Town of Branford Coastal Resilience Plan

DRAFT

May 2016

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This plan was prepared under a Community Development Block Grant Disaster Recovery (CDBG-DR) grant awarded to the Town of Branford, Connecticut for coastal resilience planning in Branford, Madison, and Milford, Connecticut.

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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 advance coastal resilience in the coming years. As time passes and our collective understanding of sea level rise is refined, Branford will have the option to update this plan to more appropriately reflect the town's evolving approaches to building resilience.

1.1 Project Goal

The overall goal of the "coastal resilience program" undertaken by the Town of Branford 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 undertaken by the Town of Branford 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 four-step process in Branford commenced years ago when other planning efforts involved the public, such as the Hazard Mitigation Plan. The specific planning process for this coastal resilience plan commenced 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 Branford 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. In Branford, the sole LMI tract[1] is located near Branford Center, in the area including Kirkland Street, Meadow Street, Montowese Street, and Main Street.

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

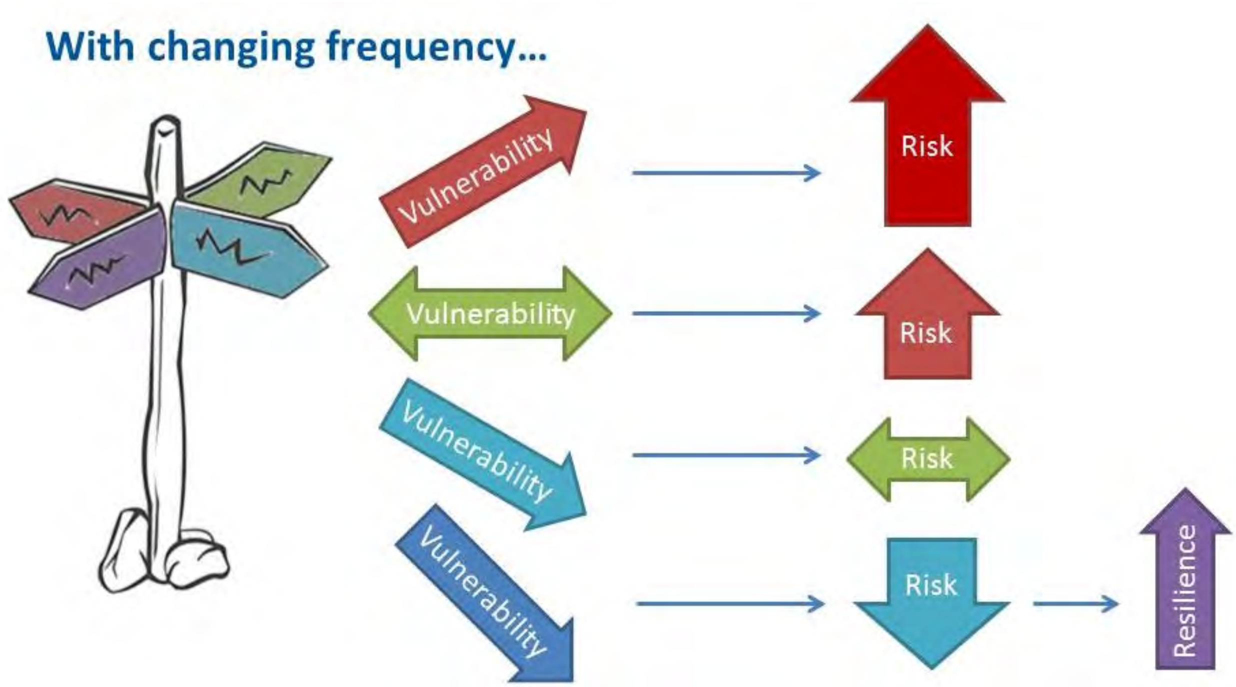
[1] At the time of the CDBG-DR grant application in 2014, the Low and Moderate Income (LMI) Census block groups were mapped based on estimates from the 2007-2011 American Community Survey (ACS) where the median income was 80% or lower of the Area Median Income (AMI). ACS estimates are based on a 5-year rolling average of a small sample size. LMI limits are revised annually. Current estimates available on the online CPD Maps viewer show that only one Census block group in Branford is currently a HUD-designated LMI area.

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.

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

Branford has approximately 28,225 residents living within 22.0 square miles of land. The Town has over 20 miles of coastline. Density varies throughout the Town, but higher density residential areas exist at the Short Beach, Double Beach, Branford Center, Pawson Park and Sunset Beach, Limewood Avenue, Haycock Point, Hotchkiss Grove, Pine Orchard, and Stony Creek neighborhoods. The less-developed areas along the coast are the Beacon Hill Preserve, Killams Point, Pleasant Point, and Jarvis Creek neighborhoods. For the purposes of this report, the coastal neighborhoods of Branford are broken into the following:

- Clark Avenue: medium-density residential peninsula with a couple of commercial properties. Most of the neighborhood is characterized by high rocky bluffs. Clark Avenue at Clark Avenue Beach (at the Yale Corinthian Yacht Club) is vulnerable to inundation from both the Sound in front and Farm River behind, as are the properties here. Inundation of this road isolates the rest of the peninsula.
- Beckett Avenue: a small beach between bedrock outcrops, fronting residential properties. This area is densely developed, and suffers from inundation and poor drainage.
- Short Beach: between Little Bay Lane and Killams Point Road, also called Pages Cove. There are two small sections of sandy beach interspersed between bedrock shorelines, homes built on bulkheads, and revetment-protected roads. Undermining and flooding of the roads is a concern here.
- Killams Point: a single, low-lying road leads to a handful of homes and the Killams Point Conference Center. The road is vulnerable to inundation, while the homes are mostly on higher bedrock.
- Double Beach: refers here to the eastern shore of the "Town Neck" extending from Lindsey Cove and the Harbour Village Condominiums south past Lanphier Cove and the Connecticut Hospice to Johnson Point. Inundation is generally not an issue, however erosion of unprotected slopes, and flooding of Sunrise Cove and Lanphier Cove homes during extreme storm events, are both risks.
- Branford Point: the inside of a large meander of the Branford River. Homes have low risk, but a number of marinas and boat launches here are vulnerable.
- Branford Center: for the purposes of this document, this name refers to the densely developed area on the northwest bank of the Branford River, including the areas south of the train tracks to Mill Creek, and north to Branford High School. Risks are generally associated with inundation from the Branford River.
- Blackstone Acres: the residential neighborhood on the east side of the Branford River, across the river from the high school. Branford River flooding can affect homes and roads.
- Indian Neck Avenue: this refers to the neighborhood on either side of Indian Neck Avenue, east of the Branford River, north of Sybil Creek, and west of Ecology Park. Significant flood events can cause inundation along the east side of Route 146. The Branford Wastewater Treatment Plant is located at the southwest corner of this area along the Branford River.
- Sybil Creek: flowing west under Waverly Park Road and South Montowese Street (Route 146), this tidal creek can inundate some adjacent properties and important roads.
- Pawson Park and Sunset Beach: Pawson Park is on the north side of Indian Neck and Sunset Beach is on the south. Both neighborhoods border significant tidal wetlands, and have homes and roads vulnerable to inundation.
- Linden Avenue: this road alone connects Indian Neck to Route 146, and for much of its length is directly along the water's edge. It is vulnerable to erosion, as well as overtopping by severe waves.
- Limewood Avenue: also Route 146 here. Built along the shoreline, fronted in one section by beach. At risk to erosion and wave action from Long Island Sound. During extreme events, can be overtopped from the north by Sybil Creek.
- Haycock Point: rocky bluffs with homes built on the shoreline, protected by seawalls.
- Hotchkiss Grove: fronted by a sandy beach, and at risk to inundation during storm events. In an extreme scenario, Route 146 here may be affected, cutting off an important connecting road. This area includes the beach south of Ozone Road. Erosion of coastline is a lesser issue here.

- Pine Orchard: including the hard-structure protected shoreline south of Island View Avenue, and the low-lying, inundation-prone Pine Orchard Yacht Club and Pine Orchard Road.
- Juniper Point: houses a few residential neighborhoods, and a Tilcon Connecticut Inc. Facility. Isolation during flooding is a concern here.
- Pleasant Point: a handful of homes on high ground here are vulnerable to isolation from flooding of Pleasant Point Road
- Stony Creek: the area east of the mouth of Stony Creek along Thimble Island Road. Higher rocky bluffs interspersed with low wetlands. Flooding of the road is an issue. This is one of the few developed coastal areas in Town dependent on individual private septic systems.
- Jarvis Creek: the rural area at the eastern end of Branford is vulnerable to flooding from Jarvis Creek, cutting off State Route 146 in two areas and impacting farmland. Recent replacement of tide gates is believed by some to be a problem here, although the tide gates are not (nor have they ever) been designed to prevent major storm surge flooding.

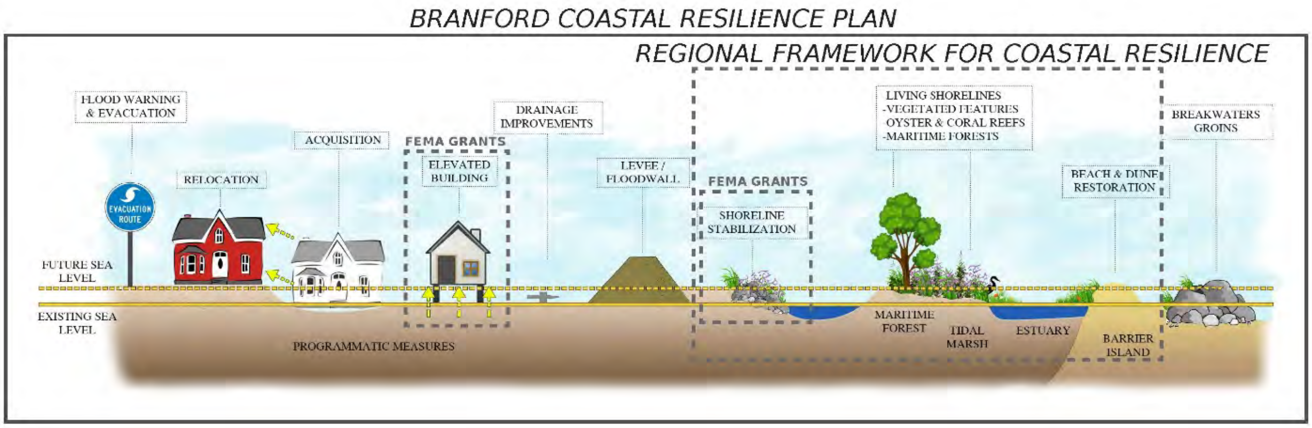
This plan does not specifically address risks along the Farm River on the western side of Branford. Farm River is mostly surrounded by undeveloped marsh and preserves, including the Beacon Hill Preserve and the East Haven Wildlife Area, and so there are few assets vulnerable to sea level rise and storm surge.

2.2.2 Existing Capabilities

There are a suite of existing regulations, plans, projects, and programs within the Town of Branford 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 Branford's resilience capabilities, and was designed to work *with* these existing documents and actions. These resources and programs (described in Appendix A) include the following:

- SCRCOG Multi-Jurisdiction Hazard Mitigation Plan
- Branford Plan of Conservation and Development
- Branford Zoning Regulations
- Branford Code of Ordinances
- TNC Salt Marsh Advancement Zone Assessments
- FEMA New Haven County Flood Insurance Study and FIRM Panels
- Individual FEMA-funded Projects
- The *Regional Framework for Coastal Resilience* (with nine other municipalities)
- Historical resources resilience planning with the Connecticut State Historic Preservation Office

The following graphic depicts the unique relationship between the Branford Coastal Resilience Plan, the ten-town *Regional Framework for Coastal Resilience* which addresses waterward resilience issues, and the individual FEMA-funded projects such as home elevations and bank stabilization along Linden Avenue.



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 Branford 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 conducted 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

Branford already has experience with coastal hazards. The neighborhoods of Short Beach, Pawson Park and Sunset Beach, South Montowese Street, Hotchkiss Grove, Stony Creek, and sections of Branford center, 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 and other locations.

Lanphier cove has seen its banks eroded landward to the point that sewage infrastructure is threatened. Linden and Limewood Avenues need to be regularly maintained to prevent failure due to erosion by high waves. Aged, undersized, and/or overwhelmed tide-controlled drainage systems have led to nuisance flooding at Jarvis Creek and Sybil Creek. Rising waters and increasing storm severity and frequency will exacerbate these problems and give rise to similar problems in other parts of town.

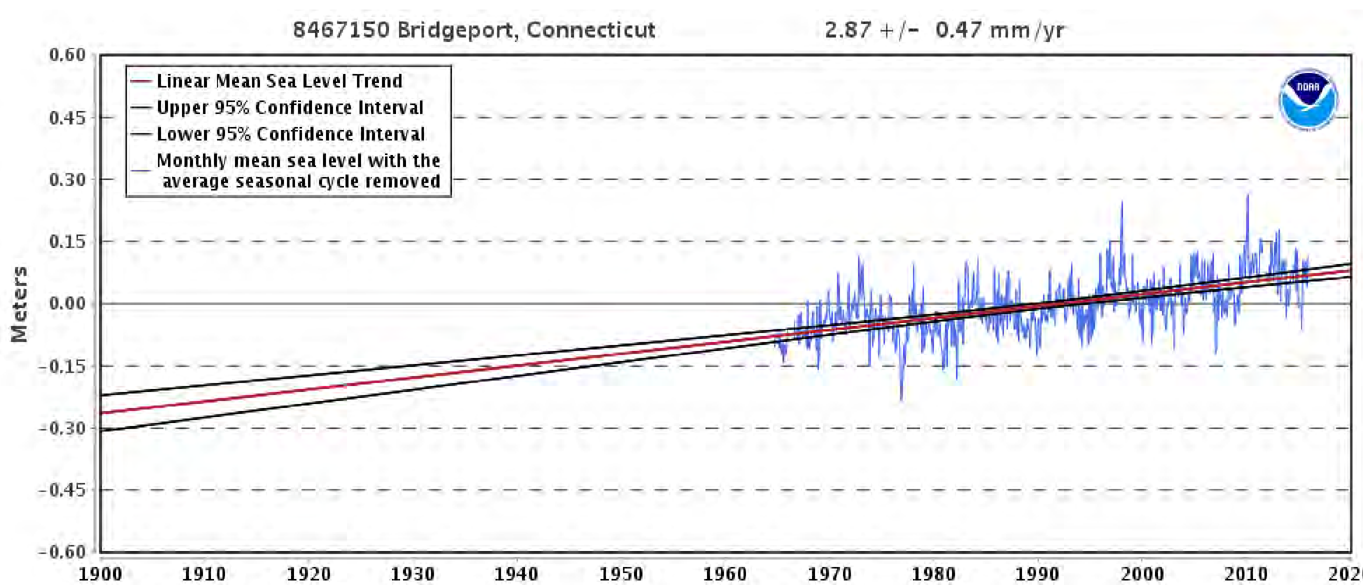
2.3 Sea Level Rise

2.3.1 Existing Conditions and Historic Trends

A single tide gauge was operated by the National Oceanic and Atmospheric Administration (NOAA) within Branford from June to November, 1989. The gauge was located in the Branford River east of Branford Point. According to data collected by this gauge (available at tidesandcurrents.noaa.gov), the mean sea level (MSL) in Branford Harbor is negative (-) 0.28 feet, or 0.28 feet below the North American Vertical Datum of 1988 (NAVD88). The average maximum elevation of high tide ("mean higher-high water, or MHHW") is 3.25 feet above the MSL, or 2.97 feet elevation (NAVD88). These figures will vary along Branford's coastline, and have likely changed since 1989, as discussed below.

The nearest ***long-term*** operational gauge to Branford is the tide gauge in Bridgeport, CT. Based on tide gauge data collected at that station between 1964 and 2014, MSL has been increasing at a rate of 2.87 millimeters (0.11 inches) per year, which is equivalent to a rise of 0.94 feet over 100 years (see Figure 1 below). The next-nearest station in New London, CT, has measured an increase of 2.58 mm/yr, or 0.85 feet-per-100-years, based on measurements since 1938.

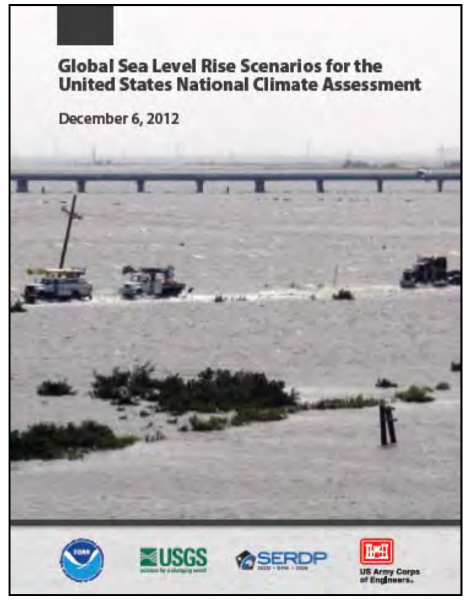
Figure 1



2.3.2 Sea Level Projections

Projections of the rate and extent of sea level rise in the future were used to determine Branford's vulnerabilities and risks 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 Branford 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:



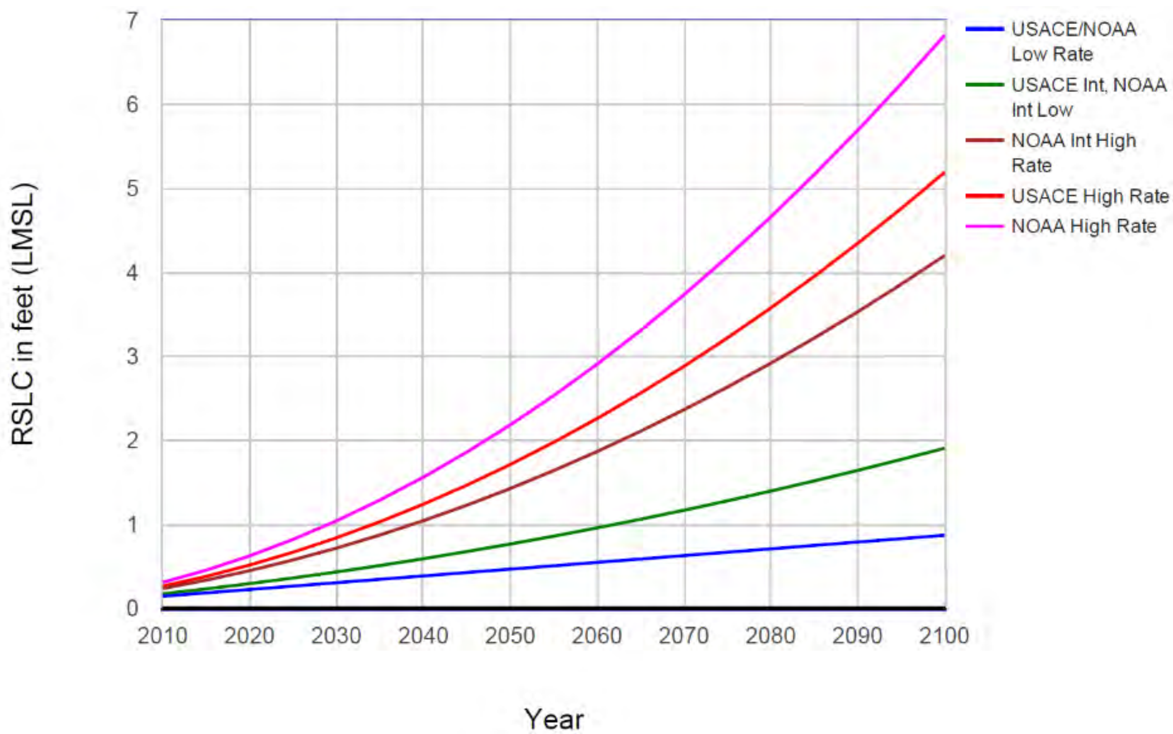
- NOAA Low and USACE Low: historic rate of sea-level change is the rate of change moving forward
- NOAA Intermediate Low and USACE Intermediate: ocean warming and the local rate of vertical land movement determine sea level change rate.
- NOAA Intermediate High: the projected rate assuming both ocean 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 8467150, Bridgeport, CT NOAA's Regional Rate: 0.00807 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	0.24	0.27	0.31
2020	0.23	0.30	0.45	0.52	0.63
2030	0.31	0.44	0.72	0.84	1.04
2040	0.39	0.59	1.05	1.24	1.56
2050	0.47	0.77	1.43	1.72	2.19
2060	0.55	0.96	1.87	2.26	2.91
2070	0.63	1.17	2.37	2.89	3.74
2080	0.71	1.40	2.92	3.58	4.67
2090	0.79	1.65	3.54	4.35	5.70
2100	0.87	1.91	4.21	5.20	6.83

Figure 2

Relative Sea Level Change Projections
Gauge 8467150, Bridgeport, 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 Branford. More information on sea level rise projections is presented in Appendix B.

2.4 Specific Vulnerabilities and Risks

2.4.1 Summary

Branford'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 Branford 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. One unique aspect of Branford's shoreline is that isolation of many neighborhoods is a risk due to erosion or inundation of coastal roads. It is also vulnerable to flooding of low-lying neighborhoods with poor drainage systems, and of properties surrounding tidal wetlands. 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 Branford's shoreline are its roads, its higher elevation coastal areas susceptible to erosion, the densely developed downtown area. Many coastal roads are vulnerable to being submerged by rising waters or eroded by waves, risking the isolation of areas of Town. While many sections of the Branford shore are protected by bedrock outcrops, less protected bluffs are experiencing erosion. Branford Center is vulnerable to inundation from the Branford River, which can have a significant impact on the Town's economy. Finally, Branford's beaches and wetlands are vulnerable to rising waters and increasing storms.

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

- Route 1 / Main Street
- Route 142
- Route 146
- Clark Avenue
- Johnsons Point Road
- Harbor Street
- Maple Street
- Linden Avenue
- Pine Orchard Road

- Totoket Road
- Thimble Island Road
- Tabor Drive
- Pleasant Point Road

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

2.4.2 Vulnerable Neighborhoods

Different neighborhoods and areas of Branford 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, with 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 Coastal Resilience Mapping Portal is not able to capture these details, so further analysis was performed with wave modeling conducted 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 Branford coastline that are at or near locations with significant concerns about coastal hazards. These are located at Short Beach, Lanphiers Cove[2], Summer Island Point (Sunset Beach), Linden Avenue, Hotchkiss Grove, and Thimble Island Road. It is important to note that the conditions at a given transect may not reflect those at

WHAT DO OTHER STUDIES SAY ABOUT BRANFORD?

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.

The NACCS process includes 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 flood-vulnerable zones to develop a weighted "exposure index." Risk is then calculated within study regions as a function of exposure index and probability of flooding.

The report states the following for Branford: "This area of high exposure extends from the Seaview Avenue area of Branford to Lindsey Cove. It includes several densely populated areas as far inland as Route 1 as well as Branford Harbor and the downtown area. Many commercial facilities fall within this area including several recreational boating marinas. The town's wastewater treatment facilities are in the area of high exposure as well. Several important local and state roads (e.g. Route 146 and 1) are included in the area of high exposure."

[2] The Lanphiers Cove cross section was subject to a FEMA map revision with revised wave runup modeling.

adjacent sites or properties. Further analysis would be required to verify or correct the results for areas currently without transects.

Both the Coastal Resilience 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 Branford coast. This analysis is presented in detail in Appendix B sections 4.2 and 4.3, and is summarized below.

Clark Avenue

This road connects the peninsular neighborhood of Paynes Point and Horton Point to mainland Branford. Most of the neighborhood is protected from coastal hazards by bedrock bluffs. Clark Avenue at Clark Avenue Beach is vulnerable to inundation from Long Island Sound to the east and Farm River from the west, as are the homes in that area. The 2020s daily high tide is projected to inundate parts of this area. Clark Avenue is partly within a FEMA velocity (VE) zone with a Base Flood Elevation (BFE) of 14 feet NAVD88.

Beckett Avenue

This neighborhood is densely developed, and already suffers from inundation and drainage-related flooding. Daily high tide flooding will impact the neighborhood by 2020s, and is projected to be widespread by the 2080s. This area experienced significant flooding during Hurricane Irene. A FEMA AE zone with a BFE of 11-13 feet NAVD88 extends inland here.

Short Beach

State Route 142 and a dozen homes run east-to-west here, with a wetland to the north and Pages Cove to the south. The homes are in an AE zone with a BFE of 11 feet NAVD88, and the edge of the road is within a VE zone of BFE 14 feet. Erosion of the road is a concern here. Furthermore, daily high tide overtopping is projected to occur as soon as the 2050s.

Killams Point

This is a sparsely populated area on the east side of Granite Bay. By the 2020s, the northern end of the only road connecting the neighborhood to the rest of Town is projected to be inundated daily. That road is with a VE zone with a 14-foot BFE (NAVD88). Other sections of the road are also vulnerable to flooding and erosion. Properties themselves are generally not vulnerable to inundation.

WHAT DO OTHER STUDIES SAY ABOUT BRANFORD?

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 Branford shoreline:

Accretion
Horton Point, Indian Neck Point, Haycock Point, Hotchkiss Grove Beach (partial), Pine Orchard Beach, Stony Creek.

Erosion
Johnson Point, Lindsey Cove, Indian Neck, Limewood Beach, Hotchkiss Grove Beach (partial).

Johnsons Point

The southern tip of the Killams Point/Double Beach Peninsula is most vulnerable to isolation from inundated roads, but is also susceptible to flooding of homes and property. By the 2020s, multiple locations of daily road inundation are projected, making travel difficult within this area. By the 2080s, much of Johnsons Point Road will be flooded during high tides, and the entire neighborhood will be isolated.

Double Beach

This area is generally not susceptible to inundation from high waters alone, nor do projections show the inundation extent increasing over time. Erosion of unprotected slopes is an issue, as well as wave damage to structures. Erosion is particularly problematic in Lanphiers Cove, and Sunset Cove to the south is also vulnerable. Some homes are built directly on the water below the higher ground that protects most of the area from flooding. Flooding of Sunrise Cove and Lanphiers Cove homes during extreme storm events is also a risk.

Branford Point

Homes in this area have low direct risk, but a number of marinas and boat launches are vulnerable as soon as the 2020s. Daily flooding of Harbor Street by Mill Creek is projected to be a concern by the 2020s as well. During extreme events, isolation of this area by inundation of Harbor Street and Stannard Avenue is possible.

Branford Center

The area south of Interstate 95 around the Branford River is vulnerable to sea-level rise despite not being located directly on the shore of Long Island Sound. Sites are projected to experience flooding during the daily high tide by the 2020s. This area includes Meadow Street and Hammer Field, which is a very low-lying area vulnerable to extensive flooding if the Branford River is able to overtop its bank and flow through a small railroad underpass.

Blackstone Acres

This residential neighborhood on the east side of the Branford River is vulnerable to isolation by inundation of two key roads. This is projected to occur during daily high tide by the 2050s. High tide in the 2080s, or storm surge events, will affect many properties both on the river bank and in a low-lying inland area.

WHAT DO OTHER STUDIES SAY ABOUT BRANFORD?

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 Branford 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."

Indian Neck Avenue

Areas to the east of Indian Neck Avenue are vulnerable to flooding. Tabor Drive is projected to be flooded by 2020s daily high tides, as is Ark Road by the 2050s. A present-day category 2 hurricane event would impact both Indian Neck Avenue and South Montowese Street, causing significant isolation problems. Isolation will be a major problem as sea levels and storm surges increase. A large storm may inundate this area in such a way that the Branford River will effectively overtop its banks and flow directly south along South Montowese Street and over Limewood Beach into Long Island Sound.

The TNC model predicts that by the 2020s, daily inundation will threaten some sections of the Wastewater Treatment Plant, and remain near the same level with sea level rise. The site is at high risk of flooding during storm events.

Sybil Creek

Flowing west under Waverly Park Road and South Montowese Street (Route 146), this tidal river can inundate some boundary properties and important roads. Projections show daily flooding on and near Waverly Park Road by the 2020s, isolating the Waverly Park neighborhood. Daily flooding is also projected to occur to the west of South Montowese Street by the 2020s, impacting the fire station located at that site. Under a storm surge scenario, Sybil Creek may overtop its bank and merge with Long Island Sound to the south over Limewood Avenue.

Pawson Park and Sunset Beach

Both of these neighborhoods border significant wetlands, and have homes and roads vulnerable to inundation. Sunset Beach borders a VE zone with a BFE of 13 feet (NAVD88), while its inland areas are in AE zones with 11 and 12 foot BFEs. Pawson Park BFEs are 12 feet. Roads in the Sunset Beach neighborhood are vulnerable to high tide flooding under 2020s projections. Pawson Road is projected to be at risk to high tide flooding by the 2080s.

Linden Avenue

Linden Point, at the western end of Linden Avenue, is at risk to high tide flooding based on 2020s sea level rise projections. The rest of the road is outside of projected inundation zones even through the 2080s category 2 storms, but is vulnerable to erosion and undermining.

Limewood Avenue

Limewood Avenue is fronted by Limewood Beach, which is very vulnerable to rising tides. The road itself shows some risk of daily high tide inundation projected to the 2080s, but the main hazard here is erosion. Category 2 storm surges may overtop the road, connecting Long Island Sound to Sybil Creek.

Haycock Point

The Sybil Creek side of this neighborhood is at risk to high tide flooding by the 2020s. The south, Long Island Sound side of the neighborhood is vulnerable to present day category 2 storm conditions. A significant portion of the neighborhood falls within a 12-foot BFE AE zone.

Hotchkiss Grove

The homes between 2nd and 6th Avenues are vulnerable to storm surge flooding, and are projected to be at risk of high tide flooding by the 2080s. Additionally, the narrowness of the strip of developed land between Hotchkiss Cove to the east and Sybil Creek to the west raises concerns about evacuation routes and possible isolation. Another significant concern in this area is the vulnerability of higher-elevation waterfront properties to erosion. Properties from 1st Avenue eastward to Brown Point are particularly susceptible to this risk.

Pine Orchard

Low-lying neighborhoods on the south-western edge of the Pine Orchard Golf Course, as well as Pine Orchard Road, are expected to experience daily inundation problems by the 2020s at the earliest or the 2050s at the latest.

Juniper Point

Totoket Road experiences flooding during present-day large storm events, but likely will be flooded during daily high tides by the 2080s, cutting of the eastern Pine Orchard neighborhood of Juniper Point.

Pleasant Point

A handful of homes on high ground here are vulnerable to isolation from flooding of Pleasant Point Road, the only road to the Pleasant Point neighborhood. It is projected to be flooded daily as soon as the 2020s. The Amtrak Rail that passes through this area is also at risk of daily flooding by the 2020s, with increased risk in multiple locations by the 2050s.

Stony Creek

Stony Creek Road is currently flooded during large storm events, and may be flooded daily by the 2080s. Thimble Island Road risks daily flooding by the 2050s, isolating neighborhoods to the south. Already, residents have noted increasing frequency of this road flooding. This is one of the few areas in Town dependent on private individual septic systems, which are likely at risk to rising groundwater levels and increased incidents of flooding.

Jarvis Creek

The rural area at the eastern end of Branford is vulnerable to flooding from Jarvis Creek, cutting off Leetes Island Road (State Route 146), which connects Branford to neighboring Guilford, in two areas and impacting farmland. By the 2020s it can be expected to be flooded during the daily high-tide, although Sawmill Road would still be passable, and the east-west route still traversable overall. By the 2050s, multiple locations on Leetes Island Road, as well as a portion of Sawmill Road, will see daily flooding, isolating Branford from Guilford.

Inundation Risks by Neighborhood

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

	Daily High Tide					
Neighborhood	**Risk to Structures**			**Risk to Roads**		
DHT Decade→	2020s	2050s	2080s	2020s	2050s	2080s
Clark Avenue	Low	Low	Low	Low	Med	Med
Beckett Avenue	None	Low	Med	Low	Low	Med
Short Beach	Low	Low	Med	Low	Low	Med
Killams Point	Low	Low	Med	Med	Med	High
Johnsons Point	Low	Med	Med	Med	Med	High
Double Beach	Low	Low	Low	None	None	None
Branford Point	None	None	Low	None	Low	Low
Branford Center	Low	Low	Med	Low	Low	Med
Blackstone Acres	None	Low	Low	None	Low	Med
Indian Neck Avenue	Low	Low	Med	Low	Med	Med
Sybil Creek	Med	High	Critical	Med	Med	High
Pawson / Sunset	Low	Low	Med	Low	Med	High
Linden Avenue	None	Low	Low	None	None	None
Limewood Avenue	None	Low	Low	Low	Low	Low
Haycock Point	Low	Low	Low	None	Low	Low
Hotchkiss Grove	Low	Low	Med	Low	Low	Med
Pine Orchard	Low	Low	Med	Med	Med	Med
Juniper Point:	None	Low	Low	Low	Low	Med
Pleasant Point:	None	None	None	Low	Low	Med
Stony Creek:	Low	Low	Med	Low	Low	Med
Jarvis Creek:	Low	Low	Low	Low	Med	High

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 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 Branford.

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
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

Measure	Summary	Benefits	Barriers to Implementation
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 Branford

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 Branford to implement;
- Not relevant to Branford’s particular geography, geology, and hazard profile; and/or
- Socially unacceptable to Branford’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 Branford’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 Branford 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
	Wastewater Treatment Plant Floodproofing
	Sewer Pumping Station Elevation and Floodproofing
	Establishment of Community Wastewater Systems
	Strengthen Power Utilities
	Tide Gate Maintenance
Home Protection	Elevation
Business Protection	Elevation or floodproofing
Regulatory Tools	Flood Damage Prevention Modifications: • Freeboard • V zone standards in Coastal A zones
	Other Zoning Modifications: • Height Limit Flexibility

Categories of Options	Specific Options
	• Reconstruction Flexibility
Coastal Realignment	Road Retirement (with or without alternate route development)
	Property Acquisitions

Because Branford has so many areas at risk of isolation, road elevations and related efforts focused on ensuring emergency access to all neighborhoods during and after storms, will be a large part of Branford's resilience efforts.

Assisting homeowners with elevating 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.

Beach replenishment and nourishment through sediment placement and control efforts will not likely be a significant part of Branford's resilience efforts in the short term, although there may be areas where it makes sense in the long term. Similarly, dune restoration will not likely be a significant need in Branford, although there are limited areas such as Limewood Beach where dunes are present and could be enhanced.

Although tidal marsh living shorelines are not appropriate for most of the Branford coast, the Town is encouraged to explore the use of soft, hybrid, and green/gray alternatives to hard-shoreline protection. Such techniques include bioengineered banks. Hard structural protection measures should be implemented where necessary, especially in the densely developed areas or where infrastructure is in danger of damage from floods and erosion.

Although it would represent a significant investment, development of community wastewater treatment systems should be explored for the neighborhoods at the eastern side of the town that are not served by the municipal wastewater treatment plant.

Finally, Branford should consider enacting 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.

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.

3.3.1 Application of Adaptation Options in Branford

The following section summarizes some of the specific challenges in Branford 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 Protections

Branford's shoreline is densely developed in some areas, 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 with protective structures.

Sections of the Town with assets such as buildings, utilities, 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 Clark Avenue, Beckett Beach, Short Beach, Double Beach, Lanphiers Cove, Linden Avenue, Limewood Avenue, Haycock Point, Hotchkiss Grove, Pine Orchard, and Stony Creek. Many of these neighborhoods are already protected by hard structures, which should be monitored and maintained, and some upgraded, moving forward.

> **WHAT DO OTHER STUDIES SAY ABOUT BRANFORD?**
>
> **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 Branford coast falls within the "Shoreline District D" designated by this project. This district is defined as dominantly "rock and marshes." This zone is identified as having the second-lowest potential for installation of natural infrastructure projects.

Hard structures are planned for at least two areas listed above:

- FEMA has obligated a mitigation grant to the Town for coastal bank stabilization along Linden Avenue, with design and construction scheduled for 2016-2017.
- CT DOT is working on a design for road reconstruction that will include a bulkhead or seawall along Limewood Avenue.

These are areas that would be difficult for incorporation of green infrastructure given the steep slopes and wave energy. However, in the case of Limewood Avenue, beach nourishment in front of the bulkhead or seawall would provide some habitat and aesthetic functions to the beach.

Jetties, breakwaters, groins, and other hard structures that are used to reduce the energy of waves and currents, may be useful for

> **WHAT DO OTHER STUDIES SAY ABOUT BRANFORD?**
>
> **Modeling Site Suitability of Living Shorelines in Connecticut (2015)**
>
> This web tool developed by UConn depicts the following sites as potentially suitable for offshore breakwaters: Clark Avenue beach, Beckett Avenue beach, Shot Beach, Double Beach, Branford Point Beach, Pawson Park/Indian Neck, Linden Avenue, Limewood Beach, and Hotchkiss Grove.

areas with eroding beaches or bluffs. Branford's irregular coastline and offshore islands creates a situation where most of the sandy or erodible shoreline sections are already somewhat protected from wave action. This limits suitable sites for these types of shoreline protection. Areas where they may be appropriate include Beckett Beach, Linden Avenue, Limewood Beach, and Hotchkiss Grove. These sediment-control structures are often used in concert with beach nourishment projects.

One specific area that is not currently protected by hard structures is the neighborhood of Blackstone Acres. This neighborhood is somewhat vulnerable to inundation now, and vulnerability is expected to increase in the future. One option for protection moving forward is to construct a floodwall or a levee. Space is limited by homes on one side and tidal wetlands on the other.

Another area that requires a form of structural protection is the Meadow Street and Hammer Field section of Branford Center. A small railroad underpass allows floodwaters from Branford River to flow into the Hammer Field neighborhood. A promising mitigation option here is to install a temporary floodgate system at the underpass that can be deployed during storm events.

Finally, hard structure is believed necessary to protect an eroding bank in Lanphiers Cove where a sewer pipe is at high risk of undermining and failure. A revetment may be feasible in this area.

Options for Blackstone Acres, Meadow Street, and Lanphiers Cove will be discussed in more detail in section 4.

Soft Shoreline Protection

Some sections of Branford are able to be served using soft shoreline protection such as beach and dune nourishment, which is often more aesthetically acceptable and more supportive of natural systems and processes.
Areas where soft protection measures may be implemented include Clark Avenue, Beckett Beach, Short Beach, Double Beach, Limewood Avenue, Hotchkiss Grove, Pine Orchard, and Stony Creek.

Dune restoration or construction is generally not a great fit for Branford due to the Town's geography. 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. Most Branford beaches do not have this space. However, the small Clark Avenue beach and the eastern edge of Limewood Avenue Beach may be good candidates for *moderate* dune creation or enhancement.

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. Hotchkiss Grove may be a candidate for this kind of project.

WHAT IS A LIVING SHORELINE?

A definition of "living shoreline" was provided on Page 20. 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 Branford.

WHAT DO OTHER STUDIES SAY ABOUT BRANFORD?

Modeling Site Suitability of Living Shorelines in Connecticut (2015)

This web tool developed by UConn depicts one site as potentially suitable for beach nourishment: Lanphiers Cove.

Living Shorelines

Bioengineered Banks

Bioengineered bank treatments may be appropriate options where wave energy is not extremely high such as Short Beach, Lanphier Cove in area Double Beach area, sections of Hotchkiss Grove, and sections of Stony Creek. Based on the damage from storms Irene and Sandy, bioengineered bank treatments may not be suitable at sites such as the Linden Avenue embankment.

Created and Restored Tidal Wetlands

Branford's irregular shoreline creates numerous protected coves and tidal wetland areas that would support the created or restored tidal wetland form of living shorelines. However, most areas in Town suitable to tidal marshlands already support them. Significant tidal marshlands in Branford include those in or around the East Haven Marsh Wildlife Area, Kelsey Island, Killams Point, The Branford River, Pawson Park and Sunset Beach, Sybil Creek, Pine Orchard, and Jarvis Creek. Therefore, further tidal marsh restoration will not be a priority for the Town in the short term. However, ensuring the continued viability and inland migration of existing marshland with sea level rise will be a critical consideration for tidal wetland areas in the long term.

Artificial Reefs

Recent living shoreline projects like the Stratford reef ball project may be feasible in Branford between Kelsey Island and Horton Point, at Branford Point, off of the Stony Creek neighborhood, and near the mouth of Jarvis Creek. When siting such a project it is important to determine whether the reef balls would survive a powerful coastal storm while meeting the living shoreline objectives of increased vegetation and ecological value. The sites listed in the *Modeling Site Suitability of Living Shorelines in Connecticut* (2015) web tool as suitable for offshore breakwaters (Clark Avenue beach, Beckett Avenue beach, Shot Beach, Double Beach, Branford Point Beach, Pawson Park/Indian Neck, Linden Avenue, Limewood Beach, and Hotchkiss Grove) might also be suitable for artificial reefs, depending on water depths.

Roadways and Transportation

The layout of Branford is such that even if some major roads are impassable, other routes would remain open and available for most residents. Nevertheless, multiple neighborhoods may be completely isolated under high water conditions. Under current conditions there are already roads that experience chronic flooding, and neighborhoods that are isolated during storms.

Some of the most significant roads at risk in Branford include Route 1, State Route 142, State Route 146, Clark Avenue, Grove Street, Killams Point Road, Stannard Avenue, Johnsons Point Road, Harbor Street, Maple Street, Main Street, Woodvale Road, Tabor Drive, Ark Road, Pawson Road, Linden Avenue, Waverly Park Road, Pine Orchard Road, Pleasant Point Road, Totoket Road, and Thimble Island Road. Some of these roads (especially the State Routes 142 and 146) are vulnerable to flooding in multiple locations.

Areas of the Town vulnerable to isolation with increasing risk include: southern Clark Avenue; the Grove Street neighborhood north of Short Beach; Killams Point; Johnson Point and Spring Road at the southern end of the Double Beach area; Branford Point; the northern part of Blackstone Acres; all of Indian Neck including Pawson Point, Sunset Beach, and Linden Avenue; the area west of South Montowese Street; Limewood Avenue; Waverly Park north of Sybil Creek; Pine Orchard, Pleasant Point; and the southern end of Thimble Island Road. Additionally, eastward evacuation may be hindered by flooding of Route 146, and east-west transit may be hindered by flooding of roads along Branford River, including Route 1. 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.

A sequenced list of vulnerable sites is presented in Appendix C to help prioritize road elevation and reinforcement efforts.

Transportation adaptation options for these roads may include:

- Roadway elevation to reduce frequency and depth of high tide flooding and storm surge flooding;
- Roadway strengthening and reinforcement to withstand inundation;
- Roadway abandonment to avoid continuous maintenance of at-risk road; and
- Construction of alternative routes in locations with lower risk.

Infrastructure Retrofits and Upgrades

Drainage

Some areas of Branford have adequate protection from inundation and wave action, but still experience damage due to failing, inadequate, or malfunctioning drainage infrastructure. This is an important vulnerability at Beckett Beach. Beckett Avenue already suffers 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.

Wastewater

The Branford Water Pollution Control Facility (WPCF) is within a mapped floodplain and will be affected by sea level rise and coastal storms. At the time that the facility was designed, the 100-year flood elevation at the site was calculated to be 12 feet (NAVD88). After FEMA updated its maps in 2013, the base flood elevation (BFE) here was recalculated as 13 feet. Most structures within the facility remain above the BFE, although the "freeboard," or the extra height above the BFE, has decreased.
A significant concern at the WPCF is the vulnerability of underground systems and basements to flooding through insufficiently elevated doors, windows, hatches, vents, conduits, light fixtures, cracks, and other openings. Specific adaptation options appropriate for the WPCF include sealing cracks and conduits, and installation of deployable flood doors or hatches.

In addition to the WPCF, many of Branford's sewer pumping stations lie within hazard zones and may be vulnerable to sea level rise. One example is the pumping station at Sailor Lane, which is not housed in a pump house. Construction of a floodproofed pump house around this and other unprotected stations is suggested.

About 15% of Branford households rely on septic systems for sanitary wastewater treatment. Any of these systems that exist near the coast are vulnerable to sea level rise and coastal hazards. The Stony Creek and Pleasant Point neighborhoods both rely on private septic systems to treat wastewater. Development of community systems in these locations is suggested.

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 Branford 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 Beckett Beach, Killams Point, Blackstone Acres, Pawson Park and Sunset Beach, homes around Sybil Creek, and Hotchkiss Grove.

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 Killams Point Area, the Mill Creek wetland, the inland Branford River wetlands, Pawson Park, Sybil Creek, the Pine Orchard Marsh Wildlife Area, the Washburn and Reed Preserves, and the many islands located just off the coast.

Other Options

Other adaptation options – such as regulatory tools and incentives – apply throughout Branford. 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 Branford Options Summary

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

Possible Options	Shoreline Protection					Infrastructure						Structure		Realignment		
Appropriate Neighborhoods	Hard Protection	Beach Nourishment	Dune Restoration	Non-Structure Living Shoreline	Bioengineered Banks	Drainage Improvement	Pumping Station Retrofit	Community Wastewater	Strengthen Power Utilities	Road Elevation	Tide Gate Maintenance	Structure Elevation	Floodproof Structures	Alternate Route Development	Property Acquisition	Road Retirement
Clark Ave	X	X					X		X	X		X			X	
Beckett Beach	X	X				X	X		X	X	X	X			X	
Short Beach	X	X		X	X		X		X	X		X			X	
Killams Point									X	X				X		
Johnsons Point									X	X					X	
Double Beach	X	X		X	X		X		X			X			X	
Branford Point							X		X	X		X	X			
Branford Center	X					X	X		X	X	X	X	X			
Blackstone Acres	X					X	X		X	X	X	X				
Indian Neck Ave									X	X		X				X
Sybil Creek							X		X	X	X	X			X	
Pawson Park							X		X	X	X	X				
Linden Ave	X			X	X		X		X							
Limewood Ave	X	X	X						X	X		X			X	
Haycock Point	X								X			X				
Hotchkiss Grove	X	X	X			X	X		X			X			X	
Pine Orchard	X	X							X	X	X	X				
Juniper Point									X	X						
Pleasant Point								X	X	X						
Stony Creek	X	X				X		X	X		X	X	X	X		
Jarvis Creek									X	X	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 Branford.

The two specific neighborhoods and two specific infrastructure assets that should be targeted for more focused planning efforts were selected 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
Clark Ave	X	X	X			X	
Beckett Beach	X	X	X	X	X		X
Short Beach	X	X	X	X			X
Killams Point				X			
Double Beach			X	X*	X**	X	X
Branford Point						X	X
Branford Center	X	X	X	X	X	X	X
Blackstone Acres	X	X	X	X		X	X
Indian Neck Ave	X		X			X	X
Sybil Creek			X	X	X		
Pawson Park	X		X	X			X
Linden Ave	X		X			X	
Limewood Ave	X		X				
Haycock Point							
Hotchkiss Grove	X		X	X			
Pine Orchard	X		X	X		X	
Juniper Point						X	X
Pleasant Point						X	X
Stony Creek	X		X	X		X	X
Jarvis Creek						X	X

Branford Center is the area with the most columns checked (seven) whereas Blackstone Acres and Becket Avenue are the areas with the second-most columns checked (six). Other neighborhoods with many columns checked (five) are Short Beach, Double Beach, and Stony Creek. Areas with four columns checked are Clark Avenue, East of Indian Neck Avenue, Pawson Park (and Sunset Beach), and Pine Orchard.

Branford Center and Blackstone Acres are the two neighborhoods with the most columns checked and were therefore selected for neighborhood-scale planning:

- Branford Center is clearly in need of more focused design efforts. One area that is the subject of frequent complaints is the neighborhood of Meadow Street and Hammer Field. This area is inundated by water from the Branford River flowing through a small underpass below the train tracks. The neighborhood itself includes many residences, a number of commercial properties, a secondary emergency shelter, and the large open-space of Hammer Field. There are a number of neighborhood-scale approaches to adaptation applicable here, and so this location will be selected for a neighborhood concept design. One of the adaptation options involves blocking the railroad underpass, an action which itself can be accomplished in many ways. Therefore, options specific to preventing water from passing through the underpass will be considered as a separate focused infrastructure design.

- The second neighborhood design that will be addressed with more focused planning efforts will be applied to Blackstone Acres. This area is vulnerable to Branford River flooding, and faces similar risks to other neighborhoods adjacent to the river. Therefore, the designs presented for consideration in this neighborhood should also help guide planning efforts for other neighborhoods.

One infrastructure design explored in more detail is a bank revetment concept for Lanphier Cove, located in the Double Beach neighborhood of Branford. Ongoing erosion of a steep bank threatens an underground sewer line here, and that line can be considered a critical facility. Although the greater neighborhood is not at risk of future inundation, Lanphier cove itself is, so the vulnerability of the sewer line will increase with sea level rise. With these considerations in mind, it is clear that this site is an important one for more focused resiliency efforts, and therefore will be selected for that purpose.

In summary, the four selections for focused planning are:

<u>Neighborhoods</u>
- Meadow Street/Hammer Field (in the Branford Center area)
- Blackstone Acres

<u>Infrastructure</u>
- Meadow Street Railroad Underpass Flood Prevention
- Lanphier Cove bank protection

The results of these plans are discussed below.

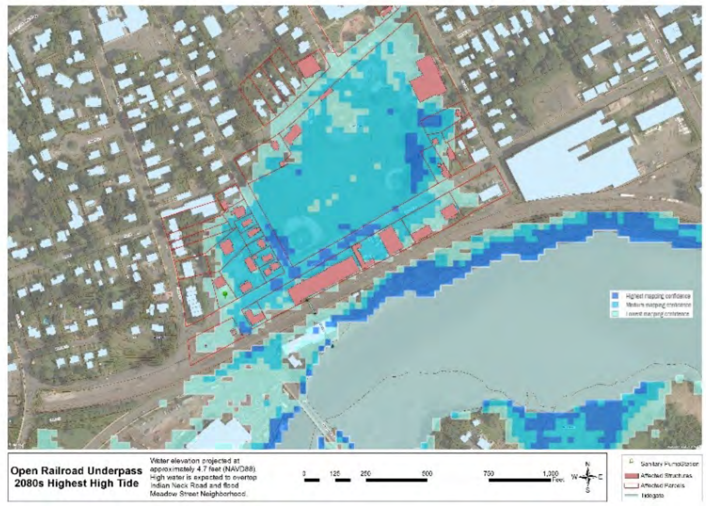
4.1 Neighborhood Conceptual Plans

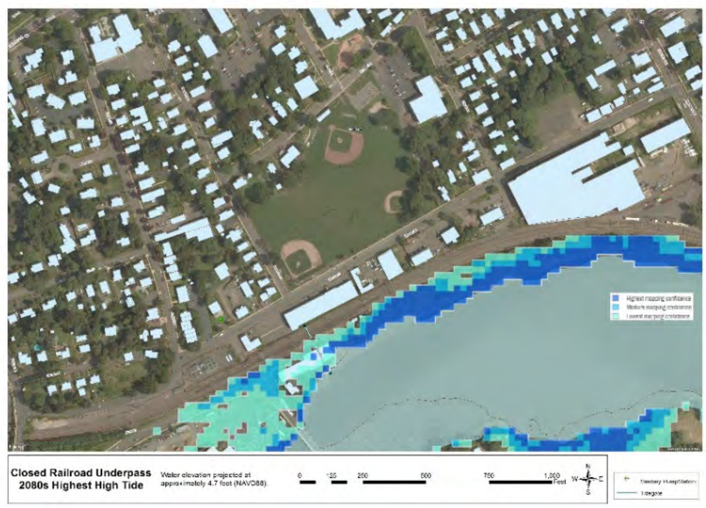
This plan presents **two examples** for building resilience at the neighborhood scale. These examples are Meadow Street and Blackstone Acres. Both examples show resilience methods that may or *may not be* desired or cost-effective. The examples demonstrate that there may be tradeoffs and choices to make 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.

Meadow Street

The Meadow Street, or Hammer Field, neighborhood is a low-elevation bowl-shaped area that includes residential, commercial, and industrial buildings, a public park, and the Branford Parks and Recreation Department's "Community House," which is a secondary emergency shelter. There is also an electrical substation and a sewer pumping station located in flood-prone areas of the neighborhood.

While the neighborhood is separated from the Branford River the train-tracks, a small underpass allows vehicles, pedestrians, and water to pass between the south and north sides of the tracks. The base of the underpass is the lowest-elevation spot in the area, and houses important stormwater infrastructure assets. This neighborhood is vulnerable to poor drainage during large rain events, riverine flooding from the Branford River, and high tides or storm surges moving northward from Long Island Sound. The main source of water into the neighborhood from the river is overtopping of the narrow strip of land between the railroad underpass and the river. An additional risk is water surcharging through stormwater drainage infrastructure. Finally, accumulation of water in the bowl-shaped neighborhood can occur through normal rainfall conditions, without any interaction with the river.





Floodable neighborhood (top) and Flood Gate at the Underpass (bottom) during a projected 2080s high tide.

Much of the neighborhood lies within a FEMA 1% annual-chance floodplain (Zone AE), with a base flood elevation of 12 feet NAVD88.

The neighborhood plans developed for this area focus on preventing floodwaters from entering the neighborhood through the railroad underpass, upgrading storm drainage infrastructure to prevent surcharging or drainage failures, and installing stormwater pumping stations to remove ponded water during storm surge or future extreme high tide events.

The two neighborhood protection alternatives are summarized below:

Alternative Description	Modeled Outcome	Approximate Cost to Town ($)	Approximate Cost to Residents ($)
Floodable Neighborhood	Some structures already elevated, but additional elevations would be necessary. Critical facilities such as the pumping station, electrical substation, and emergency shelter, may need to be protected or relocated.	1,800,000 to 2,300,000	9,300,000
Flood Wall at Underpass	Should be minimally disruptive and protect the neighborhood through 2050s category 2 storms. Additional elevation of the railroad would be required to remove the neighborhood from the FEMA hazard zone	813,000 (Without railroad elevation)	Uncertain; would depend on SD/SI requirements

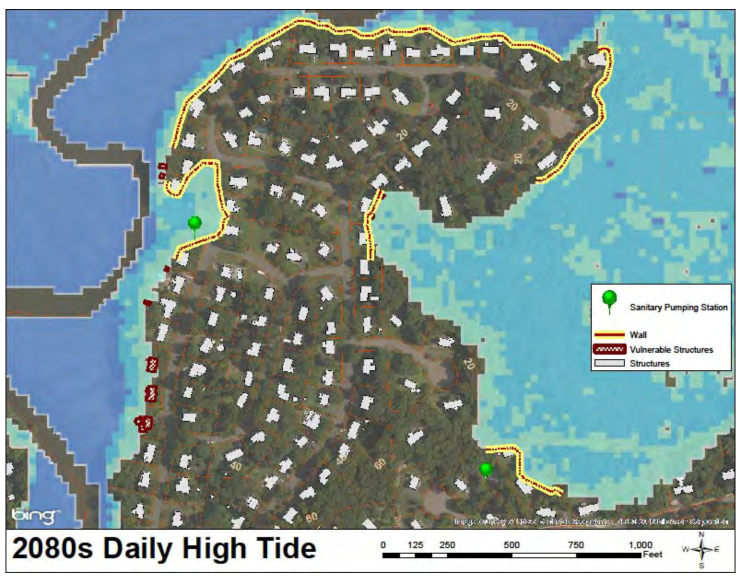
Details on the designs, costs, and effectiveness of these alternatives are provided in Appendix E.

Blackstone Acres

Blackstone Acres is located to the east of the Branford River, across from Branford High School. It is a higher-elevation peninsula that juts northward, with the Branford River on the west and a tributary and associated wetland to the east and north. It is vulnerable to both tidal and upland flood events, with two main areas of risk.

The first area is homes located on the peninsula's "outer" edge, along the water.

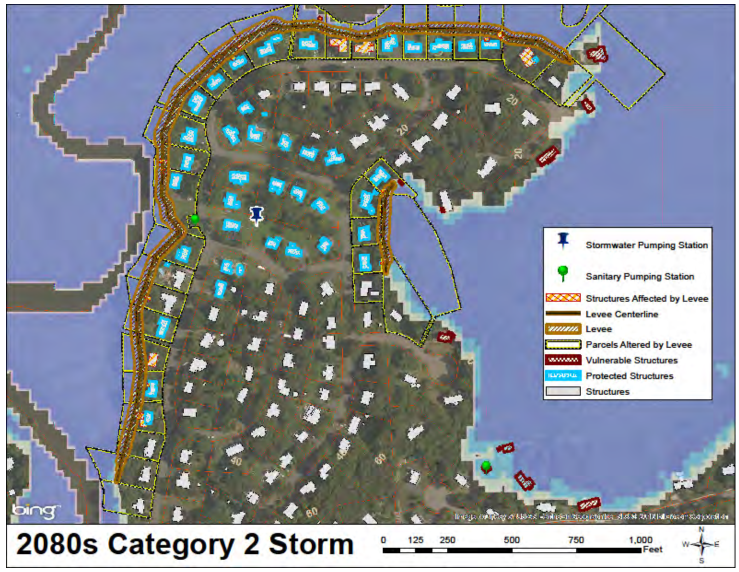
The second are homes and infrastructure located in the low-lying "belt" of the peninsula, where poor drainage or high water levels can inundate homes, roads, and a sewage pumping-station. The vulnerable roads are Riverside Drive and Woodvale Road, and during flood events the area north of the "belt" can be isolated. Homes between these two roads and between Hawthorne Terrace and Oakdale Place are at risk of flooding. These homes were flooded during Hurricane Sandy.



Floodwall system during projected 2080s high tide.

Much of the neighborhood lies within a FEMA 1% annual-chance floodplain (Zone AE), with a base flood elevation of 9 feet NAVD88.

The three protection alternatives are summarized in the table below.



Levee system during projected 2080s category 2 Storm.

Blackstone Acres differs significantly from Meadow Street in the way in which floodwaters access the area. At Meadow Street, floodwaters enter through a single point, and even during extreme flood events access would be through a limited area. It will be possible to protect the entire area from most flooding simply by blocking off the railroad underpass and drainage infrastructure. In Blackstone Acres, water can access the neighborhood from all directions. Building only part of a surge-protection berm or levee, for example, will have no positive impact, unless large parts of the neighborhood are abandoned.

Alternative Description	Modeled Outcome	Approximate Cost to Town ($)	Approximate Cost to Residents ($)
Floodable Neighborhood: Elevate homes, as well as a road to maintain access	Many elevations would be necessary. Access during and after storm events would be maintained, but the road would have to be significantly elevated.	1,000,000	9,800,000
Construct a **flood wall** system to protect against high tide through 2080s sea-level-rise conditions.	With improved drainage infrastructure, will protect neighborhood from high tides. Wall will not provide protection from storm surges.	1,330,000	Uncertain; would depend on SD/SI requirements
Construct a **dike or levee** system to protect against base flood elevations (1%-annual-chance, or category 2, storm) through 2080s sea-level-rise conditions.	With improved drainage, will protect most of the neighborhood from all but the most extreme flood events. Requires acquisition and displacement of many properties and structures.	3,800,000	0

On the other hand, risks at Blackstone Acres will most likely progress over time in a manner that could be tolerated, which could be reflected in prioritized order of operation for adaptation options. Branford could begin by immediately improving drainage infrastructure. The Town could then improve daily high tide protection by constructing a wall by the 2050s or 2080s. Over those decades, the Town could also work to acquire the property necessary to build a berm or dike system and protect the neighborhood against future high waters and storm surges.

The Blackstone Acres neighborhood is more reflective of the types of vulnerabilities faced throughout the Town as compared to Meadow Street.

4.2 Infrastructure Conceptual Plans

This plan also presents two examples of choices for building resilience through infrastructure projects. The conceptual designs prepared for the Meadow Street Railroad Underpass and Lanphier Cove can be used to make additional planning decisions for these two areas, and may provide a basis for further design.

Meadow Street Railroad Underpass

A low-clearance underpass (known as the "cattle crossing") runs below an elevated railroad, connecting Indian Neck Road to the south to Meadow Street to the north. The opening allows high water to enter Meadow Street, Hammer Field, and the surrounding neighborhood. Future daily high tides could become significantly problematic, and storm events are already an issue.

From LiDAR data, the Branford River needs to rise to an elevation of less than 6 feet (NADV88) to enter cattle crossing. The underpass road elevation is less than 4 feet. Many areas north of the underpass are lower than 6 feet in elevation. The Coastal Resilience Tool's Medium Sea Level Rise projection puts daily high tide at 7.3 feet elevation by the 2080s.

The railroad is elevated to between 10 and 12 feet (NAVD 88) in this area, and higher to the east and west away from the site. The Coastal Resilience Tool's Medium Sea Level Rise estimates put floodwaters at 10.0 feet during a Category 2 storm by the 2050s, and 10.8 feet by the 2080s.

This area is currently mapped as a FEMA AE zone (1%-chance annual flood event). The AE zone includes the elevated railroad, indicating a 1%-annual chance flood is expected to overtop the railroad.

Three resilient infrastructure options were proposed, as summarized in the table below:

Alternative Description	Outcome	Approximate Cost to Town ($)
Abandon and Fill Opening	Permanently prevent entry of floodwaters, but lose valued access route and important stormwater infrastructure.	577,500
Install Manual Floodgates	Prevent flooding during larger storm events. Requires advance notice and manual deployment, so not feasible for high tide or flash flood protection.	188,000
Install Automatic Floodgates	Prevent all flood events without need for human intervention. More expensive than manual floodgates. Allow continued access.	313,000
Additional	Extends flood protection to include base flood events and	300,000+

Protection along Railroad	projected 2080s category 2 hurricanes	

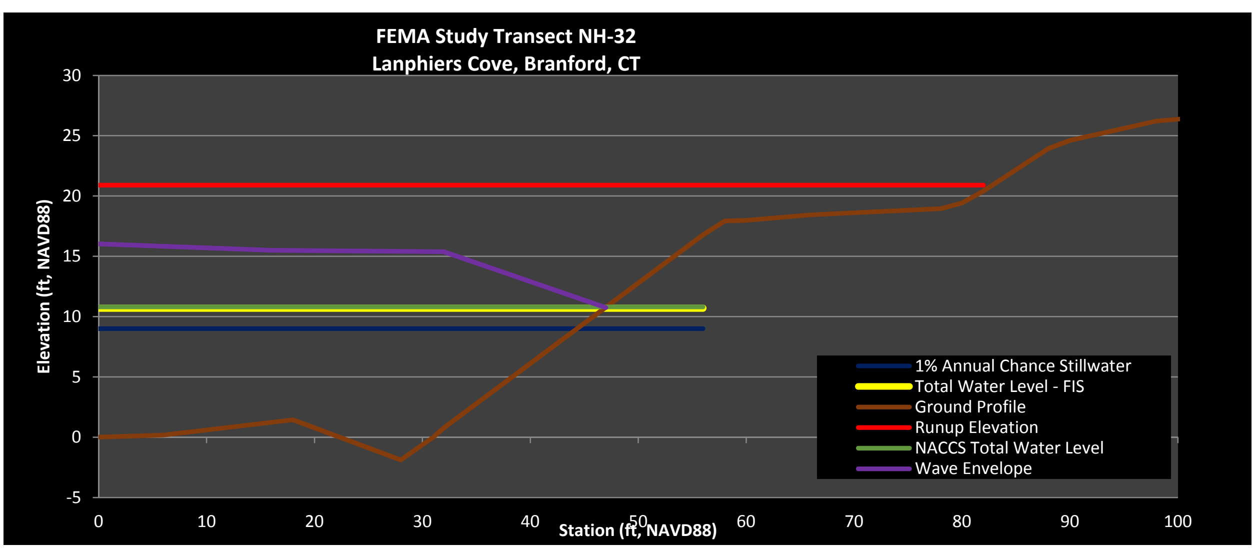
The options presented illustrate that there are numerous methods of addressing even smaller, site specific issues. Additionally, the complexities of installing a single flood gate are highlighted, including ensuring access is maintained while effective automated deployment is achieved.

Automatic Floodgates

For long-term protection from storm-surge inundation, or for removal of inland areas from the FEMA hazard zone, the railroad must be elevated above the base flood elevation. Considerations of sea level rise will call for increased elevation above the current BFE. Such a project requires coordination with and cooperation from the railroad, and is beyond the scope of this plan. Because the Town is planning ahead, it is feasible for resilience at this site to be achieved through multiple steps. Installation of a floodgate will protect the inland neighborhood from high tide through projected 2080s conditions, and additional steps to protect against storm surges can be taken later.

Lanphier Cove

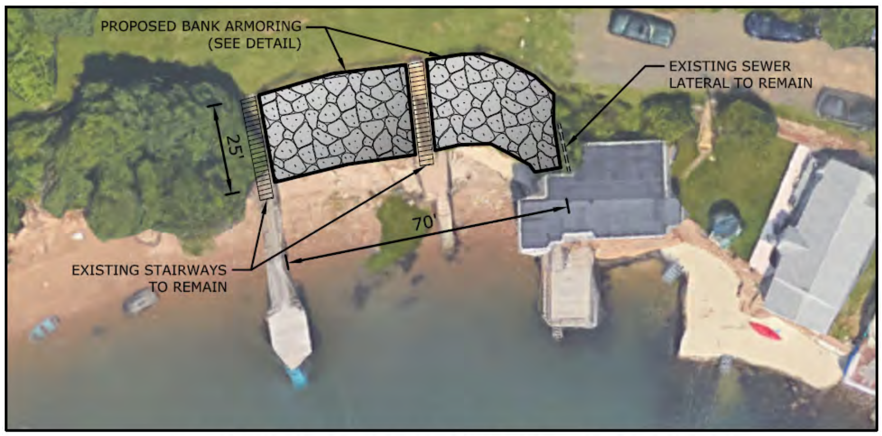
Lanphier Cove is an east-facing cove north of the Connecticut Hospice and east of Route 142. To the north and south, the cove is bounded by bedrock bluffs. The cove itself includes a small sandy beach, most of which is underwater during high tide. Inland of this beach is a steep rise of about 18 feet to higher bench. A sewage pipe is buried within this higher bench, carrying wastewater to the pumping station at the eastern end of Lanphiers Cove Road. A topographical transect of this area was collected by FEMA, and wave setup and runup modeling was run (see below. Explanation of this figure is provided in Appendix B).



A Letter of Map Revision was subsequently approved for Lanphier Cove, reducing the effective base flood elevation from 21 feet to 15 feet. However, the runup modeling still implies that wave energy can be significant here.

The steep slope leading from the beach to the upper bench is susceptible to erosion, and the remains of previous revetment projects are clearly visible in the field. A particularly vulnerable area is located in the northern section of the beach at Lanphier Cove. The steep bank here has less vegetation than other areas, and a home is constructed at the end of the steep bank. Erosion of the bank is significant, and there is concern that the sewer pipe may be vulnerable. The hazard at this site is wave energy and erosion, rather than inundation.

The option presented here is the installation of a riprap revetment. Stones would be installed such that they interlock and minimize voids, at a slope of 2:1 (two feet in width for every foot in height). The difference in elevation between the top and bottom of the eroding bank here is approximately 12.5 feet, resulting in a riprap width of approximately 25 feet.



SHORELINE STABILIZATION - PLAN VIEW
SCALE 1" = 30'

The cost of the proposed revetment material, construction, including site preparation and restoration, and allowing for contingency costs, gives an estimated total of $110,000.

Other approaches do exist, including incorporation of green infrastructure concepts into any bank stabilization project, or even allowing erosion to continue after removing the sewer infrastructure and rerouting wastewater elsewhere. If owners of the homes along the water here are interested, the Town can also consider pursuit of funding to acquire and remove those properties. Decreasing the number of hard structures in the site may allow wave energy to be spread over a larger area, instead of focused on individual spots, diminishing erosion rates at those locations. As sea level rise continues and storm intensity increases, erosion risks will increase throughout Branford into the future.

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 and coordinate its actions. The agency should 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 may 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
Town of Branford Coastal Resilience Plan

Action		Timeframe	Funding Sources
Townwide Regulatory Changes			
TR1	Relax the 35-ft height restriction to facilitate elevation projects for 2 and 3-story homes	2017-2018	• Not applicable
TR2	Adopt freeboard that exceeds the State-recommended one foot	2017-2018	• Not applicable
TR3	Enforce V zone standards in coastal A zones (to the limit of moderate wave action)	2017-2018	• Not applicable
TR4	Require that developers who will be removing fill or rock from a property within the Town's coastal zone first perform an analysis of the changes that work will have on the property's flood risk and status within the NFIP	2018-2019	• Not applicable
TR5	Increase Townwide tree and limb maintenance to limit road blockage and power outages during storms	2017-2018	• Operating Budget
Townwide Promotion of Property Protection			
PP1	Partner with property owners to apply for FEMA mitigation grants to elevate homes	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	A one-time promotion should be scheduled for mid-2016	• Shore Up CT (ending in 2016)
PP3	Encourage homeowners to consider avoiding continued risk by having the Town acquire their property	Annual Outreach	• FEMA HMA
Clark Avenue Projects			

	Action	Timeframe	Funding Sources
CA1	Elevate Clark Avenue Road to maintain access	2020-2021	• CIRCA (design) • STEAP • Bonds or capital improvement
	Beckett Avenue Beach Projects		
BB1	Retrofit drainage systems to prevent high-tide surcharging	2017-2019	• STEAP • Bonds or capital improvement
BB2	Pursue beach nourishment at Beckett Avenue Beach	2020-2023	• CIRCA (design) • STEAP • Bonds or capital improvement
BB3	Encourage Homeowners to elevate properties	Annual Outreach	• FEMA HMA • Shore Up
	Short Beach Projects		
SB1	Upgrade drainage system to prevent flooding of inland properties (tide-gate)	2025-2030	• STEAP • Bonds or capital improvement
SB2	Work with the State to pursue elevation of Route 142 here	2030	• CT DOT
	Killams Point Projects		
KP1	Elevate Killams Point Road near Short Beach Road to prevent isolation of Killams Point	2020-2025	• CIRCA (design) • STEAP • Bonds or capital improvement
KP2	Construct road through wooded area to connect Killams Point Road to Turtle Bay Drive as alternative egress	2030-2035	• CIRCA (design) • STEAP • Bonds or capital improvement
KP3	Coordinate with Killams Point Conference Center to ensure they have appropriate emergency and evacuation plans prepared.	2016-2017	• Not applicable
	Johnsons Point Projects		
JP1	Elevate Johnsons Point Road to prevent isolation during future high tides.	2018-2020	• CIRCA (design) • STEAP • Bonds or capital improvement
JP2	Upgrade Spring Road bridge to maintain access during future high tides and storm events.	2020-2025	• CIRCA (design) • STEAP • Bonds or capital improvement
	Double Beach Projects		
DB1	Stabilize Lanphier Cove eroding bank to protect sewer infrastructure	2017-2018	• CIRCA (design) • STEAP • FEMA HMA
DB2	Pursue acquisition of properties located completely within the VE zone at Lanphier Cove	2025-2030	• FEMA HMA

	Action	Timeframe	Funding Sources
DB3	Consider rerouting sewer infrastructure over time to minimize vulnerability to erosion and other coastal risks	2030-2035	• Bonds or capital improvement
Branford Point Projects			
BP1	Elevate Harbor Street at Mill Creek Crossing to maintain access	2030-2035	• CIRCA (design) • STEAP • Bonds or capital improvement
Meadow Street/Hammer Field Projects			
MS1	Install automatic flood gate at Meadow Street railroad underpass to protect against high tide and storm surge	2025-2030	• FEMA HMA • CIRCA (design) • STEAP • Bonds or capital improvement
MS2	Upgrade drainage system to allow for water removal when flood elevations are too high for gravity-driven drainage	2018-2020	• STEAP • Bonds or capital improvement
MS3	Coordinate with Railroad to elevate railroad berm over time to protect against higher base flood elevations	2030-2050	• Railroad • CT DOT
MS4	Coordinate with electric utility to ensure substation continues to be protected from flooding	2017-2018	• Eversource
MS5	Consider status of emergency shelter in this neighborhood as flood risks increase in the future	2017-2018	• Operating budget for town facilities
MS6	Elevate Indian Neck Avenue between the underpass and the Branford River to ensure access during flooding	2020-2025	• CIRCA (design) • STEAP • Bonds or capital improvement
Downtown Area Projects			
DT1	Upgrade drainage system at Village Green Court	2018-2020	• STEAP • Bonds or capital improvement
Blackstone Acres Projects			
BA1	Construct floodwalls around the Blackstone Acres neighborhood to protect from rising high tides	2019-2021	• FEMA HMA • Bonds or capital improvement
BA2	Elevate the lower-lying segment of Woodvale Road in Blackstone Acres to maintain access to the northern part of the neighborhood during floods.	2025-2030	• CIRCA (design) • STEAP • Bonds or capital improvement
BA3	Install a stormwater pumping-station between Oakdale Place and Hawthorne Terrace in Blackstone Acres to remove water when flood elevations are too high for gravity-driven drainage.	2022-2024	• STEAP • Bonds or capital improvement

	Action	Timeframe	Funding Sources
BA4	Acquire properties and construct levee around the neighborhood to protect from storm surges	2030-2050	• FEMA HMA for acquisitions • Bonds or capital improvement
	Indian Neck Avenue Area Projects		
IN1	Consider abandoning the vulnerable section of Tabor Road and elevate Ark Road as the alternate egress/access.	2017-2019	• Bonds or capital improvement
IN2	Work with the State to pursue elevation of Route 146 near Branford River Crossing	2030-2035	• CT DOT
	Sybil Creek Projects		
SC1	Install or improve tide gate at Route 146 Crossing to protect upstream areas from surge and high tide	2020-2022	• STEAP • Bonds or capital improvement
SC2	Pursue Linden Avenue elevation near Route 146	2022-2025	• CIRCA (design) • STEAP • Bonds or capital improvement
SC3	Continue pursuit of home elevation on Waverly Road	Annual outreach	• HUD
SC4	Pursue property acquisitions in Waverly Rd and Crouch Rd area	Annual outreach	• FEMA HMA
SC5	Elevate Waverly Park Road to maintain access to Waverly Park during flooding	2021-2023	• CIRCA (design) • STEAP • Bonds or capital improvement
	Pawson Park Projects		
PP1	Pursue Linden Avenue Bank Stabilization near Bayberry Lane	Underway	• FEMA HMA • CIRCA (design) • STEAP
PP2	Complete Linden Avenue Bank Stabilization near Old Pawson Road	Underway	• FEMA HMA
PP3	Upgrade Linden Avenue drainage systems to handle overwash from storm surges	2018-2020	• Bonds or capital improvement
PP3	Develop neighborhood-specific evacuation plan to enact before isolation from road flooding	2016-2017	• Not applicable
	Limewood Avenue Projects		
LA1	Work with CT-DOT to stabilize Route 146 at Limewood Beach	2016-2018 Short Term	• CT DOT
LA2	Pursue beach nourishment at western end of Limewood Beach	2017-2018	• CIRCA (design) • CT DOT (partial property owner) • Bonds or capital improvement
LA3	Pursue dune enhancement at eastern end of Limewood Beach	2018-2019	• CIRCA (design) • STEAP • Bonds or capital improvement

	Action	Timeframe	Funding Sources
LA4	Work with State to pursue elevation of Route 146 at Limewood Beach	2025	• CT DOT
	Hotchkiss Grove Projects		
HG1	Work with Hotchkiss Grove residents to identify where dunes and walls can be used together with flood protection	2017-2018	• FEMA HMA • CIRCA (design) • STEAP • Bonds or capital improvement
HG2	Retrofit Hotchkiss Grove drainage systems to reduce tidal backflow	2018-2020	• STEAP • Bonds or capital improvement
HG3	Consider Beach Nourishment	2022-2025	• CIRCA (design) • STEAP • Bonds or capital improvement
	Pine Orchard Projects		
PO1	Elevate Pine Orchard Road near Club Parkway to maintain east-west passage during floods	2023-2026	• CIRCA (design) • STEAP • Bonds or capital improvement
PO2	Pursue beach nourishment south of Island View Avenue	2030-2032	• CIRCA (design) • STEAP • Bonds or capital improvement
	Stony Creek Neighborhood Projects		
SC1	Fortify Branford Trolley Trail Bridge abutments at Stony Creek.	2018-2020	• CIRCA (design) • STEAP • Bonds or capital improvement
SC2	Develop neighborhood-specific evacuation plan to enact before isolation from road flooding	2017-2018	• Not applicable or within the annual EMD budget
SC3	Work with the State to pursue elevation of Route 146 at vulnerable locations along Stony Creek	2020-2025	• CT DOT
	Jarvis Creek Projects		
JC1	Assist/support resolution of problems related to the tide gate replacement	2016-2017	• Operating budget
JC2	Work with the State to pursue elevation of Route 146 at vulnerable locations along Jarvis Creek	2018-2020	• CT DOT
	Municipal Wastewater System		
WW1	Floodproof the Wastewater Treatment Plant	2020	• FEMA HMA • Bonds or capital improvement

	Action		Timeframe	Funding Sources
WW2	Elevate or Floodproof Vulnerable Sewer Pumping Stations, including: • Beckett Avenue • Little Bay Lane • Pages • Central (Meadow St) • Riverside Drive (Blackstone) • Blocks • Sybil (@ 146) • Summer Island • Hotchkiss Grove • Clark Avenue • Johnsons Point • Branford Point • Frank Street			• FEMA HMA • STEAP • Bonds or capital improvement

Implementation Strategy for Roads
Town of Branford Coastal Resilience Plan

Ranked Lists of Townwide Road Elevations (some are listed above)

Funding may include:

- FEMA HMA (for roads with high traffic counts and detour times; benefit cost ratio must exceed 1.0)
- STEAP (depending on eligibility)
- CIRCA (for innovative resilience designs)
- CDBG-DR (future appropriations)
- Municipal bonds and capital improvement budgets

Rank	State Roads	Town Roads	Private Roads
1	Route 146 @ Jarvis Creek	Linden Avenue	Johnsons Point Road
2	Route 142 @ Short Beach & Grove Street	Indian Neck Ave @ Branford River	Killams Point Road
3	Route 146 @ Sybil Creek crossing	Waverly Park Road	Spring Road
4	Route 146 @ Branford River	Pine Orchard Road	
5	Route 146 @ Limewood Beach	Clark Avenue	
6	Route 1 @ Branford River / Pisgah Brook	Thimble Island Road	
7	Route 146 @ Stony Creek	Harbor Street	
8	Route 142 @ Beckett Beach	Woodvale Road	
9	Route 142 @ Stannard Avenue	Maple Street	
10		Main Street	
11		Ark Road (alternate access may apply here)	
12		Pleasant Point Road	
13		Pawson Road	

14		Totoket Road	
15		Grove Street	
16		Stannard Avenue	

Implementation Strategy Table Legend:

TR – Townwide Regulatory
PP – Town Promotion of Property Protection
CA – Clark Avenue
BB – Beckett Avenue Beach
SB – Short Beach
KP – Killams Point
JP – Johnsons Point
DB – Double Beach
BP – Branford Point
MS – Meadow Street/Hammer Field
DT – Downtown Area
BA – Blackstone Acres
IN – Indian Neck Avenue
SC – Sybil Creek
PP – Pawson Park
LA – Limewood Avenue
HG – Hotchkiss Grove
PO – Pine Orchard
SC – Stony Creek
JC – Jarvis Creek
WW – Municipal Wastewater System

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.

CIRCA has indicated that funding may continue to be available in the coming years for design of individual resilience projects. However, projects should not simply be deferred municipal public works or similar projects. Instead, they must push boundaries and become innovative resilience examples in Connecticut.

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 Branford 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.

<u>Section 205 – Small Flood Damage Reduction Projects</u>
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.

<u>Section 14 – Emergency Streambank and Shoreline Protection</u>
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.

<u>Section 208 – Clearing and Snagging Projects</u>
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.

<u>Section 205 – Floodplain Management Services</u>
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.

Appendix A
Existing Resources and Capabilities

Community Coastal Resilience Plan
Town of Branford, Connecticut
Existing Resources and Capabilities

Introduction

The initial step in the Branford 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
- Branford Plan of Conservation and Development
- Branford Zoning Regulations
- Branford Code of Ordinances
- TNC Salt Marsh Advancement Zone Assessments
- FEMA New Haven County Flood Insurance Study and FIRM Panels
- Individual HMGP-funded Projects

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

Existing Resources

Hazard Mitigation Plan

The Town of Branford 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 different hazard events, including tropical storms, nor-easters, flooding, and sea level rise. This information is summarized in Table 1, abridged from Table 4.32 in the HMP.

Table 1: Assets Vulnerable to Coastal Hazards - Branford

Hazard	Number of Parcels	Number of Buildings	Critical Facilities	Historic Assets	Population
Hurricane/Tropical Storm	13,207	26,414	19	969	28,026
Severe Winter Storm/Nor'easter	13,207	26,414	19	969	28,026
Coastal Erosion	Unknown	Unknown	Unknown	Unknown	Unknown
Flood					
1-Percent-Annual-Chance	2,564	2,986	3	321	15,190
0.2-Percent-Annual-Chance	261	51	0	15	7,099
Zone VE	968	467	0	160	2,535
Category 1 Storm Surge	1,815	1,140	1	274	10,256
Category 2 Storm Surge	2,481	2,350	2	356	12,377
Category 3 Storm Surge	2,494	2,450	5	415	14,613
Category 4 Storm Surge	2,704	2,498	3	406	18,211
Sea Level Rise	2,194	1,299	2	282	11,898

A 1%-annual-chance coastal flood (also called the 100-year event or base flood) is predicted by the Plan to cause $14 million in losses and displace 136 households.

The HMP identifies the downing of electric and communication lines by falling trees and limbs, common during coastal storms, as the Town's most significant hazard. Coastal flooding, erosion, and sea level rise, and especially the impacts of those occurrences on roadways and accessibility, are also listed as significant hazards.

Specific areas listed as being vulnerable include

- Hickory Road
- Burban Drive
- Tabor Drive
- Beckett Avenue
- Meadow Street
- Sunset Beach
- Riverside Drive
- Summer Island Road
- Waverly Park Area
- Thimble Island Road
- Shore Drive / State Route 142
- Limewood Avenue / State Route 146
- Island View Avenue
- Club Parkway
- School Ground Road
- Linden Avenue
- Offshore Island Homes
- The Branford Wastewater Treatment Plant (WWTP)
- The Connecticut Hospice

Linden Avenue is described as being particularly susceptible to flooding and erosion.

The wastewater system is also vulnerable: the WWTP is located in a flood zone and, though it is protected to the 1%-annual-chance flood event, it is isolated during flooding. An estimated 25 out of 50 sewer pumping-stations are located below the base-flood elevation, and many of them do not have backup generators. Another noted vulnerability is the location of many emergency shelters within storm surge areas.

As noted in the Plan, coastal flooding and erosion in Branford has led to a series of flood prevention and property protection projects to be completed along the Town's coastline. These projects have focused on structural protection from erosion.

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

- Comprehensive Master Plan
- Capital Improvements Plan
- Economic Devel9opment Plan
- Local Emergency Operations Plan
- Transportation Plan
- Stormwater Management Plan
- Coastal Zone 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. Some suggested mitigation actions include:

- Installation of Backup Generators
- Development of a Microgrid
- Elevation of Roadways
- Improvement of Stormwater Drainage
- Installation of Flood Gates

Chapter six identifies hazard mitigation projects for each town participating in the SCRCOG plan. For this review we focused on projects that address coastal hazards or all flooding hazards for the Town of Branford. These projects are summarized within table 1 at the end of this memo.

Branford Plan of Conservation and Development

Branford's 2008 Plan of Conservation and Development (POCD), titled "Branford's Window to the Future," includes several areas that are relevant to coastal resilience planning, including sea level rise preparation and stormwater and flooding management. It mentions how sea level rise will increase flooding and may impact emergency services. The named action is "be cognizant and vigilant about how global sea level rise may affect existing and future development in coastal areas." The flooding section specifically names Meadow Street, Totoket Road, and Briarwood Lane as areas of concern. The plan mentions considering participation in the Community Rating System (CRS) program to access credit for floodplain management. To address stormwater the plan calls for continued "resources (time and money) to addressing and managing drainage issues," and specifically suggests providing stormwater treatment and restricting run-off from new development."

The POCD also identifies the goals of protecting water quality, protecting biological resources, utilizing utilize green energy, and reducing light pollution. One specific goal is to enhance wetlands and watercourses, including streams, lakes, ponds and rivers, Lake Saltonstall, and the Branford River. The POCD also calls for the implementation of the 2005 Open Space Plan, which includes the improvement of open space acquisition tools, managing town open space, and enhancing coastal access.

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 Branford 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 1,138.3 acres of Branford land by the 2080s. Currently, 81.2% of that land is suitable to sustaining a salt marsh ecosystem, but only 28% of the 1,138.3 acres is protected land.

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 Branford's coastline has remained fairly static over the last century, with average change (growth) of 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 portion of the Branford coastline between Linsay Cove and Seaview Avenue, which includes the Pawson Point neighborhood, Linden Avenue, and Limewood Avenue, is classified by this study as being a “high exposure” area. This area extends as far inland as Route 1 and the Downtown Branford, including Branford Harbor. Many state and local roadways (such as Routes 1 and 146), commercial facilities, recreational boating marinas, and the Branford Wastewater Treatment Plant, are at high risk.

The NACCS also assesses the applicability of a variety of general adaptation options to certain coastal types. The coast of Branford 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								
Manmade Structures (Sheltered)	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 Branford coast falls within the "Shoreline District D" designated by this project. This district is defined as dominantly "rock and marshes." This zone is identified as having the second-lowest 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

The Blue Plan 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.

Ongoing Studies

A number of concurrent coastal-resilience-related research efforts are taking place in the City of Milford at the same time as this project:

Southern Connecticut Regional Framework for Coastal Resilience

This project is funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grants Program. The study focuses on green infrastructure and coastal resiliency options for ten Connecticut municipalities. It is possible that the grant will result in a conceptual design for a natural or green infrastructure project in Branford. As of the date of this plan, the Stony Creek pedestrian bridge is the leading candidate for a conceptual design. Mitigation of bridge abutment scour is desired and may be achievable with a combination of hard and green infrastructure.

Historical Resources Planning

This project is funded by a grant from the National Park Service to the Connecticut State Historic Preservation Office (SHPO) through the Hurricane Sandy appropriations. The study focuses on providing technical assistance to coastal communities for protecting historic resources (such as registered historic structures and districts) from future floods and storm surges. The Town of Branford will be participating in summer and fall 2016.

Municipal Resilience Planning Assistance Project

Researchers at the University of Connecticut (UConn) are investigating the vulnerabilities of Connecticut wastewater treatement infrastructure, roads, and public safety assets, to flooding from rivers and storm surges now and with sea level rise. Funding for the study comes through the Community Development Block Grant Disaster Recovery (CDBG-DR) program. The $1,205,450 grant is administered by the Connecticut Department of Energy and Environmental Protection (DEEP) with UConn as a contractor. Through the research, DEEP will develop tools for municipalities to build resilience into their infrastructure systems, as well as technical assistance programs to support those and existing resilience tools.

Coastal Resilience Projects

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

TABLE 3

Town of Branford Potential Projects

Project	Description	Category	Action	Funding	Reduced Risks	Green Infr.
Linden Avenue at Bayberry Lane	Erosion is threatening Linden Avenue near Bayberry Lane. Green or hybrid approaches may be possible to stabilize the bank and reduce risk of road collapse.	Shoreline Infrastructure -- Bank Protection	Create		Road; Sewer System	No
Linden Avenue at Old Pawson Road Wall Replacement	This section of Linden Avenue is the sole egress for 400 homes. A stacked concrete block wall protects the edge of the road from erosion, but the wall is collapsing. New protection is needed and hybrid approaches may be possible with project #803.	Shoreline Infrastructure -- Bank Protection	Replace with Other	HMGP	Road; Sewer System	No
Linden Avenue at Old Pawson Road Bank Protection	This section of Linden Avenue is the sole egress for 400 homes. The edge of the road is not protected from bank erosion. New protection is needed and hybrid approaches may be possible with project #802.	Shoreline Infrastructure -- Bank Protection	Create	HMGP	Road; Sewer System	No
Linden Avenue at Linden Shores	This portion of Linden Avenue was repaired after storms Irene and Sandy. Hard shoreline protections were used to stabilize the bank and reduce the risk of future erosion.	Shoreline Infrastructure--Bank Protection--Seawall	Replace with Other		Road; Sewer System	No
Indian Neck Avenue RR Underpass	A small "cattle crossing" beneath the railroad alignment allowed the storm surge from Storm Sandy to flood the area to the north. An automatic or manual flood protection closure is desired for this opening.	Shoreline Infrastructure--Flood Protection System	Create		Critical Facility; Buildings	No

Conclusion

Branford has a great variety of capabilities in its existing Town plans and regulations, local and regional studies, and planned or ongoing coastal protection projects.

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
Vulnerability and Risk Assessment

TOWN OF BRANFORD
COMMUNITY COASTAL RESILIENCY PLAN

Vulnerability and Risk Assessment
Prepared as a section to be added to the complete plan

1 Introduction

The Town of Branford is partnering with the Town of Madison 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 Branford 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:

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."

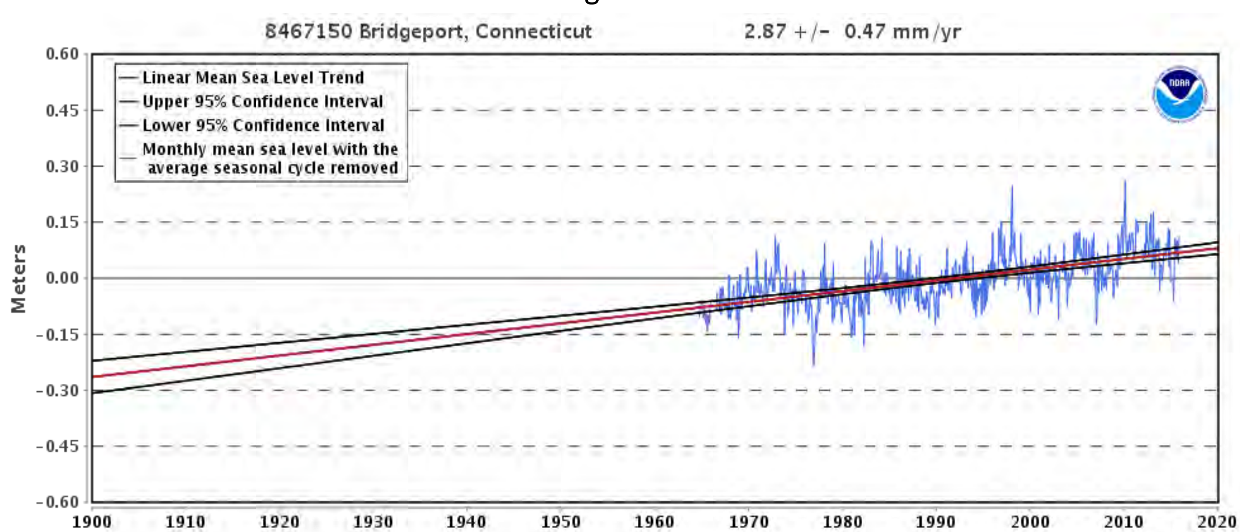
Sea level rise is not consistent around the world, and is affected by local variations in currents, temperature, and changes in land surface elevation. It has long been expected that the rate of sea level rise in Connecticut will be slightly higher than the global projections due to the effects of regional 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

A single tide gauge was operated by the National Oceanic and Atmospheric Administration (NOAA) within Branford from June to November, 1989. The gauge was located in the Branford River east of Branford Point. According to data collected by this gauge (available online at tidesandcurrents.noaa.gov), the mean sea level (MSL) in Branford Harbor is negative (-) 0.28 feet, or 0.28 feet below the North American Vertical Datum of 1988 (NAVD88). The average maximum elevation of high tide ("mean higher-high water, or MHHW") is 3.25 feet above the MSL, or 2.97 feet elevation (NAVD88). These values will vary along Branford's coastline, and have likely changed since 1989, as discussed below.

The nearest operational gauge to Branford is the tide gauge in Bridgeport, CT. Based on tide gauge data collected at that station between 1964 and 2014, MSL has been increasing at a rate of 2.87 millimeters (0.11 inches) per year, which is equivalent to a rise of 0.94 feet over 100 years (see Figure 1 below). Another station in New London, CT, has measured an increase of 2.58 mm/yr, or 0.85 feet-per-100-years, based on measurements since 1938.

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:

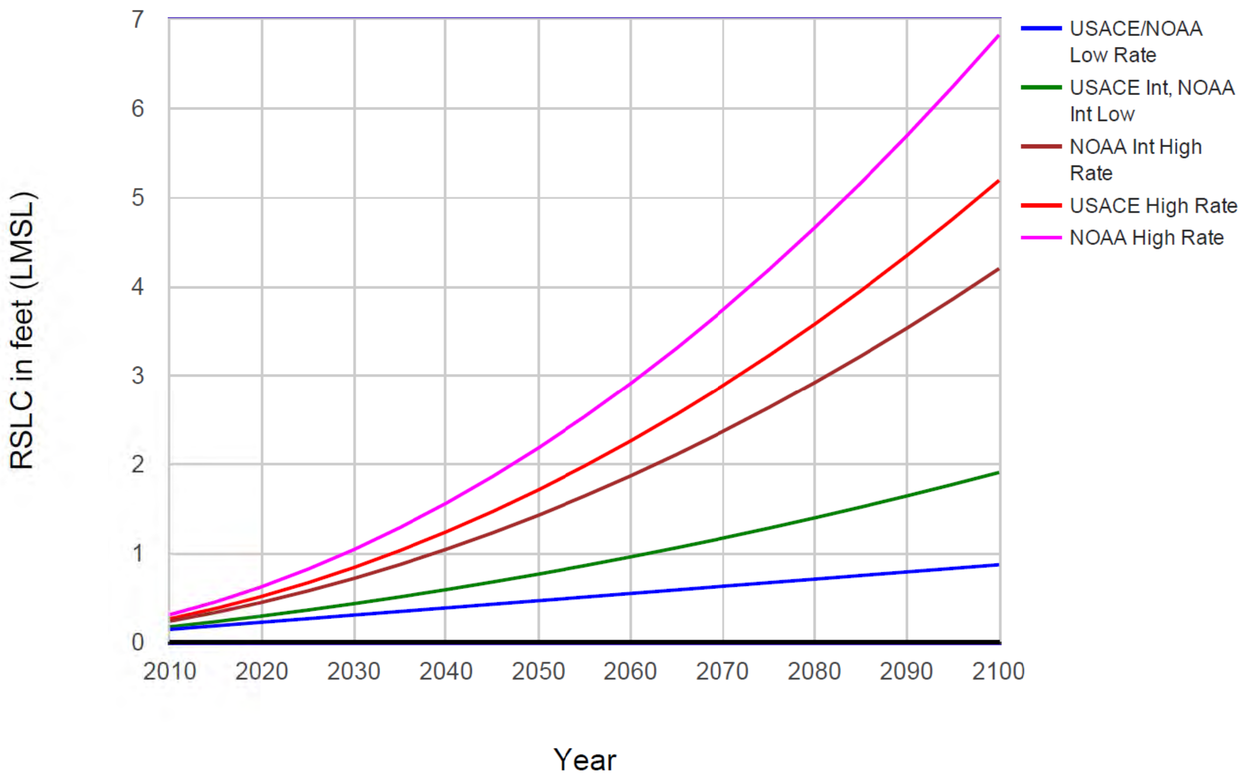
- *NOAA Low and USACE Low*: This curve uses the historic rate of sea-level change as the rate of change moving forward.
- *NOAA Intermediate Low and USACE Intermediate*: This curve projects future sea level rise based only on ocean warming and the local rate of vertical land movement. Ocean warming leads 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 8467150, Bridgeport, CT NOAA's Regional Rate: 0.00807 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	0.24	0.27	0.31
2015	0.19	0.23	0.34	0.38	0.46
2020	0.23	0.30	0.45	0.52	0.63
2025	0.27	0.36	0.58	0.67	0.82
2030	0.31	0.44	0.72	0.84	1.04
2035	0.35	0.51	0.88	1.03	1.29
2040	0.39	0.59	1.05	1.24	1.56
2045	0.43	0.68	1.23	1.47	1.86
2050	0.47	0.77	1.43	1.72	2.19
2055	0.51	0.86	1.64	1.98	2.54
2060	0.55	0.96	1.87	2.26	2.91
2065	0.59	1.06	2.11	2.57	3.31
2070	0.63	1.17	2.37	2.89	3.74
2075	0.67	1.28	2.64	3.22	4.19
2080	0.71	1.40	2.92	3.58	4.67
2085	0.75	1.52	3.22	3.96	5.17
2090	0.79	1.65	3.54	4.35	5.70
2095	0.83	1.78	3.86	4.76	6.25
2100	0.87	1.91	4.21	5.20	6.83

Figure 2

Relative Sea Level Change Projections
Gauge 8467150, Bridgeport, 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 Branford.

2.3.2 Sea Level Rise Viewer Tools

Several sea level rise viewer tools are available for assessing future sea levels in the Branford 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 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 Branford 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.

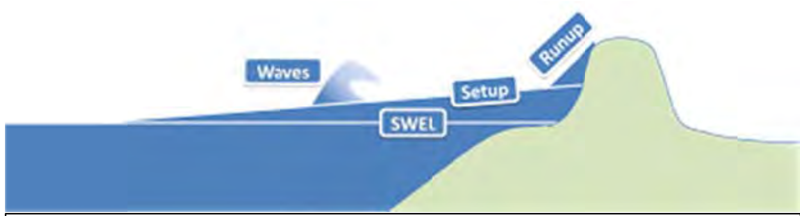


Figure 3:
Conceptual representation of stillwater elevation (SWEL), wave setup, and wave runup.

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.

Coastal Hazard Analysis Modeling Program

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 Branford, 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.

[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 Branford remain static, risks will increase.

Therefore, Branford 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.

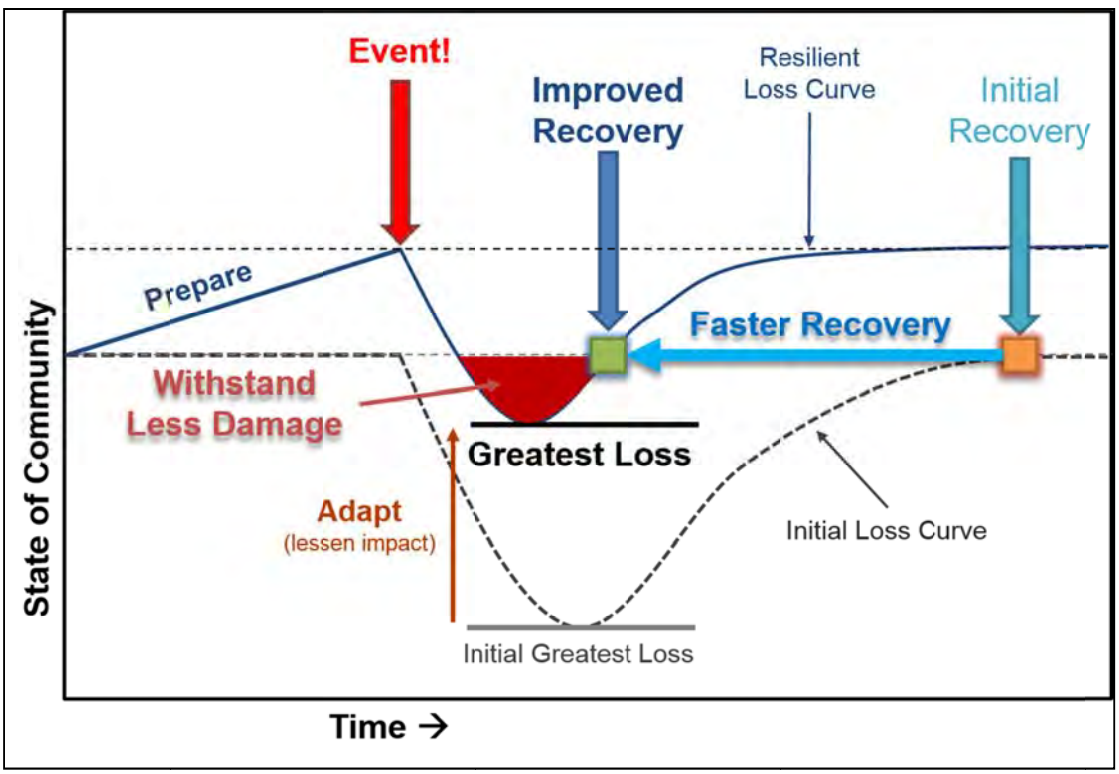


Figure 4 – Resilience Loss Recovery Curve, based on CARRI, 2011.

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 Branford 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 Branford 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 Branford 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

Branford 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 Branford are not limited to residents. Social vulnerabilities can be found among the business community. Many people who do not live in Branford are employed in town or own a business in town. As such, they have significant fiscal or emotional investment in Branford. 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 Branford 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 Branford. 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.

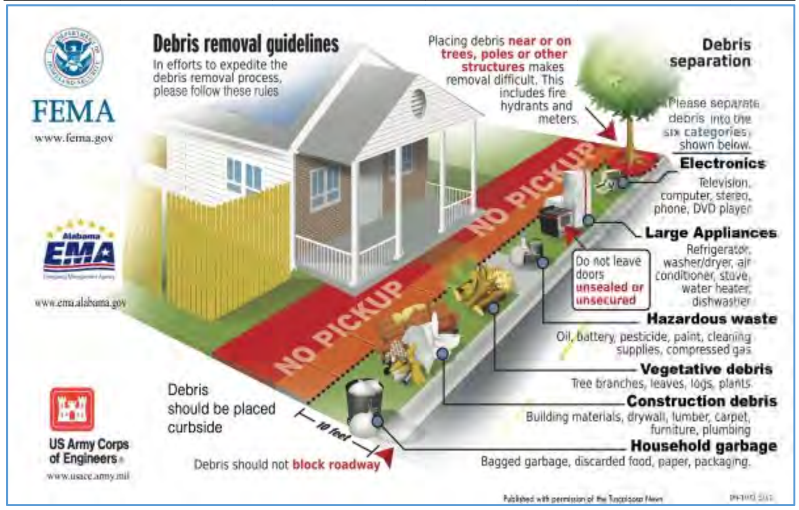
4.1.2 Economic

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.

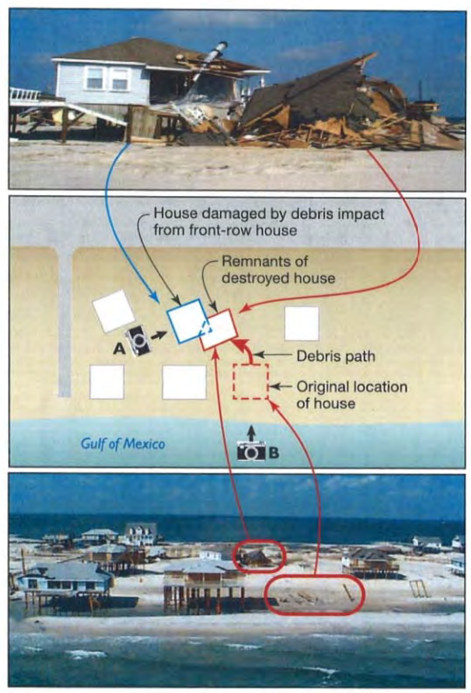
Figure 5



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.

Figure 6



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.

Branford'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 Double Beach, Indian Neck, and Hotchkiss Grove, 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 Sunset Beach, Waverly Park Road, and Pine Orchard, 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.

The Branford Plan of Conservation and Development lists the Short Beach, Branford Center, Indian Neck at South Montowese Street, Hotchkiss Grove, and Stony Creek Beach neighborhoods as among the Town's high-density residential areas. Branford Center and Stony Creek Beach are listed as "nodes." These neighborhoods are all at risk for future flooding, and further development in 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.

Important commercial nodes in the coastal areas of Branford include the Town Center and the Stony Creek Beach neighborhood, as highlighted in the City's 2008 Plan of Conservation and Development (POCD). Both of these areas 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 Branford. 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 Branford include Kelsey's Boatyard, the Yale Corinthian Yacht Club, and Branford Point Marina. The Yacht Club is considered a business in this report because it employs people. 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. Branford does not consider any of its water-dependent businesses to be critical facilities. Though few in numbers, 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 Branford, 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 Branford. 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

There are three State roads in Branford that are vulnerable to future sea level-rise and flooding:

- Route 1 / Main Street
- Route 142
- Route 146

Town Roads and Bridges

Some of the most significant town roads vulnerable under a range of future scenarios include:

- Clark Avenue
- Johnsons Point Road
- Harbor Street
- Maple Street
- Linden Avenue
- Pine Orchard Road
- Totoket Road
- Thimble Island Road
- Tabor Drive
- Pleasant Point Road

Small bridges and culverts are located at many locations.

Railroads

In general, the railroad line through Branford 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 west of Pleasant Point Road at the intersection of the Amtrak and Ballard Terminal Railroad Company. 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.

Milford already experiences problems with inadequate storm drainage, with issues occurring commonly at Village Green Court (near the High School). 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.

The state of tide gates throughout Branford is of particular concern to local residents and Town officials. Specific gates of concern include those at the following locations:

- Sybil Creek at the South Montowese Street / State Route 146 crossing
- Jarvis Creek at the State Route 146 crossing

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 supply in Branford is supplied by the South Central Connecticut Regional Water Authority (SCCRWA). 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.

Approximately 8,300 customers in Branford were on the public water supply system in 2004.

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)

Only 15% of Branford households rely on subsurface sewage disposal systems (septic systems) for sanitary wastewater treatment. Any of these systems that exist near the coast 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.
- The eastern part of Town south of route 95 does not receive public sewer service for the most part, and residents utilize septic systems. The neighborhoods around Thimble Island

Road and Stony Creek are the most densely populated in this area, as well as the most vulnerable to coastal hazards.

Public Wastewater Management

The Town of Branford is served by a single Water Pollution Control Facility (WPCF) located on Block Island Road. Sections of this facility currently lie within the FEMA Special Flood Hazard Area (SFHA) zone AE, and so are currently vulnerable to the 1% annual-chance flood event. Sea level rise is projected to increase daily high tide elevations in this area, leading to minor sections of the WPCF being vulnerable to high tide by the 2050s and 2080s.

A significant vulnerability to Branford's wastewater system lies within its wastewater pumping stations. Many of these pumping stations lie at low elevations, and risk failure during future high tides or storm events. Table 3 summarizes the vulnerabilities of Branford's coastal pumping stations. The column titled "SFHA" indicates which FEMA-designated Special Flood Hazard Area each station falls within, if any. The other columns indicate the degree of confidence given by TNC's Coastal Resiliency Mapping Tool that each station will be inundated under future conditions (Daily, Category 2 Storm event ("Cat 2"), Category 3 Storm event ("Cat 3"). The "medium" projection was used for this table. Cells are color-coded for emphasis.

Table 3

Pump Station Location	Likelihood of Flooding											
	Present Day			2020s			2050s			2080s		
	FEMA	Cat 2	Cat 3	Daily	Cat 2	Cat 3	Daily	Cat 2	Cat 3	Daily	Cat 2	Cat 3
Branford Point	AE	Med	High	No	Med	High	No	Med	High	Low	Med	High
Beckett Ave	No	Med	High	No	Med	High	No	High	High	Low	High	High
Blocks	AE	Med	High	No	High	High	Low	High	High	Low	High	High
Bradley Ave	AE	Med	High	Low	Med	High	Low	High	High	Low	High	High
Burban	No	No	Low	No	No	Med	No	No	Med	No	No	Med
Clark Ave	AE	Low	Med	No	Med	High	Low	Med	High	Low	High	High
Farm River	AE	Low	Med	No	Low	High	No	Med	High	No	Med	High
Damascus	AE	Low	Med	No	Med	High	No	Low	High	No	Med	High
Dominican	No	Low	Low	No	Low	Low	No	Low	Low	No	Low	Med
Frank St	AE	Low	High	No	Med	High	No	Med	High	No	Med	High
Harbor St	AE	High	High	Low	High	High	Med	High	High	Med	High	High
Johnsons Point	AE	Med	High	No	Med	High	Low	High	High	Low	High	High
Lanphier Season	VE	Low	High	Low	Med	High	Low	High	High	Med	High	High
Lanphier Cove	No	No	Low	No	No	Low	No	No	Low	No	No	Med
Linden Shores	No	No	Low	No	No	Low	No	No	Low	No	No	Med
Little Bay Lane	AE	Med	High	No	Med	High	No	High	High	Low	High	High
Maltby	AE	Low	High	No	Med	High	Low	High	High	Low	High	High
Central	AE	High	High	No	High	High	Low	High	High	Low	High	High
Pages	AE	High	High	Low	High	High	Med	High	High	Med	High	High
Pawson Rd	No	No	Low	No	No	Low	No	No	Med	No	No	Med
Pine Orchard	AE	High	High	Low	High	High	Low	High	High	Med	High	High
Riverside Dr	AE	Med	High	Low	High	High	Low	High	High	Low	High	High
River Rd	AE	Low	High	Low	Med	High	Low	Med	High	Low	High	High
So Montowese	AE	Low	High	No	Low	High	No	Med	High	No	Med	High
Summer Island	AE	Med	High	No	Med	High	No	Med	High	No	High	High
Sunrise Cove	No	No	Low	No	No	Med	No	Low	Med	No	Low	Med
Sybil	AE	Med	High	Low	Med	High	Low	High	High	Med	High	High
Hotchkiss Grove	AE	High	High	No	High	High	Low	High	High	Low	High	High
Tidelands	X500	Low	Med	No	Low	High	No	Med	High	No	Med	High
WWTP (Inter)	AE	No	Med	No	No	Med	No	Low	Med	No	Low	Med
Greenview	X500	Low	Med	No	Low	Med	No	Med	Med	No	Med	High

The following is a list of the locations of Branford's most vulnerable pumping stations:

- Branford Point
- Beckett Avenue
- Blocks
- Burban Drive
- Frank Street
- Harbor Street
- Johnsons Point
- Linden Shores
- Little Bay Lane
- Maltby Street
- Central
- Pawson Road
- Pine Orchard
- Riverside Drive
- South Montowese Street
- Sunrise Cove
- Sybil Creek

Electricity

The greatest threats to the electrical grid associated with increased coastal hazards are wind-related. These are not directly addressed in this report. However, 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.

In addition, it is 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, and Emergency Healthcare Facilities

Branford's emergency services are found in the following locations, and have the following vulnerabilities:

- Fire Stations:
  - Short Beach Fire Company 4 is located at the intersection of Shore Drive and Clark Avenue. This station is vulnerable to category 3 hurricane flooding.
  - Branford Fire Department Headquarters is on North Main Street / Route 1 near Branford Center. It is not vulnerable to coastal flooding.
  - The M.P. Rice House Company Number 2 is on Main Street near the intersection with Lincoln Ave and Bradley Street, near the town center. It is not vulnerable to coastal flooding.
  - Indian Neck Pine Orchard Company 9 is at Linden Avenue and Route 146 near Sybil Creek. It will be vulnerable to projected 2050s daily high tide flooding. It was damaged during Irene.
  - The fire house on Pine Orchard Road across from Hotchkiss Grove Road is not vulnerable to coastal flooding.
  - The fire house located in the same building as the Stony Creek Museum at the intersection of Thimble Island Road and School Street is not vulnerable to coastal flooding.
- Police Station:
  - The Branford Police Department is near the center of town on Laurel Street. It is not vulnerable to coastal flooding.
- Healthcare:
  - The Connecticut Hospice is right on the water at Double Beach Road and Johnsons Point Road. It is not vulnerable to inundation, based on the Coastal Resilience tool.

Shelters

Emergency shelters are considered to be an important subset of critical facilities as they are needed in emergency situations. City officials have designated five community shelters, which have the following vulnerabilities:

- Primary Shelter – Mary T. Murphy School, 14 Brushy Plain Rd. This shelter is not vulnerable to coastal flooding.

- Alternate Shelter – Branford Recreation Center, 46 Church St. This shelter is vulnerable to 2050s daily flooding.
- Alternate Shelter – John B. Sliney School, 23 Eades St. This shelter is not vulnerable to coastal flooding.
- Alternate Shelter – Walsh Intermediate School, 185 Damascus Rd. This shelter is not vulnerable to coastal flooding.
- Alternate Shelter – Branford High School, 185 East Main St. This shelter may be vulnerable to Category 3 storm flooding.

<u>Access and Evacuation Routes</u>

The Indian Neck/Pine Orchard fire company is the only emergency response facility that is significantly vulnerable to coastal flooding. The Connecticut Hospice is vulnerable to coastal storm related hazards such as high winds and debris, though not to inundation. The Branford Recreation Center is the only emergency shelter that is significantly vulnerable to coastal flooding.

Other than these sites, the vulnerabilities of Branford'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 Paynes Point and Horton Point, Johnson Point, Branford Point, Indian Neck, the area west of South Montowese Street, Pine Orchard, Pleasant Point, and the southern end of Thimble Island Road. Additionally, eastward evacuation may be hindered by flooding of Route 146, and east-west transit may be hindered by flooding of roads along Branford River, including Route 1. 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

<u>Tidal Wetlands</u>

Branford'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 Branford include the Beacon Hill Preserve, the East Haven Marsh Wildlife Area, the Pawson Park Marsh Wildlife Area, the Pine Orchard Marsh

Wildlife Area, the Washburn Preserve, and the Reed Preserve. Numerous other pockets of marshes are found throughout the city.

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 (for example, 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 Branford 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. Branford 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. Branford'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 Embayment 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.

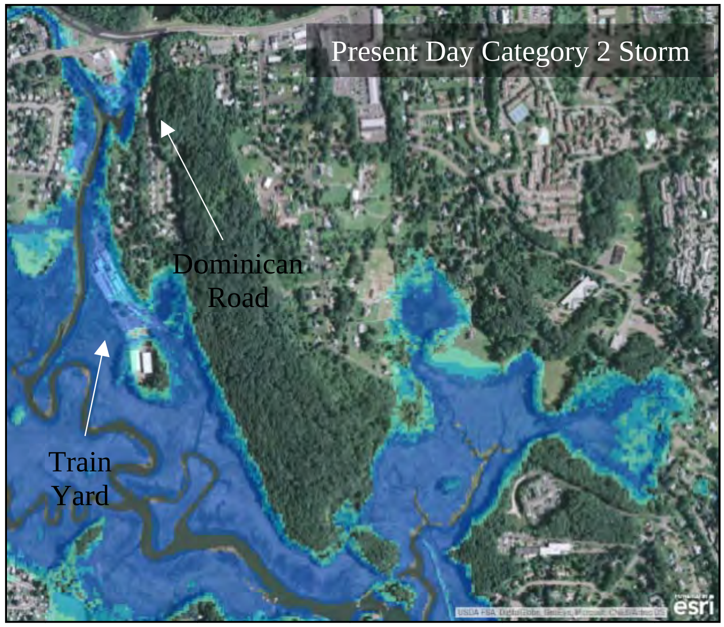
4.2 Vulnerabilities by Region

During meetings with Branford officials, a number of specific areas of interest were pointed out. The peninsula of Indian Neck risks being isolated from flooding of or damage to the vulnerable roads of Linden Avenue, Limewood Avenue, and South Montowese Street where it crosses Sybil Creek. Other neighborhoods that also regularly experiences problems are Pawson Park and Sunset Beach. A FEMA HMGP application related to Linden Avenue is moving forward. Many low-lying areas around Indian Neck also suffer from regular flooding, including other neighborhoods around Sybil Creek, such as Hotchkiss Grove. Beckett Avenue in the Short Beach neighborhood experienced significant flooding during Irene, and Hammer Field north of Meadow Street experiences regular flooding. Other problem areas include Pleasant Point Road and Totoket Road in the Pine Orchard area, and Village Green Court and neighboring roads, which suffer from flooding of Branford River.

These and other specific areas – Short Beach, Killams Point and Johnsons Point, the inland Branford River, Indian Neck, Pine Orchard/Pleasant Point, and the Hoadley Neck wetland area – are explored in further detail in this section.

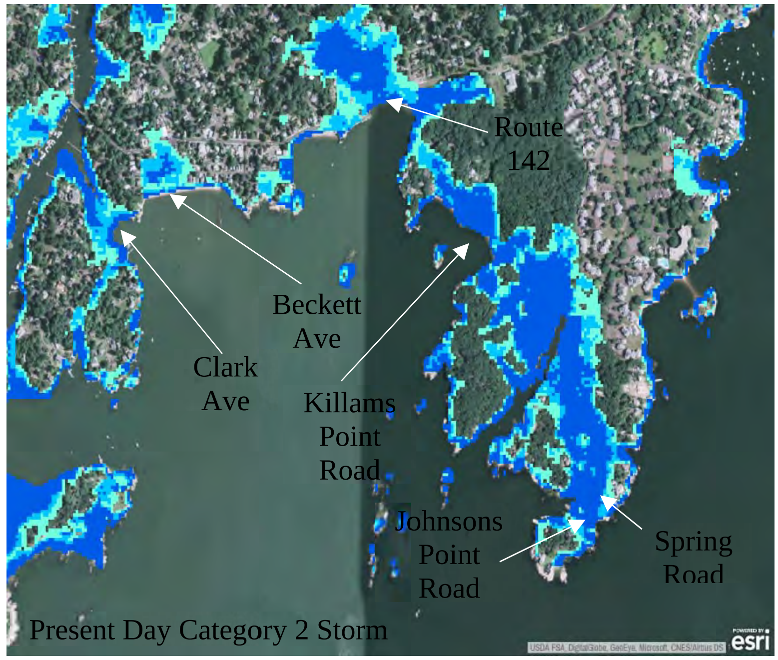
Beacon Hill Preserve Area

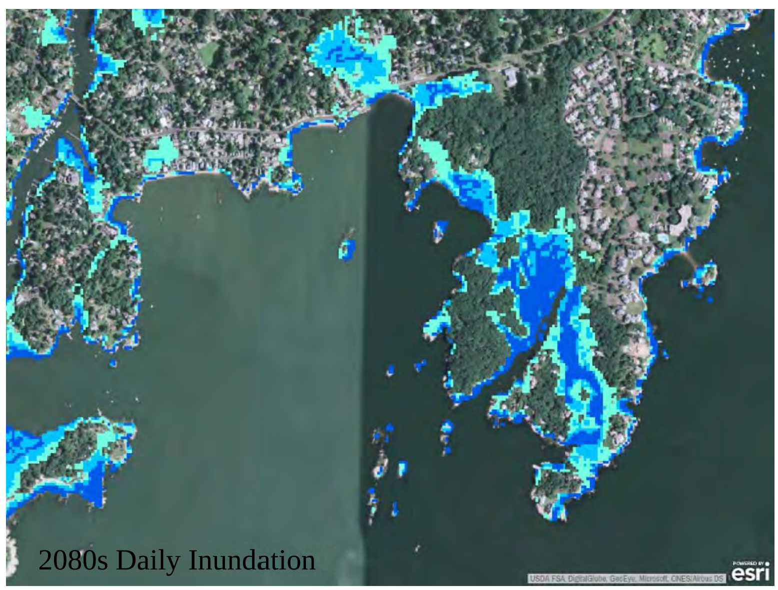
The western side of Branford is bordered by Lake Saltonstall and the Farm River. Farm River is mostly surrounded by undeveloped marsh and preserves, including the Beacon Hill Preserve and the East Haven Wildlife Area. Nevertheless, a low-lying train yard, part of "The Shore Line Trolley Museum," is at risk of inundation today during a Category 2 Hurricane. By the 2020s, that site will risk partial inundation, and by the 2080s complete inundation, during daily high tide. Additionally, one house on the west side of Dominican Road may experience daily inundation by the 2080s or inundation during category 2 hurricanes by the 2050s.



Hurricane Irene Flooding
Image: Shore Line Trolley Museum

Granite Bay Area





The Farm River flows into the West side of Granite Bay. This area, similar to much of the rest of Branford, is defined by a high, rocky coastline interspersed with lower-elevation beaches and lowlands. The Paynes point and Horton Point peninsula on the western edge of the bay is medium-density residential with a couple of commercial properties. Most of the neighborhood is protected from coastal hazards due to the rocky coastline. Homes behind Clark Avenue Beach are more vulnerable to flooding from both Long Island Sound and Farm River. Such an event would also isolate Horton Point and Paynes Point.

Beckett Avenue experienced significant flooding during Hurricane Irene, and along with the parallel, farther inland street Shore Drive, continues to be a low elevation, vulnerable location.

State Route 142 near Glen Street is also at risk of inundation, and is an important through-way. Homes inland of the road abut a wetland, and are also vulnerable.

Properties along Killams Point Road on the west side of the bay are generally not vulnerable to inundation, though those directly along the water's edge may be susceptible to wave runup and overwash damage. The road itself, however, is vulnerable to both flooding from high waters and undermining from erosion. Either would isolate a number of properties, as well as the Killams Point Conference Center.

A similar situation exists with Johnsons Point Road and Spring Road. The southern tip of the Killams Point/Double Beach Peninsula is most vulnerable to isolation from inundated roads, but is also susceptible to flooding of homes and property. By the 2020s, multiple locations of daily inundation are projected, making travel difficult. By the 2080s, much of Johnsons Point Road will be flooded during high tides, and the entire neighborhood will be isolated.

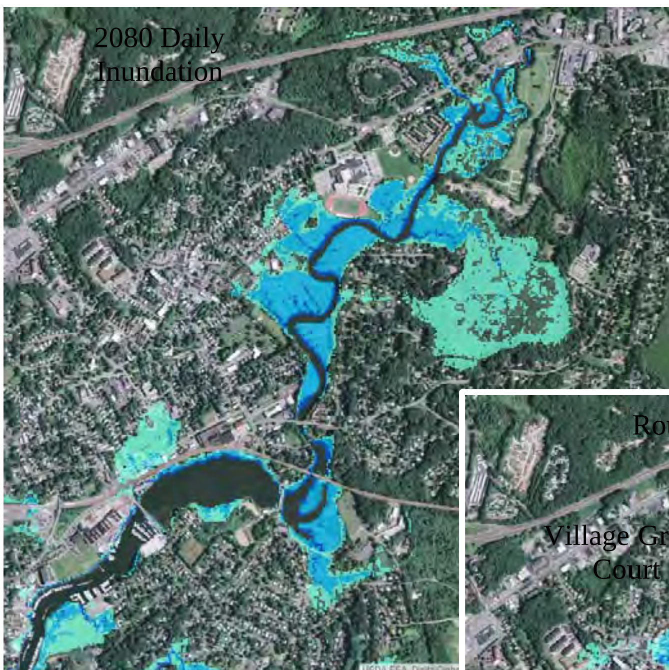
The TNC model projects that a present-day category 2 storm event would flood and damage all of the roads listed above. By the 2080s, the daily high-tide will have a similar scope of damage, flooding Clark Avenue, Beckett Avenue, Route 142, Killams Point Road, Johnsons Point Road, and Spring Road.

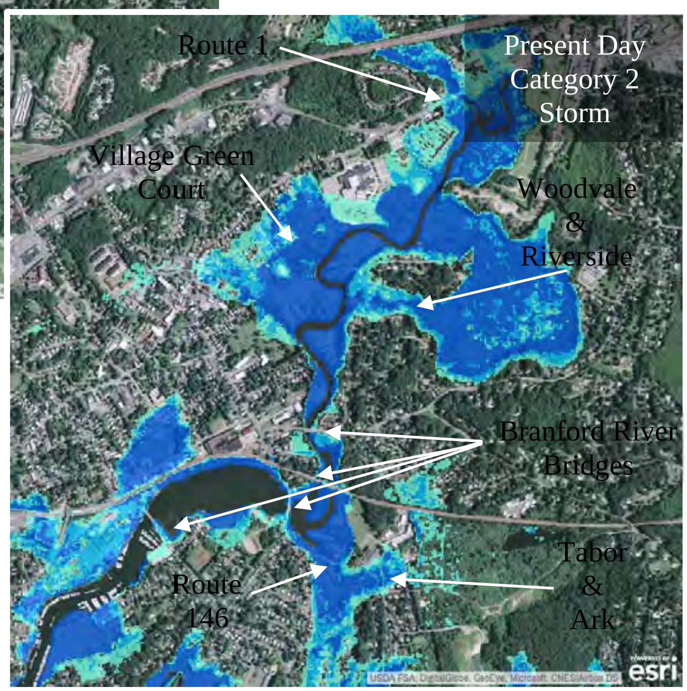
Double Beach

The relatively densely developed section of Town that extends from Lindsey Cove and the Harbour Village Condominiums south past Lanphier Cove and The Connecticut Hospice to Johnson Point is generally not susceptible to inundation from high waters alone. Erosion of unprotected slopes is an issue, however, as well as wave damage to structures. Erosion is particularly problematic in Lanphiers Cove, and Sunset Cove to the south is also vulnerable.

Inland Branford River and Branford Center

The area south of Interstate 95 around the Branford River is vulnerable to sea-level rise despite not being located directly on the shore of Long Island Sound. Vulnerable areas in this part of town include State Route 1 where it crosses Pisgah brook, Montowese Street (State Route 146) and Harbor Street where they cross Branford River, and Hammer Field on the North side of Meadow Street. These sites are expected to experience flooding during the daily high tide by the 2020s. Additionally, a present-day category 2 hurricane event would impact the following areas: Riverside Drive and Woodvale Road, isolating that neighborhood; Hamre Lane, Aceto Street, and Village Green Court, a neighborhood that already produces regular complaints of drainage issues; Indian Neck Avenue where it crosses Branford River; Tabor Drive and Ark Road, isolating neighborhoods; and increased flooding of the roads listed previously. The TNC model shows increased likelihood and extent of flooding to these areas over the next 75 years during storm events. By the 2080s the daily high tide will impact many of the same roads that are impacted during a present day category 2 storm, though to a lesser extent.





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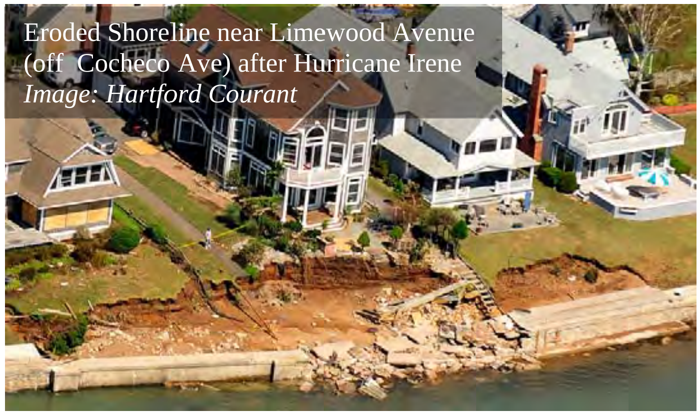
Indian Neck and Sybil Creek

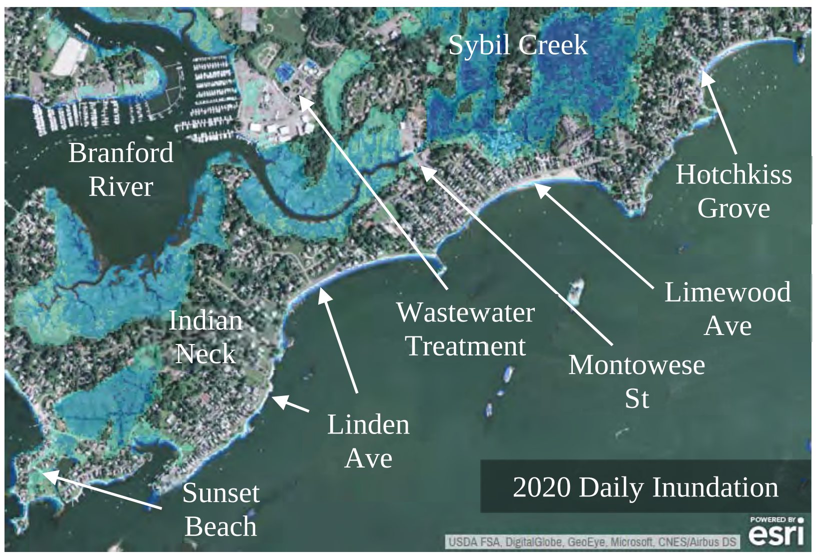
Indian Neck is a peninsula on the east side of the mouth of the Branford River. Sybil Creek flows west under route 146 into the Branford River on the North Side of Indian Neck. Thus, this area is susceptible to flooding from Branford River, Sybil Creek, and Long Island Sound. This has led to a high number of flood-damage incidents in the past, with a key risk being the loss of all roads to and from the peninsula, isolating residents. Additionally, the Branford Wastewater Treatment Plant sits across from Indian Neck at the confluence of Sybil Creek and the Branford River.



Eroded Shoreline near Limewood Avenue (off Cocheco Ave) after Hurricane Irene
Image: Hartford Courant

Beyond inundation risks, erosion poses a threat to this area. Particularly vulnerable are Linden Avenue and Limewood Avenue, both of which are placed immediately adjacent to the water's edge. Both roads are protected by revetments that have to be regularly maintained.

The TNC model predicts that by the 2020s, daily inundation will threaten some sections of the Wastewater Treatment Plant, the Sunset Beach area and Bayberry Lane (on the west side of Indian Neck), and neighborhoods on the southern bank of Sybil Creek. Additionally, high-tide will come close to Linden and Limewood Avenues (important throughways) and may overtop South Montowese Street where it crosses Sybil Creek. Waverly Park Road, which crosses Sybil Creek to the east of South Montowese, is also projected to be inundated regularly by the 2020s, cutting-off the only access to a neighborhood. By the 2080s, high tide will inundate the entire Sunset Beach area, large swaths of property bordering Sybil Creek, South Montowese Street and Waverly Park Road at Sybil Creek, and 4th and 5th streets in the Hotchkiss Grove neighborhood to the east of the Neck. Sections of Linden and Limewood Avenues will also likely be underwater daily. Loss of passage by South Montowese, Linden, and Limewood, will isolate some neighborhoods completely and significantly increase transit times to others. Daily inundation at the Wastewater Treatment Plant will remain near the same level as in the 2020s.



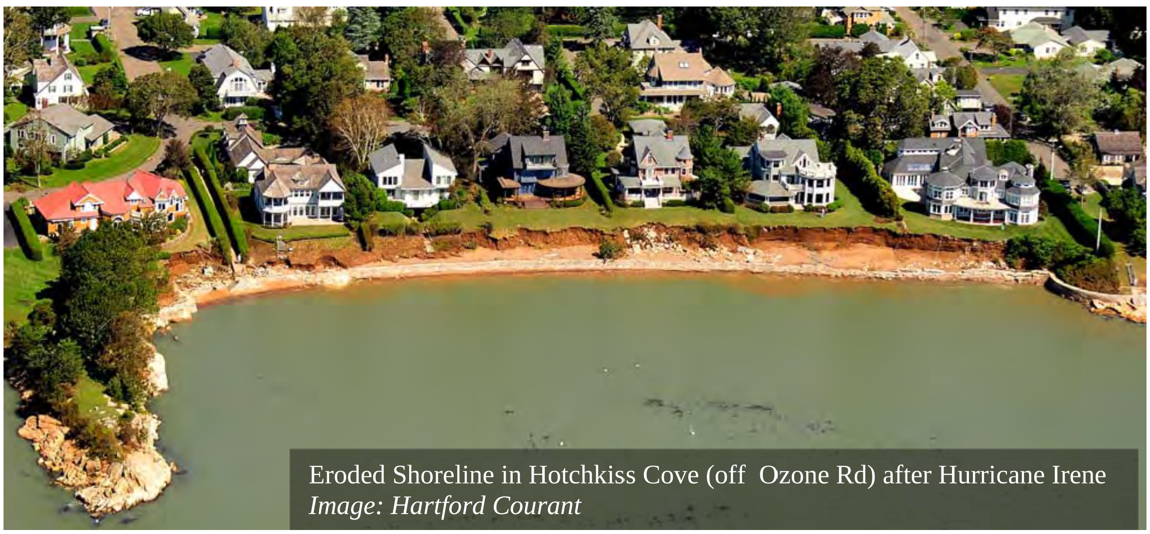
By the 2050s, a category 2 hurricane will flood Linden Avenue, Limewood Avenue, and South Montowese Street in multiple locations. Under this scenario State Route 146 and Indian Neck Ave will also be flooded where they cross Branford River farther north. The combined effects of this loss of road passage will be the total isolation from the rest of the Town of the area around Foote Memorial Park as well as Indian Neck. Additionally, inundation of roads along Long Island Sound, Branford River, and Sybil Creek, will be widespread. The Wastewater Treatment Plant will also see significant flooding, although not significantly worse than would be expected during a present-day category 2 storm.

Note in the image above that a large storm may inundate this area in such a way that the Branford River will effectively overtop its banks and flow directly south along South Montowese Street and over Limewood Beach into Long Island Sound.

Hotchkiss Grove to Pine Orchard

Hotchkiss Grove is briefly mentioned in the previous section in the context of inundation vulnerability. Specifically, the homes between 2nd and 6th Avenues are vulnerable to storm surge flooding, and are projected to be vulnerable to daily high tide flooding by the 2080s. Additionally, the narrowness of the strip of developed land between Hotchkiss Cove to the east and Sybil Creek to the west raises concerns about evacuation routes and possible isolation.

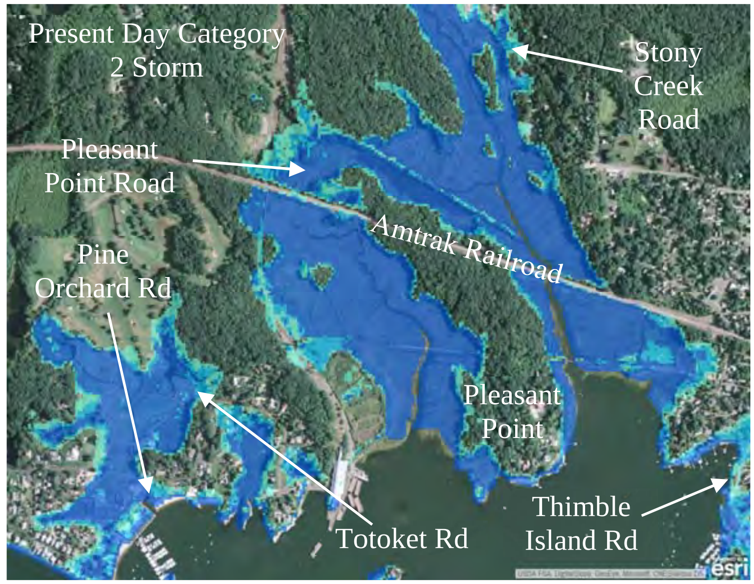
A significant concern east of this area toward Pine Orchard is the vulnerability of higher-elevation waterfront properties to erosion. Properties from 1st Avenue eastward to Brown Point are particularly susceptible to this risk. The image below shows erosion caused by Hurricane Irene in 2011.

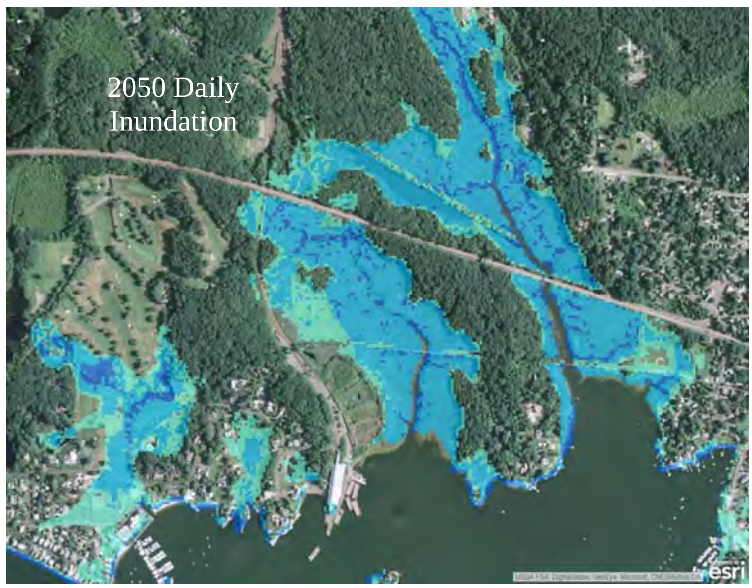


Eroded Shoreline in Hotchkiss Cove (off Ozone Rd) after Hurricane Irene
Image: Hartford Courant

Pine Orchard to Stony Creek

The Pine Orchard and Stony Creek neighborhoods sandwich the Pine Orchard Marsh Wildlife area, the small neighborhood of Pleasant Point at the southern tip of a peninsula, and Stony Creek itself. The area is commonly subject to flood events. Low-lying neighborhoods on the south-western edge of the Pine Orchard Golf Course, as well as Pine Orchard Road, are expected to have daily inundation problems by the 2020s, or the 2050s at the latest. Currently that area is vulnerable to category 2 storm swells.



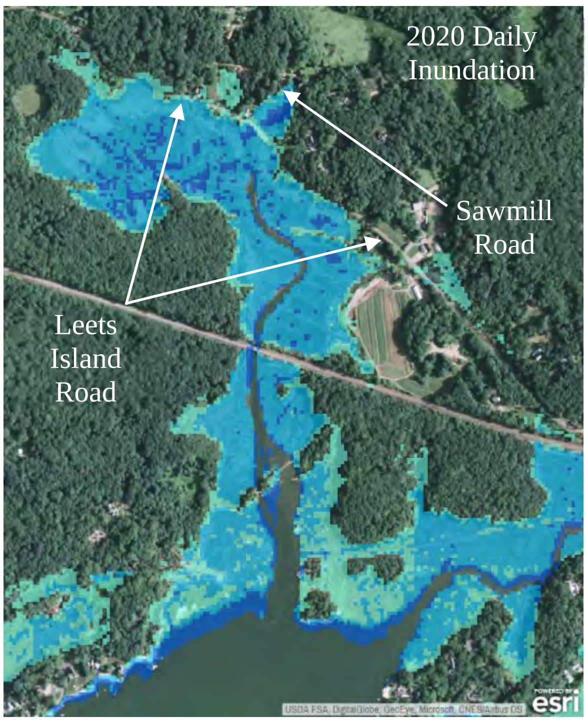


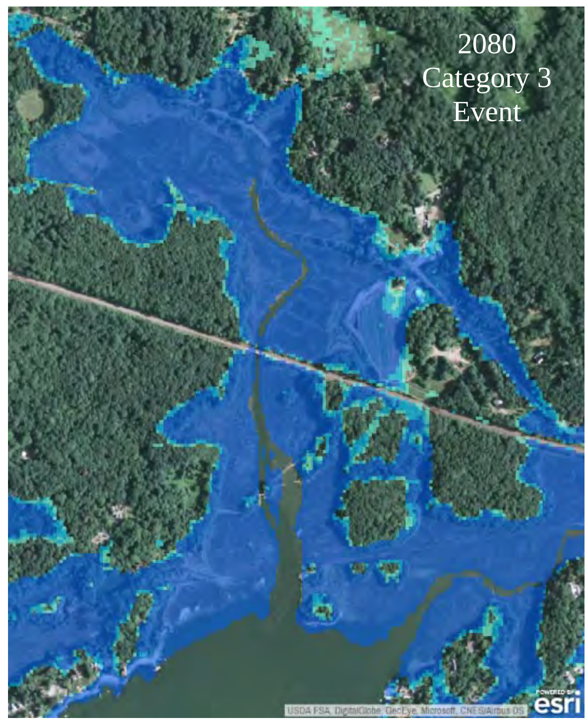
Totoket Road also experiences flooding during present-day large storm events, but likely will be flooded during daily high tides by the 2080s, cutting of the eastern Pine Orchard neighborhood. Pleasant Point road, the only road to the Pleasant Point neighborhood, may be flooded daily as soon as the 2020s.

Stony Creek Road is currently flooded during large storm events, and may be flooded daily by the 2080s. Thimble Island Road risks daily flooding by the 2050s, isolating neighborhoods to the south. Already, residents have noted increasing frequency of this road flooding. The Amtrak Rail that passes through this area is also at risk of daily flooding by the 2020s, with increased risk in multiple locations by the 2050s.

Hoadley Neck

The eastern edge of Branford is very sparsely populated, with a large amount of forested landscape and wetland, as well as some agriculture. Therefore, vulnerabilities here are low. Nevertheless, Leets Island Road (State Route 146), which connects Branford to neighboring Guilford, is vulnerable. By the 2020s it can be expected to be flooded during daily high-tide, although Sawmill Road would still be passable, and the east-west route still traversable overall. By the 2050s, multiple locations on Leets Island Road, as well as a portion of Sawmill Road, will see daily flooding, isolating Branford from Guilford. This extent of flooding is already seen in a present-day category 2 storm event. By the 2080s, during a category 3 hurricane, Leets Island Road would be completely inundated in this area, as well as much of Sawmill Road. This area already experiences flooding issues, which may be related to a poorly-functioning tide gate.





4.3 Wave Set-up and Run-up Hazards

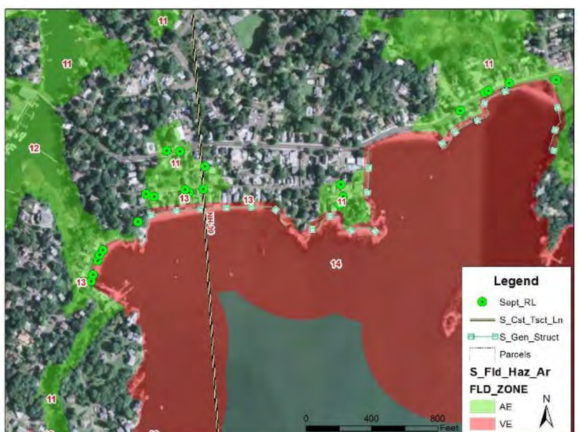
Recall that wave setup and runup can increase the height of floodwater above the "stillwater" elevation, and that the extent of those effects are related to the topography of the coastline at a particular location. The TNC Coastal Resilience Mapping Portal is not able to capture these details, so further 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 seven FEMA topographical transects along the Branford coastline that are at or near locations with significant concerns about coastal hazards. These are located at Short Beach (Beckett Avenue), Lanphiers Cove, Summer Island Point (including Sunset Beach Road), Montgomery Parkway (across Linden Avenue), Hotchkiss Grove, and Thimble Island Road. 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.

Short Beach (FEMA transect NH-30)

This transect shows a frontal seawall or bulkhead rising to about 8.0 feet elevation (NAVD88), followed by a decrease in height. The bowl-like shape of the neighborhood, which is also reflected in the FEMA Special Flood Hazard Area (SFHA) map and the TNC maps in the previous section, is clearly visible here. The minimum land surface elevation is 6.9 feet. Both the FEMA and the USACE models show this surface being overtopped by a 2% annual-chance storm, and the USACE model shows that a 10% annual-chance storm may overtop the bulkhead as well. In a 1% annual-chance flood events, inundation extends far inland, and wave heights near the shore will be very high.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Hazard Analysis Program	6.6	8.2	8.9	11.3	11.2
USACE Advanced Circulation Model (all values include wave setup)	7.9	9.7		10.8	13.9

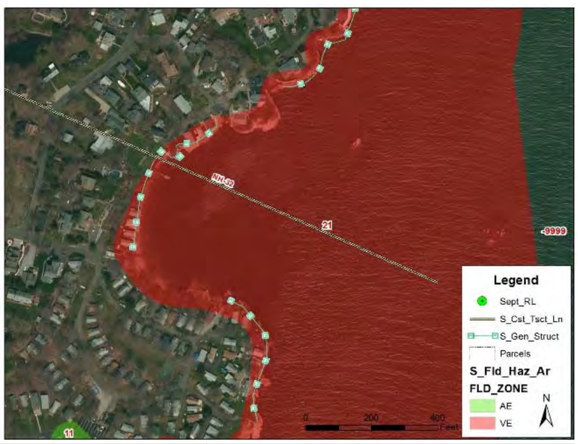


Short Beach FEMA transect and DFIRM

Lanphiers Cove (FEMA transect NH-32)

This area has a FEMA velocity (VE) zone mapped right up to the land edge. The steepness and height of the coastal bank is visible in the transect. Neither the FEMA nor the USACE calculated total water level figures show 1% annual-chance floodwaters overtopping the 17.9 foot elevation (NAVD88) bank, however wave runup modeling predicts water can get as high as 20.9 feet elevation. This runup elevation dominates over wave heights due to the steeply sloped bluff. It is important to note that there are homes constructed in front of the steep slope at lower elevations. These are at high risk.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Hazard Analysis Program	6.6	8.2	9.0	10.7	11.2
USACE Advanced Circulation Model (all values include wave setup)	7.9	9.7		10.8	13.9

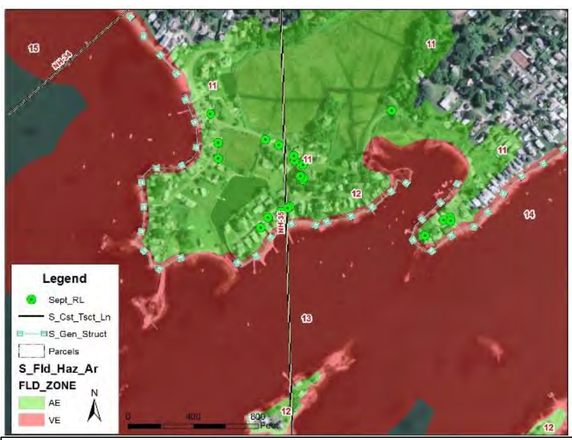


Lanphiers Cove FEMA transect and DFIRM

Summer Island Point (FEMA transect NH-35)

This transect passes over Clam Island (which has six houses on it) a small stretch of open water, Summer Island Point Road, Sunset Beach Road, and the tidal wetland, before reaching the higher ground elevations of Sunset Manor Road. The ground profile of Clam Island reaches 9.3 feet elevation (NAVD88), which is above the base flood elevation of 9.0 ft. The rest of the ground profile is below the base flood stillwater elevation. Wave setup and runup increase the flood risk, especially by elevating the water surface above the ground surface at Clam Island. Wave action remains high across the transect. All of Summer Island Road and Sunset Beach Road are within a FEMA mapped AE zone, with the surrounding VE zone extending slightly inland of the mapped protective structures. Direct damage from inundation, as well as from wave action during inundation events, are important hazards at this site.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Hazard Analysis Program	6.6	8.2	9.0	11.0	11.4
USACE Advanced Circulation Model (all values include wave setup)	7.9	9.7		10.8	13.9

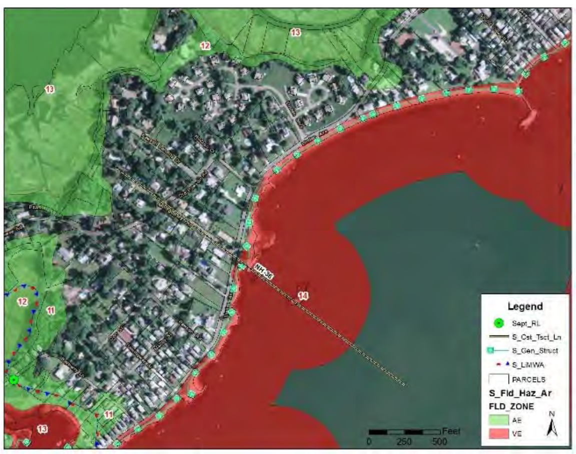


Summer Island Point FEMA transect and DFIRM

Linden Avenue (FEMA transect NH-36)

Linden Avenue is constructed directly on the shoreline here, with some sections located within the VE zone. The transect reflects the offshore bedrock outcrop of Bishop Rock before reaching a steep rocky shore and a lower grassy platform. There is a second rise, behind which is Linden Avenue. Inland of that, Montgomery Parkway rises steadily. Linden Avenue here is about 16 feet in elevation (NAVD88). The maximum modeled runup elevation is nearly 12 feet elevation, right at the toe of the slope leading to the road. This highlights the erosion risk to the road at this site.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Hazard Analysis Program	6.5	8.1	9.0	11.7	11.5
USACE Advanced Circulation Model (all values include wave setup)	7.9	9.7		10.8	13.9



Linden Avenue FEMA transect and DFIRM

Hotchkiss Grove (FEMA transect NH-37)

This area's coastline has a concave shape, with a very steeply sloped land surface at the water's edge gently curving landward to become flat at about 12.7 feet elevation. In continues to curve, with a low point of 12.3 feet elevation, before rising steadily inland. The specific site of this transect is characterized by a bedrock shoreline, which is very different than the immediately adjacent beach, which is vulnerable to inundation. This area is vulnerable to runup effects during a base flood event, as shown from the model results below.

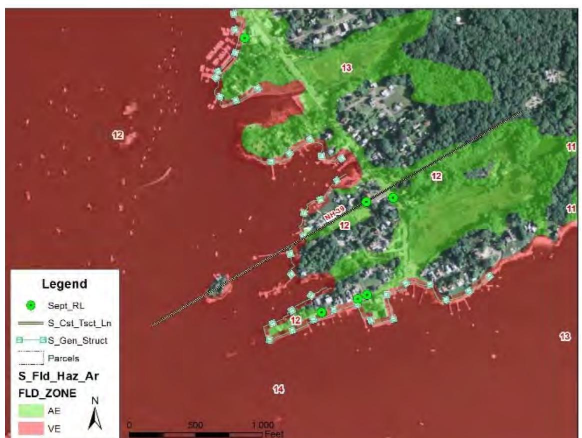
Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Hazard Analysis Program	6.5	8.1	9.0	11.9	11.7
USACE Advanced Circulation Model (all values include wave setup)	7.9	9.7		10.8	13.9

Hotchkiss Grove FEMA transect and DFIRM

Thimble Island Road (FEMA transect NH-39)

This part of Branford is characterized by narrow, high-elevation, rocky areas, interspersed by low elevation wetlands and neighborhoods. The main vulnerability here is to the low-lying roads. This transect was taken across the high-elevation Wheeler Island, a section of open water, and then a steep wall that appears to front a boat ramp. After the ramp the transect follows Long Point Road, which peaks at around 13 feet (NAVD88) before dropping back down to the lower-elevation Thimble Island Road. The NACCS total-water figure shows a 1% annual chance storm inundating only the front section of Long Point Road, while the FEMA model shows water reaching almost, but not completely, to Thimble Island Road. This modeling does not show the alternative routes water can take to reach those inland low-elevation areas.

Study	Annual-Chance Storm (elevation values in feet NAVD88)				
	10%	2%	1%	1 % with setup	0.2%
FEMA Coastal Hazard Analysis Program	6.4	8.1	9.0	11.7	12.0
USACE Advanced Circulation Model (all values include wave setup)	7.9	9.7		10.8	13.9



Thimble Island Road FEMA transect and DFIRM

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 Branford's coast. It is important to note, though, that properties constructed on high elevation, bedrock shorelines may be protected from inundation and wave-hazards, 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

Branford'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 Branford are also susceptible to wind related hazards.

Among the greatest threats to Branford's shoreline are undermining of shoreline roads, erosion of properties, isolation of areas due to flooded roads, inundation from high waters, and flooding of properties surrounding tidal wetlands. 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.

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

Appendix C
Review of Options for Coastal Resilience

COMMUNITY COASTAL RESILIENCE PLAN
TOWN OF BRANFORD, 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 combination 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 Branford 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 Branford.

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
Branford is served by the South Central Connecticut Regional Water Authority (SCCRWA) 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. Therefore, Branford's municipal water supply is not significantly vulnerable, and adaptation is not currently necessary.

Options for areas that may still rely on individual private wells are listed below but not described in detail. See the Branford Vulnerability and Risk Assessment Memo for more information about vulnerabilities of the Town's water resources.

Private Water Supply Adaptation Options

- 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
The Town of Branford is served by a single Water Pollution Control Facility (WPCF). Vulnerable aspects of the municipal wastewater system include the low-elevation WPCF itself, the sewer pumping-stations that are also often located at relatively low elevations, and sewer pipe infrastructure.

Municipal wastewater infrastructure adaptation options include:

- New Construction/ Reconstruction – municipal treatment facilities, or septic systems where relevant, should be constructed at elevations that consider sea level rise.
- Retrofits – steps to protect a facility without relocating it include, but are not limited to:
    - Construction of flood walls or berms around structures
    - Floodproofing of structures or specific components
    - Elevation of structures or specific components
    - Protection of electrical supply and systems through elevation, floodproofing, and backup generators
    - Hardening of and preventing sedimentation or backflow at facility outfall
    - Protection of access to facilities through road elevation
    - Protect records, files, and personnel
    - Enable facilities to be operated remotely
- Harden Pumping Stations – steps include, but are not limited to:
    - Elevation of station or components

- Floodproofing station without elevating
- Use of submersible pumps to allow for continued operation during flooding
- Providing standby power in case supply is cut off by flooding or storm activity
- Setting station up for rapid repair, rather than attempting to prevent all damage
- Installation of backflow prevention

Coastal properties in Branford not served by the WPCF have subsurface sewage disposal systems (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, extension of municipal service to properties not yet part of that system, or – in extreme cases – vacating properties.

Septic system adaptation options include:

- 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.
- Extension of Municipal System: this option would require considerable investment into piping and pumping infrastructure to carry wastewater from isolated areas to the Town's treatment facility. It would also require reevaluation and possibly an increase of the facility's capacity.

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 Branford'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 Branford'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 Branford 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. Branford 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

Branford 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, Branford 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 Branford

3.1 Development of Branford-Specific Options

The comprehensive list of options presented previously includes adaptation measures that may be: technically, financially, or otherwise unfeasible for Branford to implement; not relevant to Branford's particular geography, geology, and hazard profile; or socially or politically unacceptable to Branford'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 Branford's municipal leaders and residents.

During the meeting on September 11, 2015 to commence this planning process, Branford representatives discussed septic system hardening, floodproofing of the wastewater treatment plant, elevation of roads, drainage system improvement, construction of flood protection structures, and property acquisition.

A public meeting was held on November 18, 2015, in which Branford residents were invited to learn about the Coastal Resilience Plan, and discuss the Town's vulnerabilities and hazards. At this meeting, residents brought up hard shore-protection structures, hardening of the Town's power grid, protection of the Wastewater Treatment Plant and sewer pumping-stations, and maintenance of evacuation routes, as important priorities.

Based on those two meetings and the additional considerations listed previously, the following categories and subcategories of options were presented to Branford residents at the public meeting on February 23, 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
- Critical Facilities
    - Relocation
    - Establishment of Satellite Facilities
- Utility Management
    - Stormwater Drainage Improvements

- Wastewater Protection
- Water Supply Protection
- Acquisition and 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:

- Upgrade and floodproof, or relocate, sewer pumping stations
- Upgrade or properly maintain tide gates on tidal wetlands
- Improve drainage infrastructure
- Install floodgates at appropriate locations
- Extend public sewer service where necessary and feasible
- Construct alternative modes of egress where necessary and feasible

Finally, feedback from the public about resilience options was solicited through an online survey. Respondents indicated they were in strongly in favor of improving drainage systems, strengthening coastal utilities, and nourishing beaches and dunes. Residents also indicated support for elevating coastal roads, building seawalls and bulkheads, and constructing breakwaters and groins. Very few residents were against creating "Living Shorelines," but the majority expressed no opinion. The desired improvement mentioned most frequently in the survey was increased reliability of electric and communication infrastructure through a combination of strengthening and burial, and faster response times. Elevating coastal roads was also mentioned frequently.

Branford Neighborhoods

To consider adaptation options for Branford on a finer scale, the Town was divided into regions based on topographical features, hazard profiles, and existing neighborhoods. Due to the interspersion of high bedrock points, steep sandy coves, and low-elevation wetlands, the Town has been divided into a large number of small regions. These are as follows:

- Clark Avenue: medium-density residential peninsula with a couple of commercial properties. Most of the neighborhood is characterized by high rocky bluffs. Clark Avenue at Clark Avenue Beach (at the Yale Corinthian Yacht Club) is vulnerable to inundation from both the Sound in front and Farm River behind, as are the properties here. Failure of this road isolates the rest of the peninsula.
- Beckett Avenue: a small beach between bedrock outcrops, fronting residential properties. This area is densely developed, and suffers from inundation and poor drainage.
- Short Beach: between Little Bay Lane and Killams Point Road, also called Pages Cove. There are two small sections of sandy beach interspersed between bedrock shorelines, homes built on bulkheads, and revetment-protected roads. Undermining of the roads is a concern here.
- Killams Point: a single, low-lying road leads to a handful of homes and the Killams Point Conference Center. The road is vulnerable to inundation, while the homes are mostly on higher bedrock.
- Johnsons Point: The southern tip of the Killams Point/Double Beach Peninsula is made up of high bedrock bluffs connected by low lying roads. The area is most vulnerable to isolation from inundated roads, but is also susceptible to flooding of homes and property. By the

2080s, much of Johnsons Point Road will be flooded during high tides, and the entire neighborhood will be isolated.

- Double Beach: refers here to the eastern shore of the "Town Neck" extending from Lindsey Cove and the Harbour Village Condominiums south past Lanphier Cove and the Connecticut Hospice to Johnson Point. Inundation is generally not an issue, however erosion of unprotected slopes, and flooding of Sunrise Cove and Lanphier Cove homes during extreme storm events, are both risks.
- Branford Point: the inside of a large meander of the Branford River. Homes have low risk, but a number of marinas and boat launches here are vulnerable.
- Branford Center: for the purposes of this document, this name refers to the densely developed area on the northwest bank of the Branford River, including the areas south of the train tracks to Mill Creek, and north to Branford High School. Vulnerabilities come from inundation from the Branford River.
- Blackstone Acres: the residential neighborhood on the east side of the River, across from the high school. Branford River flooding can affect homes and roads.
- Indian Neck Avenue: this refers to the neighborhood on either side of Indian Neck Avenue, east of the Branford River, north of Sybil Creek, and west of Ecology Park. Significant flood events can cause inundation along the east side of Route 146. The Branford Wastewater Treatment Plant is located at the southwest corner of this area along the Branford River.
- Sybil Creek: flowing west under Waverly Park Road and South Montowese Street (Route 146), this tidal river can inundate some boundary properties and important roads.
- Pawson Park and Sunset Beach: Pawson Park is on the north side of Indian Neck and Sunset Beach is on the south. Both neighborhoods border significant wetlands, and have homes and roads vulnerable to inundation.
- Linden Avenue: this road alone connects Indian Neck to Route 146, and for much of its length is directly along the water's edge. It is vulnerable to erosion, as well as overtopping by waves.
- Limewood Avenue: also Route 146 here. Built along the shoreline, fronted in one section by beach. Vulnerable to erosion and wave action from Long Island Sound. During extreme events, can be overtopped from the north by Sybil Creek.
- Haycock Point: rocky bluffs with homes built on the shoreline, protected by seawalls.
- Hotchkiss Grove: fronted by a sandy beach, vulnerable to inundation during storm events. In an extreme scenario, Route 146 here may be affected, cutting off an important connecting road. This area includes the beach south of Ozone Road. Erosion of coastline is an issue here.
- Pine Orchard: including the hard-structure protected shoreline south of Island View Avenue, and the low-lying, inundation-prone Pine Orchard Yacht Club and Pine Orchard Road.
- Juniper Point: houses a couple residential neighborhoods, and a Tilcon Connecticut Inc. Facility. Isolation during flooding is a concern here.
- Pleasant Point: a handful of homes on high ground here are vulnerable to isolation from flooding of Pleasant Point Road
- Stony Creek: the area east of the mouth of Stony Creek along Thimble Island Road. Higher rocky bluffs interspersed with low wetlands. Flooding of the road is an issue. This is one of the few areas in Town dependent on private septic systems.

- <u>Jarvis Creek</u>: the rural area at the eastern end of Branford is vulnerable to flooding from Jarvis Creek, cutting off State Route 146 in two areas and impacting farmland. An improperly-functioning tide-gate is a problem here.

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

Table 2: Adaptation Options for Branford Neighborhoods

Possible Options		Shoreline Protection					Infrastructure						Structure		Realignment		
		Hard Protection	Beach Nourishment	Dune Restoration	Non-Structure Living Shoreline	Bioengineered Banks	Drainage Improvement	Pumping Station Retrofit	Community Wastewater	Strengthen Power Utilities	Road Elevation	Tide Gate Maintenance	Structure Elevation	Floodproof Structures	Alternate Route Development	Property Acquisition	Road Retirement
Appropriate Neighborhoods	**Clark Ave**	X	X					X		X	X		X			X	
	Beckett Beach	X	X				X	X		X	X		X			X	
	Short Beach	X	X		X	X		X		X	X		X			X	
	Killams Point									X	X				X		
	Johnsons Point									X	X					X	
	Double Beach	X	X		X	X		X		X			X			X	
	Branford Point							X		X	X		X	X			
	Branford Center	X					X	X		X	X		X	X			
	Blackstone Acres	X					X	X		X	X		X				
	Indian Neck Ave									X	X						X
	Sybil Creek							X		X	X	X				X	
	Pawson Park							X		X	X		X				
	Linden Ave	X			X	X		X		X							
	Limewood Ave	X	X	X						X	X		X			X	
	Haycock Point	X								X							
	Hotchkiss Grove	X	X	X			X	X		X			X			X	
	Pine Orchard	X	X							X	X						
	Juniper Point									X	X						
	Pleasant Point								X	X	X						
	Stony Creek	X	X				X		X	X		X		X	X		
	Jarvis Creek									X	X	X					

3.2 Application of Adaptation Options in Branford

The following section summarizes some of the specific problem sites around Branford 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. Branford 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

Branford'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 Clark Avenue, Beckett Beach, Short Beach, Double Beach, Blackstone Acres, Linden Avenue, Limewood Avenue, Haycock Point, Hotchkiss Grove, Pine Orchard, and Stony Creek. Most of these neighborhoods are already protected by hard structures, which should be monitored and maintained, and may be upgraded, moving forward.

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. Branford's irregular coastline and offshore islands creates a situation where most of the sandy or erodible shoreline sections are already somewhat protected from wave action. This limits suitable sites for these types of shoreline protection. Areas where they may be appropriate include Beckett Beach, Linden Avenue, Limewood Beach, and Hotchkiss Grove. These sediment-control structures are often used in concert with beach nourishment projects.

One specific area that is not currently protected by hard structures is the neighborhood of Blackstone Acres. This neighborhood is somewhat vulnerable to inundation now, and vulnerability is expected to increase in the future. One option for protection moving forward is to construct a floodwall or a levee. Space is limited by homes on one side and tidal wetlands on the other.

Another area that requires a form of structural protection not listed above is the Meadow Street and Hammer Field section of Branford Center. A small railroad underpass allows floodwaters from Branford River to flow into the Hammer Field neighborhood. A promising mitigation option here is to install a temporary floodgate system at the underpass that can be deployed during storm events.

3.2.2 Soft Shoreline Protection

Some sections of Branford are able to be served using soft shoreline protection such as beach and dune nourishment, which is often more aesthetically acceptable and more supportive of natural systems and processes.

Areas where soft protection measures can be implemented include Clark Avenue, Beckett Beach, Short Beach, Double Beach, Limewood Avenue, Hotchkiss Grove, Pine Orchard, and Stony Creek.

Dune restoration or construction is generally not a great fit for Branford due to the Town's geography. 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. Most Branford beaches do not have this kind space. However, the eastern edge of Limewood Avenue Beach may be a good candidate for this work. 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. Hotchkiss Grove may be a candidate for this kind of project.

3.2.3 Living Shorelines

Bioengineered Banks

Bioengineered bank treatments may be good options for Short Beach, Lanphier Cove in the area Double Beach, sections of Hotchkiss Grove, and sections of Stony Creek.

Created and Restored Tidal Wetlands

Branford's irregular shoreline creates numerous protected coves and low-lying wetland areas that would support the created or restored tidal wetland form of living shorelines. However, most areas in Town suitable to tidal marshlands already support them. Significant tidal marshlands in Branford include those in or around the East Haven Marsh Wildlife Area, Kelsey Island, Killams Point, The Branford River, Pawson Park and Sunset Beach, Sybil Creek, Pine Orchard, and Jarvis Creek.

Further tidal marsh restoration will not be a priority for the Town. Ensuring the continued viability and inland migration of existing marshland with sea level rise will be an important consideration at all tidal wetland areas in the future.

Artificial Reefs

Recent living shoreline projects like the Stratford reef ball project may be feasible in Branford between Kelsey Island and Horton Point, at Branford Point, off of the Stony Creek neighborhood, and near the mouth of Jarvis Creek. When siting such a project it is important to determine whether the reef balls would survive a powerful coastal storm.

3.2.4 Roadways and Transportation

The layout of Branford is such that even if some major roads are impassable, other routes should remain open for most residents. Nevertheless, multiple neighborhoods may be completely isolated under high sea level conditions, while others may remain technically accessible but have all major throughways cut off. Under current conditions there are already roads that experience chronic flooding, and neighborhoods that are isolated during storms.

Some of the most significant roads at risk in Branford include State Route 1, State Route 142, State Route 146, Clark Avenue, Grove Street, Killams Point Road, Stannard Avenue, Johnsons Point Road, Harbor Street, Maple Street, Main Street, Woodvale Road, Tabor Drive, Ark Road, Pawson Road, Linden Avenue, Waverly Park Road, Pine Orchard Road, Pleasant Point Road, Totoket Road, and Thimble Island Road. Some of these roads (especially the long State Routes) are vulnerable to flooding in multiple locations.

Areas of the Town vulnerable to isolation include: southern Clark Avenue; the Grove Street neighborhood north of Short Beach; Killams Point; Johnson Point and Spring Road at the southern end of the Double Beach area; Branford Point; the northern part of Blackstone Acres; all of Indian Neck including Pawson Point, Sunset Beach, and Linden Avenue; the area west of South Montowese Street; Limewood Avenue; Waverly Park north of Sybil Creek; Pine Orchard, Pleasant Point; and the southern end of Thimble Island Road. Additionally, eastward evacuation may be hindered by flooding of Route 146, and east-west transit may be hindered by flooding of roads along Branford River, including Route 1. 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.

The following ordered lists are suggested to prioritize road elevation and reinforcement efforts.

State Roads:

1. Route 146 at Sawmill Road, the eastern edge of Town
2. Route 146 at the Stony Creek crossing (near 106 Stony Creek Road)
3. Route 146 near house number 199 (199 Stony Creek Road)
4. Route 146 at Limewood Point (note: a DOT project is underway here)
5. Route 146 at the Sybil Creek crossing
6. Route 1 at the Branford River / Pisgah Brook crossings (intersection with Mill Plain Road
7. Route 142 at Stannard Avenue
8. Route 142 at Short Beach (near the intersection with Grove Street)
9. Route 142 at Beckett Beach

Town Roads:

1. Clark Avenue
2. Grove Street
3. Killams Point Road
4. Johnsons Point Road
5. Stannard Avenue
6. Harbor Street
7. Indian Neck Avenue
8. Maple Street
9. Main Street
10. Woodvale Road
11. Tabor Drive (or retire road)
12. Ark Road (alternate access may apply here)
13. Pawson Road (or retire/designate alternative routes)
14. Linden Avenue
15. Waverly Park Road
16. Pine Orchard Road

17. Totoket Road
18. Pleasant Point Road
19. Thimble Island Road at Three Elms Road/Indian Point Road, south of Buena Vista Road, and at its southern end where it meets Flying Point Road and Prospect Hill Road.

Transportation adaptation options for these areas may include:

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

3.2.5 Infrastructure Retrofits and Upgrades

Drainage
Some areas of Branford have adequate protection from inundation and wave action, but still experience damage due to failing, inadequate, or malfunctioning drainage infrastructure. This is an important vulnerability at Beckett Beach. Beckett Avenue already suffers 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.

Wastewater
The Branford Water Pollution Control Facility (WPCF) is within a mapped floodplain and will be affected by sea level rise and coastal storms. At the time that the facility was designed, the 100-year flood elevation at the site was calculated to be 12 feet (NAVD88). After FEMA updated its maps in 2013, the base flood elevation (BFE) here was recalculated as 13 feet. Most structures within the facility remain above the BFE, although the "freeboard," or the extra height above the BFE, has decreased.

A significant concern at the WPCF is the vulnerability of underground systems and basements to flooding through insufficiently elevated doors, windows, hatches, vents, conduits, light fixtures, cracks, and other openings. Specific adaptation options appropriate for the WPCF include sealing cracks and conduits, and installation of deployable flood doors or hatches.

In addition to the WPCF, many of Branford's sewer pumping stations lie within hazard zones and may be vulnerable to sea level rise. One example is the pumping station at Sailor Lane, which is not housed in a pump house. Construction of a floodproofed pump house around this and other unprotected stations is suggested.

About 15% of Branford households rely on septic systems for sanitary wastewater treatment. Any of these systems that exist near the coast are vulnerable to sea level rise and coastal hazards. The Stony Creek and Pleasant Point neighborhoods both rely on private septic systems to treat wastewater. Development of community systems in these locations is suggested.

3.2.6 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 Branford 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 Beckett Beach, Killams Point, Blackstone Acres, Pawson Park and Sunset Beach, homes around Sybil Creek, and Hotchkiss Grove.

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

3.2.7 Other Options

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

One action considered an adaptation measure is the implementation and maintenance of evacuation plans for areas vulnerable to flood damage or isolation, for which other adaptation methods will be insufficient, unfeasible, or not cost-effective. Evacuation plans should be developed by the Killams Point Conference Center, by the Town for homes in the Sunset Beach neighborhood, and for areas along Limewood Avenue.

4 Conclusions

The Town of Branford 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, active pursuit of resilience projects and grants, the placement of a majority of coastal homes on bedrock bluffs that are not vulnerable to inundation or erosion, and municipal water and sewer utilities that serve most coastal residents.

Road elevation and hardening, and related efforts focused on ensuring emergency access to all neighborhoods during and after storms, will be a large part of Branford's resilience efforts. 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. The Town is encouraged to explore the use of hybrid and green techniques such as bioengineered banks and constructed wetlands, where applicable. Hard structural protection measures should be implemented where necessary, especially in the densely developed areas around the Town Center, where space is limited. Though a significant investment, development of community wastewater treatment systems should be explored for the neighborhoods at the eastern end of Town that are not served by the municipal treatment plant. Finally, Branford 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 concentrations of RL properties is located as follows, from west to east:

- Clark Avenue Beach and Beckett Avenue Beach (14)
- Short Beach (5)
- Meadow Street (2)
- Aceto Street (4)
- Blackstone Acres (3)
- East of South Montowese Street (5)
- Sunset Beach (16)
- Linden Avenue (4)
- Limewood Beach (13)
- Hotchkiss Grove (17)
- Pine Orchard (7)
- Stony Creek (8)

Additionally, Severe Repetitive Loss (SRL) properties are located at Clark Avenue Beach and near Beckett Avenue Beach.

Low-to-Moderate Income (LMI) Census Tracts

At the present time, only Branford center is an LMI tract[1]. However, as of 2014, LMI tracts were located near Branford Center, in the area including Kirkland Street, Meadow Street, Montowese Street, and Main Street; at Blackstone Acres; and in the greater Short Beach area including Clark Avenue Beach and Beckett Avenue Beach.

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.

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[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 only one Census block group in Branford is currently a HUD-designated LMI area.

Areas of Branford that experienced the greatest extent of damage include: the Clark Avenue, Beckett Avenue, and Short Beach area; Lanphier Cove and Sunrise Cove; Meadow Street; the downtown area near Main Street, Svea Avenue, Aceto Street, and Willow Road; Blackstone Acres; areas along the east side of South Montowese Street including Ark Road, Woodside Drive, and Newton Road; homes around Sybil Creek and Limewood Beach, especially near Waverly Park Road; the Sunset Beach area; Hotchkiss Grove; Island View Avenue in Pine Orchard; and Stony Creek.

Some of the most extensive damages during that storm occurred in the Beckett Avenue neighborhood, including areas not directly impacted by flooding. The most severe flood-related damages occurred at the Waverly Park Road crossing with Sybil Creek.

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 Beckett Avenue, Killams Point, Meadow Street, Blackstone Acres, Sunset Beach, Waverly Park Road, Hotchkiss Grove, Pine Orchard, and Stony Creek. The Double Beach neighborhood is not vulnerable to inundation from increasing daily high-tides due to sea level rise, but its high banks are susceptible to accelerated erosion.

Locations of Critical Facilities

Several of Branford's critical facilities are situated in areas of relatively high risk. These include the Short Beach Fire Company 4 located near Beckett Avenue Beach, the Indian Neck Pine Orchard Company 9 next to Sybil Creek, and the Branford Recreation Center (an alternate shelter) near Meadow Street.

The Branford Water Pollution Control Facility is located in a SFHA and will be at increasing risk over the long term. As the only wastewater treatment plant in Town, this facility serves LMI census tracts. There is a sewer pipe vulnerable to continued erosion of the shoreline, as well as accelerated erosion and inundation from future sea level rise, which has been identified at Lanphier Cove, in the Double Beach neighborhood. This pipe is considered a "critical facility" in the summary table in the "Conclusion" section of this memo.

At-Risk Roads

Roads at risk of flooding during daily high tides are listed in the Vulnerability and Risk memo. The inability to travel along some of these roads will isolate areas of town. This information is summarized in the table below:

Vulnerable Road	Isolated Area
Clark Avenue	Paynes Point & Horton Point
Johnsons Point Road	Johnson Point
Stannard Avenue Harbor Street	Branford Point
Meadow Street	
Riverside Drive Woodvale Road	Northern Blackstone Acres

Vulnerable Road	Isolated Area
Indian Neck Avenue South Montowese Street (Route 146) Tabor Road	East of S. Montowese Street
Linden Avenue	Indian Neck
Pine Orchard Road Island View Avenue	Pine Orchard
Totoket Road	Juniper Point
Pleasant Point Road	Pleasant Point
Thimble Island Road	Stony Brook
Route 146 Route 142 Route 1	East-West Travel

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 include the entire area of the Branford River, Stony Creek, Pawson Park and Sunset Beach, Beckett Avenue, Branford Center, Pleasant Point, Juniper Point, and Jarvis Creek.

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

Neighborhood	Number of Mentions
Clark Ave	3
Beckett Beach	6
Short Beach	11
Killams Point	0
Double Beach	1
Branford Point	3
Branford Center	20
Blackstone Acres	2
Indian Neck Ave	3
Sybil Creek	5
Pawson Park	5
Linden Ave	6
Limewood Ave	9
Haycock Point	0
Hotchkiss Grove	3
Pine Orchard	7
Juniper Point	1
Pleasant Point	1
Stony Creek	11
Jarvis Creek	4

Conclusion

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

Neighborhood	RL Properties	LMI Census Tracts	Irene & Sandy Damage	DHT Risk 2020s-2050s	Critical Facilities	At-Risk Roads	Public Input
Clark Ave	X	X	X			X	
Beckett Beach	X	X	X	X	X		X
Short Beach	X	X	X	X			X
Killams Point				X			
Double Beach			X	X*	X**	X	X
Branford Point						X	X
Branford Center	X	X	X	X	X	X	X
Blackstone Acres	X	X	X	X		X	X
Indian Neck Ave	X		X			X	X
Sybil Creek			X	X	X		
Pawson Park	X		X	X			X
Linden Ave	X		X			X	
Limewood Ave	X		X				
Haycock Point							
Hotchkiss Grove	X		X	X			
Pine Orchard	X		X	X		X	
Juniper Point						X	X
Pleasant Point						X	X
Stony Creek	X		X	X		X	X
Jarvis Creek						X	X

* Due to increased erosion risks
** References the vulnerable sewage infrastructure at Lanphier Cove

Branford Center is the area with the most columns checked (seven) whereas Blackstone Acres and Becket Avenue are the areas with the second-most columns checked (six). Other neighborhoods with many columns checked (five) are Short Beach, Double Beach, and Stony Creek. Areas with four columns checked are Clark Avenue, East of Indian Neck Avenue, Pawson Park (and Sunset Beach), and Pine Orchard.

Branford Center and Blackstone Acres are the two neighborhoods with the most columns checked and were therefore selected for neighborhood-scale planning:

- Branford Center is clearly in need of more focused design efforts. One area that is the subject of frequent complaints is the neighborhood of Meadow Street and Hammer Field. This area is inundated by water from the Branford River flowing through a small underpass below the train tracks. The neighborhood itself includes many residences, a number of commercial properties, a secondary emergency shelter, and the large open-space of Hammer Field. There are a number of neighborhood-scale approaches to adaptation applicable here, and so this location will be selected for a neighborhood concept design. One of the adaptation options involves blocking the railroad underpass, an action which itself can be accomplished in many ways. Therefore, options specific to preventing water from passing through the underpass will be considered as a separate focused infrastructure design.

- The second neighborhood design that will be addressed with more focused planning efforts will be applied to Blackstone Acres. This area is vulnerable to Branford River flooding, and faces similar risks to other neighborhoods adjacent to the river. Therefore, the designs presented for consideration in this neighborhood should also help guide planning efforts for other neighborhoods.

One infrastructure design explored in more detail is a bank revetment concept for Lanphier Cove, located in the Double Beach neighborhood of Branford. Ongoing erosion of a steep bank threatens an underground sewer line here, and that line can be considered a critical facility. Although the greater neighborhood is not at risk of future inundation, Lanphier cove itself is, so the vulnerability of the sewer line will increase with sea level rise. With these considerations in mind, it is clear that this site is an important one for more focused resiliency efforts, and therefore will be selected for that purpose.

In summary, the four selections for focused planning are:

<u>Neighborhoods</u>
- Meadow Street/Hammer Field (in the Branford Center area)
- Blackstone Acres

<u>Infrastructure</u>
- Meadow Street Railroad Underpass Flood Prevention
- Lanphier Cove bank protection

Appendix E-1
Meadow Street Resilience Concept

MILONE & MACBROOM

Meadow Street, Branford CT, Neighborhood Adaptation Concepts

The Meadow Street, or Hammer Field, neighborhood is located on the west side of the Branford River, south of Branford Center and just north of the railroad tracks. It is a low-elevation bowl-shaped area that includes individually owned private residences, apartments and condos, a number of commercial and industrial buildings, a public park, and the Branford Parks and Recreation Department's "Community House," which is a secondary emergency shelter. There is also an electrical substation and a sewer pumping station located in flood-prone areas of the neighborhood.

While the neighborhood is separated from the Branford River by an elevated railroad grade, a small underpass allows vehicles, pedestrians, and water, to pass between the south and north sides of the tracks. The base of the underpass is the lowest-elevation spot in the area, and important stormwater infrastructure is located at the underpass to reduce the potential for stormwater flooding. This neighborhood is vulnerable to poor drainage during large rain events, riverine flooding from the tidal Branford River, and high tides or storm surges moving northward from Long Island Sound. The main source of water into the neighborhood from the river is overtopping of the narrow strip of land between the railroad underpass and the river. An additional risk is water surcharging through stormwater drainage infrastructure. Finally, accumulation of water in the bowl-shaped neighborhood can occur during excessive precipitation events, without any interaction with the river.

Much of the neighborhood lies within a FEMA 1% annual-chance floodplain (Zone AE), with a base flood elevation of 12 feet NAVD88.

The neighborhood plans developed for this area focus on preventing floodwaters from entering the neighborhood through the railroad underpass, upgrading storm drainage infrastructure to prevent surcharging or drainage failures, and installing stormwater pumping stations to remove ponded water during storm surge or future extreme high tide events.

The specific scenarios explored are:

- A floodable neighborhood
- Protection from projected high tides and storm events by blocking the railroad underpass

Although these two outcomes are different, it is possible to pursue one outcome for the short term and another outcome for the long term. It is important to note that the second scenario does not protect the neighborhood from projected Category 2 storm surges in the 2080s, because these projected storm surges may overtop the railroad embankment and tracks.

Alternatives

"Floodable Neighborhood"

Concept A depicts a combination of options that will protect property and assets in the neighborhood while allowing flooding to occur. No flood walls or flood gates would be constructed by the Town, and flood protection measures would be the responsibility of individual property owners. The stormwater drainage pipe running under the railroad tracks to the southeast of the underpass would be updated to prevent water surcharging during high river stages.

Daily High Tide flooding is not expected to impact the neighborhood through the underpass until the 2050s, when TNC's mid-range projections show the high water elevations being approximately equal to the low elevation of the land surface between the underpass and the river (3.9 feet). If water does overtop the low ground in this area and flow northward into the neighborhood, approximately 50 structures could be affected by flooding. Over time, the increasing daily high tides would extend to an increasing number of properties. This is summarized in the table below:

Structure Type	2050s High Tide	2080s High Tide	Current Category 2 Storm	FEMA SFHA	2080s Category 2 Storm
Residential	24	28	58	60	63
Commercial	7	8	10	10	10
Industrial	5	5	5	5	5
Institutional	0	0	2	2	2
"Open Space"	9	9	9	9	9
Other/Unknown	2	2	2	3	2
Power Substation	2	3	3	3	3
Pumping Station	1	1	1	1	1
Total	**50**	**56**	**90**	**93**	**95**

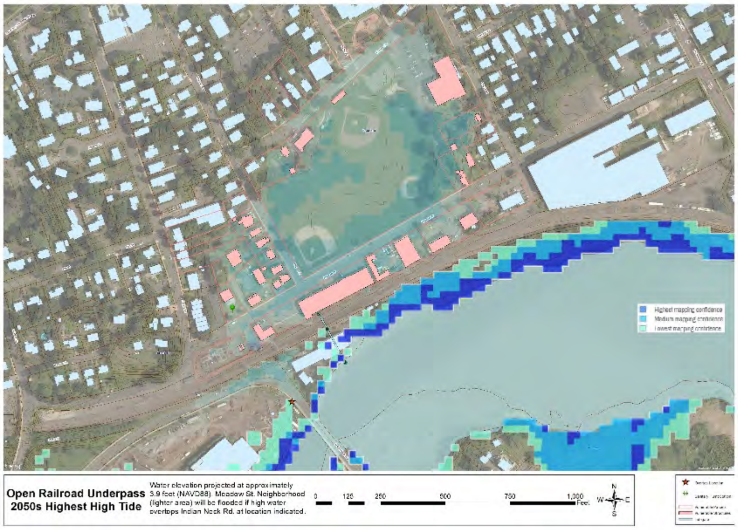
For the floodable neighborhood concept, homes may be elevated to address frequent property flooding, while nonresidential structures may be elevated or floodproofed. A stormwater pumping station would be constructed in the low-lying eastern section of Hammer Field to remove stormwater that can no longer drain directly through the existing pipe. This pumping station could also pump stormwater against the higher base level occurring during high tides. Roadways would be maintained as floodable, perhaps being reconstructed using materials that are more resilient to frequent inundation. Water and sewer systems would be hardened and made more watertight. All property owners with flood insurance would continue to hold flood insurance.

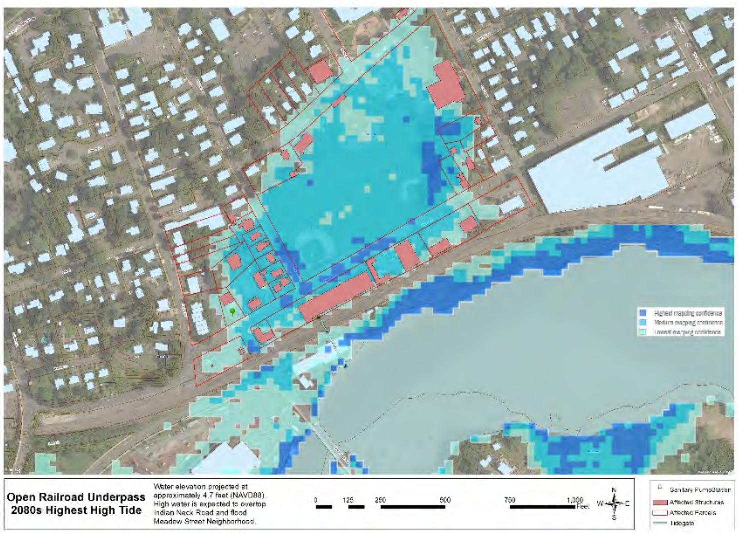
Three important facilities are located in this neighborhood, and would be at increasing risk of flooding under a "Floodable Neighborhood" scenario. At the eastern end of Hammer field, and at the eastern extent of projected flooding, is the Branford Parks and Recreation Department's "Community House," which is a secondary emergency shelter. Under a floodable neighborhood scenario, this building's lower levels should be floodproofed. It is recommended that Branford explore whether this location should be maintained as a secondary shelter and thus ensure that it is able to operate after flood events, or designate a less at-risk site as a replacement.

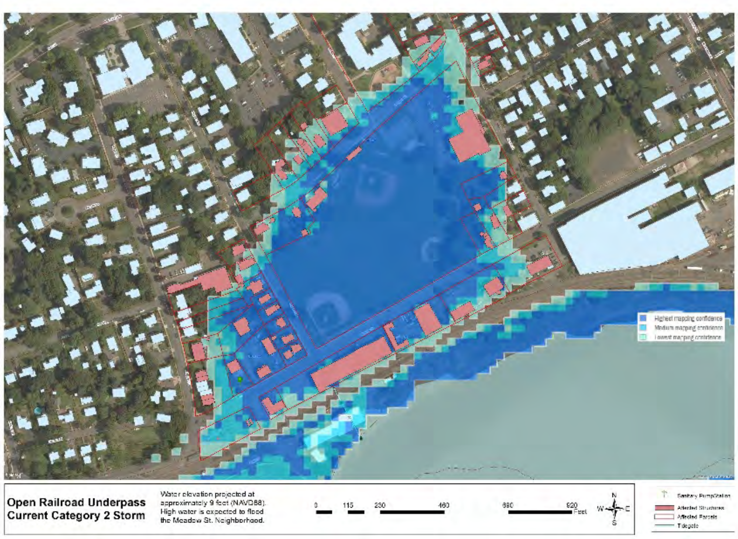
An electrical substation and a sewer pumping station are also located in areas of the neighborhood with flood risk. The sewer pumping station is located within a closed pump house, which can be floodproofed to allow for continuous pump operation. Floodproofing or relocation of the electrical substation would be the responsibility of the electric utility.

Meadow Street Neighborhood Resilience Concept

These graphics show the extent of flooding under different conditions assuming no flood prevention measures are being taken. Structures affected by flooding are highlighted, though the "floodable neighborhood" plan calls for them to be elevated or floodproofed.







MILONE & MACBROOM

"Flood Wall at Underpass"

Concept B depicts an option that will protect the neighborhood from flooding during the daily high tides in the 2020s, 2050s, and 2080s and storm surges in the 2020s and 2050s. This option will not protect the neighborhood from projected 2080s category 2 storm conditions. This will be discussed below.

In this concept, a flood gate would be installed and maintained on the river-side of the railroad underpass, or "cattle crossing." This would be built on the Town's property rather than the railroad's property, and along with earthworks tying the gate into the railroad berm, would be elevated to prevent overtopping by storm surges through the 2080s (about 11 feet elevation, NAVD88). Wave action or water velocities that might increase the effective flood elevation, risking overtopping of the gate, are not as much a concern at this site as they would be along the open shoreline. The gate would be open during low-water conditions to allow for passage of pedestrian and vehicular traffic through the underpass, and closed during predicted high-water events. The gate may be designed to close automatically as water levels rise, or may require human activation, depending on the needs and capabilities of the Town.

With the gate closed, the railroad berm will act as a flood-prevention levee and hold back water during high-stage conditions. This levee would protect the properties listed in the Concept A description above, through a 2050s category-2 hurricane.

Stormwater systems within the protected area would need to be upgraded under this new scenario, in which water would not be able to flow naturally into the Branford River. Storm drains with backflow prevention would be installed to prevent surcharging from the stormwater system during high tides. A stormwater pumping station would be installed to remove stormwater from areas that can no longer drain directly from streets. This pumping station could also pump stormwater against the higher base level occurring during high tides.

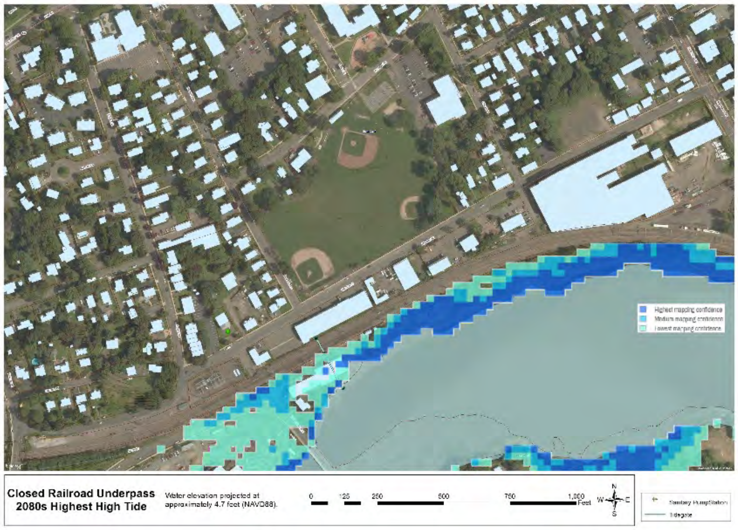
This concept will provide long-term protection against flooding to the properties around Meadow Street. However, the railroad berm elevation is currently below 11 feet in elevation in some areas. Projections in the Coastal Resilience tool put a category 2 storm surge stillwater elevation at around 10.8 feet here, while the FEMA SFHA for this site has a base-flood elevation of 12 feet. This means that by the 2080s, a category 2 storm may overtop the railroad, flooding the neighborhood. It also means that this design would not qualify the neighborhood for a FEMA map revision, and property owners would continue to be required to purchase flood insurance. In the long term, it is suggested that the Town attempt to work with the railroad to elevate the embankment to at least 13 feet to protect the railroad and the neighborhood from future flooding. In that scenario, it is possible the railroad berm could be accredited and maintained as a flood protection system, and a FEMA map revision could be obtained. Property owners would then no longer be required to elevate their homes and would have the option to discontinue insurance policies after the FEMA map revision.

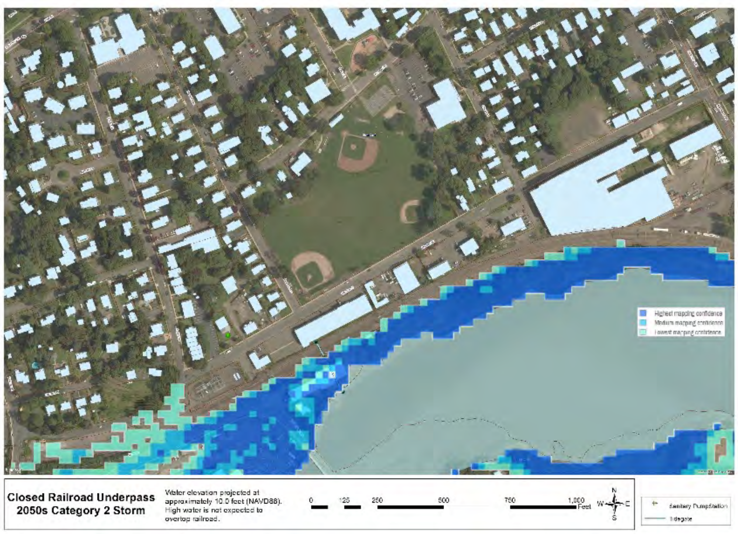
The implementation of this alternative is shown in the figures below.

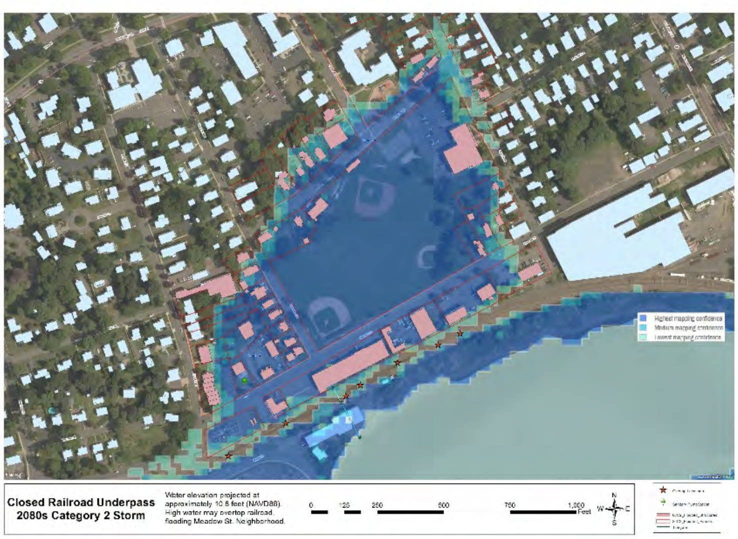
Meadow Street Neighborhood Resilience Concept

These figures depict the impact that installation of a flood-gate would have on parcels and properties within the Meadow Street neighborhood. Note that the neighborhood is protected from flooding through a 2050s category 2 storm surge scenario.

The bottom figure indicates, with stars, potential sites where water may overtop the railroad during a category 2 storm under 2080s sea level conditions.







Planning Level Costs for Alternatives:

“Floodable Neighborhood”

Costs associated with the floodable neighborhood concept would be borne mainly by property owners. An upper level cost estimate assumes *all* 63 residential structures would be elevated at a cost of $100,000 per structure (including structures that have already been elevated to FEMA base flood elevations) to a future design elevation that takes sea level rise and frequent flooding into account. The total would be $6.3 million. Floodproofing of the other 20 non-residential properties would cost an additional 10-15% of the property value per property, according to FEMA citations. Based on appraised values of the non-residential properties in this area, floodproofing would cost around $146,000 per property or a total of nearly $3.0 million. Finally, floodproofing the nine Branford-owned recreational properties, as well as the one pumping station house, would add $1.3 million.

Municipal costs associated with upgrading drainage systems and repaving roads would be minimized in accordance with the approach described above. Stormwater systems would be minimally upgraded over time, allowing the neighborhood to drain naturally each day at low tide. Roadways would be maintained as floodable, perhaps being reconstructed using materials that are more resilient to frequent inundation. A stormwater pumping station would be constructed on Town property at Hammer Field. Over time this could cost the town an estimated $500,000 to $1 million.

Overall, maintaining a floodable neighborhood could cost the Town around $1.8 million to $2.3 million. The cost to local residents and businesses could total $9.3 million.

“Flood Wall at Underpass”

Costs to the Town for installation of the floodgate would depend on the type of gate installed and the amount of fill required to ensure it is effective at preventing flooding. An estimate of these costs is as follows:

Approximately 350 cubic yards of fill would be required to connect the flood gate to the elevated railroad berm. At $35 per cubic yard this would cost around $12,250. The gate itself is estimated to cost from $150,000 (manually deployed) to $250,000 (automatic). Site preparation, construction, and post-construction site restoration can be expected to add around $25,000 to $50,000.

Municipal costs associated with upgrading drainage systems and constructing a stormwater pumping station on Town property at Hammer Field would cost the town an estimated $500,000.

Potential elevation of the railroad to prevent extreme events will require collaboration with the railroad, and is not addressed in this document.

In total, a reasonable planning-level cost estimate to construct a system to prevent both daily high tide and storm surge flooding in the future is around $813,000 when the costs of the gate, stormwater system upgrades, and installation of a pumping station are summed.

While this would protect the neighborhood against daily high tide flooding and some storms, it would not prevent a FEMA base flood or a 2080s category 2 storm from overtopping the railroad track. Therefore, buildings would not be removed from the flood zone and flood insurance would continue to be required of property owners. Elevation and floodproofing would continue to be required when substantial damage (SD) or substantial improvement (SI) thresholds are triggered, but perhaps at somewhat lower costs than those developed for the floodable neighborhood plan above.

Summary

The two neighborhood protection alternatives are summarized below:

Alternative Description	Modeled Outcome	Approximate Cost to Town ($)	Approximate Cost ($) to Residents and Business Owners
Floodable Neighborhood	Some structures already elevated, but additional elevations would be necessary. Critical facilities such as the pumping station, electrical substation, and emergency shelter, may need to be protected or relocated.	1,800,000 to 2,300,000	9,300,000
Flood Wall at Underpass	Should be minimally disruptive and protect the neighborhood through 2050s category 2 storms. Eventually, additional elevation of the railroad would be required to remove the neighborhood from the FEMA hazard zone.	813,000 (Without railroad elevation)	Uncertain; would depend on SD/SI requirements

Conclusion

While both options may be technically feasible for the Meadow Street neighborhood, they vary considerably in capital costs and social costs. Consider the following:

- The floodable neighborhood shifts much of the cost 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 future high tide and storm surges requires installation of a flood gate and stormwater pumping station, both of which can be accomplished on Town property. This option is very cost-effective and would cause limited disruption to the neighborhood.
- The floodgate option may require manual activation of the gate prior to storm events, creating the potential for human error leading to neighborhood-wide flooding. Automatically closing gates would avoid this issue.
- The floodgate option would *not* result in a FEMA map revision under current conditions. Therefore, even that plan would be considered a temporary solution, and additional consideration would be required in the future.

Because the Town is planning ahead with this coastal resilience plan, the two options for Meadow Street could be viewed as steps rather than two different outcomes. It would be feasible, for example, to provide protection from the daily high tide through the next 30 to 50 years simply by upgrading existing drainage systems, while taking steps to eventually construct a flood gate system and install stormwater pumping stations. On the other hand, it would be feasible to provide protection from storm surge through the next 50 years with the flood gate option and then revert to a floodable neighborhood if there is consensus for that outcome.

Appendix E-2
Blackstone Acres Resilience Concept

MILONE & MACBROOM

Blackstone Acres, Branford CT, Neighborhood Adaptation Concepts

Blackstone Acres is located to the east of the Branford River, across the river from Branford High School. It is a higher-elevation peninsula that juts northward, with the Branford River on the west and a tributary and associated wetland to the east and north. It is vulnerable to both tidal and non-tidal flood events, with two main areas of risk. The first area is homes located on the peninsula's "outer" edge, along the water. The second are homes and infrastructure located in the low-lying "belt" of the peninsula, where poor drainage or high water levels can inundate homes, roads, and a sewage pumping station. The vulnerable roads are Riverside Drive and Woodvale Road, and during significant tidal flood events the area north of the "belt" can be isolated. Homes between these two roads and between Hawthorne Terrace and Oakdale Place are at risk of flooding. These homes were flooded during Hurricane Sandy.

Much of the neighborhood lies within a FEMA 1% annual-chance floodplain (Zone AE), with a base flood elevation of 9 feet NAVD88.

The neighborhood plans developed for this area depict three potential different outcomes:

- A floodable neighborhood
- Protection from the daily high tide with a flood wall of nominal height and width
- Protection from storm surges with an earthen levee or berm system

Although these three outcomes are different, it is possible to pursue one outcome for the short term and another outcome for the long term.

Alternatives

"Dry Except During Storm Surge Events"

Concept A depicts a combination of options that will protect the neighborhood from flooding during the daily high tides in the 2020s, 2050s, and 2080s. A flood wall would be installed and maintained on privately owned parcels with a design height that is equal to the projected daily high tide in the 2080s plus a reasonable freeboard. These walls would be located as far inland as would be agreeable and feasible, both to limit the height requirements and therefore lower costs, and to allow for inward migration of wetland ecosystems. Flood walls would not be designed to prevent flooding from storm surges.

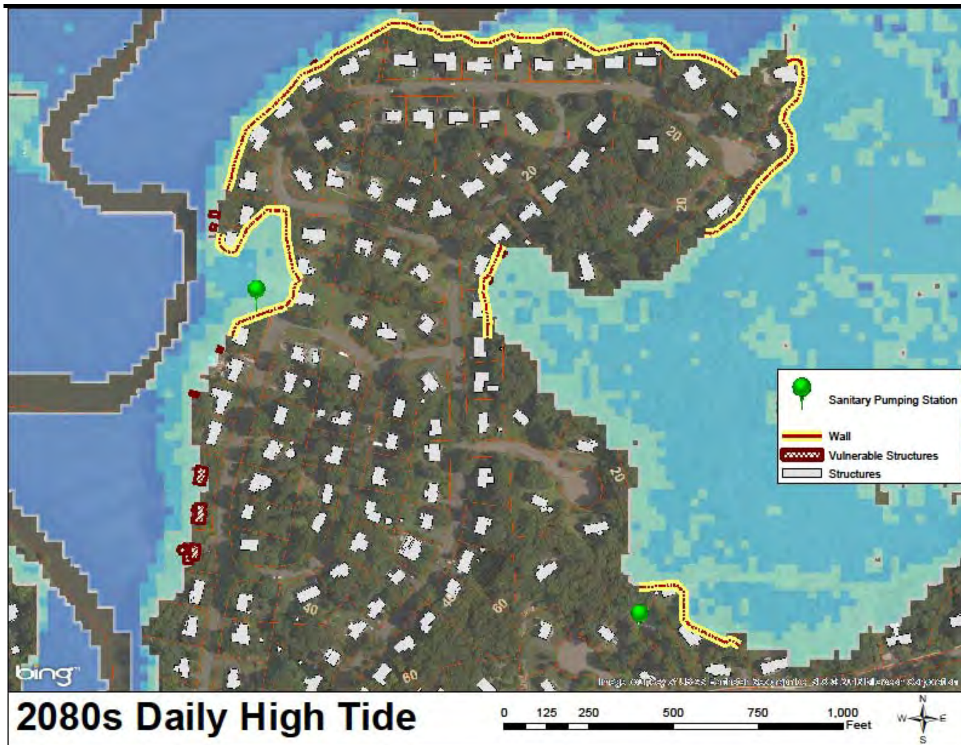
It is important to note that under this design, the Riverside Drive sewage pumping station would fall outside the wall's protective area, and therefore could be regularly submerged by future daily high tides. The station is currently fitted with a submersible pump, and its flood-proofed features would need to be maintained and upgraded over time.

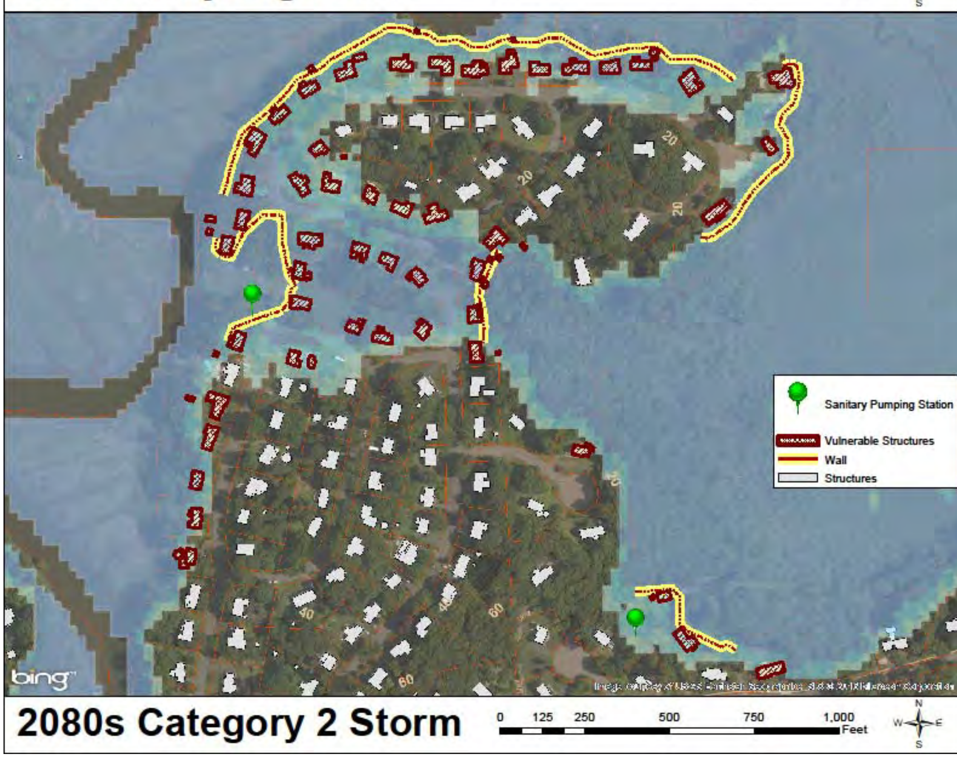
Stormwater systems within the protected area would need to be upgraded over time. In addition, backflow prevention would be installed to prevent surcharging from the stormwater system during high tides. A stormwater pumping station would be installed in the area behind 27 Riverside Drive to remove stormwater from areas that can no longer drain directly from streets. This pumping station could also pump stormwater against the higher base level occurring during high tides.

Over time, property owners will still need to elevate homes as they currently do (when substantial damage and substantial improvement thresholds are triggered) in order to protect homes from storm surges.

Approximately 41 houses would be protected from daily high tide through the 2080s under this plan. Approximately 32 property owners would need to grant permanent easements for the Town to maintain flood walls. Approximately 14 structures that are not residences and three that are would remain in vulnerable areas, and would need to be elevated, protected, relocated, demolished, or left unchanged based on owner preferences and means, and regulatory constraints. All property owners with flood insurance would continue to hold flood insurance. The implementation of this alternative is shown in the figures below.

Blackstone Acres Neighborhood Resilience Concept





These graphics show the impact of the wall protection-system on flooding under different conditions. Note that high tide flooding is prevented through the 2080s decade. Category 2 Storm flooding is not precluded by the presence of the wall.

The stormwater pumping station that would be installed is not pictured here.

Blackstone Acres Neighborhood Resilience Concept

“Dry in Perpetuity”

Concept B depicts a combination of options that will protect the neighborhood from flooding during the daily high tides in the 2020s, 2050s, and 2080s and storm surges in the 2020s, 2050s, and 2080s. A levee, dike, or berm system would be installed and maintained along the peninsula’s edge with its front edge located along or slightly inland of the alignment of currently mapped wetland extents. The rear edge would be located an appropriate distance inland to provide a suitable width for the dike. Where possible, the dike would be located to allow space on the river- or wetland-side such that upland migration of wetland ecosystems could occur as sea levels continue to rise.

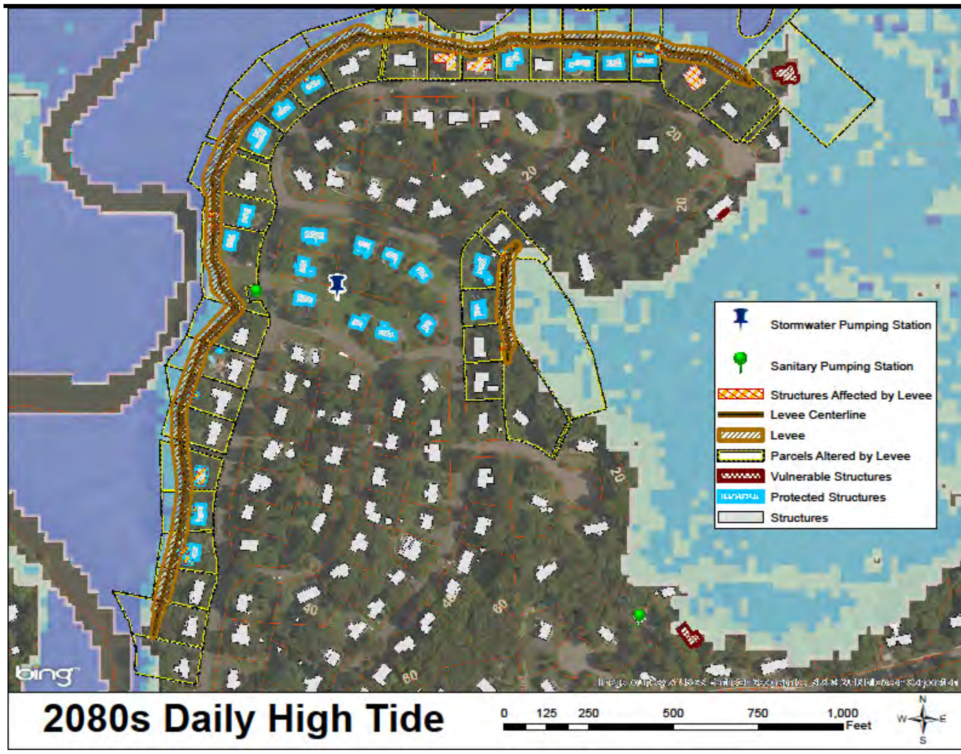
The levee would have design height that is equal to the projected storm surge in the 2080s plus a reasonable freeboard. The levee would impact around 35 privately owned lots, and would necessitate the displacement of approximately 21 structures including sheds, garages, pools, and a few homes. Many of the remaining property owners would need to grant permanent easements for the Town to maintain the dike systems. Other properties would not be protected by the levee due to limited space or risk. Additional parcels would be affected, but they are either Town-owned or do not currently have structures. It is important to note that a more thorough exploration of the structural needs of such a dike, as well as incorporation of coastal and wetland construction regulations, may result in a scenario where the impact of this option would be greater than that discussed here.

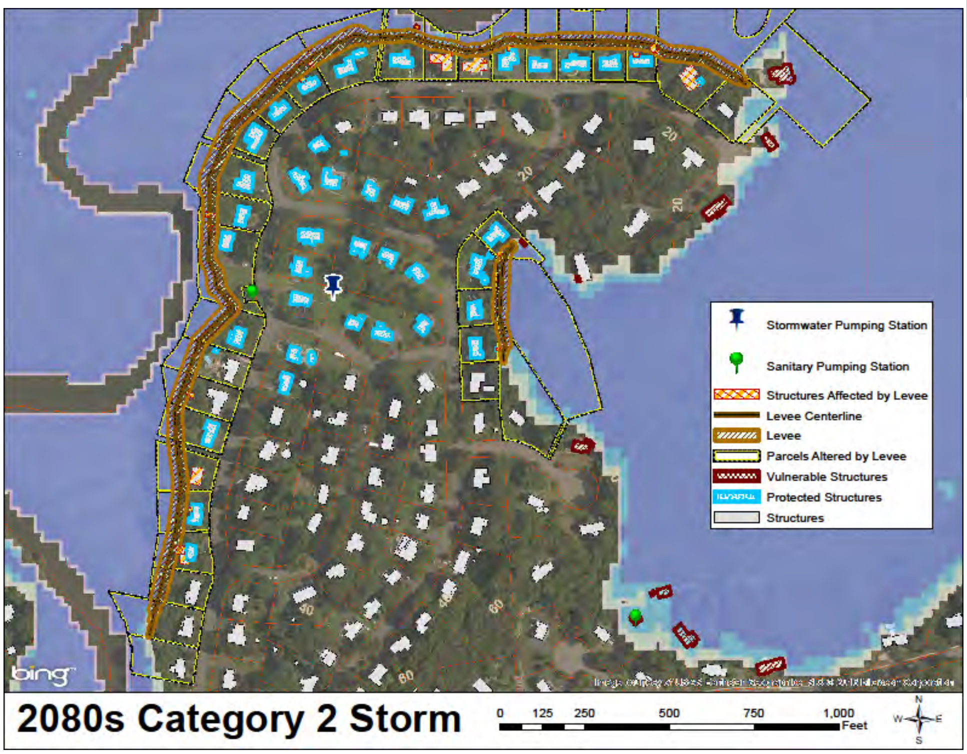
Stormwater systems within the protected area would need to be upgraded under this new scenario, in which water is not able to flow naturally into the Branford River. Storm drains with backflow prevention would be installed to prevent surcharging from the stormwater system during high tides. A stormwater pumping station would be installed to remove stormwater from areas that can no longer drain directly from streets. This pumping station could also pump stormwater against the higher base level occurring during high tides.

Property owners would not be required to elevate their homes if the dike system was accredited and maintained as a flood protection system and a FEMA map revision was obtained. Approximately 65 structures (including homes, pools, garages, and sheds) would be protected through projected 2080s Category 2 Storm conditions. Property owners with flood insurance would have the option to discontinue insurance policies after the FEMA map revision.

The implementation of this alternative is shown in the figures below.

Blackstone Acres Neighborhood Resilience Concept





These figures depict the impact that construction of a levee-protection-system would have on parcels and properties within the Blackstone Acres neighborhood, as well as on flooding under different conditions. Note that even under Category 2 Storm surge conditions projected to the 2080s decade, the neighborhood would be protected from flooding.

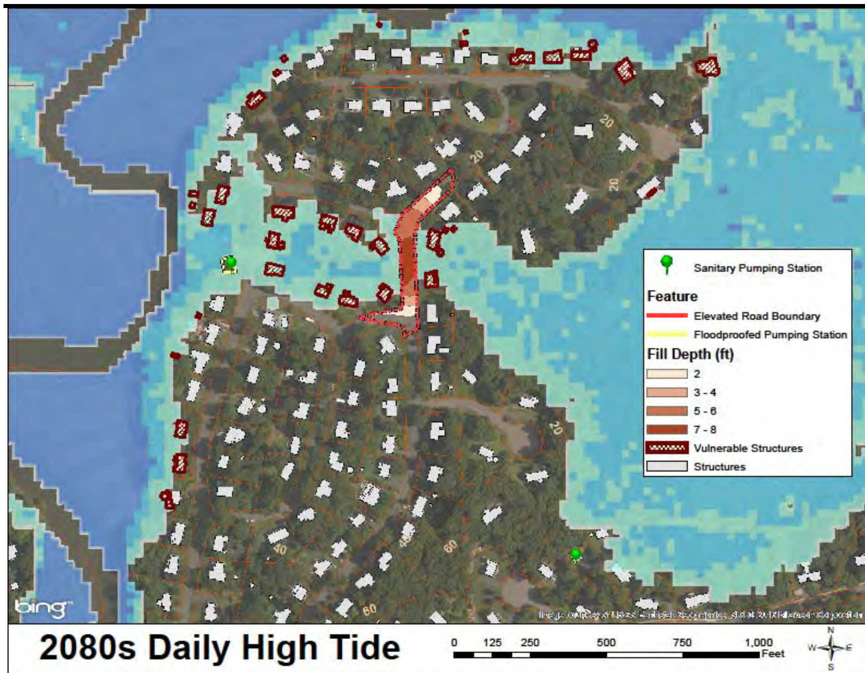
Blackstone Acres Neighborhood Resilience Concept

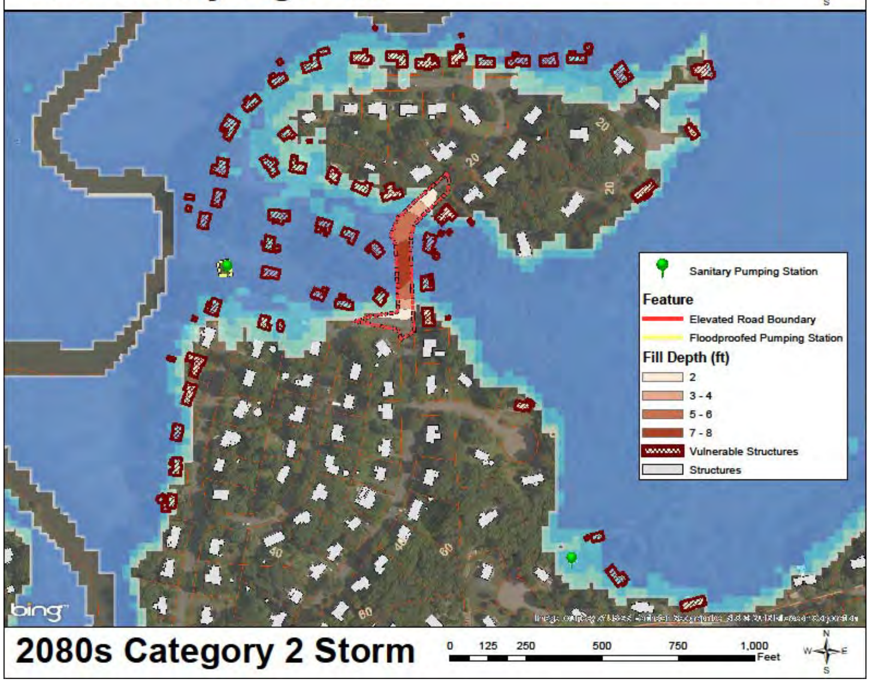
"Floodable Neighborhood"

Concept C depicts a floodable neighborhood. Dikes and flood walls would not be constructed. Over time, the increasing daily high tides would extend to an increasing number of properties. All homes would be elevated in such a way to allow frequent tidal flooding. Stormwater systems would be minimally upgraded over time, allowing the neighborhood to drain naturally each day at low tide. Roadways would be maintained as floodable, perhaps being reconstructed using materials that are more resilient to frequent inundation. Water and sewer systems would be hardened and made more watertight. All property owners with flood insurance would continue to hold flood insurance.

In order to prevent the isolation of the northern section of the neighborhood during daily high tide, or even storm surge, events, a small section of Woodvale Road would be elevated to be above the projected 2080 Category 2 storm surge elevation. This activity could also be incorporated into the "Dry Except during Storm Surge Events" concept. In that scenario, the road would be protected by the sea walls from daily high tide inundation, but could be elevated further to ensure accessibility during storms.

Blackstone Acres Neighborhood Resilience Concept





These graphics show the extent of flooding under different conditions assuming no flood prevention measures are being taken. Structures affected by flooding are highlighted, though the "floodable neighborhood" plan calls for them to be elevated. The lower figures, depicting category 2 storm conditions, are nearly identical to the "Dry Except During Storm Surge Events" graphics, since the floodwall discussed earlier would not prevent storm surge flooding.

Planning Level Costs for Alternatives:

Wall Construction

The wall around the neighborhood would be approximately 4,033 feet long in order to allow space for wetland migration, minimize length and height requirements, and be sufficiently long to prevent floodwaters from entering the neighborhood around the wall's sides.

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 four to five 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 $806,500 for the flood wall.

Approximately 33 property owners would need to grant permanent easements for the City to maintain the flood walls. For planning purposes, the cost for securing the easements is assumed to be at least $1,000 per property, or $33,000.

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.

In total, a reasonable planning-level cost estimate to construct a system to prevent daily high tide flooding in the future is around $1.33 million when the costs of the wall, easements, stormwater system upgrades, and pumping station are summed.

Construction would not impact flood insurance rates for neighborhood properties. Approximately 98 structures would need to be elevated over time as substantial damage/ substantial improvement thresholds were reached, which is current practice. This cost would be borne by property owners, which is the current situation. At approximately $100,000 per home, this cost would be around $9.8 million in total.

Dike/Berm System Construction:

In order to accommodate the Coastal Resilience Tool's projected Category 2 Storm under a "medium" sea level rise scenario through the 2080s, a dike would have to be a minimum of 12 feet elevation, NAVD88. Because of the lack of wave action here, it is believed unnecessary to provide for wave heights, setup, or runup. Therefore, it is reasonable to plan for construction to 12 foot elevation minimum.

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 five feet to allow for maintenance. Ground surface elevation along the neighborhood 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 Blackstone Acres was made. These figures are summarized in the following table:

Section ID	**Approx. Relative Height** (feet)	**Base Width** (feet)	**Length** (feet)
0	2	15	45.7727
1	4	25	29.368
2	6	35	35.9757
3	8	45	998.006
4	10	55	43.8653
5	10	55	681.324
6	6	35	580.468
7	8	45	543.825
8	6	35	13.0465
9	4	25	12.483
10	2	15	15.2312
11	2	15	12.9491
12	4	25	22.3188
13	6	35	44.6887
14	8	45	146.567
15	6	35	84.7445
16	4	25	27.1721
17	2	15	24.154
18	8	45	245.506
19	8	45	24.1873

The dike heights and widths will vary because the existing ground surface elevation will vary. This complicates the estimate of construction. However, using the dimensions in the above table, the total volume of material for the dike system will be around 30,000 cubic yards. At an estimate of $35/cubic yard for compact fill material this would cost at least $1 million. Pre-construction preparations, the construction itself, and post-construction site restoration costs, would add about $357,500.

The dike would necessitate the displacement of approximately four homes. 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. A review of the assessor data for Blackstone Acres reveals an average appraised value of $315,000 per property for the affected properties. Understanding that market values are typically higher yet variable from year to year, the average appraised value of $315,000 is hereby used for planning. Acquiring four properties would cost at least $1.26 million. At $50,000 per home, demolition will cost $200,000.

Some of the remaining property owners would need to grant permanent easements for the Town 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 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.

The total cost to the Town, based on the above costs and adding contingency costs to create a more conservative planning estimate, would be approximately $3.8 million.

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 65 structures, 38 of them homes, would benefit from this cost savings.

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.

"Floodable Neighborhood"

Costs associated with the floodable neighborhood concept would be borne mainly by property owners. An upper level cost estimate assumes *all* 98 structures would be elevated at a cost of $100,000 per structure (including structures that have already been elevated to FEMA base flood elevations) to a future design elevation that takes sea level rise and frequent flooding into account. The total would be $9.8 million.

Municipal costs associated with upgrading drainage systems and repaving roads would be minimized in accordance with the approach described above. Stormwater systems would be minimally upgraded over time, allowing the neighborhood to drain naturally each day at low tide. Roadways would be maintained as floodable, perhaps being reconstructed using materials that are more resilient to frequent inundation. Over time this would cost the town an estimated $500,000.

A significant cost to the Town would be the elevation of Woodvale Road to maintain access to the northern part of the neighborhood during flood events. To provide a conservative estimate, we assume the road would be elevated to 12 feet NAVD88 in order to keep it dry even during a projected 2080s decade Category 2 storm event. Importing fill, constructing the elevated road, paving, updating road utilities and restoring the site post-construction are estimated to cost a total of around $540,000.

Overall, maintaining a floodable neighborhood would cost the Town around $1 million. As noted above, the bulk of the costs of this option ($9.8 million) would fall on the individual homeowners to adapt to the daily high tide flooding and future storm surges.

Blackstone Acres Neighborhood Resilience Concept

Summary

The following table summarizes the options presented above:

Alternative Description	Modeled Outcome	Approximate Cost to Town ($)	Approximate Cost to Residents ($)
Floodable Neighborhood: Elevate homes, as well as a road to maintain access	Many elevations would be necessary. Access during and after storm events would be maintained, but the road would have to be significantly elevated.	1,000,000	9,800,000
Construct a **flood wall** system to protect against high tide through 2080s sea-level-rise conditions.	With improved drainage infrastructure, will protect neighborhood from high tides. Wall will not provide protection from storm surges.	1,330,000	Uncertain; would depend on SD/SI requirements
Construct a **dike or levee** system to protect against base flood elevations (1%-annual-chance, or category 2, storm) through 2080s sea-level-rise conditions.	With improved drainage, will protect most of the neighborhood from all but the most extreme flood events. Requires acquisition and displacement of many properties and structures.	3,800,000	0

Conclusion

While all three options may be technically feasible for the Blackstone Acres neighborhood, they vary considerably in capital costs and social costs. Consider the following:

- The floodable neighborhood shifts much of the cost 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 be challenging but 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.
- The design for protection from storm surges requires a dike system that would displace private properties. Therefore, this option is the most costly and would cause the greatest disruption to the neighborhood. However, this is the only option that could result in a FEMA map revision and eventual discontinuance of flood insurance for approximately 38 property owners.
- Aspects of these different options can be combined with one another, or stand alone. For example, construction of a floodwall could occur with elevation of Woodvale Road, or Woodvale and Riverside could be elevated to create a levee system that doubles as a road and protects inland properties.

Because the Town is planning ahead with this coastal resilience plan, the three options for Blackstone Acres could be viewed as steps rather than three different outcomes. It would be feasible, for example, to provide protection from the daily high tide through the next 30 to 50 years with the flood wall option, while taking steps to eventually construct a dike system if there is consensus. On the other hand, it would be feasible to provide protection from the daily high tide through the next 30 to 50 years with the flood wall option and then revert to a floodable neighborhood if there is consensus for that outcome.

Appendix F-1
Cattle Crossing Flood Gate Resilience Concept

MILONE & MACBROOM

“Cattle Crossing” Floodgate Concept

Meadow Street Underpass, Branford CT

Infrastructure Resilience Concept

Hazard Setting

A low-clearance underpass (known as the “cattle crossing”) runs below an elevated railroad, connecting Indian Neck Road to the south to Meadow Street to the north. The opening allows high water to enter Meadow Street, Hammer Field, and the surrounding neighborhood. Future daily high tides could become significantly problematic, and storm events are already an issue.

Existing Conditions

From LiDAR data, the Branford River needs to rise to an elevation of less than 6 feet (NADV88) to enter cattle crossing. The underpass road elevation is less than 4 feet. Many areas north of the underpass are lower than 6 feet in elevation. The Coastal Resilience Tool’s Medium Sea Level Rise projection puts daily high tide at 7.3 feet elevation by the 2080s.

The railroad is elevated to between 10 and 12 feet (NAVD 88) in this area, and higher to the east and west away from the site. The Coastal Resilience Tool’s Medium Sea Level Rise estimates put floodwaters at 10.0 feet during a Category 2 storm by the 2050s, and 10.8 feet by the 2080s.

This area is currently mapped as a FEMA AE zone (1%-chance annual flood event). The AE zone includes the elevated railroad, indicating a 1%-annual chance flood is expected to overtop the railroad.

Proposed Infrastructure Resilience Concept

Protection of the cattle crossing from flooding can be accomplished through installation of a flood gate, or by abandoning and filling the opening.

Abandon and Fill Opening

This option permanently prevents water from entering the cattle crossing. All traffic would be rerouted around this site, any internal infrastructure removed, and the opening

Abandon Opening

would be filled. Because no action would have to be taken before or during high-water events, there is no opportunity for flooding to occur through human or mechanical errors.

There is currently important stormwater infrastructure located within this underpass, and the north-south access it provides to vehicles and pedestrians is important to municipal leaders and Town residents. Therefore, this option is not recommended.

Install Manual Floodgates

This option allows for continued use of the crossing during normal conditions while preventing the entrance of water during significant flood events. It is not a reasonable method for preventing high tide inundation in the coming decades because it requires manual deployment every time water levels are elevated. It is also susceptible to human error, and requires advance notice of flood events. Sea level rise projections make protection of this site during daily high tide events important, so this option is not recommended.

Manually Deployed Floodgate

Install Automatic Floodgates

This option allows for continued use of this crossing while preventing the entrance of water during flood or high tide events. A gate that closes automatically avoids the need for human deployment, and therefore the possibility of human error. Many types and styles of automatically closing floodgates exist such as the "HYFLO Self Closing Flood Barrier." The installed gate here would be connected to a new earthen embankment attached to the elevated railroad track. The height of the gate can be altered based on the level of protection desired.

Other Floodgate Styles

Elevating the Railroad

For long-term protection from storm-surge inundation, or for removal of inland areas from the FEMA hazard zone, the railroad must be elevated above the base flood elevation. Considerations of sea level rise will call for increased elevation above the current BFE. Such a project requires coordination with and cooperation from the railroad, and is beyond the scope of this memo.

Preliminary Cost Estimates

Abandon and Fill Opening

The costs associated with this option include the cost of fill to block the underpass, construction, and the removal and relocation of stormwater infrastructure. Using a conservative estimate of 1,500 cubic feet of fill material for $35 per cubic foot, material alone would cost $52,500. Construction costs would add an approximate $25,000. Stormwater infrastructure relocation would add approximately $500,000 to the project costs. The total estimated cost for this option is approximately $577,500.

Install Manual Flood Gates

Approximately 350 cubic yards of fill would be required to connect the flood gate to the elevated railroad berm. At $35 per cubic yard this would cost around $12,250. The gate itself is estimated to cost around $150,000. Site preparation, construction, and post-construction site restoration can be expected to add around $25,000. The total cost of this option would be around $188,000.

Install Automatic Flood Gates

Approximately 350 cubic yards of fill would be required to connect the flood gate to the elevated railroad berm, costing around $12,250. Site preparation, construction, and post-construction site restoration can be expected to add around $50,000. The gate itself is estimated to cost around $250,000. The total cost of this option would be around $313,000.

Elevating Railroad

This option requires coordination with and cooperation from the railroad, and is beyond the scope of this memo. However, the cost of interrupting railroad operations, elevating the berm, and reconstructing the railroad, can be expected to cost multiple millions of dollars.

Other options may exist *within* this alternative, such as constructing a floodwall on top of or alongside the railroad berm. To give an idea of the minimum amount such a project would cost, the cost of building such a wall can be estimated. The minimum length a floodwall would need to be to prevent overtopping of the railroad by a present-day base flood event is 1,500 feet. At $200 per food of wall the cost would be $300,000.

“Cattle Crossing” Floodgate Concept

Summary

The resilient infrastructure options proposed are summarized in the table below:

Alternative Description	Outcome	Approximate Cost to Town ($)
Abandon and Fill Opening	Permanently prevent entry of floodwaters, but lose valued access route and important stormwater infrastructure.	577,500
Install Manual Floodgates	Prevent flooding during larger storm events. Requires advance notice and manual deployment, so not feasible for high tide or flash flood protection.	188,000
Install Automatic Floodgates	Prevent all flood events without need for human intervention. More expensive than manual floodgates. Allow continued access.	313,000
Additional Protection along Railroad	Extends flood protection to include base flood events and projected 2080s category 2 hurricanes	300,000+

Conclusion

The options presented in this memo illustrate that there are numerous methods of addressing even smaller, site specific issues. Additionally, the complexities of installing a single flood gate are highlighted, including ensuring access is maintained while effective automated deployment is achieved.

Because the Town is planning ahead with this coastal resilience plan, it is feasible for long-term planning to consist of multiple steps. Installation of a floodgate at this site will protect the inland neighborhood from high tide through projected 2080s conditions, but additional steps to harden this infrastructure against storm surges will be required.

Appendix F-2
Lanphier Cove Revetment Resilience Concept

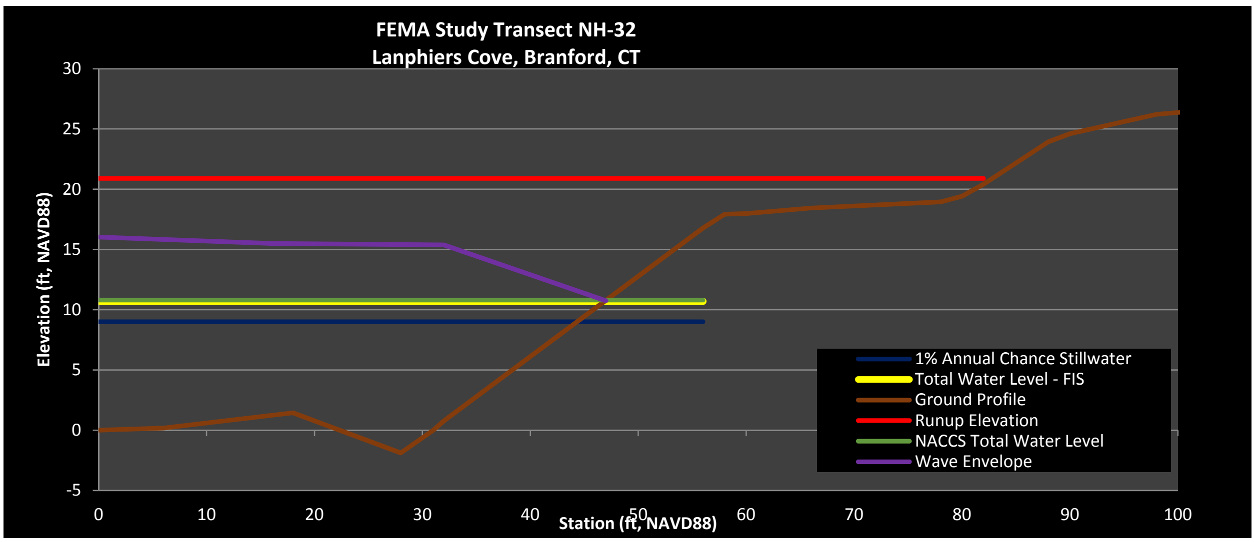
MILONE & MACBROOM

Lanphier Cove, Branford CT, Infrastructure Resilience Concepts

Hazard Setting

Lanphier Cove is an east-facing cove north of the Connecticut Hospice and east of Route 142. To the north and south, the cove is bounded by bedrock bluffs extending east into Branford Harbor. The cove itself includes a small sandy beach, most of which is underwater during high tide, and about eight residential structures built right on the beach or partly over the water. Inland of this beach and these properties is a steep rise of about 18 feet to a higher topographic bench. A sewer pipe is buried beneath this bench, carrying wastewater from properties to the north (Howard Avenue, Rustic Road, Brocketts Point Road) to the pumping station at the eastern end of Lanphiers Cove Road. A topographical transect of this area was developed by FEMA, and wave setup and runup modeling was conducted (see below; explanation for this figure is provided in Appendix B of the Coastal Resilience Plan).

A Letter of Map Revision was subsequently approved for Lanphier Cove, reducing the effective base flood elevation from 21 feet to 15 feet. However, the runup modeling still implies that wave energy can be significant here.



The steep slope leading from the beach to the upper bench is susceptible to erosion from waves, and the remains of previous revetment projects are visible. A particularly vulnerable area is located in the northern section of the beach at Lanphier Cove. The steep bank here has less dense vegetation than other areas, and a home is constructed at the end of the steep bank. Erosion of the bank has been significant, and there is concern that the sewer pipe may be exposed and undermined.

Lanphier Cove Bank Resilience Concept

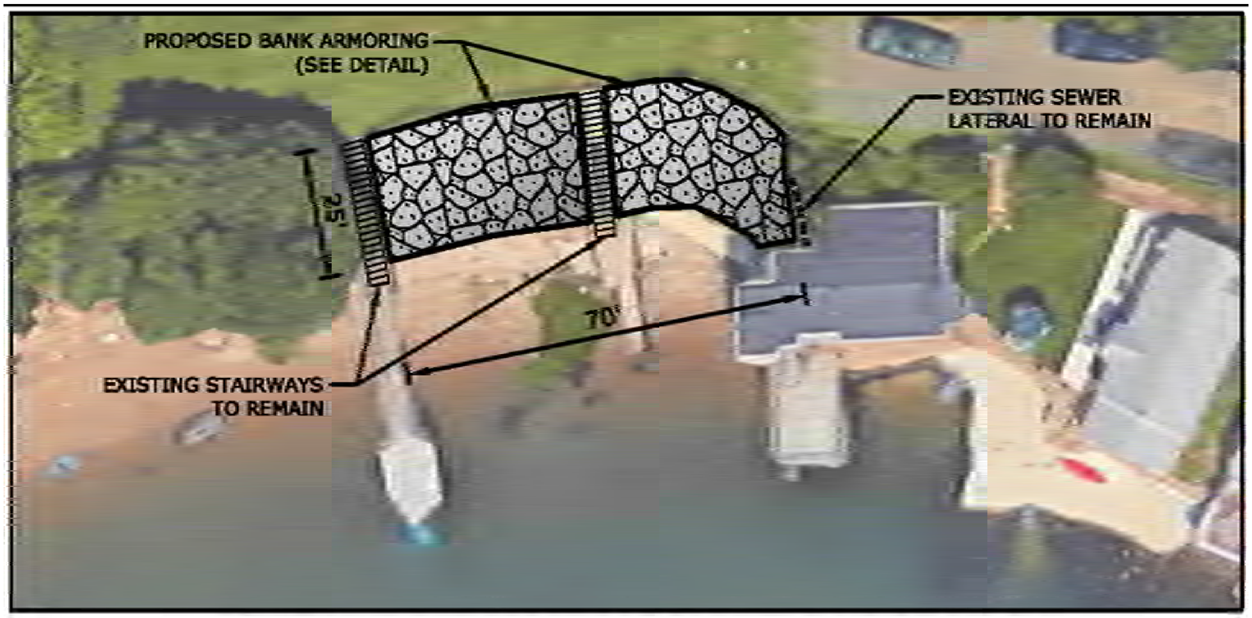
Proposed Infrastructure Resilience Concept

Eroding bank at eastern end of site

Protection for the sewer infrastructure at this site could be accomplished through bank stabilization in the short term. Protective measures would likely only be required in the bank area extending from the residential property located at the northern edge of the beach, south to the southern staircase and long wooden pier. This is a length of approximately 70 feet along the shoreline.

The option presented here is the installation of a riprap revetment. Stones would be installed such that they interlock and minimize voids, at a slope of 2:1 (two feet in width for every foot in height). The difference in elevation between the top and bottom of the eroding bank here is approximately 12.5 feet, resulting in a riprap width of approximately 25 feet.

The conceptual design for this revetment is attached below.



SHORELINE STABILIZATION - PLAN VIEW

SCALE 1" = 30'

Preliminary Cost Estimate

The cost of the proposed revetment material is approximately $61,500. Construction costs, including site preparation and restoration, will add around $30,000. Adding a reasonable contingency brings the estimated total cost to $110,000.

Conclusion

The option presented in this memo is one possible way to address the risk of bank erosion and the vulnerability of the sewer infrastructure at this site. Other approaches do exist, including incorporation of green infrastructure concepts into any bank stabilization project, or even allowing erosion to continue after removing the sewer infrastructure and rerouting wastewater elsewhere. If owners of the homes along the water here are interested, the Town can also consider pursuit of funding to acquire and remove those properties. Decreasing the number of hard structures in the site may allow wave energy to be spread over a larger area, instead of focused on individual spots such as the site addressed in this memo, diminishing erosion rates at those locations. As sea level rise continues and storm intensity increases, erosion risks will increase throughout Branford into the future.

Because the Town is planning ahead with this coastal resilience plan, it is feasible for long-term planning to consist of multiple steps. For example, construction of a riprap revetment may provide protection from high tide and storms through the next 30 to 50 years, while the Town takes steps to eventually install green infrastructure and reroute the wastewater infrastructure.

Appendix G
Notes from Public Meetings

DATE: November 18, 2015
MMI #: 2619-09
PROJECT: Branford Coastal Resilience Plan

SUBJECT: Notes from Public Meeting (Risk/Vulnerability Assessment)
LOCATION: Branford Fire Department

ATTENDEES:

Janice Plaziak, P.E., Town Engineer
David Murphy, P.E., CFM, MMI
Scott Choquette, CFM, Dewberry
Sarah Hamm, CFM, Dewberry
Noah Slovin, MMI

A public meeting was held on November 18, 2015 to introduce the Town of Branford coastal resilience planning effort to residents and the public. The specific goal of this meeting was to clarify the term "Coastal Resilience," describe the specific types of coastal hazards and the specific Town assets vulnerable to those hazards that will be addressed in the plan, explain how hazards and vulnerabilities can be expected to change in the future, and solicit information and participation from the public.

Ms. Plaziak conducted the meeting. She began by introducing Mr. Murphy, who in turn introduced the representatives of MMI and Dewberry. Mr. Murphy then gave a presentation outlining the following topics: Coastal Resilience Background; Project Funding and Planning Steps; Assessing Vulnerabilities and Risk, What is Vulnerable and What is at Risk; Inundation and Surge Risks by Geography; Additional Types of Risk in Selected Areas; Next Steps. Ms. Hamm presented the section on "Additional Types of Risk in Selected Areas."

After the presentation, Ms. Plaziak moderated a question-and-answer session. Questions (denoted by "Q") and Answers ("denoted by "A") were as follows:

Q How much has sea level increased over the last 10 or 20 years?

- **A** Mr. Murphy replied that this will be checked for Branford, but the typical range is 1 to 2 mm per year[1]. One of the attendees described needing to move a coastal diving board more frequently in advance of king tides and coastal storms in recent years, which he believes is evidence of a generally higher tide level.

Q How much is sea level expected to rise in the future?

- **A** This was briefly discussed during the presentation but additional details can be provided.

Q What are the benefits of "soft" versus "hard" structures? Will "hard" structures be used when appropriate? (General concern about inadequacy of "soft" / "green" coastal protection expressed). What is the appropriate design life span for hard structures?

- **A** Mr. Murphy briefly discussed this topic and indicated that coastal structures will be a key consideration of the plan. He also noted that many coastal structures are

[1] Relative sea level rise at Boston and Woods Hole gauges over the last 100 years is estimated at 26 cm (10 inches) according to the United State Geological Survey.

designed for 20-50 years which is relatively brief; and noted that many of our coastal structures are much older than this and have exceeded their life expectancy.

Q Can the presentation be posted online? Can the presentation that will be given at the next meeting be posted online ahead of the meeting?

- **A** Ms. Plaziak agreed to post presentations on the town's web site.

Q Two electrical substations are in areas of flood risk and should be addressed.

- **A** Ms. Plaziak indicated that Eversource was looking at these stations, and it may be that only one station will be operating in the near future.

Q Will the wastewater treatment plant be considered?

- **A** Mr. Murphy stated that this will be included. Ms. Plaziak indicated that some floodproofing had already been done around the year 2000. She also explained that the town has an emergency response plan for the facility, and gate valves can be closed prior to floods. Hurricane Sandy nearly flooded the facility, but did not. She also explained that the town is evaluating pumping stations and elevating generators and hatchways when possible.

Q What are some of the solutions that will be explored / implemented? What kinds of legal issues will the Town face when trying to implement said solutions?

- **A** Will be discussed at the next meeting.

Q Are there resources available to individual homeowners on how to protect their own property?

- **A** Ms. Plaziak is the Town Floodplain Manager and can be contacted to set up a consultation.

Q There are many other coastal studies being performed and sources of information on coastal features/processes that exist. Are these being incorporated into the planning efforts?

- **A** Mr. Murphy said these are being considered. For example, the Army Corps of Engineers' recent North Atlantic Coast study is being considered, and results were incorporated into one of the slides tonight.

Q Will marine life be considered?

- **A** Mr. Murphy explained that the 10-town regional coastal resilience planning effort is focused on reduction of risk to ecosystems, and Branford is a participant, but the town's individual coastal resilience plan will not be focused on aquatic ecosystems.

Q Will the plan include cost estimates for recommended actions?

- **A** Mr. Murphy stated that cost estimates will be provided and funding sources will be identified.

Q Will associations and non-governmental agencies be eligible for funding?

- **A** Mr. Plaziak answered that in most cases, the town would be the applicant for funding.

Q How can different organizations within the Town advocate for themselves when the Town is deciding where to implement different measures?

Q A resident related his Hurricane Sandy story. His family evacuated mainly because they were concerned about not being able to leave after the storm due to downed trees. He believes that downed trees and power lines blocking roads is a significant issue, and urged that this be addressed in the plan. He also stated that sandy was eroded by Sandy and did not return as it has done after other storms.

A Mr. Murphy indicated that these are the sorts of issues that can be addressed in the plan.

Q Do the hazard models being used for the plan account for wave action and erosive energy, or only for high water levels?

A Wave action and erosion will be taken into account for some of the concept-level designs.

After the question-and-answer session, attendees were invited to inspect paper copies of projected inundation risk maps and Hurricane Sandy flooding extent maps, and to ask questions of any of the consultants[2] or Ms. Plaziak. Attendees inspected the 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[3].

[2] The resident that related his Hurricane Sandy experience provided additional information. He is very concerned about trees coming down onto roads even without the downed power line issue, and would like more active tree management in town. He also explained that height limitations have impeded home elevations in Branford. His house is one of the severe repetitive loss properties on Little Bay Land in Short Beach; he had $300,000 in losses (combined Irene/Sandy).

[3] Prior to the meeting, the owner of 19 Juniper Point Road and 22 Juniper Point Road discussed his concerns outside the venue. These are undeveloped parcels that he anticipated will be developed (one single-family home on each).

Notes From Public Meeting

DATE: February 23, 2016
MMI #: 2619-09
PROJECT: Branford Coastal Resilience Plan

SUBJECT: Notes from Public Meeting
LOCATION: Branford Fire Department

ATTENDEES:

Janice Plaziak, P.E., Town Engineer
Jamie Cosgrove, First Selectman
David Murphy, P.E., CFM, MMI
Scott Choquette, CFM, Dewberry
Noah Slovin, MMI
Branford Residents

A public meeting was held on February 23, 2016, to discuss possible plans and actions leading to coastal community resiliency in the Town of Branford. The goals of this meeting were to review the concepts of coastal resilience and community resilience, to describe broadly the many different approaches to adaptation, to discuss adaptation options relevant to the Town of Branford, and to solicit input and participation from the public with regards to specific options and vulnerabilities.

Ms. Plaziak began by introducing Mr. Murphy, who in turn introduced the representatives of MMI and Dewberry. Mr. Murphy then gave a presentation outlining the following: review of project steps and progress; review of coastal resilience concepts; approaches to coastal hazard adaptation; specific adaptation options. Mr. Choquette continued the presentation, covering specific neighborhoods within the town and describing some of the adaptation projects relevant to each.

Mr. Slovin then presented specific project ideas for two neighborhoods, showing how the effects of each project can be visualized and quantified under different sea level rise and storm surge scenarios to assist with decision-making. The Meadow Street and Hammer Field neighborhood was presented first, with the adaptation options being: (a) elevating homes, floodproofing non-residential buildings, upgrading tide gates and drainage infrastructure, and protecting the Community Center (an emergency shelter) to create a floodable neighborhood; and (b) protecting the neighborhood from flooding entirely by blockading the railroad underpass (the "cattle-crossing") with temporary floodgates or permanent fill. The second neighborhood presented was "Blackstone Acres," where the adaptation options were (a) elevating homes and Woodvale Road to create a floodable neighborhood with access maintained; (b) building a floodwall around much of the neighborhood to protect against future daily-high-tide flooding; or (c) building a larger dike around much of the neighborhood to protect against current and future storm-surge flooding.

After the presentation, Mr. Murphy opened the floor to a brief question-and-answer session. Questions (denoted by "Q") and Answers ("denoted by "A") were as follows:

Q What are the sea-level-rise values for the projections being used?

A We will double-check and provide the figures.

Q Is the Town building resilience into its projects, in a broader sense?

A Yes – for example, during the upgrading of sewer pumping stations. Six stations are being upgraded through a bonded capital improvement project. Flood levels are being considered during the upgrades.

Q Has the Town elevated any roads yet?

A No, this has not occurred specifically as a resilience measure. This plan will help identify which roads are candidates for elevating.

After the question-and-answer session, the workshop segment of the meeting began. A series of printed maps of vulnerable neighborhoods across Branford were used to prompt attendees to provide input about specific projects for each neighborhood. Maps showed aerial photos, street names, FEMA Special Flood Hazard Areas, sewer pumping stations, and storm drains. The neighborhoods, and the discussion surrounding each, were as follows.

Short Beach

Ms. Plaziak described some of the existing conditions in this neighborhood. Flooding is common, coming from both Long Island Sound and runoff from Short Beach Road / State Route 142 due to storm drain problems. Some of the damage here is caused by wave action. There is a pumping station in the neighborhood that has been made more resilient to flooding. Ms. Plaziak explained that six pumping stations around Town are undergoing upgrades, with floods being considered. These are bonded projects.

One attendee suggested that homeowners in this neighborhood should elevate their properties on an individual basis, rather than having the Town build a wall, berm, or other flood protection system. Another attendee asked about the process of elevating homes. Mr. Murphy explained that it is the decision of the homeowner, but that there are many grants available to aid in the cost, especially through FEMA, as well as the Shore Up CT loan program. A third resident asked if the Town has elevated any roads in this neighborhood. This has not yet occurred.

Pawson Park / Indian Neck

Linden Avenue is vulnerable here. The intersection of Old Pawson Road and Linden Avenue was pointed to as particularly at-risk. One resident suggested that Linden Avenue is overtopped by high waves during storms, and drainage systems here are inadequate to handle that water, leading to undermining of the road as the water flows back to the sound.

Roads in Sunset Park are low and are already flooded regularly. Two residents confirmed this. Many homes in this area have already been elevated due to substantial damage or substantial improvement requirements.

An attendee was curious about flooding issues at the South Montowese Street / State Route 146 crossing of Sybil Creek at the northeastern edge of this neighborhood where it transitions into Limewood Beach (discussed below). Some time was spent discussing the current state of the tide gate at this crossing, and current plans to repair and upgrade it. Currently, one of the two gates is sealed closed, and the other seems to allow water to flow in both directions unregulated.

Limewood Beach to Hotchkiss Grove

Attendees were curious about the combined effects of flooding from the Sound and from Sybil Creek to the north. Ms. Plaziak explained that during large storms, the Branford River can overtop its banks and flow south into Sybil Creek, and then continue over the Limewood Beach neighborhood into Long Island Sound, forming one flooded waterbody.

One resident explained that floodwalls located in Hotchkiss Grove are designed to protect against wave action, but not against inundation from very high water. She expressed concern that building higher walls to effectively prevent flooding would negatively impact views, and the value of homes in the area. Mr. Murphy acknowledged that this is an important consideration in planning for resilience in any community.

Ms. Plaziak suggested that beach nourishment at Limewood Beach and in front of Seaview Avenue may be worth consideration. One attendee referred to a nourishment method he had heard was employed elsewhere, where large, crisscrossing cement "coins" were placed on the beach through the winter to trap sediment, and subsequently removed in the summer.

An attendee pointed out that different types of storms, and factors such as wind direction, require different adaptation methods, and therefore any project put into place will likely not work for some storm events. Mr. Murphy agreed that it's important to recognize that projects are necessarily designed with certain storm scenarios in mind, but may not prevent damage if a different type of event occurs.

Another attendee said that the pumping station in Hotchkiss Grove, at the corner of 3rd and 4th Avenues, is very old, and wondered whether an option would be to replace it with a station located outside of the flood zone.

The state of a CT DOT-sponsored revetment project along Limewood Avenue / State Route 146 at the western edge of Limewood Beach was discussed. Work is expected here, but has not yet begun. The project should extend to Crouch Lane, where the State-maintained wall ends.

Meadow Street

Attendees had questions about the conceptual design described during the presentation. One question was about the type of floodgate that could be installed at the cattle crossing. Mr. Murphy explained that there were a variety of options, and that considerations included whether it should be automated (to react to contact with water) or manually-operated, and how regularly it would be closed. One resident suggested simply filling the crossing, and another asked about the frequency with which the underpass is used. Ms. Plaziak explained that it was used quite often by both vehicle and pedestrian traffic, and that important stormwater infrastructure is located under the road there. Other residents agreed that the crossing should remain open.

An attendee asked about the Community Center's role as a shelter, and whether its location in an inundation zone impacts its usability. Ms. Plaziak explained that it is not a primary shelter, and in her experience has only been used during the recovery period after an event, once floodwaters had receded. In her opinion there is not a need to find a new location for that shelter.

Ms. Plaziak said that there is a storm-drain system here that needs to be repaired.

Blackstone Acres

Mr. Murphy asked attendees about their thoughts regarding the suggested adaptation projects for this neighborhood. He said that approximately 40 homes are expected to be impacted by future sea level rise and storm events, and asked whether that was an appropriate number to pursue flood protection on a neighborhood scale. Attendees said that building a dike to protect this neighborhood seemed like a good idea. Mr. Murphy asked why building a neighborhood-scale protective structure made sense in this neighborhood but not at Short Beach, where attendees had agreed that individual homes should be elevated on a house-by-house basis. He posed the question that perhaps there was a threshold of a certain number of homes affected by flooding that, once reached, justified neighborhood-scale protection. First Selectman Cosgrove noted that Short Beach was different because it's a directly coastal neighborhood and some of the damage is caused by waves, so a dike would be less effective there.

One attendee asked about how dikes are paid for. Ms. Plaziak answered that a dike must be built as a complete system, and therefore cost is shared across a neighborhood. Mr. Murphy said that there may be grants available for that kind of work in the future.

An attendee asked about the condo at the corner of Riverside Drive and Pine Orchard Road, which is partially located in the FEMA flood zone. Mr. Murphy said that his firm is working with a similar situation where a protective structure, such as a wall, will be built, and the condo will team with the municipality to apply for a map revision. Ms. Plaziak noted that site-specific solutions would apply here, as well.

Stony Creek

A resident of the neighborhood described near-weekly road flooding, and said that she is getting tired of this happening. She does not drive through the flooded section of road. She has lived in the neighborhood since 1986, and said that flooding has gotten noticeably worse over the years, especially the last four years. She feels that elevating the road needs to happen.

Ms. Plaziak explained that there used to be another road or right-of-way farther inland and uphill, but it was abandoned by the Town years ago, and the property has been divided among private landowners. Reopening that road seems unlikely. Ms. Plaziak further expressed skepticism about installation of public sewer systems in the neighborhood, at least in the near future.

Jarvis Creek

One resident of this part of Town expressed frustration with the state of the State Route 146 crossing at the Creek. He said that many cars drive through here during flood events and are being damaged by the saltwater. He also said that the tide gates downstream of the crossing need to be maintained, and asked about ownership and responsibility. Ms. Plaziak explained that it is complicated, and there is disagreement on that count.

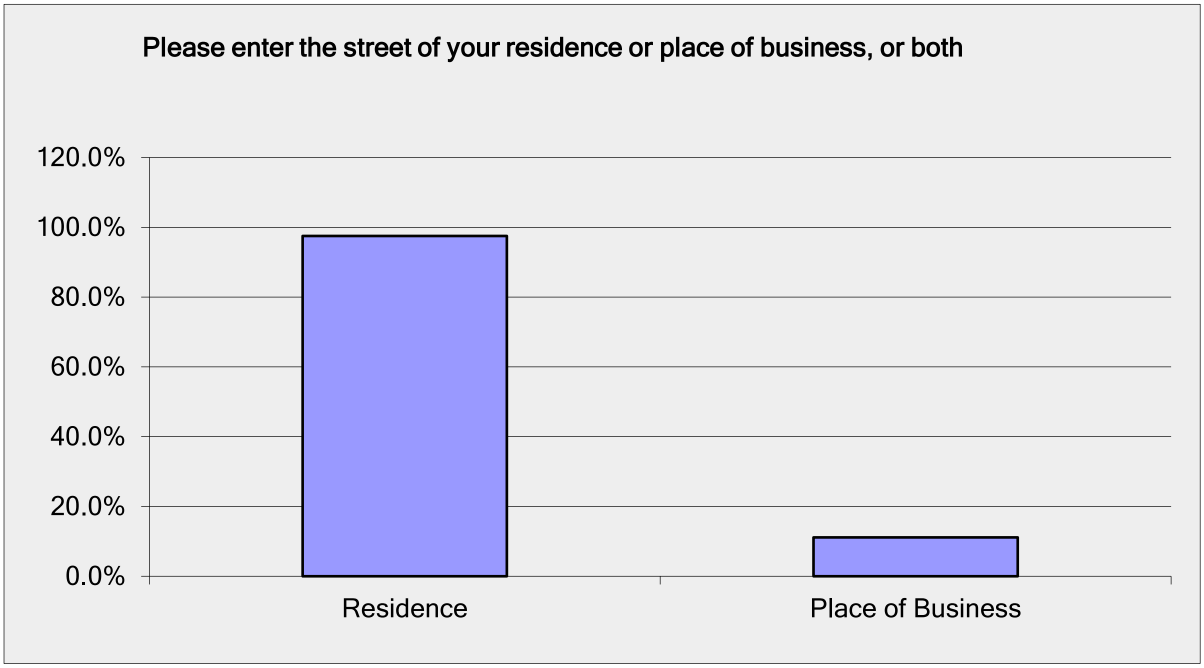
This led to further discussion about tide gates that are owned by the Town. It was agreed that better coordination between the State and Towns is generally needed throughout Connecticut.

Appendix H
Results from Online Survey

MILONE & MACBROOM

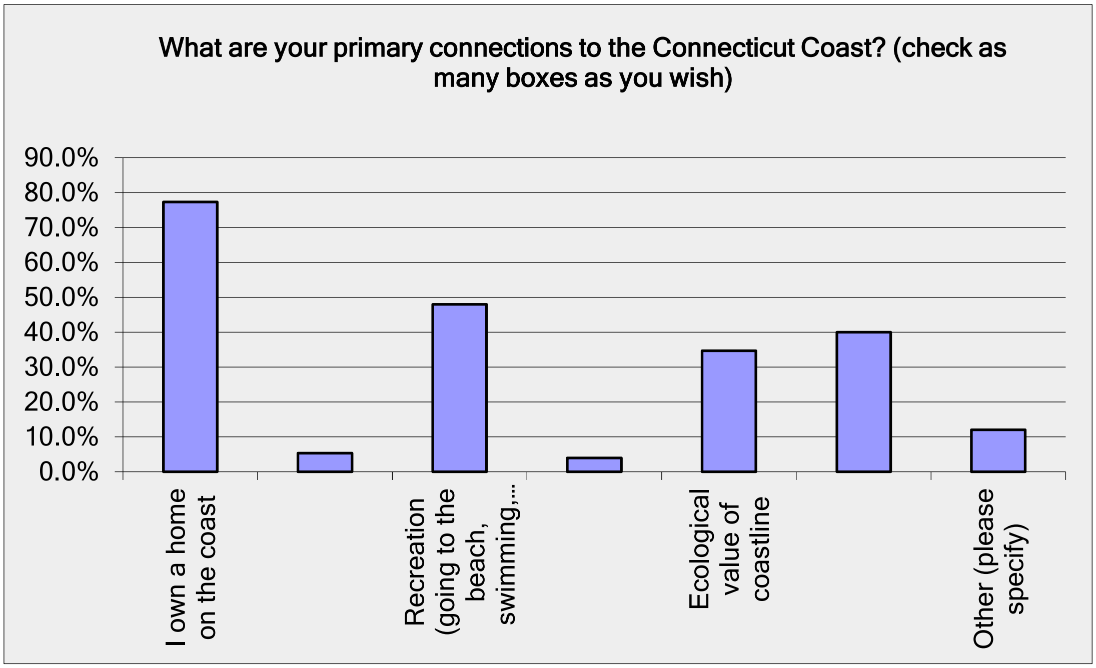
Branford Coastal Resilience

Please enter the street of your residence or place of business, or both		
Answer Options	Response Percent	Response Count
Residence	97.5%	79
Place of Business	11.1%	9
	answered question	81
	skipped question	2



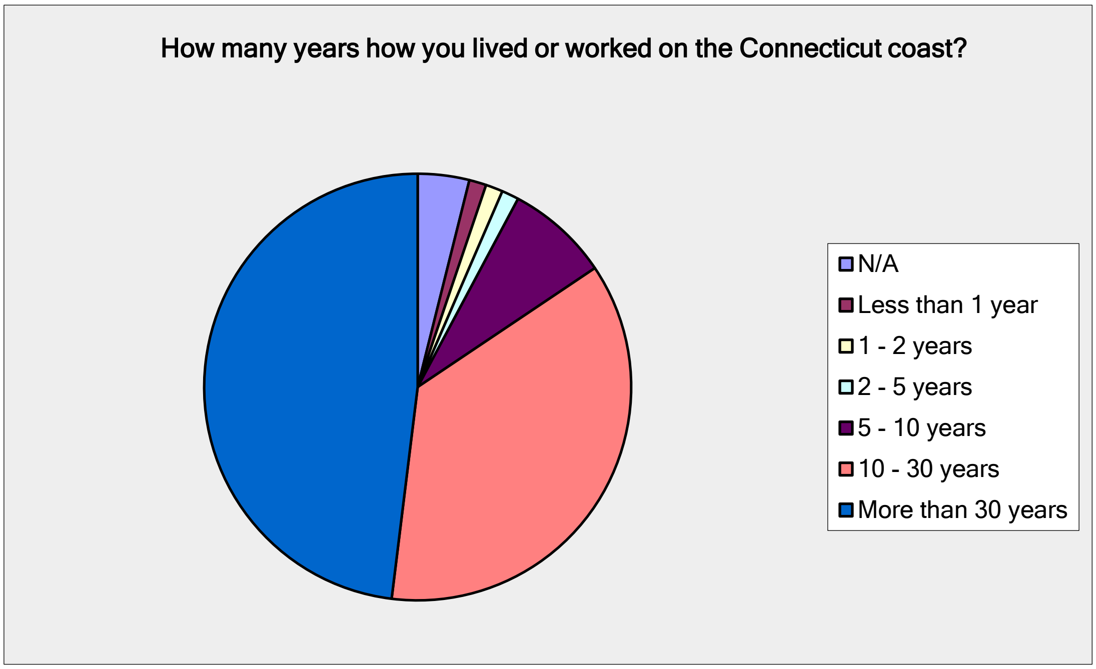
Branford Coastal Resilience

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	77.3%	58
I own a commercial property on the coast	5.3%	4
Recreation (going to the beach, swimming, boating,	48.0%	36
Income (fishing, tourism, etc)	4.0%	3
Ecological value of coastline	34.7%	26
Aesthetic (I like how it looks)	40.0%	30
Other (please specify)	12.0%	9
	answered question	75
	skipped question	8



Branford Coastal Resilience

How many years how you lived or worked on the Connecticut coast?		
Answer Options	Response Percent	Response Count
N/A	3.9%	3
Less than 1 year	1.3%	1
1 - 2 years	1.3%	1
2 - 5 years	1.3%	1
5 - 10 years	7.8%	6
10 - 30 years	36.4%	28
More than 30 years	48.1%	37
	answered question	77
	skipped question	6

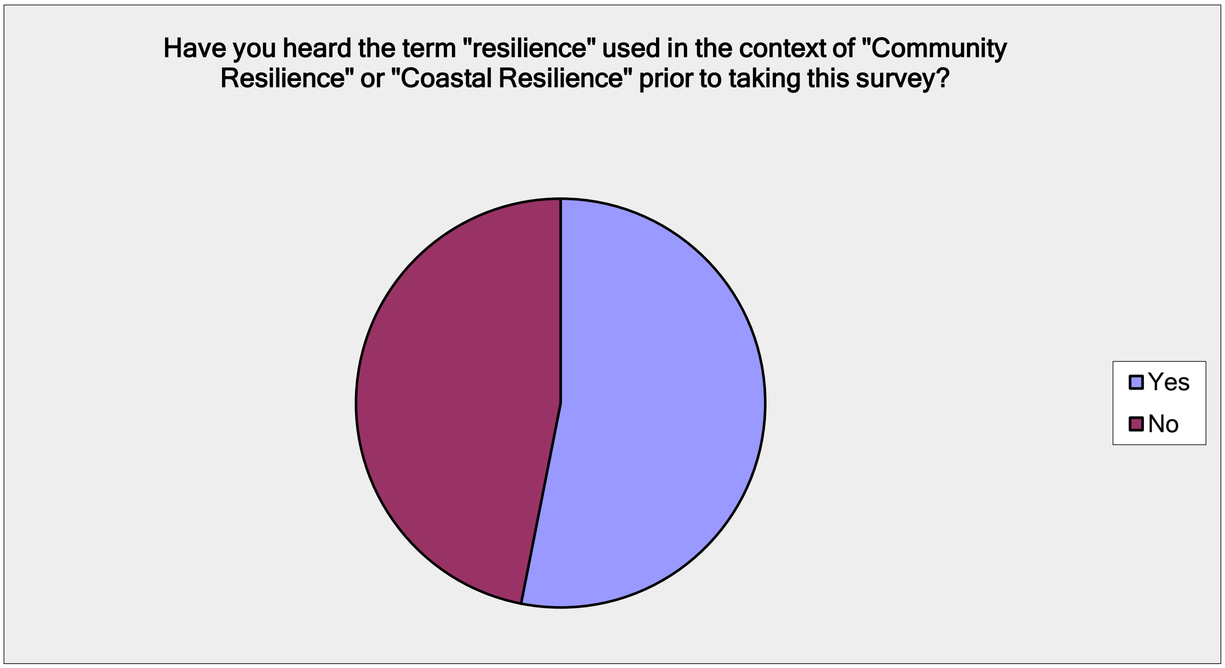


Branford Coastal Resilience

What does the term "resilience" mean to you?	
Answer Options	Response Count
	55
answered question	55
skipped question	28

Branford Coastal Resilience

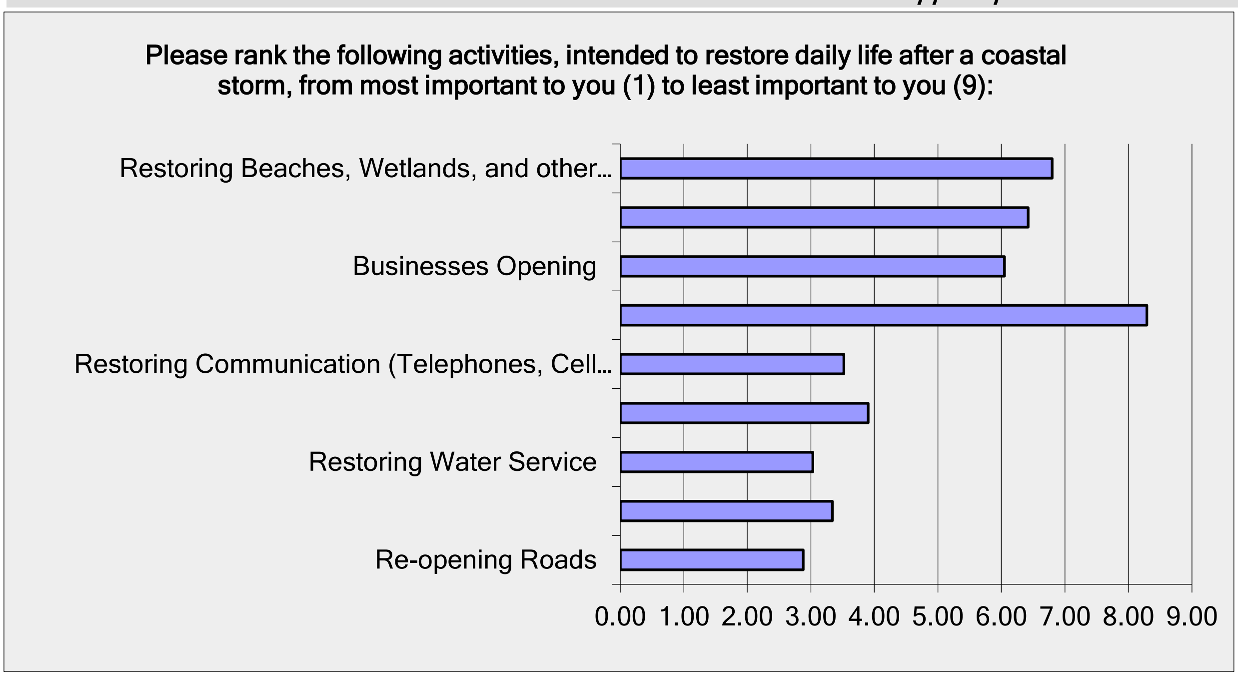
Have you heard the term "resilience" used in the context of "Community Resilience" or "Coastal Resilience" prior to taking this survey?		
Answer Options	Response Percent	Response Count
Yes	53.1%	34
No	46.9%	30
	answered question	64
	skipped question	19



Branford Coastal Resilience

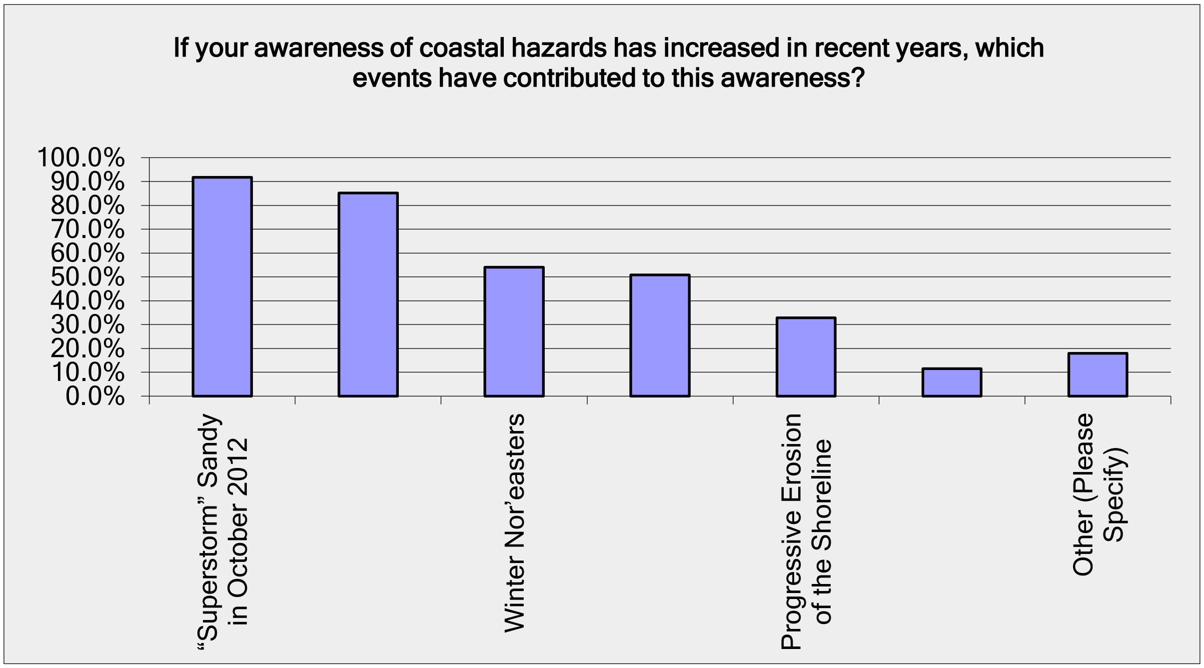
Please rank the following activities, intended to restore daily life after a coastal storm, from most important to you (1) to least important to you (9):

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
Re-opening Roads	18	13	4	13	8	1	0	2	0	2.88	59
Making my Home Livable	19	8	4	9	10	2	2	1	3	3.34	58
Restoring Water Service	7	18	15	11	5	1	1	0	1	3.03	59
Restoring Wastewater Collection and Disposal (Sewer or Septic System)	5	9	13	8	13	5	3	2	0	3.90	58
Restoring Communication (Telephones, Cell Phones, Internet)	8	8	17	9	11	7	1	0	0	3.52	61
Tourists Returning	3	0	0	1	0	1	3	4	47	8.29	59
Businesses Opening	2	2	4	4	4	18	11	17	0	6.05	62
Repairing Damaged Buildings	0	1	5	1	7	12	19	16	1	6.42	62
Restoring Beaches, Wetlands, and other Coastal Landforms	2	2	0	3	2	9	18	18	7	6.80	61
										answered question	65
										skipped question	18



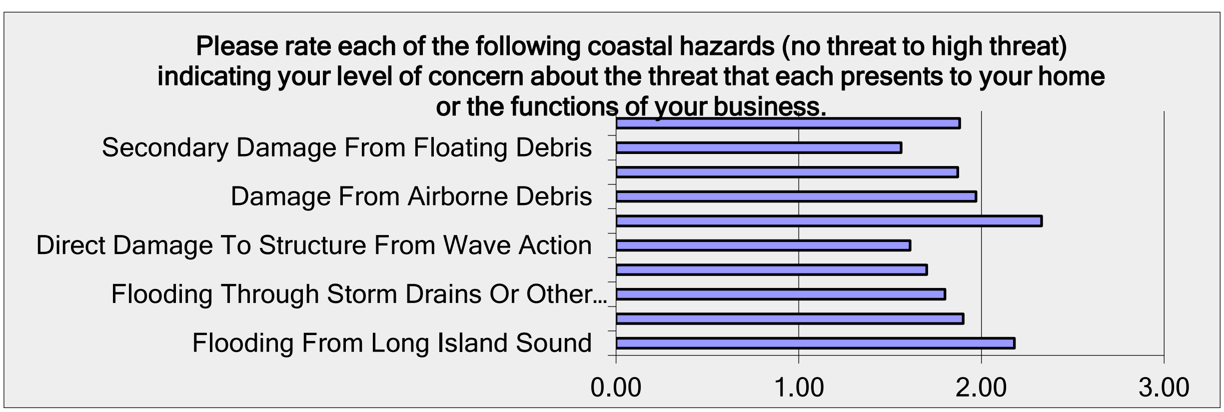
Branford Coastal Resilience

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	91.8%	56
Hurricane/Tropical Storm Irene in August 2011	85.2%	52
Winter Nor’easters	54.1%	33
High-Tide Flooding without a Storm Event	50.8%	31
Progressive Erosion of the Shoreline	32.8%	20
Significant Coastal Events outside of Connecticut	11.5%	7
Other (Please Specify)	18.0%	11
	answered question	61
	skipped question	22



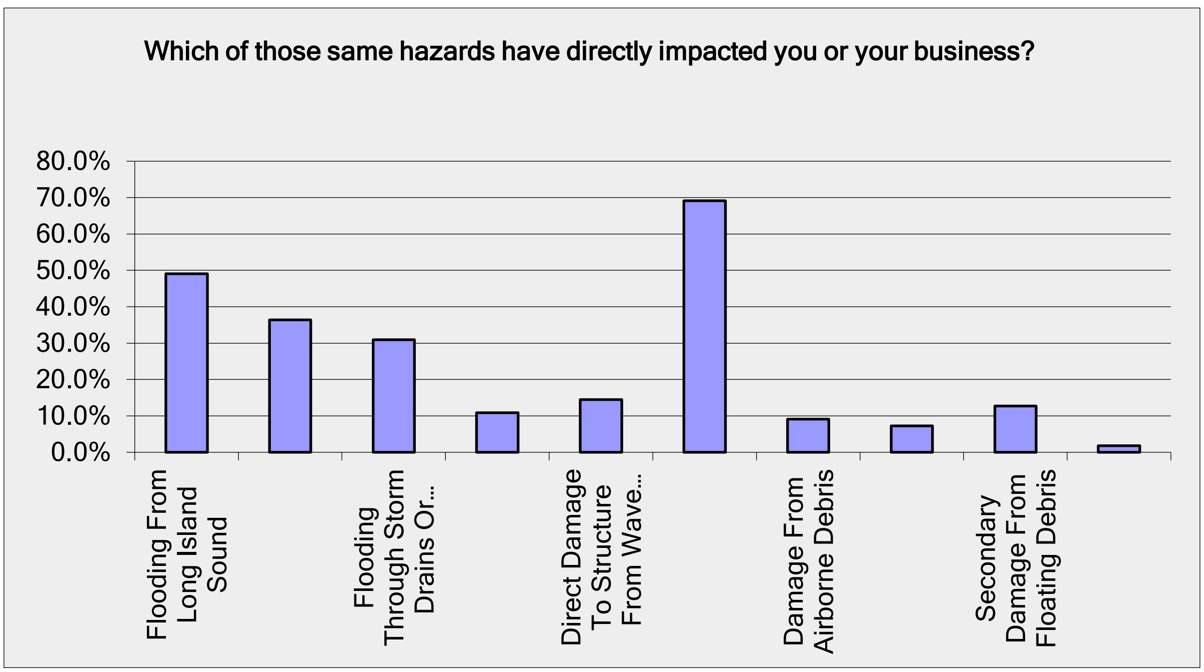
Branford Coastal Resilience

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	15	20	26	2.18	61
Flooding From Tidal Rivers And Estuaries	24	18	18	1.90	60
Flooding Through Storm Drains Or Other Drainage Infrastructure	24	24	12	1.80	60
Erosion Of Land Under Structure	27	24	9	1.70	60
Direct Damage To Structure From Wave Action	36	13	12	1.61	61
Direct Damage From High Winds	6	28	26	2.33	60
Damage From Airborne Debris	14	34	12	1.97	60
Contamination From Overflowing Septic Systems Or Wastewater Treatment Facilities	20	28	12	1.87	60
Secondary Damage From Floating Debris	32	24	5	1.56	61
Secondary Damage From Natural Gas Or Propane Leaks	16	34	9	1.88	59
Comments					5
				answered question	61
				skipped question	22



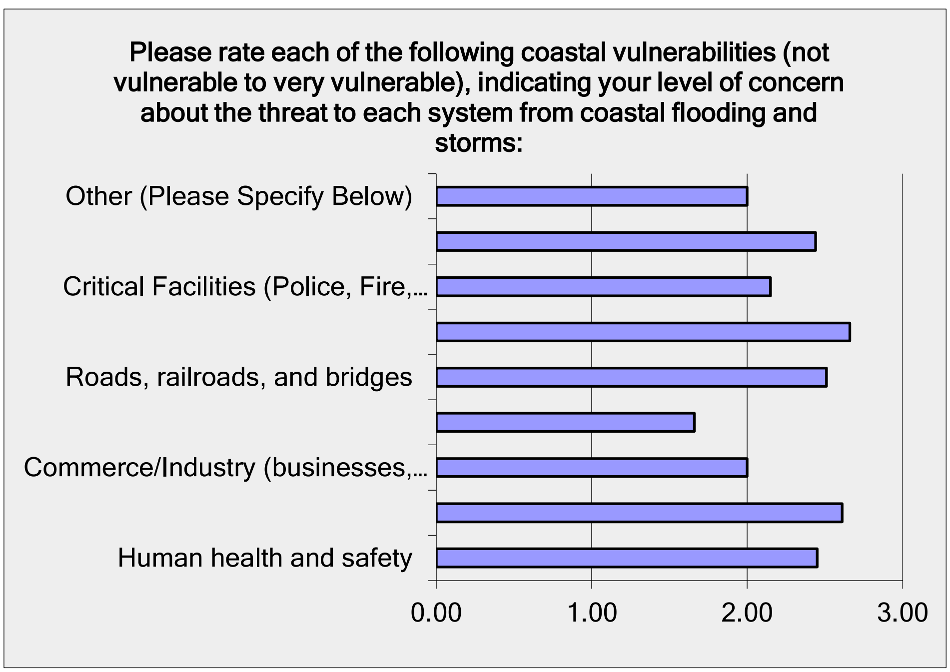
Branford Coastal Resilience

Which of those same hazards have directly impacted you or your business?		
Answer Options	Response Percent	Response Count
Flooding From Long Island Sound	49.1%	27
Flooding From Tidal Rivers And Estuaries	36.4%	20
Flooding Through Storm Drains Or Other Drainage	30.9%	17
Erosion Of Land Under Structure	10.9%	6
Direct Damage To Structure From Wave Action	14.5%	8
Direct Damage From High Winds	69.1%	38
Damage From Airborne Debris	9.1%	5
Contamination From Overflowing Septic Systems Or	7.3%	4
Secondary Damage From Floating Debris	12.7%	7
Secondary Damage From Natural Gas Or Propane	1.8%	1
Other (Please Specify)		6
	answered question	55
	skipped question	28



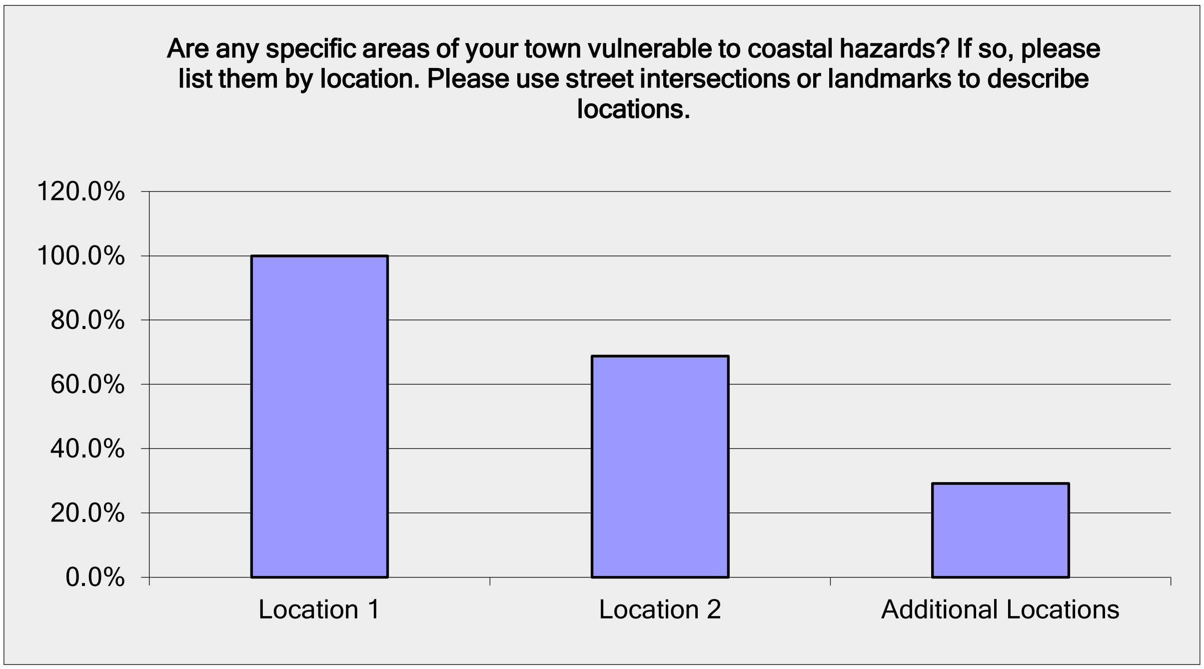
Branford Coastal Resilience

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	3	27	30	2.45	60
Homes	3	18	40	2.61	61
Commerce/Industry	10	40	10	2.00	60
Tourism	27	25	7	1.66	59
Roads, railroads, and bridges	2	26	33	2.51	61
Utilities (water, wastewater, electricity, gas,	0	21	40	2.66	61
Critical Facilities (Police, Fire, Hospitals, Shelters)	8	35	17	2.15	60
Natural Systems (Tidal Wetlands, Coastal	5	24	32	2.44	61
Other (Please Specify Below)	2	2	2	2.00	6
Comments					4
				answered question	61
				skipped question	22



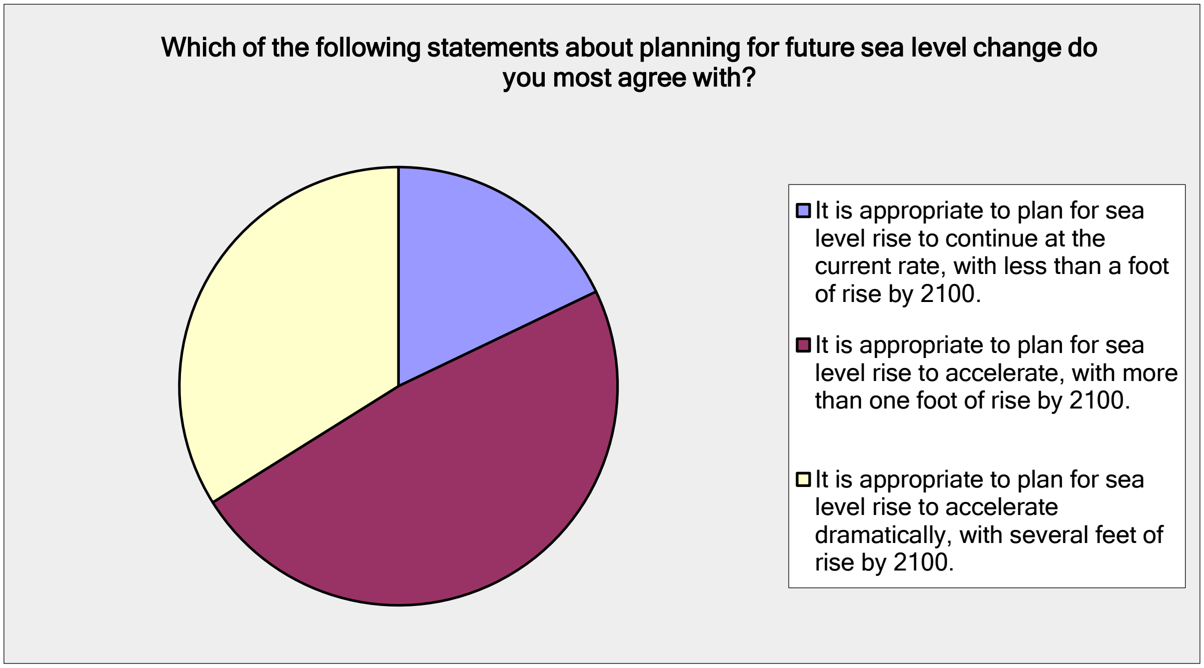
Branford Coastal Resilience

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%	48
Location 2	68.8%	33
Additional Locations	29.2%	14
	answered question	48
	skipped question	35



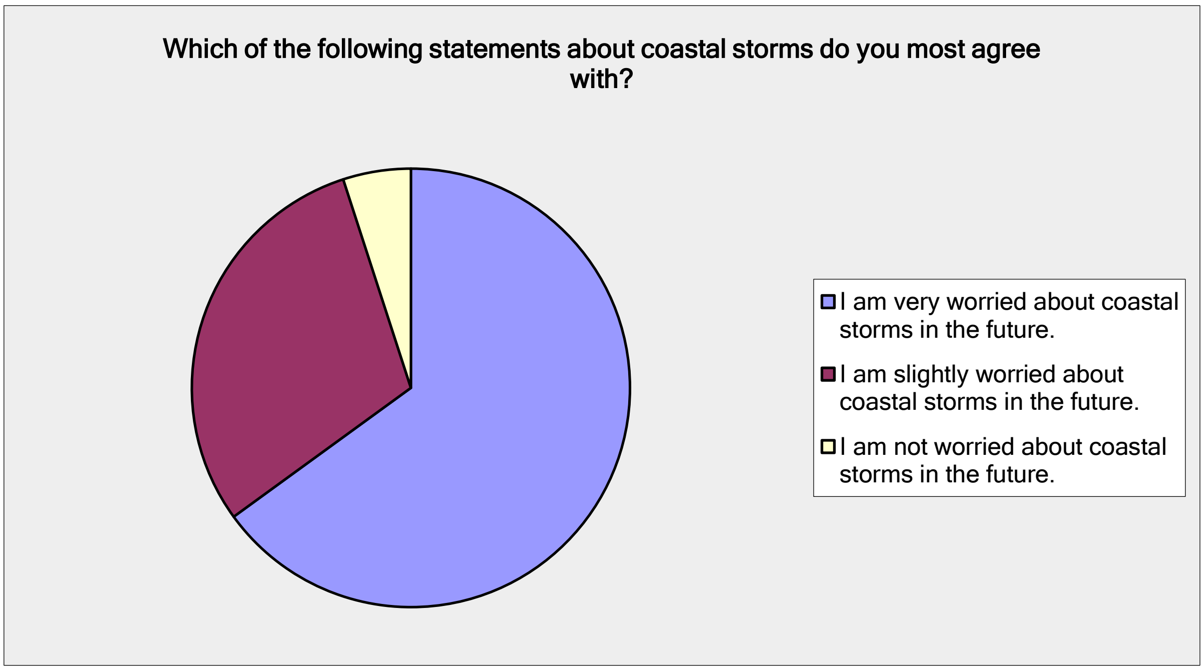
Branford Coastal Resilience

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	17.9%	10
It is appropriate to plan for sea level rise to accelerate,	48.2%	27
It is appropriate to plan for sea level rise to accelerate	33.9%	19
Comments		6
	answered question	56
	skipped question	27



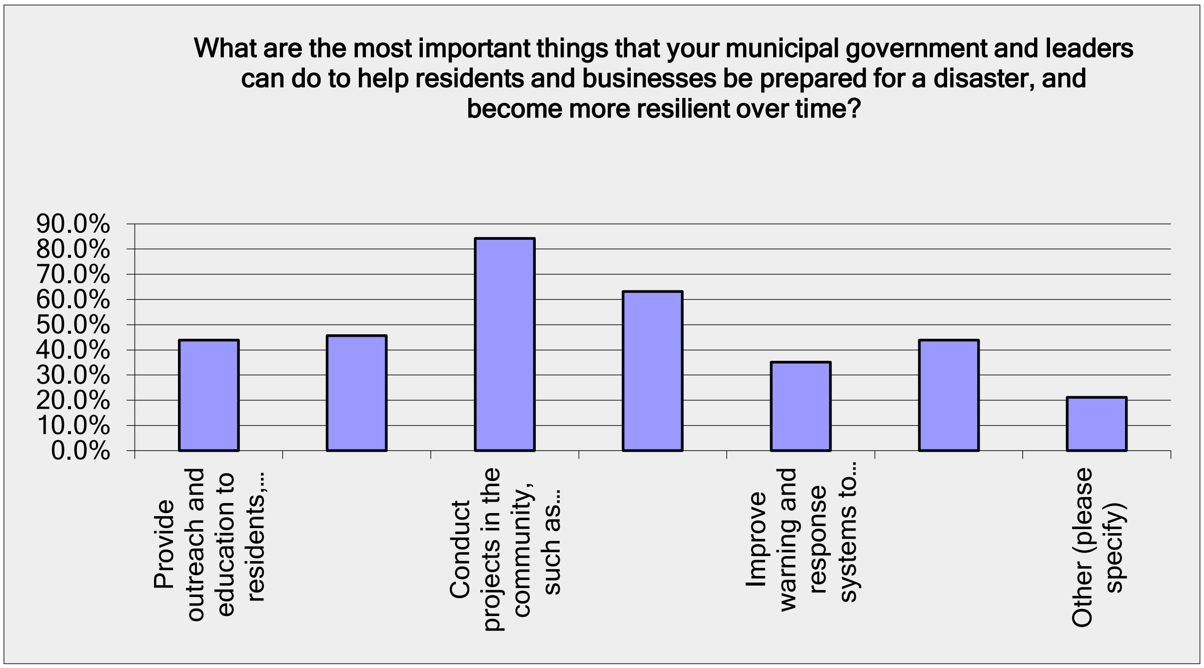
Branford Coastal Resilience

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.	65.0%	39
I am slightly worried about coastal storms in the future.	30.0%	18
I am not worried about coastal storms in the future.	5.0%	3
Comments		5
	answered question	60
	skipped question	23



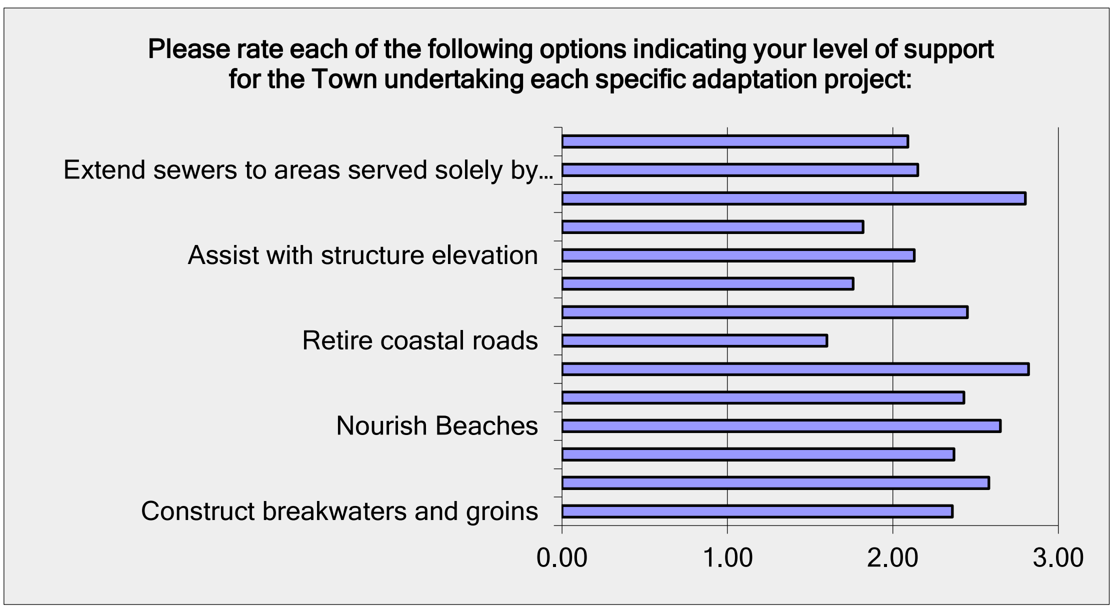
Branford Coastal Resilience

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,	43.9%	25
Provide technical assistance to residents, businesses,	45.6%	26
Conduct projects in the community, such as drainage	84.2%	48
Make it easier for residents, businesses, and	63.2%	36
Improve warning and response systems to improve	35.1%	20
Enact and enforce regulations, codes, and ordinances	43.9%	25
Other (please specify)	21.1%	12
	answered question	57
	skipped question	26



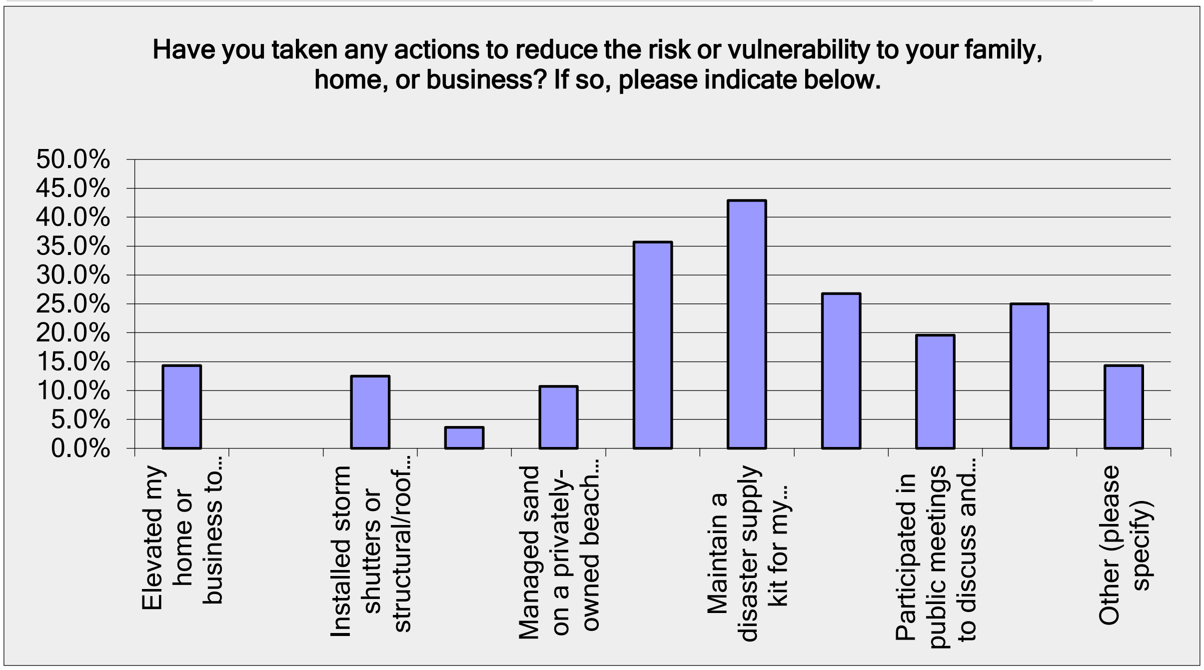
Branford Coastal Resilience

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	10	14	29	2.36	53
Restore Dunes	2	18	32	2.58	52
Create “Living Shorelines”	3	26	22	2.37	51
Nourish Beaches	1	17	36	2.65	54
Build seawalls and bulkheads	10	11	33	2.43	54
Improve drainage systems	1	8	46	2.82	55
Retire coastal roads	30	14	9	1.60	53
Elevate coastal roads	7	17	32	2.45	56
Buyout and retire coastal	29	9	16	1.76	54
Assist with structure elevation	17	12	24	2.13	53
Assist with structure relocation	22	16	13	1.82	51
Strengthen coastal utility	3	5	46	2.80	54
Extend sewers to areas served solely by septic systems	15	16	23	2.15	54
Extend water service to areas that utilize wells	14	20	19	2.09	53
Other (please specify)					6
				answered question	59
				skipped question	24



Branford 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	14.3%	8
Flood-proofed my business to reduce flood damage	0.0%	0
Installed storm shutters or structural/roof braces to	12.5%	7
Replaced my overhead utility lines with underground	3.6%	2
Managed sand on a privately-owned beach to reduce risk	10.7%	6
Developed a disaster plan for my family, home, or	35.7%	20
Maintain a disaster supply kit for my family, home, or	42.9%	24
Participated in public meetings to discuss the Plan of	26.8%	15
Participated in public meetings to discuss and approve	19.6%	11
I have not taken any of these actions	25.0%	14
Other (please specify)	14.3%	8
	answered question	56
	skipped question	27



Branford 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
	40
answered question	**40**
skipped question	**43**

Branford Coastal Resilience

Please provide any additional comments or questions to be addressed as the Coastal Resilience Plan is developed:	
Answer Options	Response Count
	16
answered question	16
skipped question	67

Branford 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	100.0%	28
Email Address	100.0%	28
	answered question	28
	skipped question	55