf Beach
East Wharf Beach
Ridgewood/ Soundview
Chipman Point
Webster Point
Circle Beach
East River Beach
Circle Beach
Tuxis Island
Hogshead Point
N

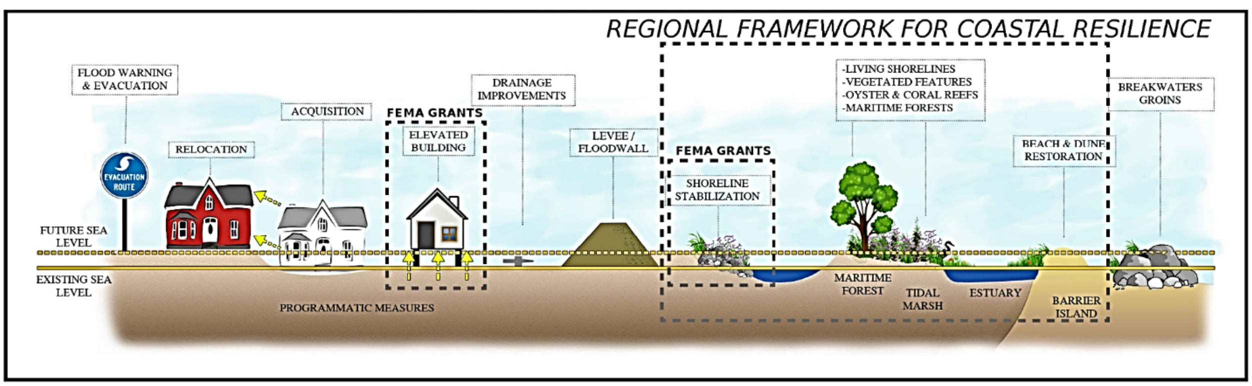
2.2.2 Existing Capabilities

There are a suite of existing regulations, plans, projects, and programs within the Town of Madison that relate to, address, or are otherwise pertinent to the Town's pursuit of becoming a more resilient coastal community. This plan acknowledges the contribution that these resources make to Madison's resilience capabilities, and was designed to work *with* these existing documents and actions. These resources (described in Appendix A) include the following:

- SCRCOG Multi-Jurisdiction Hazard Mitigation Plan
- Madison Plan of Conservation and Development
- Madison Zoning Regulations
- Madison Code of Ordinances
- TNC Salt Marsh Advancement Zone Assessments
- TNC Hazard and Community Resilience Workshops Summary of Findings
- FEMA New Haven County Flood Insurance Study and FIRM Panels
- Individual Drainage, Flood Mitigation, and Roadway Resilience Projects
- Individual HMGP- and CDBG-DR-Funded Projects

The following graphic depicts the unique relationship between the Madison Hazard Mitigation Plan and this Coastal Resilience Plan (which covers a subset of all of the hazards in Madison). Meanwhile, the ten-town Regional Framework for Coastal Resilience addresses waterward resilience issues, which is a subset of this Coastal Resilience Plan.

MADISON COASTAL RESILIENCE PLAN



All of the relevent municipal planning documents recognize sea level rise and coastal storms as a key issue in need of consideration. The SCRCOG Multi-Jurisdiction Hazard Mitigation Plan identifies locations vulnerable to future sea level conditions, tracks mitigation projects, and suggests additional possibilities. The Madison Plan of Conservation and Development specifically addresses sea level rise as an important factor in future development, and encourages protection of open space, coastal habitats and natural resources, and infrastructure.

The studies being performed by the Town, the State, and other parties cover Salt Marsh sustainability, shoreline change and sediment dynamics, the future evolution of coastal hazards and socio-economic vulnerabilities, aquatic and shoreline habitats, and multi-hazard effects on coastal resilience.

Monitoring the state of these projects and plans, ensuring collaboration and communication between the responsible entities, and building on this baseline to fill knowledge and implementation gaps, will be essential in creating a resilient Town.

2.2.3 Existing Challenges

Madison already has experience with coastal hazards. The neighborhoods of Green Hill Place, Garnet Park, Circle Beach Drive, Smith Bay, and Fence Creek regularly experience flooding at especially high high-tide events, such as those associated with low-pressure systems or full- or new-moon conditions. Residents suffer from blocked access to homes, and damage to property and vehicles on a regular basis in those locations. Middle Beach Road needs to be regularly maintained to prevent failure due to erosion by high waves. Malfunctioning tide-controlled drainage systems have led to problems at Green Hill Road. Rising waters and increasing storm severity and frequency will exacerbate these problems and give rise to as yet nonexistent problems in other parts of town.

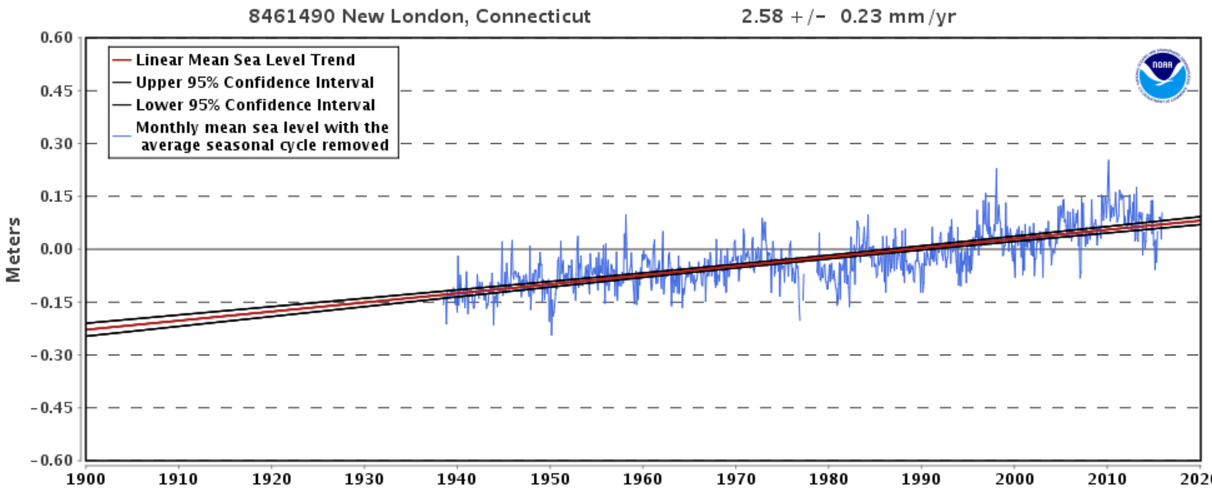
2.3 Sea Level Rise

2.3.1 Existing Conditions and Historic Trends

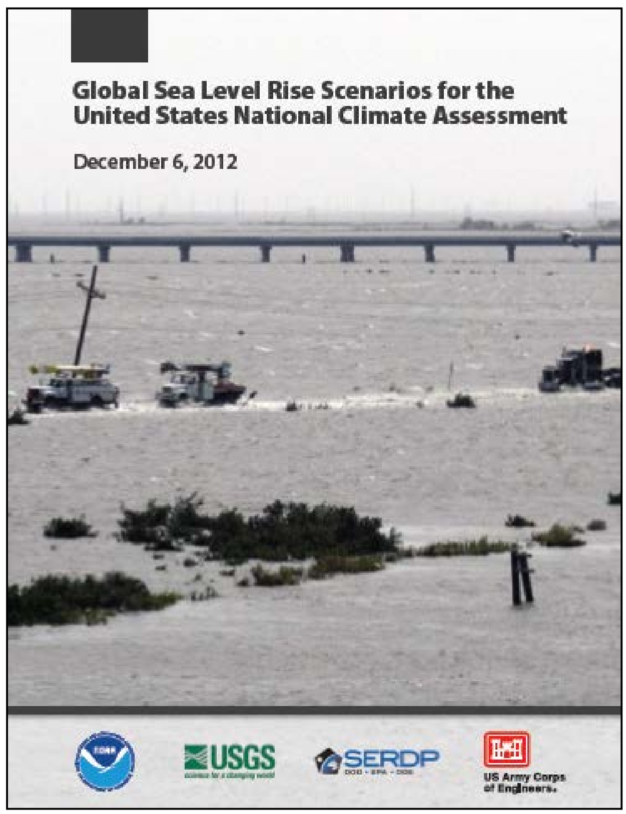
There are no National Oceanic and Atmospheric Administration (NOAA) tide gauges within Madison, however a gauge has been operated by NOAA in Clinton to the east. The Clinton gauge was located south of Riverside Drive in the mouth of the Hammonasset River, and collected data from June to October, 2002. According to data collected by this gauge (available online at tidesandcurrents.noaa.gov), the mean sea level (MSL) at the eastern edge of Madison is negative (-) 0.33 feet, or 0.33 feet below the North American Vertical Datum of 1988 (NAVD88). The average maximum elevation of high tide ("mean higher-high water, or MHHW") is 2.62 feet above the MSL, or 2.29 feet elevation (NAVD88). These values will vary along Madison's coastline, and have likely changed since 2002, as discussed below.

The nearest ***long-term***, currently operational gauge to Madison is the tide gauge in New London, CT. Based on tide gauge data collected at that station between 1938 and 2014, MSL has been increasing at a rate of 2.58 millimeters (0.101 inches) per year, which is equivalent to a rise of 0.85 feet over 100 years (see Figure 1 below). Another station in Bridgeport, CT, has measured an increase of 2.87 mm/yr, or 0.94 feet-per-100-years, based on measurements since 1964.

Figure 1



2.3.2 Sea Level Projections



Projections of the rate and extent of sea level rise in the future were used to determine Madison's vulnerabilities to future coastal conditions. Uncertainties exist with regard to multiple factors that contribute to sea level change, including the rate of change in the land surface elevation, the extent and rate of glacial melting, and changes in human development and greenhouse-gas emission patterns. For this reason, multiple projections are available. For planning purposes, it is advisable to use medium or high sea-level rise projections such that a community will be better protected against worse-case scenarios.

The U.S. Army Corps of Engineers hosts a sea level projection web tool ("Sea-Level Change Curve Calculator") at http://www.corpsclimate.us/ccaceslcurves.cfm. The calculator provides sea level rise projections using both U.S. Army Corps of Engineers and NOAA projections at existing tidal gauges. The nearest gauge to Madison is the tide gauge in Bridgeport. Calculated sea level rise for this gauge is depicted in the following table and graph. In each case, the base year is 1992. Rates are as follows:

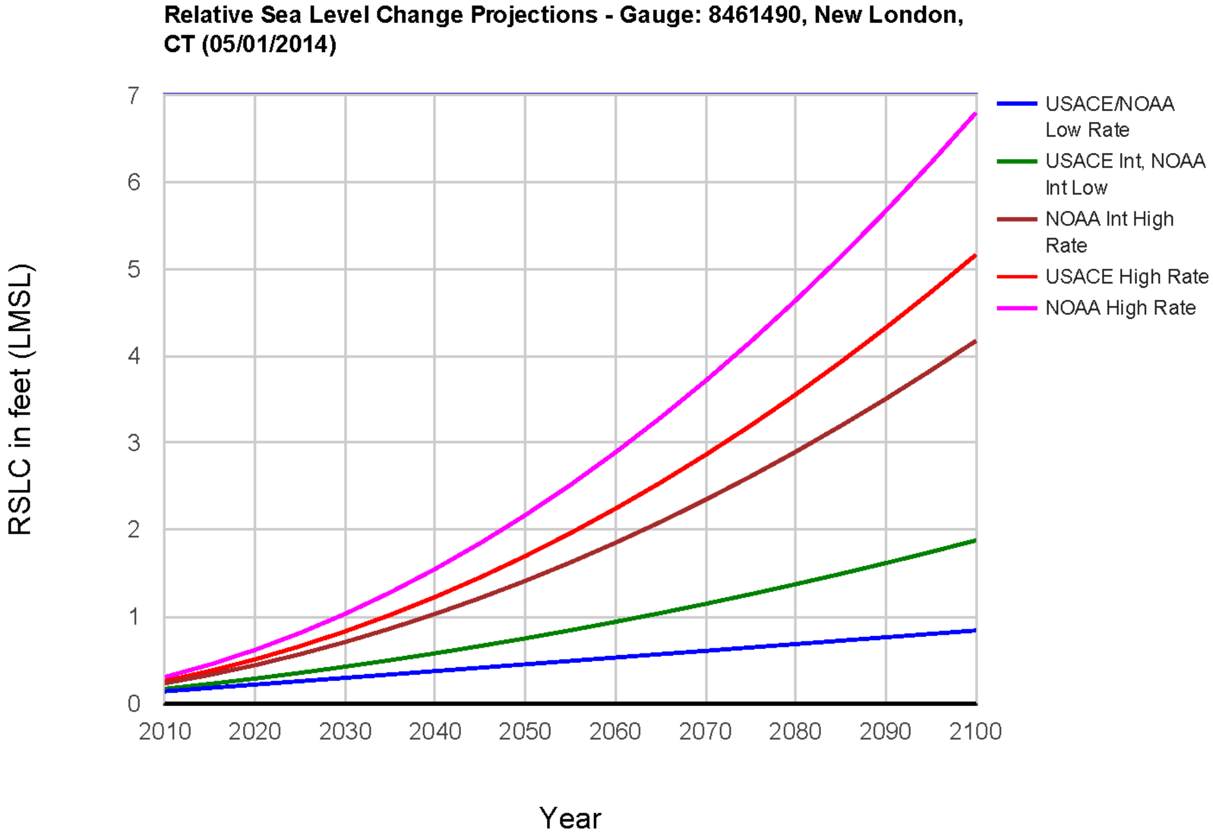
- NOAA Low and USACE Low: historic rate of sea-level change is the rate of change moving forward
- NOAA Intermediate Low and USACE Intermediate: ocean warming and the local rate of vertical land movement determine sea level change rate.
- NOAA Intermediate High: the projected rate assuming both ocean warming and a moderate rate of melting of the arctic ice sheets.
- USACE High: considers both the most recent IPCC projections and modified National Research Council projections with the local rate of vertical land movement added.
- NOAA High: rate based on heating of the oceans and a maximum loss of the ice caps.

Table 1

Gauge 8461490, New London, CT NOAA's Regional Rate: 0.00778 feet per year Values expressed in feet relative to the 1992 Local Mean Sea Level (LMSL)					
Year	USACE Low NOAA Low	USACE Int NOAA Int-Low	NOAA Int-High	USACE High	NOAA High
2010	0.14	0.17	0.23	0.26	0.31
2020	0.22	0.29	0.44	0.51	0.62
2030	0.30	0.42	0.71	0.83	1.03
2040	0.37	0.58	1.03	1.23	1.55
2050	0.45	0.75	1.41	1.70	2.17
2060	0.53	0.94	1.85	2.24	2.89
2070	0.61	1.15	2.35	2.86	3.71
2080	0.68	1.37	2.90	3.56	4.64
2090	0.76	1.62	3.51	4.32	5.67
2100	0.84	1.88	4.17	5.16	6.80

Figure 2

Relative Sea Level Change Projections
Gauge 8461490, New London, CT



The ranges calculated in Figure 1 and Table 1 are quite wide, but even the low projections show that sea level rise will continue throughout the current century. The USGS has demonstrated that sea levels along the mi-Atlantic and northeast coasts of the United States are already rising three to four times faster than the global average since 1990. This heightens the need for resilience planning in Madison. More information on sea level rise projections is presented in Appendix B.

2.4 Specific Vulnerabilities and Risks

2.4.1 Summary

Madison's coastal neighborhoods are diverse and each will be faced with a combination of vulnerabilities with sea level rise and the increased incidence and severity of coastal storms. Generally, coastal **hazards** can include:

- Stillwater Inundation – flooding from high water without the effects of waves
- Wave Setup and Runup – wave action allows water to reach areas that would otherwise be protected
- Wave Action – can cause damage to buildings directly
- Erosion of coastal banks
- Erosion of beaches
- Drainage-related flooding (outlet submerged and/or insufficient capacity of systems)
- Wind – can directly damage structures to blow debris into structures

Risks and vulnerabilities in the Town of Madison were determined through review of documents such as the SCRCOG Multi-Jurisdiction Hazard Mitigation Plan, discussion with Town representatives, public meetings, an online survey, and utilization of The Nature Conservancy's Coastal Resilience Mapping Portal. Madison's shoreline specifically is most susceptible to inundation of low-lying structures and neighborhoods, erosion and undermining of coastal roads and properties, and various threats to private septic systems. These risks are anticipated to increase over time due to sea level rise and climate change, and may be compounded by continuing trends of increased development and population growth. High winds during storm events, which are also predicted to increase with climate change, may put further pressure on vulnerable coastal communities.

Coastal **vulnerabilities** can fall under a variety of categories, as follows:

- Social – Residents, business community, and visitors
- Economic – Residential Properties, commercial/industrial businesses, municipal resources, tourism, and future development.
- Infrastructure – Roads, bridges, railroads, stormwater, seawalls, tide gates, the marina, and municipal facilities.
- Utilities – Public and private water supplies, septic systems, telecommunications, and electricity.
- Emergency Services – Fire, police, medical, sheltering, evacuation/egress.
- Natural Systems – Tidal wetlands and other coastal landforms.

The most vulnerable aspects of Madison's coastal area are its roads, septic systems, and buildings. Many coastal roads are vulnerable to being submerged by rising waters or eroded by waves. The Town does not have a municipal wastewater utility, so every home has a septic system that will need to be protected from encroaching seawater. Homes and commercial buildings are vulnerable to inundation from Long Island Sound or backwatering of rivers during storm events, as well as to erosion, failed drainage infrastructure, and damage from high winds. Some commercial and industrial activities are vulnerable.

On the other hand, much of Madison's land area is located inland, and the Town overall is not very densely developed. While the Town faces a number of different types of coastal hazards, the number of people exposed to those hazards will remain relatively low when compared to more densely developed coastal municipalities. Additionally, Madison's emergency services are not directly vulnerable to coastal flooding or storms, and emergency access to most areas that are vulnerable should remain passable in most storm scenarios.

Significant roads at risk of flooding under future sea level rise (daily high tide flooding) and storm scenarios include:

- Route 1 / Boston Post Road
- Green hill Place
- Garnet Park Road
- Circle Beach Road
- Surf Club Road
- Middle Beach Road West
- Island Avenue
- Middle Beach Road
- Scotland Avenue
- Seaview Avenue

Vulnerabilities and risks within Madison are described in significant detail in Appendix B.

2.4.2 Vulnerable Neighborhoods

Different neighborhoods and areas of Madison face different hazards presented by current and future daily-high-tide and hurricane conditions. The expected extent of flooding from sea level rise and storm surge effects was determined using The Nature Conservancy's Coastal Resilience Mapping Portal, as described in Appendix B section 2.3.2. It is important to note that these projections are predictions of future conditions based on currently available data. The most immediate projections (those of conditions in the 2020s) have the highest level of confidence, which uncertainty increasing farther in the future.

Wave setup and runup can increase the height of floodwater above the "stillwater" elevation, and the extent of those effects are related to the topography of the coastline at a particular location. The TNC Coastal Resilience Mapping Portal is not able to capture these details, so further analysis was performed with wave modeling software used by FEMA and USACE, as described in Appendix B section 2.3.3. These modeling tools determine the effects of waves through analysis of topographic transects. There are five FEMA transects along the Madison coastline that are at or near locations with significant concerns about coastal hazards. These are located at Circle Beach, Smith Bay, Middle Beach Road West (West Wharf and Crescent Beach area), and Bayview Terrace. It is important to note that the conditions at a given transect may not reflect those at adjacent properties. Further analysis would be required to verify or correct the results for areas currently without transects.

Both The Nature Conservancy's sea level rise and storm surge mapping tool, and the wave setup and runup models from FEMA and USACE, were used to assess risk and vulnerability at different neighborhoods long the Madison coast. This analysis is presented in detail in Appendix B sections 4.2 and 4.3, and is summarized below.

Green Hill Road

This dead-end road passes through a wetland on its way to five homes on the east bank of the East River, and is susceptible to flooding from the wetland and isolation. The wetland drains south under Green Hill Road and then under State Route 95. Flooding of this wetland onto Green Hill Road is projected to occur regularly during non-storm conditions as soon as the 2020s, isolating properties. This area falls within a FEMA AE zone with a base flood elevation (BFE) of 9 feet NAVD88)

Green Hill Place

This mostly commercial area is vulnerable to flooding from the East River and an adjacent wetland. It is projected to experience daily nuisance flooding by the 2020s. Flooding will affect both roads and structures. Present-day conditions already cause regular minor inundation here. The FEMA AE zone here as a BFE of 11 feet (NAVD88).

> **WHAT DO OTHER STUDIES SAY ABOUT MADISON?**
>
> **Analysis of Shoreline Change in Connecticut:**
> **100 Years of Erosion and Accretion (July 2014)**
>
> *A cooperative effort between the Connecticut Department of Energy and Environmental Protection, UConn CLEAR, and Connecticut Sea Grant*
>
> ---
>
> The analysis shows the following trends along the Madison shoreline:
>
> *Accretion*
> Chipman Point, end of Oak Avenue, Webster Point area.
> Rates around 0.3 to 0.5 meter/year.
>
> *Erosion*
> West end of Circle Beach, end of Soundview Avenue, east of Harbor Avenue, end of Overshore Drive, east of Madison Surf Club, between Tuxis Road and Gull Rock Road, in front of one section of Middle Beach Road, and at Hammonasset State Beach.
> Rates around -0.3 to -0.7 meter/year.

Garnet Park

This area is susceptible to isolation, as well as inundation. Most properties are within FEMA AE zones with BFEs of 11 or 12 feet, NAVD88. The surrounding waterways and wetlands are mapped as velocity (VE) zones with a BFE of 13 feet. Projections show Garnet Park Road overtopped by daily high tide flooding of Baily Creek by the 2020s, isolating the entire neighborhood. Baily Creek and Neck River floodwaters will connect over Meadow Lane and Garnet Park Road, further isolating residents. Isolation issues are projected to increase over time. A category 2 storm would cause widespread inundation of roads and homes.

Circle Beach

The homes here are within a VE zone with a BFE of 13 feet. Homes are already elevated, and the main concern is isolation from flooding of the road, which is projected to occur on a daily basis by the 2020s. By the 2050s, high tide is projected to over all of the lots here.

Ridgewood/Soundview

This neighborhood is protected from inundation by its somewhat higher elevation, and from wave energy by revetments. There is no beach at high tide here. Projections show low vulnerability to daily high-tide inundation through the 2080s. Erosion may be a concern here.

Buffalo Bay

This area is characterized by sandy beaches and homes that are mostly on high ground and not vulnerable to flooding. Projections show this area is not vulnerable to sea level rise.

Smith Bay

The southern ends of all of these relatively densely settled roads tend to be lower in elevation than the beaches they lead to, and are protected from water and sand by bulkheads. Drainage problems are already apparent in these areas. By the 2050s, daily high tides are projected to impact both roads and properties at the ends of Toffee Lane, Overshore Drive, Pleasant View Avenue, Beach Avenue, Harbor Avenue, and Kelsey Place. The southernmost properties here fall within a VE zone with a BFE of 14 feet NAVD88, while AE zones with BFEs of 13 or 14 feet extend inland.

WHAT DO OTHER STUDIES SAY ABOUT MADISON?

Conceptual Regional Sediment Budget for USACE North Atlantic Division (March 2015)

A conceptual regional sediment budget (CRSB) was developed for the USACE North Atlantic Division as a component of the Comprehensive Hurricane Sandy study.

Net sediment transport in Long Island Sound was found to be toward the west with local reversals. The CRSB along the Madison shoreline was found to be "balanced." The CRSB for Long Island Sound was found to be accreting.

The report recommends "better characterization of regional sediment transport patterns for beaches along Long Island Sound. Although this area is less vulnerable to direct impact from hurricanes and northeasters, there are navigation channels and sediment management activities that could reduce future erosion of this area."

Surf Club Beach

This area is vulnerable to widespread flooding of wetlands and other open space by future high tides. Most of that flooding is limited to undeveloped areas, and will not impact structures. Flooding that originates here can, however, extend eastward and impact properties at West Wharf.

West Wharf & Crescent Beach

Inundation here comes mostly from wetlands located inland. Daily High Tide flooding may impact around seven homes in these two neighborhoods by the 2020s, and submerge a number of roads. By the 2050s, daily flooding will have spread considerably, impacting around 20 homes, and isolating as many as 25. A present-day category 2 storm will inundate most of this area, affecting around 80 structures and inundating all of the local roads. This area is within a FEMA AE zone with a BFE of 12 feet NAVD88. Some waterfront homes are partially in a VE zone with a BFE of 14 feet.

Middle Beach Road

Island Avenue, Tuxis Road, Gull Rock Road, and Park Ave, are all within an AE zone with a BFE of 12 feet NAVD88. During large storm events, flooding of properties and inundation of roads is an issue.

However, the main concern here is the vulnerability of Middle Beach Road itself, which is constructed immediately alongside the water here. One stretch of road falls within the VE zone, with a BFE of 14 feet. Erosion and undermining of this road is a major vulnerability.

Middle Beach

Homes and the road are vulnerable to storm surge. BFEs are 14 feet NAVD88 on the shore and 12 feet inland.

Fence Creek

Homes surrounding the wetland of Fence Creek, specifically those on Linden Lane, are vulnerable to daily high tide flooding by the 2080s. The section of Middle Beach Road between Fence Creek and Long Island Sound is vulnerable to flooding from the creek as well as wave runup from the Sound. By the 2020s, high tide flooding is projected to affect a dozen properties on the inland side of Middle Beach Road.

Seaview Beach

No homes are located on the water-side of Seaview Avenue at Seaview Beach, removing vulnerability there. The road itself is not projected to be impacted by high tide flooding through the 2080s. A category 2 storm will impact parts of Seaview Avenue.

Webster Point

Homes are at higher elevations here and are not susceptible to future high tides. A category 2 storm will impact some properties adjacent to Tom's Creek at Hammonasset State Park.

Inundation Risks by Neighborhood

The following table summarizes the risks of different Madison neighborhoods to inundation over time:

	Daily High Tide					
Neighborhood	**Risk to Structures**			**Risk to Roads**		
DHT Decade→	**2020s**	**2050s**	**2080s**	**2020s**	**2050s**	**2080s**
Green Hill Road:	None	None	None	Med	High	High
Green Hill Place:	Med	High	High	Med	High	High
Garnet Park:	Low	Med	Med	Med	High	High
Circle Beach	Low	High	High	Med	Med	Med
Ridgewood/Soundview:	None	None	Low	None	None	Low
Buffalo Bay:	None	None	None	None	None	None
Smith Bay:	Low	Med	Med	Low	Med	High
Surf Club Beach:	Low	Low	Med	Low	High	High
West Wharf	Low	Med	Med	Low	Med	High
Middle Beach Road:	None	Low	Low	Med	High	High
Middle Beach:	None	None	Low	None	None	None
Fence Creek:	Low	Low	Med	Low	Low	High
Seaview Beach:	None	None	None	None	None	None
Webster Point:	Low	Low	Low	None	None	None

In this table, hazard levels are defined as follows:

- **None –** no coastal structures or roads are affected by flooding
- **Low –** fewer than approximately 25% of the roads or structures in the coastal area are affected by flooding
- **Med –** between approximately 25% and 50% of the roads or structures in the coastal area are affected by flooding
- **High –** between approximately 50% and 75% of the roads or structures in the coastal area are affected by flooding
- **Critical –** greater than approximately 75% of the roads or structures in the coastal area are affected by flooding

More information about neighborhood vulnerabilities, including wave runup modeling results, is discussed in Appendix B.

3 Coastal Adaptation Strategies

3.1 Approaches to Adaptation

The Intergovernmental Panel On Climate Change (IPCC) published the landmark paper "Strategies for Adaptation to Sea Level Rise" in 1990. Three basic types of adaptation were presented in the report:

- **Retreat** involves no effort to protect the land from the sea. The coastal zone is abandoned.
- **Accommodation** means that people continue to use the land at risk but do not attempt to prevent the land from being flooded.
- **Protection** involves protecting the land from the sea so that existing land uses can continue.

In 2010, NOAA's Office of Ocean and Coastal Resource Management published the manual "Adapting to Climate Change: A Planning Guide for State Coastal Managers." According to the manual, NOAA's seven categories of "Climate Change Adaptation Measures" are:

- Impact Identification and Assessment
- Awareness and Assistance
- Growth and Development Management
- Loss Reduction
- Shoreline Management
- Coastal Ecosystem Management
- Water Resource Management and Protection

Elements of *protection, retreat*, and *accommodation* are found in several of these categories and subcategories of adaptation. NOAA notes that these adaptation measures are organized into categories that describe their primary purpose but, in many cases, they serve multiple purposes and could fit into multiple categories.

A thorough evaluation of adaptation approaches and options is described in Appendix C. This chapter provides an overview.

3.2 Adaptation Options

Coastal adaptation strategies include both planning (nonstructural) and structural-related modifications. Nonstructural measures include preparedness, emergency response, retreat, and regulatory and financial measures to reduce risk. Structural measures include dikes, seawalls, groins, jetties, temporary flood barriers, and the like. Ideally, the measures that are taken should be robust enough to provide adequate protection and flexible enough

WHAT IS A LIVING SHORELINE?

Many definitions of "living shoreline" are available in the literature. Restore America's Estuaries (2015) provides a broad definition that "living shoreline are any shoreline management systems that is designed to protect or restore natural shoreline ecosystems through the use of natural elements and, if appropriate, man-made elements. Any elements used must not interrupt the natural water/land continuum to the detriment of natural shoreline ecosystems."

SAGE (2015) notes that living shorelines achieve multiple goals such as:

- Stabilizing the shoreline and reducing current rates of shoreline erosion and storm damage
- Providing ecosystem services and increasing flood storage capacity
- Maintaining connections between land and water ecosystems to enhance resilience.

to allow them to be adapted to changing future conditions. Such robustness and flexibility typically require combinations of methods rather than one solution.

Structural measures can be site-specific, "neighborhood-scale," or large-scale structures that protect multiple square miles of infrastructure. Site-specific measures pertain to floodproofing a specific structure on a case-by-case basis. Neighborhood-scale measures apply to a specific group of buildings that are adjacent to each other. Large-scale structures might include large dike and levee systems or tide gates that can prevent tidal surge from moving upstream.

Table 3 provides a summary of adaptation and resilience methods considered for Madison.

Measure	Summary	Benefits	Barriers to Implementation
Structural Measures			
Hard Shore-Protection	Structure parallel to shore (seawall, levee, bulkhead, revetment)	• Long-lasting • Effective	• False sense of security • Expensive maintenance • Ecosystem damage
Sediment Management Structures	Structures reduce wave energy & manage sediment	• Long Lasting • Support natural processes	• Does not address stillwater inundation • Secondary Impacts
Soft Shore-Protection	Replenish sediment and dunes	• Support natural processes • Support ecosystems • Aesthetic	• Regular maintenance • May not be long-lasting
Green Infrastructure	Natural elements reduce wave energy and trap sediment	• Support natural processes • Support ecosystems • Aesthetic • May use structural support	• Limited areas of applicability
Living Shorelines	Creation/restoration of tidal marsh	• Reduce wave energy • Critical habitat	• Limited areas of applicability • Does not address stillwater inundation
Stormwater Management	Remove water from low areas while preventing backflow	• Support other protection methods	• May be expensive • Requires maintenance • Does not address direct hazards
Transportation Infrastructure	Elevate roads or create alternative egresses	• Protect emergency access and evacuation	• Elevation may increase hazards for neighboring properties
Elevation	Raise structure above flood level	• Reduce insurance premium • Open to residences • Permitted in V zones	• Harder to access • "Dead space" under structure • Difficult for some buildings
Wet Floodproofing	Abandon Lowest Floor, Remove all contents	• Relatively inexpensive	• Extensive post-flood cleanup
Dry Floodproofing	Waterproof structure, install barriers at openings	• Relatively inexpensive • Does not require additional land	• Manual barrier installation • Subject to storm predictions • Vulnerable to flow & waves
Floodwalls & Levees	Concrete or earthen barriers protection	• Prevent water contact • Avoid structural retrofits	• May require large area • Obstructs views
Temporary Flood Barriers	Plastic or metal barrier	• Prevent water contact • Relatively inexpensive	• Manual installation • Subject to storm predictions • Short-term only

Measure	Summary	Benefits	Barriers to Implementation
Relocation	Move structure to safer location	• All vulnerability removed • Open to residences	• Decreased value of new site • Loss of neighborhood cohesion • Expensive
Regulatory Tools			
Building Code	Increase standards for structures	• Protect new & improved construction	• Older structures often exempt
Zoning Regulations	Prevent hazardous development patterns	• Control degree of risk in hazardous areas	• Balance with economic pressures
Easements	Control activities on private land	• Work with landowners for mutual benefit	• Private landowner may not be willing partners

3.3 Options Relevant to Madison

The comprehensive list of options presented above and evaluated in Appendix C includes adaptation measures that may be:

- Technically, financially, or otherwise not feasible for Madison to implement;
- Not relevant to Madison's particular geography, geology, and hazard profile; and/or
- Socially unacceptable to Madison's citizens.

To develop a suite of viable options for the Town's consideration, coastal resilience projects undertaken by other communities were reviewed, local physical and political factors were considered, and options were discussed with Madison's municipal officials and residents. Details of this process are discussed in Appendices C and G. The suite of options most applicable to the Town of Madison is summarized in the following table:

Categories of Options	Specific Options
Hard Shoreline Protection	Seawalls
	Bulkheads
	Revetments
	Dikes
	Groins
	Offshore breakwaters
Soft Shoreline Protection	Beach Restoration or Nourishment
	Dune Creation or Restoration
Hybrid Shoreline Protection	Bioengineered bank stabilization
	Artificial Reefs (reef balls)
Infrastructure Improvements, Retrofits, and Hardening	Storm Drain Maintenance and Improvement including pumping stations
	Road Elevation
	Establishment of Community Wastewater Systems
	Strengthen Power & Water Utilities
	Tide Gate Maintenance
Home Protection	Elevation
Regulatory Tools	Flood Damage Prevention Modifications: • Freeboard • V zone standards in Coastal A zones
	Other Zoning Modifications: • Height Limit Flexibility • Reconstruction Flexibility
Coastal Realignment	Road Retirement (with or without alternate route development)
	Property Acquisitions

Madison's resilience efforts will be varied because of the diverse types of risks it faces. Some areas require structural protections from inundation, others need hard defenses against erosion, and at other sites beach and dune nourishment are appropriate. Much of the work that will be needed in the future will relate to the private septic systems located around the Town. Protecting and maintaining at-risk roads will also be an important action. Assisting homeowners to elevate their residences, or purchasing properties from those who no longer wish to invest in protecting their residences, should also be a continuing focus of the Town. Madison is encouraged to explore the use of hybrid and green techniques, including bioengineered banks and dune restorations, where suitable. Finally, Madison should enact a suite of regulatory changes to support resiliency efforts, including making height restrictions flexible in the case of home elevations, and altering zoning regulations to encourage development away from hazard areas.

3.3.1 Application of Adaptation Options in Madison

The following section summarizes some of the specific challenges in Madison where different adaptation options may be relevant. Many of the sites are listed under multiple options, indicating that there are multiple approaches to resiliency at that location, or that the best option would be to implement multiple adaptation measures in unison.

Hard Shoreline Protection

Much of Madison's shoreline is densely developed, and options in many neighborhoods will be limited to ensure basic protection of important assets. Some of this protection may be accomplished through shoreline management and protective structures.

Sections of the Town with assets such as structures, roads, and other infrastructure located very close to the water, may require hard shoreline protection. Such areas may include those that are not geographically conducive to softer shoreline protection, those without the space to implement other protection methods, those with high banks susceptible to erosion, or those with naturally hard or rocky shorelines where structures may be vulnerable to wave action.

WHAT DO OTHER STUDIES SAY ABOUT MADISON?

North Atlantic Coast Comprehensive Study (January 2015)

The North Atlantic Coast Comprehensive Study (NACCS) was authorized by the Disaster Relief Act of 2013 on January 29, 2013. The study area included the Atlantic Ocean coastline, back-bay shorelines, and estuaries within portions of the USACE North Atlantic Division.

Region-specific analyses provide information on risks and vulnerabilities specific to particular areas. This process begins with assessment of current and projected flooding conditions and delineation of vulnerable areas. Population density and infrastructure, social vulnerability, and environmental and cultural resources, are characterized within those flood-vulnerable zones to develop a weighted "exposure index." Risk is then calculated within the study regions as a function of exposure index and probability of flooding.

The entire Madison coastline is classified by this study as being a "high exposure" area, with the exception of the northern coast of the Hammonasset Natural Area. The main assets of concern for this area, as listed in the document, are Routes 1 and 154, the Hammonasset Connector, significant pockets of residential development, and supporting local roads and utilities.

These areas may include Ridgewood/Soundview, Smith Bay, and Middle Beach Road. Additionally, implementing hard protection structures at Garnet Park may be advisable to prevent flooding without infringing on the surrounding protected wetlands.

Jetties, breakwaters, groins, and other hard structures that are used to reduce the energy of waves and currents, may be useful for areas with eroding beaches or bluffs. Madison's open and sandy coastline creates a situation where most of the shoreline is erodible. This translates into many suitable sites for these types of shoreline protection. Areas where they may be appropriate include Smith Bay, Surf Club Beach, West Wharf Beach, and the East Wharf Beach area.

Soft Shoreline Protection

Some sections of Madison are able to be served using soft shoreline protection, which is often more aesthetically acceptable and more supportive of natural systems and processes.

Areas where soft protection measures can be implemented include Circle Beach, Buffalo Bay, Smith Bay, Surf Club Beach, West Wharf, the bay to the east of West Wharf, Middle Beach, Seaview Beach, and Webster Point.

One site in Madison particularly suitable for a dune restoration project is Surf Club Beach. A dune already exists here, but has been repetitively washed out and degraded by recent large storm events. Restoring the dune to its full extent would help prevent high waters from overtopping the shoreline and causing flooding along Surf Club Road, Holly Park Road, Parker Avenue, and Flower Avenue.
There is currently a dune stabilization project, involving planting dune vegetation, being implemented between Toffee Lane and Kelsey Place in Smith Bay.

> **WHAT DO OTHER STUDIES SAY ABOUT MADISON?**
>
> **Connecticut Coastal Design Project (2014-2015)**
>
> *The Connecticut Coastal Design Project was an effort coordinated by The Nature Conservancy's Coastal Resilience Program to create a dialogue between coastal engineers, regulatory agents, coastal geomorphologists, landscape design professionals, and natural resource managers around the implementation of environment and ecosystem supportive shoreline protection projects.*
>
> The coast of Madison falls within the "Shoreline District E" designated by this project. This district is defined as dominantly "glacial drift and beaches." This zone is identified as having the highest potential for installation of natural infrastructure projects.

Possibilities for both Surf Club Beach and Smith Bay are discussed in more detail in section 4.

Living Shorelines

- Bioengineered Banks

Areas that may be suitable to bioengineered banks include Soundview/Ridgewood, Garvan Point where there is currently a bulkhead in need of maintenance, the homes east of West Wharf, Middle Beach, and the homes at the mouth of Fence Creek.

- Created and Restored Tidal Wetlands

> **WHAT IS A LIVING SHORELINE?**
>
> A definition of "living shoreline" was provided on Page 14. In general, the living shorelines of interest to communities in Connecticut include tidal marsh restoration or protection projects, bioengineered bank protection, beach nourishment, and vegetated dune restoration or creation. The latter three are believed appropriate as risk reduction methods in Madison.

Madison's developed shoreline, fronted by beaches and hard structures, and exposed to the Sound, does not create many areas that would support the created or restored tidal wetland form of living shorelines. Madison does contain significant tidal marshlands, such as those around the East River, inland of Garvan Point and the Surf Club, adjacent to Fence Creek, and within Hammonasset State Park, but these are protected from wave energy. Thus, Madison is not characterized by eroding marsh fronts, and so living shoreline projects focused on tidal marsh restoration will not be relevant to this geography.

- Artificial Reefs

Likewise, recent living shoreline projects like the Stratford reef ball project do not have a parallel feasible setting in Madison, aside from along the East River and at Webster Point. The Madison shore between Circle Beach and Webster Point is unlikely to contain any sites suitable to such a project where the reef balls would survive a powerful coastal storm.

Infrastructure Retrofits and Upgrades

- Drainage

Some areas of Madison have adequate protection from inundation and wave action, but still experience damage due to failing, inadequate, or malfunctioning drainage infrastructure. Areas that would benefit from upgrades to these systems include Green Hill Road and Smith Bay.

The southern ends of roads in Smith Bay already suffer from routine storm-drain "surcharging," when high water levels in the sound push water backwards through the drainage infrastructure to discharge into otherwise protected low areas.

- Roadways and Transportation

The layout of Madison is such that even if some major roads are impassable, other routes should remain open for most residents. Nevertheless, there are some neighborhoods that might be isolated under high sea level conditions, alternate routes would need to be determined for those that are technically accessible but have had major throughways cut off, and under current conditions there are already roads that experience chronic flooding.

WHAT DO OTHER STUDIES SAY ABOUT MADISON?

The Nature Conservancy Community Resilience Workshops

The Town of Madison and The Nature Conservancy (TNC) formed a partnership to increase awareness of risks, strengths, and vulnerabilities within Madison associated with natural and climate-related hazards. This partnership carried out a series of presentations, interviews, outreach, and "Hazard and Community Resilience" workshops in order to facilitate education, planning, and implementation of priority adaptations actions. At these workshops, Town and TNC representatives worked with attendees to define hazards, identify present and future vulnerabilities and strengths, and develop and prioritize actions.

The top hazards listed in the report include coastal flooding and storm surge, inland flooding, and wind. Specific concerns noted include vulnerability of the road network, the railroad's susceptibility to coastal flooding, power distribution, isolation during coastal flood events, and the vulnerability of septic systems.

Highlighted vulnerable areas include Neck Road, Garnet Park, Circle Beach, Middle Beach, Fence Creek, East and Neck River Marsh, East and West Wharf, Salt Meadow Park, Neck River, Hammonasset State Park, Surf Club Beach, State Route 1.

Some of the most significant roads at risk in Madison include State Route 1, Green Hill Place, Garnet Park Road, Circle Beach Road, Surf Club Road, Middle Beach Road West, Island Avenue, Middle Beach Road, Scotland Avenue, and Seaview Avenue. Some of these roads are vulnerable to inundation while others, like Middle Beach Road, are vulnerable to erosion. Areas of Town vulnerable to isolation include Circle Beach, Garnet Park, areas east of the Hammonasset Connector on Route 1, and possibly Seaview Beach and neighborhoods off of Neck Road during extreme events. Access to areas east of Fence Creek could be cut off from the Fire Station and Urgent Care center if Route 1 is flooded. Additionally, east-west transit or evacuation may be hindered by flooding of State Route 1 by the East River, Bailey Creek, Neck River, or Toms Creek.

Transportation adaptation options for these neighborhoods may include:

- Roadway elevation
- Roadway strengthening and reinforcement
- Roadway abandonment
- Mapping of alternative routes
- Construction of alternative routes

- Water

Public water supply distribution may be vulnerable to erosion in areas where pipes are built close to the shoreline. Drinking water infrastructure location data was not made available for this effort, so specific vulnerable locations are not known. However, potential areas of concern include the east end of Circle Beach Road, Middle Beach Road, and the bridge over Fence Creek. Specific adaption options applicable to these locations include bank protection and relocation of water mains.

- Wastewater

Properties throughout Madison's coastline will need to consider retrofitting or relocating their septic systems. This is a particular concern in low-lying areas such as Green Hill Place, Garnet Park, Circle Beach, the southern end of the Smith Bay finger roads, homes adjacent to the Fence Creek wetland, and some homes along Toms Creek at Hammonasset State Park. It is especially important that areas that use well water protect their septic systems to prevent contamination of their drinking water sources.

- Electricity

Wind hazards are similar throughout the Town of Madison, although the lack of protection provided by topography, plants, or other structures, along the shoreline can increase risks to waterfront locations. Wooded areas will be more vulnerable to falling trees and limbs taking out power lines, and low-lying areas will be more vulnerable to the effects of flooding and a rising groundwater table on the viability of both above- and below-ground utilities.

One methods of strengthening the electrical grid, or building resilience against power loss, is to develop a "microgrid" to allow for a small area to be powered during a regional outage. Madison neighborhoods that may be good candidates for such a project include the commercial properties at Green Hill Place, the western end of Garnet Park, and the Mercy by the Sea complex.

Private Property Protection

All properties within flood zones are required to have flood protection measures implemented, but additional actions should be taken to prepare for rising seas. Furthermore, there are some areas of Madison where neighborhood-scale protective measures, such as construction of floodwalls or nourishment of beaches, are not feasible or would not provide adequate protection to individual structures. In such areas, individual property owners should implement additional flood protection measures.

These areas include Garnet Park, Circle Beach, and the peninsula at the mouth of Fence Creek.

Elevation of residential properties should be pursued in all flood-prone neighborhoods.

Natural Resource Protection

Areas that can be targeted to protective measures include the wetlands alongside the East River, including those near Green Hill Road and Green Hill Place, Baily Creek, Neck River, the Circle Beach area, the wetlands around the Madison Surf Club, Fence Creek, and municipal land around Webster Point.

Other Options

Other adaptation options – such as regulatory tools and incentives – apply throughout Madison. Relevant regulatory tools will vary based on the needs of specific locations. Some examples of specific planning, zoning, and regulatory options include:

- Adoption of freeboard requirements that exceed the State-required one foot
- Enforcement of V-zone requirements in coastal A-zones (up to the limit of moderate wave action)
- Relaxation of the 35-foot height restriction to facilitate elevation projects for 2 and 3-story homes
- Elimination of restrictions that prevent people from reconstructing more resilient homes (for example, the width restriction that comes into play when people tear down and reconstruct nonconforming houses)
- Implementation of the Community Rating System Maintenance Plan and the Program for Public Information
- Partnering with property owners to apply for FEMA mitigation grants
- Promotion the Shore Up and similar loan programs to assist homeowners with property protection

3.3.2 Madison Options Summary

The following table summarizes where different adaptation options are most applicable throughout the Madison shoreline.

Possible Options		Shoreline Protection					Structures & Infrastructure							Realignment		
		Hard Protection	Beach Nourishment	Dune Restoration	Non-Structure Living	Bioengineered Banks	Drainage Improvement	Strengthen Power Utilities	Strengthen Water Distribution	Community Wastewater	Road Elevation	Structure Elevation	Floodproof Structures	Road Retirement	Alternate Route Development	Property Acquisition
Appropriate Neighborhoods	Green Hill Road						X				X			X	X	X
	Green Hill Place						X				X	X	X	X	X	
	Garnet Park	X							X	X	X	X				
	Circle Beach		X	X	X			X	X	X		X				X
	Ridgewood/Soundview	X	X		X	X		X								
	Buffalo Bay		X	X	X			X								
	Smith Bay		X	X			X	X		X						
	Surf Club Beach			X			X						X			
	West Wharf	X	X	X	X			X			X	X	X			
	Middle Beach Road	X				X		X						X	X	
	Middle Beach		X	X				X								
	Fence Creek						X			X	X					X
	Seaview Beach							X								
	Webster Point							X								

4 Conceptual Plans

In addition to an assessment of current and future hazard and risk conditions, and development of a general list of adaptation approaches and options, part of the scope of this planning project was to develop a set of more specific concept designs for protection of two neighborhoods and two infrastructure assets in Madison.

The two specific neighborhoods and two specific infrastructure assets that should be targeted for more focused planning efforts were chosen based on the participation of members of the public, impacts from Storm Sandy, the location of low to moderate-income (LMI) populations, locations of critical community facilities, and the results of the vulnerability and risk assessment. This decision process is described in Appendix D. The following table cross-references the issues of interest listed in the paragraph above:

Neighborhood	RL Properties	LMI Census Tract	Irene & Sandy Damage	DHT Risk 2020s-2050s	Critical Facilities	At-Risk Roads	Public Input
Green Hill Road							X
Green Hill Place			X	X		X	X
Garnet Park	X		X	X		X	
Circle Beach	X		X	X		X	
Ridgewood/Soundview							
Buffalo Bay							
Smith Bay	X		X	X			X
Surf Club Beach	X	X*	X	X		X	X
West Wharf	X	X*	X	X		X	X
Middle Beach Road	X	X*	X	X		X	X
Middle Beach		X*	X				X
Fence Creek	X	X*	X	X		X	
Seaview Beach						X	
Webster Point			X				

* These areas are not Low or Moderate Income, but do fall within a tract that has a lower median income level than the rest of the Madison Coastline.

Surf Club Beach, West Wharf, and Middle Beach Road are the areas with the most columns checked (six). Fence Creek is the neighborhood with the second-most columns checked (five), followed by Green Hill Place, Garnet Park, Circle Beach, and Smith Bay (four columns checked).

Because Middle Beach Road has the highest number of checked columns and is an important route for travel both during normal and emergency conditions, it will be selected for more focused infrastructure design.

Green Hill Place is somewhat unique in this list because it is inland, and a commercial area. It is listed as an important commercial center in the Madison Plan of Conservation and Development, yet is often overlooked in the context of coastal hazard mitigation and restoration efforts. This area has been specifically highlighted by Town officials as being an area of interest. For these reasons, Green Hill Place will be selected for more focused planning efforts. Additionally, because of its proximity and the similar nature of the hazards faced (inundation of roads by wetlands), the Green Hill Road neighborhood will be included in that plan.

The hazards faced by Surf Club Beach and West Wharf – two neighboring and even overlapping neighborhoods – are very similar. Overtopping of the shoreline leads to flooding of structures and roads. Much of the threat at the Surf Club Beach area is from overtopping of the Town-owned beach, a situation that will make mitigation efforts easier to accomplish. Additionally, projected daily inundation will affect more residences in this area than in neighboring West Wharf. Therefore, the Surf Club Beach neighborhood will be chosen for more detailed designs. Because the flood threat is from a point source – overtopping of the beach at a specific location – an infrastructure design approach is more appropriate here than a neighborhood-wide effort.

For an additional neighborhood to be included for more focused planning, the Smith Bay (or "South of Neck Road" finger roads) area was selected. This neighborhood experience regular flooding from many locations, making a neighborhood-scale plan appropriate. It is relatively densely settled and, though not classified as LMI, home values here tend to be lower than some of the other at-risk neighborhoods. Options at this location are diverse, and will provide a useful example of multiple adaptation approaches to guide future planning in Madison.

In summary, the four selections for focused planning are:

<u>Neighborhoods</u>

- Green Hill Place / Green Hill Road
- Smith Bay

<u>Infrastructure</u>

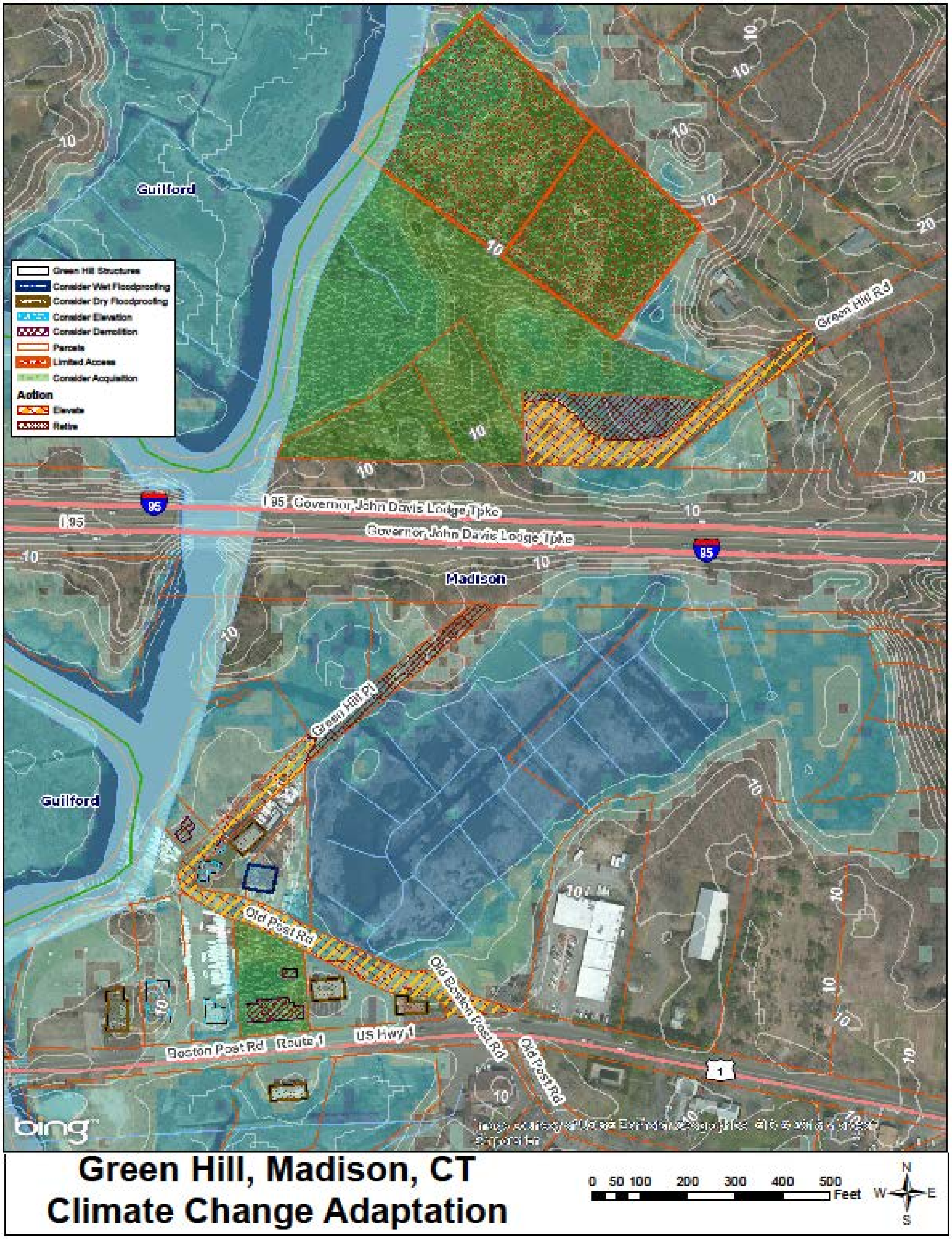
- Middle Beach Road
- Surf Club Beach

The results of these plans are discussed below.

4.1 Neighborhood Conceptual Plans

This plan presents **two examples** for building resilience at the neighborhood scale. These examples are Green Hill and Smith Bay. The examples show resilience methods that may or *may not be* desired or cost-effective. The examples demonstrate that there may be tradeoffs and choices to make when reducing shared risks to build resilience, but taking a phased approach may help the Town address the most urgent and well-understood vulnerabilities and risks in the short term while addressing remaining vulnerabilities and risks later.

Green Hill



MILONE & MACBROOM

The “Green Hill” neighborhood actually describes two different neighborhoods separated by State Route 95. Green Hill Road is located north of 95 and leads from Wildwood Avenue westward, where it dead-ends after a small wetland. There are four or five residential properties that have this road as their only access route, and are cut-off during flood events when the wetland inundates the road. The wetland is connected to another wetland to the south of 95 by a culvert under the highway. This neighborhood is bordered to the west by the East River, and properties are vulnerable to flooding from large storm events. Most of the neighborhood is with a FEMA AE zone, with a couple of areas designated as the 0.2% annual-chance flood zone.

Green Hill Place refers to the commercial area to the south of 95 alongside the East River, and includes Old Post Road and State Route 1. There are approximately 11 properties in this zone that are vulnerable to flooding, many of them already experiencing water issues on a regular basis. Flooding can come from the East River or from the wetland located to the northeast of the neighborhood. This wetland connects to the wetland north of 95 that impacts the Green Hill Road area.

This plan presents three adaptation actions that can be taken in the Green Hill Road neighborhood, and a suite of structure-specific measures that can be implemented in the Green Hill Place area to the south. These are summarized below:

Alternative Description	Modeled Outcome	Approximate Cost ($)
Green Hill Road		
Elevate Road to allow access during storms	Allows access during flood events, but does not address individual home protection or access between elevated road and homes	852,500
Elevate Road to allow access during high tide	Allows access through the 2080s. Does not address storm conditions	613,700
Retire the road and pursue **acquisition** of properties vulnerable to isolation	Would remove all vulnerabilities, but requires interest of homeowners and funding	1,630,000
Retrofit **drainage** system to prevent high-tide flooding from south of 95	Could prevent high tide flooding through the 2080s, but does not address storm surge. May create issues with wetland regulations.	500,000
Green Hill Place		
Elevate Structure	Applicable to five structures that have already been elevated but may require more elevation in the future. Required for a sixth, residential property.	500,000
Dry Floodproof Structure	Applicable to five buildings that appear to be structurally appropriate for such measures.	152,000
Wet Floodproof Structure	Applicable to one structure incapable of supporting dry floodproofing measures.	15,000
Acquire Parcel	Recommended approach for one parcelswith a structure in poor shape located in a high-risk zone.	50,000
Do Nothing	A couple of structures are already protected from current flood conditions and may not need additional retrofits for many years. Retrofits may not be cost-effective for other structures, which may be maintained as-is until no longer worthwhile.	0
Elevate Road	Certain sections of road must be elevated to maintain access in the face of rising sea levels.	450,000

Details on the designs, costs, and effectiveness of these alternatives are provided in Appendix E.

Smith Bay

East of Mercy by the Sea is a series of private roads extending south from Neck Road to Smith Bay. These roads, between Twin Coves Road and Shorelands Drive, are relatively densely settled residential areas that are relatively high in elevation and protected from inundation. However, the southern ends of all of these roads drop down, are typically lower in elevation than the beaches they lead to, and are protected from water and sand by bulkheads. Drainage problems are already apparent in these areas. The southernmost properties here fall within a VE zone with a BFE of 14 feet NAVD88, while AE zones with BFEs of 13 or 14 feet extend inland.

The end of Toffee Lane and Overshore Drive are particularly vulnerable, and may experience daily flooding by the 2020s. By the 2050s, daily high tide may also impact Pleasant View Avenue, Beach Avenue, Harbor Avenue, and Kelsey Place. A Category 2 storm under current conditions can be expected to inundate the southern edges of all of the roads in this neighborhood, and to impact over 70 homes.

This memo presents adaptation actions that can be taken in the Smith Bay neighborhood. The main vulnerabilities these actions attempt to address are those posed by direct inundation of structures, inundation of roads, and drainage issues associated with very low elevation roads that are below the surrounding land surfaces. These actions are summarized below:

Description	Modeled Outcome	Approximate Cost ($)
High Tide Protection This alternative includes: • Dune Restoration • Seawalls	Building up existing dunes and constructing or improving seawalls should protect the neighborhood from high tide flooding through 2080s for a reasonable cost and with minimal effect on the neighborhood's character. Drainage improvements will be necessary.	Dune: 18,600 Wall: 475,000 Easement: 46,000 **Municipal Total: 539,600**
Floodable Neighborhood This alternative includes: • Home Elevations • Road Elevations	Approximately 160 structures will have to be elevated to protect them against future high tides and storm surges, at great cost to owners. Elevating roads may maintain access during floods and serve to create barriers to high tide flooding. Elevations will be required over time regardless, unless the storm surge protection option is implemented.	Homes: 158,000,000 Roads: 591,400 **Municipal Total: 591,400**
Storm Surge Protection This alternative includes: • Levee Construction	This alternative is the most expensive for the Town, will require acquisition and demolition of around 27 properties, will remove views of and access to the shoreline, and significantly alter the neighborhood's character. It is the only option presented to remove the neighborhood from the FEMA flood zone.	Levee: 3,000,000 Acquisition: 16,700,000 **Municipal Total: 19,700,000**
Drainage System Retrofits	All of the above alternatives will require installation of duckbill outlets on storm drains, tide gates on streams or elsewhere when appropriate, and possibly installation of stormwater pumping stations.	**500,000**

Details on the designs, costs, and effectiveness of these alternatives are provided in Appendix E.

4.2 Infrastructure Conceptual Plans

This plan also presents two examples of choices for building resilience through infrastructure projects. The conceptual designs prepared for Middle Beach Road and Surf Club Beach can be used to make additional planning decisions for these two areas, and may provide a basis for further design.

Middle Beach Road

The area of Middle Beach Road, between Tuxis Road and Park Avenue, has reoccurring flooding issues in the existing conditions. As a result, the existing seawall and revetment require regular rebuild and repairs. The flooding impacts the road and the utilities as well. The area surrounding Middle Beach Road is a densely populated area with vital infrastructure components. Many homes are potentially impacted by the 1-percentannual -chance event (see Fig.1 below). In addition, a substantial amount of infrastructure is impacted along this section of shoreline.

FEMA Flood Zones at Middle Beach Road

This area is in need of a greater level of protection during storm events and extreme high tide levels.

According to the most recent FEMA study in this area (Study Transect NH-53) the 1-percent-annual chance flood level (with wave setup) + Runup would be near 22.43 feet NAVD88. The only way to prevent flooding completely would be to build a higher wall in combination with beach or marsh seaward of the revetment in order to absorb the wave energy to prevent erosion and damage to the wall. This alternative would also require the construction of offshore wave attenuation structures in order to break the larger waves offshore.

The estimated approximate cost for implementing the protection features for this site is on the order of $500,000

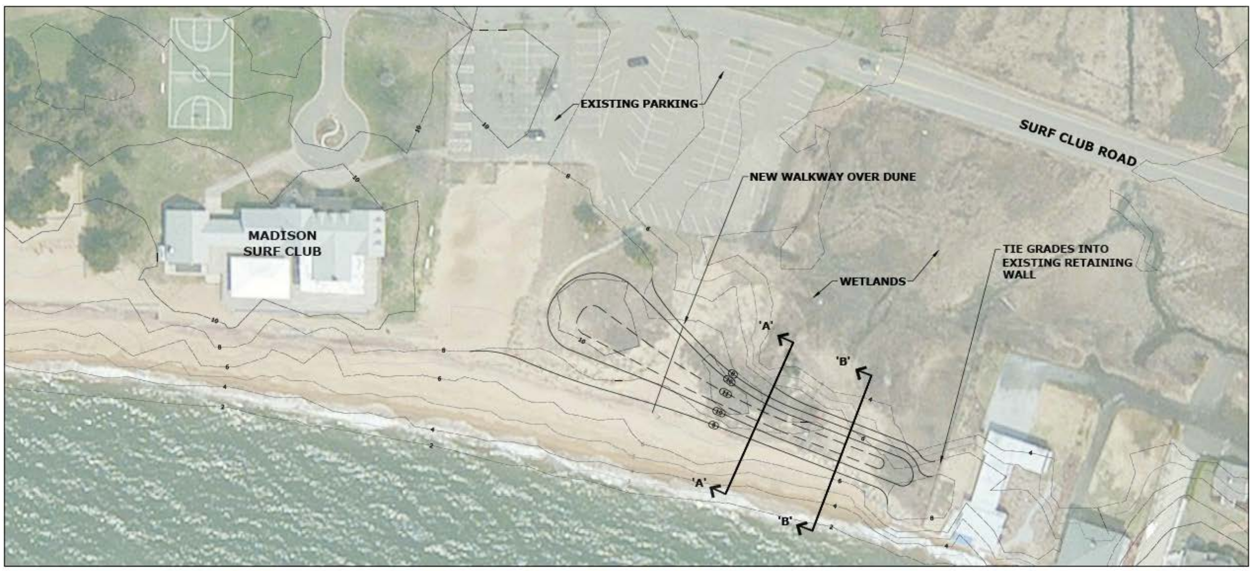
It may be cost beneficial to also consider mitigating to flooding to a lesser return period storm (i.e. 10-percent-annual chance flood event). Another alternative could be to retire the section of road just inland of the top of the revetment and design an alternative route for access for the current residents.

Details on this alternative are provided in Appendix E.

Surf Club Beach

It has been determined that much of the damage experienced in the area around the Madison Surf Club results from storm surge overtopping the beach, inundating the wetlands, and flooding properties and roads from behind. The spot where beach overtopping occurs is reflected in the inland intrusion of the FEMA VE zone as mapped on the Flood Insurance Rate Map, and has been identified as a breached dune located to the east of the Madison Surf Club and west of private properties.

We believe that a combined beach and dune nourishment and stabilization project would be appropriate for this site. This form of green infrastructure could diminish flood extents, protect properties, and support coastal habitats and ecosystems. It is possible that the dune would migrate inland over time, as sea level rises, making it a more flexible and adaptive approach to flood hazards than hard infrastructure solutions.



PROPOSED DUNE

PROPOSED DUNE PERSPECTIVE

The cost of importing sand and constructing a dune is estimated at approximately $51,000. Using material from a local source should significantly decrease this estimate, while secondary protections to prevent dune erosion or increase dune stability would increase costs, if deemed necessary. Benefits of this adaptation option include improving the aesthetic and ecological resources at the site.

Details on this alternative are provided in Appendix E.

4.3 Conceptual Plans Summary

These designs are intended to illustrate the costs, benefits, and tradeoffs presented by different adaptation options, as well as how the unique characteristics of vulnerable areas will impact which types of adaptation methods are appropriate. They may also be used as a starting point for development of more in-depth designs, or even as visual aids for discussions about the avoidance of high-cost, low-benefit alternatives. Implementation of any of these projects will require further analysis to be performed.

5 Implementation

A number of steps must be taken to implement this Coastal Resilience Plan. First, the appropriate municipal agency must be identified or created to administer this plan. The Hazard Mitigation committee is the appropriate entity for prioritizing and tracking the actions presented in this plan. This committee's involvement will ensure that objectives from the Hazard Mitigation Plan and the Coastal Resilience Plan are addressed in a coordinated manner. Specific actions in this coastal resilience plan should be implemented by specific agencies such as the Flood and Erosion Control Board and Planning and Zoning Commission, and departments such as Public Works, Land Use, and Emergency Management.

5.1 Implementation Matrix

A matrix of coastal resilience actions and implementation strategies is provided below.

Implementation Strategy
City of Madison Coastal Resilience Plan

	Action	Responsible Agency or Department	Timeframe	Funding Sources
Townwide Regulatory Changes				
TR1	Relax the 35-ft height restriction to facilitate elevation projects for 2 and 3-story homes	Planning and Zoning	2017-2018	• Not applicable
TR2	Eliminate restrictions that prevent people from reconstructing more resilient homes (for example, the width restriction that comes into play when people reconstruct nonconforming houses)	Planning and Zoning	2017-2018	• Not applicable
TR3	Adopt freeboard that exceeds the State-recommended one foot	Planning and Zoning	2017-2018	• Not applicable
TR4	Enforce V zone standards in coastal A zones (to the limit of moderate wave action)	Planning and Zoning	2017-2018	• Not applicable
TR5	Increase Townwide tree and limb maintenance to limit road blockage and power outages during storms	Public Works	2016-2017	• Operating Budget
TR6	Strengthen coordination with utility providers to prevent installation of utility infrastructure in at-risk locations	Selectman's Office	2016-2017	• Not Applicable
TR7	Provide technical assistance to owners of nonresidential property interested in pursuing floodproofing	Building Department	2017-2018	• Operating Budget
Townwide Promotion of Property Protection				
PP1	Partner with property owners to apply for FEMA mitigation grants to elevate homes	Planning and Zoning	Annual outreach in April of each year (HMA applications are due in June or July each year)	• FEMA HMA
PP2	Promote the Shore Up and similar home elevation loan programs	Planning and Zoning	A one-time promotion should be scheduled for mid-2016	• Shore Up CT (Ending in 2016)
Green Hill Projects				

	Action	Responsible Agency or Department	Timeframe	Funding Sources
GH1	Implement Green Hill Road Resilience Project: • drainage upgrade • road elevation • property acquisition	Public Works, Planning and Zoning, Selectman's Office	Drainage: 2019-2021 Elevation: 2030-2040 Acquisition: 2035-2045	• FEMA HMA • STEAP • Bonds or capital improvement
GH2	Implement Green Hill Place Resilience Projects • building floodproofing • road elevation • property acquisition	Public Works, Planning and Zoning, Selectman's Office	2018-2022	• CDBG-DR • SBA-ODA • FEMA HMA • STEAP • Shore Up • Bonds or capital improvement • CT DOT
Garnet Park Projects				
GP1	Elevate Garnet Park Road at Baily Creek crossing to prevent isolation	Public Works	2018-2020	• CIRCA (design) • STEAP • Bonds or capital improvement
GP1	Elevate Garnet Park Road west of Baily Creek	Public Works	2020-2022	• CIRCA (design) • STEAP • Bonds or capital improvement
GP3	Elevate other Garnet Park neighborhood roads as needed	Public Works	2023-2030	• CIRCA (design) • STEAP • Bonds or capital improvement
Circle Beach Projects				
CB1	Consider utilizing an alternative, flood-resilient method of road paving and/or maintenance	Public Works	2030	• Operating Budget
Smith Bay Projects				
SB1	Drainage Improvements	Public Works	2017-2018	• STEAP • Bonds or capital improvement
SB2	Seawall Construction	Public Works	2019-2021	• FEMA HMA • Bonds or capital improvement
SB3	Road Elevations	Public Works	2022-2025	• CIRCA (design) • STEAP • Bonds or capital improvement
SB4	Dune Restoration	Public Works	2022-2025	• USACE
SB5	Home Elevations	Planning and Zoning	2016-2030	• FEMA HMA • Shore Up

	Action	Responsible Agency or Department	Timeframe	Funding Sources
SB6	Consider development of a community wastewater system	Public Works	2030	• FEMA HMA • Capital Improvement Program
	Madison Surf Club Projects			
SC1	Dune Restoration	Public Works	2016-2017	• CIRCA (design) • STEAP • Bonds or capital improvement
SC2	Repair steel bulkhead at Garvin Point or replace with alternative protection	Public Works	2022-2025	• FEMA HMA • Bonds or capital improvement
SC3	Elevate Surf Club Road	Public Works	2026-2030	• CIRCA (design) • STEAP • Bonds or capital improvement
	West Wharf / Crescent Beach Projects			
WW1	Elevate Middle Beach Road West	Public Works	2020-2025	• CIRCA (design) • STEAP • Bonds or capital improvement
WW2	Update drainage systems	Public Works	2025-2030	• STEAP • Bonds or capital improvement
	Middle Beach Road Projects			
MBR1	Repair revetment	Public Works	Ongoing	• CIRCA (design) • STEAP • FEMA HMA
MBR2	Consider installation of offshore wave attenuation and energy-dampening infrastructure, such as breakwaters and artificial wetlands	Public Works	2030	• CIRCA (design) • USACE • CDBG-DR
MBR3	Consider development of a community wastewater system	Public Works	2050	• FEMA HMA • Capital Improvement Program
MBR4	Elevate Island Avenue to allow access during or after storm events	Public Works	2030-2040	• CIRCA (design) • STEAP • Bonds or capital improvement
	Fence Creek			
FC1	Consider development of a community wastewater system	Public Works	2025	• FEMA HMA • Capital Improvement Program

	Action	Responsible Agency or Department	Timeframe	Funding Sources
FC2	Support efforts to control and remove invasive plant species (especially *phragmites*) that interfere with sediment transport and drainage	Public Works	Ongoing	• Not Applicable
FC3	Elevate Middle Beach Road near Fence Creek to maintain access during future high tides	Public Works	2040-2050	• CIRCA (design) • STEAP • Bonds or capital improvement

Townwide Road Elevations (Some Listed Above)

• State Route 1 @ Bailey Creek	• Harbor Avenue
• State Route 1 @ East River	• Toffee Lane
• State Route 1 @ Clinton Line	• Overshore Drive
• Green Hill Road	• Surf Club Road
• Green Hill Place	• Flower Avenue
• Old Post Road	• Parker Avenue
• Jonathan's Landing	• Middle Beach Road West
• Garnet Park Road	• Island Avenue
• Meadow Lane	• Tuxis Road
• Riverside Lane	• Middle Beach Road
• Stone Road	• Seaview Avenue
• Pleasant View Avenue	• Scotland Avenue
• Beach Avenue	• Webster Point Road

Implementation Strategy Table Legend:

TR – Townwide Regulatory
PP – Town Promotion of Property Protection
GH – Green Hill Neighborhood Projects
GP – Garnet Park Projects
CB – Circle Beach Projects
SB – Smith Bay Projects
WW – West Wharf / Crescent Beach Projects
SC – Madison Surf Club Projects
MBR – Middle Beach Road Projects
FC – Fence Creek Projects

5.2 Funding Sources

As the appropriations related to Hurricane Sandy are exhausted in 2016 and 2017, the Town will need to look toward the existing traditional State and Federal funding sources as well as new and emerging funding sources to adapt to coastal hazards and become more resilient. Examples are described below.

New and Emerging Sources of Funding

Connecticut Institute of Resilience and Climate Adaptation (CIRCA) Municipal Resilience Grant Program

During each application cycle, up to $100,000 is available from CIRCA. Project proposals should develop knowledge or experience that is transferable to multiple locations in Connecticut and have well-defined and measurable goals. Additionally, preference is given to those projects that leverage multiple funding sources and that involve collaboration with CIRCA to address at least one of the following priority areas:

- Develop and deploy natural science, engineering, legal, financial, and policy best practices for climate resilience;
- Undertake or oversee pilot projects designed to improve resilience and sustainability of the natural and built environment along Connecticut's coast and inland waterways;
- Foster resilient actions and sustainable communities –particularly along the Connecticut coastline and inland waterways –that can adapt to the impacts and hazards of climate change; and
- Reduce the loss of life and property, natural system and ecological damage, and social disruption from high-impact events.

Northeast Regional Ocean Council (NROC)

NROC is a state/federal partnership that facilitates the New England states, federal agencies, regional organizations, and other interested regional groups in their efforts to address ocean and coastal issues from a regional perspective. NROC builds capacity of New England communities through training and a small grants program to improve the region's resilience and response to impacts of coastal hazards and climate change.

National Oceanic and Atmospheric Administration (NOAA) Regional Coastal Resilience Grants

NOAA is committed to helping coastal communities address increasing risks from extreme weather events, climate hazards, and changing ocean conditions. To that end, NOAA's National Ocean Service providing funding through competitive grant awards through the Regional Coastal Resilience Grants program. Awards are made for project proposals that advance resilience strategies, often through land and ocean use planning, disaster preparedness projects, environmental restoration, hazard mitigation planning, or other regional, state, or community planning efforts. Successful proposals demonstrate regional coordination among project stakeholders, leverage resources (such as funds, programs, partnerships, and others), and create economic and environmental benefits for coastal communities. Project results are evaluated using clear measures of success, with the end goal being improved preparation, response, and recovery.

Eligible applicants include nonprofit organizations, institutions of higher education, regional organizations, private (for profit) entities, and local, state, and tribal governments. Award amounts typically range from $500,000 to $1 million for projects lasting up to 36 months. Cost sharing through cash or in-kind matches is expected. Applicants must conduct projects benefiting coastal communities in one or more of the 35 U.S. coastal states or territories.

Because the Regional Coastal Resilience Grants program favors regional approaches to resilience problems, the Town should pursue future funds with a group of municipalities (such as the Council of Governments) or with the State of Connecticut.

Regional and National Design Competitions
Although the Rebuild By Design (RBD) competition and National Disaster Resilience Competition (NDRC) awards were announced in the last three years and the competitions are complete, they have provided a new model for screening and selecting resilience grant awardees in the United States. The Town should keep abreast on future design competitions and consider pursuing these competitions as an individual applicant (if eligible), with a group of municipalities, or directly as an active participant with the State of Connecticut.

Traditional Sources of Funding

U.S. Department of Housing and Urban Development (HUD)

Community Development Block Grant (CDBG)
The Connecticut Department of Housing administers the CDBG program in Connecticut. The CDBG program provides financial assistance to eligible municipalities in order to develop viable communities by providing affordable housing and suitable living environments, as well as expanding economic opportunities, principally for persons of low and moderate income. It is possible that CDBG funding program could be applicable for floodproofing and elevating residential and non-residential buildings, depending on eligibility of those buildings relative to the program requirements.

CDBG Disaster Recovery (CDBG-DR)
After disaster declarations, and when funds are appropriated to U.S. HUD and the Connecticut Department of Housing, the Town of Madison should continue to apply for CDBG-DR grants. The Town has clearly been capable of securing CDBG-DR grants, as several ongoing and upcoming resilience projects are funded by this program.

Natural Resources Conservation Service (NRCS)

The NRCS provides technical assistance to individual landowners, groups of landowners, communities, and soil and water conservation districts on land use and conservation planning, resource development, stormwater management, flood prevention, erosion control and sediment reduction, detailed soil surveys, watershed/river basin planning and recreation, and fish and wildlife management. Financial assistance is available to reduce flood damage in small watersheds and to improve water quality. Two major programs are described below.

Emergency Watershed Protection Program (EWP)
Through the EWP program, the U.S. Department of Agriculture's NRCS can help communities address watershed impairments that pose imminent threats to lives and property. Most EWP work is for the protection of threatened infrastructure from continued stream erosion. NRCS may pay up to 75% of the

construction costs of emergency measures. The remaining costs must come from local sources and can be made in cash or in-kind services. No work done prior to a project agreement can be included as in-kind services or part of the cost share. EWP projects must reduce threats to lives and property; be economically, environmentally, and socially defensible; be designed and implemented according to sound technical standards; and conserve natural resources.

Watersheds and Flood Prevention Operations

This program element contains two separate and distinct programs, “Watershed Operations” and “Small Watersheds.” The purpose of these programs is to cooperate with State and local agencies, Tribal governments, and other Federal agencies to prevent damages caused by erosion, floodwater, and sediment and to further the conservation, development, utilization, and disposal of water and the conservation and utilization of the land. The objectives of these programs are to assist local sponsors in assessing conditions in their watershed, developing solutions to their problems, and installing necessary measures to alleviate the problems. Measures may include land treatment and structural and nonstructural measures. Federal cost sharing for installation of the measures is available. The amount depends upon the purposes of the project.

Federal Emergency Management Agency (FEMA)

Pre-Disaster Mitigation (PDM) Program

The Pre-Disaster Mitigation Program was authorized by Part 203 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act (Stafford Act), 42 U.S.C. 5133. The PDM program provides funds to states, territories, tribal governments, communities, and universities for hazard mitigation planning and implementation of mitigation projects prior to disasters, providing an opportunity to reduce the nation's disaster losses through pre-disaster mitigation planning and the implementation of feasible, effective, and cost-efficient mitigation measures. Funding of pre-disaster plans and projects is meant to reduce overall risks to populations and facilities.

Hazard Mitigation Grant Program (HMGP)

The HMGP is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The HMGP provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. A key purpose of the HMGP is to ensure that any opportunities to take critical mitigation measures to protect life and property from future disasters are not "lost" during the recovery and reconstruction process following a disaster.

HMGP is available only in the months subsequent to a federal disaster declaration. Because the State administers HMGP directly, application cycles will need to be closely monitored after disasters are declared.

Flood Mitigation Assistance (FMA) Program

The FMA program was created as part of the National Flood Insurance Reform Act (NFIRA) of 1994 (42 U.S.C. 4101) with the goal of reducing or eliminating claims under the National Flood Insurance Program (NFIP). FEMA provides FMA funds to assist states and communities with implementing measures that reduce or eliminate the long-term risk of flood damage to buildings, homes, and other structures insurable under the NFIP. The long-term goal of FMA is to reduce or eliminate claims under the NFIP through mitigation activities.

One limitation of the FMA program is that it is generally used to provide mitigation for structures that are insured or located in SFHAs.

U.S. Army Corps of Engineers (USACE)

The U.S. Army Corps of Engineers provides 100% funding for floodplain management planning and technical assistance to states and local governments under several flood control acts and the Floodplain Management Services Program (FPMS). Specific programs used by the Corps for mitigation are listed below.

Section 205 – Small Flood Damage Reduction Projects

This section of the 1948 Flood Control Act authorizes the Corps to study, design, and construct small flood control projects in partnership with non-Federal government agencies. Feasibility studies are 100% federally-funded up to $100,000, with additional costs shared equally. Costs for preparation of plans and construction are funded 55% with a 35% non-federal match. In certain cases, the non-Federal share for construction could be as high as 50%. The maximum federal expenditure for any project is $7 million.

Section 14 – Emergency Streambank and Shoreline Protection

This section of the 1945 Flood Control Act authorizes the Corps to construct emergency shoreline and streambank protection works to protect public facilities such as bridges, roads, public buildings, sewage treatment plants, water wells, and non-profit public facilities such as churches, hospitals, and schools. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is $1.5 million.

Section 208 – Clearing and Snagging Projects

This section of the 1954 Flood Control Act authorizes the Corps to perform channel clearing and excavation with limited embankment construction to reduce nuisance flood damages caused by debris and minor shoaling of rivers. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is $500,000.

Section 205 – Floodplain Management Services

This section of the 1950 Flood Control Act, as amended, authorizes the Corps to provide a full range of technical services and planning guidance necessary to support effective floodplain management. General technical assistance efforts include determining the following: site-specific data on obstructions to flood flows, flood formation, and timing; flood depths, stages, or floodwater velocities; the extent, duration, and frequency of flooding; information on natural and cultural floodplain resources; and flood loss potentials before and after the use of floodplain management measures. Types of studies conducted under FPMS include floodplain delineation, dam failure, hurricane evacuation, flood warning, floodway, flood damage reduction, stormwater management, floodproofing, and inventories of floodprone structures. When funding is available, this work is 100% federally funded.

In addition, the Corps also provides emergency flood assistance (under Public Law 84-99) after local and state funding has been used. This assistance can be used for both flood response and post-flood response. Corps assistance is limited to the preservation of life and improved property; direct assistance to individual homeowners or businesses is not permitted. In addition, the Corps can loan or issue supplies and equipment once local sources are exhausted during emergencies.

6 References

Appendix A
Existing Resources and Capabilities

Community Coastal Resilience Plan

Town of Madison, Connecticut

Existing Resources and Capabilities

Introduction

The initial step in the Madison Coastal Resiliency Project is a review of exisiting programs, plans, capabilities, and other projects that relate to, address, or are otherwise pertinent to the Town's persuit of a resilient coastal community.

Resources evaluated by Milone & MacBroom, Inc. (MMI) included:

- SCRCOG Multi-Jurisdiction Hazard Mitigation Plan
- Madison Plan of Conservation and Development
- Madison Zoning Regulations
- Madison Code of Ordinances
- TNC Salt Marsh Advancement Zone Assessments
- TNC Hazard and Community Resilience Workshops Summary of Findings
- FEMA New Haven County Flood Insurance Study and FIRM Panels
- Individual Drainage, Flood Mitigation, and Roadway Resilience Projects
- Individual HMGP- and CDBG-DR-Funded Projects

The intent of this memoradnum is to summarize the contributions of each of these programs towards the Madison Coastal Resiliency Plan.

Existing Resources

Hazard Mitigation Plan

The Town of Madison is covered under the SCRCOG Multi-Jurisdiction Hazard Mitigation Plan (April 24, 2014; Jamie Caplan Consulting/AECOM). The HMP identified assets that are vulnerable to potential threats, including tropical storms, nor'easters, urban, riverine, and coastal flooding, and sea level rise. The plan identifies 573 flood damage claims in Madison, as of December 31, 2012, noting that the most severe coastal flooding in the region has occurred as a result of high tides and storm surge caused by hurricanes, tropical storms and nor'easters. The potential for damage resulting from future flooding and storm events is increased due to the predicted sea level rise along the Connecticut shoreline, anticipated to be as much as 23 inches by the end of the century.

Vulnerable assets in the Town are summarized in Table 1, abridged from Table 4.49 on the HMP.

Table 1: Assets Vulnerable to Coastal Hazards – Madison

Hazard	Number of Parcels	Number of Housing Units	Critical Facilities	Historic Assets	Population
Hurricane/Tropical Storm	7,692	8,049	21	N/A	18,269
Severe Winter Storm/Nor'easter	7,692	8,049	21	N/A	18,269
Coastal Erosion	Unknown	Unknown	Unknown	N/A	Unknown
Flood					
1-Percent-Annual-Chance	1,767	6,391	0	N/A	14,439
0.2-Percent-Annual-Chance	905	4,970	0	N/A	10,520
Zone VE	423	1,116	0	N/A	1,478
Category 1 Storm Surge	761	1,741	0	N/A	2,681
Category 2 Storm Surge	1,022	3,033	0	N/A	5,114
Category 3 Storm Surge	1,150	3,220	0	N/A	5,470
Category 4 Storm Surge	1,114	3,402	1	N/A	5,751
Sea Level Rise	968	2,830	0	N/A	5,391

Madison contains 25 repetitive loss properties (RLP)[1] and three severe repetitive loss properties (SLRP)[2]. A 1%-annual-chance coastal flood (also called the 100-year event or base flood) is predicted by the Plan to cause $7.6 million in losses and displace 90 households.

The HMP identifies coastal flooding, coastal erosion, and sea level rise, especially in the context of isolation of neighborhoods from the rest of the community, as a primary hazard in Madison. Hurricanes and tropical storm hazards pose significant issues for the Town related to coastal flood damages (to homes and infrastructure, including seawalls), street flooding, and damage to trees, power lines, and communication.

Specific Areas listed as being vulnerable include:

- Circle Beach Road
- Middle Beach Road
- Hammonasset State Park
- Hartford Avenue
- Neck Road
- Green Hill Road
- Harbor Avenue
- Surf Club

[1] The FEMA National Flood Insurance Program (NFIP) defines a severe repetitive loss property as one which has had one of the following occur within a ten year period:
(a) at least four NFIP claim payments over $5,000 each, with the total amount exceeding $20,000
(b) at least two separate claim payments with the total amount exceeding the market value of the building

[2] FEMA defines a repetitive loss property as one which has had at least two separate claim payments of over $1000 each within a ten year period.

- The Town Campus

The Plan lists many of Madison's Planning and Regulatory Capabilities, including the following:

- Comprehensive Master Plan
- Capital Improvements Plan
- Economic Devel9opment Plan
- Local Emergency Operations Plan
- Stormwater Management Plan
- Building Codes
- Zoning Ordinances
- Land Use Planning
- Subdivision Ordinances
- Acquisition of Land for Open Space and Recreation

Regional mitigation priorities include elevating roads, installling or improving floodgates on drainage systems, protecting against erosion, and elevating buildings and homes. Chapter 6 of the SCRCOG HMP identifies a number of potential mitigation actions that could be implemented in Madison. For this review we focused on projects that address coastal hazards or all flooding hazards. These projects are summarized within table 1 at the end of this memo.

Madison Plan of Conservation and Development

Madison's 2000 Plan of Conservation and Development (POCD) was titled "A Guide to Madison's Future," and included coastal management throughout. The Town updated their plan in 2013. In a survey conducted prior to the publishing of the update, 3.3% of respondents indicated concern about issues including infrastructure, and 4% indicated concern about issues including open space and town preservation.

The 2013 Plan includes the themes of Community Character and Quality of Life, Community Development, and Conservation and Sustainability. Within these themes are plans to protect scenic resources (such as roads and vistas), protect historic resources (some of which are located within at-risk coastal areas), preserve open land, retain undeveloped land, and manage development activities in coastal areas. Chapter six of the plan focuses on actions intended to protect coastal resources, prepare for sea level rise and more frequent and severe storms, and retain a high state of emergency preparedness. Many of these actions are either directly connected or somewhat related to the Coastal Resiliency Plan.

Some of the tasks proposed by the POCD include:

- Educate and Inform Residents about Protecting Coastal Resources
- Support efforts to reduce potential pollutants associated with recreational boating
- Investigate Salt Marsh Dieback in Madison and the effect on Coastal Resources
- Complete mapping of coastal resource information
- Remain informed and aware of sea level projections and storm projections

- Participate in regional and state programs evaluating the issue of sea level rise and storm impacts
- Seek to prevent or minimize losses in vulnerable areas
- As part of the regional hazard mitigation planning process, identify potentially vulnerable areas [too sea level rise] and prepare response plans
- Encourage electric system improvements to improve service and reliability
- Identify vulnerable infrastructure locations
- Take pro-active steps to protect local infrastructure and prevent repetitive losses

Code of Ordinances and Zoning and Subdivision Regulations

The Code of Ordinances and Zoning Regulations and Subdivision Regulations of the Town of Madison are the two documents that summarize Madison's ability to manage development and construction activities in Town. Review of these documents show the Town's current regulatory capabilities with regards to mitigation of coastal hazards, as well as where improvements may be possible to strengthen those capabilities.

Madison's Zoning Regulations give the Town a broad mandate to require Coastal Site Plan Reviews for construction or modification in coastal zones, however specific resilience practices are not mentioned. Exceptions to the requirement for a Coastal Site Plan Review are numerous, and include construction or minor modification of buildings and incidental structures such as fences and walls, walkways and driveways, terraces, decks, pools, docks, underground utilities, essential above-ground utilities, and septic systems. Residential structures are limited to 50 feet in height from the original lot grade, even in flood zones requiring elevation. This limit is decreased to 30-37.5 feet for narrow lots.

The Code of Ordinances of the Town of Madison Connecticut regulate floodplain construction to minimum FEMA standards. No freeboard requirements are listed.

The Nature Conservancy Salt Marsh Advancement Zone Assessment

Maintenance of healthy natural systems is a cost-effective way to protect people and infrastructure from extreme weather and climate change into the future. As sea level rises, salt marshes will advance upslope and retreat from low-elevation areas. The Nature Conservancy (TNC) developed the Coastal Resiliency Program to help communities visualize and plan for a variety of future sea level rise scenarios and risks. Included in that program is an online tool to map future salt-marsh advancement.

The Salt Marsh Advancement Zone Assessment was written by TNC to assist communities with mapping future marsh locations and the current land uses at those locations. This information will help Madison understand which parcels are critical to ensure the continued existence of coastal natural resources in the area in the long term. Their analysis breaks future salt marsh extent down into a variety of categories to help with planning, including land that is or is not suitable for marsh habitats, land that is currently open versus developed, and land that is privately owned rather than owned by the Town, state, or federal governments.

The report projects that sea level rise will drive salt marsh advancement onto 916.6 acres of Madison land by the 2080s. Currently, 78.6% of that land is suitable to sustaining a salt marsh ecosystem, but only 43.2% of the 916.6 acres is protected land.

TNC Hazards and Community Resilience Workshops Summary of Findings

The Town of Madison and the Nature Conservancy formed a partnership to increase awareness of risks, strengths, and vulnerabilities within Madison associated with natural and climate-related hazards. This partnership carried out a series of presentations, interviews, outreach, and "Hazard and Community Resilience" workshops in order to facilitate education, planning, and implementation of priority adaptations actions. At these workshops, Town and TNC representatives worked with attendees to define hazards, identify present and future vulnerabilities and strengths, and develop and prioritize actions.

The Summary of Findings reports the top hazards, concerns, assets, and recommendations developed and expressed during these workshops. This information addresses townwide hazards, and is an excellent source of insight and guidance for continued and ongoing coastal-specific resiliency efforts.

The top hazards listed in the report include coastal flooding and storm surge, inland flooding, and wind.

Highlighted vulnerable areas include:

- Neck Road
- Garnet Park
- Circle Beach
- Middle Beach
- Fence Creek
- East and Neck River Marsh
- East and West Wharf
- Salt Meadow Park
- Neck River
- Hammonasset State Park
- Surf Club Beach
- State Route 1

Specific concerns noted include vulnerability of the road network, the railroad's susceptibility to coastal flooding, power distribution, isolation during coastal flood events, and the vulnerability of septic systems.

Other Resources

Analysis of Shoreline Change in Connecticut

A 2014 study title “Analysis of Shoreline Change in Connecticut” was performed through a cooperative effort of the Connecticut Department of Energy & Environmental Protection (CT DEEP), the Connecticut Sea Grant (CT Sea Grant) and the University of Connecticut Center for Land Use Education and Research (UCONN-CLEAR). Results show that Madison’s coastline has remained fairly static over the last century, with average growth less than five centimeters per year. This long-term trend will be taken into consideration with regards to future predictions of sea level rise and coastline recession. In addition, site-specific information will be used as necessary to inform individual resilience actions and intiatives. For example, proposed projects should be designed to address the trends in immediately adjacent areas.

North Atlantic Coast Comprehensive Study

The U.S. Army Corps of Engineers (USACE) published their report, “North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk” (NACCS) in 2015, following widespread damamage from Superstorm Sandy. The report uses results of the study to guide North Atlantic communities through the process of building coastal-storm resilience, from identifying stakeholders and partners for collaboration to monitoring program effectiveness over the long term.

Region-specific analyses provide information on risks and vulnerabilities specific to particular areas. This process begins with assessment of current and projected flooding conditions and delineation of vulnerable areas. Population density and infrastructure, social vulnerability, and environmental and cultural resources, are characterized within those flood-vulnerable zones to develop a weighted “exposure index.” Risk is then calculated within the study regions as a function of exposure index and probability of flooding.

The entire Madison coastline is classified by this study as being a “high exposure” area, with the exception of the northern coast of the Hammonasset Natural Area. The main assets of concern for Madison, as listed in the document, are Routes 1 and 154, the Hammonasset Connector, significant pockets of residential development, and supporting local roads and utilities. Route 1 and Route 95 specifically can be seen as having a very high “Exposure Index” value. Composite Risk Index results show highest risk areas at Garnet Park, parts of Smith Bay, Madison Surf Club to Crescent Beach, and the mouth of Fence Creek.

The NACCS also assesses the applicability of a variety of general adaptation options to certain coastal types. The coast of Madison is split into sections based on the type of shoreline, and relevant options for each section are noted. This information is summarized in Table 2:

Table 2: NACCS Analysis of Shoreline Adaptation

Shoreline	**Risk Reduction**	**Beach Restoration Dunes**	**Beach Restoration Breakwaters**	**Beach Restoration Groins**	**Shoreline Stabilization**	**Deployable Floodwall**	**Floodwall**	**Levee**	**Living Shoreline**	**Wetlands**	**Reefs**	**SAV Restoration**
Beaches	High	X	X	X								
Rocky Shore (Exposed)	Low										X	
Scarps (Exposed)	Low				X				X		X	
Vegetated Low Banks (Sheltered)	High						X	X				
Vegetated Low Banks (Sheltered)	Low				X				X			
Wetlands (Sheltered)	Low								X	X	X	X

The main report is supplemented by appendices that quantify storm surge and wave heights, as well as economic and social impacts. An associated report focuses on the "Use of Natural and Nature-based Features (NNBF) for Coastal Resilience."

Connecticut Coastal Design Project

The Connecticut Coastal Design Project was an effort coordinated by The Nature Conservancy's Coastal Resilience Program to create a dialogue between coastal engineers, regulatory agents, coastal geomorphologists, landscape design professionals, and natural resource managers around the implementation of environment and ecosystem supportive shoreline protection projects. The results from this project are summarized in "Workshop Summary of Findings Report on Non-Structural and Natural Infrastructure Alternatives: Current Opportunities and Constraints for Connecticut's Coast" (2015). This summary provides suggestions of types of natural shoreline protection measures, locations along the Connecticut Coast where certain measures can be expected to work best, obstacles that exist to implementation of these strategies, and methods of overcoming those obstacles.

The coast of Madison falls within the "Shoreline District E" designated by this project. This district is defined as dominantly "glacial drift and beaches." This zone is identified as having the highest potential for installation of natural infrastructure projects.

Long Island Sound Comprehensive Conservation and Management Plan

The Long Island Sound Study (LISS) is a "Management Conference" comprised of State and Federal representatives, established as part of a variety of Clean Water Act programs, with the goal of improving the water quality, habitat and wildlife diversity and abundance, and community sustainability and resiliency, within Long Island Sound and its contributing watersheds. As part of this effort, the LISS produced a Comprehensive Conservation and Management Plan (CCMP) in 2015, updating previous plans. The CCMP is built around four themes: clean water and healthy watersheds; thriving habitats and abundant wildlife; sustainable and resilient communities; and sound science and inclusive mnagement.

These themes together incorporate the plan's underlying principles of resiliency to climate change, long term sustainability, and environmental justice.

Long Island Sound Resource and Use Inventory and Blue Plan

This bill, enacted on July 1, 2015, gives the Connecticut DEEP commissioner the responsibility and authority to coordinate with a University of Connecticut Subcommittee and a Long Island Sound Resource and Use Inventory and Blue Plan (LIS RUI-BP) Advisory Committee (both established by the bill) in the development of a Long Island Sound Resource and Use Inventory (LIS RUI or "Inventory") and a Long Island Sound Blue Plan (LIS BP or "Plan"). The Inventory will account for plants, animals, habitats, and ecologically significant areas within the sound, as well as human uses including boating, fishing, hunting, aquaculture, energy facilities, shipping corridors, and power-, pipe-, and telecommunication-lines. The Blue Plan will build on this Inventory to establish a framework to guide Connecticut's future actions with regards to the Sound. The Plan will help establish goals and standards for planning and development, incorporate ecological, social, and economic needs and values, account for climate change, and serve as a basis for inter-state cooperation.

A draft plan will be developed by March 1, 2019, and will likely be relevant to future resilience efforts in coastal municipalities.

Coastal Resilience Projects

Projects that address coastal hazards and build resilience, either directly or indirectly, are being pursued and implemented throughout the Town of Madison. The most significant of those projects are summarized below.

TABLE 3

Town of Madison Potential Projects

ID	Project	Description	Category	Action	Funding	Reduced Risks	Green Infr.
1001	Green Hill Road Elevation	Flooding from tidal wetlands occurs north and south of I-95 at Green Hill Road and Green Hill Place. Road flooding can be 2'-3' deep. Elevation of the roads may be a solution. Long-term, this area may be a candidate for property acquisitions.	Hard Infrastructure--Road	Elevate		Road; Private Property	No
1003	Surf Club Dune Restoration	Dune restoration at the town's beach would provide flood protection at a critical gap. Without the dune, storm surges can cross the beach and contribute to flooding of a residential area.	Natural Coastal Infrastructure--Dune	Restore		Private Property; Town Property	Yes
1004	Surf Club Seawall Replacement	The Town's seawall at Madison Surf Club was replaced to elevation 11 feet.	Shoreline Infrastructure--Seawall	Replace in Kind		Buildings; Town Property	No
1005	Middle Beach Road Shoreline Protection	Replacement or repair of the seawall at Middle Beach Road will protect property, homes, utilities, and egress along Middle Beach Road.	Shoreline Infrastructure--Revetment--Seawall	Replace in Kind		Road; Private Property	No
1006	Surf Club Picnic Area Shoreline Protection	Seawalls protecting the picnic area at Madison Surf Club may be repaired or replaced.	Shoreline Infrastructure--Seawall	Replace in Kind		Public Access; Town Property	No

Conclusion

All of the relevent municipal planning documents recognize sea level rise and coastal storms as a key issue in need of consideration. The SCRCOG Multi-Jurisdiction Hazard Mitigation Plan identifies locations vulnerable to future sea level conditions, tracks mitigation projects, and suggests additional possibilities. The Plan of Conservation and Development names sea level rise as an important factor in future development, and considers the effect it will have on emergency services.

The studies being performed by the Town, the State, and other parties cover Salt Marsh sustainability, shoreline change and sediment dynamics, the future evolution of coastal hazards and socio-economic vulnerabilities, aquatic and shoreline habitats, and multi-hazard effects on coastal resilience.

Monitoring the state of these projects and plans, ensuring collaboration and communication between the responsible entities, and building on this baseline to fill knowledge and implementation gaps, will be essential in creating a resilient Town.

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Appendix B
Sea Level Rise and Regional Vulnerabilities

TOWN OF MADISON
COMMUNITY COASTAL RESILIENCY PLAN

Sea Level Rise and Regional Vulnerabilities
Prepared as a section to be added to the complete plan

Prepared for:

Town of MADISON, CT

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1 Introduction

The Town of Madison is partnering with the Town of Branford and the City of Milford to utilize funding from the United States Department of Housing and Urban Development (HUD) Community Development Block Grant (CDBG). This particular grant falls under the category of "Recovery Eligible Activities" and aims to address vulnerabilities observed after Superstorm Sandy by developing Coastal Resiliency Planning at the municipality level.

The stated purpose of this grant is to increase social, economic, and ecological resilience in the face of sea level rise, more frequent and severe storm surges, coastal flooding, and erosion. Extra emphasis is placed on benefiting underserved, low-to-moderate income populations and their communities.

Risks and vulnerabilities in the Town of Madison were determined through review of other Town documents such as the SCROG Hazard Mitigation Plan, discussion with Town representatives, public meetings, an online survey, and utilization of The Nature Conservancy's Coastal Resilience Mapping Portal.

This risk and vulnerability memo is one step toward developing a community Coastal Resilience Plan.

2 Sea Level Rise

2.1 Introduction

Although erosion and shoreline change have long been recognized as coastal hazards nationwide, it is only recently that sea level rise has been viewed as a hazard to be considered while planning for resilience. Indeed, continued increases in the rate of sea level rise will increase the incidence, severity, and adverse effects of flooding, erosion, and shoreline change. Consider the following:

- A continued increase in the rate of rising sea levels will inundate low areas, increase erosion of beaches and tidal marshes, increase the incidence of flooding from storm surges, and enable saltwater to advance upstream and intrude further into estuaries and aquifers.
- Future sea level rise could result in the disappearance of a large percentage of Madison's tidal wetlands unless they can advance as quickly as the rising level.
- Saltwater advancing upstream along estuaries can alter the point at which sedimentation leads to the creation of shoals and other features.
- FEMA's coastal base flood elevations will progressively rise along with sea level. This means that the 100-year and 500-year flood levels will affect lands and structures that are currently at unaffected elevations.
- As sea level rises, storm surges from hurricanes and nor'easters will reach further inland as they are starting from a higher base level.
- As sea level rises, drainage systems become less effective. Rainstorms will have the potential to cause greater flooding.

In its landmark 2001 report, the IPCC projected that global sea level may rise nine to 88 centimeters (0.30 - 2.89 ft) during the 21st century. According to the February 2007 update report by the IPCC, these predictions have been refined using six global climate models to project a more narrow range of sea level rise of 28 to 43 cm (0.92 to 1.41 ft) in the 21st century.

NOAA Technical Report OAR CPO-1, entitled Global Sea Level Rise Scenarios for the United States National Climate Assessment (December 2012) was prepared in partnership with USGS and the U.S. Army Corps of Engineers. This report is the current reference for sea level rise planning in the United States. The report states that "We have very high confidence that global mean sea level will rise at least 0.2 meters (8 inches) and no more than 2 meters (6.6 feet) by 2100."

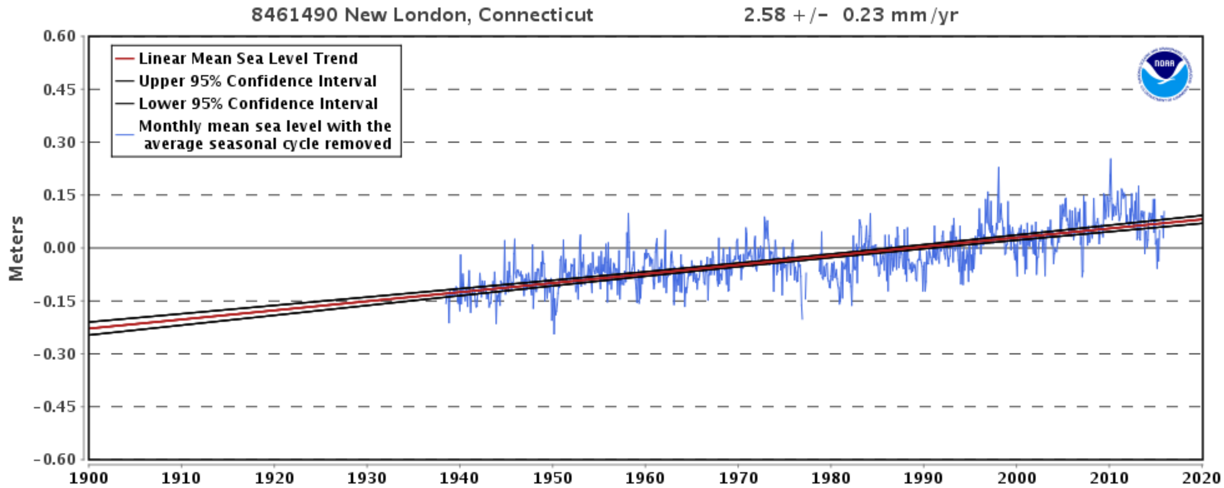
Sea level rise is not consistent around the world, and is affected by local variations in currents, temperature, and changes in land surface elevation. It has long been expected that the rate of sea level rise in Connecticut will be slightly higher than the global projections due to the effects of regional subsidence. However, more recent studies have asserted that changes in ocean circulation will increase the relative sea level rise along the Atlantic coast even more.

2.2 Existing Conditions and Historic Rise

There are no National Oceanic and Atmospheric Administration (NOAA) tide gauges within Madison, however a gauge has been operated by NOAA in Clinton to the east. The Clinton gauge was located south of Riverside Drive in the mouth of the Hammonasset River, and collected data from June to October, 2002. According to data collected by this gauge (available online at tidesandcurrents.noaa.gov), the mean sea level (MSL) at the eastern edge of Madison is negative (-) 0.33 feet, or 0.33 feet below the North American Vertical Datum of 1988 (NAVD88). The average maximum elevation of high tide ("mean higher-high water, or MHHW") is 2.62 feet above the MSL, or 2.29 feet elevation (NAVD88). These values will vary along Madison's coastline, and have likely changed since 2002, as discussed below.

The nearest ***long-term***, currently operational gauge to Madison is the tide gauge in New London, CT. Based on tide gauge data collected at that station between 1938 and 2014, MSL has been increasing at a rate of 2.58 millimeters (0.101 inches) per year, which is equivalent to a rise of 0.85 feet over 100 years (see Figure 1 below). Another station in Bridgeport, CT, has measured an increase of 2.87 mm/yr, or 0.94 feet-per-100-years, based on measurements since 1964.

Figure 1



2.3 Sea Level Rise

2.3.1 Sea Level Rise Projections

The U.S. Army Corps of Engineers hosts a sea level projection web tool ("Sea-Level Change Curve Calculator") at http://www.corpsclimate.us/ccaceslcurves.cfm. The calculator provides sea level rise projections using U.S. Army Corps of Engineers and NOAA projections at existing tidal gauges. Calculated sea level rise for the Bridgeport gauge is depicted in the following table and graph. In each case, the base year is 1992. Rates are "NOAA Low, NOAA Intermediate Low, NOAA Intermediate High, NOAA High, USACE Low, USACE Intermediate, and USACE High" as follows:

- *NOAA Low and USACE Low*: This curve uses the historic rate of sea-level change as the rate of change moving forward.
- *NOAA Intermediate Low and USACE Intermediate*: This curve projects future sea level rise based only on ocean warming and the local rate of vertical land movement. Ocean warming leads to increases in sea level rise because water expands as it heats. As ocean temperatures increase, the oceans rise to accommodate this natural expansion. This is generally considered an optimistic rate of sea level rise, meaning it is a best case scenario that minimizes future risk.
- *NOAA Intermediate High*: The orange line depicts the projected rate of sea level rise assuming both ocean warming and a moderate rate of melting of the arctic ice sheets. The increase is higher because the water expansion is exacerbated by the addition of new water from the melted ice sheets. The rate of ice sheet loss is considered the biggest unknown in climate change analysis, which is why two alternate scenarios (Intermediate High and High) are provided for ice sheet loss.

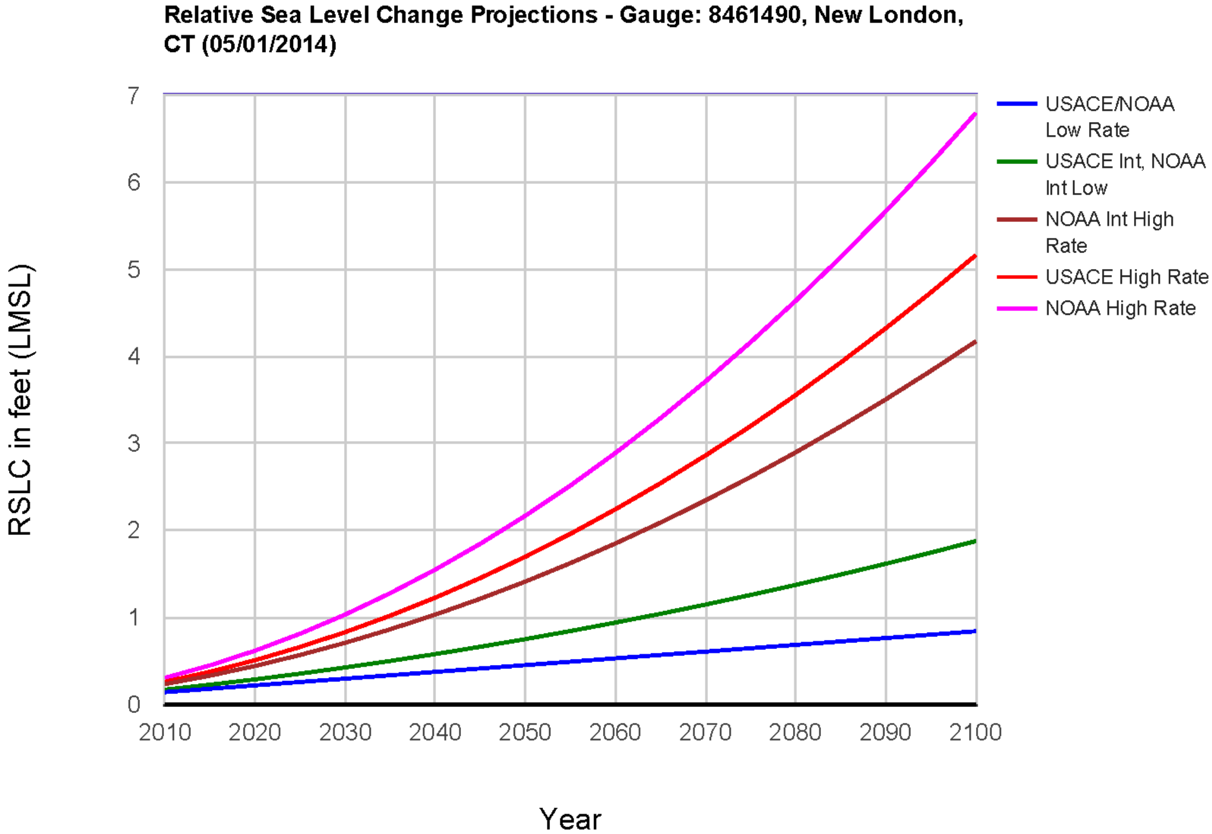
- *USACE High*: This curve is computed from the modified National Research Council's "Curve III" considering both the most recent IPCC projections and modified NRC projections with the local rate of vertical land movement added.
- *NOAA High*: The red line represents the largest increase in sea level rise based on heating of the oceans and a maximum loss of the ice caps. NOAA suggests that this highest scenario is considered an appropriate planning tool for critical facilities that have a long life cycle such as major highways, power plants, and the like.

Table 1

Gauge 8461490, New London, CT NOAA's Regional Rate: 0.00778 feet per year Values expressed in feet relative to the 1992 Local Mean Sea Level (LMSL)					
Year	USACE Low NOAA Low	USACE Int NOAA Int-Low	NOAA Int-High	USACE High	NOAA High
2010	0.14	0.17	0.23	0.26	0.31
2015	0.18	0.23	0.33	0.38	0.45
2020	0.22	0.29	0.44	0.51	0.62
2025	0.26	0.35	0.57	0.66	0.81
2030	0.30	0.42	0.71	0.83	1.03
2035	0.33	0.50	0.86	1.02	1.28
2040	0.37	0.58	1.03	1.23	1.55
2045	0.41	0.66	1.22	1.45	1.85
2050	0.45	0.75	1.41	1.70	2.17
2055	0.49	0.84	1.62	1.96	2.52
2060	0.53	0.94	1.85	2.24	2.89
2065	0.57	1.04	2.09	2.54	3.29
2070	0.61	1.15	2.35	2.86	3.71
2075	0.65	1.26	2.61	3.20	4.16
2080	0.68	1.37	2.90	3.56	4.64
2085	0.72	1.49	3.20	3.93	5.14
2090	0.76	1.62	3.51	4.32	5.67
2095	0.80	1.74	3.83	4.73	6.22
2100	0.84	1.88	4.17	5.16	6.80

Figure 2

Relative Sea Level Change Projections
Gauge 8461490, New London, CT



The ranges calculated in the above graph and table are quite wide, but even the low projections show that sea level rise will continue throughout the century. The USGS has demonstrated that sea levels along the mi-Atlantic and northeast coasts of the United States are already rising three to four times faster than the global average since 1990. This heightens the need for resilience planning in Madison

2.3.2 Sea Level Rise Viewer Tools

Several sea level rise viewer tools are available for assessing future sea levels in the Madison area including the Connecticut Coastal Hazards Viewer at http://ctecoapp1.uconn.edu/ctcoastalhazards/ and NOAA’s popular tool at http://csc.noaa.gov/digitalcoast/tools/slrviewer, and The Nature Conservancy’s (TNC) Coastal Resilience Mapping Portal at http://coastalresilience.org/. The various viewer tools can be used for decision support and local or regional planning, in addition to public education and outreach.

The Coastal Resilience Mapping Portal

The Coastal Resilience program for New York and Connecticut is a collaborative effort led by TNC in partnership with NOAA's Coastal Services Center (CSC), The Association of State Floodplain Managers (ASFPM), The Earth Institute of Columbia University (TEI), NASA's Goddard Institute for Space Studies (GISS), Pace University's Land Use Law Center (LULC), The University of Southern Mississippi (USM), and the University of California at Santa Barbara (UCSB). The Coastal Resilience Mapping Portal (CRMP) is the sea level rise viewer produced by this collaboration. The tool is an interactive decision support instrument that explores predicted flood extents in the future under different sea level rise scenarios and storm conditions. The visual information is intended to inform development and conservation decisions.

Sea level rise projections for Long Island Sound were generated under a contract between TNC, TEI, and GISS in 2010-2011. Projections are generalized to apply to the decade-long time periods of "2020s," "2050s," and "2080s." Each decade is paired with three sea level rise scenarios: "high," "medium," and "conservative." The sea level rise magnitudes are derived from models of three different emissions scenarios and seven global climate change models, coupled with historic tide gauge data, subsidence rates, and several other variables (Columbia/NASA).

Those nine sea-level rise projections are combined with modeled surge effects under three sets of conditions: no storm (in other words, only the impacts of sea level rise), Category 2 hurricane, and Category 3 hurricane. The result is a set of 27 different possible views as listed below in Table 2.

Table 2

Future Flood Scenarios Mapped by the Coastal Resilience Tool

Decade	Condition	Sea Level Rise Estimates*	Elevation (ft, NAVD 88)
2020s	No Storm	Conservative	3.3
		Medium	3.3
		High	3.7
	Category 2	Conservative	9.4
		Medium	9.4
		High	9.8
	Category 3	Conservative	12.4
		Medium	12.4
		High	12.8
2050s	No Storm	Conservative	3.8
		Medium	3.9
		High	5.2
	Category 2	Conservative	9.9
		Medium	10.0
		High	11.3
	Category 3	Conservative	12.9
		Medium	13.0
		High	14.3
2080s	No Storm	Conservative	4.5
		Medium	4.7
		High	7.3
	Category 2	Conservative	10.6
		Medium	10.8
		High	13.4
	Category 3	Conservative	13.6
		Medium	13.8
		High	16.4

*High = emissions scenario A2 + 3.28 feet (1 meter)
Medium = emissions scenario A2
Conservative = emissions scenario A1B

The Coastal Resilience decision support tool was used to evaluate different parts of Madison in the 2020s, 2050s, and 2080s. In general, the "medium" projections were utilized for making planning-level decisions, whereas the "conservative" and "high" projections were used for comparison purposes.

2.3.3 Wave Set-up and Run-up Modeling

Sea level is often described as a single elevation for an area, but this ignores variations caused by the movement of water. The average sea level, without accounting for factors such as waves, wave set-up, or wave run-up, is called the **stillwater** elevation. Waves cause sea level to fluctuate above and below the stillwater elevation, which for the purposes of planning create an effective water surface elevation that is higher than sea level. As waves approach the shoreline, the average level of water inside the surf zone increases. This is known as **wave set-up**. After waves break on the shore, the momentum of the wave pushes water further up the shoreline, such that when the water finally stops and begins to recede, it is at a higher elevation than wave set-up. This is called **wave run-up**. Wave set-up and run-up can sometimes push water over a coastal barrier (**overtopping**), even if that barrier is significantly higher than the stillwater elevation.

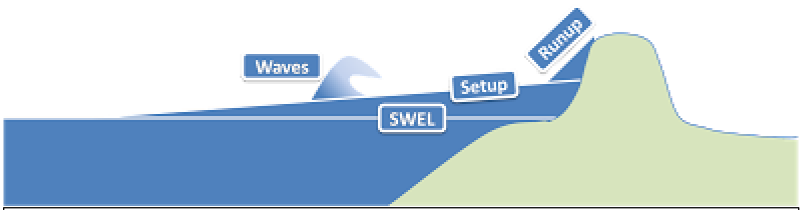


Figure 3:
Conceptual representation of stillwater elevation (SWEL), wave setup, and wave runup.

The significance of wave set-up and run-up is related to the topography of the coastline, and requires more extensive analysis than what is provided by TNC's CRMP tool. Two products that include this level of analysis were reviewed for this study.

<u>*Coastal Hazard Analysis Modeling Program*</u>

The Coastal Hazard Analysis Modeling Program version 2.0 (CHAMP 2.0) is a method developed by FEMA for performing analyses of wave-related hazards, including the effects of wave height and wave runup. This program was used as part of the preliminary New Haven County Flood Insurance Study (FIS) issued August 10, 2015[1], and results are available in database form. These data include the 1%-annual-chance stillwater elevations, wave setup elevations, wave heights and wave periods, coastal structure (revetments or seawalls) failure analyses, and runup analysis (if applicable). Another FEMA modeling tool called Wave Height Analysis for Flood Insurance Studies 4.0 (WHAFIS) was applied using CHAMP to calculate overland wave height propagation and establish base flood elevations.

The results of the wave modeling data were reviewed for a number of FEMA coastal transects within Madison, based on their proximities to known high-hazard areas. The primary hazard (overtopping, overland wave propagation) impacting each area was determined based on the final mapping methodology used in the preliminary New Haven County DFIRMs and summarized in Table 10 of the FIS.

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[1] CHAMP 2.0 was used to perform modeling of coastal hazards in the 2013 New Haven County FIS. Results from that study were brought into the 2015 FIS without change.

A detailed description of the FIS data and analysis techniques ("Coastal Summary_NewHaven.pdf) can be found submitted as part of the Technical Support Data Notebook (TSDN) package along with the preliminary New Haven FIS (8/10/2015).

The Advanced Circulation Model (ADCIRC)

On October 29, 2012, the remnants of Hurricane Sandy made landfall near Brigantine, NJ, and due to its size brought a catastrophic storm surge into the New Jersey and New York coastlines. As part of the extensive recovery effort, the North Atlantic Coast Comprehensive Study (NACCS) was authorized by the Disaster Relief Act of 2013 (Public Law 113-2) on January 29, 2013. The study area was the Atlantic Ocean coastline, back-bay shorelines, and estuaries within portions of the United States Army Corps of Engineers (USACE) North Atlantic Division. The NACCS numerical modeling and statistical analysis effort used the ADCIRC Model to generate a tremendous amount of storm forcing condition data, model results, and statistical analysis products, for the coastal regions from Virginia to Maine. The USACE maintains all of this information within the Coastal Hazards System (CHS), a national, coastal storm-hazard data storage and mining system.

ADCIRC total water level output data for this study area was extracted from the CHS and reviewed.

Model Comparison

The total water levels from the FIS for New Haven County were based on the results of a local tide gauge analysis. The NACCS total water levels were based on simulations of tropical and extratropical storms using a coupled wave and surge model. Both studies include a wave setup component at the 1%-annual-chance storm water level.

In many cases the results between the two recent studies are similar, however there are instances where the water levels are significantly different at return periods (10%, 2%, and 0.2% annual-chance) where the NACCS figures include a wave setup component and the FEMA data do not. It is recommended that the NACCS figures be used for planning purposes.

Results of wave set-up and run-up modeling is presented in section 4.3.

3 Risk, Vulnerability, and Resilience

In the context of natural hazards such as flooding, risk is commonly defined as the product or the sum of vulnerability and frequency (risk = vulnerability X frequency or risk = vulnerability + frequency). Thus, if an event has (1) a low frequency and (2) very few people, structures, or infrastructure are vulnerable to the effects of that event, then the risk is assumed to be low. If an event has a high frequency and many people, structures, or components of infrastructure are vulnerable to the effects of that event, then the risk is assumed to be high. Either low frequency coupled with high vulnerability or high frequency coupled with low vulnerability will produce moderate risk.

In the context of coastal hazards and the need for developing coastal resilience, risk will change over time because the frequency will increase. Coastal storms are believed to be increasing in frequency, and flooding will increase in frequency as sea level rises. Thus, even if coastal vulnerabilities in Madison remain static, risks will increase.

Therefore, Madison is at a crossroads with regard to reducing risk. Vulnerabilities can remain static and risk can increase, or vulnerabilities can be reduced to hold risk at bay. If vulnerabilities can be reduced even further, than risks could be lowered in the face of rising sea level and increased coastal storms, leading to increased resilience. The least desired combination of all would be the development of increased vulnerabilities while frequencies increase, because risks could rise faster than expected. Encouragement of further development in a high-risk area would increase vulnerability. Repairing damaged seawalls would retain static vulnerability. Increasing the height and improving the strength of seawalls, or elevating homes, could reduce vulnerability.

The Community and Regional Resilience Initiative (CARRI, 2011) uses a "Resilience Loss Recovery Curve" to illustrate the process of increasing or decreasing community resilience.

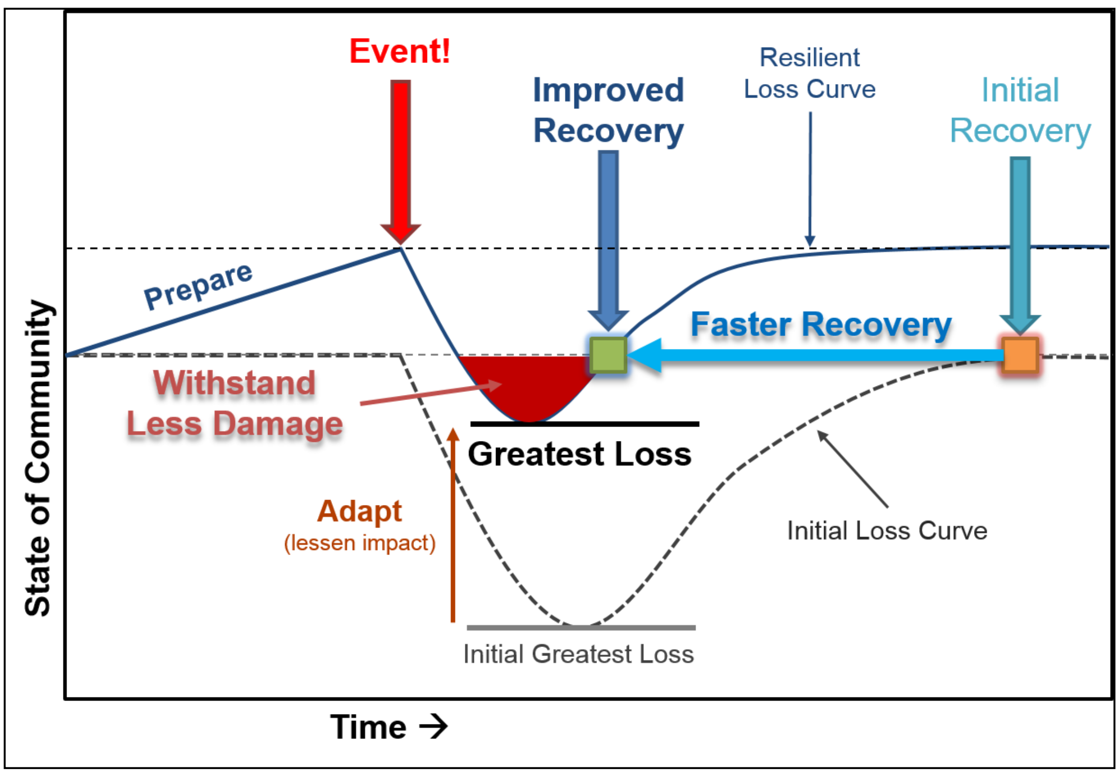


Figure 4 – Resilience Loss Recovery Curve, based on CARRI, 2011.

The Resilience Loss Recovery Curve helps explain how community function is affected by an acute disturbance such as an earthquake or hurricane, and depicts response and recovery curves. Community functions decline (blue and pink areas) as communities respond to a disaster. A more resilient community can more quickly restart local services (utilities, businesses, schools) and chart a path to a "new normal." The more resilient community incurs some losses (blue) but avoids additional losses (pink), because it has taken informed measures (anticipating threats, developing disaster response plans and recovery strategies, longer-term land use policies) in advance to minimize the impact of the disturbance (i.e., planning and mitigation).

Resilient communities may find opportunities to transform themselves and grow. Thus, a resilient community's "new normal" may be a higher level of function (solid blue, upper line) or it may be able to return to a level of function existing before the disturbance (dashed gray, lower line). Ultimately, this cycle repeats itself both before and after each disturbance resulting in opportunities to incrementally increase resilience and comprehensively reduce losses over time.

4 Vulnerabilities

Coastal hazards can impact the Town of Madison in a variety of ways, from direct injuries to residents, to damage to transportation infrastructure and utilities, to reduced economic activity following a storm event. Similarly, the types and degrees of vulnerabilities varies from one location in the city to another.

In this chapter, specific vulnerabilities to Madison are summarized both by the *type* of vulnerability and by the *locations* of these vulnerabilities.

4.1 Vulnerabilities by Type

4.1.1 Social

Social vulnerabilities to coastal hazards are focused mainly on three groups of people: residents, the business community, and visitors. These social vulnerabilities are directly linked to economic vulnerabilities, described in the next section.

Residents

Residents of Madison comprise the greatest group of people with vulnerability to coastal hazards and thus increased risk as sea level rises. More frequent coastal storms, storm surges, and flooding can cause a wide range of outcomes from minor property damage to injury and loss of life. Even the indirect outcomes of increased flooding can cause a range of problems from the slight inconvenience of waiting for low tide to traverse a key intersection, to being unable to mobilize an ambulance to the home of a person in need of medical attention. Specific regions of Madison with vulnerable properties are described in section 3.1.2 and in more detail in section 3.2. Critical facilities, as well as routes to and from those facilities, that are vulnerable to storms, are described in 3.1.3 and 3.1.5.

Business Community

Social vulnerabilities to coastal hazards in Madison are not limited to residents. Social vulnerabilities can be found among the business community. Many people who do not live in

Madison are employed in town or own a business in town. As such, they have significant fiscal or emotional investment in Madison. Increased coastal hazard risks could cause interruptions in employment, leading to loss of income and insurance; or interruptions in business continuity, leading to failure of businesses and loss of services that were provided by shuttered or failed businesses. These are all significant social issues, leading to distress for business owners and employees as well as residents. Vulnerable businesses and industries are described further in 3.1.2 and 3.3.

Visitors

Many people who neither live nor work in Madison have a great love of the community and visit often, from boaters and kayakers to hikers and cyclists. More frequent coastal storms, storm surges, and flooding can adversely impact the amenities and natural resources that draw these visitors from out of town, leaving them with fewer options for recreation in Madison. Examples range from a flooded restaurant that can no longer be visited by patrons, to an eroded beach that can no longer accommodate the level of visitors that it previously supported.

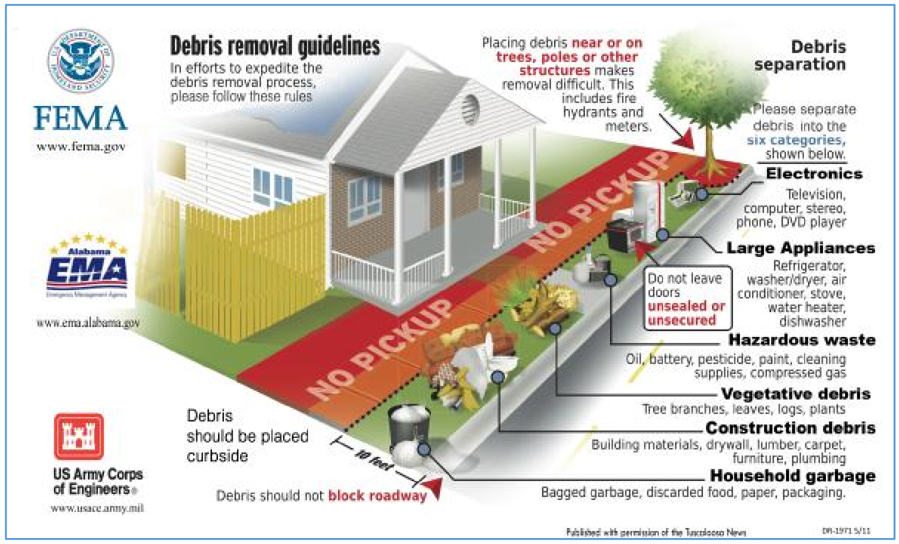
4.1.2 Economic

Residential Properties

Residential properties are directly vulnerable to coastal hazards with regard to flooding and wave action. Waves can destroy a residential structure in very little time. Floodwaters cause massive damage to the lower levels of homes, destroying heating and other equipment, furniture, important papers, and possessions. Wet and damp conditions trigger the growth of mold and mildew in flooded buildings, contributing to allergies, asthma, and respiratory infections. Gasoline, pesticides, sewage, and other aqueous pollutants can be carried into areas and buildings by floodwaters and soak into soil, building components, and furniture.

The costs to clean up a home after flooding can range from less than $10,000 to more than $100,000 depending on the damage. The amount of debris produced by flooding can be staggering. The graphic to the right (courtesy of FEMA) demonstrates the types of debris that can be generated, all requiring disposal and replacement.

Figure 5



The land surrounding homes is also vulnerable to coastal hazards. Vehicles, pools, landscaping, and outbuildings can be washed away or destroyed. Erosion can alter the ground surface. Animals can be forced out of their natural habitats and into closer contact with people. Wells and septic systems can be damaged or rendered useless as discussed in Section 3.1.4 below.

Figure 6 (courtesy of FEMA) illustrates another type of vulnerability. Debris from a damaged home can be moved by floodwaters or a storm surge and damage a nearby home.

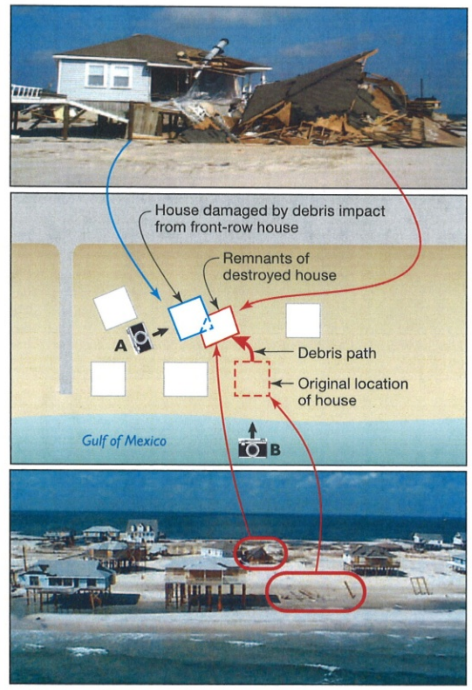
The indirect vulnerabilities to residential properties can be as bad as the direct vulnerabilities. Although a home may be situated above current and future flood elevations, access to the home may be increasingly cut off by flood waters associated with storms or even from normal high tides. Floodwaters can prevent emergency egress by blocking streets, deteriorating municipal drainage systems, and diverting municipal staff and resources. This can leave a home vulnerable to fire or other damage, leading to further economic losses.

Madison's overall tax base is heavily dependent on residential properties, and coastal properties make up a very large percentage of the residential tax base. The loss of a home leads directly to the loss of the taxes collected from the property.

Many of the homes in the near-shore densely populated areas such as Soundview Ave, Middle Beach, and Chapman Ave, are not at high risk to inundation due to sea level rise, but they are at risk to coastal hazards such as waves and winds, increased damage from storms as sea level rises, and increased frequency of isolation as roads are flooded.

On the other hand, homes in the neighborhoods of Circle Beach, Garnet Park, Surf Club Beach, and Seaview Beach, may need to address the actual encroachment of sea water under non-storm conditions. Many of those areas already have to manage high tide flooding on a monthly basis. Geographic differences are examined in Section 4.2 of this report.

Figure 6



The Madison 2013 Plan of Conservation and Development (POCD) lists nearly all of its coastal neighborhoods as among the Town's high-density residential areas. Further development in these coastal areas may increase vulnerabilities.

Commercial/Industrial Businesses

Non-residential commercial and industrial properties are directly vulnerable to coastal hazards with regard to flooding and wave action just as the residential properties described above. Waves can destroy a structure and floodwaters can cause damage. Increased flood frequency and increased flood elevations can inundate assets, equipment, and vital records such as products/merchandise and IT systems on the lower levels of a building; and damage HVAC equipment such as air conditioning units, boilers, furnaces, etc. Wells and septic systems can be damaged or rendered useless as discussed in Section 3.4 below.

A review of FEMA payments to small businesses after federal disaster declarations is quite revealing. Millions of dollars are funneled toward getting businesses back running after floods.

The commercial hub of Madison is the Town Center, as highlighted in the Town's POCD. Other important business and industrial centers are located near Green Hill Place off State Route 1 at the western Town border, at Madison Commons at the intersection of State Route 1 and Mungertown Road, and north of Hammonasset Beach State Park along State Route 1 at the Eastern edge of Town. Of these areas, only Green Hill Place neighborhood and Madison Commons are vulnerable to future sea level increases and to current and future storm conditions.

The tax base, employment, tourist draw, and potential for future growth, provided by businesses are very important to Madison. The economic implications could include the need to repair damaged facilities, pay for lost wages, and reestablish the areas as tourist destinations.

Water-Dependent Commercial/Industrial Businesses

Water-dependent businesses in Madison include East River Marine and the Garvan Point Sailing Club. These businesses will have vulnerabilities that are similar to the commercial and industrial properties described above, but may have higher overall risk by virtue of the fact that they are typically located at the water's edge. Though few in number, the water-dependent businesses have an important positive economic impact in Town.

Tourism

Section 3.1.1 described the social vulnerabilities associated with visitors of the Town of Madison, many of whom are supporting the tourism industry. More frequent coastal storms, storm surges, and flooding can adversely impact the amenities and natural resources that draw these visitors from out of town, leaving them with fewer options for recreation in Madison. Examples range from flooded restaurants that can no longer be visited by patrons, to eroded beaches that can no longer accommodate the level of visitors that it previously supported.

4.1.3 Infrastructure

With higher sea level or storm surges, roadways may become flooded or inundated more frequently, drainage systems in the roads may become ineffective, and culverts may become ineffective due to poor capacity or because they are situated at an improper elevation relative to rising sea level.

State Roads and Bridges

The only State road in Madison that is vulnerable to future sea level-rise and flooding is State Route 1 / Boston Post Road. A number of roads within Hammonasset State Park are also vulnerable, but are beyond the scope of this plan.

Town Roads and Bridges

Many town roads are vulnerable under a range of future scenarios. Some of the most significant roads at risk include:

- Green hill Place
- Garnet Park Road
- Circle Beach Road
- Surf Club Road
- Middle Beach Road West
- Island Avenue
- Middle Beach Road
- Scotland Avenue
- Seaview Avenue

Additionally, there are numerous privately owned roads that are vulnerable to flooding. Small bridges and culverts are located at many locations.

Railroads

In general, the railroad line through Madison has not historically flooded and the potential for it to flood is limited based on the future scenarios. This is because the grade is elevated above the adjacent tidal marshes and other low areas. The only section of track that appears threatened from future sea level rise and storm surges is at the western edge of Town where it crosses the East River. This location is shown to be inundated under projected flooding under current Category 2 hurricane conditions.

Stormwater and Drainage

As sea level rises, drainage systems become less effective. Rainstorms will have the potential to cause greater flooding because the stormwater will not as easily be collected and conveyed elsewhere. If the outfall of a drainage system falls below rising water levels in the future, its effectiveness will be limited.

Madison already experiences problems with inadequate storm drainage, with issues occurring commonly at Smith Bay, Short Beach. As sea level rises, more areas will likely experience decreased drainage capacity and increased risk of flooding.

Tide Gates

Tide gates are somewhat sensitive to elevation and are therefore vulnerable to sea level rise and coastal hazards. The risk of coastal flooding upstream of a tide gate is directly related to the functionality of a tide gate. Therefore it can be difficult to quantify the overall risks associated with a tide gate that will not function as needed during future coastal hazard events or simply as sea level rises.

Seawalls and Bulkheads

The effectiveness of seawalls and bulkheads is directly related to their elevations and construction. Seawalls and bulkheads will become more vulnerable to coastal storms over time as sea level rises. In turn, the properties and structures protected by seawalls and bulkheads will become more vulnerable. The increased vulnerability and increased frequency of storms will cause risk of failure and risk to protected properties to increase over time.

4.1.4 Utilities

Public Water Systems

Public water in Madison is supplied by the Connecticut Water Company (CWC) headquartered in Clinton. Sources of supply are not located in coastal flood hazard or hurricane surge zones; therefore coastal hazard risks are low.

It is conceivable that portions of the system installed in some coastal neighborhoods are close to sea level. The positive pressure maintained in a water system will prevent salt water from entering pipes. However, it is possible that salt water intrusion to fresh groundwater – or into areas that are currently above the groundwater table – could lead to corrosion of pipes. Vulnerability is likely low, but risk could increase over time as sea level rises.

Private Water Supplies

Individual private wells are vulnerable to sea level rise and coastal hazards in two important ways:

- Increased flooding and inundation can contaminate a well by allowing surface water to enter the wellhead or travel downward along the casing, rendering the well unusable until it can be disinfected and flushed.

- Rising sea levels can shift the fresh groundwater/salt water interface inland where it can intersect with wellbores that are currently landward of the interface.

If private wells are not relocated inland and elevated, or replaced by public water systems, then risks will increase over time.

Subsurface Sewage Disposal Systems (septic systems)

Madison is involved in a sewer avoidance program, and therefore the entire town is served by septic systems. All coastal properties in Madison have septic systems that are vulnerable to sea level rise and coastal hazards in two important ways:

- Increased flooding and inundation can flood a system and render it unusable, filling the septic tank and galleries and making it impossible for waste to drain away from a home or business. The system can break out and cause contamination at the ground surface.

- Rising sea levels can decrease the vertical separation between the top of the groundwater table and the bottom of the septic system, decreasing the travel time for pathogens and the adsorptive capacity of the unsaturated zone, causing increased groundwater pollution.

Because there is no public wastewater system, there is no public sewage infrastructure vulnerable to sea level rise.

Electricity

The greatest threats to the electrical grid associated with increased coastal hazards are wind-related. Additionally, increased incidence and duration of flooding can reduce the capability of Eversource to respond to outages caused by downed wires and blown transformers. For example, a utility crew could have difficulty traversing a flooded intersection to reach a coastal neighborhood where downed wires have caused a loss of power. Risks will increase over time, as the vulnerability of overhead power lines is unlikely to decrease without a concerted effort to bury electrical lines.

It is also possible that increased flooding and sea level rise can affect low-lying or buried electrical lines directly. Locations of buried utilities are not documented in a manner that allows for a rapid assessment of vulnerabilities to flooding.

Telecommunications

Wired telecommunications systems such as cable television and internet will have vulnerabilities and risks that are identical to those described above for electricity. Wireless telecommunications systems are dependent on towers, antennas, and satellites and therefore lack any direct vulnerability to coastal hazards (except for winds). However, the loss of electricity and a reduced capacity for Eversource to respond due to flooding could impact wireless telecommunications systems that require electricity to operate.

4.1.5 Emergency Services

Fire, Police, Emergency Healthcare, and Shelter Facilities

The Madison Fire Department and the Middlesex Hospital Urgent Care center are located in the Town Center off of State Route 1 / Boston Post Road between Durham Road and Wall Street. Neither is not vulnerable to projected future flood events.

The Madison Town Campus off of State Route 450 / Duck Hole Road houses The Madison Emergency Management Department, Police Department, and Fire Marshall, as well as the Town Hall. This area houses the Town's emergency shelter. The campus abuts the Hammonasset River north of State Route 95, but is not expected to be vulnerable to flood or storm events through the 2080s.

Access and Evacuation Routes

The vulnerabilities of Madison's emergency services lie in the routes to and from those facilities. Some sections of the Town risk being isolated from emergency services, emergency shelters, and general evacuation routes, during flood events. The layout of the town is such that even if major roads are impassable, other routes should remain open for most residents. Areas of the Town vulnerable to isolation include Circle Beach, Garnet Park, areas east of the Hammonasset Connector on Route 1, and possibly Seaview Beach and neighborhoods off of Neck Road during extreme events. Access to areas east of Fence Creek could be cut off from the Fire Station and Urgent Care center if Route 1 is flooded. Additionally, east-west transit or evacuation may be hindered by flooding of State Route 1 by the East River, Bailey Creek, Neck River, or Toms Creek. Many other areas risk being cut-off from the *most direct* routes to and from emergency service facilities during flooding or future high tide events. This is an important secondary risk in the context of sheltering and emergency services.

4.1.6 Natural Systems

Tidal Wetlands

Madison's tidal marshes, more broadly known as tidal wetlands, are undergoing a transformation as sea level rise, erosion, altered tidal flushing, invasive species, and "sudden marsh dieback" collectively work toward degrading the marshes from all sides. These issues are often interrelated, but this report focuses on the loss of marshes due to sea level rise and increased coastal hazards.

Some of the notable tidal wetland systems in Madison include those along the East River, Neck River, and Fence Creek, as well as those in Hammonasset State Park. Numerous other pockets of marshes are found throughout the Town.

Subsidence or drowning of tidal wetlands will occur as a result of sea level rise because they can no longer accumulate peat fast enough to stay above sea level. In Connecticut, the effect depends on location. Sea level rise appears to be altering the zonation of plant communities in southeastern Connecticut, where the tidal range averages 0.75 meters (approximately two feet). Studies have documented that at least two marsh systems are currently not keeping up with sea level rise. On Connecticut's western shore, with a tidal range of up to two meters (approximately six feet), extensive areas of low marsh vegetation have been drowned (e.g., Five-Mile River, Norwalk).

One effect of sea level rise is the tendency for marsh systems to migrate landward where they are able to do so. In developed areas where seawalls, lawns, and other structures are at the existing edge of the marsh, landward movement will be limited. The basic assumption is that some high marshes will become low marshes. Many marshes will be submerged by the 2020s. In the 2050s scenarios, uplands will be wet. In the 2080s, water will have moved past marshes. Although it is believed that some marshes will be able to advance, a net loss is anticipated. In some cases, marshes may advance into town-owned and private property.

Other Coastal Landforms

Several of Connecticut's coastal landforms are found in Madison and are vulnerable to coastal hazards in different ways.

- Rocky Shorefronts are shorefronts composed of bedrock, boulders and cobbles that are highly erosion resistant and are an insignificant source of sediments for other coastal landforms. Madison has many rocky shorefronts, and these landforms are already resilient to coastal hazards. Homes that sit atop rocky shorefronts are seldom subject to coastal wave action and will not be subject to daily inundation due to sea level rise.

- Beaches and Dunes are beach systems including barrier beach spits and tombolos, barrier beaches, pocket beaches, land contact beaches and related dunes and sandflats. In general, beaches are dynamic areas abutting coastal waters that are characterized by sand, gravel or cobbles. These areas are vulnerable to coastal hazards and sea level rise, and the risks of erosion and loss of beaches and dunes will increase over time. This is true for both small natural beaches and the larger maintained beaches.

- Intertidal Flats are very gently sloping or flat areas located between high and low tides composed of muddy, silty and fine sandy sediments and generally devoid of vegetation. Madison's intertidal flats are sensitive to the tidal cycle and tidewater elevations, and therefore are vulnerable to coastal hazards and sea level rise. Although the risk of losing these flats will increase over time, new flats will likely form where beaches and tidal wetlands were once located.

- An Estuarine Embayments is a protected coastal body of water with an open connection to the sea in which saline sea water is measurably diluted by fresh water including tidal rivers, bays, lagoons, and coves. Estuaries are sensitive to the tidal cycle and tidewater elevations, and therefore are vulnerable to coastal hazards and sea level rise. Like the tidal wetlands lining these estuaries, the estuaries will need to migrate inland to keep up with rising sea level. Much of this migration will not be readily visible, because the salt water/freshwater mixing zone will simply move upstream into the rivers.

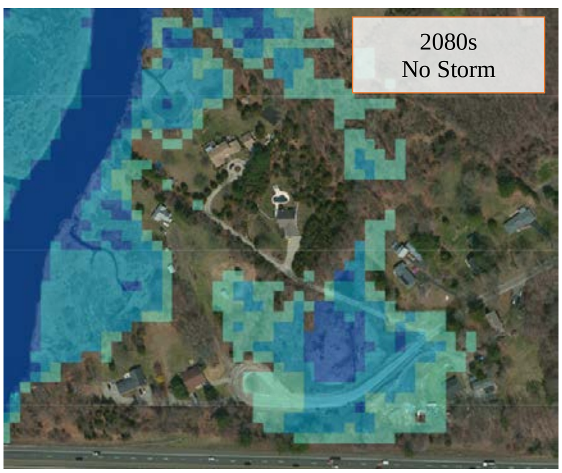
4.2 *Vulnerabilities by Region*

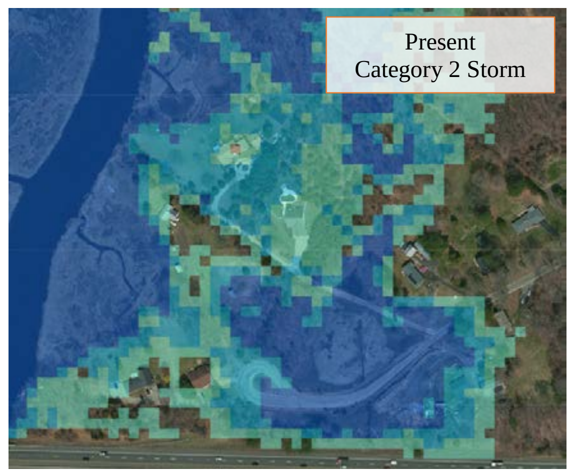
During meetings with Madison officials, a number of specific areas of interest were pointed out. These included Circle Beach, the Middle Beach Road revetment, the Madison Surf Club, the neighborhood south of Neck Road, and Green Hill Road and Place.

These and other specific areas are explored in further detail in this section.

Green Hill Road and Green Hill Place

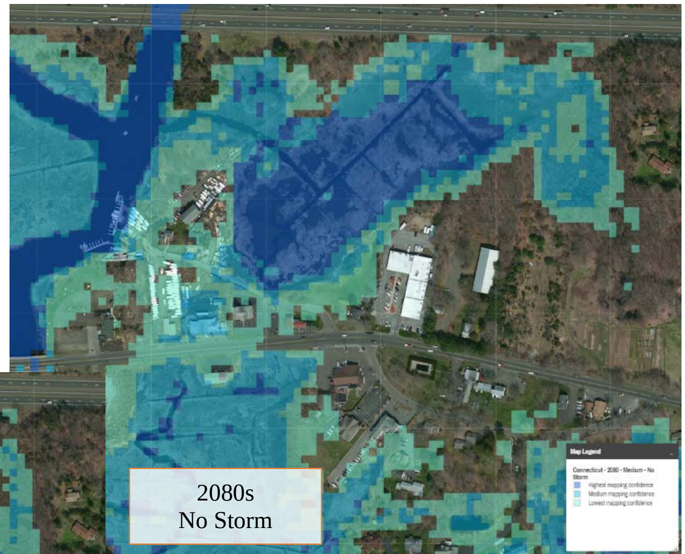
The western edge of Town around Old Post Road, Boston Post Road / State Route 1, Green Hill Place, and Green Hill Road, lies within the East River Floodplain. Green Hill Road, north of State Route 95, passes through a wetland on its way to 5 homes. Flooding of this wetland onto the road is projected to occur during non-storm conditions regularly as soon as the 2020s, although even through the 2080s there is not expected to be an overland connection to the East River. During a present-day Category 2 storm, both the road and many of the homes in this neighborhood will be flooded from overtopping of the East River.



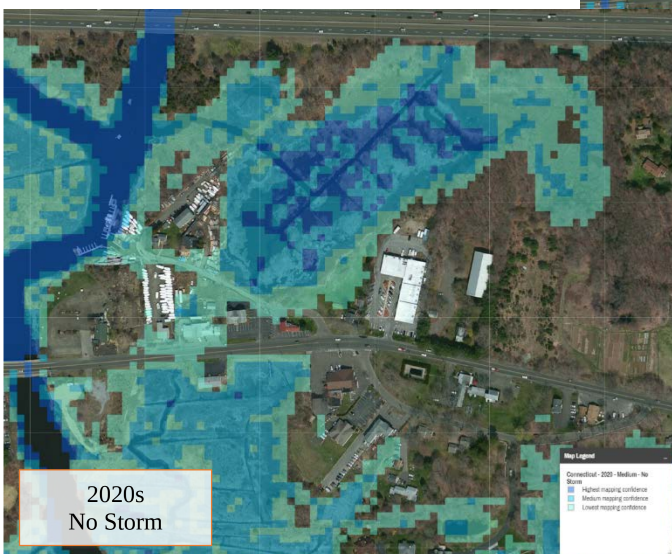


South of Route 95, State Route 1 / Boston Post Road and Green Hill Place are both projected to experience daily flooding by the 2020s. A number of businesses will also experience flooding under these conditions. The extent of flooding increases into the 2080s. This area houses East River Marine LLC, a water-dependent business.

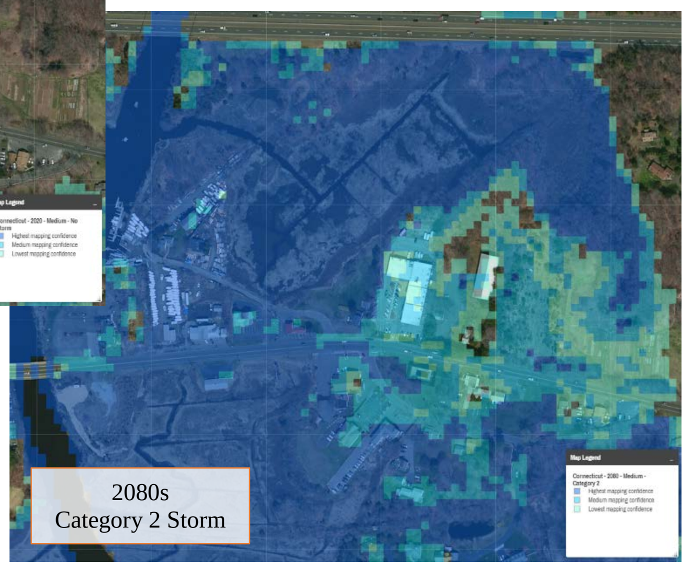
A Category 2 Hurricane, under present-day sea level, will flood other businesses to the east along Route 1. The inundation will abut Route 95 on both the north and south sides of the highway, but is not expected to overtop it.



2080s
No Storm



2020s
No Storm



2080s
Category 2 Storm

Standing Water off Route 1.

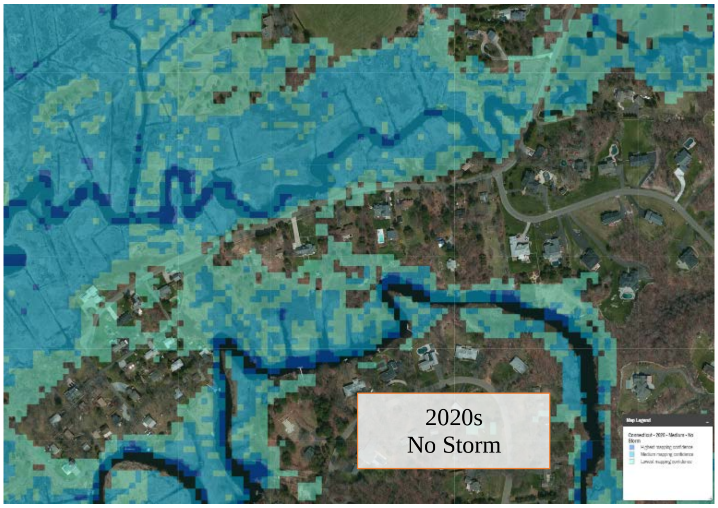
Garnet Park

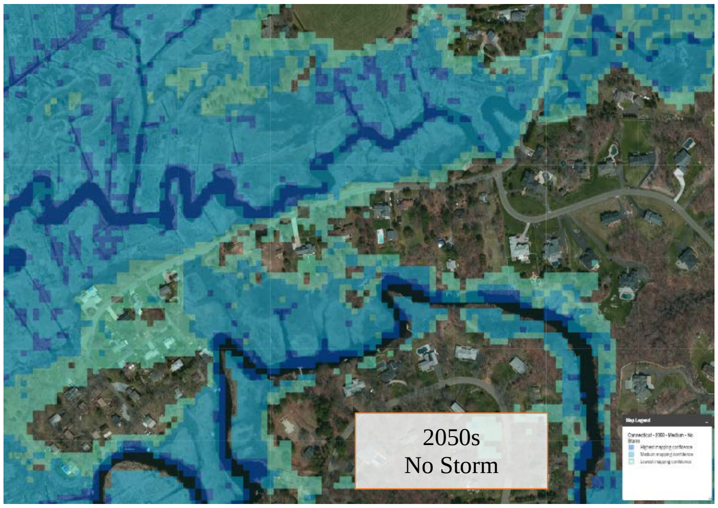
Garnet Park is a residential neighborhood west of Route 1, south of the railroad tracks, and already experiences nuisance flooding. Vulnerable homes here tend to already be elevated.

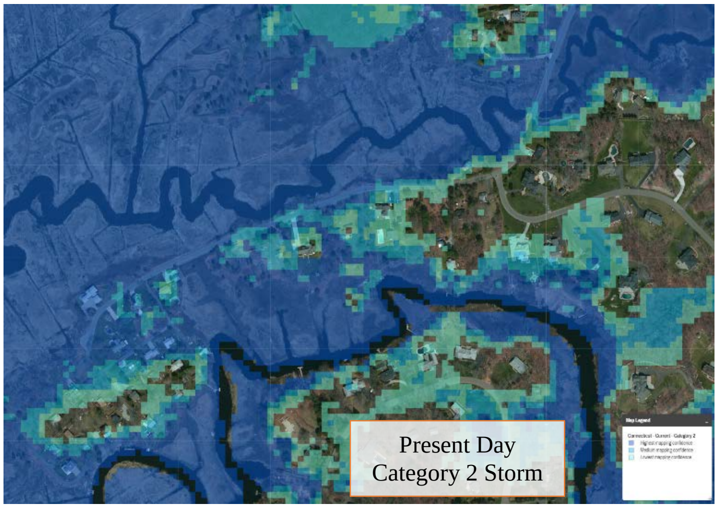
Under a medium sea level rise scenario, Garnet Park Road may be regularly overtopped by Baily Creek by the 2020s, isolating the entire neighborhood. Floodwaters from Baily Creek and Neck River may meet over Meadow Lane and Garnet Park Road. The westernmost section of the neighborhood – Canoe Road and Riverside Lane – will also likely experience daily inundation.

By the 2050s, daily inundation will affect most of Garnet Park Road, with two particularly vulnerable section at the Baily Creek crossing and just east of Meadow Lane. Arrowhead road would also be flooded regularly.

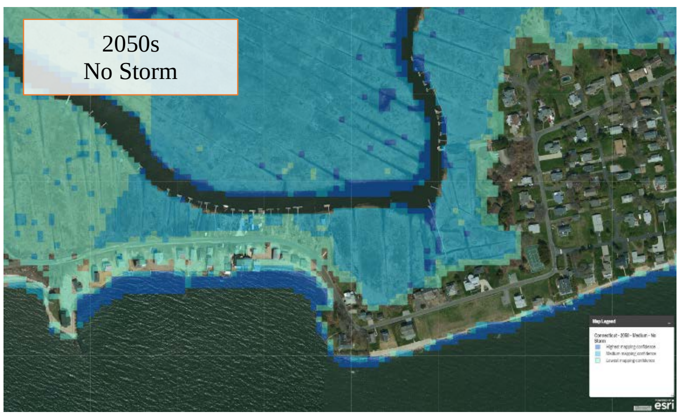
A Category 2 storm would cause widespread inundation of both the roads and the homes in this neighborhood, including Governors Way, further cutting off that neighborhood.







Circle Beach



Circle Beach lies at the southwest extent of Madison, on a narrow spit of low-elevation land deposited at the confluences of Neck River, East River, and Long Island Sound. Homes in this FEMA-mapped Velocity-Zone area are already elevated, and residents are accustomed to regular flooding. Homes are mostly on the southern side of the peninsula, where elevations are slightly higher. Daily flooding of all structures here can be expected by the 2050s.

East River Beach

The neighborhood between Ridgewood Avenue and Twin Coves Road, including the Mercy by the Sea retreat center, shows low vulnerability to daily high-tide inundation through TNC 2080s projections. Structures are built on higher ground and those on the shoreline are fronted by significant beaches. Some sections of the shoreline are rocky, but most can be expected to be susceptible to erosive forces. Low-lying wetlands may be affected by rising tides, but should not have a serious impact on nearby residences or roads.

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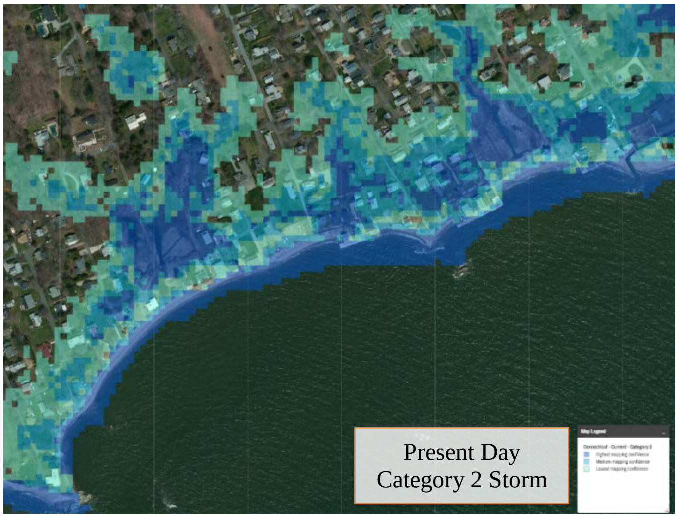
South of Neck Road / Smith Bay

East of Mercy by the Sea is a series of private roads extending south from Neck Road to Smith Bay. These roads, between Twin Coves Road and Shorelands Drive, are relatively densely settled residential areas that are relatively high in elevation and protected from inundation. However, the southern ends of all of these roads drop down, are typically lower in elevation than the beaches they lead to, and are protected from water and sand by bulkheads. Drainage problems are already apparent in these areas.

The end of Toffee Lane and Overshore Drive are particularly vulnerable, and may experience daily flooding by the 2020s. By the 2050s, daily high tide may also impact Pleasant View Avenue, Beach Avenue, Harbor Avenue, and Kelsey Place. A Category 2 storm under current conditions can be expected to inundate the southern edges of all of the roads in this neighborhood, and to impact over 70 homes.

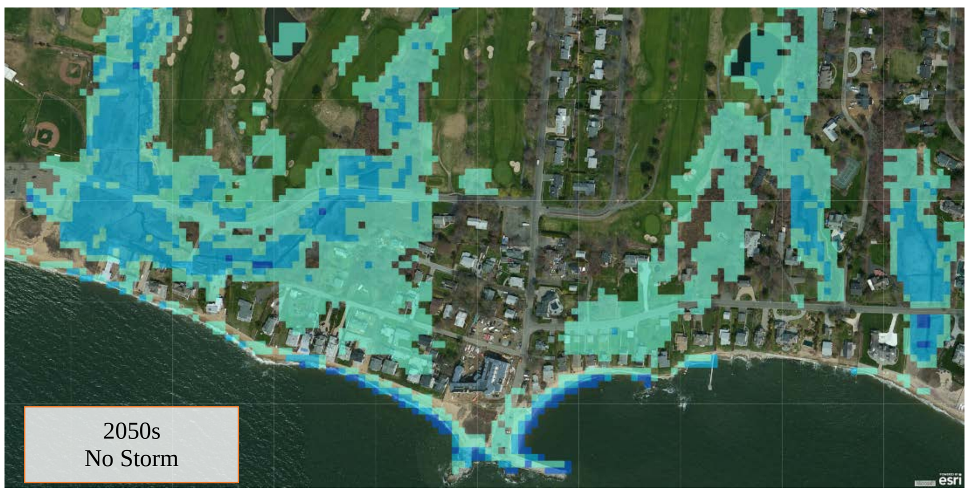


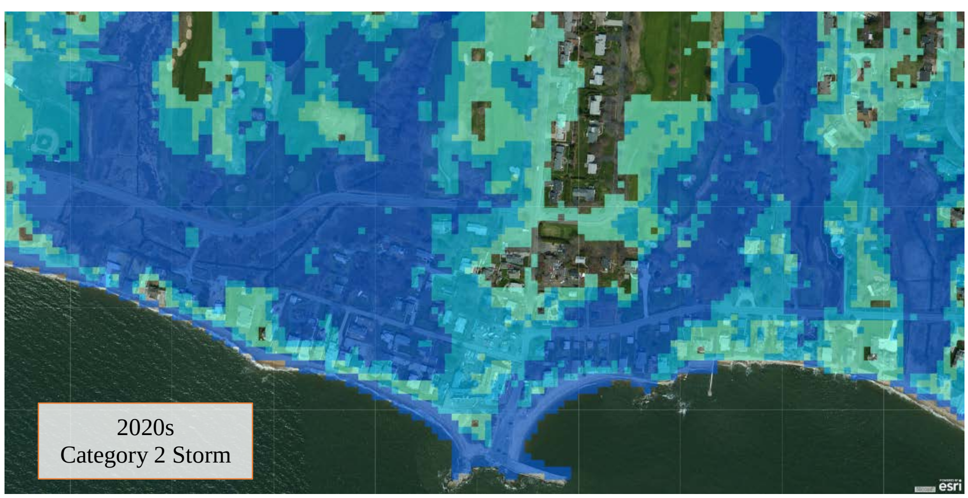
Surf Club Beach to West Wharf Beach

The Madison Surf Club is a Town park open to the public, and while it is susceptible to flooding from storms and sea level rise, its status as a park rather than a dense residential or commercial area means vulnerabilities are low. However, the neighborhood around West Wharf Beach, just to the east of the Surf Club, is vulnerable to flooding. During previous storm events, it has been observed that flooding of West Wharf Beach originated from water overtopping a washed-out dune at Surf Club Beach.

If seawater is able to overtop the relatively-higher elevation shoreline here, or if inland water is unable to drain successfully, Daily High Tide flooding may impact around seven homes and submerge parts of Surf Club Road, Holly Park Road, Parker Avenue, Flower Avenue, and Middle Beach Road West, by the 2020s. By the 2050s daily flooding will have spread considerably, impacting around 20 homes, and isolating as many as 25.

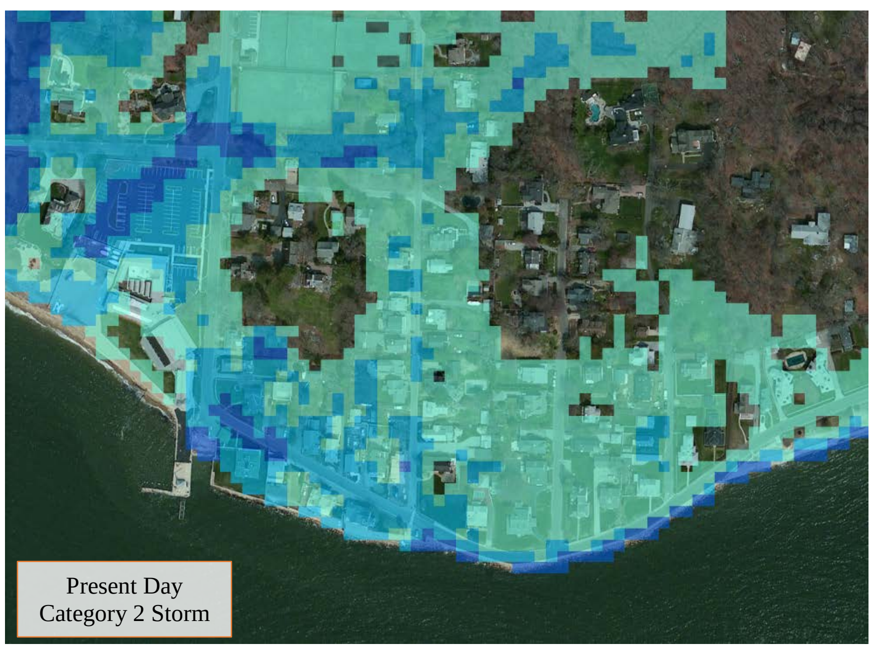
A present-day Category 2 storm would inundate most of this area, affecting around 80 structures and inundating all of the roads other than Cherry Lane. By the 2020s, such a storm would also flood Cherry Lane.





Middle Beach Road (Island to Park)

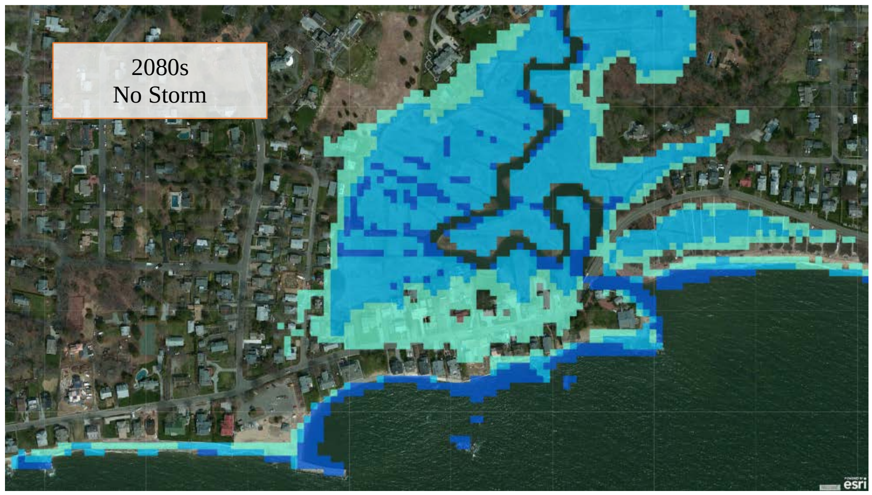
The western end of Middle Beach Road, just east of Middle Beach Road West, is constructed immediately at the edge of the water. The elevation is relatively high, and the road is protected by a stone revetment and a cement bulkhead. The road and perpendicular finger roads (Island, Tuxis, Gull Rock, and Park, are all projected to remain dry under future no-storm conditions. A present-day Category 2 storm would overtop Middle Beach Road, as well as Island Avenue from the west. Additionally, the road's location puts it at risk of undermining due to wave action. Failure of this road or of the southern part of Island Avenue risks isolating properties on Gull Rock Road and Park Avenue, and separating the Middle Beach neighborhood to the east from West Wharf Beach to the west.

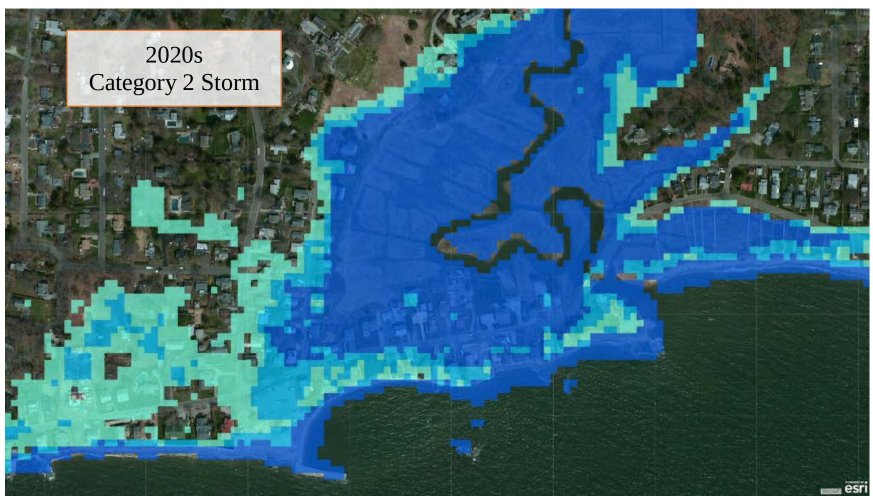


Seaview and East Wharf Beach

The main risks in the Seaview Beach and East Wharf Beach neighborhoods comes from flooding of Fence Creek. 2020s high tide flooding is projected to affect a dozen properties on the inland side of Middle Beach Road, as well as a couple of homes on the waterfront. By the 2080s, high tide water is projected to overtop both Middle Beach Road and Seaview Ave, connecting to high water from Long Island Sound. Only and additional three to five properties will be impacted, but flooding of the roads will hinder east-west travel and isolate homes. Waterfront homes are projected to remain above high waters, for the most part.

A present-day Category 2 Storm is projected to completely inundate the area west of the Fence Creek crossing, while those to the east should remain dry. Linden Lane will be flooded, as well as additional sections of Seaview Avenue. By the 2020s, a Category 2 Storm will also flood parts of East Wharf Road, increasing the risk of isolation locally.





Seaview Avenue and Pent Road Beach

This section of town is relatively densely developed, but homes are typically set back somewhat from the water's edge. No homes are located on the water-side of Seaview Avenue, removing vulnerability there, and the road itself is not projected to be impacted by high tide flooding through the 2080s. The rest of this area moving eastward also shows homes being at higher elevations and not susceptible to future high tides. A Category 2 storm, both presently and projected into future conditions, will impact some properties adjacent to Tom's Creek at Hammonasset State Park, as well as parts of Seaview Avenue. Based on TNC modeling, no other significant vulnerabilities exist here.

4.3 Wave Set-up and Run-up Hazards

Recall that wave setup and runup can increase the height of floodwater above the “stillwater” elevation, and that the extent of those effects are related to the topography of the coastline at a particular location. The TNC Coastal Resilience Mapping Portal is not able to capture these details, so further analysis was performed with wave modeling software used by FEMA and USACE, as described in section 2.3.3.

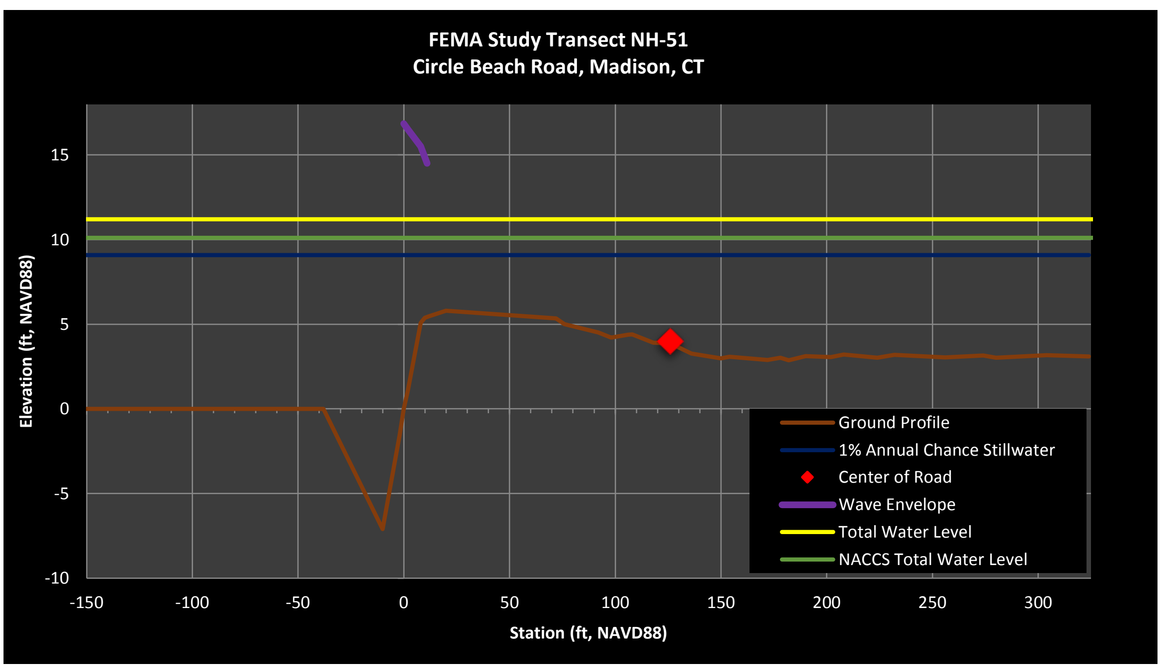
These modeling tools determine the effects of waves through analysis of topographic transects. There are four FEMA topographical transects along the Madison coastline that are at or near locations with significant concerns about coastal hazards. These are located at Circle Beach, south of Neck Road, at Middle Beach Road west of the revetment, and just east of Bayview Terrace.

Circle Beach Road (FEMA transect NH-51)

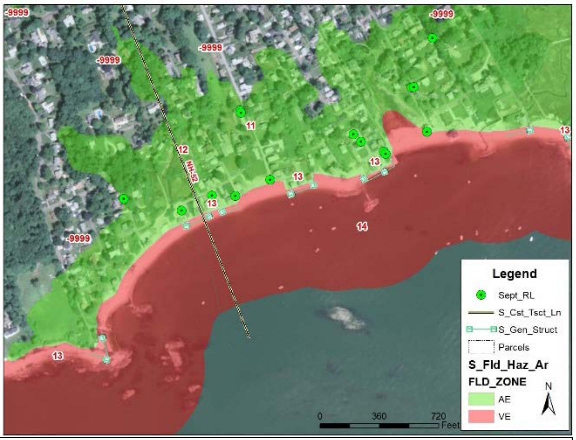
Circle Beach Road FEMA transect and DFIRM

This transect shows a horizontal offshore shelf, followed by a dip and then a steep rise in the ground profile on the Long-Island-Sound side of the peninsula, where there is a vertical concrete wall. The ground surface peaks at less than 6 feet elevation (NAVD88), followed by a gradual decline moving northward. According to both the FEMA coastal study and the NACCS model, even a 10% annual-chance storm event will lead to overtopping of the shoreline. Stillwater elevations during a storm surge and wave inundation are the driving hazards here.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Study	6.1	8.0	9.1	11.2	13.1
USACE NACCS (all values include wave setup)	7.4	9.1		10.1	13.0



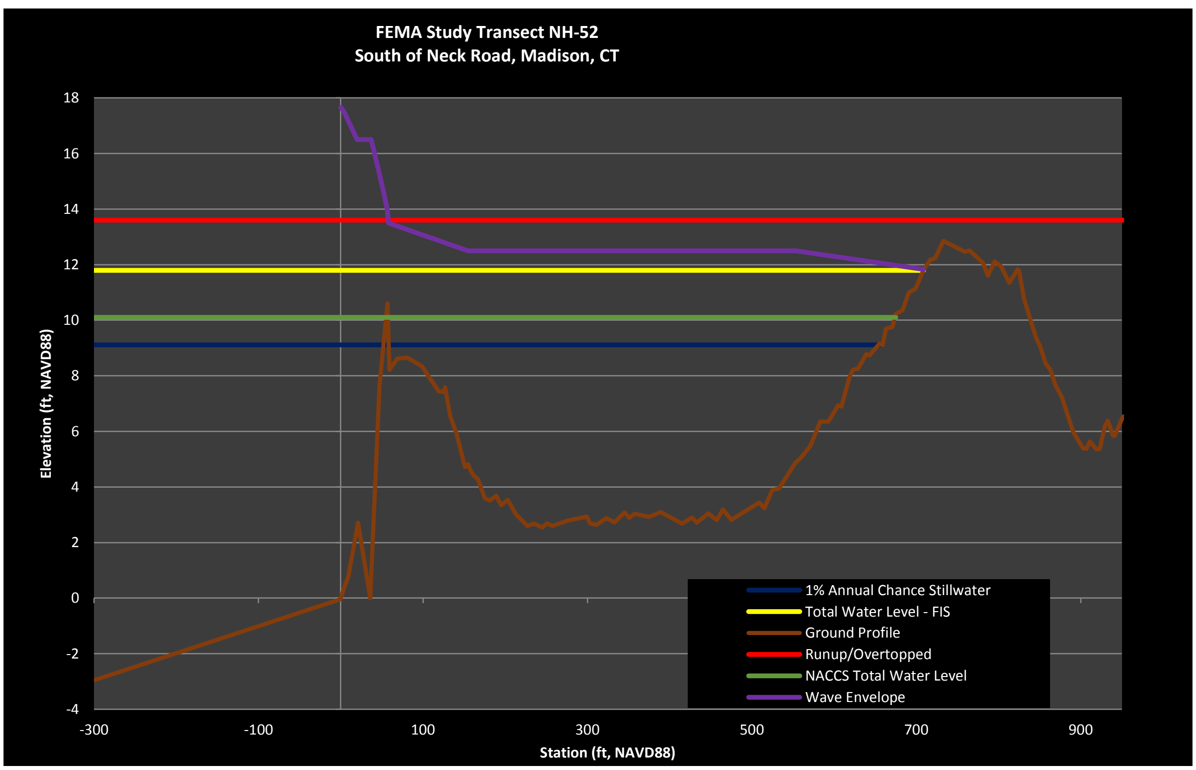
South of Neck Road (FEMA transect NH-52)



South of Neck Road FEMA transect and DFIRM

The transect at this site reflects a sandy beach backed by a vertical, 10.1-foot high (NAVD88) concrete wall. This wall protects a property sitting at around 8.3 feet elevation. Behind that is a low-elevation wetland, backed by a higher (12.8 foot) mound with a home on top. The NACCS 1% annual chance storm total water level is 10.1 feet here, and so just barely matched by the protective wall. The FEMA FIS model, however, shows total water level overtopping the wall and the property, and the wetland, at 11.8 feet. Wave action and runup increases water elevations to 13.6 or even 17.5 feet by the shoreline.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Study	6.1	8.0	9.1	11.8	13.3
USACE NACCS (all values include wave setup)	7.4	9.1		10.1	13.0

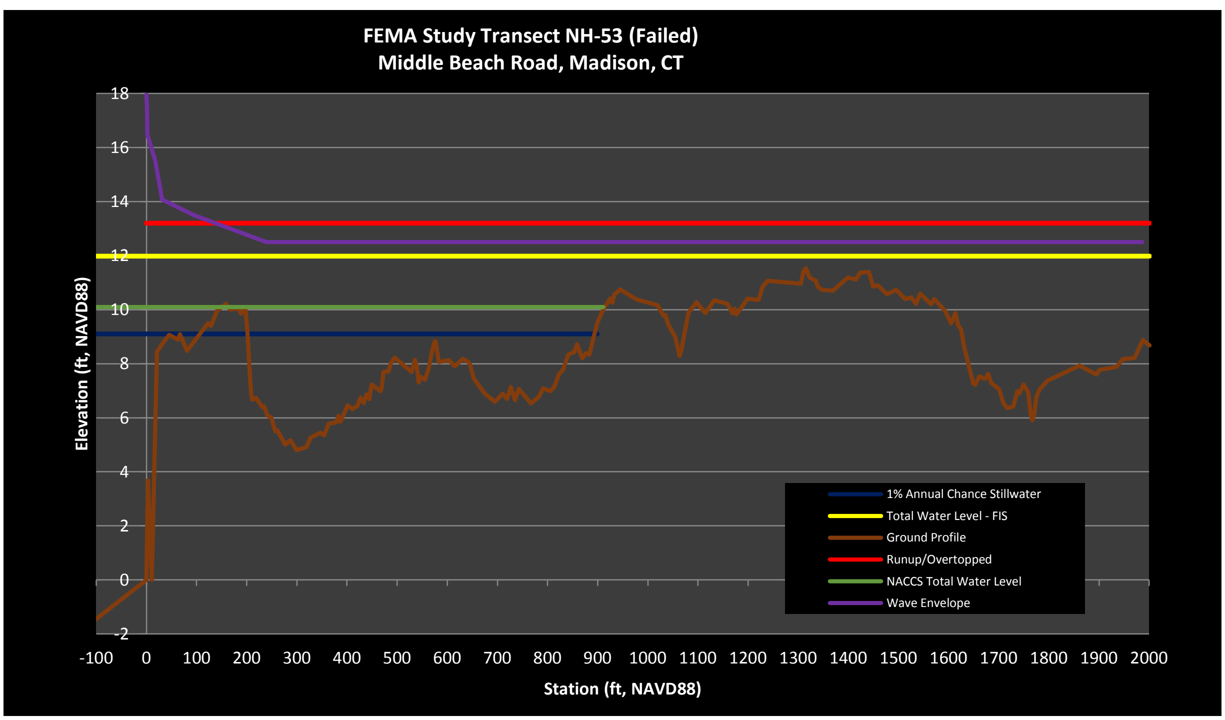


Middle Beach Road West (FEMA transect NH-53)

Middle Beach Road West FEMA transect and DFIRM

This site has a concrete wall protecting a property, with Middle Beach Road West inland. The transect has a steep southward slope, an elevated area between 9 and 10 feet NAVD88, followed by a drop-off to the road, which lies just below 7 feet NAVD88. The models show wave set-up during a 1% annual-chance storm reaching 10.1 to 12 feet elevation, overtopping the wall and the elevated property, and inundating the road behind it. Inland areas continue to be at elevations below the FIS-modeled Total Water Level of 12.5 feet, and wave action and runup behaviors make the effective flood depths even greater. The ground level doesn't rise above modeled flood elevations until near Route 1.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Study	6.1	7.9	9.1	12.0	13.5
USACE NACCS (all values include wave setup)	7.4	9.1		10.1	13.0

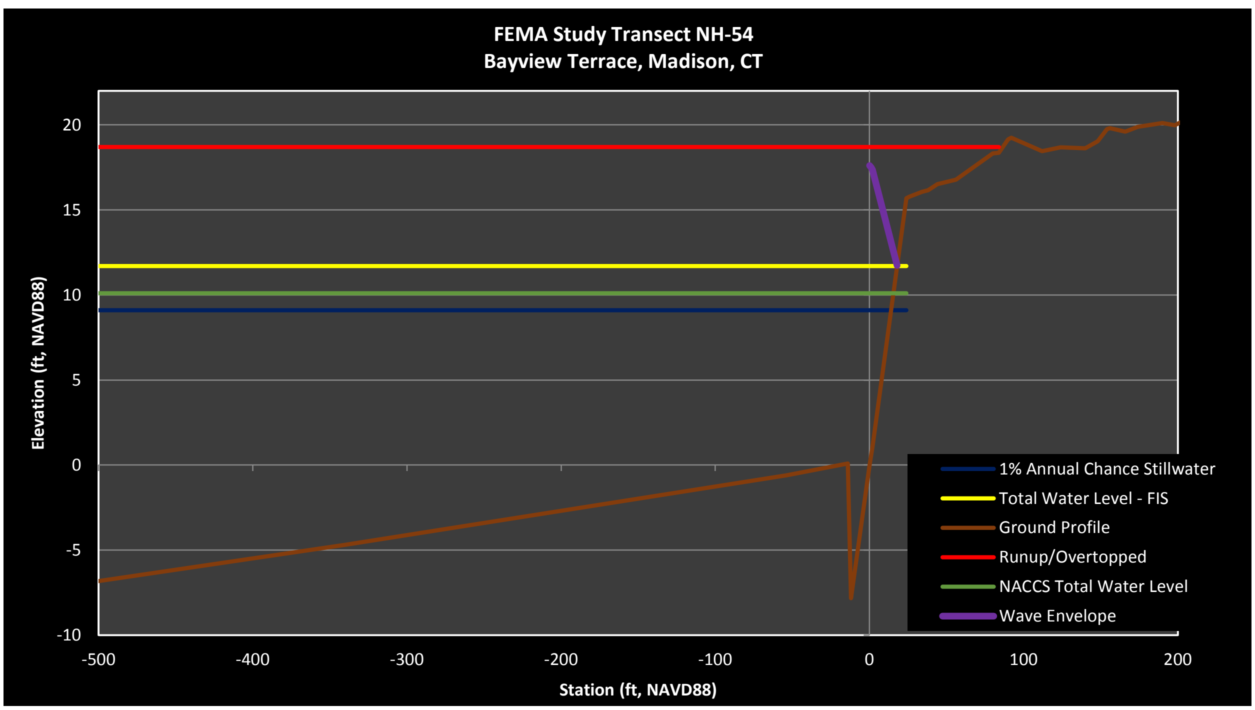


Bayview Terrace

Middle Beach Road West FEMA transect and DFIRM

A 10 foot concrete bulkhead supports a series of properties here that extend seaward about 50 feet compared to the beach-fronted property immediately westward. This steepening of the shoreline has a significant impact on flood elevations, increasing 1% annual-chance storm sea level from 13 feet to the west to 19 feet, including wave setup and runup. This added elevation overtops the bulkhead, with wave run-up – rather than surge stillwater or wave set-up – being the dominating force.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Study	5.9	7.9	9.1	11.7	13.7
USACE NACCS (all values include wave setup)	7.4	9.1		10.1	13.0



4.4 Vulnerabilities from Wind

Wind is another coastal hazard, and one about which residents have expressed concern. Hazards include direct damage to a property, secondary damage from windblown debris, and loss of infrastructure functioning due to downed powerlines or other related impacts.

Wind hazards tend to be greater where structures are not protected by topography, vegetation, or other structures. This condition characterizes shorefront properties. Hazards can be compounded by the proximity of poorly-designed structures or other debris sources. Additionally, the severity and frequency of storms is expected to increase in the future as climate continues to change, which will be reflected in increasing risk presented by high winds. Detailed analysis of wind patterns to determine specific areas of high vulnerability is beyond the scope of this project. For the purposes of this plan, wind hazards are assumed to be nearly uniform along Madison's coast. It is important to note, though, that properties constructed on high elevation shorelines may be protected from inundation, but still be vulnerable to wind effects.

The best way to protect a home or business from wind hazards is to ensure they are built to highest possible code. The best way to protect the community is to ensure such codes are enforced uniformly to prevent the secondary effects caused by damaged homes providing wind-blown debris.

5 Conclusion

Madison's coastal neighborhoods are diverse and each will be faced with a combination of vulnerabilities with sea level rise and the increased incidence and severity of coastal storms. Risks stillwater inundation, wave setup and runup, and erosion. Coastal communities such as Madison are also susceptible to wind related hazards.

Among the greatest threats to Madison's shoreline are undermining of higher-elevation waterfront land, inundation of low-elevation houses, and various threats to private septic systems. There are not many areas of Town that risk complete isolation under high-water conditions, nor is there public wastewater infrastructure in need of protection. The Green Hill Place neighborhood is the only significant commercial area vulnerable to future sea level change and storms, with the other high risk areas – Green Hill Road, Garnet Park, Circle Beach, Smith Bay, Surf Club Beach and Seaview – being mostly residential.

Risks are anticipated to increase over time due to sea level rise and climate change, and may be compounded by continuing trends of increased development and population growth. High winds during storm events, which are also predicted to increase with climate change, may put further pressure on vulnerable coastal communities.

To build resiliency to increasing hazards, Madison should review the most feasible and prudent alternatives for adaptation.

Appendix C
Review of Options for Coastal Resilience

COMMUNITY COASTAL RESILIENCE PLAN
TOWN OF MADISON, CONNECTICUT

Review of Options for Coastal Resilience

1 Evolution of Options for Coastal Resilience

Coastal adaptation strategies include both planning (nonstructural) and structural-related modifications. Nonstructural measures include preparedness, emergency response, retreat, and regulatory and financial measures to reduce risk. Structural measures include dikes, seawalls, groins, jetties, temporary flood barriers, and the like. Ideally, the measures that are taken should be robust enough to provide adequate protection and flexible enough to allow them to be adapted to changing future conditions. Such robustness and flexibility typically require a combinations of methods rather than one solution.

Structural measures can be site-specific, "neighborhood-scale," or large-scale structures that protect multiple square miles of infrastructure. Site-specific measures pertain to floodproofing a specific structure on a case-by-case basis. Neighborhood-scale measures apply to a specific group of buildings that are adjacent to each other. Large-scale structures might include large dike and levee systems or tide gates that can prevent tidal surge from moving upstream.

1.1 The IPCC Approach

The Intergovernmental Panel on Climate Change (IPCC) published the landmark paper "Strategies for Adaptation to Sea Level Rise" in 1990. This was one of the earliest reports to list the three traditional categories of adaptation "to protect human life and property." The following descriptions of these three types of adaptation are taken from the report:

- Retreat involves abandonment of the coastal zone with no effort to protect the land from the sea. This choice can be motivated by excessive economic or environmental impacts of protection. In extreme cases, entire areas may be abandoned.
- Accommodation means that people continue to use the land at risk but do not attempt to prevent the land from being flooded. This option includes erecting emergency flood shelters, elevating buildings and roads, or growing flood- or salt-tolerant crops.
- Protection can involve building structures such as sea walls and dikes, restoring dunes, and planting vegetation, to protect the land from the sea so that existing uses can continue.

1.2 The NOAA Approach

In 2010, the NOAA Office of Ocean and Coastal Resource Management published the manual *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. NOAA's seven categories of "Climate Change Adaptation Measures" and their subcategories are:

1. *Impact Identification and Assessment*
- Research and Data Collection
- Monitoring

- Modeling and Mapping

2. *Awareness and Assistance*
- Outreach and Education
- Real Estate Disclosure
- Financial and Technical Assistance

3. *Growth and Development Management*
- Zoning – regulate land use, development, building features, setbacks, shore protection, etc.
- Redevelopment Restrictions – provide safer options in the wake of property loss or damage.
- Conservation Easements – legal agreement with a landowner to restrict development.
- Compact Community Design – high density development creates opportunities to guide development away from sensitive and hazard-prone areas.

4. *Loss Reduction*
- Acquisition, Demolition, and Relocation – the most effective way to reduce losses.
- Setbacks – keep structures away from a property's most vulnerable areas.
- Building Codes – regulations to improve the ability of structures to withstand hazard events.
- Retrofitting
- Infrastructure Protection
- Shore Protection Structures – protect existing development, allowing it to stay in place.

5. *Shoreline Management*
- Regulation and Removal of Shore Protection Structures – to protect the natural shoreline.
- Rolling Easements – as the sea rises, the easement moves or "rolls" landward.
- Living Shorelines – stabilization techniques that use plantings and organic materials.
- Beach Nourishment
- Dune Management
- Sediment Management – placing, trapping, or diverting sediment.

6. *Coastal Ecosystem Management*
- Ecological Buffer Zones – provide a transition zone between a resource and human activity.
- Open Space Preservation and Conservation
- Ecosystem Protection and Maintenance – wetland migration is an important aspect of this.
- Ecosystem Restoration, Creation, and Enhancement

7. *Water Resource Management and Protection*
- Stormwater Management
- Water Supply Management

1.3 Current Approaches Including Green Infrastructure and Gray/Green Hybrids

In the context of natural and green infrastructure (see text box below), opportunities to reduce risks may include environmentally-friendly beach stabilization, restoring dunes, restoring tidal wetlands, oyster reef creation/enhancement, improving the hydrology of coastal areas, improving/removing infrastructure, and living shoreline techniques. In some cases, a combination of green and hardened infrastructure ("hybrid approaches") may be appropriate.

There have been numerous developments in the State of Connecticut over the past three years to address concerns of shoreline stabilization in a changing environment and climate. Public Act 12-101 set forth initiatives to address sea level rise, revise the regulatory procedures applicable to shoreline protection, and promote living shorelines. As a component of the Act, two terms which have been integral to the interpretation of Coastal Management Act (CMA) flood and erosion control structure policies were defined and expanded for the first time:

1. *"For the purposes of this section, "**feasible, less environmentally damaging alternative**" includes, but is not limited to, relocation of an inhabited structure to a landward location, elevation of an inhabited structure, restoration or creation of a dune or vegetated slope, or living shorelines techniques utilizing a variety of structural and organic materials, such as tidal wetland plants, submerged aquatic vegetation, coir fiber logs, sand fill and stone to provide shoreline protection and maintain or restore costal resources and habitat."*

2. *"**Reasonable mitigation measures and techniques**" includes, but is not limited to, provisions for upland migration of on-site tidal wetlands, replenishment of the littoral system and the public beach with suitable sediment at a frequency and rate equivalent to the sediment removed from the site as a result of the proposed structural solution, or on-site or off-site removal of existing shoreline flood and erosion control structures from public or private shoreline property to the same or greater extent as the area of shoreline impacted by the proposed structural solution."* [CGS section 22a-92, as amended].

Typical Definitions of Green Infrastructure (GI)

EPA: GI uses vegetation, soils, and natural processes to manage water and create healthier urban environments.

American Rivers: GI is an approach to water management that protects, restores, or mimics the natural water cycle. GI is effective, economical, and enhances community safety and quality of life. GI incorporates both the natural environment and engineered systems to provide clean water, conserve ecosystem values and functions, and provide a wide array of benefits to people and wildlife. GI solutions can be applied on different scales, from the house or building level, to the broader landscape level. On the local level, GI practices include rain gardens, permeable pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting systems.

The Nature Conservancy: GI solutions are planned and managed natural and semi-natural systems which can provide more categories of benefits, when compared to traditional gray infrastructure. GI solutions can enhance or even replace a functionality that is traditionally provided by man-made structures. GI solutions aim to build upon the success that nature has had in evolving systems that are inherently sustainable and resilient. GI solutions employ ecosystem services to create more resource efficient systems involving water, air and land use.

These changes have introduced the application of living shoreline approaches. Due to potential regulatory implications of what the definition of a living shoreline might entail, the Connecticut Department of Energy and Environmental Protection (DEEP) has developed a working definition of "living shoreline" through research of other coastal states, NOAA, and UConn. The current working definition of living shorelines according to CTDEEP is:

"A shoreline erosion control management practice which also restores, enhances, maintains or creates natural coastal or riparian habitat, functions and processes. Coastal and riparian habitats include but are not limited to intertidal flats, tidal marsh, beach/dune systems, and bluffs. Living shorelines may include structural features that are combined with natural components to attenuate wave energy and currents."

With the legislative and regulatory changes coupled with the influx of funding after Hurricane Sandy, the time is ripe in Connecticut considering natural and green infrastructure risk reduction methods along the shoreline. This may include re-evaluating some traditionally controversial techniques such as creating beaches, dunes, and tidal marsh front where they are not currently present due to decades of erosion.

Although living shorelines can broadly include tidal marshes, beaches, dunes, bioengineered coastal banks, and shellfish reefs, this memo will address most of these approaches by name (beaches, dunes, bioengineered coastal banks, and shellfish reefs) and reserve the term "living shoreline" for a created or restored tidal marsh.

1.4 Approach Summary

Elements of *protection, retreat*, and *accommodation* are found in several of the NOAA categories and subcategories of adaptation. For example, Growth and Development Management actions can be used to manage retreat or accommodation whereas Shoreline Management may include methods of protection as well as removing protection. NOAA notes that these adaptation measures are organized into categories that describe their primary purpose but, in many cases, they serve multiple purposes and could fit into multiple categories (e.g., acquisition could fit under Growth and Development Management, Coastal and Marine Ecosystem Management, and Shoreline Management in addition to Loss Reduction).

Preservation of the economic, aesthetic, and ecological values of natural coastline features and processes can be incorporated into all of the adaptation approaches discussed above. In fact, often such features provide protection themselves. Green infrastructure and other environmentally friendly approaches to adaptation provide security to communities while maintaining or enhancing the natural systems that attracted people to the coastline in the first place.

The EPA publication "Rolling Easements" (Titus, 2011) provides the most current comprehensive description of rolling easements[1] and all the adaptation measures found in this broad collection of techniques. As noted by Titus in this publication, accommodation is viable in many communities, but no longer considered sustainable for the long term; eventually protection or retreat will be the default. This is an important concept because communities will need to understand that there is a limit to how far into the future accommodation will be practical.

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[1] The term "rolling easements" encompasses a broad set of tools that can be used ensure that wetlands and beaches are able to naturally migrate inland without being stopped by shore protections or development. The term is covered in detail in section 2.4.4.

Many of the recent and current trends in adaptation planning (circa 2008 to the present) appear to be taking this into account.

2 Specific Adaptation Options

The following is a list of the most common and effective adaptation measures that are available to a typical Connecticut coastal municipality. There may be additional options not listed here. Measures may fit into many of the categories listed previously, or into only one. Measures specifically relevant to Madison are described in Section 3.

2.1 Protective Infrastructure

2.1.1 Hard Shoreline Protection

Hard shoreline protection generally includes long-lasting structures parallel to the shoreline:

- Seawalls are engineered barriers that protect land from waves and flooding
- Levees are engineered berms that protect land from flooding
- Bulkheads are engineered structures that retain soil and reduce erosion
- Revetments protect against erosion by dissipating wave energy. They may be constructed of piles of large stones (riprap), mesh cages of smaller rocks (gabions), or other materials.

Additional hard protections that are not necessarily parallel to the shoreline or that are parallel but offshore may include jetties, groins, breakwaters, and the like. These reduce the energy of wave and currents, often for the purpose of managing sediment.

Hard coastal structures will be a part of Connecticut's developed shorefront many years into the future. Hard structures will protect many miles of shoreline roads, the State's numerous water-dependent uses, and many thousands of private properties. While the regulatory climate will only rarely allow the construction of new hard structures, existing structures will need to be repaired or replaced as needed. Modifications may be prudent in some cases. However, opportunities for natural and green infrastructure are often negligible in these settings. Likewise, hybrid solutions are unlikely to be pursued. Municipalities and property owners will continue to choose the methods that have been used for decades to define the edge of the shoreline, prevent erosion, and control wave energy.

2.1.2 Soft Shoreline Protection

Soft shoreline protection aims to defend against inundation and wave power through management of beach sediment and dunes.

- Beach Replenishment involves importing sand to an eroding or eroded beach from sediment-rich areas, such as a harbor undergoing dredging. The slope and width of a beach affects wave setup and runup, and can have a direct impact on flood elevations. Overall, beaches can reduce flood risks and erosion hazards while creating public recreation opportunities, aesthetic value, and in the right conditions support unique habitats (climatetechwiki.org). Unlike hard shoreline protection measure, beach replenishment avoids addition of potentially dangerous hard debris to the high energy coastal area.

Almost every shoreline municipality in Connecticut has at least one managed beach that is periodically nourished with sand. Examples include Short Beach in Stratford, Laurel Beach in Milford, Ocean Avenue Beach in West Haven, and Hammonasset Beach in Madison. Likewise, almost every shoreline municipality has a handful of beaches where nourishment is desired by municipal officials and/or residents.

- Dune Management stabilizes these natural flood barriers to protect against surges while maintaining important natural resources. FEMA describes dunes as "important first lines of defense against coastal storms" that can "reduce losses to inland coastal development." The Lake Huron Centre for Coastal Conservation lists the benefits of dunes as including shore protection, water purification, biological diversity, erosion control, and acting as a source of sediment for natural beach replenishment.

2.1.3 Living Shorelines

Living shorelines protect from erosion while enhancing habitat and water quality and preserving the natural processes and connections between riparian, intertidal, and subaqueous areas. Projects may utilize a variety of structural and organic materials, including, but not limited to, tidal wetland plants, submerged aquatic vegetation, coir fiber logs, sand fill and stone. Utilization of this green infrastructure also supports local ecosystems and improves the aesthetic and recreational value of sites.

There are two basic types of living shoreline that meet this definition:

- Hybrid techniques incorporate non-structural approaches for erosion control in combination with more traditional approaches, such as a rock structure, to support vegetation growth. Hybrid techniques are typically applied in areas of higher wave energy.
- Non-structural techniques use natural elements such as vegetation, fill, and coir logs, to trap sediment and reduce wave energy.

Hybrid Techniques

Coastal banks in Connecticut are not protected in a continuous uninterrupted manner. There are many locations where protection is absent and erosion is taking place. Some erosion may be tolerable, providing sand for the Town's beaches. However, there are many locations where the unprotected banks occupy gaps in otherwise protected shorefronts. Because hard structures are present updrift and downdrift from these gaps, they may be eroding at a different pace than they would naturally. Additionally, when a structure does fail, it leaves a gaping hole that can open the previously protected area to rapid erosion.

Unprotected coastal banks that are moderately eroding could be left untouched. However, unprotected coastal banks that are significantly eroding may represent some of our most interesting opportunities. Bioengineering approaches could be considered for these settings, incorporating native vegetation and local earthen materials whenever possible. Incorporation of bioengineered banks into shoreline protection methods could reduce, rather than deflect, wave energy in some areas, thereby reducing deterioration of adjacent structures. Additionally, DEEP is more likely to authorize hybrid or bioengineered methods than new hard structures.

Non-Structural Techniques
Non-structural living shorelines focus on trapping sediment and supporting ecosystems. Wetlands or reefs created using these methods may provide an area with protection from waves or erosion, but typically are not used to protect a specific asset such as a structure or road.

Non-structural living shorelines include:

- Created Wetlands – structures, sediment, and vegetation installed along the shoreline in shallow areas to promote wetland habitat
- Artificial Reefs – installation of hard structures offshore to promote growth of reef-building marine life

One example of a living shoreline that has been constructed in Connecticut in the last few years is a reef ball project near Lords Point in Stratford. The reef ball rows were installed in the intertidal zone and are believed to be trapping sediment on the landward side of the intertidal zone, thus supporting new marsh grasses.

2.2 Community Infrastructure Protection

2.2.1 Stormwater Management

Low lying storm drain inlets sometimes "surcharge" (have seawater flow backwards through them) during high tide events. This can lead to flooding in areas that otherwise would be protected from coastal waters. It is important to note that the challenge of preventing flooding in low-lying coastal areas includes preventing the inflow of seawater as well as enabling the drainage of runoff flowing downhill from upland areas. This challenge is exacerbated by high sea-levels that prevent simpler "gravity flow" methods of drainage. Reducing this type of flood risk requires either: (a) pumping the stormwater out with enough force to overcome elevated seawater, or b) preventing the seawater from entering the system. Stormwater pump stations are feasible (and becoming more common with increasing sea levels) but are costly to construct and operate, and represent an ongoing maintenance burden. Preventing seawater from entering the gravity system reduces flood frequency with limited capital and operating expenses.

One step in preventing seawater infiltration into storm drainage systems is the installation of gaskets at pipe joints to make the pipes water-tight. Gasketed piping is common in water supply and sewer systems and readily available on the market.

Perhaps more important is placing a flap gate or duck bill structure on the pipe outlet. A traditional flap gates is shown below. These are typically made of steel or aluminum and open under the force of water building up in the pipe behind the gate. A duck bill is shown to the right. Either device can work for Madison.

Stormwater Flap Gate

Duck Bill Flap Gate

2.2.2 Roads and Transportation

Roadway alterations may include elevation, hardening, flood-resistant paving, abandonment, reevaluation of emergency routes, and developing alternative egress. These are described below.

- Roadway Elevation – ensures viability despite rising flood levels. While a practical approach, private properties often remain at lower, flood-prone elevations. A higher road surface can then impede drainage of floodwaters off properties.
- Roadway Hardening – strengthens coastal roads to prevent against erosion and undercutting. This is essentially a bank protection or shoreline protection method utilized specifically at a road. Specific measures are summarized in section 2.1.
- Flood-resistant Paving –roads that are regularly inundated may be made resistant to the damages caused by flooding by utilizing flood-resistant materials and construction methods.
- Roadway Abandonment – it may be acceptable to abandon some roads as the cost of elevation or maintenance becomes excessive.
- Reevaluation of Emergency Access – some emergency routes may be abandoned (without abandoning the associated road), and alternate, non-vulnerable routes determined.
- Alternative Egress – likely developed in connection with road abandonment or reevaluation of emergency access. New roads would have to be built along undeveloped right-of-ways.

2.2.3 Water and Wastewater

Some coastal communities will face serious problems related to water supply and sanitary wastewater disposal as sea level rises and groundwater rises accordingly. Adaptation methods may include retrofits to pumping stations, hardening of Wastewater Treatment Plants, and extension of sewer and water systems.

Water Supply Adaptation:
Madison is served by the Connecticut Water Company, and its water is sourced from surface reservoirs that are not vulnerable to the effects of rising seas and saltwater intrusion. The positive pressure maintained in a water system will prevent salt water from entering pipes in low elevation areas where that may be a concern. Pipes located in areas susceptible to erosion are vulnerable to ongoing wave action, increasing risks with higher water levels in the future, and storm surges. Adaptation options are limited to bank protection methods (listed in section 2.1) and relocation of pipes inland.

Areas that may still rely on individual private wells are not necessarily vulnerable to damage to water pipe infrastructure, but are at risk of saltwater intrusion into the groundwater source, or overtopping of wellheads during flood events.

Private water supply adaptation options include:

- Individual Water Treatment Systems
- Development of Community Systems – in underserved locations
- Extension of Public Water System – to properties not currently served
- Vacating Property – in extreme situations where properties may be rendered unusable

Wastewater Treatment Adaptation:
Madison is involved in a sewer avoidance program, and therefore the entire town is served by septic systems. All coastal properties in Madison have septic systems that are vulnerable to sea level rise and coastal hazards.

Adaptation methods may include construction of a new septic system, retrofits to an existing system, development of a community system, or – in extreme cases – vacating properties.

- Elevation: will typically require building a mound of fill material over the new system, and the use of pumping equipment because gravity drainage will no longer be possible. Engineered erosion control techniques may be needed to protect the mound.
- Relocation: a suitable site for a new system may be found elsewhere on a property. New systems should be constructed as far from the water and tidal marshes as possible and a minimum of 50 feet from the high tide line or edge of tidal marsh to allow for the increase in sea level rise and for marsh advancement. Leaching fields can be installed on an adjacent property with a sanitary easement approved by both property owners and the Commissioner of Public Health. The sanitary system would require a pump chamber to move the effluent to the leaching fields.
- Advanced Treatment Systems: property owners could attempt to install and maintain advanced sewage treatment facilities. While this may be feasible from an engineering

viewpoint, it is unlikely that the average homeowner would have the time and financial resources available to constantly maintain these treatment systems in working order. It is possible that larger commercial properties such as hotels or retreat centers could implement such a system.

- Alternative Treatment Systems: incinerating toilets, composting toilets, or heat-assisted composting toilets, can replace septic systems. Waste removed from composting toilets must be disposed of using methods approved by the local director of health.
- Waste Removal: effluent holding tanks can be regularly pumped out and the wastewater delivered to a sewage treatment plant elsewhere in Connecticut.
- Community Wastewater Systems: Community systems are strictly regulated by the Connecticut Department of Energy and Environmental Protection (for flows exceeding 5,000 gallons per day [gpd]) or the Department of Public Health (for flows less than 5,000 gpd); along with the local health department. It would be difficult to site sanitary systems in some shoreline neighborhoods with the appropriate sanitary setbacks to wells and coastal resources while maintaining a reasonably close distance to the neighborhoods in order to keep costs to a minimum.

2.2.4 Electricity

The greatest threats to the electrical grid associated with increased coastal hazards are wind-related. Additionally, increased incidence and duration of flooding can reduce the capability of Eversource to respond to outages caused by downed wires and blown transformers. It is also possible that increased flooding and sea level rise can affect low-lying or buried electrical lines directly.

Adaptation options that may strengthen Madison’s electrical grid include:

- Improved maintenance of trees and electric poles to lower risk of power lines being “downed”
- Burial of electrical lines to completely remove vulnerability to wind
- Flood-proofing buried electrical lines
- Development of “Microgrids” that allow areas or neighborhoods to power themselves in the event of a system-wide failure
- Installation of backup generators at municipal buildings, businesses, and residences
- Improved planning to lower recovery time

Loss of power has been noted as an important concern to many residents at meetings and through the online survey. Strengthening Madison’s power distribution grid would improve its resiliency to many hazards beyond those associated with its coastal location. Careful consideration of adaptation options is strongly recommended.

2.3 Property Protection

The National Flood Proofing Committee (NFPC) defines floodproofing as "any combination of structural or nonstructural changes or adjustments incorporated in the design, construction, or alteration of individual structures or properties that will reduce flood damages." Proper floodproofing measures can reduce flood vulnerability, however the only way to entirely prevent damage is to relocate the structures (i.e., retreat).

Floodproofing measures permitted for residential structures are more limited than those available to commercial buildings. The following section summarizes approaches to floodproofing that may be used individually or in combination for most commercial buildings. The only options available to residences are relocation or elevation.

2.3.1 Structure and/or Critical System Elevation

Elevating a structure requires raising the lowest floor so that it is above the target design level. Almost any structurally sound small building can be elevated. Design standards vary in FEMA V-zones vs. AE-zones. The process becomes more difficult and virtually impossible with a large building that has slab on grade, is constructed out of block or brick, has multiple stories, or is connected to adjacent buildings. Elevation can also create unattractive and hard to manage areas below the buildings. Elevation has gained much wider acceptance in recent years as a means of managing coastal buildings, particularly in residential areas. In commercial buildings, elevation to more than a few feet above street level makes for uninviting and hard to access retail space, so its viability is somewhat limited.

Elevation is the only measure, other than relocation, that can be used to bring a substantially damaged or substantially improved residential structure into compliance with the community's floodplain management ordinance. It is also permitted in FEMA-mapped velocity zones.

2.3.2 Wet Floodproofing

Modifying the operations and use of existing structures to allow flooding to occur while minimizing property damage is considered "wet floodproofing." Under this scenario, all contents (including utilities) are removed from below the flood elevation, and openings in the building wall are either maintained or increased in size to allow water to readily enter the lower floors. The openings allow the hydrostatic pressure inside and outside the building to equalize, reducing the potential for structural failure. All construction materials that may be inundated may be flood-resistant to avoid deterioration and mold.

2.3.3 Dry Floodproofing

Dry Floodproofing entails making a structure watertight by sealing walls and, often, floors. Openings such as doors, windows, and vents, need to be fitted with removable barriers that can be installed manually or deployed automatically during flood events. The structure being made watertight must be able to withstand the significant hydrostatic pressure that will be exerted on it during a flood event. Dry floodproofing is more often used on non-residential structures and also requires implementation planning.

2.3.4 Permanent Ringwalls, Floodwalls, and Levees

Ringwalls, floodwalls, and levees are located away from the structure to be protected and are designed to prevent the encroachment of floodwaters. It is possible to install barriers on a neighborhood scale to protect multiple buildings. A well-designed and constructed barrier prevents floodwater from exerting hydrostatic or hydrodynamic forces on buildings, as well as from wetting structures. This avoids the need for retrofits or cleanup. Floodwalls and levees may have openings for access. These can be sealed using automatically closing barriers or manually installed barriers that depend on human intervention when flooding is predicted.

Levees are earthen embankments of compacted soils. They require large amounts of land area, since, for structural purposes, they are typically constructed to be 5 to 6 times wider than they are tall. Floodwalls are constructed of a variety of materials, and do not require large amounts of space for construction. They typically are not viable in areas of very deep flooding.

2.3.5 Temporary Barriers

Temporary flood barriers are erected manually only when flooding is imminent. These systems have a lower capital cost than a floodwall or the self-closing barriers described above, but they require human intervention prior to flooding, generating a risk that the installation is not completed and the structures are not protected.

2.3.6 Structure Relocation or Abandonment

Relocating a structure is the most dependable method of reducing flood risks. The method involves moving the structure out of the floodplain away from potential flood hazards. Costs and new sites are usually major concerns associated with building relocation.

Owners of highly vulnerable properties may wish to sell their property, thereby avoiding the costs of continued protection and maintenance. The opportunity for the Town of Madison to assist residents in this situation should be embraced when it arises, and State and Federal grant funding is available to aid in such purchases.

2.4 Regulatory Tools

Many of the options listed in this section can be accomplished through, or complemented by, a variety of regulatory tools. Following is a fairly comprehensive summary, for consideration.

2.4.1 Flood Damage Reduction Code Modification

In Connecticut, municipalities have mainly one option for increasing the design standards associated with development in flood zones: modifying the municipal code, zoning regulations, and/or subdivision regulations.

There are several methods of increasing building standards to enhance coastal resilience within the framework of these codes and regulations. These are described below:

- *Freeboard* – Freeboard standards require structures to be elevated higher than the level that FEMA requires through the National Flood Insurance Program regulations. Madison already enforces a one-foot freeboard standard, which provides additional certainty that flood levels will not damage structures, and addresses difficult-to-determine factors like wave height. The Town could consider increasing its freeboard standard to two or more feet to further increase structure safety.

- *Building Height Standards* –Liberal height standards can help achieve other resiliency goals, such as structure elevation. It is important to consider the relationship between Town residential building height regulations, flood-protection elevation standards, and the economic and social impacts that an exceptionally high structure could have on a neighborhood.
- *Applying V Zone Standards in A zones* – This requirement would to cause a structure in the coastal A zone to be constructed per V zone standards, incorporating breakaway walls, certain pile foundations, and prohibitions on uses below the first floor. The application of more stringent codes not only protects a given structure; it also protects *nearby* structures from damage caused by collapsing or floating structures and debris.

2.4.2 Zoning Amendments and Other Regulatory Procedures

Zoning Regulation amendments may be used to help require freeboard and other increases in building standards. Other changes to Zoning Regulations and the Zoning Map that may be useful for increasing coastal resilience include:

- *Tidal Marsh Protection and Advancement* – Areas suitable for marsh advancement may be regulated under a resource protection model of management.
- *Transfer of Development Rights* – Such that developers continue to own coastal land, but development is relocated to less sensitive areas.
- *Flexible Development Process* – Clustered development, planned residential development, & open-space subdivision procedures allow development consistent with coastal resiliency.
- *Land Conservation for Marsh Advancement* – Protect land through conservation easements, “rolling easements,” and other arrangements. Property would remain privately owned.
- *Green Infrastructure for Private Property and Homeowner Development* – Implement incentives for property owners implementing green infrastructure improvements.
- *Water Dependent Uses* – allow commercial water-dependent uses in residential areas, to compensate property owners for loss of value due to restricted development opportunities.
- *Expedited Permits for Reconstruction after Emergency Events* – for work which meets new standards of coastal resiliency.

2.4.3 Zoning Map Overlays

Madison may wish to adopt a zoning overlay district that is delineated using a line of future daily inundation or a future storm of a given hurricane category/intensity. Any of the planning periods used in the coastal resilience tool could be used (2020s, 2050s, or 2080s). Once adopted, the town could enact any number of requirements for development or redevelopment within the overlay, including freeboard and application of V zone standards in coastal A zones. Other possibilities may include variable setbacks and buffers or restrictions on what types of renovations or expansions may be permitted for existing buildings.

2.4.4 Rolling Easements

The term "rolling easements" encompasses a broad set of tools that can be used ensure that wetlands and beaches are able to naturally migrate inland without being stopped by shore protections or development. Rolling easements can be thought of as a combination of the principles of "accommodation" and "retreat." Because it is unrealistic to prevent development of low-lying coastal lands that could eventually be submerged by a rising sea, an alternative is to allow development with the conscious recognition that the land will be abandoned if and when the sea rises enough to submerge it. From now until the land is threatened, valuable coastal land can be put to its highest use; once the land it threatened, it will convert to wetland or beach as if it had never been developed.

According to Titus (*2011*), "usually, a rolling easement would be either (a) a law that prohibits shore protection or (b) a property right to ensure that wetlands, beaches, barrier islands, or access along the shore moves inland with the natural retreat of the shore."

Regulatory Rolling Easements

- ❑ Local zoning that restricts shore protection
- ❑ Regulations that prohibit shore protection by state coastal or wetland programs, or require removal of structures standing on the beach or in the wetlands
- ❑ Building-permit conditions that require public access along the dry beach
- ❑ Building-permit conditions that require public access along the inland side of a new shore protection structure

Property Rights Approaches

- ❑ Affirmative easements that provide the public with the right to walk along the dry beach even if the beach migrates inland
- ❑ Conservation easements that prevent landowners from erecting shore protection structures or elevating the grades of their land
- ❑ Restrictive covenants in which owners are mutually bound to avoid shore protection and allow access along the shore to migrate inland
- ❑ Future interests that transfer ownership of land whenever the sea rises to a particular level
- ❑ Migrating property lines that move as the shore erodes, enabling waterfront parcels to migrate inland so that inherently waterfront activities can continue
- ❑ Legislative or judicial revisions and clarifications regarding the inland migration of public access along the shore and the rights of landowners to hold back the sea
- ❑ Transferable development rights that provide those who yield land to the rising sea the right to build on land nearby

The particular details associate with implementing the above rolling easements are too varied to fully describe in this report. As planning continues, Madison will need to determine whether and which rolling easements will be incorporated into its coastal resilience plan.

2.4.5 Property Acquisition

Coastal land acquisition should be pursued for both ecological protection and human use. Coastal land valuable for conservation includes lands with ecological significance, existing potential coastal recreation opportunities, and areas of exceptional or unique coastal conservation value. Important considerations are the proximity to other protected lands as well as providing areas for sea level rise and tidal wetlands migration. Sites to consider are undeveloped islands, intact areas of tidal marsh, undeveloped tidally influenced riverine systems, coastal woodlands, bird habitat areas (especially waterfowl areas), anadramous and diadramous fish run areas, and sites that have been shown to have habitat for Federal or State listed threatened, endangered, or species of special concern.

Categories of Property Acquisition

Property acquisition will generally fall into four major categories:

- Open Space and Undeveloped Land – including tidal marsh advancement areas
- Damaged or Vulnerable Property
- Condemned Property – such as those where providing potable water and disposing of sanitary wastewater is not possible due to feasibility or expense.
- Inland Properties –to make up for the loss of lands due to sea level advancement.

2.5 Summary of Adaptation Options

Table 1: Summary of Adaptation Options

Measure	Summary	Benefits	Barriers to Implementation
		Structural Measures	
Hard Shore-Protection	Structure parallel to shore (seawall, levee, bulkhead, revetment)	• Long-lasting • Effective	• False sense of security • Expensive maintenance • Ecosystem damage
Sediment Management Structures	Structures reduce wave energy & manage sediment	• Long Lasting • Support natural processes	• Does not address stillwater inundation • Secondary Impacts
Soft Shore-Protection	Replenish sediment and dunes	• Support natural processes • Support ecosystems • Aesthetic	• Regular maintenance • May not be long-lasting
Bioengineered Banks	Natural elements reduce wave energy and trap sediment	• Support natural processes • Support ecosystems • Aesthetic	• Somewhat limited areas of applicability
Non-structural living-shoreline	Create/restore tidal marsh, artificial reefs, other habitats	• Reduce wave energy • Critical habitat	• Limited areas of applicability • Does not address stillwater inundation
Stormwater Management	Drain low areas while preventing backflow	• Support other protection methods	• May be expensive • Requires maintenance • Doesn't address direct hazards
Transportation Infrastructure	Elevate roads or create alternative egresses	• Protect emergency access and evacuation	• Elevation may increase hazards for neighbors
Elevation	Raise structure above flood level	• Reduce insurance premium • Open to residences • Permitted in V zones	• Harder to access • "Dead space" under structure • Difficult for some buildings
Wet Floodproofing	Abandon Lowest Floor, Remove all contents	• Relatively inexpensive	• Extensive post-flood cleanup
Dry Floodproofing	Waterproof structure, install barriers at openings	• Relatively inexpensive • Does not require additional land	• Manual barrier installation • Subject to storm predictions • Vulnerable to flow & waves
Floodwalls & Levees	Concrete or earthen barriers protection	• Prevent water contact • Avoid structural retrofits	• May require large area • Obstructs views
Temporary Flood Barriers	Plastic or metal barrier	• Prevent water contact • Relatively inexpensive	• Manual installation • Subject to storm predictions • Short-term only
Relocation	Move structure to safer location	• All vulnerability removed • Open to residences	• Decreased value of new site • Expensive
		Regulatory Tools	
Building Code	Increase standards for structures	• Protect new & improved construction	• Older structures often exempt
Zoning Regulations	Prevent hazardous development patterns	• Control degree of risk in hazardous areas	• Balance with economic pressures
Easements	Control activities on private land	• Work with landowners for mutual benefit	• Private landowner may not be willing partners

3 Options Relevant to Madison

3.1 Development of Madison-Specific Options

The comprehensive list of options presented previously includes adaptation measures that may be: technically, financially, or otherwise unfeasible for Madison to implement; not relevant to Madison's particular geography, geology, and hazard profile; or socially or politically unacceptable to Madison's citizens. To develop a suite of viable options for the Town's consideration, coastal resilience projects undertaken by other communities were reviewed, local physical and political factors were considered, and options were discussed with Madison's municipal leaders and residents.

During the meeting on November 18, 2015 to commence this planning process, Madison representatives discussed road elevation, alternative methods of road maintenance, strengthening water distribution infrastructure and septic systems, maintenance of revetments, dune restoration, improved drainage systems, bank stabilization, and property acquisition.

Based on this meeting and the additional considerations listed previously, the following categories and subcategories of options were presented to Madison residents at the public meeting on January 7, 2016:

- Transportation Options
    - Elevate Roads
    - Retire Roads
- Shoreline Management
    - Living Shorelines
    - Beach Nourishment
    - Sediment Management
    - Dune-Management
    - Bioengineered Banks
- Shore Protection Structures
    - Seawalls
    - Bulkheads
    - Revetments
- Home Elevation
- Water Resource Management
    - Stormwater
    - Wastewater
    - Water Supply
- Retreat

The meeting was open to public discussion, and these and other options were discussed in more detail by attendees. Adaptation measures added during this discussion included:

- Control of tidal wetland invasive species
- Structural protections, such as storm shutters
- Hardening of gas lines and other utilities installed under coastal roads

- ❑ Passive dune restoration
- ❑ Secondary damage from septic systems, pollution
- ❑ Hardening or improving emergency communication infrastructure

Finally, feedback from the public about resilience options was solicited through an online survey. Respondents indicated they were in favor of enactment and enforcement of relevant regulations and codes, improving drainage systems, strengthening coastal utility infrastructure, restoring dunes, nourishing beaches, construction of breakwaters and groins, and to some extent creating "living shorelines." Building seawalls and bulkheads and extending water service to areas currently served by wells was supported, but also received a significant amount of opposition, according to the survey. By far the action that was most strongly supported was strengthening the electric utilities on the coastline.

Madison Neighborhoods

To consider adaptation options for Madison on a finer scale, the Town was divided into regions based on topographical features, hazard profiles, and existing neighborhoods. These regions are as follows:

- ❑ Green Hill Road: a dead-end road off of Wildwood Avenue north of Route 95. The western end of the road is susceptible to flooding from wetland that drains to the south under Route 95, isolating residences. Properties here are adjacent to East River.
- ❑ Green Hill Place: for the purposes of this project, this name refers to the commercial properties around Route 1 at the western border of Madison. The area, which includes water-dependent businesses, is vulnerable to flooding from East River and an adjacent wetland.
- ❑ Garnet Park: a strip of low-elevation residential properties jutting west off of Route 1, bounded by Bailey Creek to the north and Neck River to the south. This area is susceptible to isolation, as well as inundation.
- ❑ Circle Beach: about twenty homes constructed on a sand spit at the mouth of the East River. This area is within a VE zone.
- ❑ Ridgewood/Soundview: east of Circle Beach is a neighborhood (Ridgewood Avenue and Soundview Avenue) protected from inundation by its somewhat higher elevation, and from wave energy by revetments. There is no beach at high tide here.
- ❑ Buffalo Bay: for this project, this name refers to the beaches extending from Soundview Avenue to the Mercy by the Sea Retreat Center and Chipman Point. This area is characterized by sandy beaches and homes that are mostly on high ground and not vulnerable to flooding.
- ❑ Smith Bay: this is the name for the finger roads south of Neck Road. These private roads are relatively densely developed, and drop to very low elevations near the shoreline. Bulkheads and beaches are interspersed, and drainage issues are common.
- ❑ Surf Club Beach: the area from Garvan Point to the Madison Surf Club has wide beaches and is susceptible to flooding, but is mostly undeveloped, so vulnerabilities here are low.
- ❑ West Wharf & Crescent Beach: lower elevation neighborhood with some beach fronting the homes. Inundation comes from wetlands located inland. The neighborhood around Middle Beach Road West (Crescent Beach) is considered part of this area, though part of that section does not have a beach at high tide, and homes are protected by bulkheads.

- Middle Beach Road: this refers specifically to the section of road between Island Avenue and Park Avenue, where the road is immediately adjacent to the water and protected by riprap and seawalls.
- Middle Beach: narrow to no beach at high tide. Typically protected from flooding. Eastward edge is at East Wharf.
- Fence Creek: This includes the inland neighborhoods surrounding Fence Creek and its wetland, as well as the homes built at its mouth, which are vulnerable to flooding from the creek as well as wave runup from the Sound.
- Seaview Beach: Seaview Avenue is fronted by an undeveloped living shoreline, and backed by homes. The homes are protected from flooding.
- Webster Point: in this document, Webster Point refers to the neighborhood from Seaview Avenue until Hammonasset State Park. This area is higher in elevation, and most homes are set back from the waterfront, making risk here very low.

The suite of options most applicable to each of Madison's coastal neighborhoods is summarized in the following table:

Table 2: Adaptation Options for Madison Neighborhoods

		Shoreline Protection					Structures & Infrastructure							Realignment		
Possible Options		Hard Protection	Beach Nourishment	Dune Restoration	Non-Structure Living Shoreline	Bioengineered Banks	Drainage Improvement	Strengthen Power Utilities	Strengthen Water Distribution	Community Wastewater	Road Elevation	Structure Elevation	Floodproof Structures	Road Retirement	Alternate Route Development	Property Acquisition
Appropriate Neighborhoods	Green Hill Road						X				X			X	X	X
	Green Hill Place						X				X	X	X	X	X	
	Garnet Park	X							X	X	X	X				
	Circle Beach		X	X	X			X	X	X		X				X
	Ridgewood/Soundview	X	X		X	X		X								
	Buffalo Bay		X	X	X			X								
	Smith Bay		X	X			X	X		X						
	Surf Club Beach			X			X						X			
	West Wharf	X	X	X	X			X			X	X	X			
	Middle Beach Road	X				X		X						X	X	
	Middle Beach		X	X				X								
	Fence Creek						X			X	X					X
	Seaview Beach							X								
	Webster Point							X								

3.2 Application of Adaptation Options in Madison

The following section summarizes some of the specific problem sites around Madison where different adaptation options may be relevant. Many of the sites are listed under multiple options, indicating that there are multiple approaches to resiliency at that location, or that the best option would be to implement multiple adaptation measures in unison. Madison is characterized by long areas of shoreline with private structures. This will present a challenge going forward because it will be difficult to achieve a unified approach in many locations.

3.2.1 Hard Shoreline Protection

Much of Madison's shoreline is densely developed, and options in many neighborhoods will be limited to ensure basic protection of important assets. Some of this protection may be accomplished through shoreline management and protective structures.

Sections of the Town with assets such as structures, roads, and other infrastructure located very close to the water, may require hard shoreline protection. Such areas may include those that are not geographically conducive to softer shoreline protection, those without the space to implement other protection methods, those with high banks susceptible to erosion, or those with naturally hard or rocky shorelines where structures may be vulnerable to wave action.

These areas may include Ridgewood/Soundview, Smith Bay, and Middle Beach Road. Additionally, implementing hard protection structures at Garnet Park may be advisable to prevent flooding without infringing on the surrounding protected wetlands.

Jetties, breakwaters, groins, and other hard structures that are used to reduce the energy of waves and currents, may be useful for areas with eroding beaches or bluffs. Madison's open and sandy coastline creates a situation where most of the shoreline is erodible. This translates into many suitable sites for these types of shoreline protection. Areas where they may be appropriate include Smith Bay, Surf Club Beach, West Wharf Beach, and the East Wharf Beach area.

3.2.2 Soft Shoreline Protection

Some sections of Madison are able to be served using soft shoreline protection, which is often more aesthetically acceptable and more supportive of natural systems and processes.

Areas where soft protection measures can be implemented include Circle Beach, Buffalo Bay, Smith Bay, Surf Club Beach, West Wharf, the bay to the east of West Wharf, Middle Beach, Seaview Beach, and Webster Point.

One site in Madison particularly suitable for a dune restoration project is Surf Club Beach. A dune already exists here, but has been repetitively washed out and degraded by recent large storm events. Restoring the dune to its full extent would help prevent high waters from overtopping the shoreline and causing flooding along Surf Club Road, Holly Park Road, Parker Avenue, and Flower Avenue.

There is currently a dune stabilization project, involving planting dune vegetation, being implemented between Toffee Lane and Kelsey Place in Smith Bay.

Dunes must be located a significant distance from the water line (50 to 100 feet), and must be wide (greater than 20 feet), to be able to maintain their forms. Not all Madison beaches have this kind space. However, it may also be possible to construct a dune on a beach that is currently unsuitable if other beach building and nourishment projects are undertaken first.

3.2.3 Living Shorelines

Bioengineered Banks
Areas that may be suitable to bioengineered banks include Soundview/Ridgewood, Garvan Point where there is currently a bulkhead in need of maintenance, the homes east of West Wharf, Middle Beach, and the homes at the mouth of Fence Creek.

Created and Restored Tidal Wetlands
Madison's developed shoreline, fronted by beaches and hard structures, and exposed to the Sound, does not create many areas that would support the created or restored tidal wetland form of living shorelines. Madison does contain significant tidal marshlands, such as those around the East River, inland of Garvan Point and the Surf Club, adjacent to Fence Creek, and within Hammonasset State Park, but these are protected from wave energy. Thus, Madison is not characterized by eroding marsh fronts, and so living shoreline projects focused on tidal marsh restoration will not be relevant to this geography.

Artificial Reefs
Likewise, recent living shoreline projects like the Stratford reef ball project do not have a parallel feasible setting in Madison, aside from along the East River and at Webster Point. The Madison shore between Circle Beach and Webster Point is unlikely to contain any sites suitable to such a project where the reef balls would survive a powerful coastal storm.

3.2.4 Infrastructure Retrofits and Upgrades

Drainage
Some areas of Madison have adequate protection from inundation and wave action, but still experience damage due to failing, inadequate, or malfunctioning drainage infrastructure. Areas that would benefit from upgrades to these systems include Green Hill Road and Smith Bay.

The southern ends of roads in Smith Bay already suffer from routine storm-drain "surcharging," when high water levels in the sound push water backwards through the drainage infrastructure to discharge into otherwise protected low areas.

Roadways and Transportation
The layout of Madison is such that even if some major roads are impassable, other routes should remain open for most residents. Nevertheless, there are some neighborhoods that might be isolated under high sea level conditions. Alternate routes may need to be determined for neighborhoods that are technically accessible but risk having major throughways cut off. Under current conditions there are already roads that experience chronic flooding.

Some of the most significant roads at risk in Madison include State Route 1, Green Hill Place, Garnet Park Road, Circle Beach Road, Surf Club Road, Middle Beach Road West, Island Avenue, Middle Beach Road, Scotland Avenue, and Seaview Avenue. Some of these roads are vulnerable to inundation while others, like Middle Beach Road, are vulnerable to erosion. Areas of Town vulnerable to isolation include Circle Beach, Garnet Park, areas east of the Hammonasset Connector on Route 1, and possibly Seaview Beach and neighborhoods off of Neck Road during extreme events. Access to areas east of Fence Creek could be cut off from the Fire Station and Urgent Care center if Route 1 is flooded. Additionally, east-west transit or evacuation may be hindered by flooding of State Route 1 by the East River, Bailey Creek, Neck River, or Toms Creek.

Water
Public water supply distribution may be vulnerable to erosion in areas where pipes are built close to the shoreline. Drinking water infrastructure location data was not made available for this effort, so specific vulnerable locations are not known. However, potential areas of concern include the east end of Circle Beach Road, Middle Beach Road, and the bridge over Fence Creek. Specific adaption options applicable to these locations include bank protection and relocation of water mains.

Wastewater
Properties throughout Madison's coastline will need to consider retrofitting or relocating their septic systems. This is a particular concern in low-lying areas such as Green Hill Place, Garnet Park, Circle Beach, the southern end of the Smith Bay finger roads, homes adjacent to the Fence Creek wetland, and some homes along Toms Creek at Hammonasset State Park. It is especially important that areas that use well water protect their septic systems to prevent contamination of their drinking water sources.

Electricity
Wind hazards are similar throughout the Town of Madison, although the lack of protection provided by topography, plants, or other structures, along the shoreline can increase risks to waterfront locations. Wooded areas will be more vulnerable to falling trees and limbs taking out power lines, and low-lying areas will be more vulnerable to the effects of flooding and a rising groundwater table on the viability of both above- and below-ground utilities.

One methods of strengthening the electrical grid, or building resilience against power loss, is to develop a "microgrid" to allow for a small area to be powered during a regional outage. Madison neighborhoods that may be good candidates for such a project include the commercial properties at Green Hill Place, the western end of Garnet Park, and the Mercy by the Sea complex.

3.2.5 Private Property Protection

All properties within flood zones are required to have flood protection measures implemented, but additional actions should be taken to prepare for rising seas. Furthermore, there are some areas of Madison where neighborhood-scale protective measures, such as construction of floodwalls or nourishment of beaches, are not feasible or would not provide adequate protection to individual structures. In such areas, individual property owners should implement additional flood protection measures.

These areas include Garnet Park, Circle Beach, and the peninsula at the mouth of Fence Creek.

Elevation of residential properties should be pursued in all flood-prone neighborhoods.

3.2.6 Other Options

The other adaptation options listed above – regulatory tools and property acquisition – apply throughout Madison. Relevant regulatory tools will vary based on the needs of specific locations.

4 Conclusions

The Town of Madison is well-positioned to move forward on a variety of important projects to build resilience to coastal flooding, storms, and sea level rise. The Town's shore is well-studied, many projects have already been completed, are underway, or are in planning phases, and public support for continued resilience-building efforts is strong. The Town's capabilities include strong emergency response capabilities, main roads that are generally higher in elevation or set-back from the coast, and a relatively limited area that is susceptible to coastal hazards.

Madison's resilience efforts will be varied because of the diverse types of risks it faces. Some areas require structural protections from inundation, others need hard defenses against erosion, and at other sites beach and dune nourishment are appropriate. Much of the work that will be needed in the future will relate to the private septic systems located around the Town. Protecting and maintaining at-risk roads will also be an important action. Assisting homeowners to elevate their residences, or purchasing properties from those who no longer wish to invest in protecting their residences, should also be a continuing focus of the Town. Madison is encouraged to explore the use of hybrid and green techniques, including bioengineered banks and dune restorations, where suitable. Finally, Madison should enact a suite of regulatory changes to support resiliency efforts, including making height restrictions flexible in the case of home elevations, and altering zoning regulations to encourage development away from hazard areas.

Appendix D
Selection of Hurricane-Sandy Impacted Neighborhoods

Memorandum

Selection of Hurricane Sandy-Impacted Neighborhoods

Goal: *Based on the participation of members of the public, impacts from Storm Sandy, the location of low to moderate-income (LMI) populations, locations of critical community facilities, and the results of the vulnerability and risk assessment, the consultant will recommend up to two specific neighborhoods that should be targeted for more focused planning efforts in each municipality.*

Repetitive Loss (RL) Properties

The greatest number of RL properties is located as follows, from west to east:

- Circle Beach Road (7)
- Garnet Park (5)
- South of Neck Road (16)
- West Wharf (10 near Surf Club Beach, 10 farther east)
- Middle Beach Road (10)
- Fence Creek Peninsula (12)

Additionally, a Severe Repetitive Loss (SRL) property is located South of Neck Road

Low-to-Moderate Income (LMI) Census Tracts

At the present time, Madison does not contain any LMI tracts[1]. However, as of 2014, the area of Town north of Route 1 between Stony Lane and Scotland Avenue was an LMI tract. Currently, the Woodland Road area, near the junction of Route 95 and Route 79 is characterized by relatively low income and high unemployment. Both of those areas are outside of present and projected future coastal hazard zones.

Along the coastline itself, the central part of Town, from Surf Club Beach to Seaview Beach, is characterized by a relatively lower median income than the rest of the shoreline. While not technically Low or Moderate Income, it is worthwhile to emphasize projects in this area because of its relatively lower income level.

Areas of Damage from Tropical Storm Irene and Hurricane Sandy

The most severe damage from Tropical Storm Irene and Hurricane Sandy is generally aligned with the areas of the most RL properties listed above.

Areas of Madison that experienced the greatest extent of damage include: the Green Hill Place commercial neighborhood; Garnet Park; Circle Beach; homes South of Neck Road; homes in the West

[1] At the time of the CDBG-DR grant application in 2014, the Low and Moderate Income (LMI) Census block groups were mapped based on estimates from the 2007-2011 American Community Survey (ACS) where the median income was 80% or lower of the Area Median Income (AMI). ACS estimates are based on a 5-year rolling average of a small sample size. LMI limits are revised annually. Current estimates available on the online CPD Maps viewer show that no Census block groups in Madison are currently HUD-designated LMI areas.

Wharf Beach area; Middle Beach Road at Tuxis, Gull Rock, and Park; and the mouth of Fence Creek, especially Linden Lane. The most severe damages during that storm occurred at Circle Beach and South of Neck Road.

Areas of Risk from Daily High Tide Flooding in the 2020s and 2050s

The neighborhoods most at risk from worsening daily high tide flooding are those that already experience frequent nuisance flooding during high tides. These are Green Hill Place, Garnet Park, Circle Beach, the southern ends of the "South of Neck Road" finger roads, the Surf Club Beach/West Wharf neighborhood, and the mouth of Fence Creek. The homes in the area of Middle Beach Road do not show a high level of vulnerability to high tide flooding due to sea level rise, however the roads themselves (specifically, Middle Beach Road and Island Avenue) do. Additionally, higher water levels will further exacerbate erosion vulnerabilities at Middle Beach Road, despite models not showing the road being overtopped.

Locations of Critical Facilities

Madison's critical facilities are largely situated in areas of low risk. The Town does not have a municipal wastewater treatment facility. Critical Facility location was therefore not considered when determining key neighborhoods for planning.

At-Risk Roads

Roads at risk of flooding during daily high tides are listed in the Vulnerability and Risk memo. These are:

Vulnerable Road	Notes
Route 1 / Boston Post Road	Prevents East-West Travel
Green Hill Place	
Garnet Park Road	Isolates Garnet Park
Circle Beach Road	Isolates Circle Beach
Surf Club Road, and neighbors	Isolates Surf Club Beach Area
Middle Beach Road West	
Island Avenue	Isolates Tuxis Rd, Gull Rock Rd
Middle Beach Road	Key East-West Route
Scotland Avenue	
Seaview Avenue	

These roads are located primarily in the neighborhoods already described above: Green Hill Place, Garnet Park, Circle Beach, West Wharf, Middle Beach, Fence Creek, and Seaview Beach.

Public Input

Through public meetings and an online survey, the public was able to express concerns about specific areas in Town in need of resilience planning. Areas mentioned regularly during meetings include Green Hill Road, Green Hill Place, the Smith Bay neighborhood south of Neck Road, Surf Club Beach, Middle Beach Road, and the mouth of Fence Creek.

Through the online survey, the following areas of Town were mentioned as being vulnerable:

Neighborhood	Number of Mentions
Green Hill Road	0
Green Hill Place	9
Garnet Park	2
Circle Beach	7
Ridgewood/Soundview	0
Buffalo Bay	1
Smith Bay	6
Surf Club Beach	8
West Wharf	24
Middle Beach Road	35
Middle Beach	11
Fence Creek	3
Seaview Beach	7
Webster Point	2

Conclusion

The following table cross-references the above issues with the coastal neighborhoods.

Neighborhood	RL Properties	LMI Census Tract	Irene & Sandy Damage	DHT Risk 2020s-2050s	Critical Facilities	At-Risk Roads	Public Input
Green Hill Road							X
Green Hill Place			X	X		X	X
Garnet Park	X		X	X		X	
Circle Beach	X		X	X		X	
Ridgewood/Soundview							
Buffalo Bay							
Smith Bay	X		X	X			X
Surf Club Beach	X	X*	X	X		X	X
West Wharf	X	X*	X	X		X	X
Middle Beach Road	X	X*	X	X		X	X
Middle Beach		X*	X				X
Fence Creek	X	X*	X	X		X	
Seaview Beach						X	
Webster Point			X				

* These areas are not Low or Moderate Income, but do fall within a tract that has a lower median income level than the rest of the Madison Coastline.

Surf Club Beach, West Wharf, and Middle Beach Road are the areas with the most columns checked (six). Fence Creek is the neighborhood with the second-most columns checked (five), followed by Green Hill Place, Garnet Park, Circle Beach, and Smith Bay (four columns checked).

Because Middle Beach Road has the highest number of checked columns and is an important route for travel both during normal and emergency conditions, it will be selected for more focused infrastructure design.

Green Hill Place is somewhat unique in this list because it is inland, and a commercial area. It is listed as an important commercial center in the Madison Plan of Conservation and Development, yet is often overlooked in the context of coastal hazard mitigation and restoration efforts. This area has been specifically highlighted by Town officials as being an area of interest. For these reasons, Green Hill Place will be selected for more focused planning efforts. Additionally, because of its proximity and the similar nature of the hazards faced (inundation of roads by wetlands), the Green Hill Road neighborhood will be included in that plan.

The hazards faced by Surf Club Beach and West Wharf – two neighboring and even overlapping neighborhoods – are very similar. Overtopping of the shoreline leads to flooding of structures and roads. Much of the threat at the Surf Club Beach area is from overtopping of the Town-owned beach, a situation that will make mitigation efforts easier to accomplish. Additionally, projected daily inundation will affect more residences in this area than in neighboring West Wharf. Therefore, the Surf Club Beach neighborhood will be chosen for more detailed designs. Because the flood threat is from a point source – overtopping of the beach at a specific location – an infrastructure design approach is more appropriate here than a neighborhood-wide effort.

For an additional neighborhood to be included for more focused planning, the Smith Bay (or "South of Neck Road" finger roads) area was selected. This neighborhood experience regular flooding from many locations, making a neighborhood-scale plan appropriate. It is relatively densely settled and, though not classified as LMI, home values here tend to be lower than some of the other at-risk neighborhoods. Options at this location are diverse, and will provide a useful example of multiple adaptation approaches to guide future planning in Madison.

In summary, the four selections for focused planning are:

<u>Neighborhoods</u>

- Green Hill Place / Green Hill Road
- Smith Bay

<u>Infrastructure</u>

- Middle Beach Road
- Surf Club Beach

If and when the Town undergoes additional planning for these areas, the results of this planning phase can be used as a starting point.

Appendix E-1
Green Hill Neighborhood Resilience Concept

Green Hill Road and Green Hill Place, CT

Neighborhood Resilience Concepts

Hazard Setting

The "Green Hill" neighborhood discussed in this memo describes two different neighborhoods separated by state route 95. Green Hill Road is located north of 95 and leads from Wildwood Avenue westward, where it dead-ends after a small wetland. There are four or five residential properties that rely on this road as their only access route, and are cut off during flood events when overflow from the wetland inundates the road. The wetland is connected to a more extensive tidal wetland to the south of 95 by a culvert under the highway. This neighborhood is bordered to the west by the East River, and properties are at risk of flooding from large storm events. Most of the neighborhood is with a FEMA AE zone, with a couple of spots designated as the 0.2% annual-chance flood zone.

Green Hill Place refers to the commercial area to the south of 95 alongside the East River, and includes Old Post Road and State Route 1. There are approximately 11 properties in this zone that are at risk of flooding, and many of them already experience nuisance flooding or flood damage on a regular basis. Flooding can come from the East River or from the tidal wetland located to the northeast of the neighborhood (this tidal wetland connects to the wetland north of 95 that impacts the Green Hill Road area).

This memo presents the adaptation actions that can be taken in the Green Hill Road neighborhood, and a suite of structure-specific measures that can be implemented in the Green Hill Place area to the south. These are summarized below:

Green Hill Road:

- Elevate the Road
- Abandon the Road
- Retrofit Drainage

Green Hill Place Structural Modifications:

- Elevate
- Dry Floodproof
- Wet Floodproof
- Acquire
- Do Nothing

Green Hill Road

Elevate the Road

This concept aims to maintain access for the homes at the western end of Green Hill Road through a category 2 storm under 2080s sea level rise conditions. It is important to note that even with the road sufficiently elevated to remain dry in this scenario, most of the homes in the neighborhood would be flooded, and access would nevertheless be difficult.

As an alternative approach, the road may be elevated to a lower height to maintain access during future high tides occurring without a storm, or during smaller (more frequent) storms. Individual homeowners would then be responsible for elevating their own properties, and may be interested in elevating their driveways to connect to the road. Current homes are projected to remain above water during daily high tides through the end of the century. While elevating the road, it is recommended that the culvert connecting the wetland north of Green Hill Road to the south be upgraded for improved capacity.

Abandon the Road

In this scenario, the western end of Green Hill Road will be abandoned. Madison could transfer the road parcel to the property owners and assume that it will be privately maintained, or the Town could pursue acquisition of the at-risk private properties in the neighborhood, followed by demolition. The latter would allow the Town to open this area up to be reconnected to the East River. In this capacity, the area would support long-term tidal wetland migration from adjacent areas.

Retrofit the Drainage System

During large storms, the tidal East River can overflow and floods this neighborhood. On the other hand, high tide floodwaters can also access Green Hill Road through the culvert under Route 95. It may be possible to retrofit the drainage system to prevent northward backflow through the culvert beneath the highway while allowing southward drainage during rain events. This could be accomplished using various technologies that prevent backflows, or installation of a pumping system, or both. The Town will need to explore the characteristics of this wetland before altering its hydrology to ensure it is not violating wetland protection regulations.

Green Hill Place

There are approximately 14 structures located in the Green Hill Place neighborhood, each of which is exposed to different levels of future risk from flooding, and all of which are located within the FEMA-mapped SFHA. Each structure has its own unique features and vulnerabilities, and therefore each has its own unique suite of possible solutions. A detailed set of feasible adaptation activities applicable to each structure would require in-depth surveys and engineering studies of each, however some possible solutions are offered here.

- 5 Green Hill Place: This marina service shop is housed in what appears to be a vinyl-sided structure with a concrete foundation wall. The southern corner of the building is projected to be affected by high-tide flooding by the 2080s, but the main risk is from surge events. Some of the building's utilities, such as outdoor electric outlets and sewer pipes, are elevated. Vulnerabilities include three garage doors, two doors, and those elevated utilities. If the business operating out of this building wishes to remain in place, dry-floodproofing the building to prevent water from entering the building during future storms may be feasible.

Elevated Pipes
5 Green Hill Place

- 6 Old Post Road: This property appears to be residential. It consists of a home with a basement, constructed on elevated fill such that it is located outside of projected high tide inundation areas, and a shed, elevated about a foot off the ground. Vulnerabilities at the home include numerous basement windows, at least two vents, basement bulkhead doors, utilities and electric meters, and an outdoor air conditioning unit that is currently elevated. As base flood heights increase, the only adaptation options available to this residential structure are elevation or relocation. The associated shed can be wet floodproofed.

6 Old Post Road
Note open bulkhead door

- 27 Green Hill Place: There appears to be an abandoned house at this site. It should be demolished and the property converted to wetland/floodplain, or reconstructed in conformance with the flood damage prevention regulations.

27 Green Hill Place

- 9 Old Post Road: This wooden structure houses a commercial/ industrial land use. It is within the area projected to be affected by daily high tide by the 2080s. Its wood construction likely makes dry-floodproofing unfeasible, and it is unlikely that elevation would be possible, preferable to the owners, or cost-effective due to the use of the building. The most appropriate options for this site are demolition of the existing structure or “wet-floodproofing,” which consists of elevating utilities and creating openings to allow floodwaters to enter and exit the building. Some of this appears to have already occurred.

9 Old Post Road
Note stains from flooding, opening in sliding garage door, elevated utility to the right.

- 11 Boston Post Road (Route 1): This restaurant is located outside of projected future high-tide floodin areas, and may be slightly elevated above the ground surface. Future adaptation options include dry floodproofing and/or elevation.
- 15 Boston Post Road (Route 1): This new building is constructed on piles such that the first floor is about three feet above the ground surface. As sea level rises, it may be necessary to elevate the building further.
- 21 Boston Post Road (Route 1): This lot has been filled, and so has been elevated somewhat. It is not clear whether this will change the location’s risk to future high tide flooding. The structure itself is elevated on a cement slab. Increased elevation is an appropriate adaptation option at this site, but dry floodproofing may also be feasible.
- 25 Boston Post Road (Route 1): This is a two story building with wood siding. There are two other small structures located on the property appearing to either be used for storage or be empty. This entire property is within the high tide zone as projected out to the 2020s. There is already standing water at various locations around the property, with one puddle found to have live fish in it. These structures are the most vulnerable and at-risk in this neighborhood. The owner of the building appears to be interested in pursuing floodproofing or elevation based on discussions at the conclusion of the initial public meeting for this coastal resilience plan. The suggested solution for this site in the short-term may be to implement a combination of floodproofing, elevation, and

25 Boston Post Road

rebuilding to create a structure that will be protected from future high tides. In the long term, the best option may be to rebuild the entire structure in conformance with the flood damage prevention regulations.

- 26 Boston Post Road (Route 1): This is a currently empty building located on the south side of Route 1, jutting into a wetland. The structure is built on high ground and elevated further on a concrete slab. Some of its utilties appear to be elevated, but inconsistently so. If the building owner wishes to maintain this location, it is possible that dry-floodproofing measure and utility elevation may be sufficient to protect it into the future.

Utilities & adjacent wetland
26 Boston Post Road

- 29 Boston Post Road (Route 1): This two-story building is built on high ground outside of projected future high tides. It appears that a number of floodproofing measures have already been taken. Floodproofing the building's doors, and elevating the outdoor air conditioning unit and electric meters, may be sufficient to protec the building into the future.

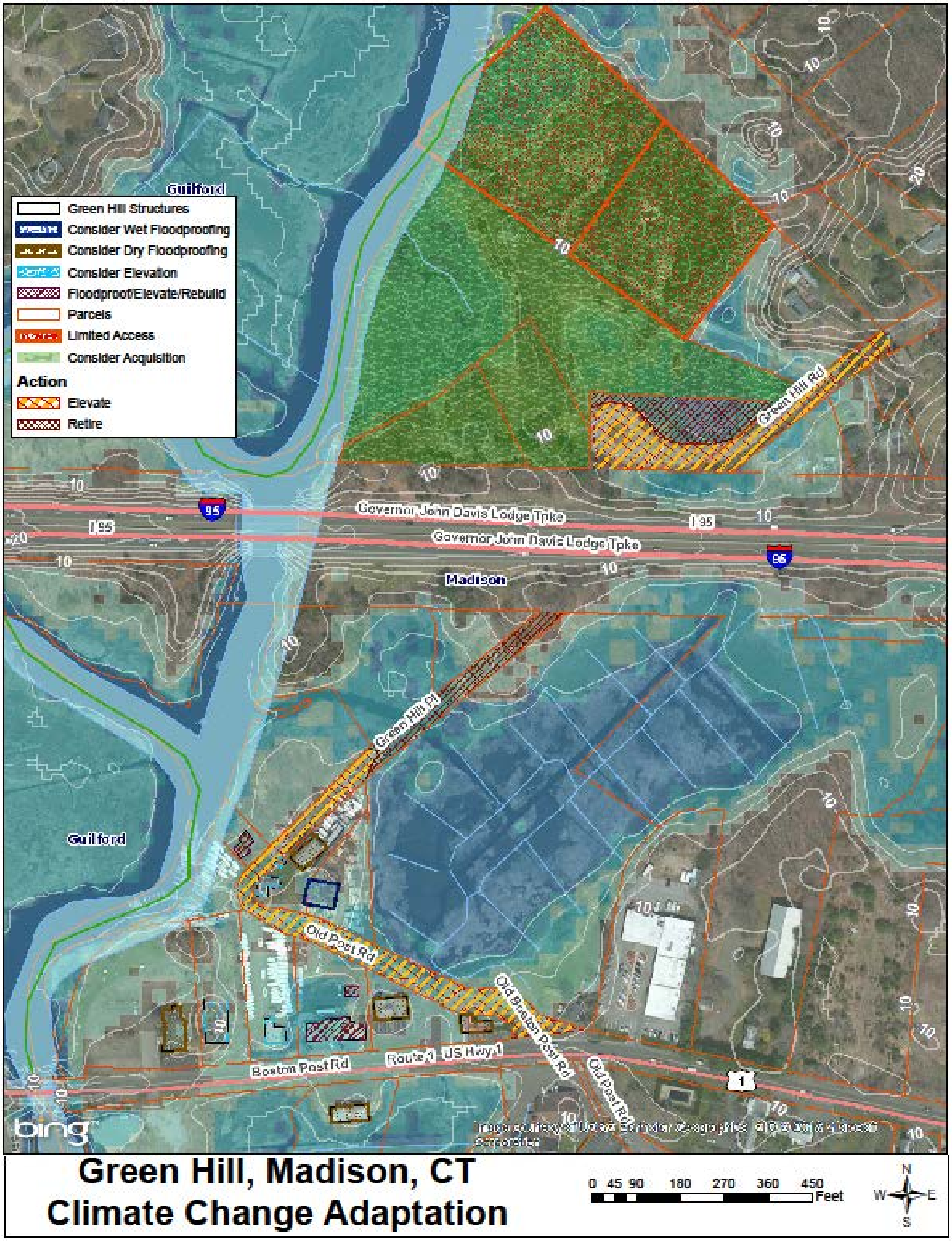
29 Boston Post Road

- 37 Boston Post Road (Route 1): This is an older building with vinyl siding, a basement, and many vulnerabilities. It is within the area projected to experience high tide flooding in the 2080s. Vulnerabilities include three basement windows, five doors, two outdoor air conditioning units, and electric lines and meters. The most appropriate option for this site is to elevate utilities and a/c units, and floodproof the building, either using "dry" or "wet" methods.

37 Boston Post Road

- Old Post Road: Part of resilience planning for this site may involve elevating Old Post Road to prevent it from being flooding by future high tides. Based on TNC's Coastal Resilience tool projections, the road should be elevated to between 6 and 8 feet, NAVD88, to remain dry through 2080s high tides while not being unreasonable higher than surrounding buildings. Because this is mostly a commercial area, it is not necessary to elevate the roads to remain passable during storm surges.

It will be important to elevate Route 1 in the future, but as this is a State-owned road, it is beyond the scope of this document.


Green Hill Structures
Consider Wet Floodproofing
Consider Dry Floodproofing
Consider Elevation
Floodproof/Elevate/Rebuild
Parcels
Limited Access
Consider Acquisition
Action
Elevate
Retire
Guilford
Madison
Governor John Davis Lodge Tpke
I 95
Green Hill Rd
Green Hill Pl
Old Post Rd
Old Boston Post Rd
Boston Post Rd
Route 1 US Hwy 1
Green Hill, Madison, CT
Climate Change Adaptation
0 45 90 180 270 360 450
Feet
N
W
E
S

Planning Level Costs for Alternatives:

Green Hill Road

Elevate the Road – Storm Surge

Costs for this alternative come from the cost of the road material and the cost of construction. The road heights and widths will vary because the existing ground surface elevation varies. Based on elevating to 12 feet NAVD88, in order to maintain access during base flood events, approximately 14,000 cubic yards of material would be needed. The cost of the material, pre-construction site preparation, and post-construction site restoration, will cost an estimated $742,500. Installing roadway utilities and a culvert will add at least $100,000 to this plan's cost.

Elevate the Road – Daily High Tide

Projections have high tide elevations increasing by 1.88 to 6.80 feet by the end of the 2080s, with the TNC Coastal Resilience Mapping Portal showing high tide levels in the Green Hill Road area reaching an elevation of around 7 to 8 feet NAVD88. Based on elevating to 8 feet NAVD88 to maintain access during future daily high tides, approximately 7,550 cubic yards of material would be needed. The cost of the material, pre-construction site preparation, and post-construction site restoration, will cost an estimated $513,700. Installing roadway utilities and a culvert will add around $100,000 to the cost.

Abandon the Road and Cease Access

The costs associated with this alternative are those required to purchase properties from current owners, the costs of demolishing the structures and removing the road, and the costs of converting the lots to open space. Five properties would be purchased, and about 50,000 square feet of road removed. A review of the assessor data for Green Hill Road reveals that the appraised values of the properties to be acquired in this plan come to a total of $1.63 million.

Retrofit the Drainage System

Upgrades to drainage infrastructure and installation of a stormwater pumping system are called for in this plan as explained above. Tideflex gate valves on storm system outfalls along with one or more pumping stations and force mains may be necessary. This can be expected to add an addition $500,000 to the overall project cost.

Green Hill Place

As explained previously, each property in this neighborhood has a different set of adaptation options. The table below summarizes suggested actions for each property, and their associated costs.

Building Address	Vulnerability	Solution	Units	Cost per Unit	Total Cost
5 GHP	Garage	Install Temporary Flood Barrier	3	3000	9000
	Doors	Install Gasketed Doors	2	2000	4000
	Utilities	Elevate	1	1500	1500
		Total			**14500**
6 OPR	Residence	Fill Basement & Elevate	1	100000	100000
6 OPR Shed	Shed	No Action	0	0	0
		Total			**100000**
9 OPR	Utilities	Elevate	unknown	1500	~3000
	Walls & Doors	Install Vents	~8	1500	~12000
		Total			**15000**
25 BPR	Entire Structure	Elevate and Floodproof	1	200000	200000
		Total			**200000**
26 BPR	Door	Install Gasketed Doors	2	2000	4000
	Meter	Elevate	2	1500	3000
		Total			**7000**
29 BPR	Door	Install Gasketed Doors	2	2000	4000
	Meter	Elevate	1	1500	1500
	A/C Unit	Elevate	1	2000	2000
		Total			**7500**
37 BPR	Door	Install Gasketed Doors	5	2000	10000
	Utilities	Elevate	2	1500	3000
	Meter	Elevate	1	1500	1500
	A/C Unit	Elevate	2	2000	4000
	Basement Window	Install Gasketed Doors	3	1500	4500
		Total			**23000**
27 GHP	Entire Structure	Acquire & Demolish	1	50000	50000
		Total			**50000**
21 BPR	None	Elevate over Time	1	100000	100000
		Total			**100000**
15 BPR	None	Elevate over Time	1	100000	100000
		Total			**100000**
11 BPR	Entire Structure	Elevate over Time	1	100000	100000
		Total			**100000**

The total cost of these projects comes to $717,000. Some of these costs would be the responsibility of property owners, while other would fall on the Town. Additional municipal costs would come from elevating Old Post Road, a project which will include updating a drainage system. To elevate the road to 8 feet NAVD88, in order to maintain dry access during daily high tide flooding through the 2080s, approximately 7,000 cubic yards of material would be needed. The cost of the material, site preparation, construction and site restoration, will cost an estimated $450,000.

Summary

The options presented above are summarized in the table below:

Alternative Description	Modeled Outcome	Approximate Cost ($)
Green Hill Road		
Elevate Road to allow access during storms	Allows access during flood events, but does not address individual home protection or access between elevated road and homes	852,500
Elevate Road to allow access during high tide	Allows access through the 2080s. Does not address storm conditions	613,700
Retire the road and pursue **acquisition** of properties vulnerable to isolation	Would eliminate all risks, but requires interest of homeowners and funding	1,630,000
Retrofit **drainage** system to prevent high-tide flooding from south of 95	Could prevent high tide flooding through the 2080s, but does not address storm surge flooding. May create issues with wetland regulations.	500,000
Green Hill Place		
Elevate Structure	Applicable to five structures that have already been elevated but may require more elevation in the future. Required for a fourth, residential property.	500,000
Dry Floodproof Structure	Applicable to five buildings that appear to be structurally appropriate for such measures.	152,000
Wet Floodproof Structure	Applicable to one structure incapable of supporting dry floodproofing measures.	15,000
Acquire Parcel	Recommended approach for one parcels with a structure in poor shape located in a high-risk zone.	50,000
Do Nothing	A couple of structures are already protected from current flood conditions and may not need additional retrofits for many year. Retrofits may not be cost-effective for other structures, which may be maintained as-is until no longer worthwhile.	0
Elevate Road	Certain sections of road must be elevated to maintain access in the face of rising sea levels.	450,000

Conclusion

The options presented in this memo are just a few possible ways to address the risks presented by increasing flood risks in these neighborhoods. Additionally, while all of the options above may be technically feasible, they vary considerably in capital costs and social costs. Consider the following:

- Abandoning Green Hill Road shifts much of the cost for road maintenance and property protection from the Town to the property owners over the long term as the level of service from roads and drainage systems is minimized and the property owners must decide on their own how to protect their homes. However, property acquisition will itself be an expensive endeavor, and is often unpopular with residents.
- The Green Hill Place commercial neighborhood is an important commercial area in Town. Balancing the economic contribution of the area with the costs of continued flood protection will be important moving into the future.

Because the Town is planning ahead with this coastal resilience plan, the options for the Green Hill neighborhoods could be viewed as steps rather than different outcomes. It would be feasible, for example, to retrofit the Green Hill Road wetland drainage system to protect properties from high tide flooding through the next 30 to 50 years, while pursuing property acquisitions where possible. The building-specific floodproofing efforts can be pursued on a case-by-case basis, with complete protection for the Green Hill Place commercial zone accomplished over decades.

Appendix E-2
Smith Bay Neighborhood Resilience Concept

Smith Bay (Finger Roads South of Neck Road), CT

Neighborhood Resilience Concepts

Hazard Setting

East of Mercy by the Sea is a series of private roads extending south from Neck Road to Smith Bay. These roads, between Twin Coves Road and Shorelands Drive, are relatively densely settled residential areas that are relatively high in elevation and protected from inundation. However, the southern ends of all of these roads drop down, are typically lower in elevation than the beaches they lead to, and are protected from water and sand by bulkheads. Drainage problems are already apparent in these areas. The southernmost properties here fall within a VE zone with a BFE of 14 feet NAVD88, while AE zones with BFEs of 13 or 14 feet extend inland.

The end of Toffee Lane and Overshore Drive are particularly vulnerable, and may experience daily flooding by the 2020s. By the 2050s, daily high tide may also impact Pleasant View Avenue, Beach Avenue, Harbor Avenue, and Kelsey Place. A Category 2 storm under current conditions can be expected to inundate the southern edges of all of the roads in this neighborhood, and to impact over 70 homes.

This memo presents adaptation actions that can be taken in the Smith Bay neighborhood. The main vulnerabilities these actions attempt to address are those posed by direct inundation of structures, inundation of roads, and drainage issues associated with very low elevation roads that are below the surrounding land surfaces. These actions are summarized below:

- Hybrid Shoreline Protection Suite
  - Beach Nourishment
  - Dune Restoration
  - Seawalls
  - Drainage System Retrofit
- Floodable Neighborhood
  - Elevate Coastal Roads
- Complete Protection
  - Levee Construction

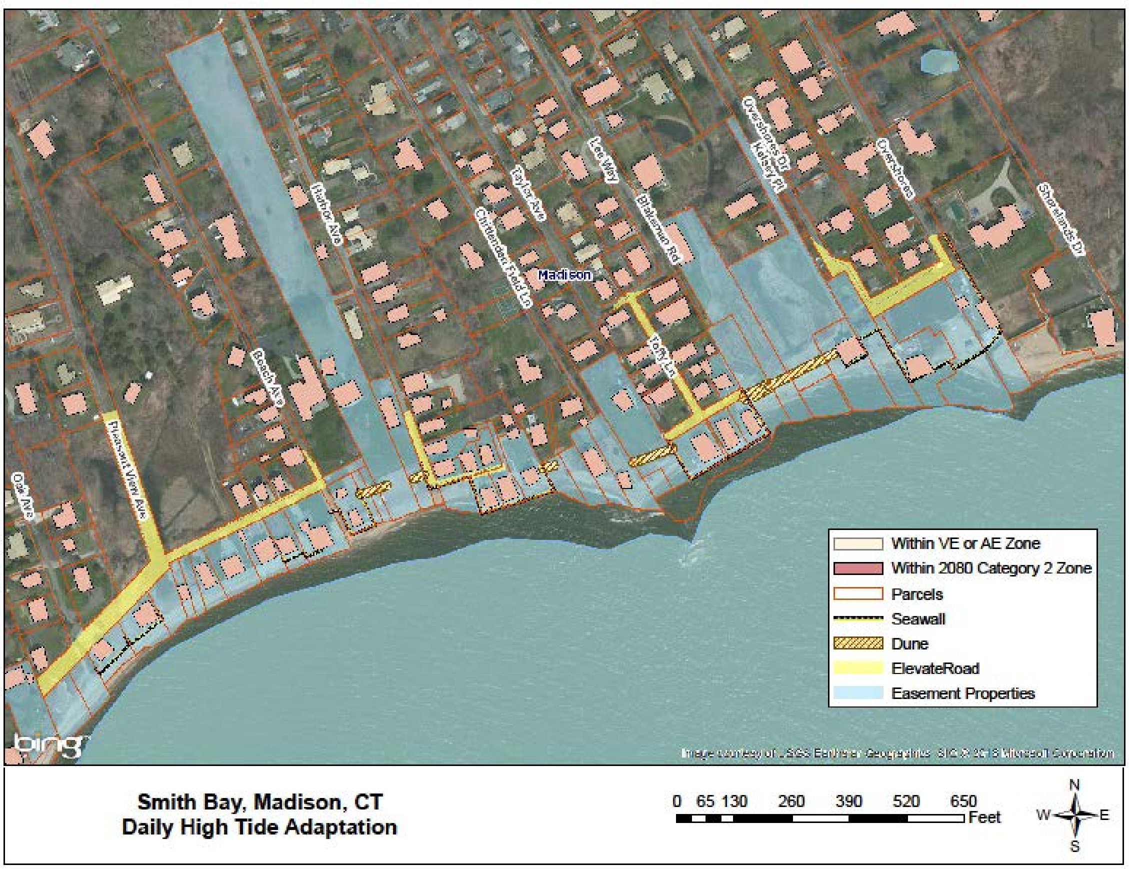
Hybrid Shoreline Protection

A number of adaptation actions can be taken in unison to protect homes in Smith Bay from Daily High Tide flooding as projected through the 2080s. This approach aims to prevent high water from overtopping a specific set of low-elevation shoreline areas, and improve drainage systems to prevent backflow (or "surcharging"). These objectives can be achieved in a number of ways.

Planning Conditions

The current "mean higher high water" (MHHW), or the average maximum elevation of high tide, in Madison is around 2.29 feet NAVD88. According to NOAA Intermediate High projections, with continued ocean warming and an intermediate degree of ice sheet melting, sea level will rise 4.17 feet here by then end of the century. This will create a MHHW of 6.46 feet by 2100. The USACE High projection adds the local rate of vertical land movement to this calculation, and gives a MHHW of 7.45 feet by 2100.

To provide a conservative estimate of planning needs in the future, the conceptual designs and costs for each action presented here were based on protection from water elevations of 8 feet NAVD88.



The image above depicts some of the following adaption options.

Dune Restoration

A dune restoration project is already taking place in this neighborhood between Toffee Lane and Kelsey Place. Continuing this effort, and raising the elevation of the dune to 8 or more feet, will help prevent overwashing of this beach. Dune restoration may also be feasible on the beach at the end of Harbor Avenue. In this case, the dune would have to be located at the eastern, narrow end of the existing beach, and may require beach nourishment to occur concurrently. This would be in order to achieve the width of beach necessary to sustain a structurally stable dune.

Seawalls

Some of the areas where sea level rise projections show water overtopping the shoreline are at sites where homes are currently constructed. These homes are protected by bulkheads and seawalls. In order to prevent future high tide flooding, Madison would have to have the height of these seawalls increased to accommodate higher sea levels, and to tie these walls in with other protections, such as dunes.

Retrofit the Drainage System

The low-lying areas that are most susceptible to flooding here are connected to the sound either by stormwater drainage systems or tidegates that allow water to flow in and out of tidal wetlands. These systems will need to be upgraded to prevent surcharging, or the backflow of water into a protected area through the drainage system, as sea levels rise. Drainage systems can be retrofitted with duckbill outlets that let water flow one direction but not the other. Tidal wetlands, or larger drainage systems, can be fitted with tidegates to prevent water from entering when sea level is above a certain elevation.

Some areas may require installation of stormwater pumping-stations to remove floodwater when sea levels are above the elevation of that area. Examples of such locations are Toffee Lane and Harbor Ave, which will be lower than the Mean High High Water elevation by the 2080.

Floodable Neighborhood

Madison may decide to allow flooding to continue unchecked in this neighborhood, instead focusing on adapting structures and infrastructure to withstand those events.

Elevate Coastal Roads

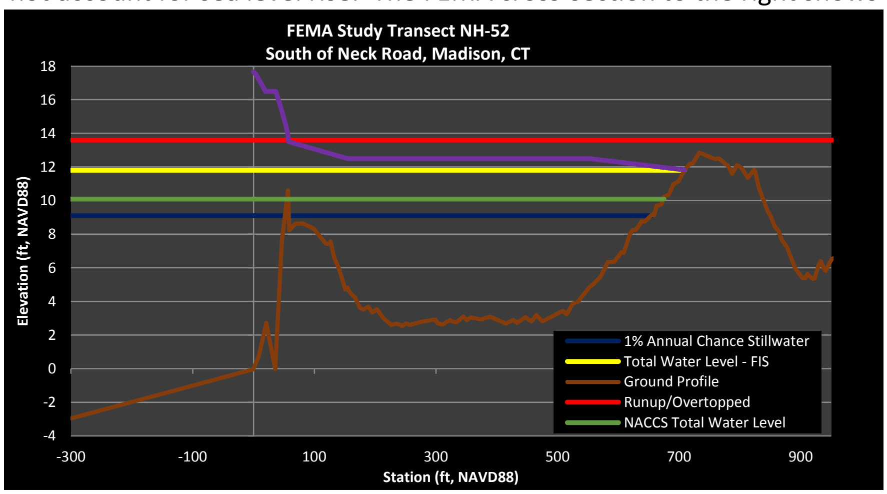
Low-lying roads could be elevated so that access to homes is not lost during every high tide. Elevation of some roads may even protect certain areas from flooding. Roads that may benefit from elevation include Pleasant View Avenue, the end of Harbor Avenue, Toffee Lane, and the end of Kelsey Place. The southern end of Overshore Drive will also be inundated regularly by the 2080s, but because the road is a loop, access to homes is not projected to be limited by this flooding. Elevation of Toffee Lane may prevent high tide waters from reaching inland areas.

Elevate Homes and Structures

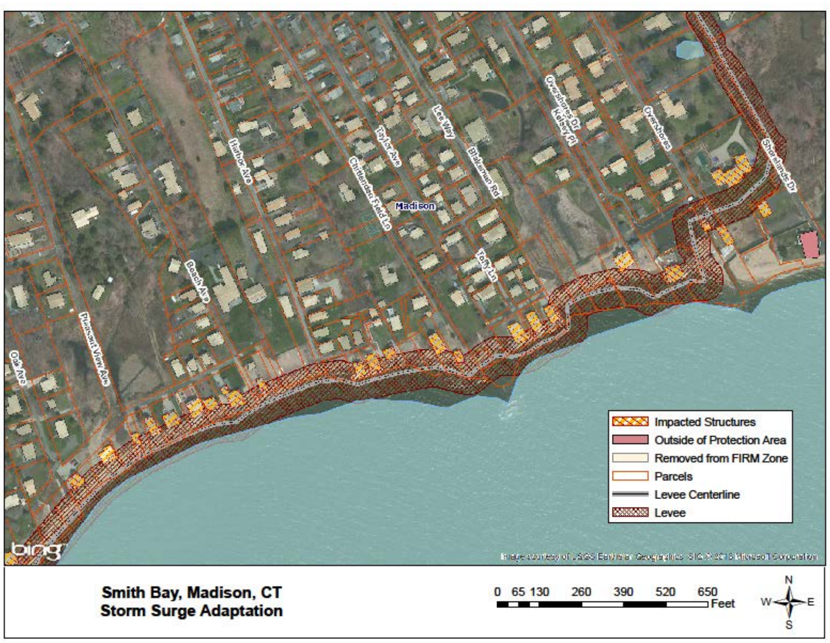
All of the homes that fall within the FEMA-mapped flood zones should be elevated. As sea levels rise and, with them, base flood elevations, home elevation requirements will increase as well. The number of homes projected to be impacted by a category 2 storm in the 2080s, and therefore should be elevated, in listed in the next section.

Levee Protection

A current base flood in the Smith Bay neighborhood has an elevation between 12 and 14 feet (NAVD88), according to FEMA calculations. In order to protect the area from that base flood elevation and the additional effects of wave setup and runup, Madison would have to construct a levee between 14 and 16 feet in elevation. Because of limited space along the coast here, the levee would either require acquisition and removal of at least 23 structures, and section of it would have to be constructed on areas currently below sea level, adding to the overall height requirements and complicating construction. These figures do not account for sea level rise. The FEMA cross-section to the right shows the ground profile and current base flood elevations. The sharp rise at the 40-foot mark reflects the existing waterside houses and protective bulkheads. Note that the "wave envelope" is mapped at nearly 18 feet elevation. That is the minimum elevation the levee would need to achieve to prevent overtopping.



The image below depicts the impact that Levee construction would have on the neighborhood.



Planning Level Costs for Alternatives:

Dune Restoration

There are a few short sections of the Smith Bay coastline that currently support some degree of dune. These areas already have relatively high elevations, so dune restoration projects at these sites, designed to protect against high tides through the end of the century, would only need to raise dune crest elevations by a few feet. Based on raising dune crests to 8 feet NAVD88, approximately 437 feet of dune would be constructed, with heights above existing dunes ranging from zero to four feet. The volume o sand required would be around 370 cubic yards.

Estimates for the cost of this action are based on costs in West Haven, CT for a recently completed project. The cost of nourishment sand material varies dramatically depending on quantity, source location, and means of transport to the site. In West Haven sand was transported to the site from Cape Cod, MA and purchased by the ton. We consider this the most conservative of planning level cost estimation, based on the distance from Madison to Cape Cod. After converting the per ton cost to cost per cubic yard we estimate $50/cubic yard. This gives a planning level cost estimate of $18,600 for the dune nourishment portion of this recommendation. Material from a local source should significantly decrease this estimate.

Secondary protection may be required to prevent dune erosion and overtopping of restored dunes during storm events. Protections may include beach nourishment, ongoing dune nourishment, installation of a hard “core” to the dune to add stability, or even construction of offshore breakwaters. Additional, detailed erosion modeling is needed to determine the most effective action. For that reason, it is not possible to provide cost estimates for those features at this time.

Seawalls

Seawalls would need to be constructed such that high water is not able to flow around the edges at lower-elevation sites. Installation of a seawall that “ties-in” to higher-elevation ground, existing seawalls, or sites of proposed dune restoration, would require an estimated 2,375 feet of wall.

FEMA 551 – Selecting Appropriate Mitigation Measures for Floodprone Structures (2007) provides estimates of between $140 and $195 per linear flood for floodwalls between four and six feet above grade. A flood wall designed to prevent daily high tide flooding in the future would need to vary from a negligible height in some locations (where ground surface is somewhat higher) to a height of five to six feet in the most low-lying areas. To be conservative, an upper linear foot cost of $200 is assumed which equates to an estimated cost of $475,000 for the flood wall.

Easements

Approximately 46 property owners would need to grant permanent easements for the City to maintain the flood walls and dunes. For planning purposes, the cost for securing the easements is assumed to be at least $1,000 per property, or $46,000.

Retrofit the Drainage System

Upgrades to drainage infrastructure and installation of a stormwater pumping system are called for in this plan as explained above. Tideflex gate valves on storm sewer outfalls along with one or more pumping stations and force mains will likely be necessary. This can be expected to add an addition $500,000 to the overall project cost.

Elevate Roads

Costs for this alternative come from the cost of the road material and the cost of construction. The road heights and widths will vary because the existing ground surface elevation varies. Based on elevating to 8 feet NAVD88 in order to maintain access during high tide events as projected through the end of the centurry, approximately 8828 cubic yards of material would be needed. At an estimate of $50/cubic yard for compact fill material and neglecting incidental costs, the elevated road would cost at least $441,400 for fill material. Construction costs and utilities will add around another $150,000.

Elevate Homes

Many of the homes in this neighborhood are already elevated to current FEMA-calculated base-flood elevations (BFE), but forward-looking planning calls for both elevating homes currently outside of mapped flood zones, and increasing the elevations of already raised structures.

The Nature Conservancy's projections show approximately 158 structures within the inundation zone of a category-2 hurricane in this area, as projected to the 2080s. With an average typical cost of a home elevation of around $1 million, it will cost homeowners around $158 million over the next few decades to bring their homes to a resilient height.

Levee System

It is important to consider all options available for coastal adaptation, both to ensure good options are not missed, and to spell out why other actions are not taken. It is our conclusion that construction of a levee to protect the Smith Bay neighborhood is not a feasible option. Planning level costs are included here as evidence of the factors that would need to be considered.

In order to accommodate even the current calculated base flood elevation, a dike would have to be a minimum of 14 feet elevation, NAVD88. To provide for wave heights, setup, and runup, while recognizing the limits on horizontal space in this location, a peak elevation of 16 feet is suggested for discussion purposes.

To be consistent with levee construction guidelines, designed to ensure structural integrity, the side slope of the dike should be approximately 2.5:1 to 5.0:1. Additionally, the crest width should be 5 feet to allow for maintenance. Ground surface elevation along the shoreline varies, and as such so would the relative height of the dike. Based on elevation values from 2-foot contours and the necessary side slopes, an approximation of dike heights and widths required to protect Point Beach was made. These figures are summarized in the following table:

FID	Ground Elevation	Height	Width
0	12	4	37
1	10	6	53
2	8	8	69
3	10	6	53
4	8	8	69
5	10	6	53
6	8	8	69
7	6	10	85
8	8	8	69
9	6	10	85
10	4	12	101
11	4	12	101
12	6	10	85
13	2	14	117
14	4	12	101
15	6	10	85
16	8	8	69
17	6	10	85
18	6	10	85
19	8	8	69
20	10	6	53
21	12	4	37

Using the dimensions in the above table, the total volume of material for the dike system will be approximately 20,000 cubic yards. At an estimate of $50/cubic yard for compact fill material and neglecting incidental costs, the dike system would cost around $2.0 million for fill material. Riprap along the waterward face of the berm or levee would cost an additional $1 million.

The dike would necessitate the displacement of approximately 27 homes. A review of the assessor data for Point Beach reveals an average assessed value of around $620,000 per property for the affected properties. This number does not include non-structural alterations to lots affected by levee construction, nor the displacement of secondary structures such as garages or sheds. Understanding that market values are typically higher yet variable from year to year, the average assessed value of $620,000 was used for planning. Acquiring 27 lots would cost at least $16.7 million.

Some of the remaining property owners would need to grant permanent easements for the City to maintain the dike systems. A separate cost has not been estimated for the easements, as it would likely be much lower than the real estate acquisitions needed for this alternative.

Upgrades to drainage infrastructure and installation of a stormwater pumping system are called for in this plan. Tideflex gate valves on storm sewer outfalls along with one or more pumping stations and force mains will likely be necessary. This can be expected to add an addition $500,000 to the overall project cost.

One financial benefit associated with the dike option is that property owners would have the choice to discontinue flood insurance policies if the levee system were accredited and maintained as a flood protection system in perpetuity. This outcome also assumes that the City would secure a LOMR from FEMA. Around 135 homes would benefit from this cost savings (158 homes minus the lots that were lost for the levee construction).

Another financial benefit associated with the dike option is that structures would not need to be elevated over time as substantial damage/ substantial improvement thresholds were reached, because the LOMR would map the structures out of the FEMA SFHA.

Finally, an additional cost that would need to be considered is the impact such a project would have on the neighborhood's feel and value. Such a levee construction project would completely remove ocean views, and significantly impede access to the waterfront.

Summary

The following table summarizes the options discussed above:

Alternative Description	Modeled Outcome	Approximate Cost ($)
High Tide Protection This alternative includes: • Dune Restoration • Seawalls	Building up existing dunes and constructing or improving seawalls should protect the neighborhood from high tide flooding through 2080s for a reasonable cost and with minimal effect on the neighborhood's character. Drainage improvements will be necessary.	Dune: 18,600 Wall: 475,000 Easement: 46,000 **Municipal Total: 539,600**
Floodable Neighborhood This alternative includes: • Home Elevations • Road Elevations	Approximately 160 structures will have to be elevated to protect them against future high tides and storm surges, at great cost to owners. Elevating roads may maintain access during floods and serve to create barriers to high tide flooding. Elevations will be required over time regardless, unless the storm surge protection option is implemented.	Homes: 158,000,000 Roads: 591,400 **Municipal Total: 591,400**
Storm Surge Protection This alternative includes: • Levee Construction	This alternative is the most expensive for the Town, will require acquisition and demolition of around 27 properties, will remove views of and access to the shoreline, and significantly alter the neighborhood's character. It is the only option presented to remove the neighborhood from the FEMA flood zone.	Levee: 3,000,000 Acquisition: 16,700,000 **Municipal Total: 19,700,000**
Drainage System Retrofits	All of the above alternatives will require installation of duckbill outlets on storm drains, tide gates on streams or elsewhere when appropriate, and possibly installation of stormwater pumping stations.	**500,000**

Conclusion

While all of the options presented in this memo may be technically feasible for the Smith Bay neighborhood, they vary considerably in capital costs and, importantly, social costs. The actions listed are further just a few possible ways to address the risks presented by increasing flooding.

Consider the following:

- The floodable neighborhood shifts most of the costs from the Town to the property owners over the long term as the level of service from roads and drainage systems is minimized and the property owners elevate their homes. The property owners would continue to pay for flood insurance as they currently do.
- The design for protection from the daily high tide may be challenging, but it has associated costs that are somewhat equitable. The Town would be responsible for capital costs for the flood protection and the property owners would continue to elevate their homes and pay for flood insurance as they currently do.
- Elevating roads may serve a dual purpose by both providing access to homes during floods, and acting as berms to control floodwaters.
- The design for protection from storm surges requires a dike system that would be very high and either require filling within Long Island Sound or displacement private properties, or both. Therefore, this option is the most costly, would cause extreme disruption to the neighborhood, and would involve navigation of multiple regulatory issues. However, this is the only option that could result in a FEMA map revision and eventual discontinuance of flood insurance for approximately 130 property owners.

Because the Town is planning ahead with this coastal resilience plan, the options for the Smith Bay neighborhood could be viewed as steps rather than different outcomes. It would be feasible, for example, to retrofit the Smith Bay wetland and low-elevation road drainage systems to protect properties from high tide flooding through the next 30 to 50 years, while pursuing funding for seawall construction. Similarly, dune restoration and seawall construction can be performed at flooding “hotspots”, and gradually expanded over time. Meanwhile, home elevations or acquisitions can continually be pursued on a case-by-case basis.

Appendix F-1
Middle Beach Road Coastal Resilience Concept

Middle Beach Road Nourishment

The area of Middle Beach Road, between Tuxis Road and Park Avenue, has reoccurring flooding issues in the existing conditions. As a result, the existing seawall and revetment require regular rebuild and repairs. The flooding impacts the road and the utilities as well. This area is in need of a greater level of protection during storm events and extreme high tide levels.

The area surrounding Middle Beach Road in Madison, CT is a densely populated area with vital infrastructure components. Many homes are potentially impacted by the 1-percentannual -chance event (see Fig.1 below). In addition, a substantial amount of infrastructure is also impacted along this section of shoreline.

Fig. (1) - Effective FEMA Flood Zones at Middle Beach Road in Madison, CT

In order to provide adequate protection to the Middle Beach Road and stop the flooding, a higher seawall with toe scour protection needs to be built in this area. Realignment of the road appears not to be an option with the amount of development in the area. Currently the elevation at the crest of the revetment is approximately 6 feet NAVD88 (Fig. 2). In addition, it is recommended that several offshore breakwaters and/or T-groins be built in front of the seawall to build up and keep sand, extend the beach, and prevent damage to the seawall and road by reducing the wave energy and breaking the larger offshore waves. This would also lower the required seawall height by lowering the wave runup and overtopping potential.

Fig. (2) - Topographic contours along the shoreline at Middle Beach Road.

The height of the wall will need to be calculated based on the desired level of protection. For example, to prevent overtopping at the 1-percent-annual chance flood event, the seawall elevation needs to be equal or greater than the 1% flood elevation plus the wave runup heights. According to the most recent FEMA study in this area (Study Transect NH-53) the 1-percent-annual chance flood level (with wave setup) + Runup would be near 22.43 feet NAVD88. The only way to prevent flooding completely would be to build a higher wall in combination with beach or marsh seaward of the revetment in order to absorb the wave energy to prevent erosion and damage to the wall. This alternative would also require the construction of offshore wave attenuation structures in order to break the larger waves offshore. In order to achieve certification from FEMA and to revise the Flood Insurance Rate Maps to show a reduced risk the seawall height would also need to be an additional 1 feet above the maximum wave runup height. It may be cost beneficial to also consider mitigating to flooding to a lesser return period storm (i.e. 10-percent-annual chance flood event).

Table (1) shows the water level recurrence intervals for Town of Madison based on the USACE NACCS study.

Table (1) - water level recurrence intervals for Town of Madison - USACE NACCS study.

Town of Madison, CT - USACE NACCS Water Levels *(all flood frequencies include wave setup)*			
10% ft., NAVD88	2% ft., NAVD88	1% ft., NAVD88	0.2% ft., NAVD88
7.4	9.1	10.1	13.0

As shown in Fig (3) below, the proposed offshore wave attenuation structures (breakwaters or T-groins) will reduce the wave impacts to the seawall and provide more protection by breaking the waves and reducing their energy which will also lead to smaller wave heights and smaller runup values on the seawall. In other words, building the offshore structures will reduce the minimum required height of the seawall for protection against any flood event by reducing the runup heights, hence the amount of overtopping

Fig. (3) - Example of offshore t-groins with sand deposit the landward side of the beach.

In order to determine the best alternative to mitigate overtopping and erosion of the seawall during any flood event along Middle Beach Road, it will be necessary to conduct further detail erosion, sediment transport, and wave analysis. It is important to study sediment movement directions in this area to better understand the sand deposition patterns for the design and finding the best location for the offshore structures to trap the sand and reduce wave energy.

Beach features will always get eroded to some extent along the stretch of shoreline and may require regular maintenance. To provide a more effective long term practice, construction of a marsh in front of the seawall could be a more environmentally friendly option. Building a marsh will absorb the wave energy to prevent erosion and damage to the wall. Building a marsh may require structures around it to contain the fill and break the larger waves.

As mentioned previously complete realignment of the road is not feasible in this area. Another alternative could be to retire the section of road just inland of the top of the revetment and design an alternative route for access for the current residents (Fig. 4). Consideration should also be made for raising the top of road elevation to prevent any ponding or standing water with a seawall raising.

Fig. (4) - Proposed section of road between Gull Rock Rd and Tuxis Rd to be retired.

The estimated approximate cost for implementing the protection features for this site is on the order of $500,000

Appendix F-2
Surf Club Beach Coastal Resilience Concept

Surf Club Beach, Madison CT, Infrastructure Resilience Concept

Hazard Setting

The area of Surf Club Beach in Madison can be divided into three sections. The first consists of the approximately 70-foot wide public beach in front of the Madison Surf Club; the second is made up of private residences built on the water to the east of the Madison Surf Club, fronted by a beach ranging from zero feet to about 60 feet wide at high tide; and the third is comprised of a complex of tidal wetlands and low-lying golf greens located inland to the north of the other two sections. The FEMA VE zone on the water has a base flood elevation of 14 feet, with the inland AE zone BFEs equaling 12 or 13 feet. In one area a finger of the VE zone extends inland, over the Madison Surf Club Beach and into the wetlands behind.

It has been determined that much of the damage experienced in this area results from storm surge overtopping the beach, inundating the wetlands, and flooding properties and roads from behind. The spot where beach overtopping occurs is reflected in the inland intrusion of the FEMA VE zone as described above, and has been identified as a breached dune located to the east of the Madison Surf Club and west of the private properties.

Current condition at the beach. The current dune is located behind the people. To the right, sand can be seen spreading inland over the reeds where the dune has been breached.

The current condition of the site is depicted on the next page. A variety of features were identified in the field and are marked on the figure. Note the two lobes of existing dunes toward the center of the image. To the east (upward in the figure) the dune has been washed out, and sand deposited inland on the wetland.


Type
beach feature
photo
riprap
structure
wrack
Type
beach edge
dune
max
maximum
minimum
structure
water
wrack
GPS_Polygons_Projected
0 12.525 50 75 100 125
Feet
Surf Club Beach, Madison, CT
Existing Condition

Proposed Infrastructure Resilience Concept

We believe that a combined beach and dune nourishment and stabilization project would be appropriate for this site. This form of green infrastructure could diminish flood extents, protect properties, and support coastal habitats and ecosystems. It is possible that the dune would migrate inland over time as sea level rises, making it a more flexible and adaptive approach to flood hazards than hard infrastructure solutions.

Planning Level Costs

The proposed dune would be built to approximately 11 feet NAVD88 in order to be consistent with the maximum elevation of the existing dune. Increasing the elevation above this would be possible, but may require concurrent beach nourishment or construction of an engineered dune core to maintain stability. The dune would be built to fill in the natural breach as well as the created breach that allows the existing walkway to access the beach. Based on existing topography, approximately 1,015 cubic yards of material would be needed to create this dune.

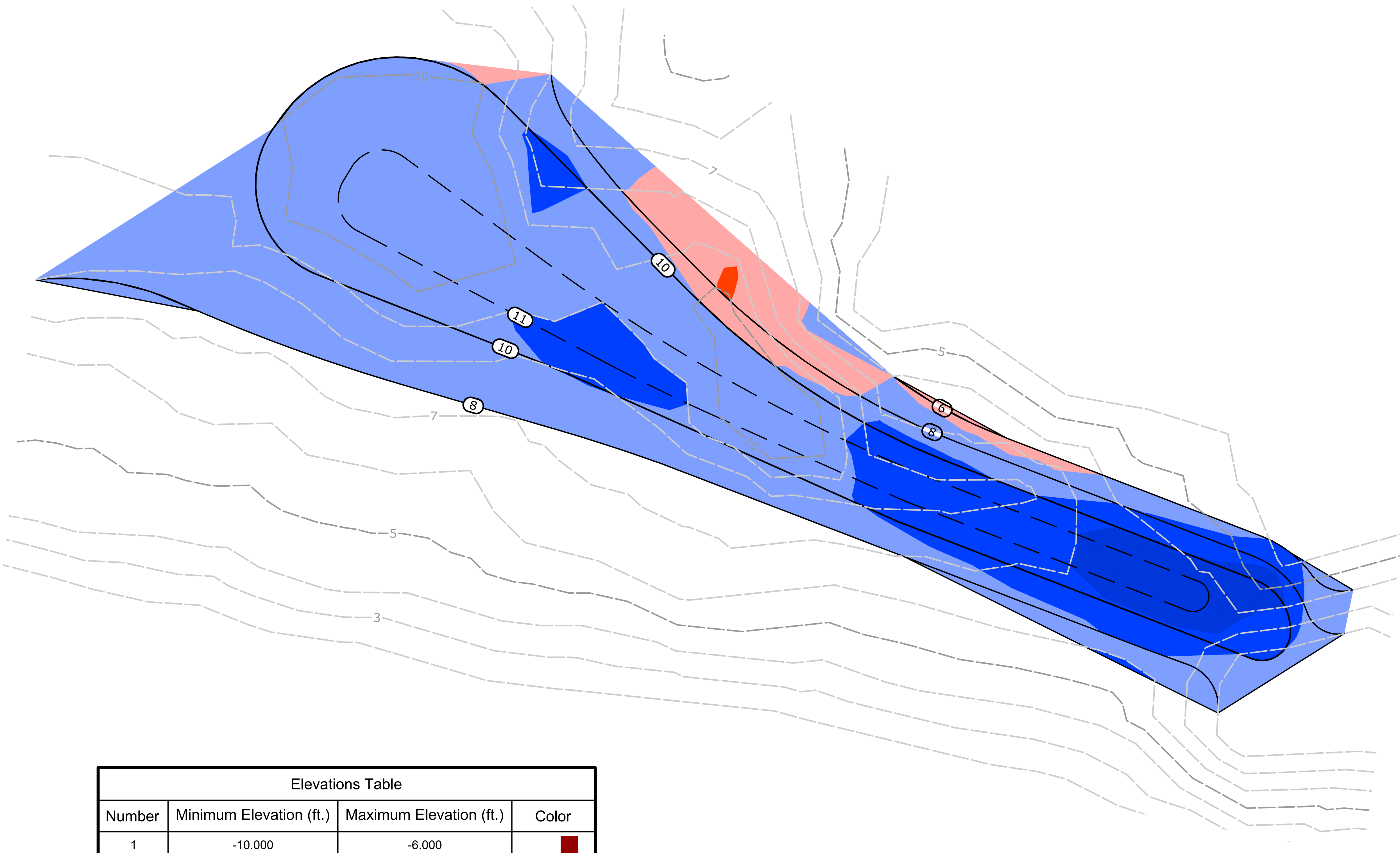
Estimates for the cost of this action are based on costs in West Haven, CT for a recently completed project. The cost of nourishment sand material varies dramatically depending on quantity, source location, and means of transport to the site. In West Haven sand was transported to the site from Cape Cod, MA and purchased by the ton. We consider this the most conservative of planning level cost estimation, based on the distance from Madison to Cape Cod. After converting the per-ton cost to cost per cubic yard we estimate $50/cubic yard. This gives a planning level cost estimate of $50,750 for the dune nourishment portion of this recommendation. Material from a local source should significantly decrease this estimate.

Secondary protection may be required to prevent dune erosion and overtopping of restored dunes during storm events. Protections may include beach nourishment, ongoing dune nourishment, installation of a hard “core” to the dune to add stability, or even construction of offshore breakwaters. Additional, detailed erosion modeling is needed to determine the most effective action. For that reason, it is not possible to provide cost estimates for those features at this time.

Construction of a new, elevated walkway to provide access to the beach may be desired, though access may be feasible around the western side of the dune. Estimates for cost of that construction are not provided here.

Conclusion

The option presented in this memo is one possible way to address the risk of beach overtopping and inland flooding in this neighborhood. Other approaches do exist, including application of “hard infrastructure” protections, individual structural adaptation measures for vulnerable buildings, or a combination of approaches. If owners of vulnerable homes here are interested, the Town can also assist them with the pursuit of funding to acquire and remove those properties. This option has additional benefits over other possible options in its aesthetic and ecological value.



Elevations Table			
Number	Minimum Elevation (ft.)	Maximum Elevation (ft.)	Color
1	-10.000	-6.000	
2	-6.000	-4.000	
3	-4.000	-2.000	
4	-2.000	0.000	
5	0.000	2.000	
6	2.000	4.000	
7	4.000	6.000	
8	6.000	10.000	

Cut/Fill Summary

2d Area	Cut	Fill	Net
21,270 Sq. Ft.	45 Cu. Yd.	1,060 Cu. Yd.	1,015 Cu. Yd.<Fill>

0' 15' 30'
0 1/2" 1"
SCALE 1" = 30'

N
W E
S

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REVISIONS

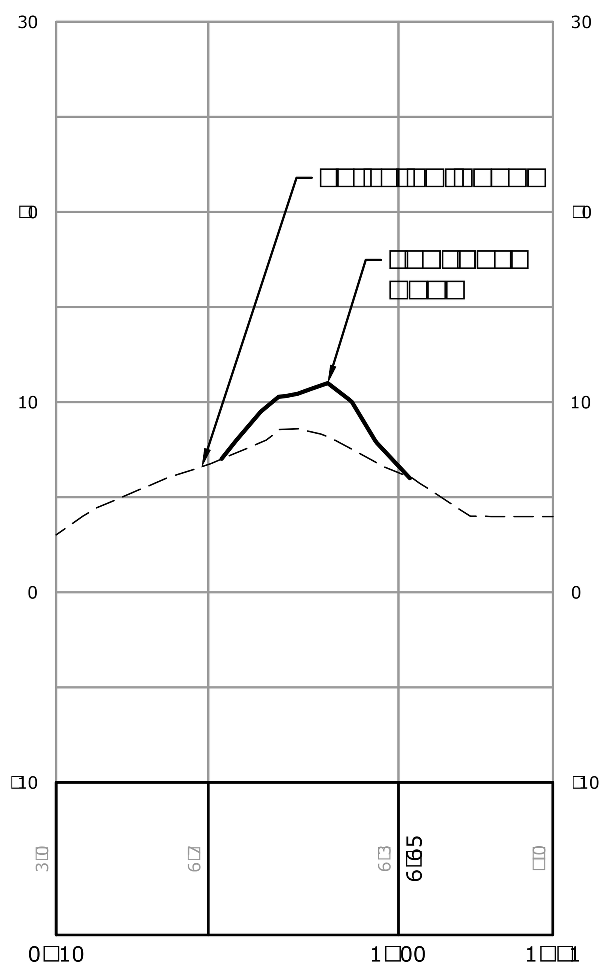
EARTHWORK - EXISTING VS PROPOSED

PROJECT NAME 1
PROJECT NAME 2
ADDRESS, STREET NAME
MADISON, CONNECTICUT

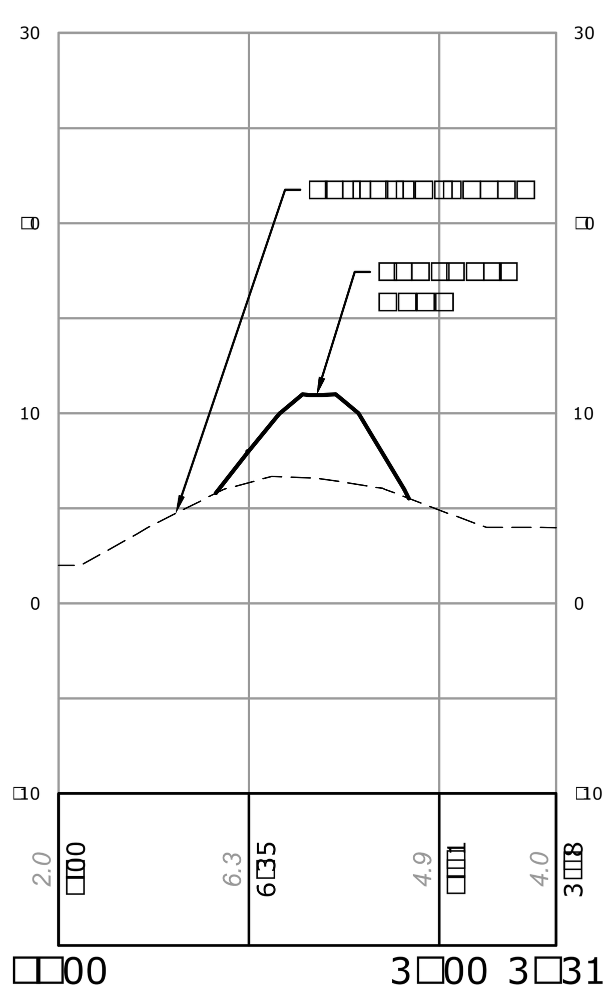
DESIGNED	DRAWN	CHECKED
--	HAR	JCW

SCALE 1"=30'
DATE APRIL 27, 2016
PROJECT NO. 2619-09
SHEET NO. 1 OF 1

Drawing: C:\USERS\HANNAHR\APPDATA\LOCAL\TEMP\ACPUBLISH_8872\V-EARTHWORK.DWG Layout Tab:11X17
Plotted by: HANNAHR On this date: Wed, 2016 April 27 - 4:55pm



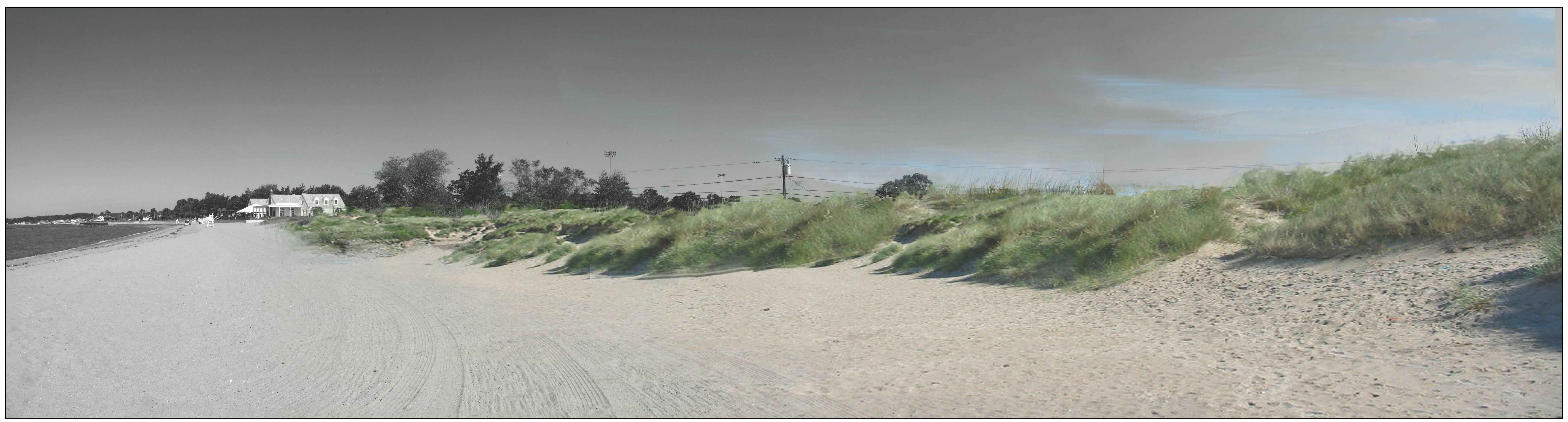
CROSS SECTION 'A-A'



CROSS SECTION 'B-B'

PROPOSED DUNE

NOT TO SCALE



PROPOSED DUNE PERSPECTIVE

NOT TO SCALE

MADISON SURF CLUB

DUNE RESTORATION

SURF CLUB ROAD
MADISON, CONNECTICUT

APRIL 28, 2016

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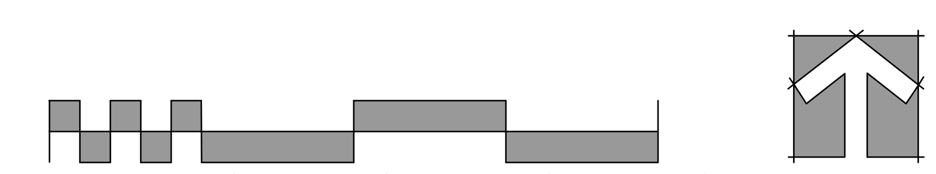


Appendix G
Notes from Public Meetings

Notes from Public Meeting

DATE: January 07, 2016
MMI #: 2619-09
PROJECT: Madison Coastal Resilience Plan

SUBJECT: Notes from Public Meeting (Risk/Vulnerability Assessment)
LOCATION: Madison

ATTENDEES:

David Murphy, P.E., CFM, MMI
Noah Slovin, MMI
Scott Choquette, CFM, Dewberry
Madison Planning & Zoning Commission Members
- Chairman Ronald Clark
- Vice-Chairman Francine Larson
- Secretary Christopher Traugh
- James Matteson
- Thomas Burland
- John K. Mathers
- Joseph Bunovsky, Jr.
- Brian Richardson
Michael Ott, P.E., L.S., Town Engineer
David Anderson, Town Planner
Madison Residents

A public meeting was held on January 7, 2016 to introduce the Town of Madison coastal resilience planning effort to residents and the public. One goal of this meeting was to clarify key concepts and terms related to Coastal Resilience Planning, such as resilience, risk, hazard, vulnerability, and adaptation. Other goals were to describe specific types of coastal hazards and the specific community assets vulnerable to those hazards, to explain how hazards and vulnerabilities can be expected to change in the future, and to solicit information and participation from the public.

The meeting was recorded on video to be broadcast on the local access television station (MCTV) later. Minutes were typed by Marlene H. Kennedy, clerk, and are available through the Madison website <http://www.madisonct.org/PZ/minutes/2016/2016-01-07.pdf>.

Madison Planning & Zoning Commission (P&Z) chairman Mr. Clark conducted the meeting. He began by introducing Mr. Murphy, who in turn introduced the Mr. Choquette and Mr. Slovin. Mr. Murphy then began the PowerPoint presentation, covering the following topics: Resilience (including general concepts and issues specific to Coastal Resilience); Project Funding and Planning Steps (including coordination with other projects); and Risk (including the effects of changing climate and sea level on future risk). Mr. Choquette followed Mr. Murphy by presenting a number of slides illustrating additional complexities with regards to modeling coastal inundation and erosion risk, and noted that such complexities will be incorporated into the planning of site-specific resilience projects. Mr. Slovin then presented on the concept of vulnerability (including how climate change and sea level rise will impact future vulnerabilities, and specific categories and regions that are vulnerable to coastal hazards). Mr. Murphy closed the presentation by discussing the next steps of the project, and describing some of the adaptation and resiliency options that will be considered moving forward.

After the presentation, the floor was opened for a question-and-answer session, moderated by Chairman Clark. Questions (denoted by "Q") and Answers ("denoted by "A") were as follows:

Q April Allen (East Wharf Road) asked if anybody knew about a phragmites removal project on Fence Creek. She approached an individual seen inspecting the phragmites, who informed her the plants would be removed as part of a restoration and flood mitigation project.

- **A** None of the attendees were aware of this project. Town Planner David Anderson said he would follow up on it.

Q Nolan Hale ("Brown House") stated that his house did not experience any internal damage during the major storms because of his storm shutters, and recommended other residents install shutters. He noted that his house did experience external damage. He also stated that it seemed to him most of the coastal roads were constructed in the 1970's and are vulnerable, yet recently gas lines and other utilities are being installed in those roads. He is concerned about this. He wanted to ensure that this plan would address roads.

Q Tammy Rooney (Fort Grove Avenue) followed Mr. Hale's comment by saying that she has also seen gas lines installed, specifically along Seaview Avenue, and on the beach-side of the street. She pointed out that this is a very low-elevation road, especially near the intersection with Willard Avenue. She is very concerned about this, and believes there needs to be coordination between the Town and the utility companies, and wants to know if this plan will address the issue of coordination.

Q Walter Welsh (Grove Avenue) stated dunes and sand are important for storm and flood protection, but many are lower than they used to be. He said that passive restoration efforts (such as installation of snow fencing) are underway for ¾ miles of damaged dunes at Seaview Beach.

Q Joan Walker (Stepping Stone Lane) indicated concern about septic tanks in hazard areas and the impacts when they are damaged during storms. She is curious about what those impacts are and what sorts of solutions can be found.

Q Christopher Traugh (P&Z Secretary) wanted to know if this project would include coordination with the Hazard Mitigation Plan developed by SCRCOG. Mr. Murphy said that it would, and would also be coordinated with the regional coastal resilience plan being administered by SCRCOG.

Q Barbara Davis (Stone Road) wanted to know what the timeline was for completion of this plan, and whether it would coordinate with the town's capital improvements plan.

- **A** Mr. Murphy answered that a draft plan will be submitted in late spring or early summer, when the grant ends. He said that it is hoped that the plan's proposals will be incorporated into Madison's capital improvements plan.
- **A** Mr. Murphy also mentioned that there will be one or two additional meetings to discuss other aspects of the plan, as well as an online survey that all residents – those who can attend the meetings and those who are unable – will be able to complete.

Q Mary Kaye (Seaview Avenue) brought the discussion back to the role of the Town in regulation of utility placement, such as the gasline on Seaview Avenue.

- **A** Chairman Clark stated that utilities are regulated by the State's public utilities regulatory authority and the Department of Energy and Environmental Protection.

Q Tammy Rooney stated that it would be great if the local government could coordinate with the utility companies and the State, and reiterated displeasure with the fact of the gas-line installation, the fact that the utility company parked its vehicles on restored dunes, damaging them, and the fact that there was no coordination with local residents.

- **A** Thomas Banisch (First Selectman) stated that his office works closely with the utility companies, and should be contacted if residents ever have any problems with those companies.

Q Chairman Clark stated that a significant issue during storm events is loss of communication utilities, including landline phones, cellphones, and cable. He stated that most radio stations are network stations with syndicated shows and do not have local information. He wondered if hardening communication infrastructure was an option. He recognized that this issue might be more relevant to plans with broader focuses than this one.

Q Cecilia Fisher expressed disappointment at the timing of this meeting, especially in the context of the overall plan timeline, which ends in the early spring. She pointed out that many seasonal residents – who own many of the homes along the shore – will not be able to be present to give their input.

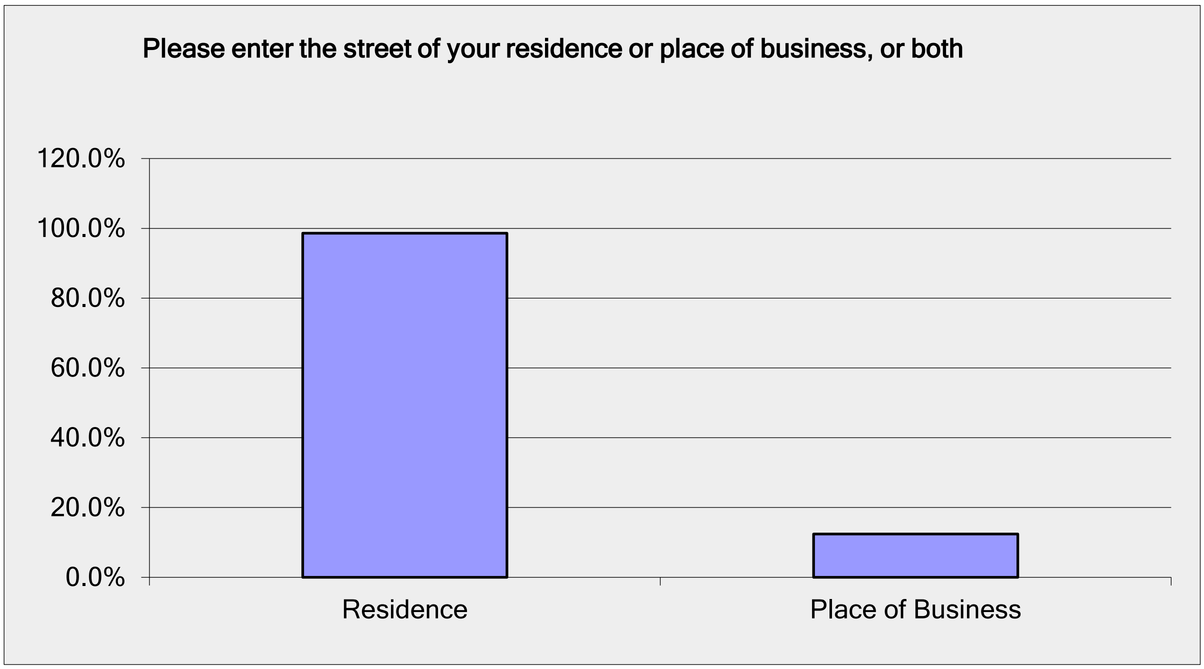
- **A** Mr. Murphy granted that the scheduling issues are unfortunate, and said that MMI will work closely with the Town to ensure the public remains informed and is able to participate and give input.

After the question-and-answer session, attendees were invited to inspect paper copies of projected inundation risk maps, to find their homes or other recognized areas, to compare flood extents to their own experiences, and to visualize how flood risks may increase in the future. The consultants, Mr. Anderson and Mr. Ott, and the P&Z members were also available for questions and discussion.

Appendix H
Results from Online Survey

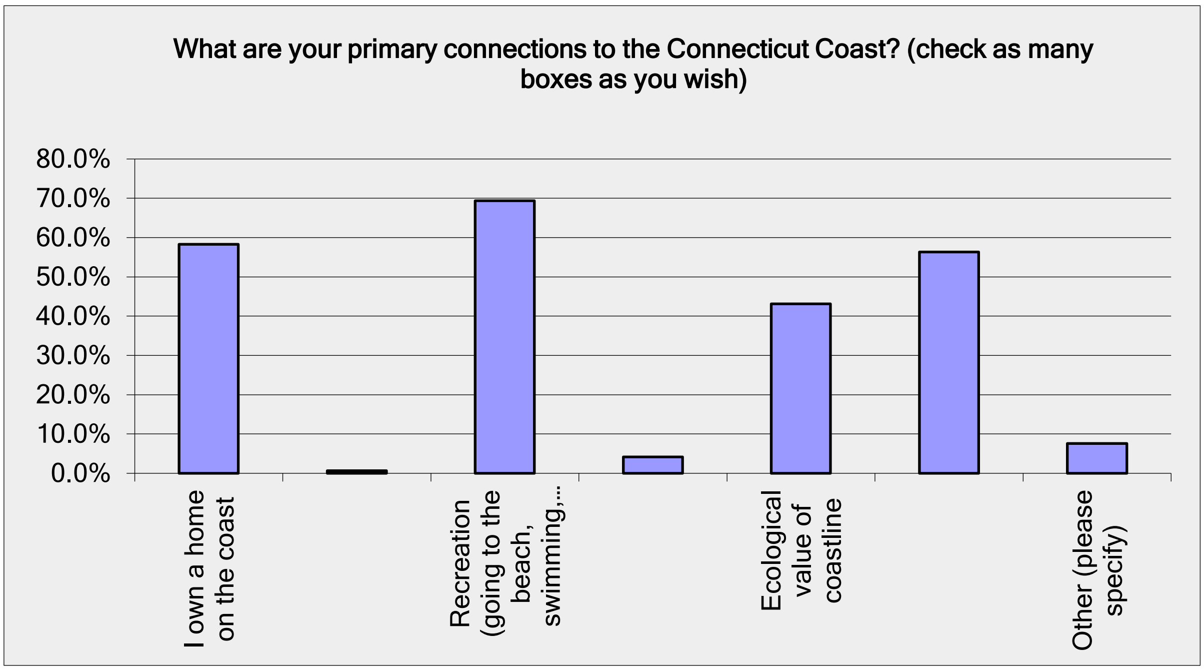
Madison Coastal Resilience

Please enter the street of your residence or place of business, or both		
Answer Options	Response Percent	Response Count
Residence	98.6%	143
Place of Business	12.4%	18
	answered question	145
	skipped question	7



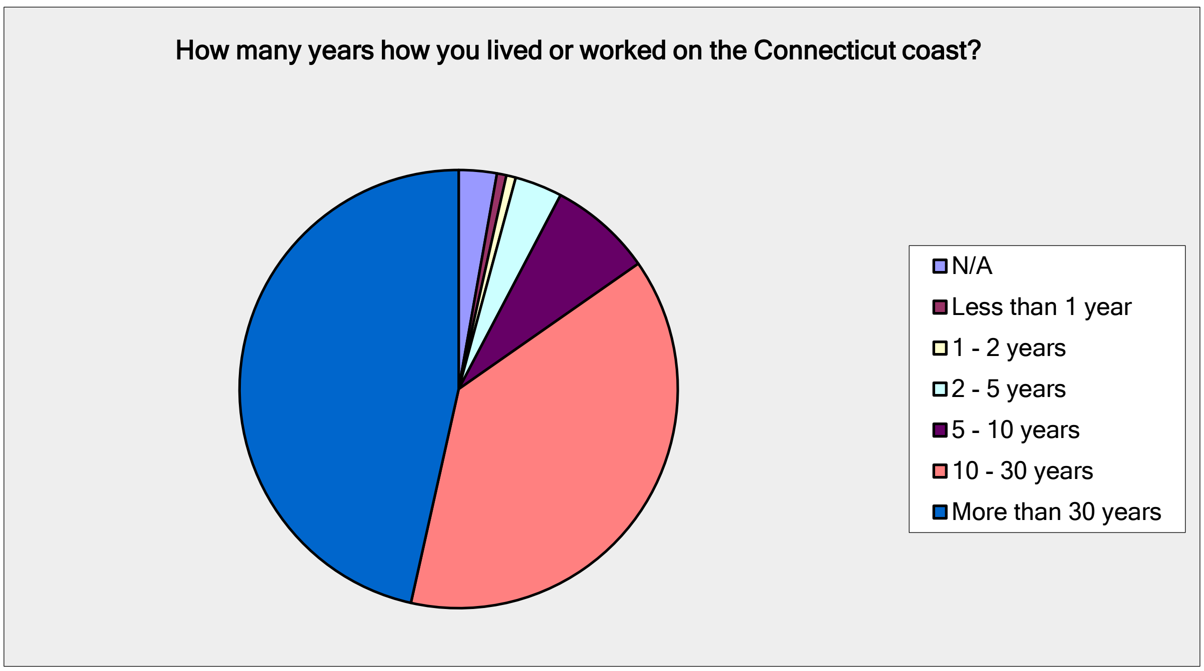
Madison Coastal Resilience

What are your primary connections to the Connecticut Coast? (check as many boxes as you wish)		
Answer Options	**Response Percent**	**Response Count**
I own a home on the coast	58.3%	84
I own a commercial property on the coast	0.7%	1
Recreation (going to the beach, swimming, boating,	69.4%	100
Income (fishing, tourism, etc)	4.2%	6
Ecological value of coastline	43.1%	62
Aesthetic (I like how it looks)	56.3%	81
Other (please specify)	7.6%	11
	answered question	**144**
	skipped question	**8**



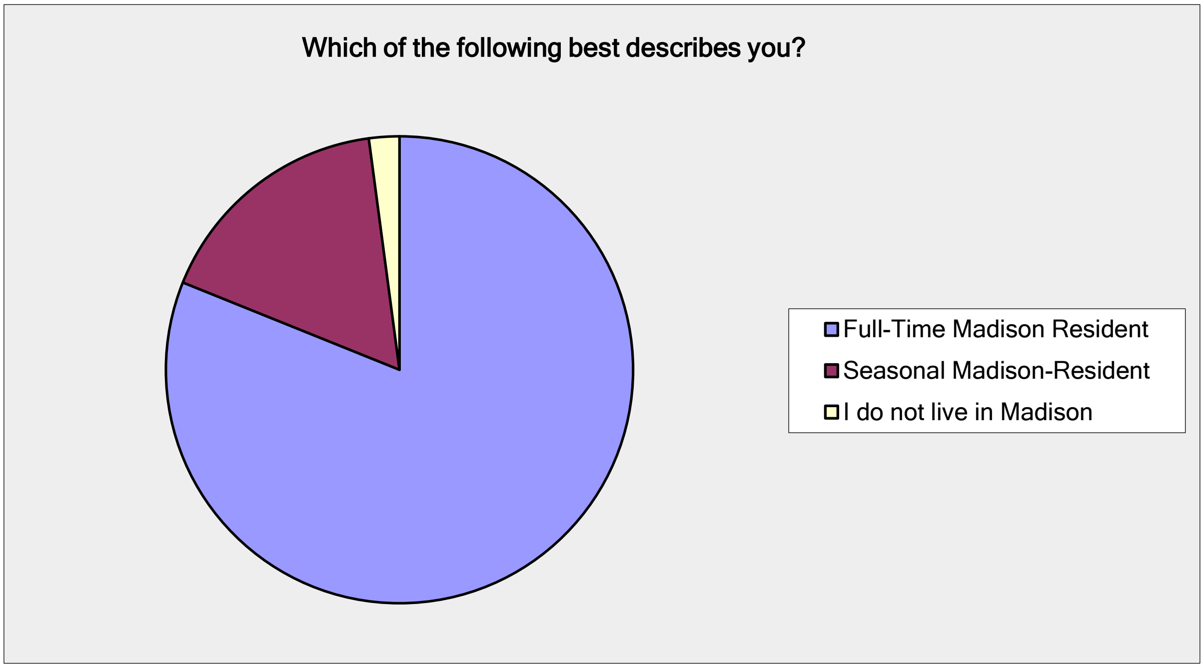
Madison Coastal Resilience

How many years how you lived or worked on the Connecticut coast?		
Answer Options	**Response Percent**	**Response Count**
N/A	2.8%	4
Less than 1 year	0.7%	1
1 - 2 years	0.7%	1
2 - 5 years	3.5%	5
5 - 10 years	7.6%	11
10 - 30 years	38.2%	55
More than 30 years	46.5%	67
	answered question	**144**
	skipped question	**8**



Madison Coastal Resilience

Which of the following best describes you?		
Answer Options	Response Percent	Response Count
Full-Time Madison Resident	81.1%	116
Seasonal Madison-Resident	16.8%	24
I do not live in Madison	2.1%	3
	answered question	143
	skipped question	9

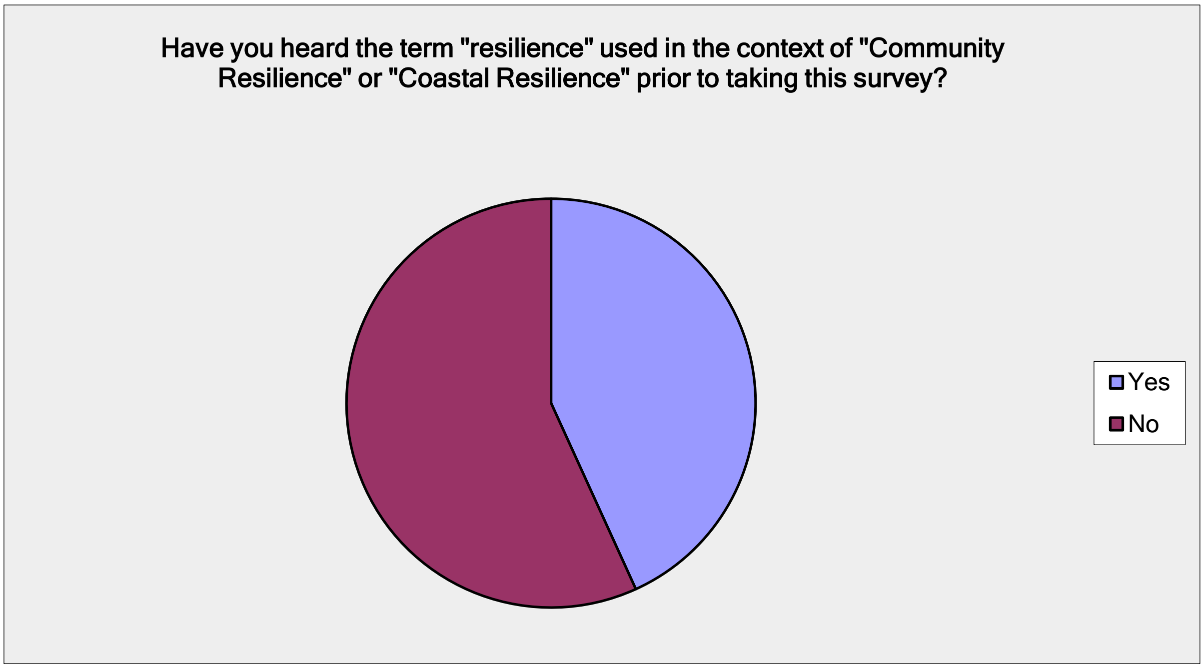


Madison Coastal Resilience

What does the term "resilience" mean to you?	
Answer Options	Response Count
	110
answered question	110
skipped question	42

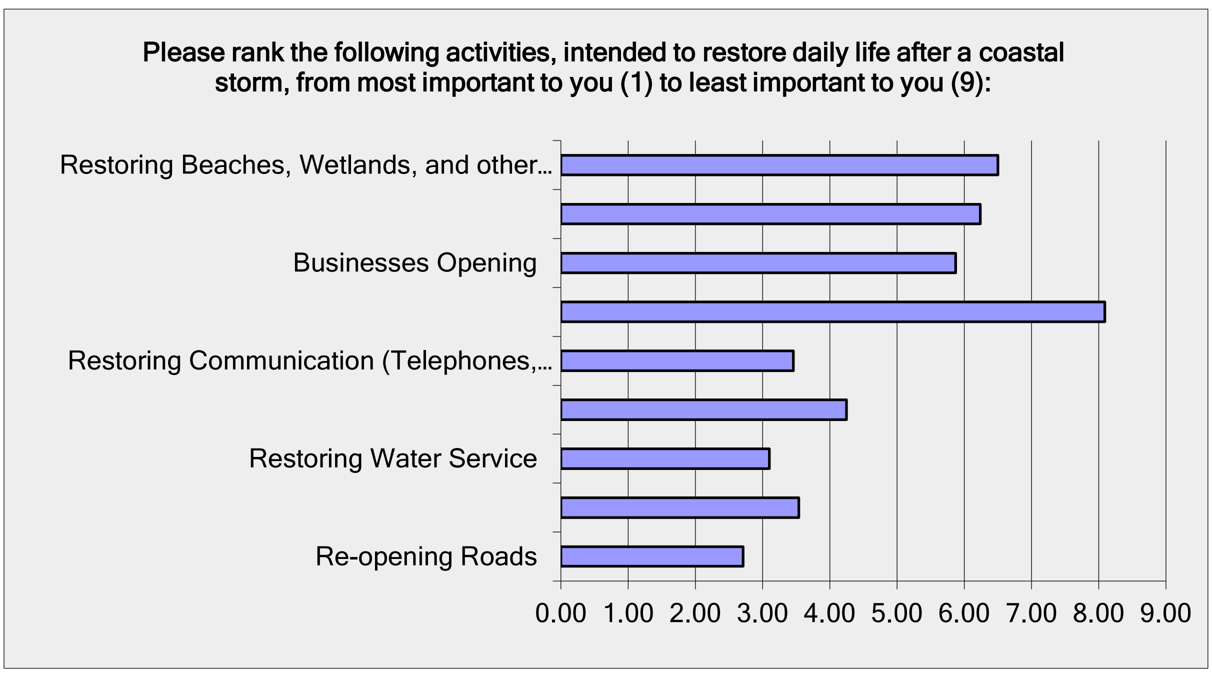
Madison Coastal Resilience

Have you heard the term "resilience" used in the context of "Community Resilience" or "Coastal Resilience" prior to taking this survey?		
Answer Options	Response Percent	Response Count
Yes	43.2%	54
No	56.8%	71
	answered question	125
	skipped question	27



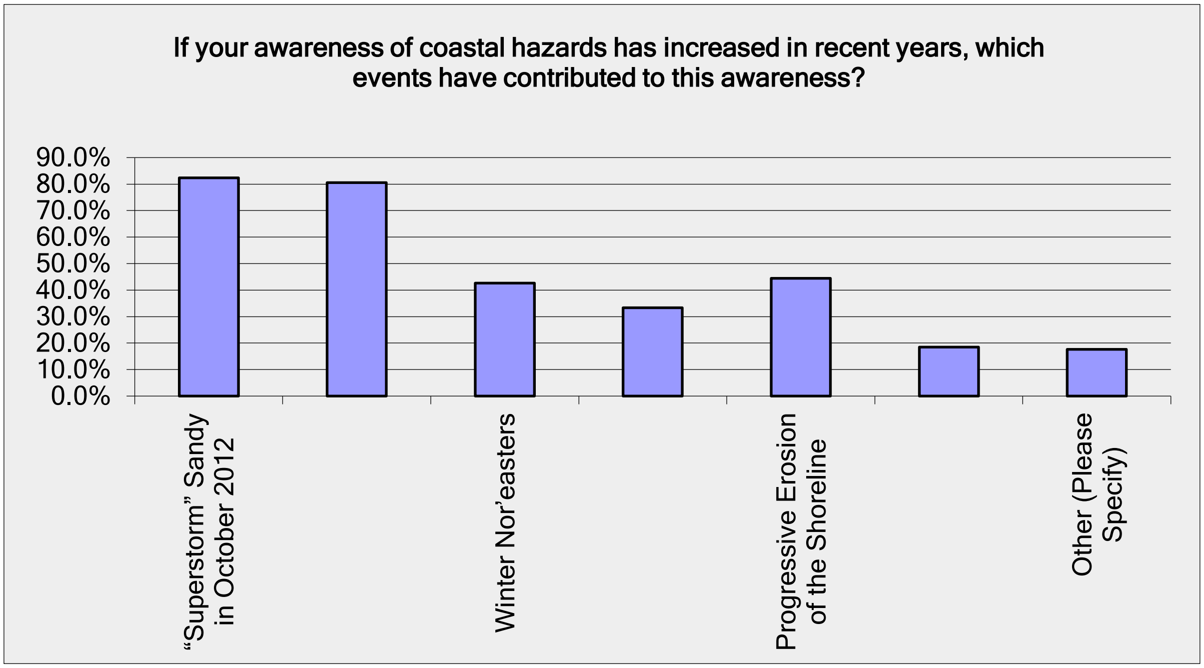
Madison Coastal Resilience

Please rank the following activities, intended to restore daily life after a coastal storm, from most important to you (1) to least important to you (9):											
Answer Options	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Rating Average**	**Response Count**
Re-opening Roads	34	23	20	16	8	2	0	2	2	2.71	107
Making my Home Livable	36	8	10	15	14	8	5	4	5	3.54	105
Restoring Water Service	12	36	26	15	5	6	3	2	1	3.10	106
Restoring Wastewater Collection and Disposal (Sewer or Septic System)	10	5	20	27	28	5	9	3	2	4.25	109
Restoring Communication (Telephones, Cell Phones, Internet)	17	27	21	16	21	3	2	4	3	3.46	114
Tourists Returning	4	4	0	0	3	6	3	5	86	8.09	111
Businesses Opening	3	3	4	9	16	34	32	13	0	5.87	114
Repairing Damaged Buildings	1	2	7	4	12	30	38	19	2	6.24	115
Restoring Beaches, Wetlands, and other Coastal Landforms	3	9	7	8	4	14	11	51	13	6.50	120
										answered question	**125**
										skipped question	**27**



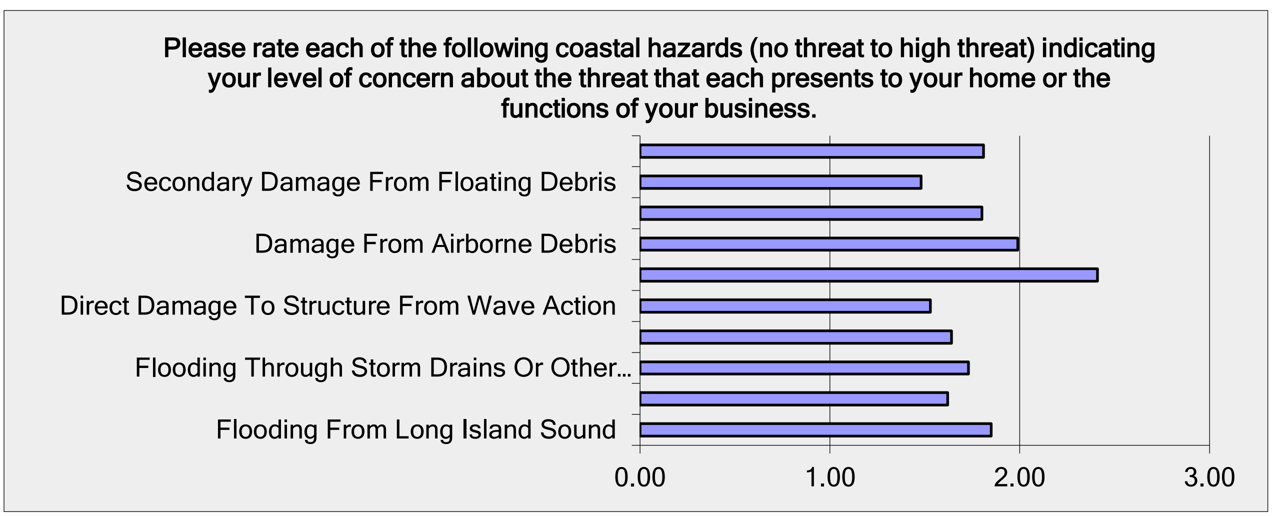
Madison Coastal Resilience

If your awareness of coastal hazards has increased in recent years, which events have contributed to this awareness?		
Answer Options	**Response Percent**	**Response Count**
“Superstorm” Sandy in October 2012	82.4%	89
Hurricane/Tropical Storm Irene in August 2011	80.6%	87
Winter Nor’easters	42.6%	46
High-Tide Flooding without a Storm Event	33.3%	36
Progressive Erosion of the Shoreline	44.4%	48
Significant Coastal Events outside of Connecticut	18.5%	20
Other (Please Specify)	17.6%	19
	answered question	108
	skipped question	44



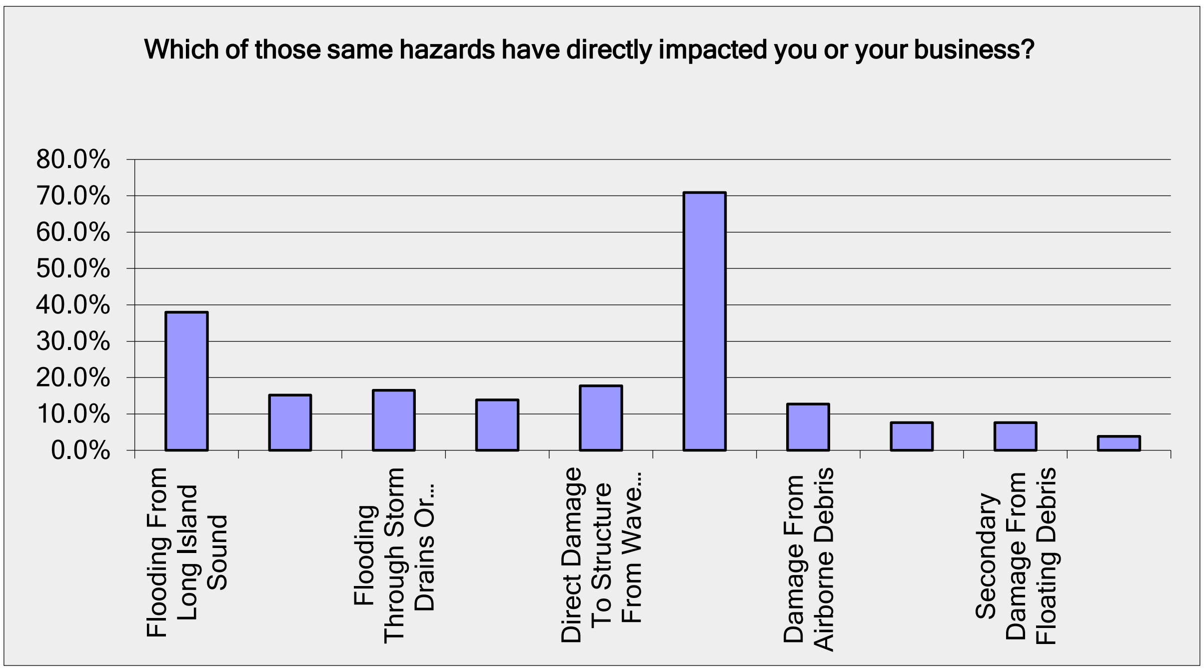
Madison Coastal Resilience

Please rate each of the following coastal hazards (no threat to high threat) indicating your level of concern about the threat that each presents to your home or the functions of your business.					
Answer Options	No Threat	Some Threat	High Threat	Rating Average	Response Count
Flooding From Long Island Sound	49	27	33	1.85	109
Flooding From Tidal Rivers And Estuaries	54	41	13	1.62	108
Flooding Through Storm Drains Or Other Drainage Infrastructure	40	57	11	1.73	108
Erosion Of Land Under Structure	54	39	15	1.64	108
Direct Damage To Structure From Wave Action	69	22	18	1.53	109
Direct Damage From High Winds	6	52	50	2.41	108
Damage From Airborne Debris	20	69	19	1.99	108
Contamination From Overflowing Septic Systems Or Wastewater Treatment Facilities	41	48	19	1.80	108
Secondary Damage From Floating Debris	63	40	6	1.48	109
Secondary Damage From Natural Gas Or Propane Leaks	38	52	18	1.81	108
Comments					6
				answered question	109
				skipped question	43



Madison Coastal Resilience

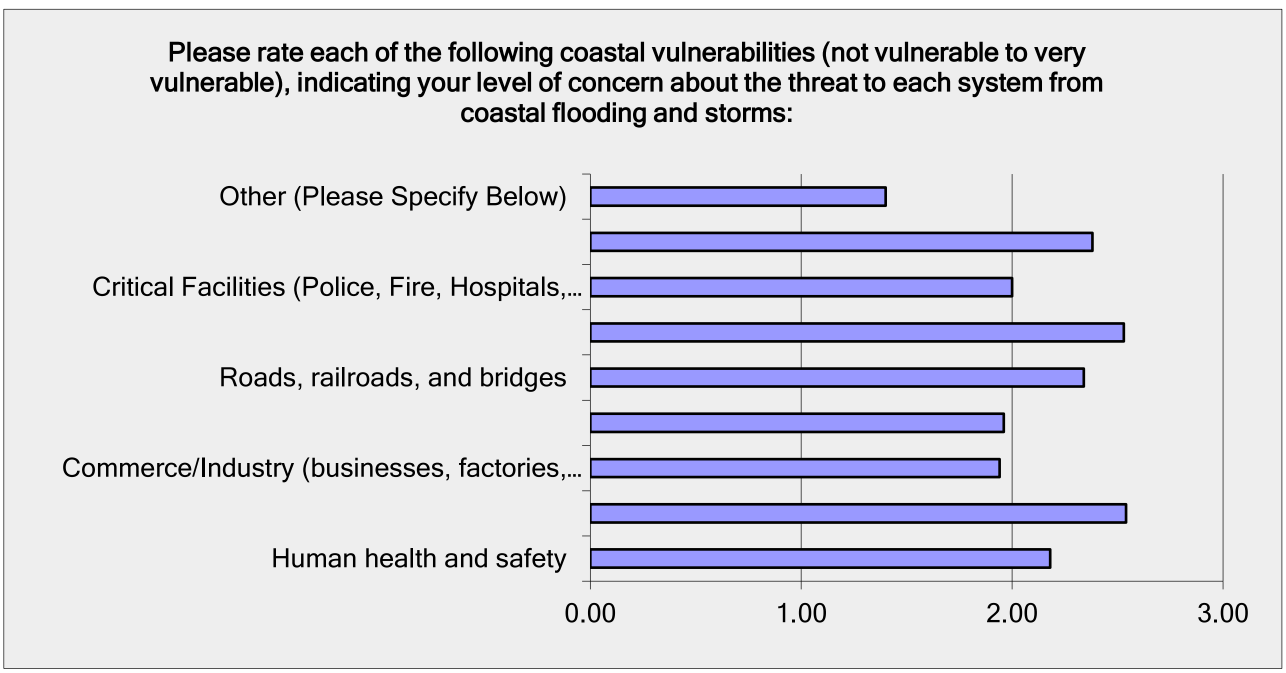
Which of those same hazards have directly impacted you or your business?		
Answer Options	**Response Percent**	**Response Count**
Flooding From Long Island Sound	38.0%	30
Flooding From Tidal Rivers And Estuaries	15.2%	12
Flooding Through Storm Drains Or Other Drainage	16.5%	13
Erosion Of Land Under Structure	13.9%	11
Direct Damage To Structure From Wave Action	17.7%	14
Direct Damage From High Winds	70.9%	56
Damage From Airborne Debris	12.7%	10
Contamination From Overflowing Septic Systems Or	7.6%	6
Secondary Damage From Floating Debris	7.6%	6
Secondary Damage From Natural Gas Or Propane	3.8%	3
Other (Please Specify)		13
	answered question	79
	skipped question	73



Madison Coastal Resilience

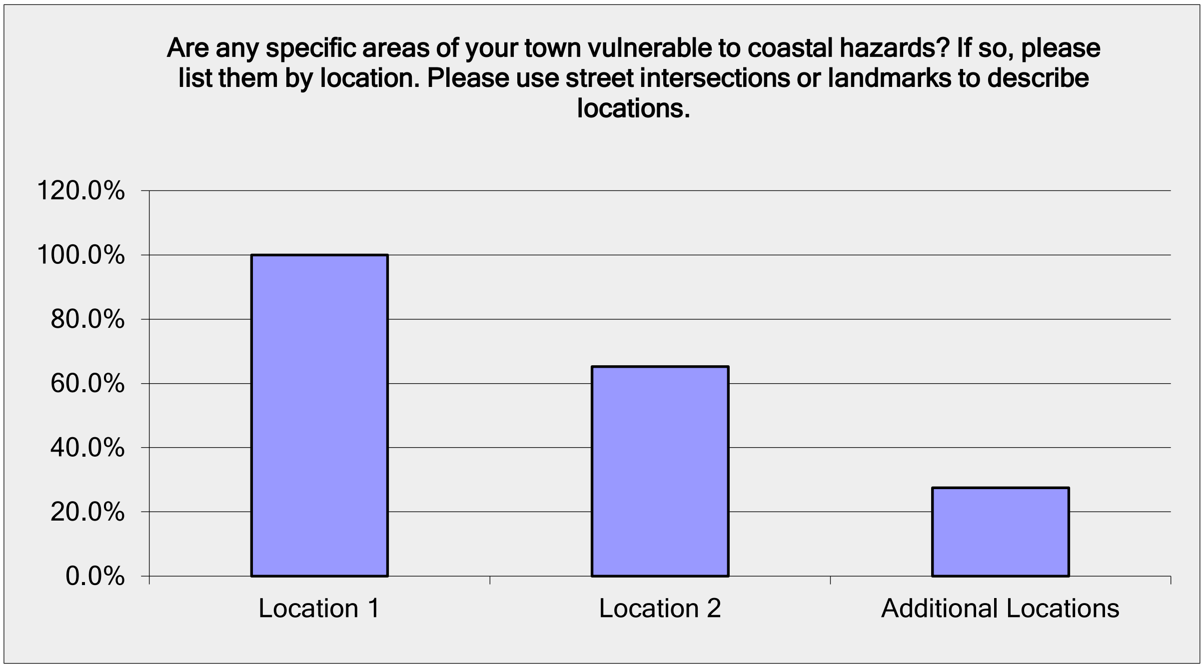
Please rate each of the following coastal vulnerabilities (not vulnerable to very vulnerable), indicating your level of concern about the threat to each system from coastal flooding and storms:

Answer Options	Not Vulnerable	Somewhat Vulnerable	Very Vulnerable	Rating Average	Response Count
Human health and safety	13	61	32	2.18	106
Homes	4	41	62	2.54	107
Commerce/Industry (businesses, factories, offices)	21	69	15	1.94	105
Tourism	31	47	27	1.96	105
Roads, railroads, and bridges	5	61	41	2.34	107
Utilities (water, wastewater, electricity, gas, communication)	2	46	58	2.53	106
Critical Facilities (Police, Fire, Hospitals, Shelters)	24	57	24	2.00	105
Natural Systems (Tidal Wetlands, Coastal Landforms)	10	46	51	2.38	107
Other (Please Specify Below)	7	2	1	1.40	10
Comments					5
				answered question	**107**
				skipped question	**45**



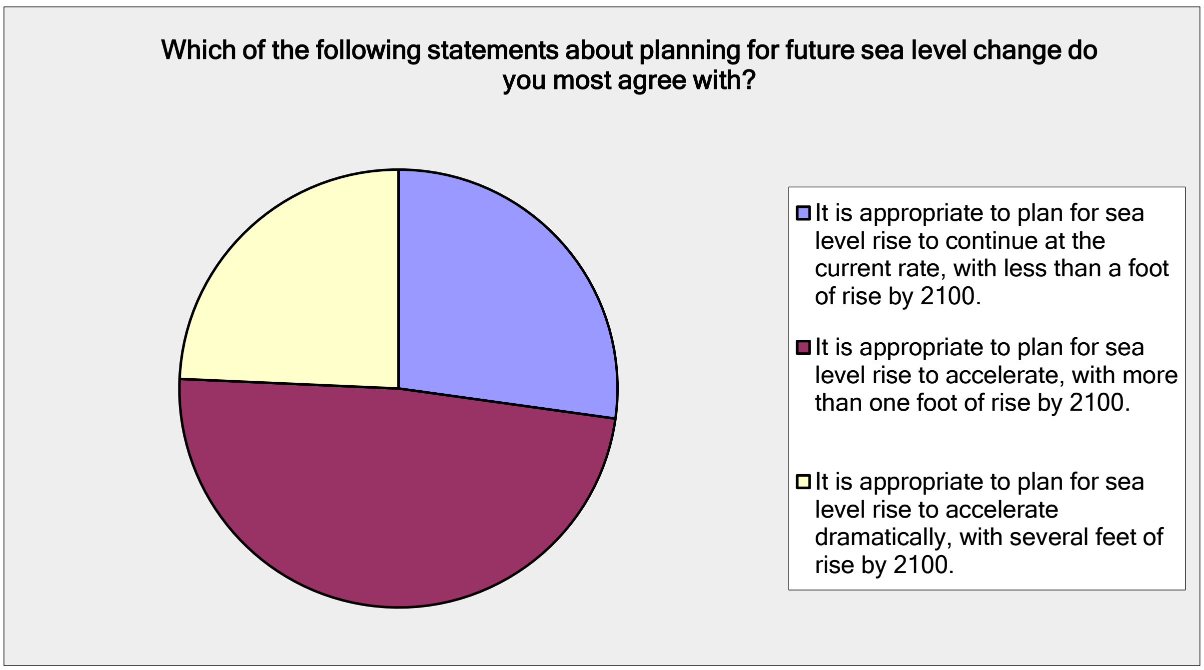
Madison Coastal Resilience

Are any specific areas of your town vulnerable to coastal hazards? If so, please list them by location. Please use street intersections or landmarks to describe locations.		
Answer Options	Response Percent	Response Count
Location 1	100.0%	69
Location 2	65.2%	45
Additional Locations	27.5%	19
	answered question	69
	skipped question	83



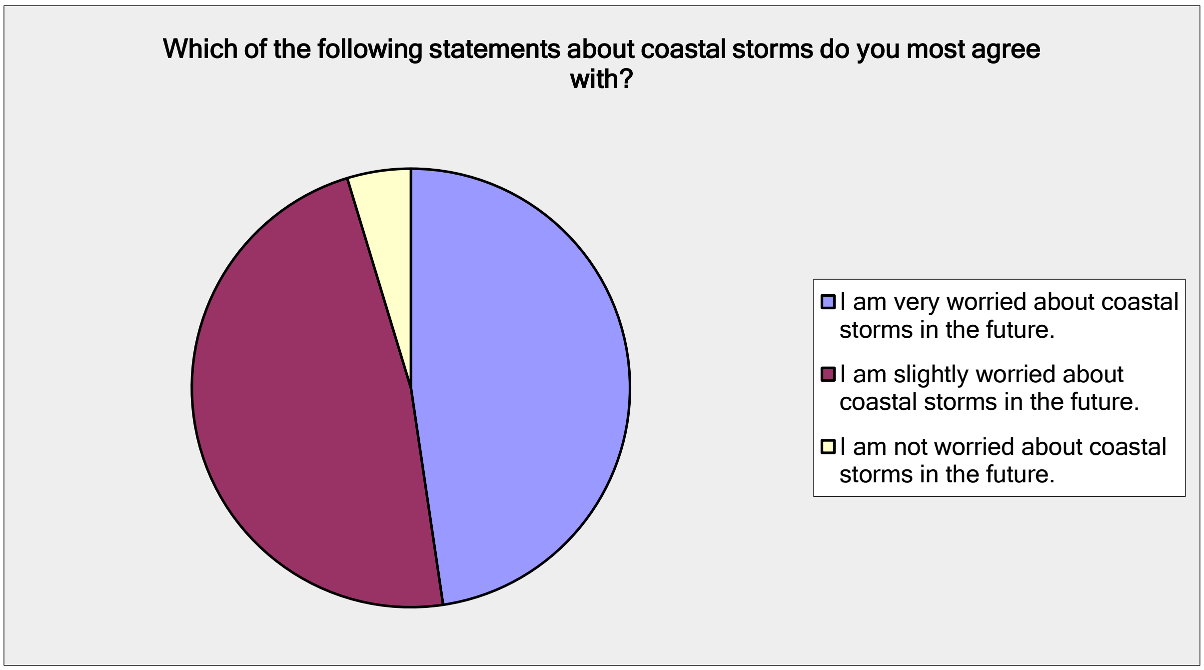
Madison Coastal Resilience

Which of the following statements about planning for future sea level change do you most agree with?		
Answer Options	Response Percent	Response Count
It is appropriate to plan for sea level rise to continue at	27.2%	28
It is appropriate to plan for sea level rise to accelerate,	48.5%	50
It is appropriate to plan for sea level rise to accelerate	24.3%	25
Comments		10
	answered question	103
	skipped question	49



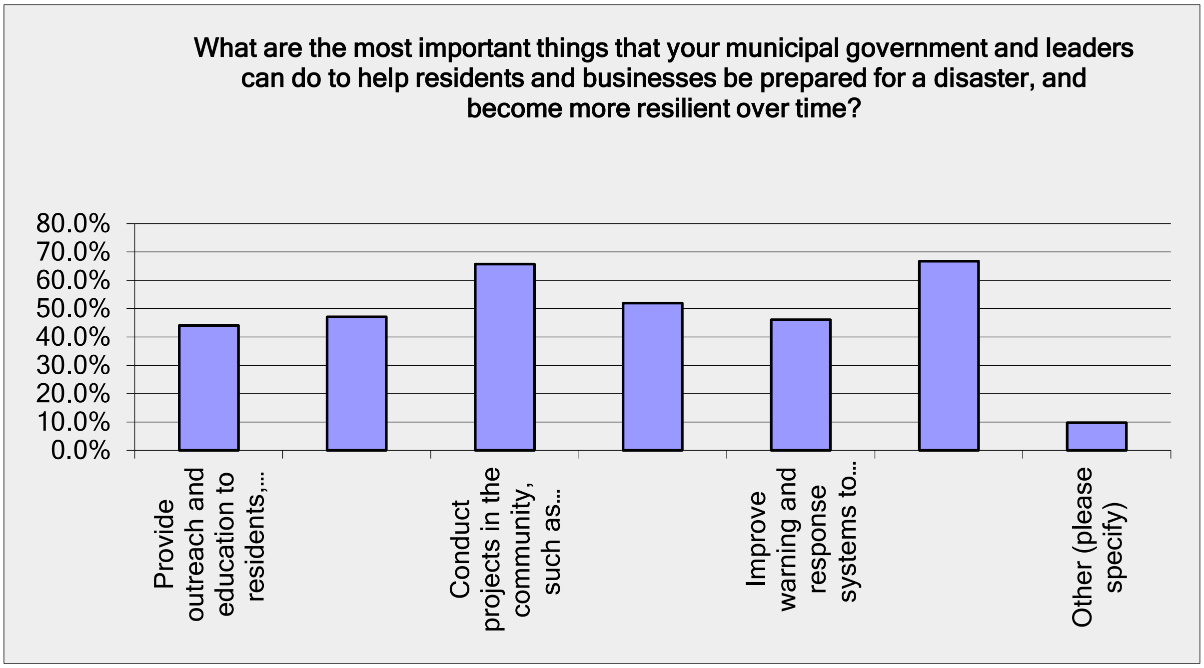
Madison Coastal Resilience

Which of the following statements about coastal storms do you most agree with?		
Answer Options	Response Percent	Response Count
I am very worried about coastal storms in the future.	47.7%	51
I am slightly worried about coastal storms in the future.	47.7%	51
I am not worried about coastal storms in the future.	4.7%	5
Comments		8
	answered question	107
	skipped question	45



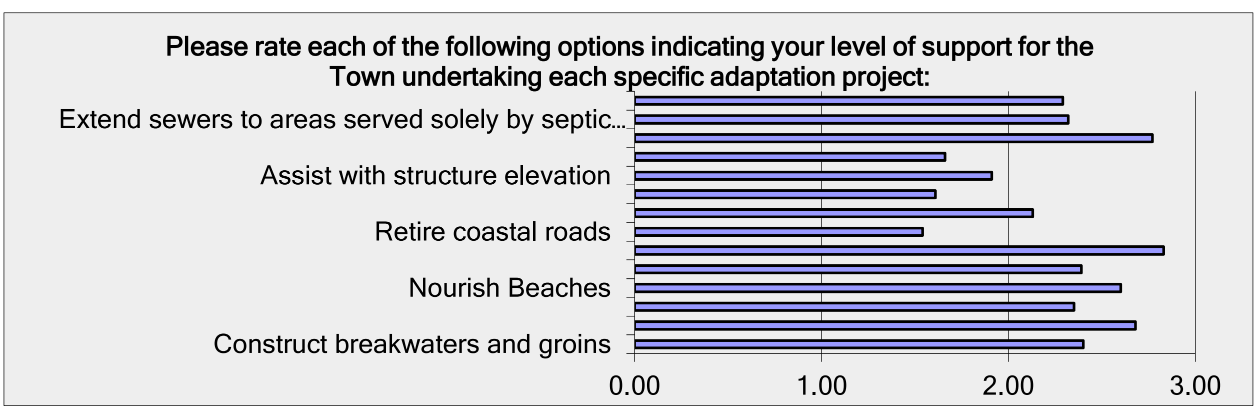
Madison Coastal Resilience

What are the most important things that your municipal government and leaders can do to help residents and businesses be prepared for a disaster, and become more resilient		
Answer Options	Response Percent	Response Count
Provide outreach and education to residents,	44.1%	45
Provide technical assistance to residents, businesses,	47.1%	48
Conduct projects in the community, such as drainage	65.7%	67
Make it easier for residents, businesses, and	52.0%	53
Improve warning and response systems to improve	46.1%	47
Enact and enforce regulations, codes, and ordinances	66.7%	68
Other (please specify)	9.8%	10
	answered question	102
	skipped question	50



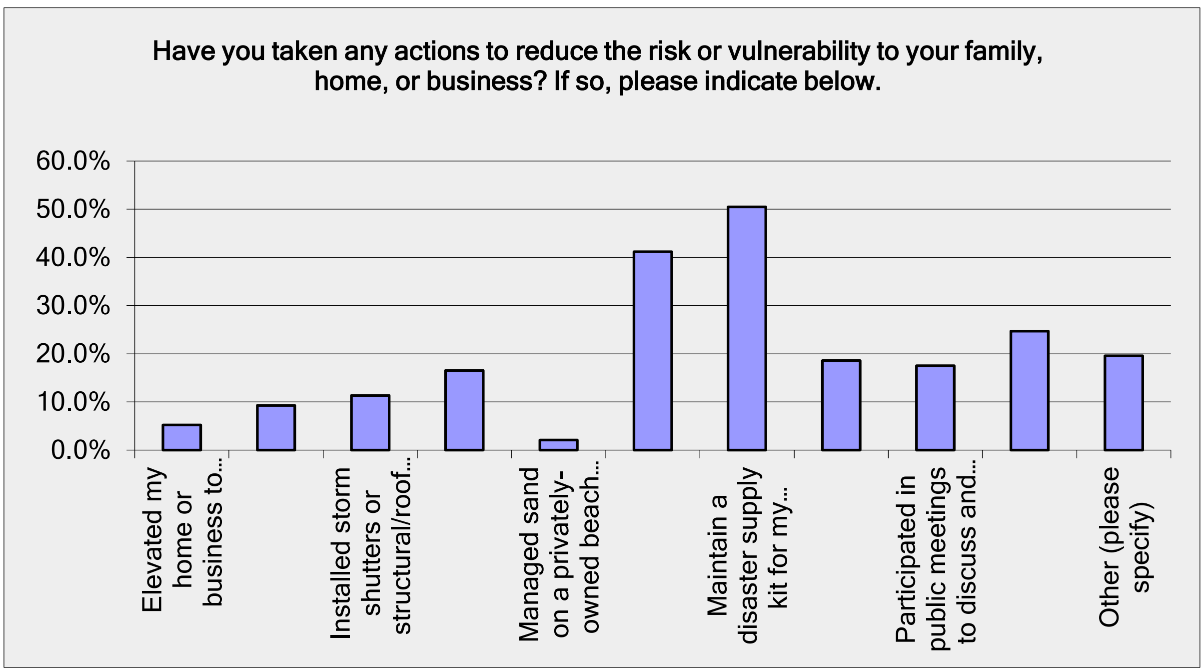
Madison Coastal Resilience

Please rate each of the following options indicating your level of support for the Town undertaking each specific adaptation project:					
Answer Options	Against	No Opinion	Support	Rating Average	Response Count
Construct breakwaters and groins	13	32	51	2.40	96
Restore Dunes	4	22	69	2.68	95
Create “Living Shorelines”	8	46	42	2.35	96
Nourish Beaches	6	26	62	2.60	94
Build seawalls and bulkheads	19	22	58	2.39	99
Improve drainage systems	2	13	86	2.83	101
Retire coastal roads	57	29	12	1.54	98
Elevate coastal roads	21	42	34	2.13	97
Buyout and retire coastal properties	53	29	15	1.61	97
Assist with structure elevation	36	37	27	1.91	100
Assist with structure relocation	43	43	10	1.66	96
Strengthen coastal utility infrastructure	4	15	80	2.77	99
Extend sewers to areas served solely by septic systems	20	27	52	2.32	99
Extend water service to areas that utilize wells	18	35	47	2.29	100
Other (please specify)					8
				answered question	104
				skipped question	48



Madison Coastal Resilience

Have you taken any actions to reduce the risk or vulnerability to your family, home, or business? If so, please indicate below.		
Answer Options	Response Percent	Response Count
Elevated my home or business to reduce flood damage	5.2%	5
Flood-proofed my business to reduce flood damage	9.3%	9
Installed storm shutters or structural/roof braces to	11.3%	11
Replaced my overhead utility lines with underground	16.5%	16
Managed sand on a privately-owned beach to reduce risk	2.1%	2
Developed a disaster plan for my family, home, or	41.2%	40
Maintain a disaster supply kit for my family, home, or	50.5%	49
Participated in public meetings to discuss the Plan of	18.6%	18
Participated in public meetings to discuss and approve	17.5%	17
I have not taken any of these actions	24.7%	24
Other (please specify)	19.6%	19
	answered question	97
	skipped question	55



Madison Coastal Resilience

If you could choose one action that could be taken in your community to reduce risks from hazards and the natural events that cause these	
Answer Options	Response Count
	60
answered question	60
skipped question	92

Madison Coastal Resilience

Please provide any additional comments or questions to be addressed as the Coastal Resilience Plan is developed:	
Answer Options	Response Count
	18
answered question	18
skipped question	134

Madison Coastal Resilience

If you wish to be notified of the progress in developing the Coastal Resilience Plan, please provide your name and email address:		
Answer Options	Response Percent	Response Count
Name	94.3%	33
Email Address	100.0%	35
	answered question	35
	skipped question	117