SOUTHEASTERN CONNECTICUT
REGIONAL FRAMEWORK
*for*
# COASTAL RESILIENCE
## FINAL REPORT

JUNE 2019

The Nature Conservancy

# Acknowledgements

The Nature Conservancy in Connecticut sincerely thanks those individuals and organizations that contributed to the success of the development of the Southeastern Connecticut Regional Resilience Vision and Regional Resilience Framework. First and foremost, we would like to thank the many municipal officials who were immensely helpful as we developed the Regional Resilient Project Catalog. Thank you all for your willingness to field our questions, meet on site, and provide constructive feedback on this work. Thank you as well to the staff and volunteers from Southeastern Connecticut Council of Governments, the Eastern Connecticut Conservation District, Connecticut College Arboretum, Friends of Ocean Beach, Avalonia Land Conservancy, and others, who helped with project identification and site tours.

For the conceptual designs, we enjoyed expert support from Todd Bobowick at the Natural Resources Conservation Services and Judy Rondeau from the Eastern Connecticut Conservation District. Thank you for your time and patience with our questions. Thank you to the staff at EcoPolitan Design for your expertise and creativity in partnering on developing groundbreaking resilience conceptual designs. Thank you to the staff and students at The Conway School, who worked tirelessly and creatively to set the Town of Stonington up for project success.

We would like to also acknowledge the commitment of our partners at the Southeastern Connecticut Enterprise Region (seCTer). Nancy Cowser and Melinda Wilson who have ably led the charge for the Regional Resilience Working Group and their enthusiasm for the work will continue to foster resilient growth in the communities of southeastern Connecticut. Additionally, we would like to thank the members of the Working Group, who took time out of their busy schedules to think through these difficult and urgent questions facing the region. Your assistance reviewing project descriptions, evaluating Plans of Conservation and Ddevelopment (POCD), and furthering the cause of resilience were invaluable.

Finally, we would like to especially thank The Community Foundation of Eastern Connecticut. Without your continued guidance and support, this important work would not be possible.


# Executive Statement

The Nature Conservancy in Connecticut spearheaded the Southeastern Connecticut Regional Framework for Coastal Resilience process in response to the growing threat of extreme weather, climate change, and socio-economic challenges in southeastern Connecticut. The project's aim was to create and support initiatives that provide proactive risk assessment, community resilience building, and conceptual design of catalytic, on-the-ground resilience-based projects. By doing so, the hope of the project's Core Team is to enable more integration of existing and future ecosystems into long range planning that can reduce risk and improve resilience for southeastern Connecticut.

This work extends a regional vision process conducted from 2016-2017. The previous effort convened over 100 partners from government, business, academia, non-profit organizations, and residents. Many of the recommendations from the regional resilience visioning process made their way into the Regional POCDs and the Comprehensive Economic Development Strategy (CEDS). The Southeastern Connecticut Enterprise Region (seCTer), who produced the CEDS worked closely with the Nature Conservancy to kick-start a Regional Resilience Working Group that advanced the recommendations in both the CEDS and the Regional Resilience Framework.

To help facilitate local, regional, and statewide collaboration on resilience, the Nature Conservancy extended an existing mapping effort to catalog important resilience-building projects throughout the municipalities along the state's coastline. Additionally, the Core Team developed conceptual designs that advance site-specific, catalytic resilience projects representative of challenges and solutions envisioned across many municipalities, regions, and state. Ultimately, the Core Team hopes this project will lead to prioritization and implementation of more resilient actions taken and more enthusiasm across communities for finding solutions to reducing vulnerabilities and reinforcing strengths to routine and extreme weather events as well as climatic change across Connecticut's coastal areas and beyond.

# Citation


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Community Resilience Building – www.CommunityResilienceBuilding.org.

PHOTO CREDIT: Susan Rubinsky

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# Executive Summary

Tropical Storms Irene and Sandy awoke many in the communities of southeastern Connecticut to the significant risk posed to local infrastructure, ecosystems, economies, and societal fabrics by extreme weather and accelerating changes in climate such as sea level rise, extended heatwaves, and intense precipitation and wind event. To address and broaden the collective dialogue on these vulnerabilities and existing strengths, the Nature Conservancy in Connecticut (TNC) launched the Southeastern Connecticut Regional Framework for Coastal Resilience. The Regional Resilience Framework prepares the ground for strategic action by assessing existing projects in the communities of southeastern Connecticut and by strengthening partnerships developed during the Southeastern Connecticut Regional Resilience Visioning process in 2016-2017 (a precursor to the Regional Resilience Framework reported herein)[1]. The overarching goal of this Regional Resilience Framework building process was to help prioritize potential actions and strengthen partnerships by providing proactive risk assessment, community engagement, and conceptual design of catalytic, on-the-ground projects. All of which is summarized and integrated within this Final Report.

This Southeastern Connecticut Regional Resilience Framework consists of four components. For the first component, the TNC Core Team inventoried resilience opportunities across nine municipalities in southeastern Connecticut. This involved highlighting opportunities for natural infrastructure to help enhance existing habitats, improve public amenities, and reduce risk from hazards over immediate and longer-term horizons(i.e. Resilient Triple Bottom Line)[2]. The Core Team worked with professional and student designers in the second component to advance several of these projects via conceptual design development. For the third component, the Core Team partnered with the Southeastern Connecticut Enterprise Region (seCTer) to continue the 2016-2017 Regional Resilience Visioning dialogues via a Regional Resilience Working Group format. The meetings of this Working Group provided a venue to identify and address short, discreet actions to improve regional resilience through collaboration. The following Regional Resilience Framework Final Report for southeastern Connecticut comprises the fourth and final component. In this report, the reader will find the methods and results from the first three components as well as the environmental, policy, and strategic context for this work.

Representatives from municipalities, non-profit organizations, regional entities, academic institutions, neighborhoods, and businesses provided invaluable wisdom and input throughout the process that shaped this Regional Resilience Framework into what it is today. The Core Team sincerely hopes that the process and reports generated will help members of these communities' secure greater clarity on the common challenges they face while providing a positive vision for continued dialogue, resource sharing, and collaborative leadership needed to create a truly resilient region in southeastern Connecticut.


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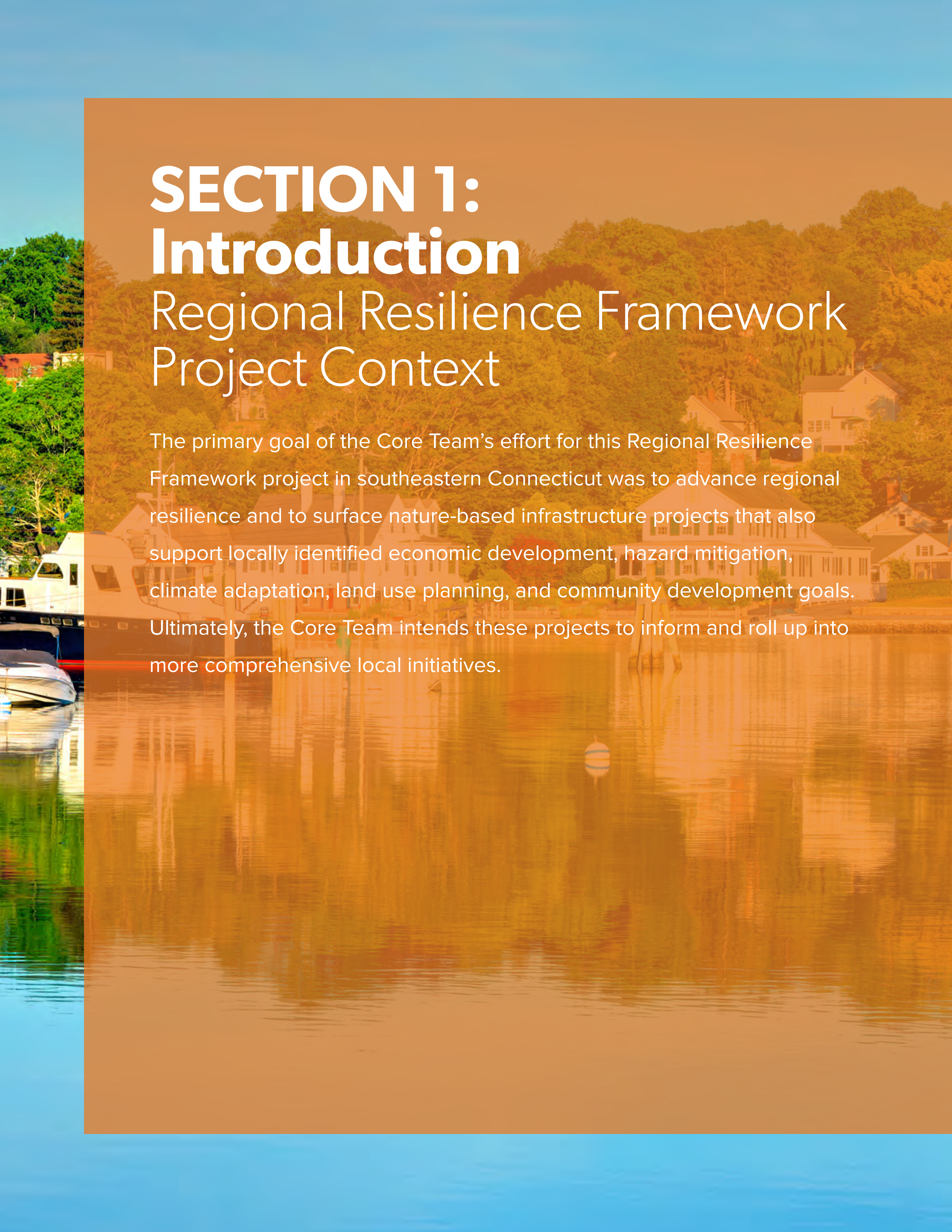


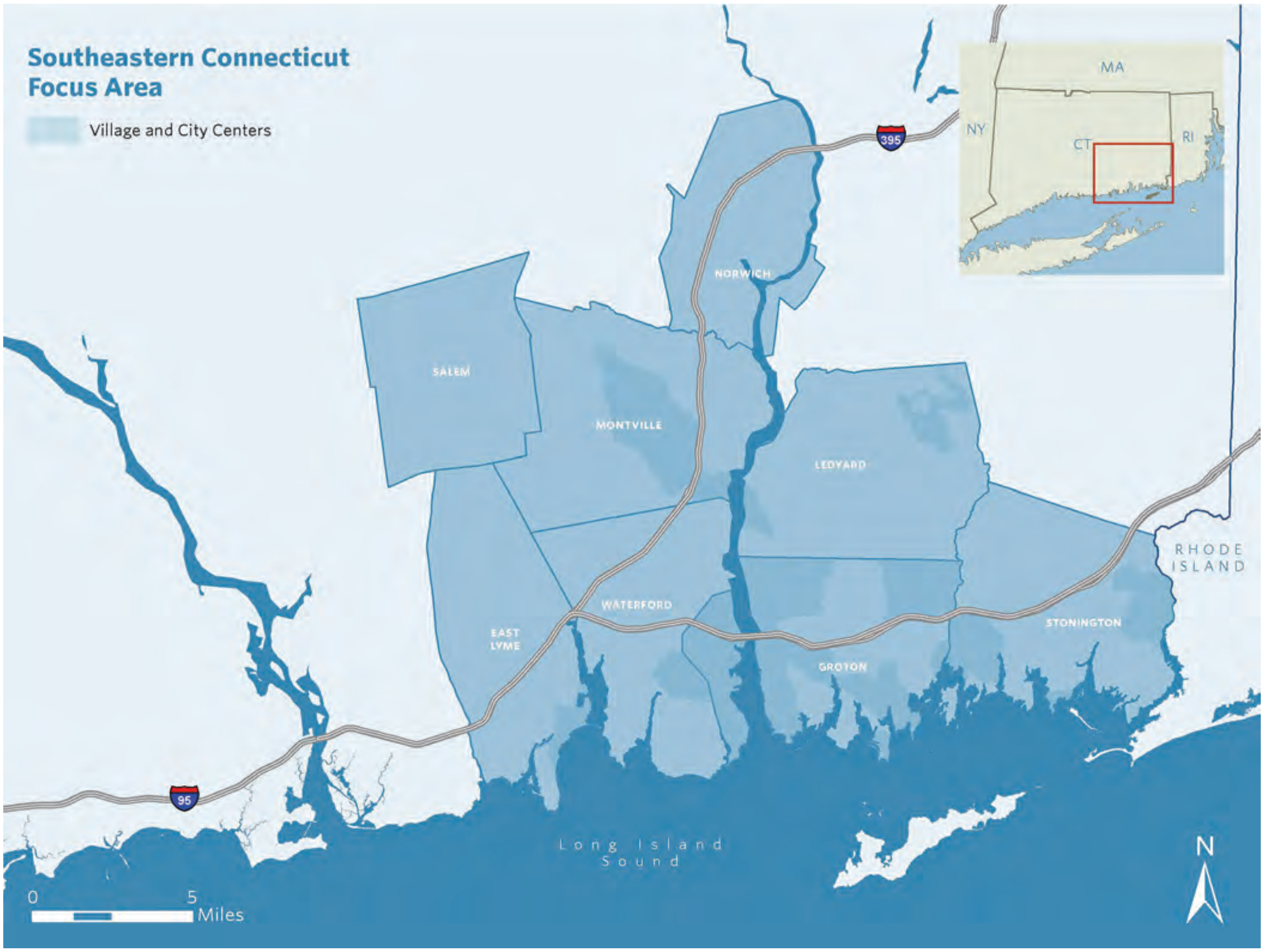
# SECTION 1: Introduction

## Regional Resilience Framework Project Context

The primary goal of the Core Team's effort for this Regional Resilience Framework project in southeastern Connecticut was to advance regional resilience and to surface nature-based infrastructure projects that also support locally identified economic development, hazard mitigation, climate adaptation, land use planning, and community development goals. Ultimately, the Core Team intends these projects to inform and roll up into more comprehensive local initiatives.

Geographically, the Southeastern Connecticut Regional Framework for Coastal Resilience encompasses the state of Connecticut's southeastern coast including the municipalities, from west to east, of East Lyme, Waterford, New London, City of Groton, Town of Groton, and Stonington, as well as the inland communities of Salem, Montville, Norwich, and Ledyard (Map 1) that intersect with fourteen individual watersheds (Map 2). The nine municipalities are represented by the Second U.S. Congressional Districts in Connecticut and are serviced by the Southeastern Connecticut Council of Government (SCCOG). This project area encompasses 214,611 residents or 7% of Connecticut's population. The Southeastern Connecticut Regional Framework for Coastal Resilience builds upon the Southeastern Connecticut Regional Resilience Vision Project which was completed in 2017. That Regional Resilience Visioning project convened over one hundred professionals from a wide range of disciplines working within and across the nine municipalities. Over the course of four workshops and a dozen meetings, the participants clarified the greatest challenges and opportunities for the region within and across six planning sectors including water, food, ecosystems, energy, transportation, and the regional economy. Many of the findings from these workshops were incorporated into the 2017 Regional Plan of Conservation and Development published by Southeastern Connecticut Council of Governments (SCCOG) and the 2017 Comprehensive Economic Development Strategy published by the Southeastern Connecticut Enterprise Region (seCTer).

In addition to local initiatives, the Southeastern Connecticut Regional Resilience Framework for Coastal Resilience draws heavily on the Southern Connecticut Regional Framework for Coastal Resilience undertaken in New Haven and Fairfield Counties by TNC, South Central Regional Council of Governments, and Connecticut Metropolitan Council of Governments[3,4].

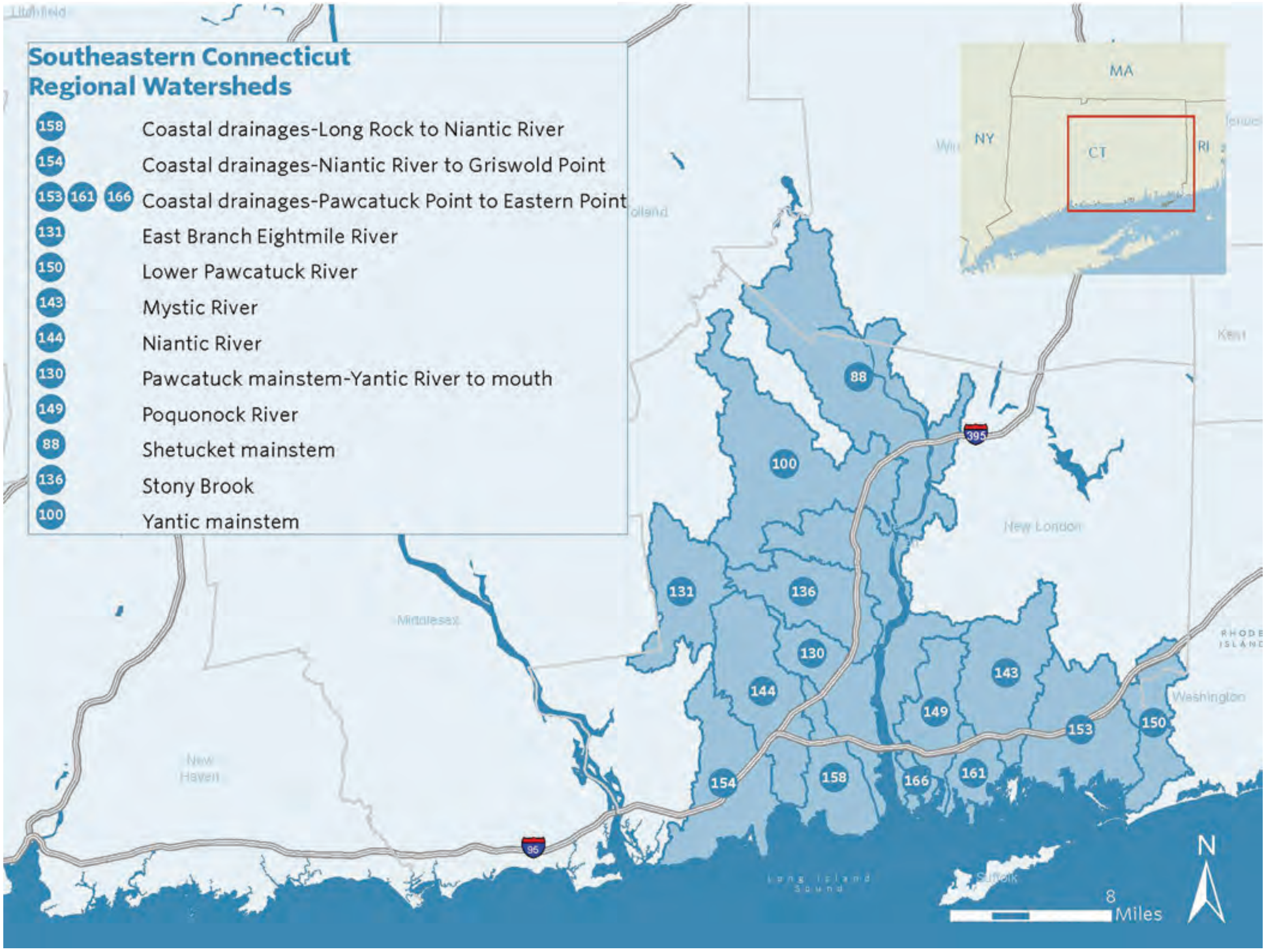



Map #1: Southeastern Connecticut Regional Framework for Coastal Resilience Focus Area

# Overview

As recently demonstrated during Tropical Storm Irene (August 2011) and Sandy (October 2012), Connecticut's communities are significantly vulnerable to extreme weather events, sea level rise, flooding, erosion, inland flooding, and coastal change. All nine of the municipalities in the project area suffer from flooding of roadways, damage to houses and other structures, and destabilization of coastal and inland natural resources. In addition, extreme temperatures due to cold snaps and heatwaves are a reoccurring and growing concern for these municipalities and the region.

In response to previous and potential natural hazards, municipalities, Council of Governments (COGs), and other partner organizations desire resilient infrastructure improvement considerations in planning documents including Plans of Conservation and Development, Hazard Mitigation Plans, Harbor Management Plans, Shellfish Commission Plans, Watershed Plans, Capital Improvement Plans, public health/social services plans, complete streets plans, transportation and mobility plans, and environmental restoration plans. While these documents comprehensively cover their geography and discipline of focus, they do not always fully connect the dots across plans and projects. As a result, municipalities and organizations can miss opportunities to collaborate on projects that may create multiple benefits to residents, built environment, and ecosystems. For instance, flooding over a road and intersection could be alleviated by localized green stormwater infrastructure and/or an upstream floodplain restoration. However, if public works officials are unaware of the interest by ecosystem restoration/watershed groups in this restoration project, they may not consider this in the design concept and project implementation at the flooded intersection. Likewise, a conservation group pursuing a living edge project may benefit from knowing that the adjacent marina is planning for erosion control to protect its structures and realize an opportunity to collaborate towards common outcomes. In addition, the time lag between plan updates can take many years,




Map #2: Southeastern Connecticut Regional Resilience Framework for Coastal Resilience Project Area Watersheds which presents another shortcoming of the traditional planning process. Municipal officials and organization staff reading each other's documents may be unsure if and how individual projects are progressing, or not. This uncertainty may confound collaboration efforts and more regionalized approaches to leveraging resources, managing risk, and promoting resilience.

To address these issues among others, the Core Team aimed to consolidate all site-specific, resilience-related projects across planning documents into a single, regional, geospatial database and subsequent, online Regional Resilience Project Application hosted on Coastal Resilience (www.coastalresilience.org) – a public-facing, freely accessible website. This database and the Regional Resilience Project "App" are the first steps towards promoting cross-boundary and cross-discipline resilience actions. Municipalities can and are leveraging this resource to highlight and prioritize projects with regional significance (i.e. a flooded road through vulnerable salt marshes that could restrict access to an important economic and social center), while local, non-governmental organizations and academic institutions may find this database and App useful and usable when searching for local projects that advance their mission. The Southeastern Regional Resilience Projects Database and App expands upon an existing effort by TNC and COGs to catalogue projects for all Connecticut's coastal communities. With this full collection of projects in hand, the various municipalities, agencies, and organizations within the state are now better situated to collaborate on and advance necessary and catalytic resilience projects.

In a heavily developed coastline like Connecticut, rarely can communities avoid the impacts of sea level rise, coastal storms, and inland flooding through fullscale shoreline relocation and/or realignment. One cannot wipe the slate clean as it were of 350 hundred plus years of settlement history, property rights, landscape alterations, and sociological and cultural evolution. Adaptation requires truly innovative design and creative land use planning within robust, diverse, and equitable teams focused on community engagement to derive meaningful solutions. This Regional Resilience Framework therefore focused on collaboratively cataloguing all potential resilience projects and designing high-priority projects identified and generated by the communities themselves. Advancing priority projects to implementation will ultimately help to minimize the consequences of extreme weather and climate change in the communities of southeastern Connecticut which is an important coastal corridor of the United States Eastern Seaboard. At the same time, these projects will strengthen the resilience of existing and future natural ecosystems within an increasingly urbanized landscape.

# REGIONAL RESILIENCE FRAMEWORK: Objectives, Project Components, Outputs

## Objectives

A principle objective of this Regional Resilience Framework process was to enhance regional resilience and to comprehensively catalogue, assess, prioritize, and design resilience projects to help reduce risk to the 214,611 residents (7% of Connecticut's current population) across nine municipalities and increase the viability of natural resources along approximately 25% of Connecticut's coastline. The Core Team executed four phased and reinforcing project components as follows:

## Project Component #1: Field Reconnaissance, Catalogue, Geospatial Database

Conduct a resilient project assessment for the entire coastline and associated watersheds for southeastern Connecticut (East Lyme, Waterford, New London, Groton, Stonington, Salem, Montville, Norwich, Ledyard) (see Map 1 and 2). This assessment categorized projects by type, strategy, objective, and municipality as well as highlighted opportunities to implement natural/green infrastructure or to enhance grey infrastructure projects with hybrid systems. This assessment has and will continue to help inform future management, policies and practices within and across the region via this Regional Resilience Framework. **Outputs and Outcomes:** A detailed geospatial dataset cataloging resilience-based projects for southeastern Connecticut. All nine municipalities in the study area as well as several advisory organizations reviewed and contributed to the project dataset. Additionally, the Core Team integrated additional data from the CT DEEP's Natural Diversity Database (NDDB), FEMA's Flood Insurance Rate Models (DFIRM), and HUD's Low to Moderate Income Areas (LMI). The final dataset of resilience projects was added to a larger geospatial database including Southern and Southwestern Connecticut on the public-facing Coastal Resilience (www.CoastalResilience.org) mapping portal (see APPENDIX H for further information and user guidance).

## Project Component #2: Regional Resilience Working Group

Host a Regional Resilience Working Group in partnership with the seCTer to sustain and accelerate a growing conversation on climate adaptation amongst land use planners, economic development professionals, emergency managers, environmental professionals, and others. The Working Group provided a high energy, action-oriented, collaborative environment where manageable issues related to resilience in southeastern Connecticut were raised and advanced – largely packaged in tasks completed in 90 minutes. **Outputs and Outcomes:** Working Group meetings convened a dedicated cohort of land use planners, economic development specialists, environmental professionals, and others to advance tasks within a wide range of resilience-related tasks. Tasks included reviewing economic resilience toolkits, strategizing on outreach efforts to local businesses, reviewing the resilience project database (Project Component #1 above), and analyzing local Plans of Conservation and Development for resilience integration opportunities.

## Project Component #3: Conceptual Designs

Scope and design highest priority natural/green infrastructure projects to help reduce risk and improve resilience in the municipalities in the project area. This involved contracting with a design firms and teams of graduate students to develop conceptual design plans for instructive and catalytic local projects with regional resilience impact. **Outputs and Outcomes:** Final conceptual design plans for catalytic resilience projects that were collaboratively developed to generate momentum to further advance nature-based solutions to reduce risk for communities, improve public amenities and quality of life, and strengthen ecosystems (i.e. “resilient triple bottom line”). These included a design for the Lake George wetland in Washington Park (City of Groton), a parking lot resiliency design for the Esker Point Park (Town of Groton), and two resilience improvement projects (coastal and inland) in downtown Mystic (Stonington).

## Project Component #4: Final Report

The final project component (herein) integrates Project Components #1, #2, and #3 as core elements of this Final Report. This Final Report serves as an immediate and long-term guide for future natural hazard mitigation, comprehensive plans, and capital expenditures within and across the nine municipalities that can advance this Regional Resilience Frameworks as well as similar endeavors elsewhere in the state of Connecticut, and beyond.

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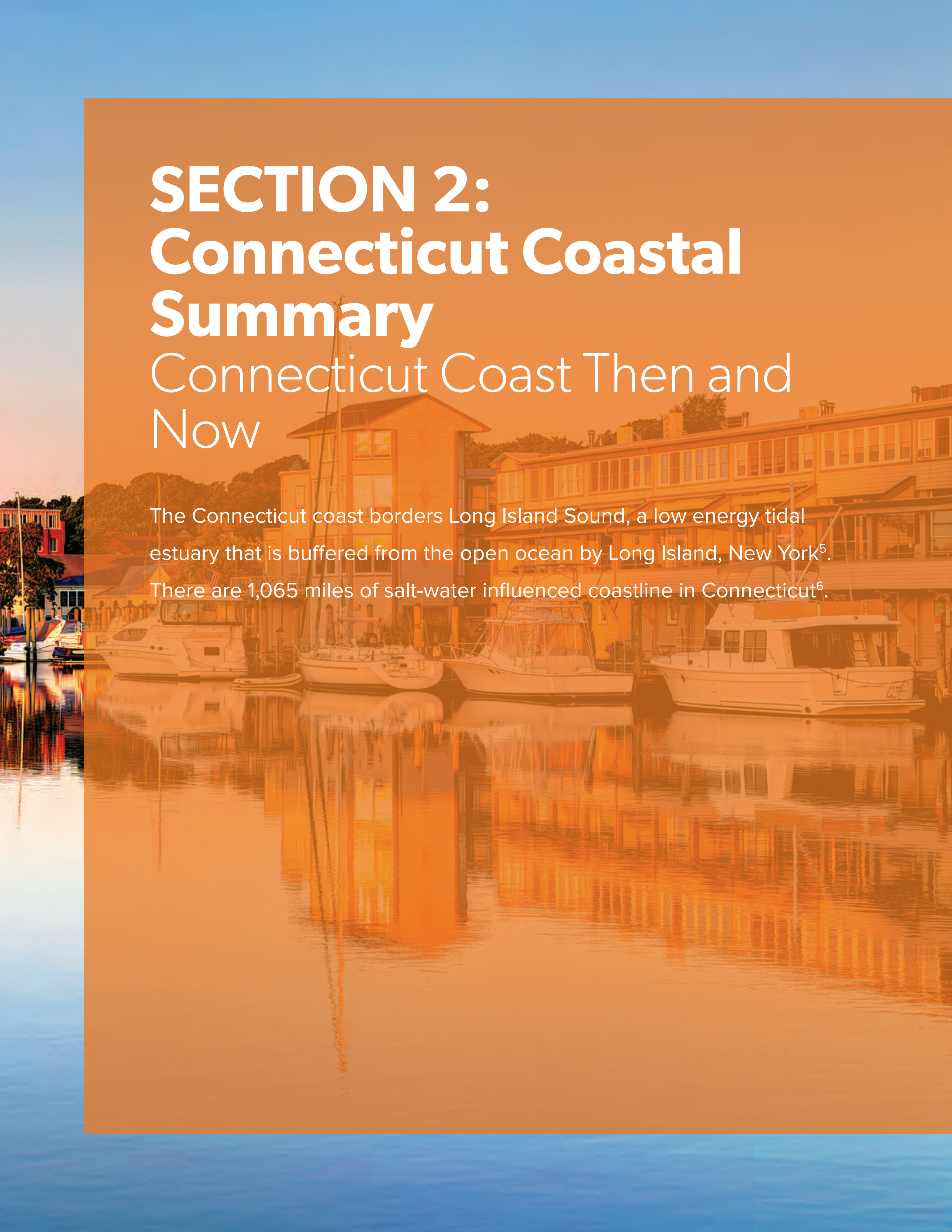


# SECTION 2: Connecticut Coastal Summary

## Connecticut Coast Then and Now

The Connecticut coast borders Long Island Sound, a low energy tidal estuary that is buffered from the open ocean by Long Island, New York[5]. There are 1,065 miles of salt-water influenced coastline in Connecticut[6].

## Geologic History

Glaciation and changes in sea level have sculpted the Connecticut coastline over the last 100,000 years. Around 20,000 years ago the glaciers began to retreat from Connecticut. Various types of sediment and rock that define the current surficial geology of the state were deposited. Fine sediments, created from sedimentary and igneous bedrock, were deposited in the central portion of the state while the eastern and western portions received consolidated and hard sediments from metamorphic bedrock[7].

In some areas, the retreating glaciers created high, inverted, spoon-shaped formations. These formations, or drumlins, are higher than the surrounding topography, making these areas less susceptible to damage from storms and sea level rise. Black Point in East Lyme and West Mystic in Groton are some examples of drumlins in the study site[8].

As the glaciers melted, sea level began to rise. The retreating glaciers created Lake Connecticut in what is currently Long Island Sound. The terminal moraine (an accumulation of glacial debris at the point of furthest glacial advancement) separated Lake Connecticut from the open ocean. As sea level continued to rise, it eventually surpassed the moraine and tidal currents entered Lake Connecticut and created the tidal estuary known as Long Island Sound[9].

In Long Island Sound, tidal forces and rising seas reshaped Connecticut's shoreline. Tidal action eroded sections of the shore, moving the sediment to other regions on the Connecticut coast that developed into beaches. Between 1,500 and 2,000 years ago, slow rising seas gave rise to inter-tidal salt marshes[10]. Salt marshes are established when rates of accretion, deposits of inorganic material and build up from decaying marsh vegetation, outpace sea level rise. These unique ecosystems offer numerous environmental and hazard mitigating benefits. Fish use them as nurseries, salt marsh plants clean water entering the Sound, and marshes themselves dampen waves during storms. When outpaced by sea level rise, marshes become submerged and/or eroded. Currently, as sea level rise continues to accelerate, marshes are beginning to be outpaced and may soon suffer substantial losses along the Connecticut coast unless afforded opportunities for advancement into upland areas[11, 12, 13].

## Colonial History

When European settlers began inhabiting the region in the 17th century, they began to modify the environment and terrain. Dams were constructed on rivers for mill operations which impeded the flow of freshwater to the Sound and the migration of many fish species. Salt marshes were initially hayed and later ditched to drain water and increase marsh hay yields.

Salt marshes were also filled to increase the amount of developable land on the coast. Much of this filling took place during the development of the railway in the 1800s, and the interstate system in the mid-1900s. These areas were often filled with polluted material and are now susceptible to inundation from storms and sea level rise. The Poquonnock Plains, site of present day's Groton-New London Airport, relate a complex history of salt marsh conversion. As a flat, lowland, this area was used for agricultural production by colonial settlers and likely earlier. In 1904, the Shoreline Railroad opened, bisecting the agricultural fields and introducing additional fill material. With the construction of an

*Figure 1: Aerial imagery of Groton-New London Airport in 1934 (left) and 2018 (right). Note the Shoreline Railroad and conversion of low-lying areas to agricultural fields.*

army base and hard-surfaced runways in 1942, much of the remaining channels and pools were filled (Figure 1: Aerial imagery of Groton-New London Airport in 1934 (left) and 2018 (right). Note the Shoreline Railroad and conversion of low-lying areas to agricultural fields.

Tide gates were installed throughout the coast to drain marshes and power coastal mills. These tide gates allow water to flow in and restrict flow at high tide. The water is returned to the Sound through a narrow channel or mill waterwheel. This slow return of water often caused prolonged inundation of salt marshes and resulted in extensive vegetation change. While the tidal mills have been removed, the tidal gates are still present in many communities, impacting the tidal flow[14].

The shoreline was heavily developed during the last century. Not only did the construction of transportation facilities fill in marshes, but it also created a barrier between the Sound and many coastal communities. Coastal properties were prime development areas for real estate and most of the Connecticut coastline is lined with houses. This shoreline development not only creates hazards for the individuals living there but also prohibits natural advancement of coastal features inland.

Coastal protection became a priority during the environmental movement of the 1960's and 1970's. The Tidal Wetlands Act of 1979 prevented the further destruction of Connecticut's remaining marshes[15]. Other conservation movements and changes in local zoning and building requirements have deterred further construction on the shoreline.

# Geomorphology of Connecticut's Coast

## Driving Factors

Connecticut's coast borders Long Island Sound, a tidal estuary buffered from the open ocean by Long Island, New York. Due to reduced fetch (distance traveled by wind or waves over open water), waves in Long Island Sound are characteristically short and steep and are derived from local winds[16].

Long Island Sound has a semi-diurnal tide cycle, in which there are two high tides and two low tides every 24 hours and 50 minutes. The geomorphology of Long Island Sound creates a funneling effect that produces higher tides on the western shore. The mean high tide varies from 2.6 feet in the east to 7.2 feet in the west[17]. The mean spring tide has an even higher variance, from 3.1 feet in the east to 8.3 feet in the west. This funneling effect also amplifies surges from tropical events, making the western coast more susceptible to damage.

Sediment transport along the Connecticut coast is variable and localized. Beaches separated by a headland experience different impacts of longshore transport. Sediments deposit on the eastern side while the western side is sediment starved and erodes. Although sediment transport is localized, it is often consistent through time. From a hazard management perspective, proper management and functioning of erosion control structures are dependent on the ability to accurately predict sediment transport. For example, existing jetties and groins were designed to trap sediment with the direction and amplitude of the littoral drift in mind[18].

## Risk Factors

Coastal flooding is an increasing risk for coastal populations and infrastructure in Connecticut. As sea level continues to rise, and storm frequency and intensity increases, hazard mitigation steps need to be in place now. Most vulnerable to inundation are coastal areas that have been altered, either through fill or channel alteration. These areas were naturally flooded and thus are often the first areas inundated during storm events.

Development along the coast prevents the natural movement of the coast, creating conflict between storms and infrastructure. Salt marshes, which act as natural buffers to dampen storm surge, need low-lying undeveloped land to advance when sea level rises. The lack of viable land for marshes to advance onto puts the coast at greater risk in the future.

Due to high cost, and environmental impact, structural flood mitigation should be the last resort in hazard mitigation. Other less harmful and expensive actions include improved land use, strategic retreat, better use of floodplains, and robust evacuation planning. To achieve these actions, a collaboration among all invested parties including local, regional, Tribal, State, Federal, NGOs, academia, business, and industry is required. While structural flood mitigation, or hardened shorelines are not ideal, they are inevitable in some situations. Municipalities must adopt a combination of structural, nonstructural, and natural methods to reduce risk. Most important, pre-disaster planning can save communities approximately 75% of post-event costs[18].

## Policy Framework

In Connecticut, state agencies and municipalities have varying levels and types of authority over coastal infrastructure and land uses. The Connecticut Department of Energy and Environmental Protection (DEEP) has much of the responsibility for regulating activities in tidal wetlands and coastal waters seaward of the Coastal Jurisdiction Line (CJL). Since Connecticut is a home rule state, municipalities have control over a broad range of activities – including inland wetlands and watercourses, planning, zoning, buildings, open space, erosion and sediment control, town property, public works and the establishment of boards and commissions. State legislation provides much of the policy framework for the implementation of this authority, as local ordinances may not conflict with state law.

State agency actions that could impact the environment are regulated through the Connecticut Environmental Policy Act (CEPA, akin to the National Environmental Policy Act). CEPA requires that before taking an action which would have a major impact on natural resources, the agency must undergo a review process which generates an Environmental Impact Evaluation (like the federal environmental impact statement). Multiple state agencies and the potentially impacted municipalities are involved in the review.

At the regional level, COGs provide municipalities with a forum for regional planning and coordination. The COGs are not regulatory entities and do not have authority over coastal development or land use. Rather, COGs may assist and advise municipalities with decisions that could impact coastal resources. In addition to COGs, Soil and Water Conservation Districts are authorized to develop soil and water conservation, erosion, and sediment control programs. These districts may hold real property, assist with DEEP programs and provide comments on local and regional projects.

The State of Connecticut has entered partnerships with other states to protect shared natural resources. The New England Water Pollution Control Commission approves the water quality classification standards for interstate water bodies, waterways and tidal waters. The Interstate Environmental Commission is a partnership between Connecticut, New York, and New Jersey to address water quality in the western portion of Long Island Sound and portions of adjacent rivers and estuaries. The Commission has the authority to restrict sewage discharge in the area and may develop and enforce regulations regarding pollution.

The restoration and protection of Long Island Sound is a state requirement for municipal and regional plans of conservation and development (having a coastal border). These plans must be "made with reasonable consideration for restoration and protection of the ecosystem and habitat of Long Island Sound" and "designed to reduce hypoxia, pathogens, toxic contaminants and floatable debris in the sound." While legislation for the Connecticut Conservation and Development Policies Plan does not specify Long Island Sound, the impacts of natural hazards on infrastructure and natural resources, and strategies to mitigate these hazards must be included in the state plan.

Using the local Plans of Conservation and Development (POCD) as a framework, municipal zoning commissions are empowered to make regulations for buildings, structures, land uses, and other aspects of zoning. Soil erosion and sediment control and the environment of Long Island Sound (in coastal communities) are state mandated requirements for local zoning regulations. While buildings and structures are regulated at the local level, all municipalities are required to adopt and enforce Connecticut's State Building Code, which covers structural, materials, electrical, plumbing, and fire control requirements.

Connecticut's water pollution legislation is more restrictive than the federal Clean Water Act. DEEP is responsible for administering the legislation and ensuring compliance with the federal CWA, as well as setting water quality standards and developing a comprehensive plan for the prevention, control and abatement of water pollution. In addition to managing surface and ground water quality, DEEP uses these standards to inform the issuance of discharge permits and orders to abate pollution. If a municipality is ordered to abate pollution, it must establish a water pollution control authority (WPCA). WPCAs may also be established regionally. Stormwater is also regulated by DEEP, but there has been past interest in the creation of municipal stormwater authorities. Coastal water quality is further regulated through the state's Coastal Management Act.

Connecticut's Coastal Management Act is the primary legislation that guides policies to minimize or eliminate "adverse impacts on coastal resources" caused by coastal development, facilities, and uses. State actions, DEEP regulations and all major state plans must be consistent with the

CMA, and the determination based on CMA considerations supersedes other reviews. Following a model program and regulations developed by DEEP, municipalities are required to review coastal site plans for buildings, uses, flood control structures and other activities so as to determine the potential adverse impact on coastal resources. The Zoning Commission (or another commission designated for coastal planning purposes) incorporate both coastal management and zoning considerations in the coastal site plan review, with an emphasis on non-structural mitigation measures that are less damaging to the environment. Municipalities must also consider water quality degradation as part of the review since the CMA considers coastal water quality degradation as an adverse impact.

Through the CMA, DEEP may also provide comments on any revisions to local POCDs, other community plans, zoning regulations and related ordinances which could impact coastal resources. In addition to DEEP, these revisions must also be submitted to the COG for comment prior to adoption.

DEEP is responsible for coordinating, monitoring and analyzing state and local floodplain management activities, and for assisting municipalities with the development of non-tidal floodplain regulations. Complementing DEEP's floodplain management authority, the agency also has the power to establish encroachment lines along waterways and flood-prone areas. Any obstruction, encroachment or hindrance beyond these lines requires a DEEP permit. While municipalities are also authorized to establish encroachment lines independent of DEEP's lines, DEEP may alter the municipal lines and regulate any encroachments over the DEEP lines. Independent of DEEP, municipalities have the authority to require the removal of material from a waterway if it could prevent the free discharge of flood waters (with the exception of some transportation projects).

Under the CMA, flood and erosion control structures/systems (hard stabilization) must be referred to DEEP for comment. These structures and systems may only be approved after finding that there is no feasible, less damaging alternative and that all reasonable mitigation measures and techniques have been implemented. In addition to hard stabilization activities, dredging, excavation, dumping, placement of fill and similar activities require a DEEP permit (through legislation independent of the CMA). DEEP has the discretion to require that the sand, gravel or other material is made available at cost to a coastal municipality for use in a flood or erosion control system, beach nourishment or habitat restoration project.

Municipalities may establish a Flood and Erosion Control Board (FECB), which is empowered to plan, lay out, acquire, construct, reconstruct, repair, maintain, supervise and manage a flood or erosion control system. If the system is approved by DEEP, a municipality may enter an agreement with the federal and/or state government. All dams, dikes, and similar structures which might pose a public danger by failure are subject to DEEP jurisdiction and require a permit for any activities related to the structure.

While DEEP has most of the authority over tidal wetlands, inland wetlands and watercourses are regulated at the municipal level. The state's inland wetlands and watercourses act authorizes the municipality to implement the act through an inland wetlands agency (or an existing board or commission). The designated agency is responsible for evaluating permits for regulated activities.

## Connecticut's Shoreline Assessments

Two key sets of resources for understanding the State's shoreline have been published in the last few years, reflecting a growing interest in making shoreline communities more resilient coupled with increased funding for research and additional funding available after disasters such as Hurricane Sandy. These are the Analysis of Shoreline Change in Connecticut as mentioned earlier and the North Atlantic Coast Comprehensive Study (NACCS) documentation. Both are described below.

### Analysis of Shoreline Change in Connecticut

The Analysis of Shoreline Change in Connecticut [DEEP, CT Sea Grant, and University of Connecticut Center for Land Use Education and Research (UCONN-CLEAR), 2014] conducted a GIS analysis using maps of the Connecticut shoreline from several different time periods between 1880 and 2006 (100+ years). The goal of the project was to "provide a high-level, quantifiable data set describing CT shoreline trends from both a statewide, regional, and a localized perspective." The report notes that results from the analysis represent shoreline movement under past conditions and are not intended for use in predicting future shoreline positions or future rates of shoreline change. The authors additionally note that the materials presented can be "reasonably used to:

- identify areas that have historically exhibited erosion or accretion trends;
- identify areas that have shown a 'trend reversal' from the long term to the short term (either changing from erosion to accretion or vice-versa);
- generally assess the speed or magnitude of change; or
- support or direct research investigations or planning purposes."

Additionally, the authors note that the materials presented should not be used to:

- differentiate/explain the cause of change;
- state with certainty the magnitude or speed of change at a given location;
- predict future rates and/or amount of change; or
- develop engineering or design plans without a review of underlying data."

## North Atlantic Coast Comprehensive Study (NACCS)

The NACCS report ("North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk") [U.S. Army Corps of Engineers, 2015] was published in January 2015. The NACCS addresses the coastal areas defined by the extent of Sandy's storm surge in the District of Columbia and the States of New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, and Virginia. The two goals of the study were:

1. Provide a risk management framework consistent with the NOAA/USACE Infrastructure Systems Rebuilding Principles
2. Support resilient coastal communities and robust, sustainable coastal landscape systems, considering future sea level and climate change scenarios, to manage risk to vulnerable populations, property, ecosystems, and infrastructure.

Key findings, outcomes, and opportunities of the NACCS include the following:

1. Flood risk is increasing for coastal populations and supporting infrastructure.
2. Improved land use, wise use of floodplains, responsible evacuation planning, and strategic retreat are important and cost-effective actions.
3. Communities should adopt combinations of solutions, including nonstructural, structural, natural and nature-based, and programmatic measures to manage risk, where avoidance is not possible.
4. Communities must identify their acceptable level of residual risk to plan for long-term, comprehensive, and resilient risk management.
5. Many opportunities exist to improve risk management, including enhancing collaboration, building new partnerships, and strengthening pre-storm planning.
6. Addressing coastal risk requires collaboration among local, regional, Tribal, State and Federal entities, NGOs, academia, business, and industry.
7. Resilience can be encouraged through the use of a coastal storm risk management framework and continued commitments to advance the state of the science with respect to sea level and climate change, storm surge modeling, ecosystem goods and services, and related themes.
8. Strategic and comprehensive monitoring is required to fully assess and adapt the coastal system to avoid future damages. Monitoring information must be made available to the public in a timely manner that allows rapid decision-making by public and private partners.
9. Pre-disaster planning and mitigation can save communities approximately 75 percent of post-storm costs.

The above findings are consistent with many other studies and sets of conclusions that have been circulated in the last few years. The statement that "Communities should adopt combinations of solutions, including nonstructural, structural, natural and nature-based, and programmatic measures to manage risk, where avoidance is not possible" is consistent with the goals of the Regional Resilience Framework project.

One of the most potentially useful components of the NACCS was the development of updated modeling that is somewhat like the traditional modeling developed for the Flood Insurance Studies. Specifically, storm surge modeling was conducted for the NACCS using the ADvanced CIRCulation (ADCIRC) long-wave hydrodynamic model. Results include water surface elevations for different storms of varying recurrence intervals, similar to the FEMA modeling found in the FIS. These results can be used to help establish design parameters for conceptual designs, as was done for the conceptual designs in this Regional Resilience Framework project.

Unfortunately, the state-by-state planning assessments contained in the NACCS were not as detailed for Connecticut as they were for other states. The Connecticut shoreline was analyzed as one segment instead of being divided into numerous segments and the narratives provided for individual municipalities or groups of municipalities were somewhat generalized. The following narratives are taken from the NACCS Report:

- CT 1_A: Stonington to Mystic. This area of high exposure encompasses the waterfront area of the town of Stonington, including Stonington Harbor, east to the village of Mystic and its harbor. There are several pockets of dense residential development along this portion of the coast that are vulnerable to storm surge inundation. The two harbors also include a fair amount of commercial development and boating infrastructure. Municipal infrastructure is also of concern including some major roads.
- CT 1_B: Groton. This area of high exposure involves the coastal area consists of the between the developed sections in Groton called Noank, Groton Long Point and the Baker's Cove area. Again, pockets of residential development are extremely vulnerable here. The Groton Airport is also within this exposure

area.

- CT1_C: New London. This area of high exposure consists of the inundated industrial and commercial area around Shaw Cove in New London. There is a small hurricane barrier here but it only protects up to a Category 1 storm surge. Impacts would include damage to commercial, industrial, berthing areas, and city services (wastewater treatment) as well as some residential structures in the Downton area.
- CT 1_D: Waterford/East Lyme. Niantic Bay includes significant commercial, residential, and port development in the Niantic and Millstone sections of town. Route 156 connects the two towns in this area of high exposure. The Millstone Nuclear Power Plant, the state's only nuclear power generating facility, is located on the east side of the bay and is adjacent to the area of high exposure.

The level of detail provided in the NACCS narratives for Stonington, Groton, New London, Waterford, and East Lyme was less than the detail provided by reviewing the individual plans and studies associated with each municipality. Nevertheless, they demonstrate the vulnerabilities and risks present in these communities.

A final piece of potential utility from the NACCS is the Conceptual Regional Sediment Budget for USACE North Atlantic Division [U.S. Army Corps of Engineers 2015]. The report notes that "development of a detailed working sediment budget is fundamental to better sediment management. A conceptual sediment budget is the first phase in development of the working budget and is intended to provide a general framework based on existing transport information from which a more detailed sediment budget can be later prepared based on rigorous data analysis and numerical modeling." This portion of the NACCS found that Long Island Sound was generally a location of accretion, and that various parts of the Connecticut shoreline were balanced between erosion and accretion.


PHOTO CREDIT: Susan Rubinsky

# SECTION 3: Weather And Coastal Hazards

## Weather Related Events

There are various types of weather-related events that affect the project area; each with their own characteristics. These include extra-tropical cyclones, also known as low pressure systems or Nor'easters. There are also tropical cyclones which are known as either tropical storms or hurricanes. Many of these weather systems have had significant impacts across the southeastern Connecticut coastline.

**Nor'easters** are relatively common in this region and can occur during all months of the year except in the summer. Some are large and have been known to last upwards of several days resulting in significant impact along the coast, as well as inland areas. The most critical aspects of these events are wind, rain, and/or snow. During Nor'easters, the wind comes out of the northeast. This is true within Long Island Sound where the current geographical position flows from northeast to southwest which orients perfectly with northeasterly winds. Most of the time these storm systems often occur in conjunction with large snowfalls, which has made emergency response and recovery much more challenging.

**Hurricanes and Tropical Storms** have resulted in significant impacts. Hurricanes of high intensity (Category 3 or greater) are not as common as a Category 1 or 2. However, these systems have resulted in tremendous amount of damage along the Connecticut shoreline. Tropical Cyclones feed off energy from extremely warm waters and therefore contain an inner warm core (the eye); an extratropical cyclone usually contains an inner cool core. Winds from a hurricane circulate counter-clockwise with the strongest winds associated along the right-front quadrant (right side) of the system. The most amount of rainfall usually occurs along the left quadrant or the left side of the storm system. The right quadrant also forces the highest storm surge due to the highest winds, fetch, and onshore flow. Therefore, determining the track and the intensity of these systems is critical for emergency purposes.

**Hurricane 1938** (Great New England Hurricane/Long Island Express): On September 21, 1938, one of the most destructive hurricane hit the Connecticut coastline as a Category-3 hurricane. Winds reached approximately 121 mph with gusts exceeding 183 mph. Roads, homes, buildings and other structures were completely flooding or underwater along the Connecticut coast. This large system generated copious amounts of rainfall prior to the hurricane making landfall between the cities of Bridgeport and New Haven. Many places along the Connecticut river valley experienced significant riverine flooding with rainfall rates exceeding 2 inches per hour with many areas measuring over 17 inches of total rainfall. The storm surge along the coast was extremely destructive and costly with many structures along the coast swept right off their foundations. The surge along the coast reached astounding levels from 10 to 12 feet and above. The mean low-water storm tide was measured at 14.1 feet in Stamford, 12.8 feet in Bridgeport, and 10.58 feet in New London which still remains as record high water level today. The hurricane struck with little warning and was responsible for 600 hundred deaths and over 308 million dollars in damage across the northeast region. The 1938 hurricane still holds the record as the worst natural disaster in Connecticut's history.

**Tropical Storm Sandy:** On October 29, 2012, Sandy made landfall along the New Jersey coastline. A Connecticut tide gauge measured a storm surge of 9.83 feet above normal tide levels in Bridgeport and New Haven measured a surge of at around 9.14 feet, which resulted in record water levels occurring at many stations during the height of the storm. The following inundation data is expressed above ground level: Fairfield and New Haven Counties averaged between 4 to 6 feet, while both Middlesex and New London Counties averaged anywhere between 3 to 5 feet. The highest storm tide and greatest inundation occurred along central portions of the Connecticut coast with the highest water mark recorded at 5.5 feet above ground level in Milford, Connecticut. Other inundation measurements of at least 5 feet were recorded for areas near the City of New Haven. Fairfield County had the highest max measurements ranging from at 4.5 to 5.8 feet. Per the National Ocean Service tide gauges, Bridgeport and New Haven both reported water levels around 5.82 feet and 5.54 feet above mean high high water (MHHW). This indicates that the inundation may have exceeded 6 feet above the ground level in parts of Fairfield and New Haven Counties. Farther to the east, the highest marks measured by the United States Geological Survey in Middlesex and New London 3.8 feet and 3.2 feet above ground level which were recorded in Clinton and Old Lyme, respectively. In addition, New London reported a water level of 4.95 feet above MHHW. The maximum inundation along the eastern parts of the Connecticut coast were estimated to be between 3 to 5 feet above the ground level. As Sandy slammed into the Jersey coastline, she never lost her large wind field and large radius of maximum winds, as it transitioned from a hurricane into a "hybrid system" containing both tropical and extratropical characteristics. However, the storm retained its hybrid status throughout landfall. The wind field from Sandy was record setting, stretching over 1,000 miles in diameter. The overall minimum central pressure of Sandy was estimated to be around 940 mb, which occurred on the 29th of October, just a few hours before landfall. This currently is the lowest barometric pressure ever recorded to make landfall along the US coast above Cape Hatteras; even surpassing the Hurricane of 1938. Sandy's death toll rose to 147 deaths (5 located in Connecticut). Sandy's damage was calculated at 65 billion dollars in damage, making it the second costliest weather disaster in United States history.

# Sea Level Rise Projections

Beginning in 2008 through 2010, the Nature Conservancy contracted with NASA Goddard Institute of Space Studies and Center for Climate Systems Research at Columbia University to generate downscaled sea level rise projection for coastline of Connecticut, New York City region, and Long Island, New York. These sea level rise projections were incorporated directly into the Nature Conservancy's Coastal Resilience tool (www.coastalresilience.org) which serves all of Connecticut's coast as well as 20 other states and 7 other nations around the world.

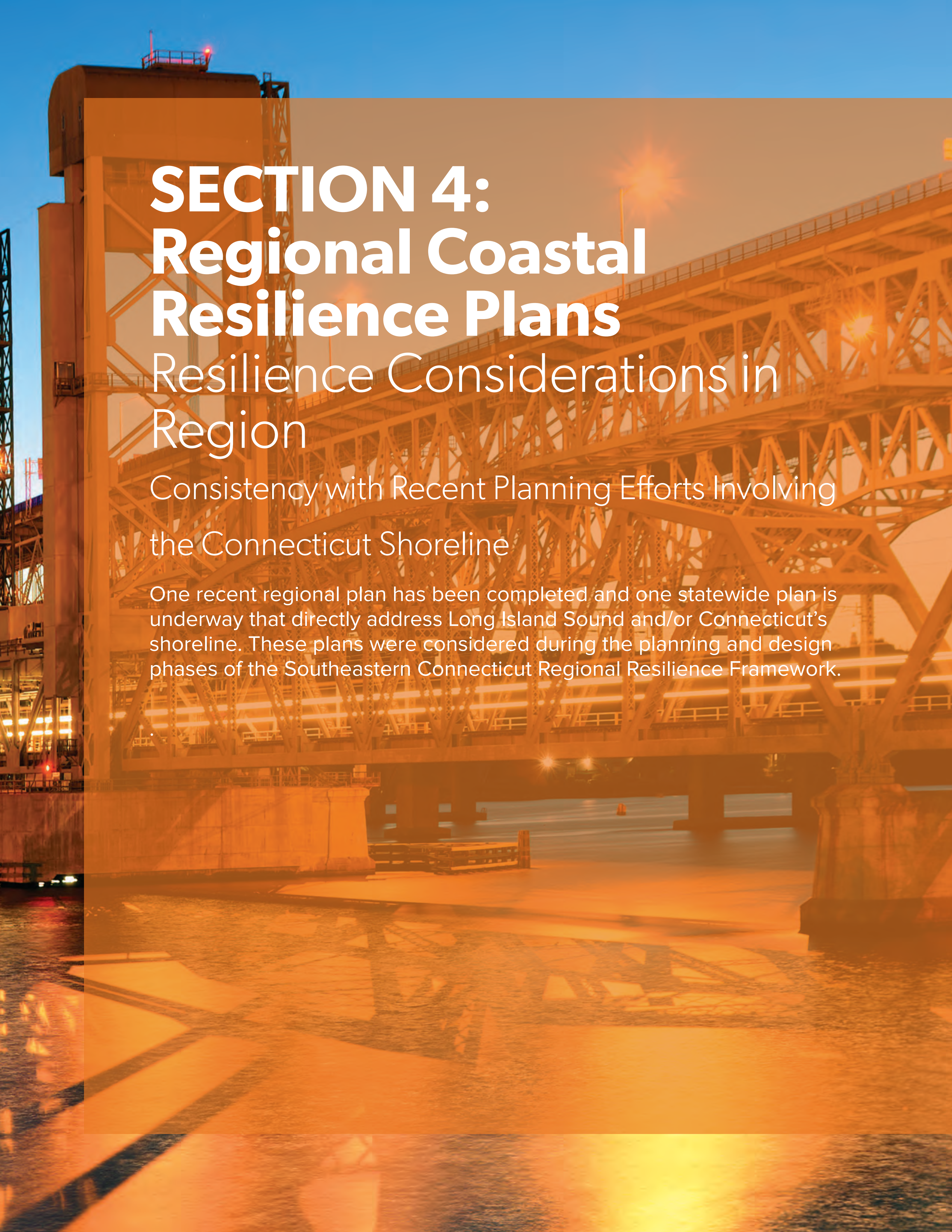
The sea level rise projections from NASA/Columbia were modeled using 7 Global Circulation Models across three emissions scenarios from the Intergovernmental Panel on Climate Change (IPCC) (B1, Ab1, A2). In addition, historic tide gauge data, observed land subsidence, local differences in mean ocean density, circulation changes, thermal expansion of sea water, and changes in ice mass due to temperature increases were incorporated into these downscaled projections. The modeling methodology was originally developed for the New York City region as part of the New York City Panel on Climate Change per a study funded by the New York State Energy Research and Development Authority (NYSERDA). An updated description of the methodology and the resulting sea level rise projections are provided in the New York City Panel on Climate Change's report entitled Climate Risk Information 2013 (http://www.nyc.gov/html/planyc2030/downloads/pdf/npcc_climate_risk_information_2013_report.pdf). Since the original sea level rise projections were run by NASA/Columbia, a supplemental analysis per New York States ClimAID Program in 2014 has resulted in an increase in projections up to 58 inches in the 2080s for New York City (http://www.dec.ny.gov/energy/45202.html#projections).

Starting in 2008, the State of Connecticut initiated a climate change study in accordance with Section 7 of Public Act No. 08-98, An Act Concerning Connecticut Global Warming Solutions, the Governor's Steering Committee (GSC) on Climate Change that established an Adaptation Subcommittee. The GSC charged the Adaptation Subcommittee with evaluating the projected impact of climate change in the state on: (1) infrastructure, including, but not limited to, buildings, roads, railroads, airports, dams, reservoirs, and sewage treatment and water filtration facilities; (2) natural resources and ecological habitats, including, but not limited to, coastal and inland wetlands, forests and rivers; (3) public health; and (4) agriculture. This assessment effort was followed by a Climate Action Plan for the state that contains the results of the above impacts assessment and recommendations for changes to existing state and municipal programs, laws or regulations to enable municipalities and natural habitats to adapt to harmful climate change impacts and to mitigate such impacts. The sea level rise projections incorporated and adopted by the State of Connecticut in the final report entitled "The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources and Public Health" where adopted directly from the New York Panel on Climate Change (NPCC - PlaNYC) as detailed in the document Climate Risk Information (2009 – Section 3: Future Projections Page 13) (http://pubs.giss.nasa.gov/docs/2009/2009_Horton_etal_1.pdf) as well as the update in 2013 (referenced above).

Public Act 13-179, passed in 2013, called for the state and municipalities to consider, for specified planning processes, four different scenarios for future SLC scenarios that had been published by the National Oceanic and Atmospheric Administration (NOAA). At the urging of various entities, including the Connecticut Institute for Resilience and Climate Adaptation (CIRCA), the UCONN Law School and The Nature Conservancy, Public Act 18-82 was enacted, which called for one scenario, localized to Long Island Sound, rather than four, to be created and periodically updated by UCONN and published by DEEP. In 2018, the assessment was completed for sea level rise recommendation for state adoption, as mandated by PA 18-82. The recommended 0.5 meter (1 foot 8 inches) increase in sea level by 2050, which matched one of the downscaled NASA/Columbia Long Island Sound projections, for a medium global temperature gradient in 2050. This recommendation was adopted by DEEP in December 2018.

In summary, the downscaled sea level rise projections presented in the Nature Conservancy's Coastal Resilience Tool were developed under contract by NASA Goddard Institute of Space Studies and the Center for Climate Systems Research at Columbia University. These very same projections were incorporated into the New York Panel of Climate Change (NPCC – PlaNYC) in 2009 and subsequently revised upwards in 2013. The 2009 sea level rise projections from NASA/Columbia were not only incorporated into the NPCC-PlaNYC actions plans but were also incorporated into the State of Connecticut's legislatively mandated, Governor's Adaptation Subcommittee's report on climate change impacts in Connecticut (Section II: Climate Change Projections and Risk Assessment – Page 8) with one projection matching the 2050 sea level rise projections recently adopted by CT DEEP.


PHOTO CREDIT: iStockPhoto



# SECTION 4: Regional Coastal Resilience Plans

## Resilience Considerations in Region

### Consistency with Recent Planning Efforts Involving the Connecticut Shoreline

One recent regional plan has been completed and one statewide plan is underway that directly address Long Island Sound and/or Connecticut's shoreline. These plans were considered during the planning and design phases of the Southeastern Connecticut Regional Resilience Framework.

## Southern Connecticut Regional Framework for Coastal Resilience

In the aftermath of Tropical Storms Irene and Sandy, the population centers of Greater New Haven and Bridgeport (Fairfield east to Madison – Fairfield and New Haven County) collectively recognized a significant level of exposure and vulnerability to the infrastructure, environment, and socio-economic assets from extreme weather events and a changing climate. To counteract immediate and longer-term risks and broaden dialogue on community resilience building, the Southern Connecticut Regional Framework for Coastal Resilience project was launched[20]. The overarching goal of this project was prioritizing actions and strengthening partnerships by providing proactive risk assessment, community engagement, conceptual design of on-the-ground projects, and the following Final Report. The principal purpose being to advance a Regional Resilience Framework, built on projects and partnerships, needed to help comprehensively improve resilience for over 591,000 residents from ten municipalities within Fairfield and New Haven County that represent over 30% of Connecticut's coast. A core goal of this project was to strengthen the resilience of existing and future ecosystems including a diverse suite of services and co-benefits alongside existing and future development activities within a population center critical to the state of Connecticut's future.

The Southern Connecticut Regional Framework for Coastal Resilience consisted of four main project components:

1. A comprehensive assessment of green/natural infrastructure project opportunities;
2. A series of workshops and meetings with municipal officials and local stakeholders;
3. Conceptual designs and cost estimates for highest priority projects;
4. A Final Report.

## Long Island Sound Comprehensive Conservation and Management Plan

The Long Island Sound Comprehensive Conservation and Management Plan 2015 – Returning the Urban Sea to Abundance [Long Island Sound Study, 2015] was a collaborative effort prepared by the Long Island Sound Study. The Long Island Sound Study (LISS) was authorized by Congress in 1985 and involves federal, state, interstate, and local government agencies, non-government organizations, industries, universities, and community groups to restore and protect the Sound. At least three objectives from the management plan are directly aligned with the Regional Framework for Resilience:

- Objective 2-1c: To increase or maintain resiliency of coastal habitats and the services they provide.
  - Strategy 2-1c1: Identify and prioritize upland, wetland, and aquatic habitats that are vulnerable to climate change impacts and take action to mitigate or adapt to these impacts.
    - HW-11: Develop and promote the use of living shoreline habitat protection methods (dunes, shorelines, coastal marshes) and living shoreline monitoring protocols.
    - HW-12: Promote the conversion of existing armored shorelines (seawalls, riprap, bulkheads, etc.) to softer living shorelines to mitigate the impacts of new (and authorized) armored shorelines.
- Objective 3-4a: To encourage and facilitate the development of regional, state, and local sustainability, mitigation, and resiliency plans and integrate them into community comprehensive plans.
  - Strategy 3-4a1: Provide support to municipalities to facilitate the development and updating of sustainability and resiliency plans that incorporate current concepts on these topics.
    - SC-23: Develop a handbook, website, and, or, other materials (e.g., regulations, funding sources, and best practices) to be used by municipal officials to aid in the development of sustainability and resiliency plans and their integration into comprehensive plans.
    - SC-24: Conduct region-wide and town-specific workshops to assist municipalities in developing sustainability and resiliency plans and integration into their comprehensive plans.
    - SC-25: Support communities as they develop and adopt new or updated stand-alone Municipal Sustainability Plans.
    - SC-26: Support communities as they develop and adopt new or updated Coastal Resiliency Plans.
- Objective 4-3a: To frame sustainability, adaptation,

and resilience in relation to the drivers of ecosystem change:

- Strategy 4-3a2: Consider the spectrum of desired ecosystem outcomes when planning and implementing resiliency of both built and natural systems.
  - SM-33: Incorporate desired ecosystem outcomes for planning and implementation of Hurricane Sandy Relief funds and ongoing coastal resiliency programs.

The planning and design phases of the Regional Framework for Coastal Resilience have helped advance progress toward these objectives and strategies.

## Connecticut Blue Plan

Public Act 15-66, An Act Concerning a Long Island Sound Blue Plan and Resource and Use Inventory, was signed on June 19, 2015 and went into effect on July 1, 2015. This "Blue Plan" legislation establishes a process by which Connecticut will develop an inventory of Long Island Sound's natural resources and uses and, ultimately, a spatial plan to guide future use of the Sound's waters and submerged lands. Currently, Connecticut's Coastal Area Management Program protects coastal resources and guides development along the State's shoreline. The development of a Blue Plan for Long Island Sound will supplement the Coastal Area Management Program's existing authority in the deeper offshore reaches of the Sound.

At the present time, draft goals for the Blue Plan have been published for comment. At least three objectives are directly aligned with this Regional Resilience Framework including:

- Goal 1: Healthy Long Island Sound Ecosystem
  - Reflect the value of biodiversity and ecosystem health in regard to the interdependence of ecosystems
  - Identify and protect special, sensitive or unique estuarine and marine life and habitats, including, but not limited to, scenic and visual resources
  - Adapt to evolving knowledge and understanding of the marine environment, including adaptation to climate change and rise in sea level

The project catalogue and design phases of the Regional Resilience Framework helped to advance progress toward these objectives.

# Coastal Resilience Planning in Region and Municipalities

SCCOG: The Southeastern Connecticut Council of Government's Multi-Jurisdiction Hazard Mitigation Plan (HMP) received FEMA approval December 2017. The HMP planning process adhered to Federal Emergency Management Agency (FEMA) standards and requirements for local hazard mitigation plans. The purpose of the HMP is to help reduce the region's vulnerability to natural hazards and ease the burden of keeping communities safe and resilient. The HMP identifies hazard risks and mitigation actions to reduce or eliminate those risks. Through the Plan, the participating municipalities are eligible for FEMA mitigation program funding before and after potential natural disasters.

The participating municipalities have been diligently working to advance or further evaluate their respective mitigation actions. In addition to managing the HMP process, SCCOG has been advancing the regional mitigation actions by assisting regional communities in joining or improving rating in the National Flood Insurance Program's Community Rating System (CRS). The CRS is a voluntary program in which communities can receive points for completing actions that improve flood resilience. Policy holders within these communities can then receive premium discounts based on their community's standing.

seCTer: The Southeastern Connecticut Enterprise Region (seCTer) completed The Comprehensive Economic Development Strategy (CEDS) for the region in 2017. The CEDS outlines a regional direction and focus for economic development. Using the findings from the Southeastern Connecticut Regional Resilience Vision workshops in 2016, the CEDS includes a "Resilience and Readiness" sub-section covering regional-, local-, and business-specific recommendations. seCTer is currently advancing this aspect of the CEDS through convening the Regional Resilience Working Group in partnership with The Nature Conservancy.

TNC: The Nature Conservancy's Community Resilience Building Program has been providing services for the coastal municipalities in the project area since 2006. The services provided have included the development of the Coastal Resilience Tool (www.coastalresilience.org) to help municipal-based leadership and staff by geospatially projecting with the most relevant data on hazards and risk along the coast of Connecticut. In addition, TNC has championed state-level policy modifications and educated communities on alternative ways to reduce risk and improve resilience from the neighborhood to regional scale. TNC also generated a parcel-scale Salt Marsh Advancement Zone Assessment for all 24 coastal municipalities to define implications for both the existing built environment from downscaled sea level rise projections and for existing salt marsh expected to advance upslope. Finally, TNC has created the Community Resilience Building (www.CommunityResilienceBuilding.org) process that has helped over 350 municipalities across seven states identify strengths and weakness and collaboratively develop comprehensive and prioritized resilience action plans. The Community Resilience Building process have helped municipalities such as Waterford and Stonington move into leadership roles on resilience in the state of Connecticut.

Select Municipalities: To date, the municipalities of Waterford and Stonington (Table 1) were each able to secure a CDBG-DR grant to generate individual community-based resilience planning documents. The grant money was allocated from the 2013 Disaster Relief Appropriations Act, which aided communities that were impacted by Tropical Storm Sandy and Irene. The planning documents were completed by consultants and their respective municipality. The goals of Waterford's Climate Change Vulnerability, Risk Assessment, and Adaptation Study were to:

1. Develop appropriate rainfall, tidal, sea level rise and storm surge scenarios for the Town of Waterford for present, near-term and long-term time frames.
2. Produce high-quality maps and graphics showing the likelihood, extent and magnitude of flooding impacts.
3. Identify critical infrastructure, facilities and natural resources in Waterford that are vulnerable to present and future flooding events.
4. Develop and prioritize potential short-term and long-term adaptation strategies, with order-of-magnitude cost estimates where appropriate, including regulatory and policy changes, to help the Town manage its infrastructure and natural resources in the face of increasing flood risks.
5. Engage the public and government officials to solicit feedback on proposed strategies so that the Town can make informed decisions that will help to avoid future costly impacts to public and private property.

The Town of Stonington Coastal Resilience Plan presents a risk assessment of critical town infrastructure as well as other essential community assets, transportation systems, and neighborhoods. Conceptual design alternatives were developed for the top community risks.

The Town of Groton also develop a coastal resilience study in 2011 funded by U.S. Environmental Protection Agency's Climate Ready Estuaries program and the Long Island Sound Study. Project partners, including CT DEEP and the ICLEI – Local Governments for Sustainability, intended in the process to create this study to serve as a model for communities in other home-rule, New England states.

The respective coastal resilience planning documents provide an opportunity for each municipality to become more resilient; economically, socially, and environmentally, towards coastal hazards and the effects of climate change. The plans all went through a multi-step, community resilience building process, from generating awareness of coastal hazards and risks, assessing coastal risks, and prioritizing opportunities. Additional steps included identifying strategies, actions, and measures that can be employed to minimize consequences and create more resilient communities. Lastly, these resources provide plans to pursue opportunities and available measures to help improve coastal resilience along the southeastern Connecticut coastline. A comparison of these three reports can be found below (Table 1).

The plans for the municipalities of Waterford, Stonington, and Groton provide a clear catalogue of their strategies, actions, and measures for the high priority areas selected. These plans inform and are informed by SCCOG's Multi-Jurisdictional Natural Hazard Mitigation Plan, most recently updated in 2017. Reports, studies, and other outside resources supported the development of these strategies and actions particularly the IPCC's "Strategies for Adaptation to Sea Level Rise", developed in 1990. This plan focused around three critical terms; Retreat, Accommodation, and Protection, each helped define and categorize many of the available opportunities and actions discussed in the planning documents. Another resourceful document that was used was NOAA's manual "Adapting to Climate Change: A planning guide for State Managers" and TNC's "Adapting to the Rise: A Guide for Connecticut's Coastal Communities" which helped define and explain the municipalities strategy, action, approaches, and available options for each high priority project by categorizing them as nonstructural, structural, nature-based features or green and natural infrastructure in an effort to provide protection and reduce risk. Other outside reports and studies that assisted in development of actions and measures were the, "Connecticut Recovery Resource Guide" and the EPA, "Rolling Easements."[21] Nonstructural category consisted of more traditional strategies concentrated on adopting or changing guidelines for preparedness, emergency response, and available financial options. On the more structural side of the matrix, some methods included hard protection like dikes, sea walls, or temporary flood barriers. For methods of soft protection, the focus was more towards beach restoration, dune nourishment and restoration of tidal wetlands. Hybrid approaches or a combination of both hard and soft solutions, focused more on beach stabilization and bioengineered banks. Other opportunities and actions were directed towards infrastructure and complying with local, state, and federal codes and regulations. Opportunities included, flood proofing or elevating a building, relocating or moving a structure, retrofitting or improving stormwater drainage and sewer systems, and other flood protection measures. Many of these strategies, actions, costs, benefits, and tradeoffs were reviewed with local town officials to identify the most comprehensible solutions to community resilience building and mitigate the impacts from coastal hazards.

## Significant Regional Planning Trends

To strengthen the understanding of the region's current context, meetings with municipal planners coupled with a detailed review of local and regional Plans of Conservation and Development (POCD) (i.e. master or comprehensive plans) were conducted. This surfaced the key trends in local-to-regional planning and initiated considerations of connections to resilience at multiple scales. The top three trends are described below as well as an elaboration on their relevance to regional resilience.

***Table 1: Comparison of municipal-based resilience plans in southeastern Connecticut***

| | Assets covered | Hazards covered | Modelling | Sea level rise assumptions | Community involvement process | Recommendations |
|---|---|---|---|---|---|---|
| **Waterford Climate Change Risk Vulnerability** | All Town-owned assets including roadways and bridges, wastewater pump stations, Town offices, beaches and wetlands. | Coastal flooding (high tide and storm surge) and riverine flood (1% annual probability) for current, 2030, and 2070 scenarios. | 2014 National Climate Assessment (Sea Level Rise) University of Idaho MACA Statistically Downscaled Climate Data (Precipitation) Woods Hole Group (Coastal Flooding) Army Corps of Engineers (Coastal Flooding) | 0.6 ft by 2030<br><br>3.2 ft by 2070 | Interactive workshop; tabling at community event; presentation of recommendations and public comment period. | Site-specific alternative adaptation strategies; planning-level cost estimates where appropriate; Town-wide policy recommendations also provided. |
| **Town of Stonington Coastal Resilience Plan** | Community facilities; historic resources; transportation; drainage and utilities. | Coastal flooding for 2030 and 2050 scenarios. | 2014 National Climate Assessment (Sea Level Rise) Consultant Model (Coastal Flooding) | 0.55 ft by 2030<br><br>1.69 ft by 2050 | Online survey; three public meetings including interactive planning exercise. | Site-specific adaptation strategies; conceptual designs for highest risk assets; neighborhood-scale planning recommendations |
| **Preparing for Climate Change in Groton, Connecticut: A Model Process for the Northeast** | Transportation routes and systems; water infrastructure; schools; residential neighborhoods; commercial areas; ecological resources; emergency services. | Coastal flooding and sea level rise; heat; precipitation; drought | NOAA's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model | 3 ft by 2100 | Three workshops, convening over 100 individuals from federal, state, and local government as well as academic, non-profit, and community partners. | General adaptation recommendations; some site-specific recommendations |

## Economic Change/Ageing Demographic

Many municipalities speak in their POCDs to the dramatic shift in the regional economic center from military and pharmaceutical output in New London and Groton to the casino and service industry around Montville and Ledyard. Though regional employment grew by ~15% between 1990 and 2000 as the new service sector picked up, the lost industrial jobs and overall median income decreased. As these trends continued, residents employed in the service sector struggled to find affordable housing in a region whose real estate market was built for higher-income families and vacationers with seasonal homes. It appears that these trends have led to a movement of young and middle-aged workers away from the region and a strong need for municipalities to diversify the housing stock. As a result of these shifts and expected continued growth, the municipalities in the focus area are concerned with protecting drinking water sources, restructuring their housing stock, and attracting young entrepreneurial talent to diversify their economies.

Adjustments to housing stock may offer an opportunity for municipalities to relocate residential areas vulnerable to sea level rise, inland flooding and extreme weather (i.e. Midway Neighborhood, Groton) to more densely developed, diverse, and resilient parts of the region. In doing so, municipalities can reduce the environmental footprint of development, protect residents from environmental hazards, and possibly attract younger and more diverse residents looking for more mixed use and walkable centers (i.e., resilient triple bottom line).

## Water Quality

As the population and economy of the region continues to grow, SCCOG and others are concerned with ensuring that areas are receiving an adequate and clean supply of drinking water. In a Regional Water Supply Plan, the largest water utility in the area (Southeastern Connecticut Water Authority) concludes that new sources of groundwater rather than surface reservoirs will be required to satisfy future development demands. As a result, protecting and developing groundwater sources is essential for the region's growth. Many of the municipalities in the focus area spend time in their POCDs discussing water sources and runoff quality. As sea levels rise and storms intensify, it will be more important than ever to protect public water sources from salt water inundation, polluted discharge, and contaminated surface runoff.

There is still much uncertainty surrounding issues of drinking water supply. These questions will most likely not be adequately answered until the state finalizes its Water Plan. One particular area of uncertainty is how much of the region's population gets its water from private well sources and how sustainable those sources will be long term. Rising sea levels may inundate aquifers near the coast making well water undrinkable, while increased precipitation could overload already stressed stormwater systems and send untreated runoff directly into waterbodies and other drinking water sources.

## Village Centers

Most of the POCDs proposed enhancing the quality of their villages to attract younger professionals and bolster their appeal to tourists. The vision that these municipalities shared were walkable, mixed use spaces that could provide alternative housing opportunities while attracting businesses and tourists. In the POCDs, these goals often included an action item for implementing "design district" overlays. These overlays were mainly concerned with maintaining the historic authenticity of the spaces but some municipalities wrote about improving the streetscapes and environmental aesthetics.

If properly planned, village center redevelopment can be a vehicle for smarter growth that minimizes environmental footprints and exposures while providing a benefit to the local economy. However, many existing village centers such as Mystic and Jordan Village in Waterford face significant flood exposure. When re-visioning these developments, both local, regional, and state planning authorities should consider the costs of long-term resilience in tandem with the economic benefits these areas can and may provide.

**Box 1: 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**. At the largest scale, the preservation and restoration of natural landscapes (such as forests, floodplains and wetlands) are critical components of green infrastructure.

**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. GI solutions are designed to fulfill a specific need, such as water purification or carbon sequestration, while often offering location-specific and valuable co-benefits, such as enhanced habitat for wildlife.

# Natural and Green Infrastructure for Resilience in Connecticut

## Natural and Green Infrastructure Defined

In the context of natural and green infrastructure, opportunities to improve resilience and 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, living shoreline techniques, and assisting local planning for major storms under current and future conditions. In some cases, a combination of green and hardened infrastructure ("hybrid approaches") may be appropriate (Box 1).

## Policy Context for Natural and Green Infrastructure

There have been numerous developments in the state of Connecticut over the past decade to address concerns of shoreline stabilization in a changing environment and climate. Public Act 12-101 set forth many 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:

- 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;" and
- "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].

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:

- "Living shorelines: 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." [other definitions will appear later in this report]

With the legislative and anticipated regulatory changes coupled with the influx of funding after Hurricane Sandy, the time is ideal for selecting and designing natural and green infrastructure (in other words, nature-based) risk reduction methods along the Connecticut shoreline as provided by this Regional Resilience Framework project.

# Review of Available Resources About the Connecticut Shoreline and Natural/Green Infrastructure

### Connecticut Coastal Design Project: Current Opportunities and Constraints for Connecticut's Coast –Non-Structural/Natural Infrastructure

At least one published resource bridges the gap between the many publications that promote green infrastructure and nature-based risk reduction solutions throughout the United States; this is the report *Connecticut Coastal Design Project: Current Opportunities and Constraints for Connecticut's Coast –Non-Structural/Natural Infrastructure*[22]. The design project was a key outcome of work conducted under The Nature Conservancy's Coastal Resilience Program in 2014-2015. The documentation lists many important outcomes and findings of the workshops and interviews conducted for the project. The key characteristics of a successful natural infrastructure project in Connecticut were identified:

- Appropriate location
- Sustainable design
- Multiple beneficiaries
- Cost effectiveness
- Stakeholder understanding

Furthermore, the characteristics of ideal locations for successful natural infrastructure projects in Connecticut were identified:

- Appropriate physical and environmental conditions
- Surrounding land use
- Adequate frontage and scale
- Strategic opportunities for initial projects

The project identified 11 obstacles to advancing natural infrastructure approaches and projects along the Connecticut coast. In 2015 and 2016, several entities (Restore America's Estuaries) made progress addressing these obstacles through conferences (Living Shoreline conference in December 2015) and design workshops. One of the obstacles, as stated in the TNC report, was ideal for addressing in the context of this Regional Resilience Framework project:

- "Currently, there is no natural infrastructure project design guidance developed specifically for Connecticut's coastal environment (generally: rocky shoreline, low energy, sediment starved). When official design guidance is made available, Connecticut's coastal engineer professionals and natural resource managers can develop a greater understanding of nonstructural options and installation strategies. The design guidance should include specific criteria (e.g. 1.5' wave, slope, fetch, etc.) for siting natural infrastructure projects. The guidance should also include a regulatory mechanism to increase the incorporation of natural infrastructure features in standard hard infrastructure projects (e.g., New Haven harbor). The guidance document(s) need to come from CT DEEP which will require education, training, and workshops for CT DEEP staff. The coastal engineering community is well suited, if willing, to support this type of collaborative education effort."

## CT Sea Grant Climate Adaptation Academy

CT Sea Grant's Climate Adaptation Academy developed and held three separate sessions about the use of living shorelines in Connecticut. The first two sessions were held in 2015 and presented basic concepts to attendees as well as examples of recent and nearby living shoreline projects. The third session was convened in 2016 as a design charrette and held at Harkness State Park. The various types of living shorelines discussed during the design charrette included beach/dune nourishment, marsh edge erosion control, living reefs, wave attenuation devices such as reef balls, marsh sills, slope regrading/ planting, and toe of slope fiber log approaches. One important point of contention during the design charrette was whether certain fortified coastal banks could be considered living shorelines, even if designed using combinations of gray and green techniques. This Regional Resilience Framework project is somewhat unencumbered by the definition of living shoreline, since all nature-based risk reduction methods are considered.

## Regional Living Shoreline Developments

In 2017, TNC worked with regional partners to evaluate the implementation of living shorelines across the region, culminating in the development of Living Shorelines in New England: State of the Practice. This report included interviews with stakeholders throughout New England and profiles and an applicability index were developed for eight living shoreline types (dune restoration [natural], dune restoration [engineered core], beach nourishment, coastal bank protection [natural], coastal bank protection [engineered core], natural marsh creation/enhancement, marsh creation/enhancement [w/toe protection] and living breakwaters).

Regional living shoreline efforts have continued with a current project to develop living shoreline monitoring guidelines for New England, led by TNC and regional partners. Pilot living shorelines projects will be monitored in each of the coastal New England states (Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut), and the data gathered will be used to develop living shoreline monitoring resources that can be used by permit writers and practitioners.

PHOTO CREDIT: iStockPhoto

# SECTION 5: Regional Resilience Framework: Project Components

## Regional Resilience Framework Project Context:

The Southeastern Connecticut Regional Resilience Framework builds upon a similar framework completed for southern Connecticut and includes four primary project components: 1) a catalog and geospatial database of resilience-building projects throughout the region, 2) conceptual designs for catalytic high-priority projects, 3) resilience working group, and 4) a final summary report.

# Project Component #1: Project Field Reconnaissance, Catalog, Geospatial Database

## Project Selection and Criteria

Coastal vulnerabilities and potential resilience projects were identified during review of existing documents (such as Natural Hazard Mitigation Plans, Plans of Conservation and Development, various watershed management plans, among others) and discussed at outreach meetings with municipal staff from planning, engineering, conservation, and/or public works departments, along with a multitude of other knowledgeable people in the region. After identifying the full suite of projects, the Core Team shared municipal-specific lists via email for feedback with the relevant planner, engineer, and/or public works official along with other knowledgeable peoples in the region. The Core Team also shared the regional list with other environmental and economic development professionals with expertise on the region. The primary criteria in selecting projects was whether the specified action would significantly alleviate the impacts of extreme weather and climate change including flooding, erosion, and/or sea level rise. The Core Team discovered many natural infrastructure projects aimed at improving water quality; however, it was determined that unless the project was also aimed at addressing one of the above impacts, it fell outside the scope of the catalog. A summary of the documents reviewed and meeting minutes from each municipal engagement with the Regional Resilience Framework can be found in Appendix A.

## Field Reconnaissance

Field reconnaissance of potential resilience projects were scheduled for January through March of 2018. Field notes and photos were recorded on a Windows Surface Pro tablet in ESRI's Survey123 application. This application included drop down menus to include the database fields such as project categories, risk reduction object, and green infrastructure status. Narrative notes recorded signs of flooding, erosion, or additional risks as well as comments on the site use and context within the surrounding neighborhood. Additionally, efforts were made to suggest possible alternative designs that would add or enhance natural elements. More detailed field reconnaissance notes are included in Appendix A.

## Geospatial Database Development

To expedite site visits, a geospatial database was pre-populated with the selected resilience projects using ESRI's Survey123 application, and ESRI's Collector app was used to take and save field notes and photos. A project description narrative was created for each project, providing an overview and distillation of field reconnaissance notes. The identified projects were then qualitatively evaluated for risk reduction impact and classified based on the following parameters: type, objective, strategy, municipality, geolocation, address, funding (if available), green infrastructure (yes/no/hybrid), and primary and secondary asset exposed. Project type, objective, and strategy classifications were standardized as outlined in Box 2 and Box 3 to facilitate screening and evaluation of potential projects.

Once data entry was completed, an overlay analysis was conducted in ArcMap 10.3 to append the following additional grant-pertinent information to the project entries: CT DEEP's Natural Diversity Areas, FEMA's flood zone and base flood elevation, HUD's low-to-moderate income percentage (within block group), and USGS's watershed (HUC-12). The intent of including this information was to enhance project screening for potential funding sources and facilitate inclusion of projects in grant applications.

The finished geodatabase was merged with similar project databases from southcentral and southeastern Connecticut and uploaded to the Coastal Resilience (www.coastalresilience.org) web mapping viewer. Directions for and guidance on accessing the Regional Resilience Project App can be found in Appendix H. Fully implemented, the online App serves as a central repository of resilience projects for all three regions, covering most of the Connecticut coast and adjacent watersheds. The functionality of the App allows users to query and display the projects by town, project type, objective, or strategy, to identify the projects that are most relevant to their needs. To visualize additional project context, users can also overlay the project points with flood and down-scaled sea level rise layers, salt marsh advancement zones, and community information such as parcel lines and zoning.

## Box 2: Regional Resilience Framework Project Type Terminology

**Coast Natural Infrastructure**
Mostly made up of coastal systems such as beaches, dunes, marshes, and estuaries. These types of natural infrastructures are critical along the coast because they reduce wave attenuation, provide protection from storm surges and flooding, and act as natural barriers to protect the vulnerable coastline and its many ecosystems from rising sea levels and future coastal storms. Ideally, implementing and constructing these green or hybrid solutions would provide the essential protective measures that are needed to restore these natural coastal systems in an effort to become resilient against a changing climate.

**Hard Infrastructure**
Is comprised of buildings, critical facilities, roads, bridges, and dams that provide us with an overall network of systems that allow our economy to function properly using transportation systems and emergency services. Improving and updating these assets is essential to prevent future destruction from all natural hazards. Ideally, upgrading, flood proofing, and retrofitting many of these structures with green solutions or other environmentally safe and stable materials will eventually strengthen our overall system and provide an effort to protect all critical infrastructures from climate change.

**Inland Natural Infrastructure**
As you step away from the coastline, there are many other networks and ecosystems that lie within urban to rural settings. Floodplains, floodplain benches, riparian buffers, wet meadows, depressions, riverine corridors, flood protection systems, and bioengineered banks are all inland structures that provide our ecosystems with protection from both urban and rural flooding, whether it's from impervious runoff or high-end rainfall events. Many of these structures could be retrofitted with green or hybrid solutions in order to restore many of the inland natural habitats and essentially protect lives, properties, homes, and roads from future erosion and flooding.

**Shoreline Infrastructure**
The shoreline consists of revetments, bulkheads, groins, breakwaters, jetties, riprap, and tide gates, which are all forms of hard structures. Hardening many of these exposed coastlines has provided crucial protection in absorbing wave energy, reducing coastal inundation and erosion along the immediate coast. Some have provided near-shore habitat for marine life such as vegetation and living organisms. Many of these structures have held our shoreline intact, especially providing protection from rising sea levels. However, hardening the coastline is not always the answer; we must look beyond and examine all other available options, whether it's retrofitting these structures with green solutions or using other reliable resources and materials to bulk-up our shorelines. Each of these structures has their advantages and disadvantages and we must take that into accountability when hardening our changing coastline.

**Stormwater Management**
Many projects focus on stormwater infrastructure and network systems located within both an urban and rural landscape. These structures include culverts, outfalls, pipes, channels, permeable pavement, green roofs, street planters, rain gardens/bioswales, infiltration galleries, green street concepts, and other drainage systems. All of which can help develop and improve LID strategies and BMP's within a city and suburban landscape. Implementing, upgrading, and monitoring stormwater infrastructure and drainage systems are vital for reducing all types of runoff, whether it's from imperious surfaces or from high-end storm events. Improving the overall network of drainage systems would essentially accommodate more flow and provide further flood protection at critical gaps. Retrofitting and installing green and natural infrastructure techniques would enhance and modify these stormwater management systems by increasing waterways, storage, and infiltration of runoff, while mitigating future flooding and erosion within cities and towns.

**Other**
A variety of projects that are currently situated at the coast or near inland areas that have been identified as either current projects or are a placeholder for future resilience opportunities and solutions along the coast. These selected project sites could be further reviewed along the immediate shoreline in an effort to become more resilient against the frequency and intensity of future storms.

## Box 3: Regional Resilience Framework Project Strategy Terminology

**Abandon**
To remove or discard something previously built; left alone.

**Acquire/Demolish**
To obtain or take over with approval; removed or replaced with something else (open space).

**Create**
Implement, develop, or construct something new.

**Create Floodplain**
Design, develop, and construct a new or existing landscape into a wetland or depression utilized for periodic flooding or overflow.

**Create Floodplain Bench**
Develop and construct a relatively narrow inclined landscape (stair –like) or similar as a fluvial terrace.

**Elevate**
To increase in height or to raise up

**Enhance**
To build up or to strengthen; improve the quality, value or extent.

**Enhance/Modify**
A combined effort in strengthening, improving, or by adding to the quality, value, and extent.

**Flood Proof**
To develop, redevelop or construct a system/ structure that would control or prevent flooding.

**Increase Capacity**
Increase the amount of space or storage; exceed limit

**Modify**
To adopt and improve; add existing to or change.

**New Area**
To remove and improve; to tidy up

**Nourish (Managed)**
Nourishment is occurring periodically for previously identified landscapes (beaches or dunes)

**Nourish (New)**
Nourishment could be applied to new landscapes (beaches or dunes) that have never been nourished before

**Re-align**
Reshape or to change direction; move differently than its original position.

**Relocate**
To move from one place to the next.

**Remove Obstruction**
To remove or discard an object in the way.

**Replace in Kind**
To put something back that is similar, a replacement designed for that specific site.

**Replace with other**
To put something back that is different, a replacement designed differently with modifications for that site.

**Restore**
To reinstall, renew, and redevelop back to its original state.

**Restore (Direct Repair)**
To fix, repair, renovate, revamp to its former condition.

**Restore (Tidal Flow)**
Improve the flow of water through channelized areas back to its original state.

**Scour Mitigation**
To stop, prevent, or control the wearing of materials from wind, water, and ice.

**Undetermined**
Not known just yet; future planning and strategies are in place.

## Project Component #2: Resilience Working Group

The overall intent of the Resilience Working Group was to provide a high energy, action-oriented, and collaborative environment where manageable issues related to resilience in southeastern Connecticut are raised and advanced – packaged in tasks completed in 90 minutes. The Working Group grew out of the Southeastern Connecticut Regional Resilience Vision project, which entailed municipal engagement and regional workshops convened at Connecticut College. Much of the information collected during these regional workshops formed the foundation for a resilience section in seCTer's Comprehensive Economic Development Strategy (CEDS). As a follow-up to writing the CEDS, seCTer was required to demonstrate implementation of each section of the report. The Working Group proved to be a natural way to move this implementation forward. The Working Group members were selected from the Visioning Workshop attendees who held knowledge of the region and strong motivation in addressing issues of resilience. Fortunately, many of these members were also involved in economic development in their communities, which made them ideally suited.

Before convening the first Working Group, the Core Team worked closely with seCTer's leadership to draft a series of possible focus areas for discussion and implementation. While the Working Group structure was intended to allow members to self-generate topics, the organizing team recognized that some direction was required in the early stages. The organizing team also made efforts to identify tasks that the Working Group could manage that would help municipalities achieve points under the Sustainable CT framework. Working Group tasks have included reviewing economic resilience toolkits, strategizing on outreach efforts to local businesses, reviewing the geospatial database, and reviewing local Plans of Conservation and Development for resilience actions and/or themes. For more detailed descriptions for Working Group meetings and possible future focus areas see Appendix E.

## Project Component #3: Conceptual Design Development

Project Component #3 consisted of a series of iterative engagements with individual, municipal-based teams, and the contractor to generate conceptual designs for high-priority projects (see Section 7). These efforts were intended to bridge a crucial gap between project identification and implementation. While full construction specification documents fell outside the scope of this grant, these conceptual designs provided an integral step by helping stakeholders better frame the possibilities and overall goals of the respective project. Additionally, these projects demonstrate the value of natural infrastructure for municipal decision-makers in Connecticut and beyond.

Conceptual designs are particularly important to fostering cross-discipline coordination and allow practitioners, regulators, and stakeholders to visualize resilient approaches including those that exemplify the 'resilient triple bottom line' – strengthening ecosystems, improving public amenities, and reducing risk to people and property. Only those projects with a 'resilient triple bottom line' were considered for conceptual design development. The smaller box in Figure 2 depicts projects selected for conceptual design while the larger box encompasses other projects included in the Regional Resilience Project Catalog.

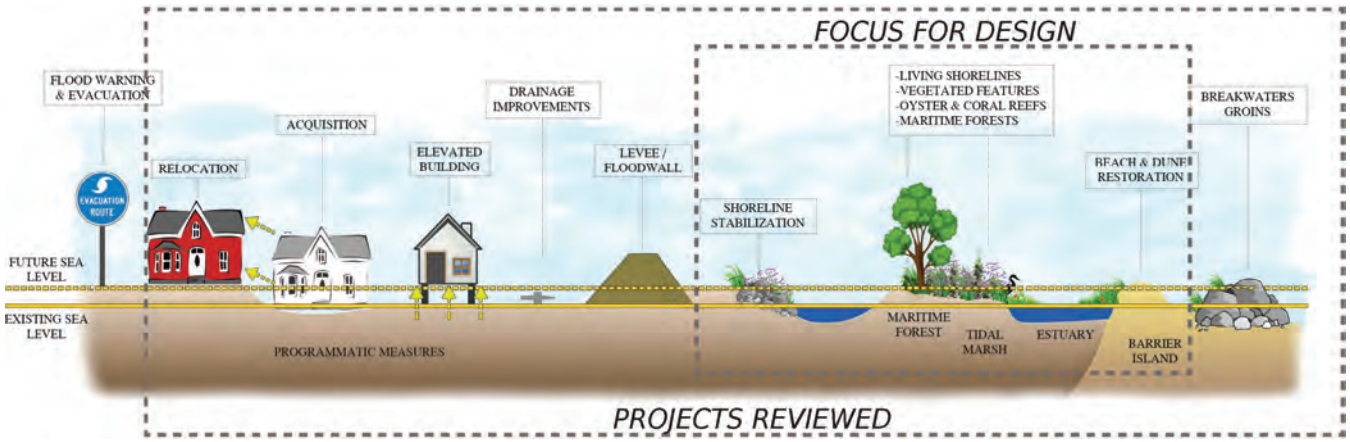
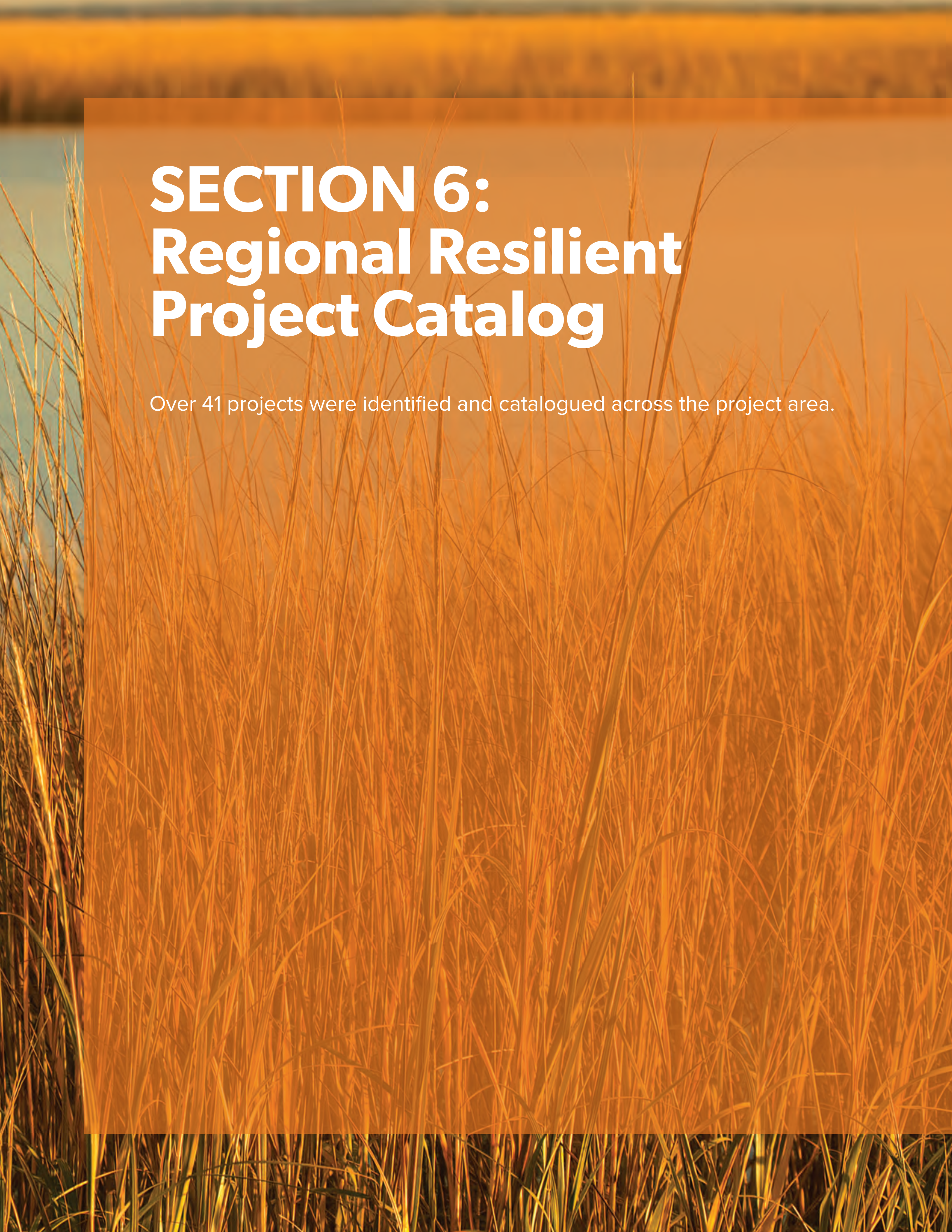



*Figure 2: Project selection focus areas for design as part of the Southeastern Connecticut Regional Framework for Coastal Resilience. Source: U.S. Army Corps of Engineers*


PHOTO CREDIT: iStockPhoto



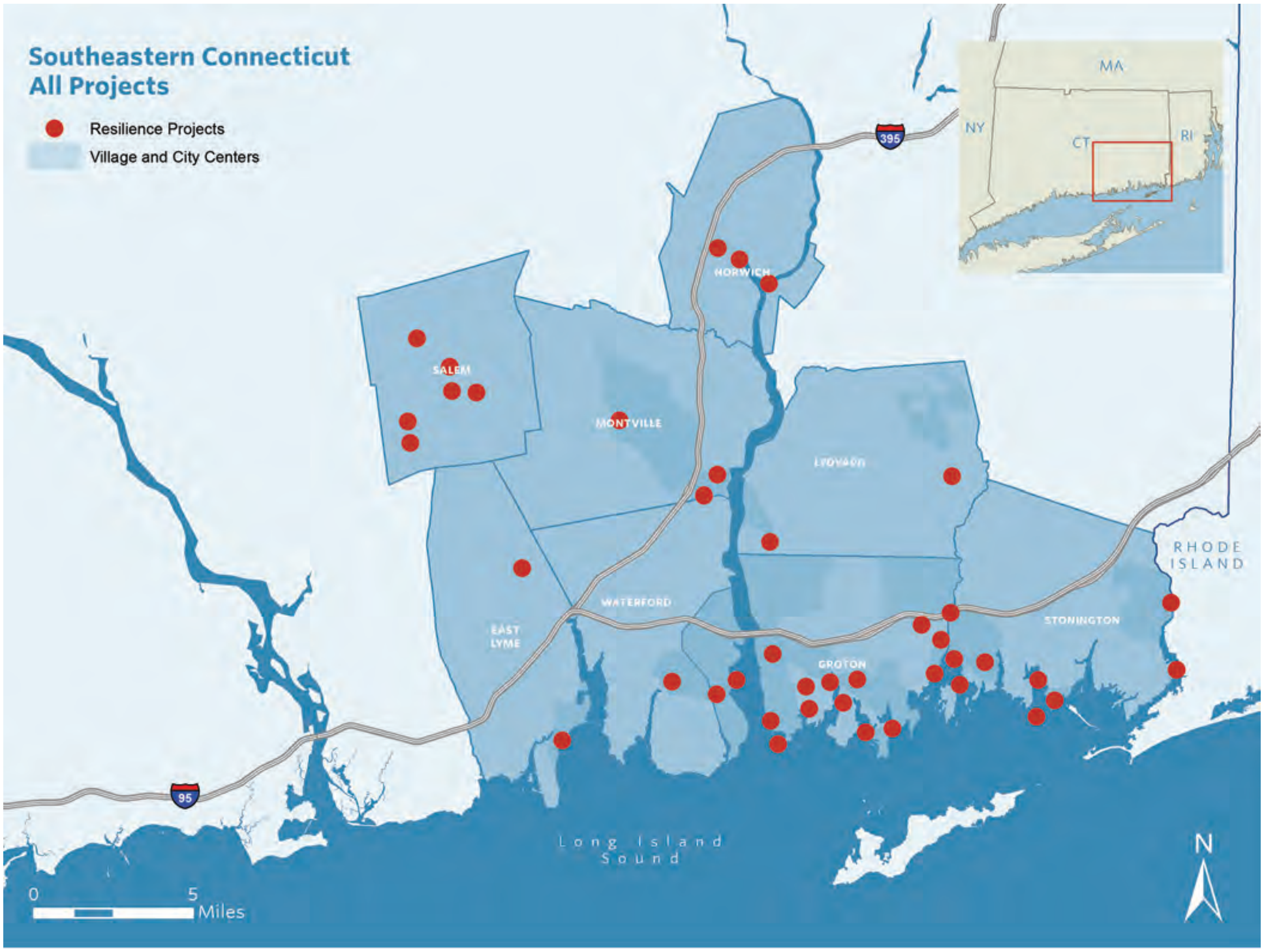
# SECTION 6: Regional Resilient Project Catalog

Over 41 projects were identified and catalogued across the project area.

Over 41 projects were identified and catalogued across the nine municipalities during Project Component #1 (Map #3). Each of the projects represents an initiative that if implemented would help to reduce risk and improve resilience at a local and ultimately, a regional scale whether directly or as a catalyst for similar projects elsewhere. The projects have been categorized by type:

- Coastal Natural Infrastructure (Map #4)
- Hard Infrastructure (Map #5)
- Inland Natural Infrastructure (Map #6)
- Shoreline Infrastructure (Map #7)
- Stormwater Management (Map #8)

Descriptions of priority projects as determined by representatives from the participating municipalities that reflect the various combinations of "type" and "strategy" are provided below (see Box 1 and Box 2 for definititions for "type" and "strategies"). A full list of the projects is provided in Appendix C (Regional Resilience Framework Projects) as well as online via the Regional Resilience Framework Project Application (see Appendix H for directions on use) on the Coastal Resilience-Connecticut decision support tool (www.coastalresilience.org or www.maps.coastalresilience.org/Connecticut/).

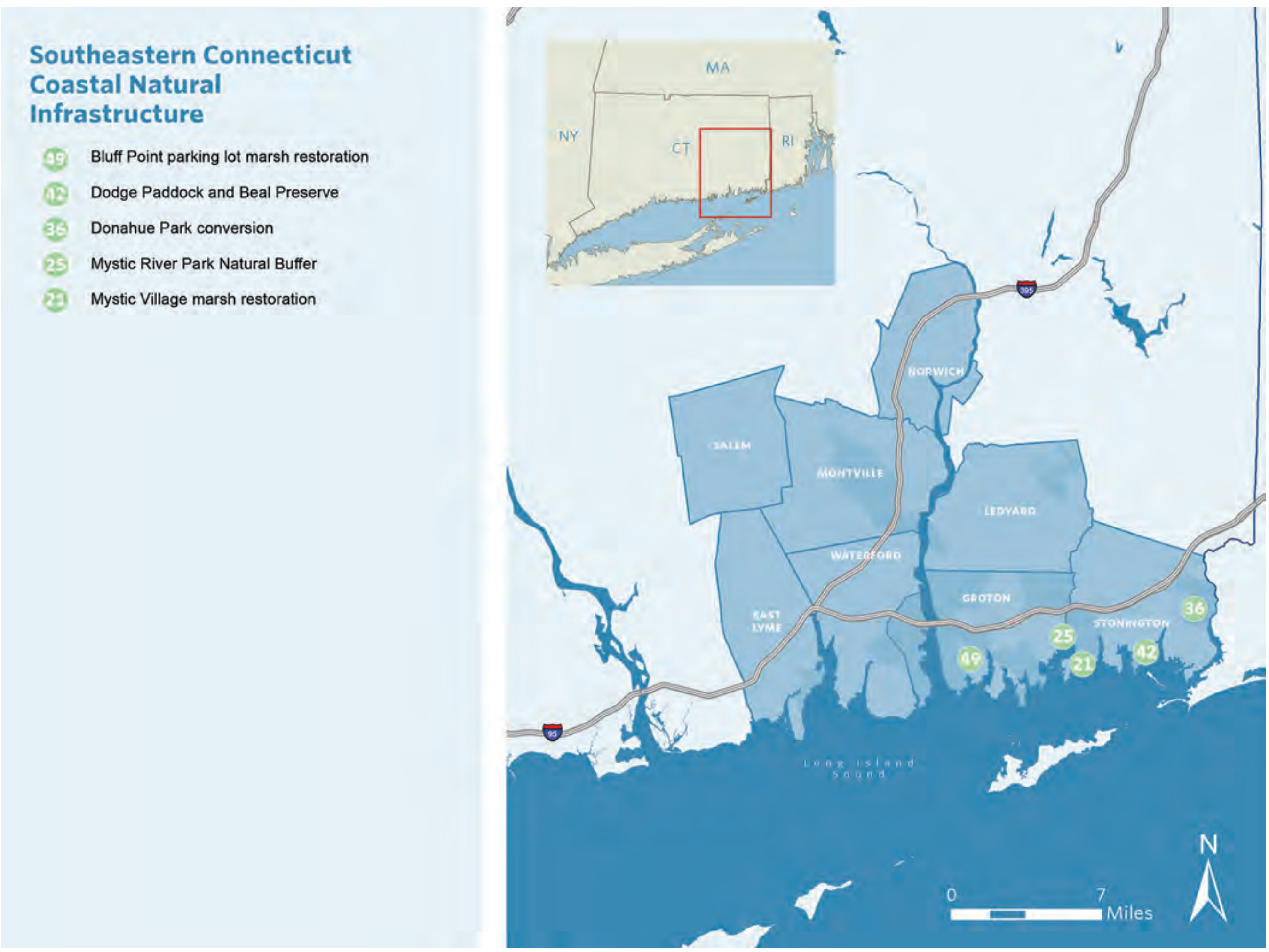



Map #3: Southeastern Connecticut Regional Resilience Projects: All Projects

# Coastal Natural Infrastructure

## 21. Mystic Village Marsh Restoration

The marsh adjacent to the Seaport Marina will advance inland over the next century. According to local sources, the marina already floods during full and new moon high tides. Removing the few buildings in the marsh advancement zone and regarding the earthworks will improve the resilience of the shoreline to erosion, increase coastal habitat, and provide a natural public amenity within walking distance of downtown Mystic. The structures in this area include a small, two-story business and parking lot, 4-5 residences, and the Seaport Marina, some of which is likely constructed on fill.




Map #4: Southeastern Connecticut Coastal Natural Infrastructure Projects

### 25. Mystic River Park Natural Buffer

The existing Mystic River Park, owned by the Mystic Fire District, will likely see regular inundation by the end of the century. Rather than constructing additional hard structures up to the water's edge, this property (and perhaps the surrounding parcels) can be adapted into a living shoreline that will protect the inland road and any additional inland hard infrastructure from erosion. This project would involve removing the existing boardwalk and sheet pile wall, regrading the park, and redesigning the landscaping and public access.

### 36. Donahue Park Conversion

Donahue Park is a small, coastal access park in downtown Pawcatuck. With community support, this currently undeveloped parcel is a strong candidate for living shoreline treatment. Such an intervention could help reduce coastal erosion to adjacent properties and provide a highly visible site to educate the community about sea level rise and adaptation solutions.

### 42. Dodge Paddock and Beal Preserve

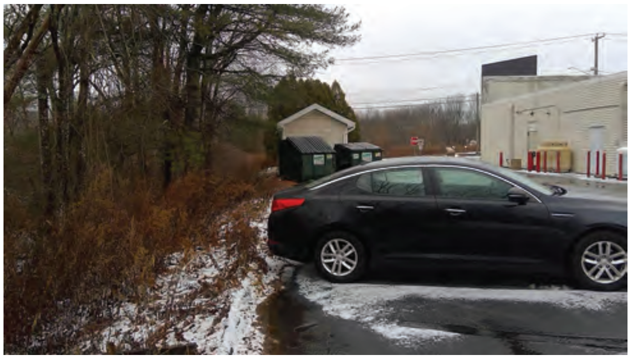
An ongoing project managed by land owner Avalonia Land Conservancy with technical assistance from DEEP and guidance from other sources. Initially, Avalonia intended to eradicate Phragmites and improve drainage in the increasingly wet preserve. Several attempted solutions proved unsuccessful. Hurricane Sandy left a gravel dune obstructing flow, flooding the Paddock and permanently blocking drainage. DEEP created an emergency drainage swale, first with Smart Ditch plastic liner, which was undermined by storm tide, then with a living shoreline/coir logs and plantings. Mystic Aquarium administered a LISFF grant to restore native marsh plants where Phragmites was removed by DEEP over 3 years. A current LISFF grant is funding an engineering study to assess storm protection strategies for the south-facing shoreline of the property. Ultimately, a hybrid living shoreline/rocky sill may be required to protect in the channel inlet from future storm damage. Current funding will also cover continued invasive removal and managing uplands for marsh migration

### 49. Bluff Point Parking Lot Marsh Restoration

The lower part of the Bluff Point parking lot is a naturally occurring tidal wetland that has been significantly degraded by car traffic. CT DEEP Parks and Wildlife divisions are managing an initiative to eventually prohibit parking in this area and restore the wetland function. Clear cutting of adjacent forest on the park land for airport access may provide an alternative parking zone. Project leads are currently waiting for state funding for an archeological survey before proceeding.

# Hard Infrastructure

## 5. Floodproofing Measures Behind Salem Four Corners Plaza



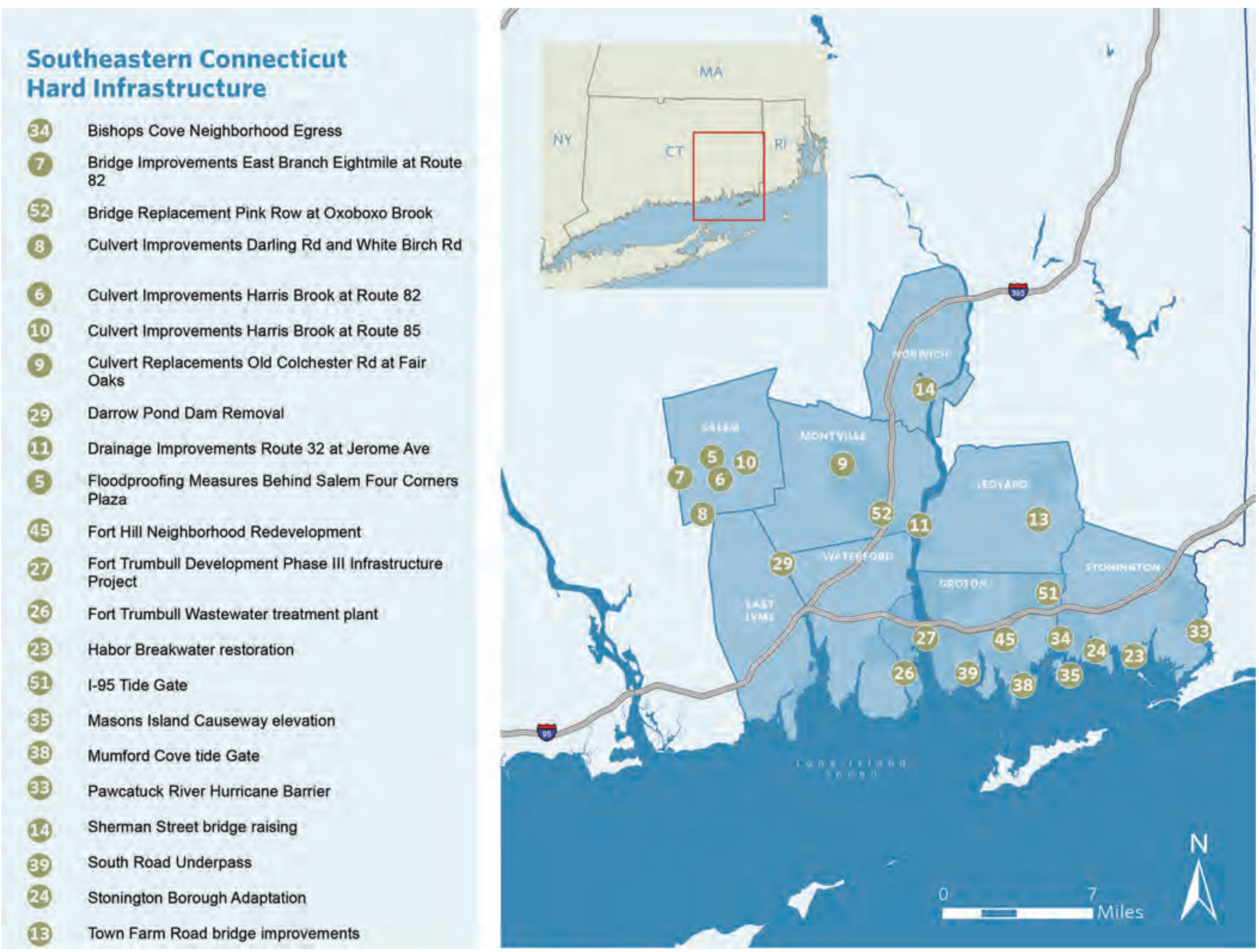
Salem Four Corners is the primary commercial center in the Town of Salem. A few businesses in this area are vulnerable to flooding from Harris Brook with recorded flooding of 1.5 feet. Of particular concern are a number of fuel tanks and electrical equipment in the rear of these buildings. Additionally, the bank holding the rear parking spaces in place appears to be eroding leading to degradation of the curb and asphalt. Possible flood proofing actions include property elevation, town acquisition and demolition, and construction of a flood wall.

## 6. Culvert Improvements Harris Brook at Route 82

Route 82 crosses Harris Brook in two locations. At the crossing closest to Salem Four Corners, the bridge appears to be too low and, according to the 2017 HMP, experiences flooding. In addition to pursing elevation of the bridge, the Town and other stakeholders may examine opportunities to expand flood storage higher up in the watershed.

## 7. Bridge Improvements East Branch Eightmile at Route 82

An existing bridge along Route 82 over the East Branch of the Eightmile River may need to be reevaluated for flood risk. A couple of other culverts to the east at Mitchell Pond should be similarly evaluated.




Map #5: Southeastern Connecticut Hard Infrastructure Projects

### 8. Culvert Improvements Darling Road and White Birch Road

A small tributary of the Eightmile East Branch crosses White Birch Road near the intersection of Darling and Gungy Roads. This spot is especially low, and flooding could undermine the roadbed's integrity over time.

### 9. Culvert Replacements Old Colchester Road at Fair Oaks

A culvert along Old Colchester Road draining Fair Oaks Swamp may be undersized and cause flooding over the roadway during intense rainfall. Additionally, there appears to be some erosion issues along a private property immediately downstream from the culvert that are currently being addressed with a small stone retaining wall. The Town has HGMP funding to expand the culvert capacity. A bench could be cut into a large field to the south-part of the adjacent schoolyard-which may reduce peak flows at the road crossing

### 10. Culvert Improvements Harris Brook at Route 85

Route 85 at Harris Brook may be prone to flooding in heavy precipitation events. A large detention basin immediately upstream from the road currently appears to catch runoff from the adjacent development. The existing road bed need to be raised if the existing box culvert is undersized for heavy precipitation events.

### 11. Drainage Improvements Route 32 at Jerome Avenue

Water, likely road runoff, floods this low section of Route 32 immediately north of the intersection with Jerome Ave . As there are no catch basins in the vicinity, water drains slowly. A long-term approach would include either connecting to the storm sewer system or evaluating opportunities for surface capture and green infrastructure.

### 13. Town Farm Road Bridge Improvements

The Town Farm Road Bridge crossing Williams Brook is low and creates a bottleneck from the adjacent wetland. Additionally, the stretch of road roughly 150 feet to the north appears lower and likely floods if the bridge is overtopped. The Town would like to raise the bridge and/or increase the stream channel width at the crossing. The Avalonia Land Conservancy (ALC) owns the adjacent Samuel Lamb and Forsberg Preserve, managing its upper slope as a meadow habitat. Project designers may consider engaging with ALC and exploring the opportunity to regrade parts of this meadow in order to widen the floodplain, increase flood storage, and slow flood velocities.

### 14. Sherman Street Bridge Raising

The Sherman Street Bridge crosses the Yantic River north of Indian Leap and the Upper Falls Dam. Two spans meet on a small island in the middle of the river channel. The City of Norwich is currently engaged in efforts with the CT DOT to replace and elevate the existing bridge spans. Bedrock streambanks and dense adjacent development significantly limit the opportunity to widen the channel at this crossing.

### 23. Harbor Breakwater Restoration

The Harbor Breakwater protects the harbor operations on the western side of Stonington Borough. Built in the early 1800s, it has fallen into disrepair, being especially damaged during hurricane Sandy. The CT Port Authority has approved funding for design work to be managed by the Town of Stonington.

### 24. Stonington Borough Adaptation

Raising the rail bed at Stonington Harbor would provide protection for the residences surrounding Lamberts Cove and Quannaduck Cove as well as important egress routes from Stonington Borough. A living shoreline where the rail bed meets the western edge of the Harbor would reduce erosion while on the eastern edge of the harbor, near the Wadawanuk Club, a berm would further protect the egress routes from flooding. The 2017 Stonington Resilience Plan estimates that these measures could protect approximately 300 acres from flooding by 2070. Further study is needed however to assess how this intervention might affect flooding in the Borough.

## 26. Fort Trumbull Wastewater Treatment Plant

The Wastewater Treatment Plant for New London and Waterford currently sits at a low spot in the greater Fort Trumbull area. While the facility appears to be well armored against coastal storms, the City should assess whether the plant is sufficiently protected against rising sea levels and future storm damage.

## 27. Fort Trumbull Development Phase III Infrastructure Project

The large Fort Trumbull development project is soon entering its third and final phase of implementation. This phase will include new streetscape construction across from the entrance to the state park. The designs may not yet have accounted for future sea level rise and should be reviewed by subject matter experts.

## 29. Darrow Pond Dam Removal

The Darrow Pond property is owned by the Town of East Lyme. An earthen roadbed runs across its outlet. A large box culvert under the road empties into a privately-owned wetland and tributary of Latimer Brook. DEEP inspectors indicate this as a high hazard dam that could wash out downstream houses and a stretch of route 161. Any action taken on this road would have significant impacts on the water levels in the Darrow Pond Open Space. The 2017 Hazard Mitigation Plan recommends that the Town prepare an Emergency Operations Plan for a dam failure event here. As this is a low traffic road, a long-term removal strategy may be appropriate.

### 33. Pawcatuck River Hurricane Barrier

The 2017 Stonington Resilience Plan concluded that Pawcatuck faces the most flood vulnerability of any village in the Town based on total land area and property values. A narrow stretch of the river channel near Stonington on the River Dockominiums and the Westerly Yacht Club is likely the best spot to locate a hurricane barrier if necessary. The study estimates that this intervention could save up to about 500 acres of inundation by mid-century. Such an intervention would likely take the form of a rip-rap wall with a removable gate in the middle to allow boat and fish passage. The resilience of this barrier system could be further enhanced through living shoreline techniques on or around the barrier. More study is needed to more accurately model local effects such an intervention would have on flooding and habitat quality.

### 34. Bishops Cove Neighborhood Egress

Long Wharf Drive provides the sole egress to the Bishops Cove Neighborhood. Virtually the entire road lies in the coastal flood zone and could seriously complicate emergency management efforts for this neighborhood. The 2017 Hazard Mitigation Plan recommends further study to better evaluate options for creating alternative egress. Given the steep slopes and a number of adjacent wetlands, there is likely not a simple solution for protecting egress. Connecting the neighborhood to either Kidds Way or Richmond Ln appear on paper to be the shortest and least costly routes; however, both of these roads face flood risk themselves. A better long-term approach may be to connect with Mistuxet Ave near the Mystic Middle School, close to half a mile to the north.

## 35. Masons Island Causeway Elevation

According to the 2017 Stonington Resilience Plan, 319 of the 412 parcels on Masons Island (87% of the islands total land mass) are currently vulnerable to coastal flooding. The existing rip-rap-bedded Masons Island Causeway serves as the only mode of land-based access to the island. The causeway itself sits at a quite low elevation and saw significant impacts during Superstorm Sandy. To ensure safe egress during flood events, the plan recommends raising the causeway to create a bridge across this stretch of the Mystic River. In conjunction, the Town would need to elevate a few of the adjoining roadways on each side of the causeway to meet the new grade of the bridge and ensure dry egress. In addition to these structural modifications, the down-river parcels on each side of the bridge could be enhanced as living shorelines to protect the soil surrounding the bridge substructure. Overall, such a project would be quite costly especially if building to future flood standards. Such an undertaking should be seriously considered against alternative actions including improved emergency planning and property buyouts.

## 38. Mumford Cove Tide Gate

This project has been included in the past two hazard mitigation plans for the Town. Flooding concerns here include Groton Long Point and Neptune Drive towards the Cove's mouth and the rail line, the wastewater treatment plant, and the Fort Hill neighborhood upriver. At this point, the Town does not have the resources to invest in a large scale flood protection system and is currently more interested in studying alternative approaches. The full width of the Cove's mouth is over to a mile, making large scale protection of Groton Long Point quite ambitious. More manageable projects may be appropriate further up the Cove. As all hard infrastructure risks significantly altering the hydrologic and tidal regimes along the coast line, all efforts should be made to explore alternative approaches including living breakwaters, property elevations, and or buyouts. In the case that a tide gate is required, designers should consider living shoreline techniques where the wall ties into the existing coast line. This would both improve the structural resilience of the tide gate while enhancing habitat in the Cove.

### 39. South Road Underpass


The South Road Underpass regularly floods and could compromise emergency response for the airport and neighborhoods south of the rail line. A catch basin at the base of the underpass could be a source of floodwaters and should be evaluated based on sea level rise projections. The Town proposes working with Amtrak to explore opportunities to elevate the rail line. Another option could include raising the road grade up to a level crossing of the tracks.

### 45. Fort Hill Neighborhood Redevelopment

All of the Fort Hill Neighborhood lies within the 500-year floodplain, with the likelihood of flooding from Mumford Cove increasing with rising sea levels this century. The existing neighborhood contains a large number of one-story World War II stock housing, constructed for the influx of laborers in the local military industries. Flooding to this neighborhood would likely displace a number of families and be devastating to the local community. The Town would like to develop a long-term buyout and redevelopment strategy for this area. While targeted levee construction could help to protect some residences, the number of flood water sources (Mumford Cove, Fort Hill Brook, and the Poquonnock River) may make full protection difficult. Buyouts on the eastern and northeastern edges of the neighborhood may be particularly advantageous for the Town as they would expand existing public open space. Where possible, the Town should also consider floodplain expansion and restoration along Fort Hill Brook to mitigate flooding and improve aquatic habitat.

### 51. I-95 Tide Gate

Old Mystic refers to the shared area of Stonington and Groton surrounding the Mystic River north of 1 -95. According to the 2017 Stonington Resilience Plan, many developed parts of this village could face 50% annual flood vulnerability by mid-century. The 1-95 bridge here could be retrofitted with adjustable tide gates that would still allow boats to navigate the river during normal conditions but close during storms and greatly reduce the flood risk to this village. This proposed project lies upstream from the more extensive, proposed Mystic Flood Protection System, which involves elevating the rail bed south of Mystic Village. The Mystic Flood Protection System would likely render the 1-95 Tide Gate Strategy irrelevant.

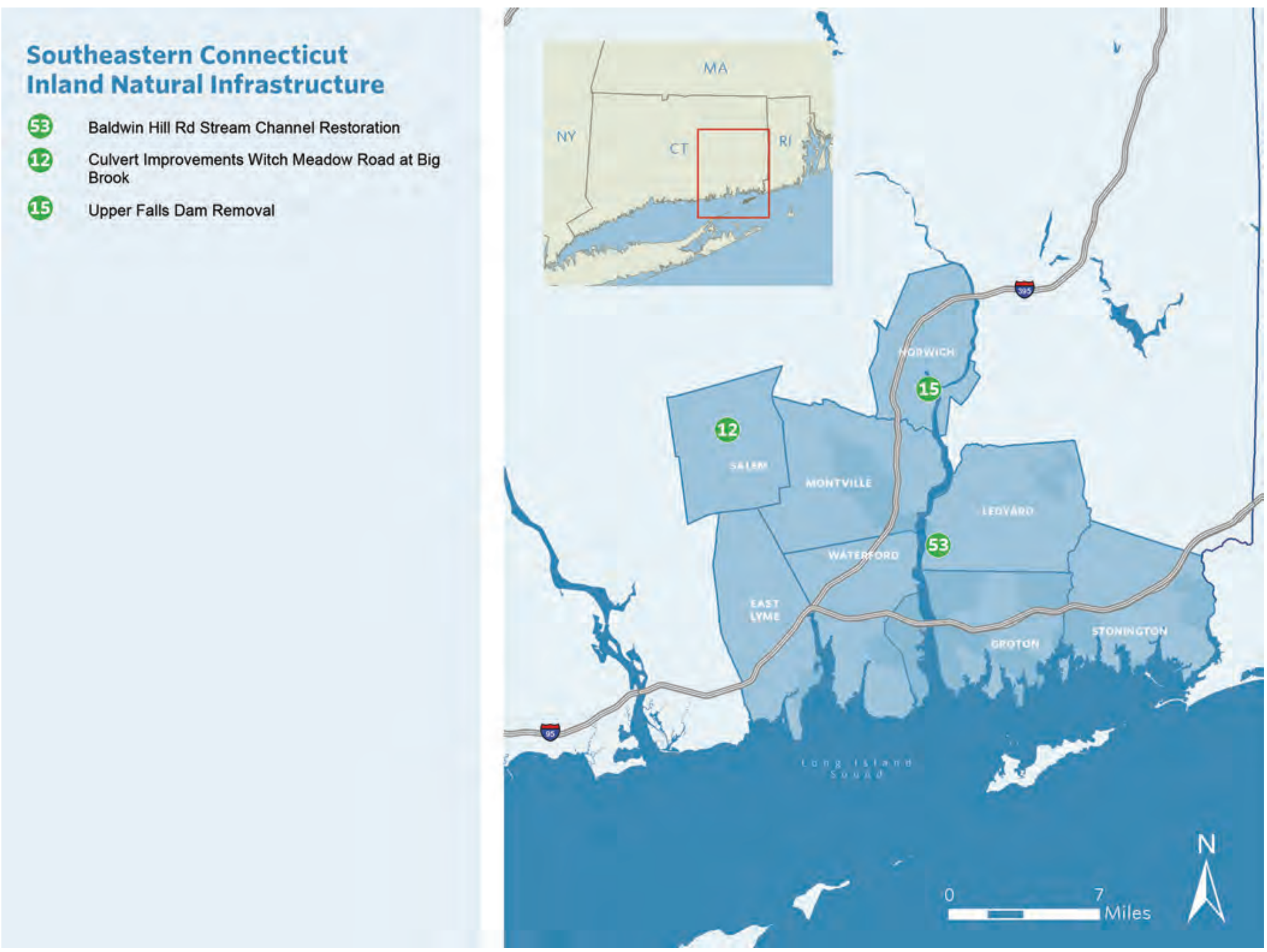
### 52. Bridge Replacement Pink Row at Oxoboxo Brook

The Bridge at Pink Row and Oxoboxo Brook floods during heavy rain events. Future study is needed to determine the feasibility and cost-effectiveness of raising or otherwise protecting this bridge. As the surrounding up and downstream land is vulnerable to flooding, any future bridge designs may consider widening and improving the stream channel. Just downstream, the Oxoboxo empties into Horton Cove off of the Thames River. Stream channel improvements could also potentially improve fish migration and habitat.

# Inland Natural Infrastructure

## 12. Culvert Improvements Witch Meadow Road at Big Brook

Witch Meadow Road crosses Big Brook immediately downstream from the remnants of an old dam. At this location, the streambed drops between 5-10 feet before entering a box culvert. An unmortared stone wall retains an adjacent parking lot and comprises the eastern bank of the river below the dam. A few residences surround the pond created by the dam. Removing the dam remnants and restoring the natural streambed could reduce the flood risk to the road.




Map #6: Southeastern Connecticut Inland Natural Infrastructure Projects

### 15. Upper Falls Dam Removal

The old hydro-electric dam up river from the Indian Leap dam is largely in disrepair and may contribute to sedimentation near the Sherman Street Bridge. Removing this dam would likely lower the water level and potentially reduce upstream flood risk.

### 53. Baldwin Hill Rd Stream Channel Restoration

Tributary of Flat Brook north of Baldwin Hill Road could potentially be enhanced to improve flood storage. Further study is needed to assess the feasibility and downstream impacts.

## Shoreline Infrastructure

### 19. Shore Avenue Drainage Improvements

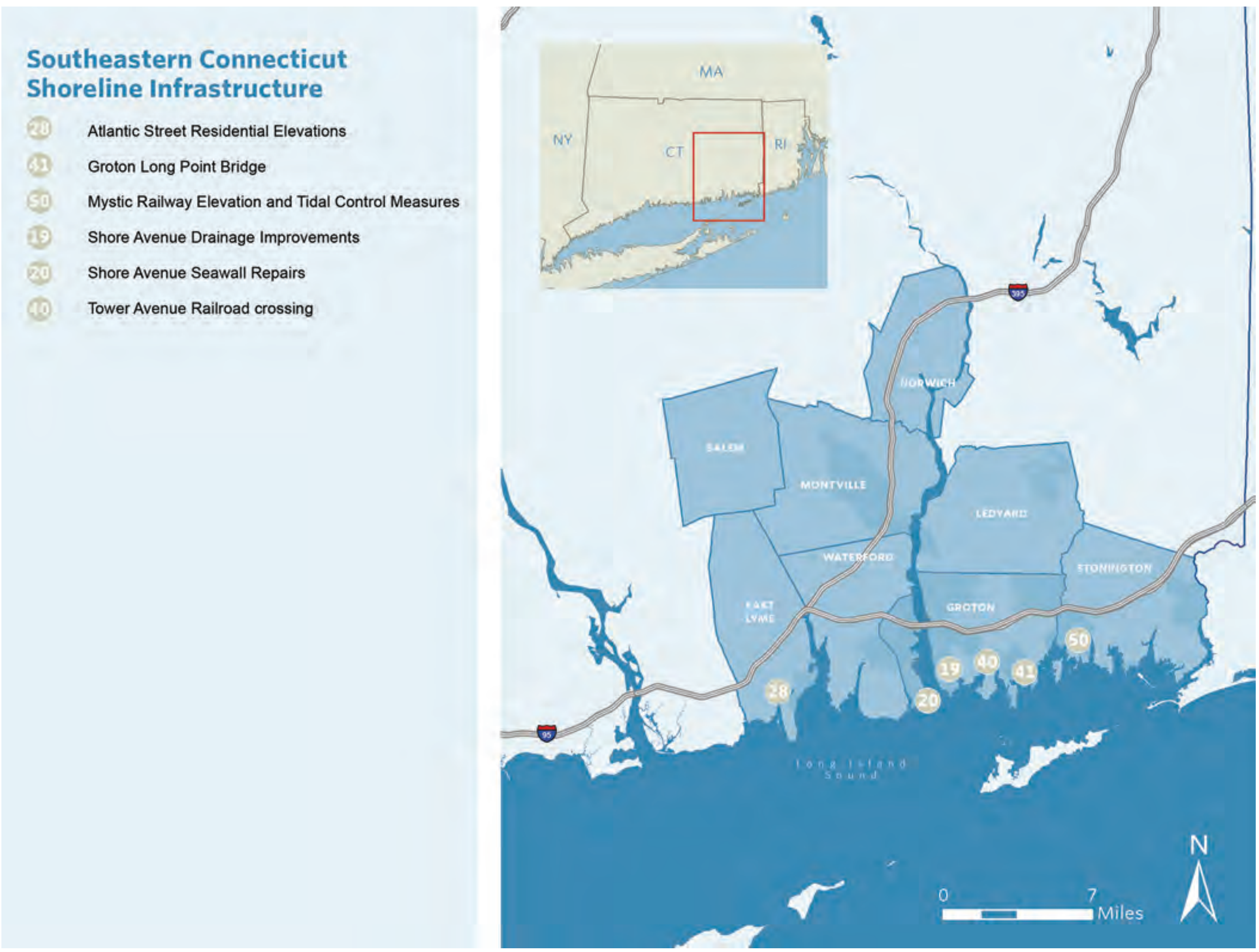
City officials observed some catch basins backing up during high tide along Shore Avenue south of the seawall, flooding the road and adjacent residences. The flooding is especially acute along an approximately 300-500 ft stretch that intersects with the drainage pipe from the golf course. Constructing green infrastructure systems on the golf course and adjacent properties may help to alleviate the severity of flooding in high precipitation events. However, any long-term flood mitigation strategy would need to involve raising or abandoning the road and adjacent properties.

### 20. Shore Avenue Seawall Repairs

Wave action has significantly eroded out the substrate beneath the existing seawall along Shore Avenue across from the golf course. The City has developed a plan to repair this seawall and is looking for funds to complete a final environmental permit. High wave energy from the sound and from boat wakes may make a living shoreline difficult in this location.

## 28. Atlantic Street Residential Elevations

Six residences stand between McCooks and Crescent Beach in the Black Rock Neighborhood of East Lyme. FEMA current lists all six as repetitive loss properties, which face significant and growing risks to coastal storm damage and sea level rise. These homes fall within the larger Black Rock Neighborhood. Black Rock lies directly in line with the outlet of Long Island Sound ("The Race") and as a result experiences the largest fetch of any coastline in Connecticut. Some of these homes are currently elevated to FEMA standards; however, requiring an additional freeboard to take into account future sea level conditions would help to further mitigate risk. As part of a coastal resilience study, the Town of East Lyme hopes to use more precise sea level modelling to require additional freeboard in its building codes. Long term, buyout of these properties by the town could connect McCooks and Crescent Beaches, expanding two already popular public amenities.




Map #7: Southeastern Connecticut Shoreline Infrastructure Projects

### 40. Tower Avenue Railroad Crossing

A potential choke point for emergency access to the airport from the west. Flooding from Birch Creek covers an approximately 500 ft channel over Tower Road near the railroad crossing. This potential project is included in the Hazard Mitigation Plan under a broader desire to address roadway elevations and structural problems around the airport. Elevating Tower Road at this point is an option, though it would involve regrading the road bed back to adjacent residential properties. Also, as much of the road extending west from this point still lies in the 100-year floodplain, targeted elevation here may not ensure dry egress. As an alternative or in conjunction with roadway studies, the Town could consider assessing opportunities for floodplain restoration in the Birch Plain corridor. Additional flood storage here may help protect a broader range of roadways and neighborhoods while also enhancing an existing public amenity.

### 41. Groton Long Point Bridge

The Town is currently conducting an engineering study to improve the resilience of the Bridge to coastal flood impacts. A project here may involve increasing the bridge span to prevent a storm surge bottle neck and/or improving the resilience of the road bed from erosion. The Bridge appears to be well supported by adjacent boulders, but there could be concern for erosion of the adjacent roadbed as sea levels continue to rise.

The problem of erosion along the eastern shoreline could potentially be compounded by an existing private jetty on Esker Point. This jetty, and other hard infrastructure on the point, may be starving the beach near the bridge of additional sediment. A living shoreline approach adjacent to the Bridge could improve the structural integrity of this important piece of shoreline infrastructure.

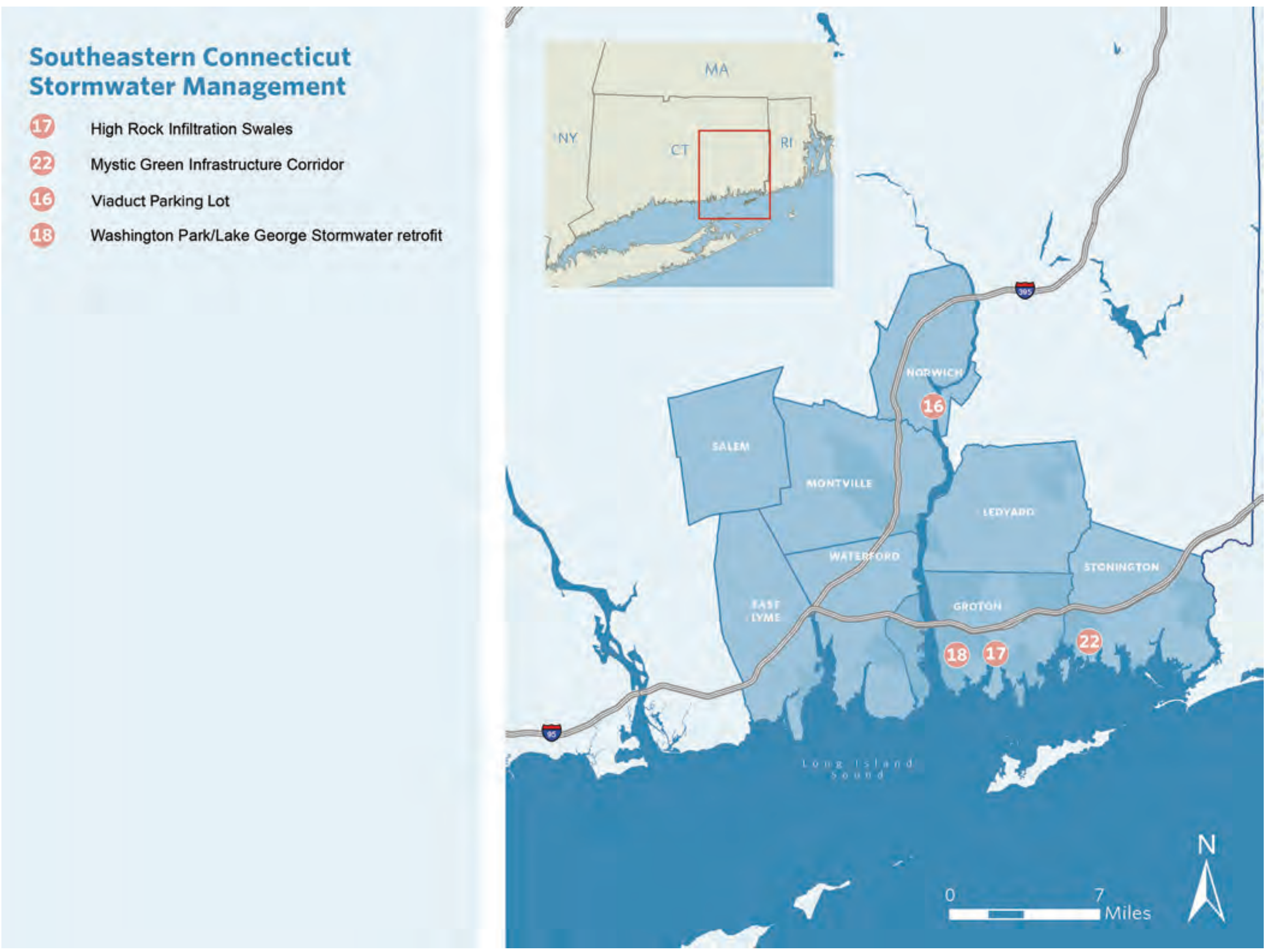
### 50. Mystic Railway Elevation and Tidal Control Measures

The Village of Mystic houses some of southeastern Connecticut's most important commercial assets as well as historical and cultural assets of international recognition. Much of the Village is vulnerable to both sea level rise and storm surge. The 2017 Stonington Resilience Plan suggests elevating the rail bed south of Mystic Village from Fort Rachel Marina to Wilcox Road. Under this proposal, the Town and railroad would also construct flood control devices such as tide gates beneath the bridges and culverts. If properly constructed, the writers of the report estimate that this barrier could protect close to 800 acres of Mystic Village from storm inundation by mid-century.

# Stormwater Management

## 16. Viaduct Parking Lot

The northern half of the Viaduct Parking Lot drains into at least two catch basins located in the middle of the aisles. The southern half sheet flows off the pavement and drains directly into the Shetucket River. The outflow zone, located directly adjacent to the bridge abutment, shows significant signs of erosion. To limit untreated stormwater from entering the river, the pavement surrounding this out-flow zone could be removed and replaced with a sedimentation trap and vegetated infiltration swale.




Map #8: Southeastern Connecticut Stormwater Management Projects

## 17. High Rock Infiltration Swales

The cul-de-sacs at the ends of D, G, and H Streets directly abut the head waters of Birch Creek. Regrading the road into a bioswale or infiltration basin that drains into the creek would reduce inflows of contaminated water.

## 18. Washington Park/Lake George Stormwater Retrofit

An existing wetland in Washington Park was levelled to create an outdoor skating pond. However, likely due to excess salt from the inflows, this pond rarely freezes over. A series of linear, artificial channels drain the wetland during the off-season but show signs of persistent erosion. The resulting sedimentation significantly clogs the downstream storm sewers. Reconstructing the wetland channels to mimic the curvatures of a natural streambed may help to slow the water and reduce erosion.

Additionally, restoring the banks and wetland with appropriate native plants can improve the overall water treatment capabilities of this feature. The City could also combine this project with improved public access and educational materials to enhance this underutilized public amenity. To further enhance water treatment capacity, the City could also remove the asphalt armoring along Meriden Street, regrade the slope and plant a buffer of native plants to intercept road runoff.

## 22. Mystic Green Infrastructure Corridor

A green corridor consisting of streetscape tree plantings and/or right-of-way bioswales could help alleviate some flooding in Mystic from inland sources. Private landowners adjacent to the corridor could also be encouraged to implement flood-mitigating landscaping. This proposed corridor would connect the Mystic drawbridge to the Pequotsepos River crossing of Williams Avenue by way of East Main Street and Broadway Avenue.

# OVERALL LESSONS LEARNED: Planning and Design Phases

Numerous lessons were generated during the identification, planning, and design phases (Project Component #1, #2, #3) of this Regional Resilience Framework project as discussed below. These lessons as provided are intended as general guidance for stakeholders looking to advance community resilience building for municipalities and regions in Connecticut and beyond.

**NATURE-BASED SOLUTIONS AND GREEN INFRASTRUCTURE WILL NOT BE POSSIBLE EVERYWHERE.** SOME COASTAL STRUCTURES WILL REMAIN AND WILL NEED TO BE REPAIRED AND EVEN ELEVATED AS NEEDED (EITHER IN KIND, OR WITH MODIFICATIONS).

Hard coastal structures will be a part of Connecticut's developed shorefront for many years into the future. These structures presently include and will continue to include seawalls, bulkheads, revetments, groins, and breakwaters. These hard structures will protect many miles of shoreline roads, the State's numerous water-dependent uses, countless public amenities, and many thousands of private properties. In municipalities, such as City of New London and Groton, hard structures are the only barrier standing between open water and critical systems in the southeastern part of the city. Similar situations with critical infrastructure can be found in many other municipalities.

While the regulatory climate will only rarely allow the construction of new hard structures in Connecticut, existing structures will need to be repaired or replaced as needed. Modifications may be prudent in some cases in response to changing site conditions due to sea level rise and intense precipitation events. However, opportunities for natural and green infrastructure are 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 coastal and riverine edges, prevent erosion, and directly deflect wave energy and flood waters. Some coastal structures will need to be enhanced, modified, or replaced over time. In limited instances, new hard structures may be necessary to protect infrastructure or people.

IN CERTAIN SITUATIONS, SUCH AS COASTAL AND RIVERINE BANK PROTECTION, **NATURE-BASED SOLUTIONS MAY ACHIEVE THE DESIRED RESULTS OF FLOOD PROTECTION AND/OR EROSION MITIGATION.**

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; for example, where it is providing sand for the State's beaches. However, there are many locations where the unprotected banks occupy gaps (or risk) 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.

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. Green and hybrid approaches should be considered for these settings; incorporating native vegetation and local earthen materials whenever possible.

**LIVING EDGES OR SHORELINES MAY BE FEASIBLE TO ESTABLISH IN THE INTERTIDAL ZONE** WHERE THEY ARE NOT ALREADY PRESENT, AND MANY **EXISTING TIDAL WETLAND SYSTEMS MAY BE FEASIBLE LOCATIONS FOR MARSH ENHANCEMENT.**

There are many examples of tidal wetlands and natural shoreline features that are established and functioning without intervention. Small pockets of smooth cordgrass (*Spartina alterniflora*) can be found in many places along the Connecticut shoreline where wave energy is generally high, but outcrops or structures are providing some shelter. By replicating these conditions, tidal wetlands may establish in areas where they have recently been lost, or perhaps where they have been absent for many years.

LIKE HARD STRUCTURES, **TIDE GATES WILL CONTINUE TO EXIST** AS PART OF CONNECTICUT'S COASTAL LANDSCAPE.

WHERE POSSIBLE, **TIDE GATES CAN BE REPLACED TO ENHANCE TIDAL FLUSHING AND PROMOTE A HEALTHIER ECOSYSTEM**, DRIVING OUT INVASIVE SPECIES. **FLOOD PROTECTION BENEFITS MAY ALSO BE IMPROVED, GIVEN THE OPPORTUNITY TO REPLACE AGING INFRASTRUCTURE WITH NEW INFRASTRUCTURE.**

Some stakeholders advocate for true engineered flood protection systems such as walls, dikes, and berm systems in some locations.

Notable flood protection systems are found in several inland locations in Connecticut such as the communities of Hartford, Torrington, Watertown, Ansonia, Derby, and Pawcatuck. These flood protection systems were installed many decades ago to reduce risk of flooding in densely developed areas adjacent to rivers. However, coastal flood protection systems are rare in Connecticut.

- Stonington: The Amtrak rail bed currently provides some degree of protection to the Village of Mystic and a few smaller neighborhoods in the Town. This protection, though, will decrease as sea levels continue to rise. The 2017 Stonington Coastal Resilience Plan suggests that the Town coordinate with Amtrak to elevate the rail bed to protect important historic and economic assets. The plan also proposes constructing a new flood wall near the mouth of the Pawcatuck River to protect the upstream Village from storm surge. Such interventions may be prohibitively expensive and some express concern the such a dramatic alteration could lead to unintended consequences for those communities that fell outside of the wall.
- Groton: The 2017 Natural Hazard Mitigation Plan suggests installing flood/tide gates at Mumford Cove and Groton Long Point. This system could protect vulnerable properties within the Fort Hill neighborhood; however, little to no analysis exists to support such a structure. Given that flooding to the neighborhood could come from Mumford Cove, the Poquonnock River, or Fort Hill Brook, a more comprehensive study is needed to determine the effectiveness of a Mumford Cove flood gate.

Although flood protection systems are not typically feasible to construct as natural or green infrastructure, several opportunities may exist to incorporate these features into some of the design elements. For example, the Stonington plan recommends living shorelines where the rail bed ties into the mainland. This flood protection would still be hard infrastructure at heart, but greener elements would soften the appearance and perhaps prevent erosion and scour around the hard elements.

NUMEROUS SECTIONS OF **COASTAL ROADS WILL NEED TO BE ELEVATED** TO REDUCE THE FREQUENCY OF FLOODING, AND THEREFORE REDUCE THE RISK OF FLOODING.

**IF A ROADWAY WERE ABANDONED, RISK WOULD BE ELIMINATED.** IN MANY CASES, ROAD ABANDONMENT NEEDS TO BE PAIRED WITH INCREASING THE LEVEL OF SERVICE OF ANOTHER ROAD, OR CREATION OF ALTERNATE ACCESS.

## SCOUR IS A PROBLEM IN SOME COASTAL SETTINGS, POSING RISK TO BRIDGES.

Where scour has been observed, or is posing risk to bridges, it may be possible to utilize hybrid solutions to stabilize the area subject to scour. Green or solely nature-based solutions may be more challenging to use in these areas, depending on the velocities found in the channels.

## **WATER, WASTEWATER, AND STORMWATER UTILITY INFRASTRUCTURE WILL NEED TO BE STRENGTHENED, ELEVATED, CREATED, OR RELOCATED** OVER TIME, EITHER AS A MEASURE TO SOLELY INCREASE RESILIENCE OR REDUCE ASSOCIATED FLOODING.

Many of the municipalities recognize the nexus between coastal resilience projects and stormwater management using rain garden, bioswales, and other traditional inland green infrastructure projects.


PHOTO CREDIT: Susan Rubinsky

# SECTION 7: Conceptual Designs

## Conceptual Design Summary: Project Selection and Design

Two high-priority resilience project conceptual designs and one planning area design projects were selected to advance through an iterative conceptual design process. These projects meet the “resilient triple bottom line” requirement that incorporates effective nature-based alternatives for reducing risks to ecosystems, people, and infrastructure. For example, the Lake George Washington Park Wetland Enhancement project will reduce erosion and sediment overload in downstream storm-water infrastructure. The Esker Point Parking Lot Retrofit on the other hand will prevent further shoreline loss on an important municipal amenity. Both projects could result in significant direct ecological benefits if the restored habitats become more resilient to storm surge and heavy precipitation events. The one planning area design project for the Village of Mystic in Stonington provided similar, yet tailored, alternatives for two subareas – coastal and inland portions of the Village.

# Conceptual Designs

The projects selected to advance through a conceptual design process were arrived at through a detailed assessment, cataloguing, and prioritization process with a diverse suite of stakeholders. While the conceptual designs represent high priority projects, they address challenges found in communities throughout the region and beyond. Therefore, planners, designers, and engineers can apply variations on the concepts and techniques in other locations.

In each case, the conceptual designs try to adhere to a “resilient triple bottom line” approach to community resilience building — reduce risk to people, property, and the environment; enhance a public amenity or quality of life for residents; and increase the viability and function of natural infrastructure and ecosystems.

## Lake George Washington Park Wetland Enhancement

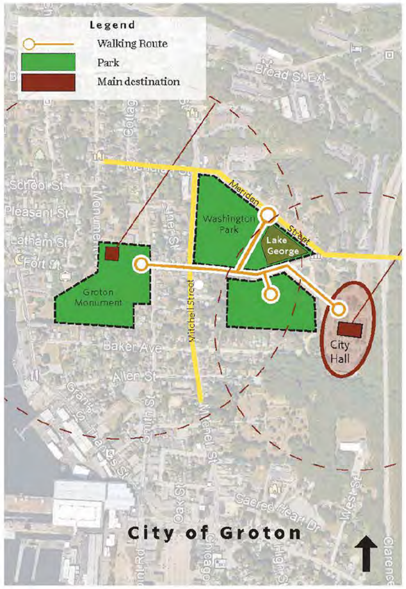
Conceptual Design Basis: The City of Groton experiences significant sedimentation in its stormwater system downstream from the Lake George wetland in Washington Park. The wetland is currently the receiving body for several stormwater outfalls and is the headwaters for the west branch of Birch Plain Creek. Since at least the 1990s, the City has excavated linear channels, presumably to prevent standing water near a public space. The velocities created in these channels likely contribute to the erosion of the wetland and subsequent downstream sedimentation.

The Lake George wetland currently harbors a healthy mix of native plants and lies along a well traversed urban walking route between two important civic structures (Groton Monument and City Hall). This combination of factors makes the site well-suited to enhance as a public amenity and educational piece.

With the goal of reducing downstream sedimentation, the conceptual design recommends rerouting the existing linear channels. Introducing a sinuous channel shape could slow the water velocity, stabilize the banks, and reduce further erosion. Slowing down the water in this way will also enhance the ability of the wetland to absorb stormwater during peak flows, reducing the overall water volume entering the storm sewer.

Where appropriate, the material excavated from the new channels can be mounded across the wetland and around the edges. Creating topographic complexity in this way will create more microclimates and encourage further species diversity. Adding boardwalks and educational signs would enhance the pedestrian experience and recast the space from a problem to a community asset.

# Lake George Washington Park Wetland Enhancement




Context Map
1" = 500'


**Summary Elements**

- The "Lake George" wetland lies along a well-traversed urban walking route and about halfway between two important civic structures.
- The wetland currently harbors a healthy mix of native plants.
- Liner channels may be contributing to wetland erosion and downstream sedimentation in the City's storm sewer.
- Re-directing the channels in a sinuous pattern will slow the water velocity, stabilize the banks, and reduce further erosion.
- Slowing down the water will also enhance the ability of the wetland to absorb stormwater during peak flows, reducing the overall water volume entering the downstream storm sewer.
- Creating topographic complexity by altering the channel, constructing mounds, and re-grading edges will encourage further species diversity.
- Adding boardwalks and educational signs would enhance the pedestrian experience and recast the spaces as a community asset and compliment to Washington Park.

Conceptual Wetland Enhancement Plan
1" = 125'


Existing Conditions
1" = 150'
Contours = 1'


Context Map
2x Vertical Scale

Proposed Wetland Enhancement Perspective

The Nature Conservancy
Connecticut

The Nature Conservancy in Connecticut
55 Church Street, Third Floor
New Haven, CT 06510

**Lake George Wetland Enhancement**
Washington Park
Groton, CT 06340

## Esker Point Parking Lot Retrofit – At Palmer's Cove

Conceptual Design Basis: Esker Point contains a public beach that is a popular summer destination for residents of the Town of Groton and the surrounding communities. Summer concert series, in particular, attract hundreds. A large parking lot immediately to the North serves these users and provides parking for public works vehicles and snow dumping. A smaller, less-trafficked park lies adjacent to this parking lot on Palmer Cove. The park is primarily used by boaters using a recently renovated boat launch and picnickers using the tables. The shoreline of this park appears to be eroding, a process that will likely increase as sea level rises. The Core Team and municipal leadership/staff identified this site as a promising location to promote living shoreline techniques as a one component of an overall approach to increasing resiliency to the Esker Point Parking Lot and associated amenities.

# Esker Point Parking Lot Retrofit – At Palmer's Cove


SITE PLAN: CURRENT STORM SURGE EXPOSURE
SOURCE: CT DEEP
06/2008 SLOSH

Palmer Cove
Groton Connecticut

**Coastal Resilience Planning**

March 01, 2019

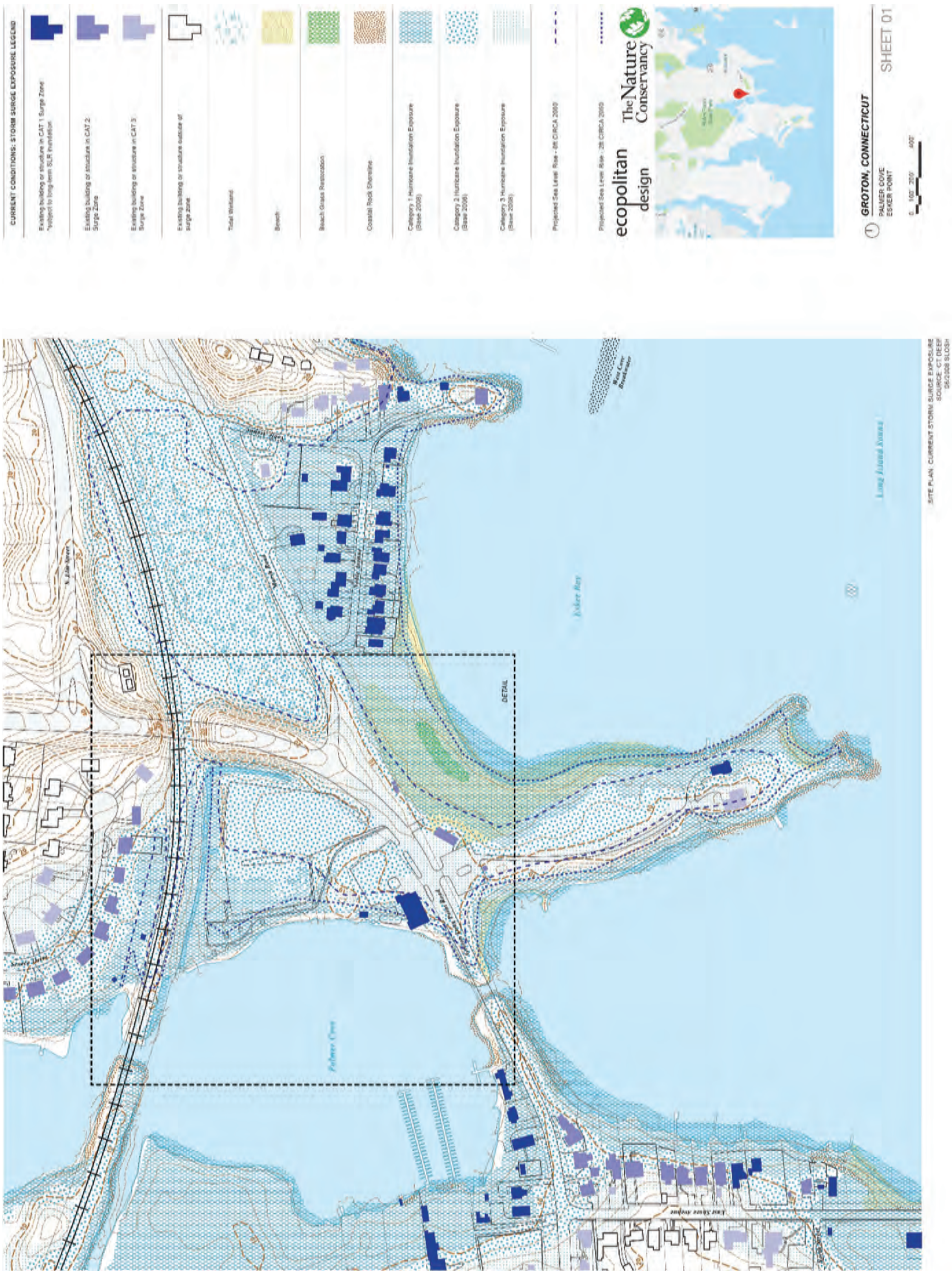
Sheet 01 Site Plan
Sheet 02 Site Analysis & Existing Conditions Study
Sheet 03 Conceptual Design
Sheet 04 Perspective, Soils & Section

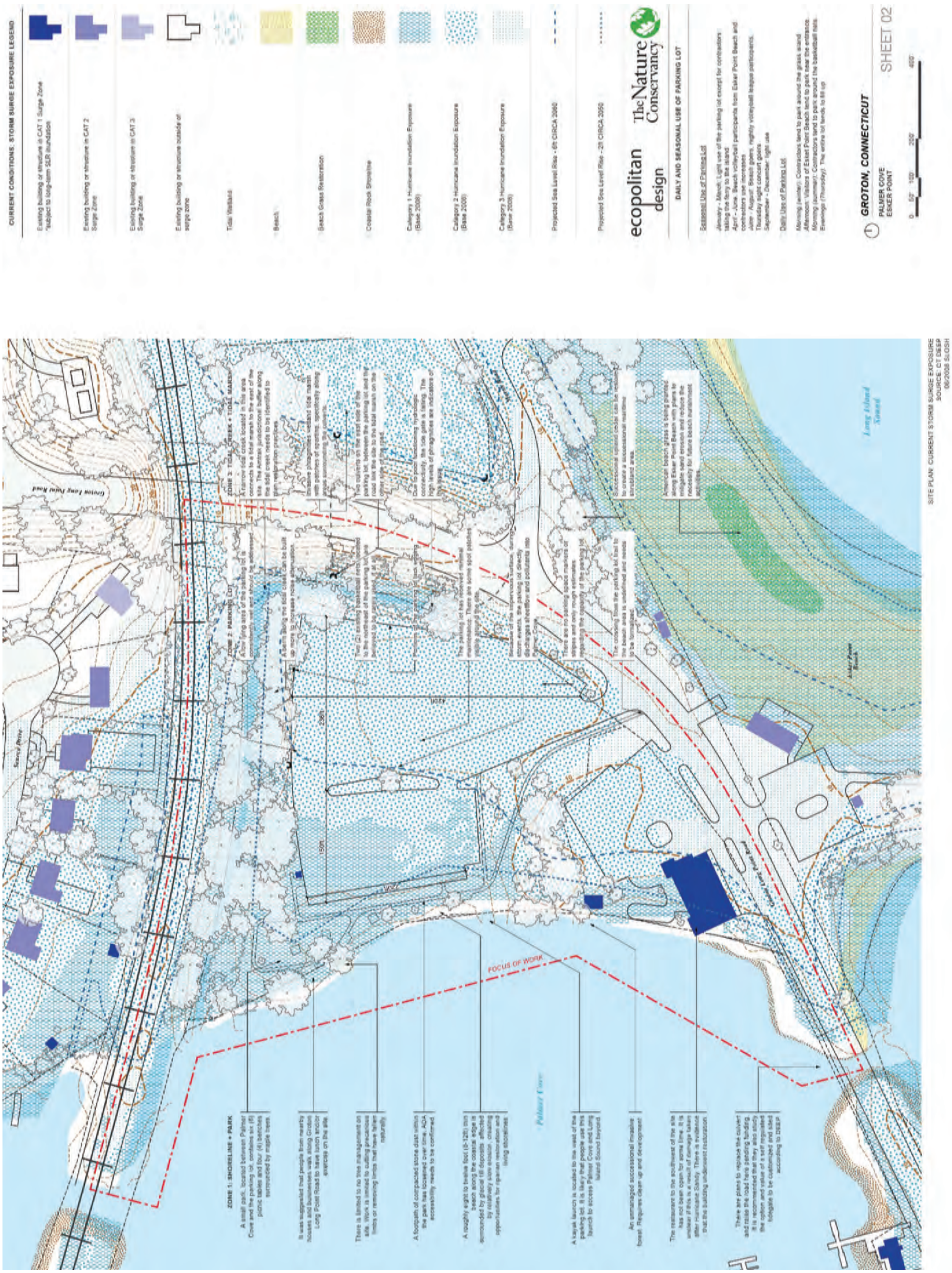
ecopolitan design

The Nature Conservancy

**GROTON, CONNECTICUT**
PALMER COVE
ESKER POINT

0 100' 200' 400'


CURRENT CONDITIONS: STORM SURGE EXPOSURE LEGEND
Existing building or structure in CAT 1 Surge Zone *subject to long-term SLR inundation
Existing building or structure in CAT 2 Surge Zone
Existing building or structure in CAT 3 Surge Zone
Existing building or structure outside of surge zone
Tidal Wetland
Beach
Beach Grass Restoration
Coastal Rock Shoreline
Category 1 Hurricane Inundation Exposure (Base 2008)
Category 2 Hurricane Inundation Exposure (Base 2008)
Category 3 Hurricane Inundation Exposure (Base 2008)
Projected Sea Level Rise - 86 CIRCA 2080
Projected Sea Level Rise - 28 CIRCA 2050
ecopolitan design
The Nature Conservancy
GROTON, CONNECTICUT
PALMER COVE
ESKER POINT
SHEET 01
DETAIL
Palmer Cove
Esker Bay
Long Island Sound
SITE PLAN: CURRENT STORM SURGE EXPOSURE




SITE PLAN: LONG TERM ECOLOGICAL DESIGN PROPOSAL
THE NATURE CONSERVANCY
ECOPOLITAN DESIGN

**LONG-TERM ECOLOGICAL DESIGN PROPOSAL LEGEND**

| NO. | DESCRIPTION |
|---|---|
| 01 | Existing tidal creek inlet |
| 02 | New constructed living shorelines with embedded marsh migration Designed Experiment and experimental study |
| 03 | Existing tree to remain |
| 04 | Bioengineered riparian edge and restoration |
| 05 | Arrange existing benches and tables to take advantage of new park and plantings |
| 06 | New restored maritime shrubland community or other no/low maintenance planting strategies |
| 07 | Introduce specimen trees and more geometric planting strategies along north of site to define and expand park boundaries |
| 08 | New Specimen Tree |
| 09 | Consider opportunities for added privacy around outhouse amentity |
| 10 | Designated zone for tables and planted vegetation in parking area |
| 11 | Existing trail updated to current ADA accessibility standards |
| 12 | Existing tidal creek breach point |
| 13 | Narrow wooden pedestrian footbridge to connect parking area to park |
| 14 | Designated zone for planted vegetation in parking area |
| 15 | Remove existing concrete pad and replace with pervious pavers to increase the size of the park, increase water infiltration, introduce additional planting strategies |
| 16 | New parking lot bioswale. Final sizing and feasibility to be determined by further analysis *(see below for preliminary estimates) |
| 17 | New pedestrian trail |
| 18 | Limit vehicular access of parking area to specific Groton events when a higher parking capacity is needed |
| 19 | New landscaping in bioswale to increase function and aesthetics |
| 20 | Drainage grate linked underground to adjacent bioswale |
| 21 | New formalized canoe and kayak launch site |
| 22 | Existing accessible parking spaces to remain |
| 23 | Moveable bollards to prevent vehicular access. Controlled by Groton |
| 24 | New bicycle racks |
| 25 | New bench seating area |
| 26 | Lift and re-level existing low-lying area prone to standing water |
| 27 | New painted key for half court basketball area |
| 28 | Move existing basketball hoops to this area |
| 29 | Replace existing tide gate with new smart tide gate |
| 30 | New plantings along parking lot edge |
| 31 | Existing parking lot with new painted parking lines for efficiency |
| 32 | New planted parking lot island |
| 33 | Flexible parking spaces available when bollards are active |
| 34 | New trail and planted parking lot island |
| 35 | New painted parking lot island |
| 36 | Habitat restoration of maritime shrubland community and targeted removal of existing plants and invasives |
| 37 | Existing rocky coastal edge |
| 38 | New wooden footbridge connecting to new vehicular bridge |
| 39 | New scenic overlook connected to new vehicular bridge |
| 40 | New vehicular bridge with smart tide gate below |
| 41 | New pedestrian trail to connect to future trail network |
| 42 | New pedestrian sidewalk to connect to existing sidewalk |
| 43 | Clean creek bank and remove invasives |
| 44 | New forested wetland community and alley of red maple |
| 45 | New trail steps |
| 46 | Direction of stormwater flow |
| 47 | Permeable pavers with or without grass coming out |

*We calculated the drainage area of the parking lot to be roughly 400'X500' or 20,000 SF or 4.6 acres. Multiplying this by the runoff coefficient for impervious surfaces of 0.9, provides the total area of runoff that needs to be treated for the specific drainage area from a water quality (.38 acre feet) and water quantity (0.9 acre feet) perspective. Based on EPA recommendations, an appropriate basin size can be calculated by multiplying the total sf of treatment by a cooefficient of 0.7. If designed as a bioretention garden scaled to 50' x 500' (or 25,000 SF) we anticipate roughly 0.36 acre feet of water quality and the same quantity treatment, assumeing 6" of water, 1' of soil (20% porosity), and 1' drainage medium (40% porosity). This will mostly address runoff and water volume is less of an issue since the drainage discharges into the Cove.

ecopolitan design

The Nature Conservancy

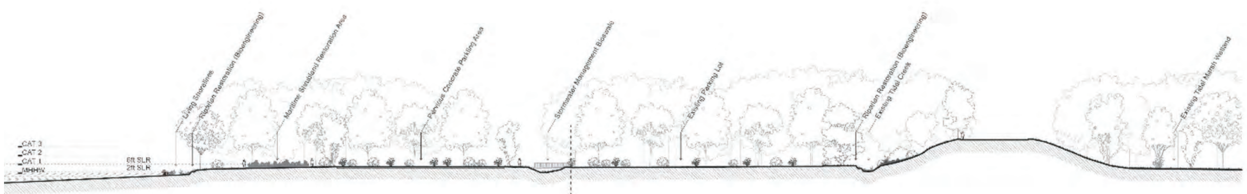
**GROTON, CONNECTICUT**

PALMER COVE
ESKER POINT

SHEET 03

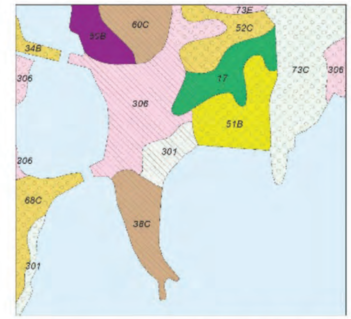
0 50' 100' 200' 400'

SITE PERSPECTIVE: LONG TERM ECOLOGICAL DESIGN PROPOSAL
THE NATURE CONSERVANCY
ECOPOLITAN DESIGN




SITE SECTION: LONG TERM ECOLOGICAL DESIGN PROPOSAL
THE NATURE CONSERVANCY
ECOPOLITAN DESIGN

QUATERNARY GEOLOGIC AND SOILS MAP




| NO. | DESCRIPTION | STRM DET | STRM INF |
|---|---|---|---|
| 17 | Shallow Organic - Inland | Least | Least |
| 34B | --- | --- | --- |
| 38C | Glaciofluvial | Least | Least |
| 50B | Melt-out Till | Somewhat | Least |
| 51B | Melt-out Till | Somewhat | Least |
| 52C | Melt-out Till | Somewhat | Least |
| 60C | Melt-out Till | Least | Least |
| 68C | --- | --- | --- |
| 73C | Melt-out Till - Moderate to bedrock | Somewhat | Least |
| 73E | Melt-out Till - Moderate to bedrock | Least | Least |
| 301 | Urban Influenced | Not Rated | Not Rated |
| 306 | Urban Influenced | Not Rated | Not Rated |

Glacial Ice-laid Deposits: Thin till deposits
late Wisconsinan, Illinoian

Glacial Meltwater Deposits: Uncorrelated meltwater deposits
late Wisconsinan

ecopolitan
design

The Nature Conservancy

GROTON, CONNECTICUT
PALMER COVE
ESKER POINT
SHEET 04

0 50' 100' 200' 400'

# Village of Mystic Resilience Planning

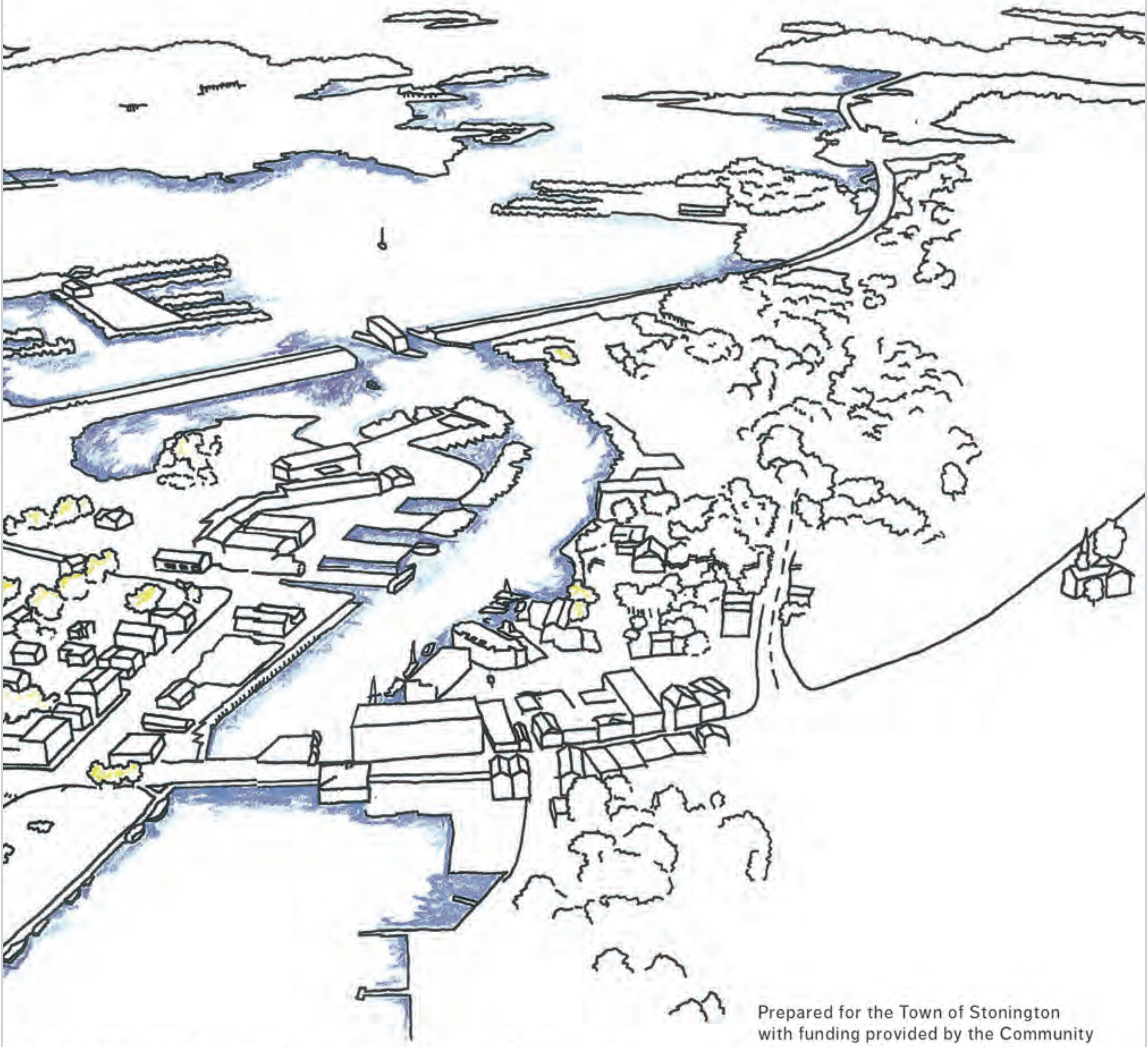
Conceptual Design Basis: The Stonington Coastal Resilience Plan identifies the Village of Mystic as a key asset vulnerable to rising sea levels and flooding-related hazards. Restaurants, retail businesses, and a popular marina make the area an important economic driver for the region. In addition, numerous historic buildings sites carry enormous cultural value for Connecticut, New England, and the country. The Coastal Resilience Plan suggests two broad approaches for addressing flooding issues in the Village: 1) Developing surge protection and erosion control measures along the coastal edge and into the harbor and 2) Maximizing stormwater infiltration and management inland before it reaches downtown, overloading the sewer.

The Core Team and the Stonington leadership/staff engaged with The Conway School, a master's program in sustainable landscape design and planning, to task two teams of graduate students to develop site-specific plans, conceptual renderings, and recommendations for coastal and inland portions of the Village of Mystic. The conceptual designs generated are specifically suited to advance the Stonington Coastal Resilience Plan via the identified vulnerabilities in the Village of Mystic.

Key excerpts from The Conway School's Village of Mystic Shoreline Conceptual Designs are provided on pages 71-109.

Key excerpts from The Conway School's Village of Mystic Inland Conceptual Designs are provided on pages 110-146.

# Shoreline Interventions for Coastal Resilience



Martha Abbott | Caitlin Broman | Bo Carpen | Winter 2019

Prepared for the Town of Stonington with funding provided by the Community Foundation of Eastern Connecticut via a grant to The Nature Conservancy.

## PROJECT OVERVIEW:
## COASTAL RESILIENCE FOR MYSTIC, CONNECTICUT

Mystic is a historic village located along the southeastern coast of Connecticut. The village lies at an estuary, straddling both sides of the Mystic River where it meets the Mystic Harbor. The village extends across portions of the towns of Groton and Stonington.

The name Mystic derives from the Pequot term missi-tuk, a large river whose waters are driven into waves by tides and winds. The Pequot native people established villages along the Mystic River centuries ago and since then, the area has undergone numerous settlements.

Dutch settlers arrived in Pequot territory in 1611. In response, the Pequots joined the fur trade, strengthening their economic and political power in order to extend their dominion into other tribal regions. The arrival of English settlers in the early 1630s shifted the distribution of power in the region (Landry). Tensions escalated between native peoples and Europeans over control of the fur trade, land holdings, and isolated attacks from both sides. The Pequot War broke out in 1636, the first major conflict between colonists and native peoples in Mystic (The Society of Colonial Wars). In 1637, the English massacred up to 500 Pequot people at Mystic Fort. This event, known as the Mystic Massacre, was a pivotal moment in the war that ultimately led to the downfall of the Pequot people. Today's Mystic consists of land that was granted to European veterans of the Pequot War (Pyror).

Throughout the eighteenth and nineteenth centuries, Mystic was an active seaport with a strong economy based on agriculture, manufacturing, and ship building (Connecticut Trust for Historic Preservation). The Mystic Bridge was built in 1819, connecting the east and west sides of the Mystic River (Mystic River Historical Society). Mystic Village developed into New England's primary port for sealing, whaling, and trade; the harbor drew in merchant vessels and sailors from around the world (Mystic River Historical Society). The vibrant economy required extensive development of the coastline to accommodate the visiting ships and sailors. The booming economy allowed for prosperous residents to build structures in Greek Revival and Queen Anne fashion, the most popular architectural styles of the nineteenth century. The narrow streets of downtown, connected by small through-streets that lead to the water, are reminders of this historical building phase. Mystic's history as a seaport hub remains visible in its intact historic districts, museums, and cultural events. Mystic attracts a large tourist crowd in the summer months, drawn to the area for its unique intact village and its boat access.

Centuries of development around the water have resulted in a hardened shoreline, dominated by structures like bridges, piers, docks, and marinas. Shoreline hardening allows human development to come up to the edge of water and land and provides boat access to the water. The coastal area of Mystic is defined by human interventions for business and boating; few natural open areas remain. Land use in Mystic is primarily residential; it is home to approximately 4,000 year-round residents. Today, Mystic Village seeks to balance its historic resources and water access with the anticipated effects of climate change on the coastal community.

The Northeast United States is experiencing an increase in the intensity and frequency of storm events as a result of climate change (USGCRP). The quantity of rain that falls during heavy rain events (defined as the heaviest 1% of all daily events) increased by 71% between 1958 and 2012 (USGCRP 2014). The Northeast is also experiencing the global trend of sea level rise. Rising sea levels will exacerbate the impacts of storm surge, flooding, and erosion on coastal communities (USGCRP).

Floods in Mystic are increasing in intensity and frequency. The village of Mystic has a long history of impact from hurricanes and other storm events. Most recently, the direct path of Superstorm Sandy missed Mystic, yet the area still experienced significant flooding and related storm damages. In recognition of climate change and increased stressors on coastal communities, the Town of Stonington commissioned a coastal resilience plan, published in August 2017.

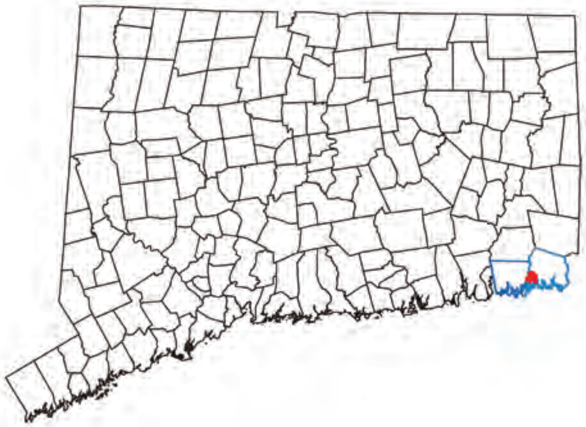
The *Coastal Resilience Plan* employed a three-step approach to address coastal resilience. It established a climate baseline by modelling sea level rise and storm surge on the land. It identified areas at risk within Stonington by factoring degrees of hazard, exposure, and vulnerability. Finally, it developed a broad outline of resilience strategies and next steps. The *Coastal Resilience Plan* is an invaluable resource for the Town of Stonington and its residents. The research and analysis in the *Coastal Resilience Plan* forms the basis for this study.

The *Coastal Resilience Plan* identified Mystic as an area at high risk given its geophysical characteristics, including its low elevation and exposure to the water, and its wealth of historic and cultural resources. Mason's Island, a residential barrier island connected to Mystic by a causeway, was also identified as an area at high risk.

In 2019, the Town of Stonington commissioned two reports, *Shoreline Interventions for Coastal Resilience* and *Inland Interventions for Coastal Resilience*, as the next steps in the implementation process of interventions for climate adaptation and mitigation. These reports identify suitable sites for interventions and present illustrative renderings for a defined project area that includes the Stonington and Groton sides of Mystic, and Mason's Island. *Shoreline Interventions for Coastal Resilience* focuses on living shorelines as a strategy to adapt to and mitigate sea level rise and storm surge inundation. *Inland Interventions for Coastal Resilience* focuses on green infrastructure as a strategy to manage stormwater, in response to the trend of increasing precipitation as a result of climate change.

The two plans work independently of each other but can be used in concert to provide a comprehensive view of coastal climate resilience.

The plans include proposed interventions that are site-specific to Mystic Village, Stonington. Yet, the intention is that these recommendations can be modified for application in similar historic communities along the Atlantic coast. Mystic Village has the opportunity to minimize damage to its historic built environment and provision for the effects of climate change, and, in doing so, become a model for other coastal communities.




The project area encompasses all of Mystic, in both Stonington and Groton, as well Mason's Island, a part of Stonington.

Downtown Mystic experiences a water sandwich effect; pressures of inundation from sea level rise and stormwater runoff from residences at higher runoff accumulate in the low-lying downtown area.

# Executive Summary

The Coastal Resilience Plan, developed for the Town of Stonington in 2017, identified Mystic Village as a highly vulnerable neighborhood due to its low elevation and density of development directly along the coast. The plan broadly outlined a number of coastal resilience measures including the use of living shorelines.

Living shorelines are coastal resilience strategies that use vegetation and natural organisms to create structures that can decrease wave energy, erosion, and storm surge flooding along the coastline. Living shoreline projects mimic or enhance natural ecosystems through design interventions and restoration projects.

In contrast to traditional hard infrastructure, living shorelines can grow and adapt to changing conditions over time making them a particularly attractive approach for coastal protections in light of the continuing future threats of sea level rise. In addition to buffering the coastline from waves and storms, living shorelines can provide many additional benefits to local communities. Living shorelines can enhance coastal habitats, improve water quality, increase green spaces along the shoreline, and provide new growing opportunities for local shellfishing industries.

This report investigates the use of living shorelines in Mystic to increase coastal protections. Based on the landscape of the project area, two types of living shoreline techniques were evaluated in comparison to site conditions: marsh enhancement/creation projects and living breakwaters. Suitability was determined by analyzing landscape characteristics and forces of water movement acting upon the shore. Harbor traffic, development patterns, and existing ecological resources such as tidal wetlands and shellfishing habitats were taken into consideration to balance the protection of both boat access and local ecosystems. Looking at these factor together helped to guide an understanding of where areas of conflict and opportunity might arise for siting living shoreline projects. The result of these analyses indicated that the low-lying elevation of Mystic offers broad opportunities for living shoreline projects, yet dense existing development along the coastline and a busy harbor constrain space for interventions.

Intervention strategies must be developed to maximize protections in a highly developed coastal community with limited space. Prioritizing protections of existing tidal marsh ecosystems and prioritizing interventions on un-devloped land may be one way to approach the challenge of limited space.

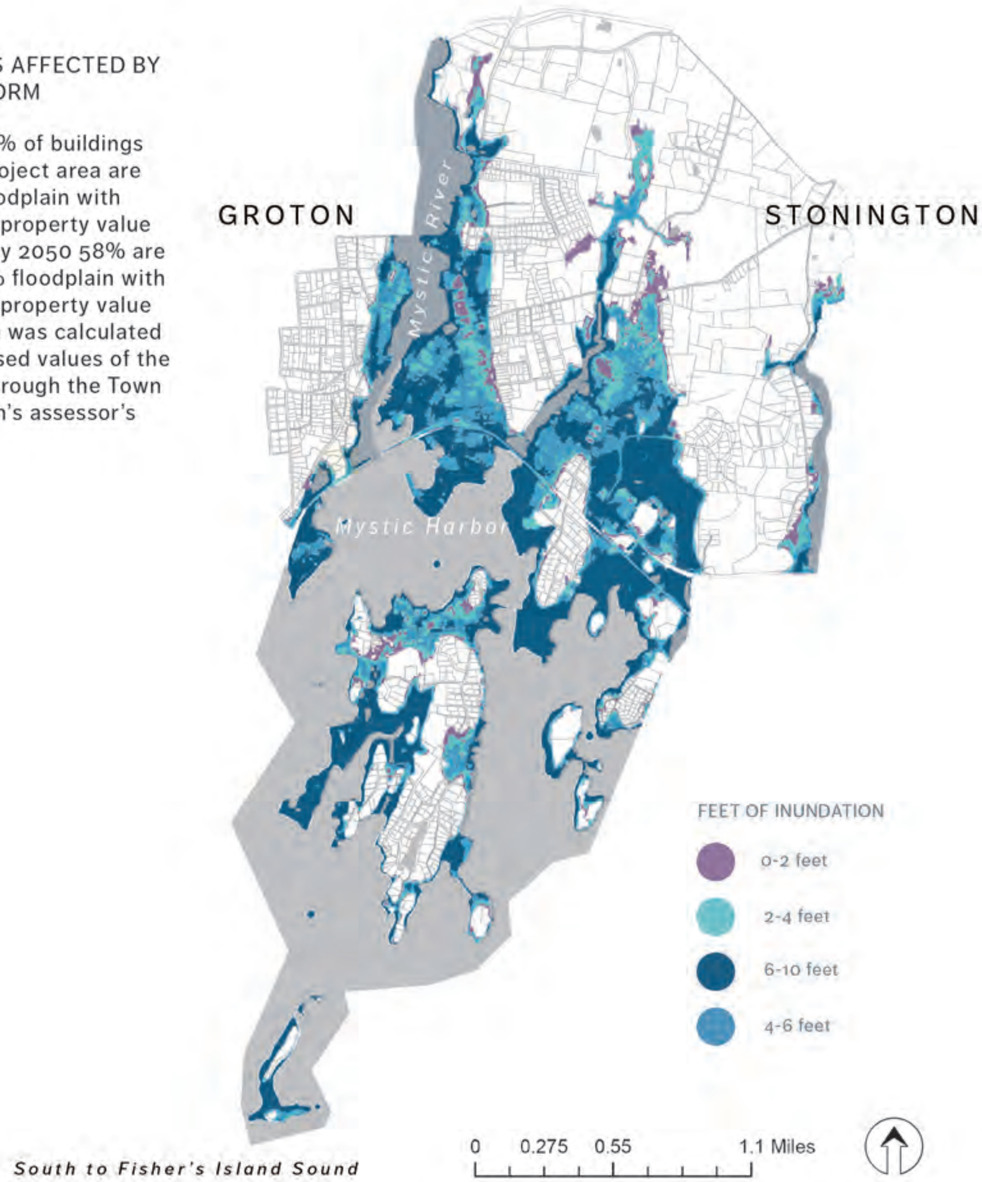
Overall, the greatest challenges to implementing living shoreline projects in Mystic will be working with private land owners and negotiating space in an area with high development pressure. In order to achieve community-scale protections, land owners must join together and work across property lines.

The method of evaluating living shoreline suitability developed in this project is meant to be replicable for similar coastal communities. The report is intended to increase awareness of living shoreline techniques, generate deeper conversations about coastal resilience, and inspire the community to take action.

PROPERTY AT RISK

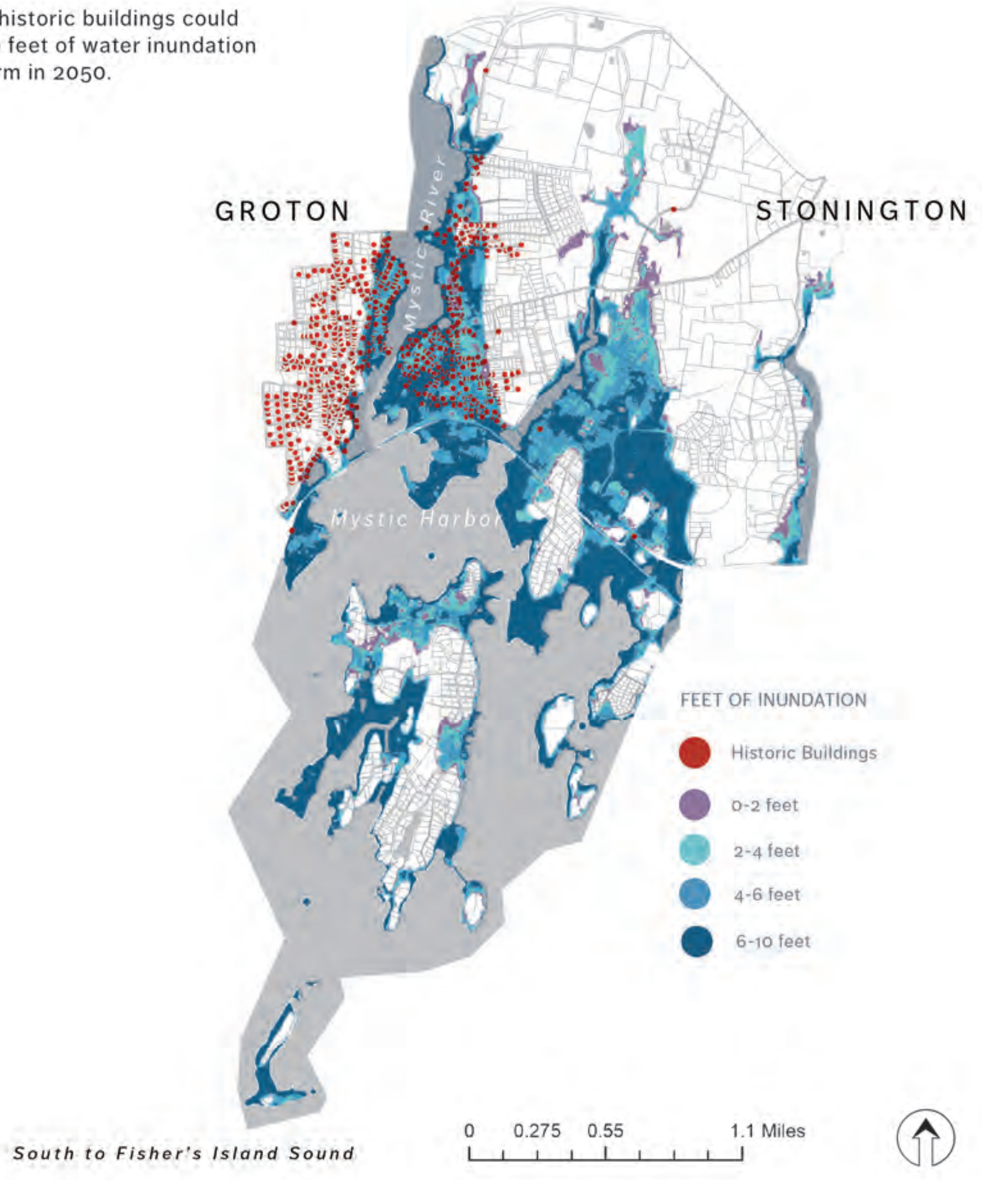
PROPERTIES AFFECTED BY 2050 1% STORM

Currently 55% of buildings within the project area are in the 1% floodplain with $486 million property value at risk, and by 2050 58% are within the 1% floodplain with $586 million property value at risk. Value was calculated by the assessed values of the properties through the Town of Stonington's assessor's office.



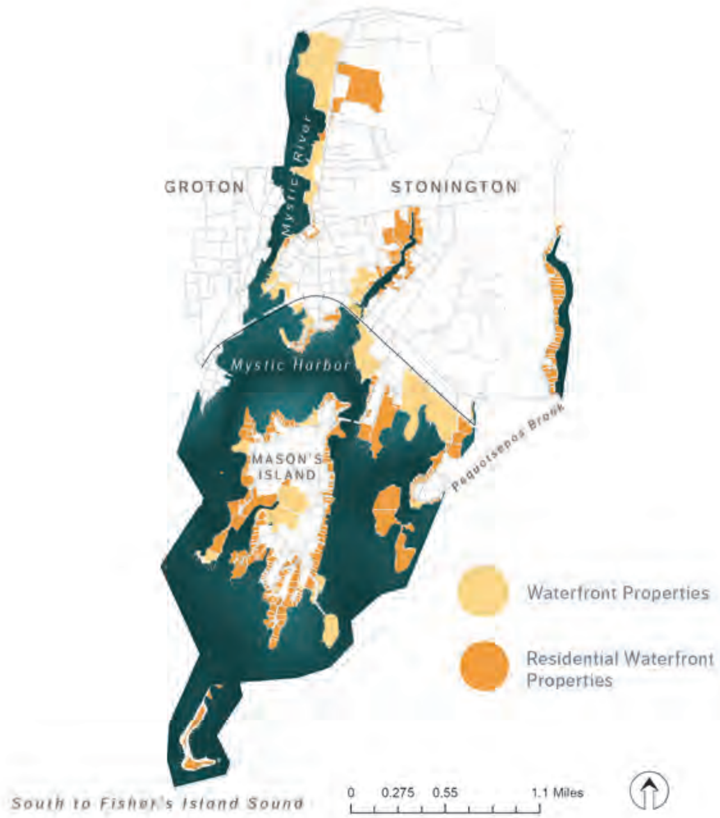
HISTORIC BUILDINGS
AFFECTED BY 2050 1% STORM

The majority of historic buildings could experience 4-10 feet of water inundation during a 1% storm in 2050.




19 INTRODUCTION

# Waterfront Residential




86% OF ALL WATERFRONT PROPERTIES ARE RESIDENTIAL

Living on or near water has historically been, and continues to be, desirable for many people, including the residents of Mystic. Of all waterfront properties in the project area 86% are residential.

While there are few residential properties along Mystic's waterfront, the shoreline of Mason's Island is almost entirely lined with residential properties and residences are concentrated within the Pequotsepos Brook inlet. Living in such close proximity to the sea comes with significant risk that will only increase as the years go by.

This section investigates how residential property owners, located along the shore, can better protect themselves and their homes in the face of climate change. There is an opportunity for these property owners to not only protect their own properties from storm damage, but also improve the town's resilience and protect its community assets by creating a living shoreline buffer.

WATERFRONT RESIDENTIAL

# Mason's Island

Mason's Island, referred by the Algonquin Native American tribe as Chippachaug, meaning a separated place, is situated at the mouth of the Mystic River. The island is Mystic's southernmost landmass within the Mystic Harbor and is the first line of defense against incoming wind and waves.

The marsh and living breakwaters suitability analyses (pages 83, 91) indicate the majority of all residential parcels along the shoreline of Mason's Island having the necessary site conditions for marsh establishment and living breakwaters. The following pages present concepts for a stretch of parcels along the Island's eastern shore. This area of focus was chosen because the residences are highly susceptible to flooding and sea level rise, away from boat congestion, and in an area where water quality is impaired, but levels of impairment are low enough for recreational shellfishing to still occur. Installing living breakwaters that employ bi-valves may help to improve the water quality.

The following recommendations function as a template to be replicated in other waterfront residential properties along Mystic's shoreline and in other coastal communities, where applicable. This template is intended to inspire residential property owners to implement living shoreline strategies, and to help municipalities work with individual property owners to create a more resilient community. Further site analysis and storm surge modeling will be necessary before implementing these techniques.


APPROACH METHODOLOGY

- Living Breakwater Establishment
- Marsh Creation
- Wetland Connectivity
- Economic Incentives

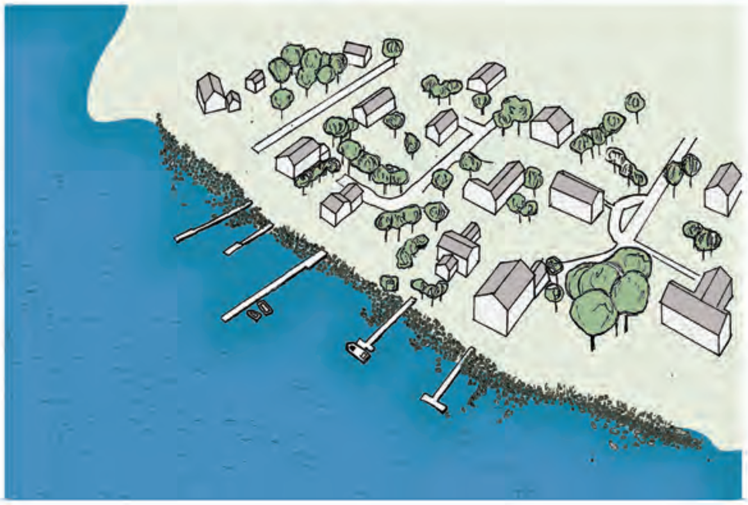
SPECIAL CONSIDERATIONS

- Permit Process
- Funding
- Neighborhood Concerns

FOCUS AREA

## EXISTING SHORELINE

The shoreline is a "rocky shore" consisting 75% or more of rocks with a thin strip of sparse vegetation. Replacing rocks with marsh vegetation can buffer residential waterfront properties from wave action.



## SEA LEVEL RISE BY 2050


Sea Level Rise by 2050

By 2050, sea levels will rise approximately 20". The encroaching sea level will create a distance as little as approximately 30 feet between some properties. Establishing living breakwaters will accumulate sediment for marsh to grow between the breakwaters and the shoreline as sea levels rise. Residents should also consider relocating their buildings as sea levels are expected to continually rise.

## FEMA FLOOD ZONE

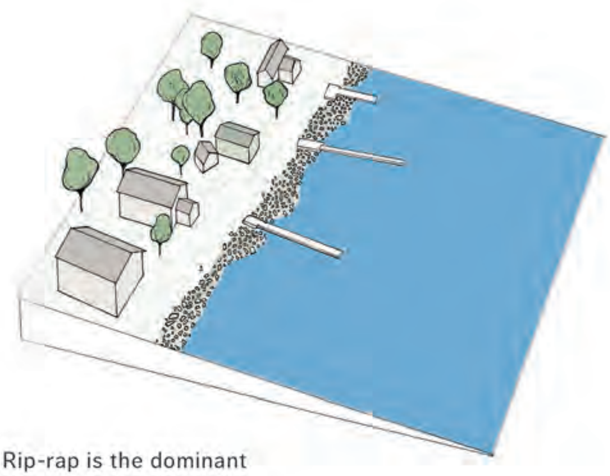

100-Year Floodplain  Flood Hazard Zone (FEMA VE-ZONE)

Currently the majority of waterfront properties are located within the 100-year storm floodplain and all waterfront properties are located within FEMA's flood hazard zone. FEMA's flood hazard zone is an area that is more vulnerable to the hazardous impacts of storm events than properties located further inland. Establishing living breakwaters offshore can help reduce the impact storm events have on the shoreline residences. Residents within the floodplain should consider elevating their buildings not just above base flood level (2 feet), but above the highest storm inundation level estimated for a 2050 100-year storm along the waterfront (6-10 feet) (FEMA 2050 100-year storm Data)

LIVING SHORELINE CONCEPTS FOR MASON'S ISLAND

It is recommended that waterfront residential property owners within the focus area soften their shoreline by replacing rip-rap with vegetation. Creating marsh habitat along the shoreline can buffer properties from wave action, and establishing living breakwaters further offshore can provide additional protection to the residential buildings and the marsh itself. If residential property owners intend to implement both living shoreline strategies, it is strongly suggested that the establishment of living breakwaters be the first course of action, followed by marsh creation, as the marsh is more likely to succeed in an environment with less wave intensity. Marsh species are able to adapt with the rising seas as they migrate upland as water levels encroach further inland. They also expand offshore as the accumulation of sediment provided by living breakwaters provides a growing medium for marsh species.

CURRENT SHORELINE:



Rip-rap is the dominant shoreline structure of residential properties along the eastern coast of Mason's Island.

WHAT IS RIP-RAP?

Rocks placed along shorelines or riverbanks to prevent erosion by stabilizing slopes; a common and conventional approach to help stabilize eroding shorelines.

WHAT'S WRONG WITH IT?

When water is deflected off riprap, wave energy increases, causing increased erosion to areas further downstream.

Riprap disrupts the natural functions of the riparian zone which typically consists of vegetation; these functions include pollution filtration, trapping and holding sediment, and providing wildlife habitat.

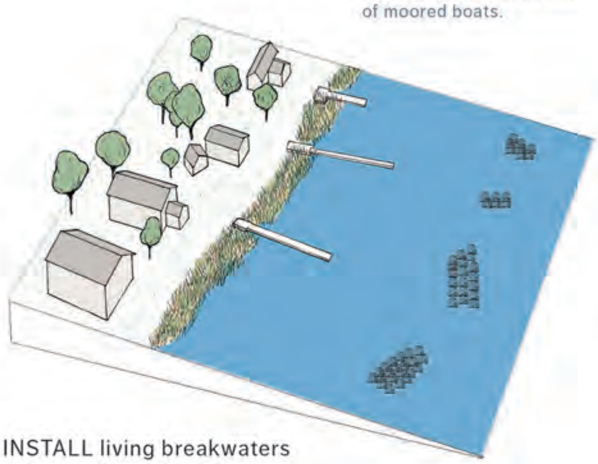
Uniform rip-rap shorelines lack the nooks and crannies that fish and other aquatic species require for shelter.

Rocks reflects direct sunlight into the water thereby increasing water temperatures.

108 COASTAL RESILIENCE

WITHIN 10 YEARS:

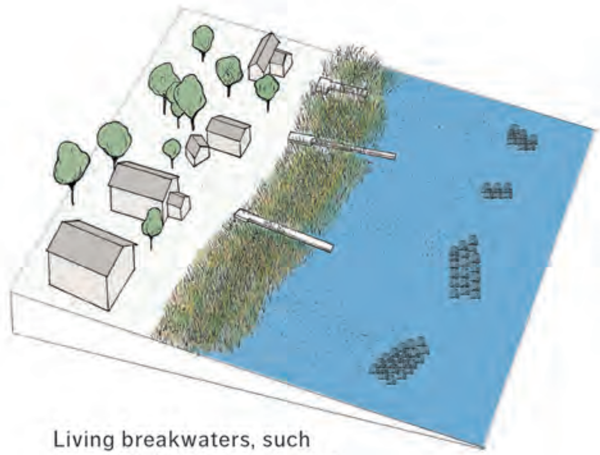
Breakwaters 100 feet from shore in an area free of moored boats.



INSTALL living breakwaters between the subtidal and intertidal zone.

ESTABLISH marsh habitat within the intertidal zone, inland of living breakwaters.

IN 20 YEARS:



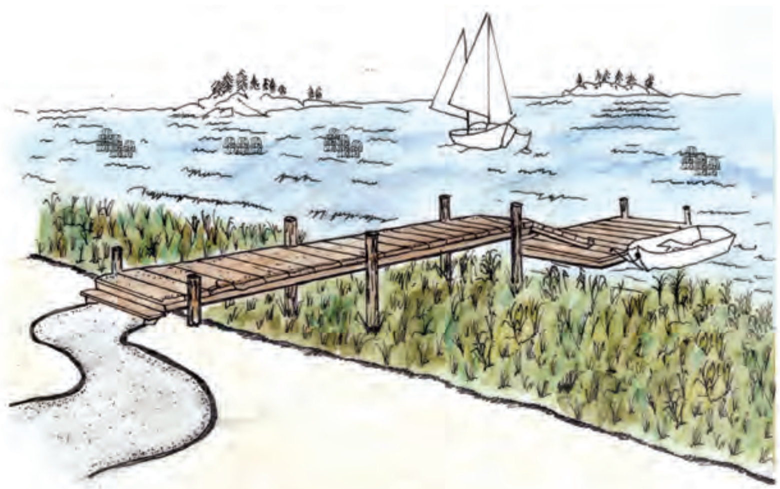
Living breakwaters, such as reef balls, encourage the accumulation of sediment behind the structures and within the expanding marsh habitat, which provides further medium into which marsh species can grow. This accumulation of sediment is extremely important to prevent marsh species from drowning due to sea level rise.

16 feet of marsh habitat reduces wave height by 50% (Subramanian et al, 2006).

Reef balls can attenuate 30% of wave energy (Mattei, 2017).

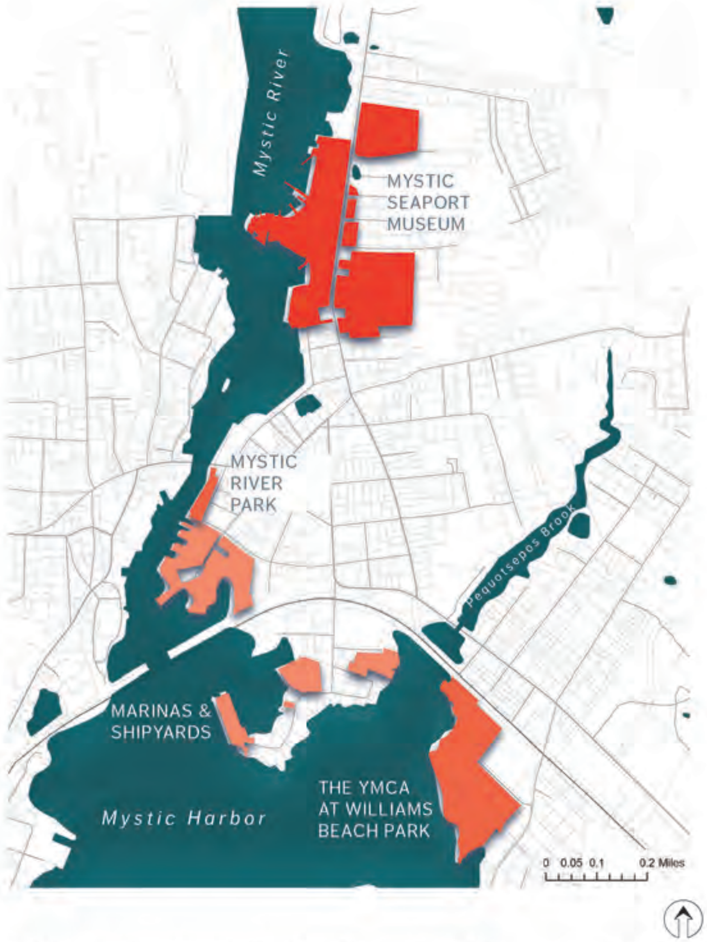
LIVING SHORELINE CONCEPTS
FOR MASON'S ISLAND

Residents living along the waterfront can transform their shoreline into a beautiful green space as a way of protecting their home. Waterfront property owners who invest in living shorelines reap the benefits of creating a protective buffer for their home, greening the shoreline and supporting wildlife.



Creating a living shoreline along a residential property does not have to disrupt the resident's interaction with their waterfront. Living breakwaters come in many different shapes and sizes, and can be arranged in a gap-like fashion to allow boats to navigate between them. While the property owner, after establishing a marsh, may not be able to walk directly into the water from shore, having a raised dock would allow them to access their boat or serve as a launching pad for marine activities like swimming or snorkeling.

## Non-Residential




Mystic Village has a highly developed coastline. The majority of properties in the village are residential, yet commercial, public, and non-profit properties occupy key parcels along the river and harbor frontage. These non-residential parcels are vital to the health of the community, specifically the community's recreational activities, like boating, and educational institutions.

Concepts for living shoreline interventions on commercial, public, and non-profit properties employ both living breakwaters and marshes to enhance coastal resilience.

These concepts take into consideration current land use and planned development in Mystic Village, while also proposing a more radical envisioning of future commercial zoning and tidal wetland protections.

# Downtown Mystic

Finding space for coastal resilience interventions in the downtown area is a challenge because of the density of development, minimal available landward space, and the low elevation of the land.

There is little elevation change where land and water meet between downtown and the Mystic River. As such, vertical slopes, like revetments, are common along the Mystic River.

Pedestrian access to the river's edge is widely available throughout downtown Mystic; boardwalks and piers provide not only access to moored boats, but also a walking path for residents and tourists alike.

In terms of planning at the town level, initiatives to discourage development in tidal flood zones come to head with initiatives to continue economic development in a village-style.

HISTORY AT RISK

Mystic Village is unique as its downtown consists of two nationally registered historical areas—the Mystic River Historic District along the west side of the river and the Mystic Bridge Historic District along the east side of the river.

Within the historic districts, 351 historic buildings lie in the floodplain. The overall area is most covered by impervious surfaces. The combination of valuable historic buildings and impervious surfaces makes the area particularly susceptible to damage from inundation, as flood waters have no where to go.

RECOMMENDATIONS

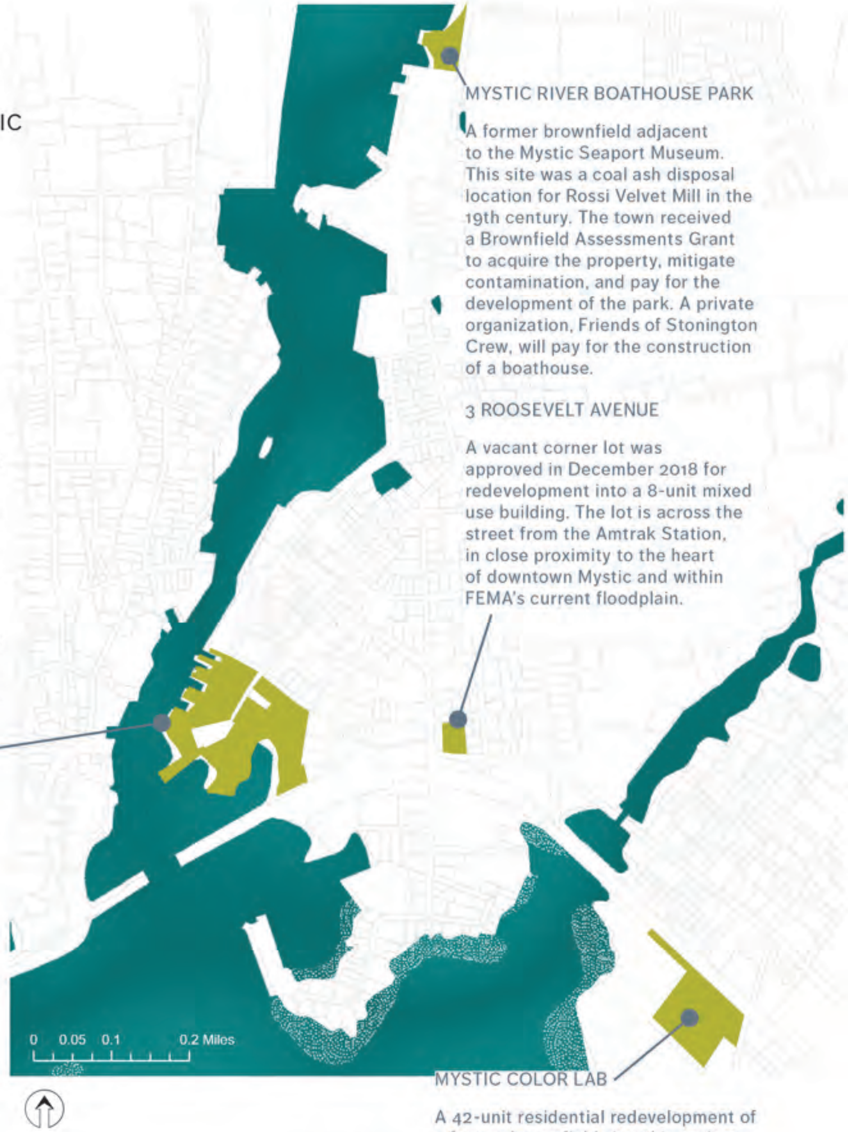
Resilience interventions for downtown Mystic will require a balance between the desire for development, the desire for coastal access, and the need to protect community assets. This report makes one recommendation for the downtown area—a re-envisioning of the Mystic River Park boardwalk—but the guiding design concept (diversity of edge conditions) is replicable throughout riverfront properties in Mystic.

## CONSIDERATIONS: PLANNED DEVELOPMENT IN MYSTIC

Mystic Village is experiencing growth and development energy. In particular, young working professionals and families demonstrate increasing interest in property ownership and residence in Mystic. Real estate interest is reflected in the numerous development projects underway.

New construction in the coastal area has implications for the health of the shoreline and therefore the coastal resilience of the rest of the community.

The town of Stonington could balance the desire for new development and coastal resilience by revising the zoning and building requirements for new construction.




### MYSTIC RIVER BOATHOUSE PARK

A former brownfield adjacent to the Mystic Seaport Museum. This site was a coal ash disposal location for Rossi Velvet Mill in the 19th century. The town received a Brownfield Assessments Grant to acquire the property, mitigate contamination, and pay for the development of the park. A private organization, Friends of Stonington Crew, will pay for the construction of a boathouse.

### 3 ROOSEVELT AVENUE

A vacant corner lot was approved in December 2018 for redevelopment into a 8-unit mixed use building. The lot is across the street from the Amtrak Station, in close proximity to the heart of downtown Mystic and within FEMA's current floodplain.

### SEAPORT MARINE

Seaport Marine is a series of parcels at the mouth of the Mystic River that totals 11.5 acres. The site is in the approval process for a complete overhaul. The historic shipyard and marina will be replaced with a hotel, public plaza, restaurant, apartment complex, townhouses, multi-family housing, marina, boardwalk, and kayak pavilion. The proposed development includes a steel bulkhead, dredge basin, and two 15-foot-wide living shorelines to account for sea level rise and storm surge inundation.

### MYSTIC COLOR LAB

A 42-unit residential redevelopment of a former brownfield site; this project was fully approved by the town in 2017 but construction has not begun. One small portion of the property, "the panhandle," will be under conservation easement.

### STORM SURGE INUNDATION

Storm surge models show that planned development in Mystic is within 2-10 feet of flooding from a 1% storm in 2050.

### INTERTIDAL PROJECTIONS

The projected intertidal range, the area between high and low tide, in 2050 will reach the Seaport Marine Development and the Mystic River Boathouse Park.

121 RECOMMENDATIONS

## REIMAGINING MYSTIC RIVER PARK

Mystic River Park, a 1.5-acre parcel, is at the heart of downtown Mystic. A broad swath of boardwalk forms the edge between water and land; it is level with the park green and offers little for shoreline resilience. In the summertime, visitors walk the boardwalk and sit on benches, visiting shops and enjoying the view of the river.

Mystic River Park is highly vulnerable to sea level rise. Sea level rise projections for 2050 indicate that Mystic River Park will overlap with the intertidal zone, the range between high and low tide levels. This projected coexistence with the intertidal zone indicates a high level of need for Mystic River Park to plan for increased daily flooding pressure.

Mystic River Park has a uniform edge, a boardwalk. A diversity of edge types is one approach to coastal resilience that integrates gray and green infrastructure. Just like an ecosystem, infrastructure resilience increases as the diversity increases.

The implementation of a diversity of edge conditions, using both gray and green forms, can serve as a model for other riverfront properties in the downtown Mystic area.

SITE DETAILS

Owner(s): Mystic Fire District

Area: 1.5 acre

Use(s): Park

APPROACH METHODOLOGY

Create Floodplain Terraces

Soften Armored Structures

Diversify Edge Conditions

SPECIAL CONSIDERATIONS

Limited space

Historic character and aesthetics



122 COASTAL RESILIENCE

REPLACE BOARDWALK

Tiered gabions offer a slight increase in elevation along the waters edge. The porosity of stones, held in form by wire mesh, and new plantings slow the incoming waves.

INTEGRATE VEGETATION

Water-loving plants occur in equal intervals along the gabion steppe and at the waters edge.

POST EDUCATIONAL SIGNAGE & CREATE NEW GATHERING AREA

Wooden planks create a new gathering area that is fun and safe for children to climb. Educational signage offers insight into the new design, the ecological value of the new vegetation, and coastal resilience for visitors. Educational signage may help with community buy-in.

WHY NOT LIVING BREAKWATERS AND MARSHES?

The two primary living shoreline intervention forms examined by this report, living breakwaters and marsh enhancement and creation, are not applicable to the current environmental conditions of Mystic River Park. The narrow width of the Mystic River and it's concentration of boating activity, coupled with the density of development on land means that there is not adequate space to implement these living shoreline interventions.

In a tight space, greening gray infrastructure and softening the overall armoring of the gray infrastructure can enhance resilience and offer benefits.

## TIDE POOL GABIONS

Along developed coastlines, little space exists for landward interventions to account for sea level rise and storm surge inundation. In Mystic, this is particularly true as development comes up to the edge where land meets water.

Tide pool gabions along the Mystic River in downtown Mystic may, in some scenarios, offer an adaptive approach to coastal resilience.

Gabions are a conventional and affordable gray infrastructure technique to stabilize steep edges. Gabions consist of wire mesh boxes filled with stone; gabions often form stepped walls to create a gradual edge.

The use of grouped stone, rather than a flat material such as concrete, provides more surface texture that may potentially dissipate wave energy during strong water currents.

Tide pool gabions integrate elements of green infrastructure, creating spaces for vegetation and water pooling. Tide pool gabions might be a good fit for edges of downtown Mystic in place of a bulkhead.

Tide pool gabions can be incorporated with walkways to offer pedestrians access to the coastline and views of the water and exciting marsh plants. The vegetation selected for this area should range between low and high marsh species that can withstand a range of inundation.

NON-RESIDENTIAL

# Mystic Seaport Museum

The Mystic Seaport Museum (MSM) consists of a 19-acre campus along the Mystic River. With approximately 4,000 feet of river frontage, the MSM is a majority owner of river access in the village.

At the community meeting, attendees identified the MSM as a highly vulnerable area. Given its river frontage, the campus is at high risk for flooding both in the event of storm surge and more regular tidal pressure from sea level rise.

The MSM is a regional asset and a strong driver of tourism in the village. Some of its many historic resources include the Charles W. Morgan, the last wooden whaleship in the world dating from 1841, a model historic whaling village, and an extensive collection of maritime artifacts.

The Henry B. duPont Preservation Shipyard at the MSM is an active wooden shipbuilding facility employing historic methods. It's the workplace of 25 shipwrights as well as an educational asset for the public to observe the processes. The MSM is also a robust resource for college and graduate level research initiatives through Williams College and the Munson Institute.

In recognition of their assets and vulnerability, the MSM is in the process of resilience planning for the 2050 storm. The following concepts function as preliminary design suggestions. In the greater scheme of coastal resilience for Mystic, such interventions integrated have replicable elements for other area institutions, including the Mystic Art Museum, along the west side of the Mystic River.

EXISTING CONDITIONS


PROJECTED INUNDATION LEVELS
1% STORM IN 2050

1-5 feet

5-10 feet

10-15 feet

SITE DETAILS

Owner(s): Mystic Seaport Museum

Area: ~19 acres

Use(s): museum, research institution

APPROACH METHODOLOGY

Relocate Buildings

Create Marsh Park

Diversify Edge Conditions

SPECIAL CONSIDERATIONS

Account for limited space

Protect historic character and aesthetics

PLANNING FOR 2050

A map of inundation levels for the 1% storm in 2050 indicates severe flooding on the majority of the Museum's campus.

The area affected by flooding includes the historic village, the preservation shipyard, and administration buildings.

POTENTIAL STRATEGIES FOR 2050:

> Relocate model historic village. The village is located in an area of deep inundation and the cultural value at risk is high.

> Reduce south parking lot area to allow for the natural expansion of the existing tidal pond.

> Diversify shoreline edge conditions; integrate tide pool gabions with bulkheads.

> Replace central green with marsh park.

> Replace fixed piers with floating docks.

REIMAGINED CENTRAL GREEN

At the heart of the museum campus lies an open green space for visitors, including families and school groups, to picnic and play games throughout the year.

Currently, the green is surrounded by the museum's model historic village to the north and west. The south end of the green is directly exposed to the river.

The green lies at a low elevation, lower than the surrounding bulkhead that creates an edge between the campus and the river. As a result, regular flooding from the Mystic River already occurs during rain events and from tidal flows.

Given the low elevation, absence of buildings, and tendency to flood, the central green is a prime area for a marsh-based living shoreline intervention.

Sea level rise projection shows that by 2050, the central green will be mostly located within the intertidal zone. Based on this projection, the Mystic Seaport Museum could begin planting tidal marsh species and related upland species that are also salt tolerant.

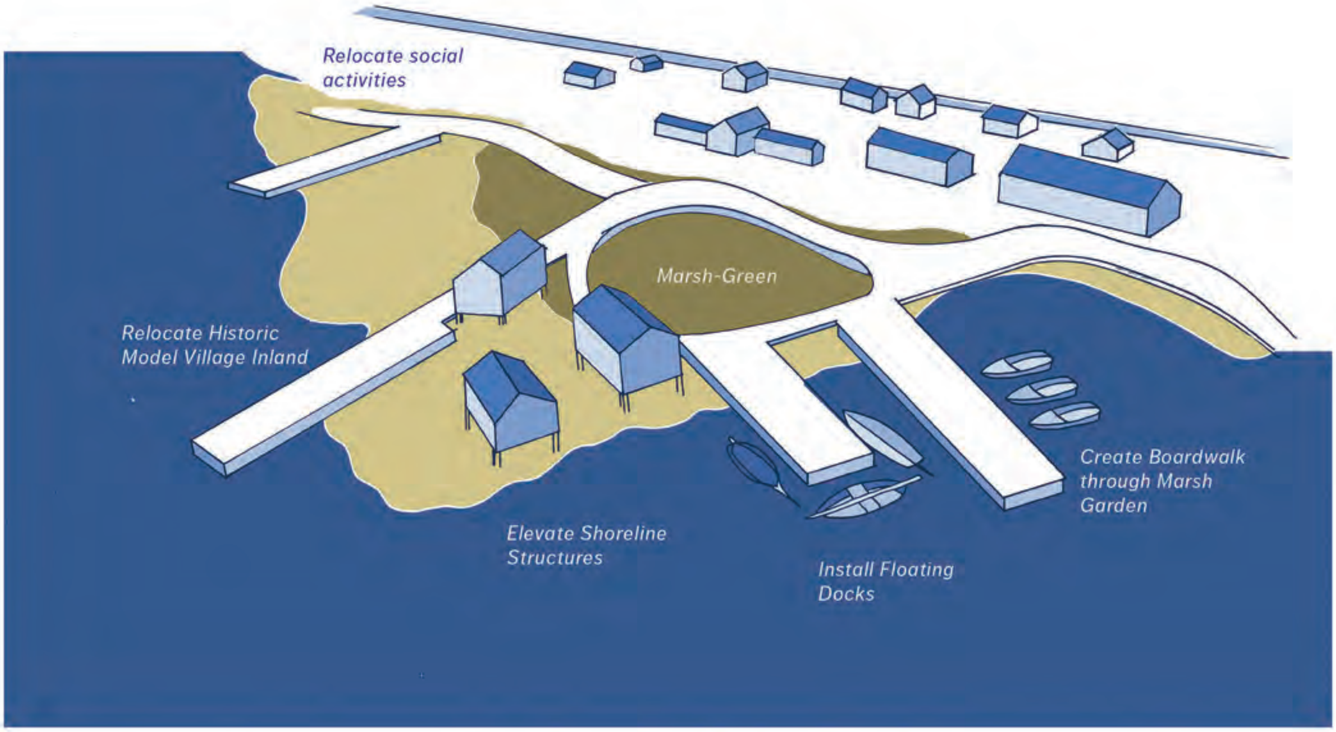
The new marsh-green is both a coastal resilience strategy and educational opportunity. By establishing a marsh, the Museum introduces a "sponge" to its campus. The sponge would serve as the first line of defense, absorbing incoming waters and lessening the impact of flooding further inland.

Marshes are critical natural habitats; educational programming on their ecological services, species varieties, and need for protection could be a regional asset in steps to protect wetland marshes on a larger scale.

Further research will be necessary to assess the health of the existing soil in the green and its drainage tendencies. It is likely that the space is heavily compacted from years of use and it is possible that sediment fill has been introduced over years of development in the area. Soil compaction and soil material type will have implications for the ability to establish marsh species. Soil augmentation, by fertilizing and aerating, may be a possible solution.

Steps to establishing a central marsh may include a site-scale engineering analysis to assess the feasibility of removing parts of the bulkhead. Removing the bulkhead would restore riverine connections and create a hydrological connection between the marsh park and Mystic River. The museum will also need to work with town and state authorities to determine the permitting process.

In the meantime, a transition away from lawn coverage and related landscaping practices, like mowing and fertilizing, will begin the conversion.




THE MARSH-GREEN

The central marsh would become an estuarine interidal habitat, hospitable to mixed herbaceous marsh species that are salt-intolerant.

The Mystic Seaport Museum can begin to consider how a new landscape, filled with native marsh species, could develop into a campus asset.

The marsh-green could include plant species like Swamp Rose, Sweet Flag, and Sea Lavender.

Sweet Flag

NON-RESIDENTIAL

# The YMCA at Williams Beach Park

The mouth of Pequotsepos Brook exemplifies coastal land use in Mystic. A historic and active shipyard and private residences share a small area with beach access, transportation infrastructure, and community recreational space.

Yet, recommendations for mixed-use and beloved coastal areas—like the YMCA at Williams Beach Park—are challenging to gain public buy-in. Coastal communities are hesitant to fundamentally change interaction with the coastline; proximity to the coast is often taken for granted.

The threat of sea level rise and storm surge inundation requires communities to seriously reconsider fundamental shifts. The area is vulnerable to sea level rise and storm surge due to its direct exposure to the Mystic Harbor and the Pequotsepos Brook.

Intervention recommendations for the YMCA and the surrounding waters combine marsh enhancement and creation, expansion of tidal wetland buffers, shipyard and marina storm preparedness requirements, and living breakwater establishment.

NEW INTERTIDAL RANGE

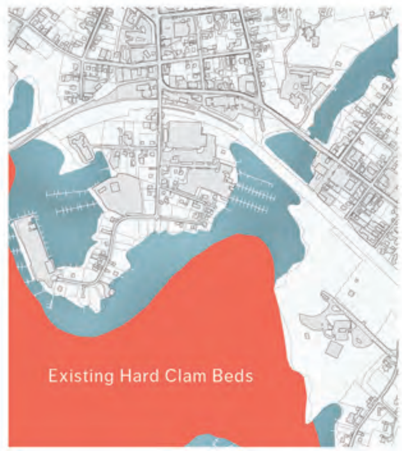
Sea level rise projections for 2050 indicate that the intertidal zone, the range between high and low tides, will move inland. The vacant lots, private residences, and parts of YMCA are included within this new intertidal area.

Coastal communities can choose to resist inland encroaching tidal range, or can choose to make land use changes to allow the water to move inland.


SHELLFISHING

Hard clam habitats are adjacent to the YMCA. The existence of hard clam habitats suggests that other bivalve species, such as oysters, are likely to live in the water here.

The presence of hard clam beds is not a disqualifier for living breakwaters. In fact, oysters, mussels, and scallops are all bivalves that create breakwater forms, meaning they attach to one another and create rigid structures. In contrast, hard clams do not build structures.




HYDRIC SOILS

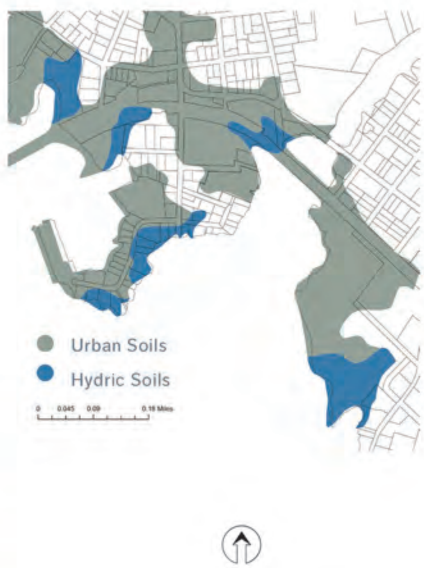
Hydric soils form under conditions of saturation, flooding, or ponding for a long enough period to create anaerobic conditions in the soil (NRCS Soils).

The presence of hydric soils indicates the area is suitable for marsh vegetation or currently contains marsh vegetation.

URBAN-INFLUENCED SOILS

Urban-influenced soil classification reflects the term presence of development in the area; sediment fill was brought in to make the area buildable.

The presence of urban-influenced soils indicates that more study of the soil is necessary to assess its capacity to host marsh vegetation.




129 RECOMMENDATIONS

## MOUTH OF THE PEQUOTSEPOS BROOK

The mouth of the Pequotsepos Brook is suitable for marsh enhancement, marsh creation, and living breakwater installation.

Marsh enhancement involves identification of vacant wetland areas, assessment of existing wetland health, and planting suitable marsh species.

Living breakwater installation requires collaboration across town and state jurisdictions, as well as collaboration with the Mystic Harbor Commission and local shellfishing enterprises.

The living breakwater location will overlap with existing hard clam beds. Living breakwater implementation may enhance the shallow water landscape for bivalve habitat and, by doing so, increase the population of hard clams in the area for recreational harvesting.

The greatest challenge to this recommendation is public buy-in. Overtime, private residences in the floodplain will be subject to higher insurance rates due to storm damage probability; therefore, stakeholders like home owners may be more inclined to sell land to the town and regional conservation groups.

The town of Stonington has the opportunity to strongly enforce buffer requirements around the intertidal zone, a highly vulnerable area.

### SITE DETAILS

Owner(s): The YMCA

Mystic Shipyard East

Homeowners

Use(s): marina, public recreation, residential.

### APPROACH METHODOLOGY

Connect Wetlands

Implement Breakwaters

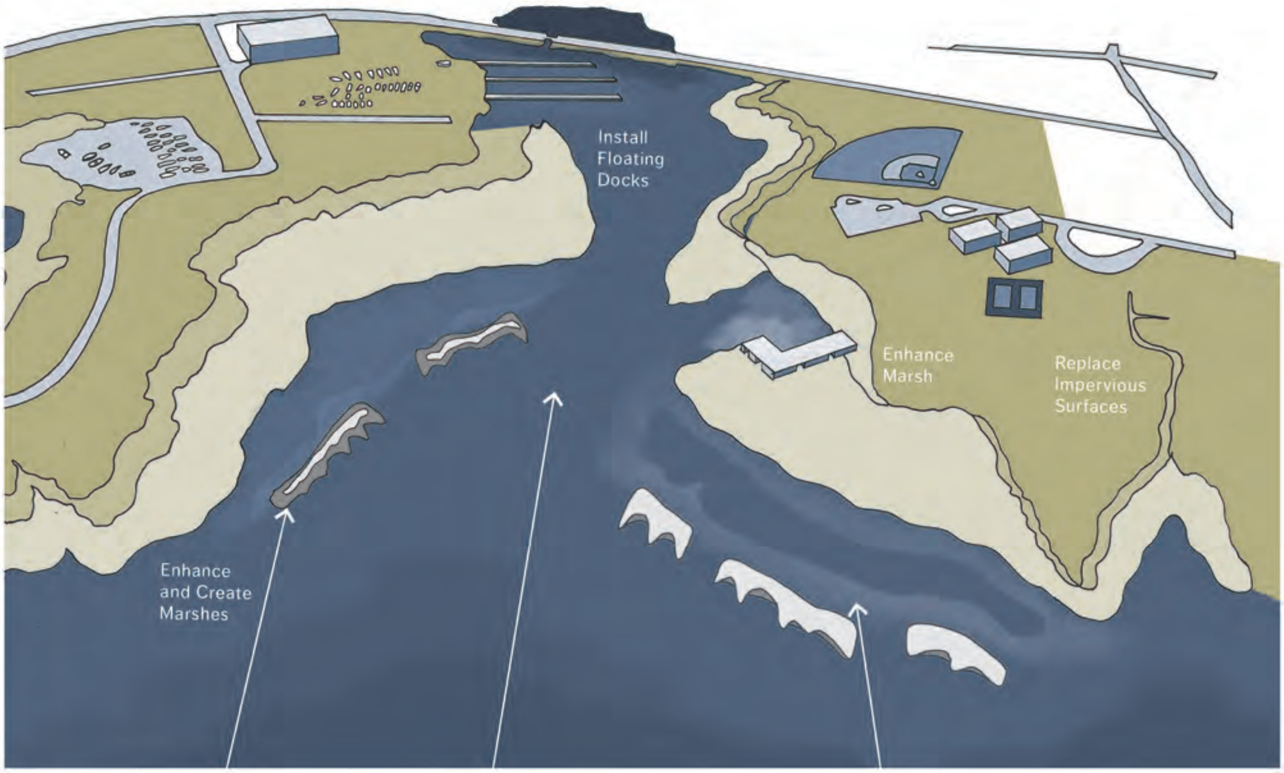
Re-Zone Floodplain and Acquire Flood-Prone Residences

Implement Storm Preparedness Requirements

### SPECIAL CONSIDERATIONS

Public perception of land acquisition and rezoning.

Viability of breakwaters in high traffic zone.




### SITE LIVING BREAKWATERS

The exact distance between living breakwaters and the shoreline varies depending on environmental conditions, specifically tidal range. Living breakwaters must be located within the subtidal, nearshore zone. The distance from shore ranges from 30-130 feet. Further site analysis will be necessary.

### MAINTAIN BOAT AND KAYAK PATHS

Flags marking the living breakwater zones will help maintain ease of navigation in the area.

### RESTORE SHALLOWS

Strategic location of living breakwater structures will help accrue sediment landward of the structures.

As sediment builds up, the shallow, muddy intertidal area will begin a process of restoration. Flora and fauna, like eelgrass and clams, thrive in the muddy, low water zone.

RECOMMENDATIONS

# Coastal Wetland Parks

Within the project area 10% of parcels are undeveloped land. When faced with the question of how to integrate coastal intervention strategies into a densely developed shoreline, utilizing these undeveloped lands may represent a more readily available solution to finding space for change.

Re-imaging undeveloped land as coastal wetland parks using the strategy of wetland connectivity can create dynamic zones of coastal resilience and floodwater retention, while increasing community open space and public access to the waterfront. Redesigning large areas as floodable wetland parks recognizes the important protective capacities of existing coastal wetlands and protects them for their future utility as public assets. By incorporating wetland boardwalks and outdoor learning lab community spaces, wetland parks can provide new opportunities for recreation and education that can garner community buy-in and support pride of place.

Creating wetland parks by putting undeveloped land adjacent to existing wetlands and waterbodies into conservation and redesigning existing town open space to accommodate tidal and flood waters may increase coastal protections by expanding marsh areas and siting living breakwaters, while also increasing public recreational opportunities. Language in both *Stonington's Open Space Plan* (2007) and the *State of Connecticut's Coastal and Estuarine Land Conservation Program Plan* speak to the importance of both coastal resilience and recreational access to the coast in their guiding principles and conservation priorities. The community of Mystic has strongly expressed the desire for more recreational space (Stonington Open Space Plan, 2007).

Coastal wetland parks could address the lack of public recreational opportunities on the waterfront and coastal resilience in Mystic Village. Proposed wetland parks could be sponge-like with marsh species that absorb flooding and act as protective buffers between ocean storms and valuable coastal development, potentially diminishing the amount of flooding that reaches homes and businesses.

PROCESS

An overlay of the marsh suitability model, existing wetlands, areas subject to inundation, and land acquisition opportunities (in the form of existing open space and vacant lots) suggests locations for wetland parks. Areas subjected to highest inundation frequency indicate spaces most vulnerable to both current and future storm surges and sea level rise. These areas of lowest local elevation function as pathways where floodwaters move inland. Existing undeveloped parcels, including protected open space, unprotected green space, and vacant or unbuildable lots provide opportunities to connect existing wetlands with areas of projected marsh advancement thereby creating large areas of vegetative buffers.

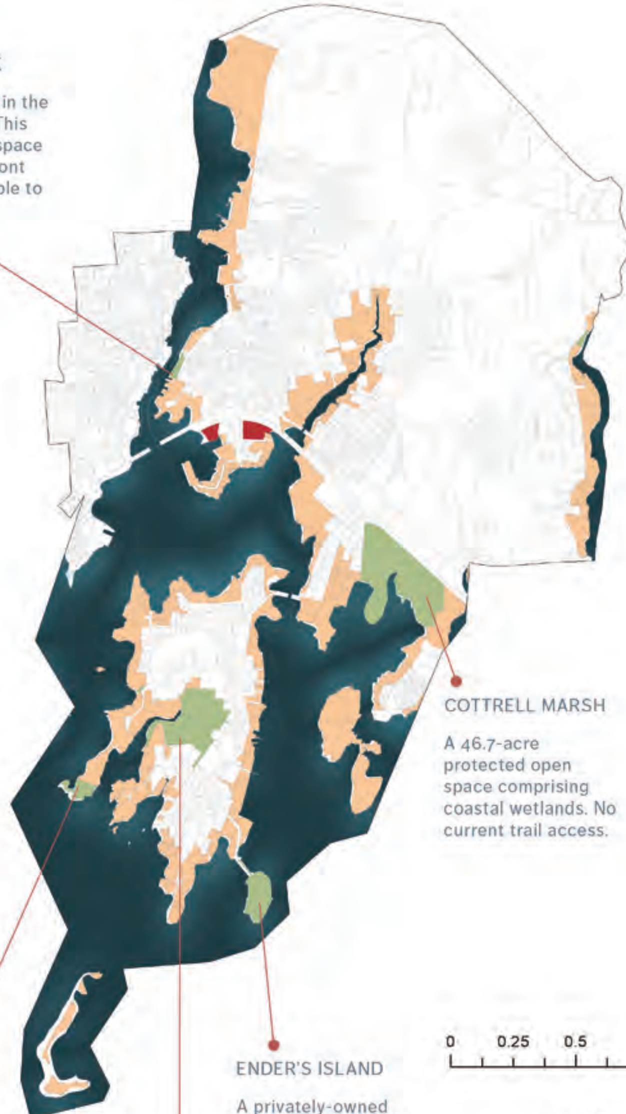
## PUBLIC SHORELINE ACCESS

Currently, public access to the waterfront is limited in Mystic, as most of the waterfront is commercial or residential property.

A review of land ownership within Mystic shows this pattern clearly, with only a few parcels of public open space along the waterfront. Mystic River Park is one of these parcels, offering a highly valued community gathering space on the river boardwalk. While a number of large protected open spaces along the coastline have potential for public recreational access, few of these spaces currently contain trails.

However, these areas in some cases may be accessible by kayak or small boat. For the most part, large recreational space is confined to the water for boats and other water based sports, while access to the shore from the land is very limited.

Redesigning these open spaces as wetland parks could improve coastal resilience and expand public access to the water.




### MYSTIC RIVER PARK

A small park located in the heart of downtown. This beloved community space is one of few waterfront green space accessible to the public.

### COTTRELL MARSH

A 46.7-acre protected open space comprising coastal wetlands. No current trail access.

### ENDER'S ISLAND

A privately-owned retreat is open daily to the public. Access may be limited during events.

### GREAT MARSH PRESERVE

A 46.5-acre conservation easement managed by The Nature Conservancy.

Contains trails available to Mason's Island residents and great potential for siting coastal resilience interventions and education components.

### RAM'S POINT PRESERVE

A 4.6-acre protected open space containing both tidal wetland and higher elevation shrub habitat is only accessible by kayak.

## POTENTIAL COASTAL WETLAND PARKS

Based on these design criteria, a number of potential sites for wetland parks were identified within the project area. These sites provide examples of how a wetland connectivity strategy can be used in Mystic to align coastal resilience with the town's open space and recreational goals. The following pages offer more detailed analyses of the proposed sites, walking through the identification process and including a discussion of the challenges specific to each location. These plans are preliminary designs with renderings meant to inspire a re-envisioning of these properties and communicate how changes could look in the future. While these specific sites are suggested for further study and acquisition, they can also be viewed as templates representing how undeveloped coastal land can be adapted for increased coastal resilience.


### 1 MASON'S ISLAND WETLAND COMPLEX

The southwestern point of Mason's Island encompassing Ram's Point has a high inundation probability from both future storm surges and sea level rise. Supporting the marsh expansion with added sediment, regrading, and protecting adjacent lands (currently privately owned) will increase the buffering capacity of these resource areas for the surrounding residential community.

### 2 SOUTHEAST MYSTIC WETLANDS PARK

Connecting the protected open spaces of Cottrell Marsh and Bishops Cove by protecting the wetlands in between and modifying existing infrastructure can allow for future tidal marsh advancement and increased protection of this residential side of the village.

OPEN SPACE AND RECREATION

## Cottrell Marsh & Bishop's Cove

There is an opportunity to connect the existing protected tidal wetland complex of Cottrell Marsh with the inland brackish wetlands surrounding the open space in Bishop's Cove. This could be achieved by increasing wetland protections within the vacant lots that connect these two spaces and/or acquiring the privately owned parcels for conservation.

Acquiring connecting parcels between these two protected wetland areas could protect this space for the future inland migration of the coastal wetlands, thereby preserving this habitat as a protective buffer. Establishing a trail network of wetland boardwalks could serve the community by offering recreational access to a large currently inaccessible area. Outdoor learning space could be incorporated for schools and community groups to learn about the importance of coastal wetlands and observe the effects of sea level rise within their own community.

SITE DETAILS

Area: 108 combined acres

Owner(s):

- Avalonia Land Conservancy
- Bishop's Cove Condominium Association
- Adjacent Land Owners

Uses: Recreational

APPROACH METHODOLOGY

Connect Wetlands

Implement Breakwaters

Acquire Flood-Prone Vacant Lots

Create Conservation and Trail Easements

SPECIAL CONSIDERATIONS

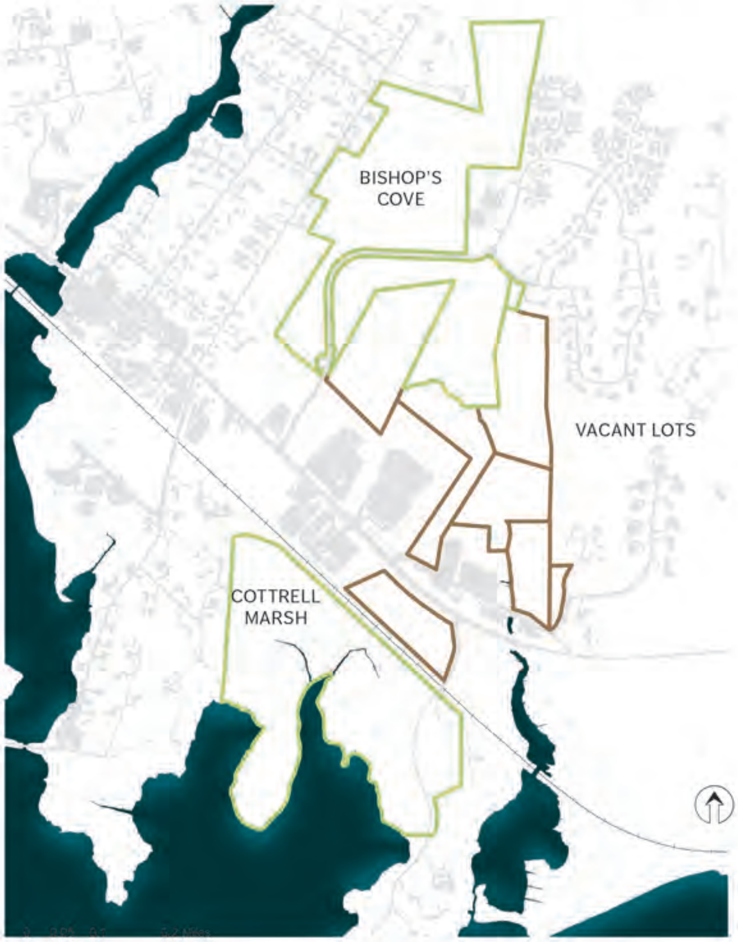
Land Ownership

Neighborhood Concerns

Increased Traffic

Parking Needs

Funding/Grants




136 COASTAL RESILIENCE


COTTRELL MARSH is a healthy tidal wetland complex located east of downtown and south of the Amtrak railroad on Latimer Point in Mystic. The 46.7 acre property represents an intact coastal habitat of great diversity and importance to local shoreline and migrating birds, as well as acting as a shellfish and fish nursery. The CT DEEP Natural Diversity Database identifies 80% of the property as important natural communities hosting endangered and threatened species. Within this designated area CT DEEP has classified the intertidal marine estuary and coastal woodland as Critical Habitats.


The lower part of the property, dominated by tidal marsh, is cut with many tidal creeks that maintain natural tidal flows and drainage creating the conditions for a rich coastal habitat. The site hosts many native marsh grasses including Spartina species, Black Rush, Spikegrass, and Arrowgrass, as well as forbs such as Asters, Sea Lavender, Seaside Goldenrod, and Gerardia. This vegetation supports a healthy population of marsh invertebrates that in turn attracts feeding aquatic crabs and fish species, which provides food sources for a diversity of coastal birds. Bird species monitored on site include Osprey, Great Blue Herons, Great Egrets, Snowy Egrets, Glossy ibis, American bitterns, Yellow Crowned Nights Herons, Black Ducks, warblers, and Salt Sharp-Tailed Marsh Sparrows. Ribbed mussels are known to colonize the marsh's peat edges and the subtidal area between the marsh and Andrew's Island is known to be a popular recreational clamming spot. Upland areas of higher elevations near the edges of the property are filled with a mix of shrub habitat and wooded knolls dominated by native oaks with Tupelo, Sassafras, and blueberry in the understory.


The site was originally acquired in 1968 by The Nature Conservancy then transferred to the Avalonia Land Conservancy in 1992. While there are no trails through the wetland itself, the coastal area does provide passive recreational opportunities for kayakers and bird-watchers. The management plan for the property does allow recreational use and there remains an opportunity to expand public access if developed in a way that mitigates any potential adverse effects to the habitat. The location has been the site of many recent scientific studies and since 2015 has been used by the New England Wild Flower Society for collecting local ecotypes of native salt marsh seeds for restoration projects.

The future of Cottrell Marsh is uncertain given potential inundation from sea level rise. The management plan for the property developed in 2015 specifically states that the impoundment created by the Amtrak railroad tracks will prevent marsh migration. These tracks significantly inhibit natural patterns of sedimentation that would assist the marsh to adapt in elevation. The plan calls for the continued study of the site to monitor how the habitat responds to this impending threat.

(Cottrell Marsh Property Management Plan, 2015)

## SOUTHWEST MYSTIC WETLAND PARK CONNECTING BISHOP'S COVE AND COTTRELL MARSH

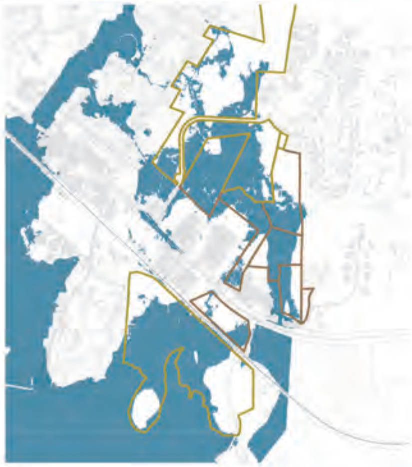
Close up views of the marsh suitability model reveal this area to be a potential hot spot for marsh advancement. Storm surge probability patterns also indicate this area being a main flood pathway into the inland, correlating with the lower elevation of this area compared to the surround terrain. Accordingly, views of sea level rise and storm surge projections show substantial inundation putting the properties and road infrastructure in between these wetland areas in risk of frequent nuisance flooding.

### MARSH ADVANCEMENT

Results of the marsh suitability models indicate a large potential area of marsh advancement from the coastal area into the inland wetland

### SEA LEVEL RISE IN 2050

Projected sea level rise will change the extent of the shoreline; the majority of these parcels will experience daily tidal flooding.



### STORM SURGE PROJECTIONS CURRENT 1% STORM

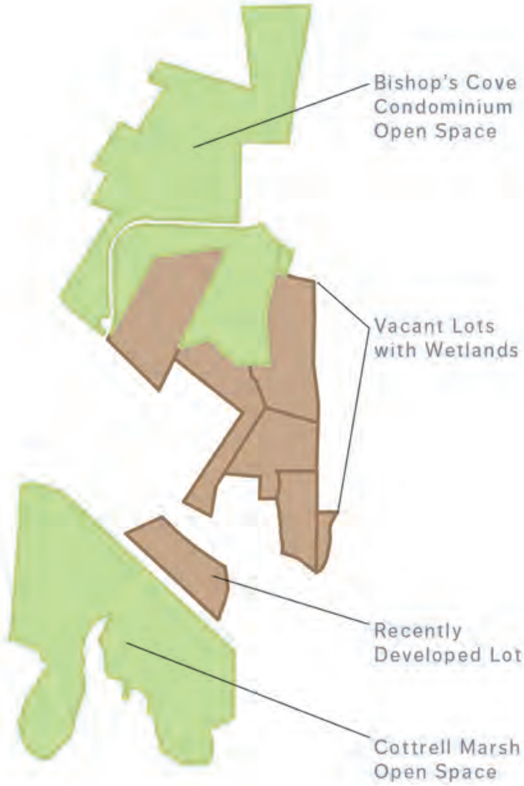
Storm surge probability maps show a inundation pattern suggesting that this area is a flood pathway

ENVISIONING SOUTHWEST MYSTIC WETLAND PARK

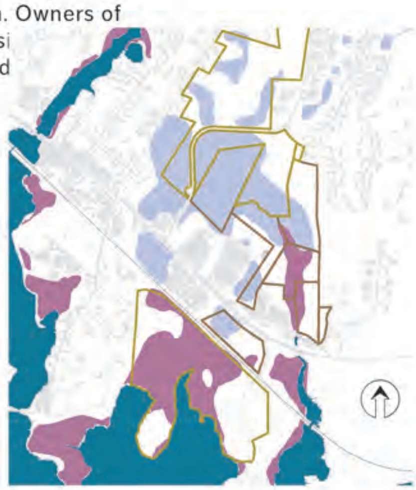
## POTENTIAL CONNECTING PARCELS

The vacant lots in this location are zoned Coastal Residential (RC-120), a zone that contains coastal areas including coves, estuaries, tidal marshes. This zone was established to protect these natural habitats and ensure flood protection (Zoning Regulations, 2018), and requires a 100-foot buffer extending from the delineated wetland boundary where no-development is allowed.

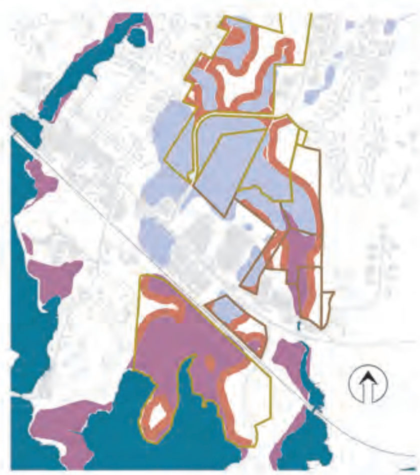
Due to the extent of existing wetlands, many of these lots have been designated as unbuildable. While development is unlikely in these areas, the pressure of residential development due to the high property value of coastal land may result in future building in seemingly confined locations. Due to this development pressure, increasing land protections through acquisition may be the best option for preventing more development in this high vulnerability area and protecting space around these wetlands to accommodate potential future marsh migration. Owners of vacant lots with extensi
may be more interested







Parcels that comprise the proposed park space consist of protected open space (green) and vacant lots (brown).

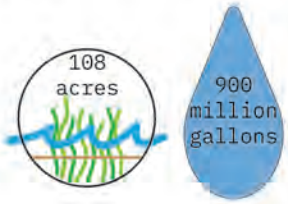


Wetland protection buffer requirements differ depending on a parcel's zoning. Mapping this buffer (in orange) helps identify what ares of wetland lack current protections and thereby prioritize parcels for acquisition.

## ENVISIONING SOUTHWEST MYSTIC WETLAND PARK

### ADAPTATION + MITIGATION

Creating wetland parks is both an adaptive and mitigative strategy in response to climate change. If the area of the southwest wetland park were supported to convert into tidal marsh by protecting land for future migration and restoration projects, the resulting tidal wetland complex could offer a significant capacity to hold floodwaters and store carbon. The combined area of 108 acres, if converted to marsh, could hold over 900 million gallons of water. The space could also help to drain and clean upland stormwater during heavy precipitation events.




### 1 PARK ENTRANCE

An existing road with roundabout could be redesigned into a small parking lot with bike parking to encourage alternative transportation and limit an increase in traffic to the neighborhood.

### 2 TRAIL NETWORK WITH WETLAND BOARDWALK

A walking trail connecting higher elevation areas along the edges of the park could take the form of a loop trail offering recreational opportunities for local residents and visitors. Incorporating boardwalk sections could bring people into closer interaction with the marsh. These spaces could serve as outdoor learning labs to be used by local school groups and allow visitors to observe their local environment.


### 3 MODIFY INFRASTRUCTURE

Connecting these wetland areas would necessitate making modifications to existing infrastructure that currently has fragmented these spaces, preventing water movement between Cottrell Marsh and the inland wetland.

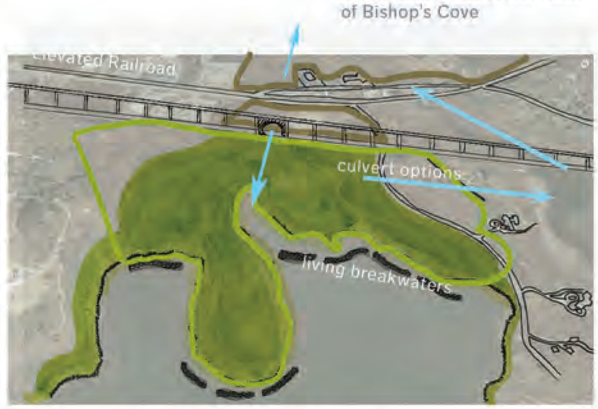
### 4 IMPLEMENT BREAKWATERS

Living breakwaters could be implemented along the foot of Cottrell Marsh to increase protections to the shoreline and maintain the integrity of this important ecosystem. Enhancing the marine ecosystem with new shellfish habitats in this area may also help to further support the shoreline birds known to inhabit the area.

## CREATE RECREATIONAL SPACE

A raised boardwalk through the wetlands park could create recreational and educational opportunities for the community, in line with principles laid out in *Stonington's Open Space Plan* (2015).

Blue arrows indicate two suggested locations for culverts to reconnect Cottrell Marsh to the inland wetlands of Bishop's Cove


Modifying infrastructure would be necessary in order to re-establish the hydrological connection between the different wetlands areas. One option may be to remove the impoundment created by the Amtrak line and creating a culvert underneath the railroad line and Route 1. This option could be incorporated into the plan to raise the railroad line, as recommended by the *Coastal Resilience Plan* (2017). The project to raise the Amtrak line was one of the highest priority suggestions made in the Plan for the town of Mystic.

Another option may be to create a culvert to connect Cottrell Marsh to the Stonington River, which is connected to the Bishop's Cove area via existing culverts beneath the railroad and highway. However, these culverts will also need to be enlarged to accommodate future higher tidal elevations.Both options necessitate working with private land owners and modifying infrastructure for increased future water levels.

OPEN SPACE AND RECREATION

# Mason's Island

Strengthening protections of existing tidal marshes and siting restoration interventions along the southwestern point of Mason's Island encompassing Ram's Point may assist the tidal wetland complex to expand in pace with sea level rise and provide increased buffering capacity against storm surges for the surrounding residential community. Living shoreline projects could be designed in the areas surrounding Clam Point, Mud Cove, and Bass Strait by working with local residents or land acquisition to increase the size of the conservation easement.

As a barrier island, Mason's Island protects the inner harbor from exposure to the open ocean. Landforms such as Ram's Point and Clam Point that extend along the southwest of the island, help to obstruct the southerly and westerly winds that predominate in this area (Weather Spark). Prioritizing preservation of the landforms can help to maintain their protective capacities, benefiting not only the residents of Mason's Island, but the larger community surrounding Mystic Harbor.

Two protected open space areas are located along this southwest stretch of the island, Ram's Point Preserve and the Great Marsh conservation easement, both managed by Avalonia Land Conservancy. There are a number of key connecting parcels situated between these open spaces which will be strongly affected by sea level rise. Working with private land owners to site coastal interventions in these locations is essential to preserving these landforms from inundation from future sea level rise.

SITE DETAILS

Owner(s):

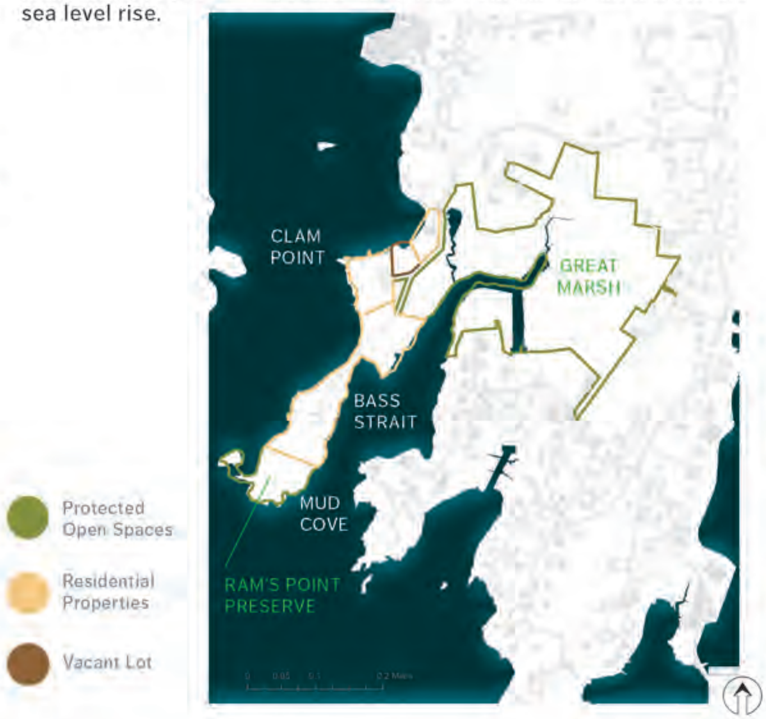
- Avalonia Land Conservancy
- Private Land Owners

APPROACH METHODOLOGY

- Enhance Marshes
- Implement Breakwaters
- Work with Landowners
- Extend Trail Network
- Create Kayaking Park

SPECIAL CONSIDERATIONS

- Private Ownership
- Erosion/Subsidence
- Access/Local Traffic

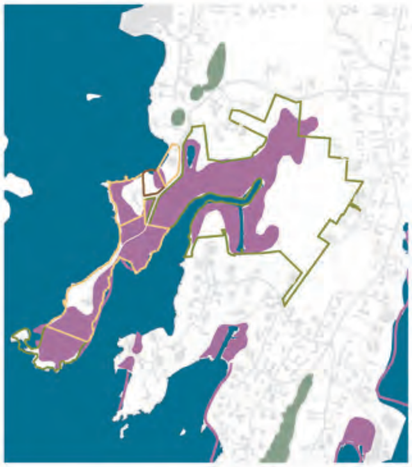


MARSH SUITABILITY MODEL

Results of the marsh suitability model in this area indicates significant potential marsh expansion on Clam Point and Ram's Point, correlating with the projected Sea Level Rise in the area.

LAND USE

Current land use practice indicates that the key connecting parcels between these protected open spaces are residential properties and one privately owned vacant lot with extensive tidal wetlands.



SEA LEVEL RISE PROJECTIONS 2050

A closer look at sea level rise projections in this area indicate widespread inundation by daily high tides in the future. This suggests the need to work with private land owners to preserve property or otherwise address this future changing condition.

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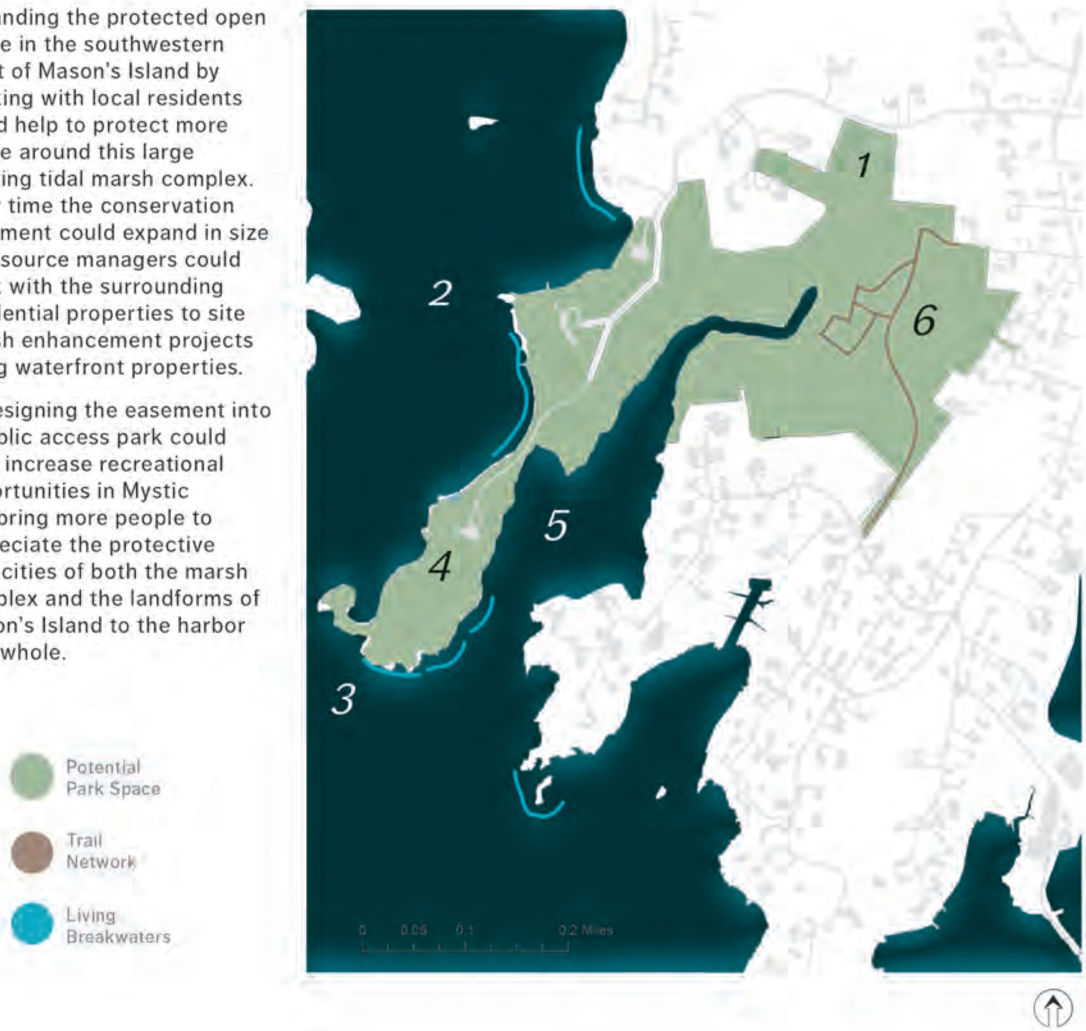
RECOMMENDATIONS

ENVISIONING SOUTHWEST MASON'S ISLAND PARK

Expanding the protected open space in the southwestern point of Mason's Island by working with local residents could help to protect more space around this large existing tidal marsh complex. Over time the conservation easement could expand in size or resource managers could work with the surrounding residential properties to site marsh enhancement projects along waterfront properties.

Redesigning the easement into a public access park could both increase recreational opportunities in Mystic and bring more people to appreciate the protective capacities of both the marsh complex and the landforms of Mason's Island to the harbor as a whole.




*1* ENTRANCE TO BOARDWALK AND BIKE PARKING AREA

A higher elevation area off of School House road may offer space for a park entrance with a small number of car parking spots to encourage bike transportation and limit increasing car traffic to the neighborhood.

*2* LIVING BREAKWATERS

Structural components designed to provide added protections to the landforms of Clam and Ram Points can help to address the higher exposure to wave energy in these areas.

*3* POTENTIAL MARSH ENHANCEMENT

Ram's Point Preserve may offer space for a marsh restoration project to address recent erosion that has resulted in a loss of marsh area on the western side of Ram's Point.

## 4 MANAGE MARSH WITH RESIDENTIAL PROPERTIES

The town could work with private land owners to develop living shoreline projects along vulnerable stretches of the coastline of Ram's Point and Clam Point. Landscape management plans could be created to better support marsh expansion and preserve this important landform.

## 5 KAYAKING PARK

Picnic spaces created within Ram's Point Preserve, only accessible by water, could create a "kayaking park" to encourage water-based recreation and get more people to interact with the tidal marsh habitat to learn and appreciate its dynamic beauty. Collaboration with local recreational groups and kayaking outfitters in town may help generate excitement and buy in for the creation of this new local destination.

## 6 TRAIL MANAGEMENT & PARK DESIGN

There are a number of trails within the higher-elevation, eastern side of the easement that are accessible to nearby residents. Public access to this trail network could be improved by developing a public access trail map and designing a clear entrance to the park with parking. This could open the space to the larger community and bring greater appreciation for this community asset. Educational signage and outdoor learning lab spaces could be incorporated into the space to teach about coastal resilience and the many ecological services offered by tidal marshes.

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# Inland Interventions for Coastal Resilience in Mystic, Connecticut

LISA KRAUSE | GRETA MOORE

Winter 2019

Prepared for the Town of Stonington
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to The Nature Conservancy

The Nature Conservancy
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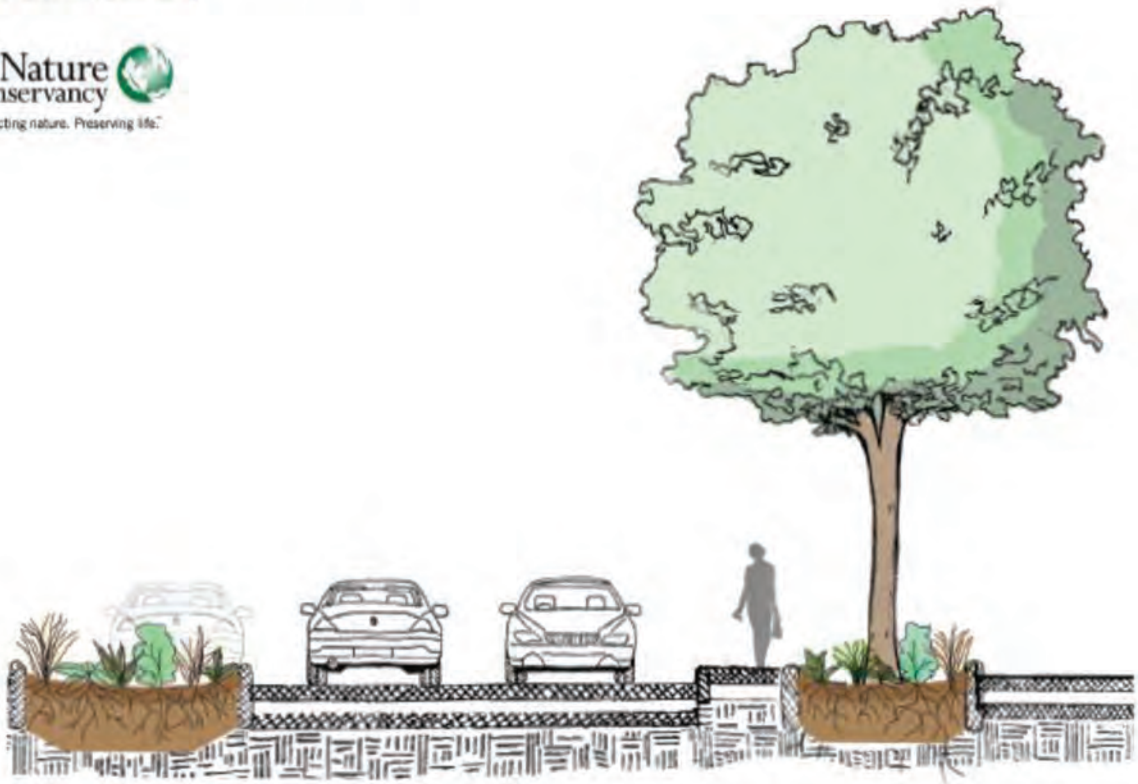


# Project Overview

This report, *Inland Interventions for Coastal Resilience*, is paired with *Shoreline Interventions for Coastal Resilience*. Together these reports provide a comprehensive view of coastal climate resilience in the village of Mystic through analysis and proposed interventions that address the impacts of sea level rise, storm surge, and increased precipitation as a result of climate change.

Mystic is a historic village located along the southeastern coast of Connecticut. The village lies at an estuary, straddling both sides of the Mystic River where it meets the Mystic Harbor. The village extends across portions of the towns of Groton and Stonington.

The name Mystic derives from the Pequot term missi-tuk, a large river whose waters are driven into waves by tides and winds. The Pequot native people established villages along the Mystic River centuries ago and since then, the area has undergone numerous settlements.

Throughout the eighteenth and nineteenth centuries, Mystic was an active seaport with a strong economy based on agriculture, manufacturing, and ship building (Connecticut Trust for Historic Preservation). The Mystic Bridge was built in 1819, connecting the east and west sides of the Mystic River (Mystic River Historical Society). Mystic Village developed into New England's primary port for sealing, whaling, and trade; the harbor drew in merchant vessels and sailors from around the world (Mystic River Historical Society). The vibrant economy required extensive development of the coastline to accommodate the visiting ships and sailors. The booming economy allowed for prosperous residents to build structures in Greek Revival and Queen Anne fashion, the most popular architectural styles of the nineteenth century. The narrow streets of downtown, connected by small through-streets that lead to the water, are reminders of this historical building period. Mystic's history as a seaport hub remains visible in its intact historic districts, museums, and cultural events. Mystic attracts a large tourist crowd in the summer months, drawn to the area for its unique intact historic village and its boat access.

Centuries of development around the water have resulted in a hardened shoreline, dominated by structures like bridges, piers, docks, and marinas. Shoreline hardening allows human development to come up to the edge of water and land and provides boat access to the water. The coastal area of Mystic is defined by human interventions for business and boating; few natural open areas remain. Land use in Mystic is primarily residential; it is home to approximately 4,000 year-round residents. Today, Mystic Village seeks to balance its historic resources and water access with the anticipated effects of climate change on the coastal community.

The Northeast United States is experiencing an increase in the intensity and frequency of storm events as a result of climate change (USGCRP). The quantity of rain that falls during heavy rain events (defined as the heaviest 1% of all daily events) increased by 71% between 1958 and 2012 (USGCRP 2014). The Northeast is also experiencing the global trend of sea level rise. Rising sea levels will exacerbate the impacts of storm surge, flooding, and erosion on coastal communities (USGCRP).

Floods in Mystic are increasing in intensity and frequency. The village of Mystic has a long history of impact from hurricanes and other storm events. Most recently, the direct path of Superstorm Sandy missed Mystic, yet the area still experienced significant flooding and related storm damages. In recognition of climate change and increased stressors on coastal communities, the Town of Stonington commissioned a coastal resilience plan, published in August 2017.

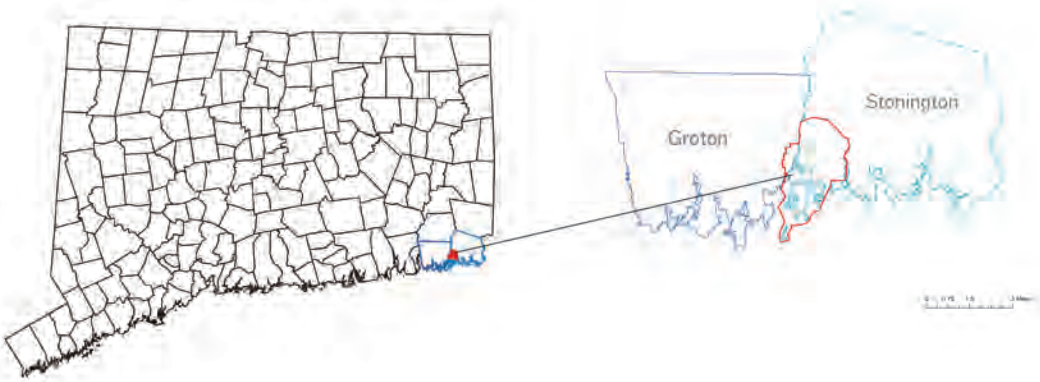
The *Coastal Resilience Plan* employed a three-step approach to address coastal resilience. It established a climate baseline by modelling sea level rise and storm surge on the land. It identified areas at risk within Stonington by factoring degrees of hazard, exposure, and vulnerability. Finally, it developed a broad outline of resilience strategies and next steps. The *Coastal Resilience Plan* is an invaluable resource for the Town of Stonington and its residents. The research and analysis in the *Coastal Resilience Plan* forms the basis for this report.

The *Coastal Resilience Plan* identified Mystic as an area at high risk given its geophysical characteristics, including its low elevation and exposure to the water, and its wealth of historic and cultural resources. Mason's Island, a residential barrier island connected to Mystic by a causeway, was also identified as an area at high risk.

In 2019, the Town of Stonington commissioned two reports, *Shoreline Interventions for Coastal Resilience* and *Inland Interventions for Coastal Resilience*, as the next steps in the design process of interventions for climate adaptation and mitigation. These reports identify suitable sites for interventions and present illustrative renderings for a defined project area that includes the Stonington and Groton sides of Mystic, and Mason's Island. *Shoreline Interventions for Coastal Resilience* focuses on living shorelines as a strategy to adapt to and mitigate sea level rise and storm surge inundation. *Inland Interventions for Coastal Resilience* focuses on green infrastructure as a strategy to manage stormwater, in response to the trend of increasing precipitation as a result of climate change.

The two reports work independently of each other but can be used in concert to provide a comprehensive view of coastal climate resilience.

The reports include proposed interventions that are site-specific to Mystic Village, Stonington. Yet, the intention is that these recommendations can be modified for application in similar historic communities along the Atlantic coast. Mystic Village has the opportunity to minimize damage to its historic built environment and provision for the effects of climate change, and, in doing so, become a model for other coastal communities.



# Executive Summary

In 2017, the town of Stonington commissioned a *Coastal Resilience Plan* to help the community plan for future impacts of climate change. The plan identified green infrastructure as an approach to adapting to increased intensity and frequency of storm events and mitigating the impacts of stormwater.

Green infrastructure is an approach to managing stormwater by treating it close to its source while delivering environmental, social, and economic benefits. This is largely done by replacing impervious surfaces with vegetation and well-draining soils that slow, spread, and filter otherwise untreated runoff. Green infrastructure decreases the amount of water entering the municipal stormwater system, which can relieve pressure during heavy precipitation events, consequently reducing the likelihood of damage to existing infrastructure and the cost of repair. Additionally, the quality of stormwater entering water bodies and the water table improves when stormwater is intercepted by a tree canopy, absorbed through roots, and/or filtered through soil or permeable surfaces. These processes remove pollutants and cool stormwater.

In contrast to green infrastructure, Mystic's stormwater is currently managed in a separate storm sewer system that collects only stormwater runoff from impervious surfaces via catch basins and discharges it untreated into surrounding water bodies. In heavy precipitation events, large volumes of water move from higher elevations and collect in low-lying areas causing localized flooding. Additionally, during storm surges or especially high tides, water from the Mystic River and Mystic Harbor enters the storm sewer system outfalls which are concentrated along the coast and backflows through the storm pipes and out the catchment basins into the streets. These conditions can result in both large and small floods that pose a significant risk to Mystic's historic and cultural assets, tourist activity, and day-to-day quality of life. Stormwater carries pollutants directly into Mystic River, Mystic Harbor, and the Pequotsepos River, which can result in these water bodies becoming impaired.

As the climate continues to change, the negative impacts of stormwater will only intensify. This report aims to address these challenges through conceptual green infrastructure designs and guidelines that respond to the particular conditions in Mystic. General green infrastructure parameters are included that help identify optimal site conditions and guide implementation. Strategies are divided into the three categories of non-residential, residential, and green streets. Recommendations were created based on an analysis of the existing stormwater conditions in Mystic, with a focus on impervious surfaces, drainage patterns, and habitat. This report is intended to serve as a catalyst for future detailed site design projects, both in Mystic and in similar coastal communities. Next steps are highlighted, including outreach and education, identifying funding sources, and conducting detailed site analysis where green infrastructure strategies are proposed.

## GRAY INFRASTRUCTURE VS. GREEN INFRASTRUCTURE

Culvert

Catchment basin/
storm drain

### GRAY INFRASTRUCTURE

Stormwater runoff is water from rain, snow melt, and other precipitation events that runs off impervious surfaces—surfaces that offer no infiltration. These can include roofs, parking lots, streets, and compacted soil. Most cities and towns manage stormwater using gray infrastructure, an engineered system of pipes and basins designed to quickly move water away from the built environment. A typical gray infrastructure system collects water from impervious surfaces via catchment basins and storm pipes, and discharges it into water bodies via outfalls. In heavy rain events, large volumes of runoff can stress and overwhelm gray infrastructure systems, causing floods and resulting in damage to pipes and culverts. Also, these systems offer no water quality treatment.

Green roof

Treebox filter

### GREEN INFRASTRUCTURE

In contrast, green infrastructure is an approach to managing stormwater by treating it close to its source while delivering environmental, social, and economic benefits. This is largely done by directing runoff from impervious surfaces into areas planted with vegetation growing in soils that slow, sink, and filter otherwise untreated runoff. Green infrastructure decreases the amount of water entering the municipal stormwater system, which can relieve pressure during large precipitation events, consequently reducing the likelihood of damage to existing infrastructure and the cost of repair. Additionally, the quality of stormwater entering the water table improves when stormwater is intercepted by a tree canopy, absorbed through roots, and/or filtered through soil, because pollutants are removed and the temperature of stormwater decreases. Green infrastructure strategies can be implemented on small and large scales, from residential rain gardens to floodable parks. Porous pavements and rainwater collection for reuse via cisterns are often considered along with green infrastructure techniques that incorporate plants.

Curb-cuts funnel runoff to bioswales
Photo credit: Chris Hamby

Curb-cuts direct runoff to street trees
Photo credit: Chris Hamby

Vegetated medians intercept stormwater and shade streets.
Photo credit: Chris Hamby

In addition to reducing flooding and improving water quality, green infrastructure can:

- Increase water availability:
  Rainwater captured in rain barrels or cisterns can be used for irrigation, thus decreasing the demand for potable municipal water (U.S. EPA 2015a).
- Reduce the heat island effect:
  Trees help reduce ambient temperatures by shading areas underneath and through the process of evapotranspiration (U.S. EPA 2018a)
- Improve air quality:
  Vegetation helps decrease ambient temperatures, consequently reducing air pollution caused by smog, which is exacerbated by higher temperatures. Additionally, harmful particulates are intercepted by leaves and bark (U.S. EPA 2015a). One study in Philadelphia found that increasing tree canopy could improve air quality enough to significantly reduce mortality, hospital admissions, and work loss days (U.S. EPA 2015a).
- Sequester carbon:
  Vegetation and soils take in and store carbon. This reduces the amount of $CO_2$ in the atmosphere and thus works to mitigate global warming.
- Enhance habitats:
  Even small amounts of vegetation can provide habitat for birds, insects, mammals, reptiles, and amphibians. Additionally, green infrastructure can create a link between habitats, allowing wildlife to move between otherwise isolated areas. Decreasing stormwater runoff, thus reducing pollution and erosion, can improve the quality of aquatic habitats (U.S. EPA 2015a).
- Green streetscapes:
  Adding diverse vegetation to an urban environment can transform an otherwise unsightly neighborhood into one that is lush and green.
- Save money:
  By reducing the need for intensive gray infrastructure systems such as pipes and large detention facilities, the costs of managing stormwater can be lowered (U.S. EPA 2015a). Also, when gray systems fail (eg. culvert collapse) it is expensive to fix them.
- Educate communities about watershed health:
  Educational signs near green infrastructure can help educate community members about the impacts of stormwater on watershed health.

# Recommendations

This section applies green infrastructure strategies outlined in the Toolbox to sites within three categories associated with different land uses: non-residential properties, residential properties, and streetscapes. By treating stormwater in streetscapes and on individual properties with various techniques, Mystic can decrease the amount of water entering the municipal stormwater system. This can relieve pressure during large precipitation events, consequently reducing the likelihood of damage to existing infrastructure and the cost of repair, and improve the quality of stormwater entering waterbodies and the water table.

TOOLBOX OF GREEN INFRASTRUCTURE STRATEGIES

Photo Credit: Chesapeake Bay Program

## NON-RESIDENTIAL

*commercial, industrial, and town-owned properties*

Other benefits:

- Demonstrates green infrastructure in highly visible locations (e.g. to shoppers, employees, park visitors, etc.)
- Provides educational opportunities.
- Serves as models for other green infrastructure projects.

## RESIDENTIAL

*Single-family residential properties*

Other benefits:

- Builds partnerships between municipal government and community members.
- Gives residents ownership over watershed health.
- Inspires neighbors to manage stormwater on-site.

## GREEN STREETS

*Municipal and state-owned rights-of-way including parking lanes, sidewalks, and medians*

Other benefits:

- Greens neighborhoods.
- Improves travel experience for vehicles, pedestrians, and cyclists.

# Toolbox

The 2017 Stonington *Coastal Resilience Plan* suggests green infrastructure solutions such as permeable paving, green roofs, bioswales, rain gardens, and rainwater harvesting to reduce harmful effects of stormwater runoff on water quality and reduce flooding. Spatial criteria and construction parameters for these and other green infrastructure strategies were evaluated with emphasis placed on those that provide co-benefits including improving air quality, sequestering carbon, increasing wildlife habitat, and greening the village of Mystic. The design parameters that follow are intended to serve as an introduction to a range of tools that may be appropriate interventions in Mystic with applications in other similar coastal communities. Further site-specific analysis is needed before the preparation of construction documents. Based on analyses for the village of Mystic the following green infrastructure strategies were identified as potential interventions:

## VEGETATED FILTRATION STRIPS

bioswale, tree trench, flow-through planter

*slows, cools, and removes pollutants from runoff.*

## BIORETENTION FACILITIES

treebox filter, raingarden, bioretention area, green roofs

*temporarily stores and removes pollutants from runoff.*

## PERMEABLE PAVING

permeable asphalt, permeable pavers, structural soil

*temporarily stores runoff and infiltrates where soil conditions allow.*

## RAINWATER HARVESTING

cistern, rainbarrel, dry well, stormwater chamber

*stores runoff for reuse or gradual release into the ground or stormwater system.*

Sources for construction details on the following pages include:

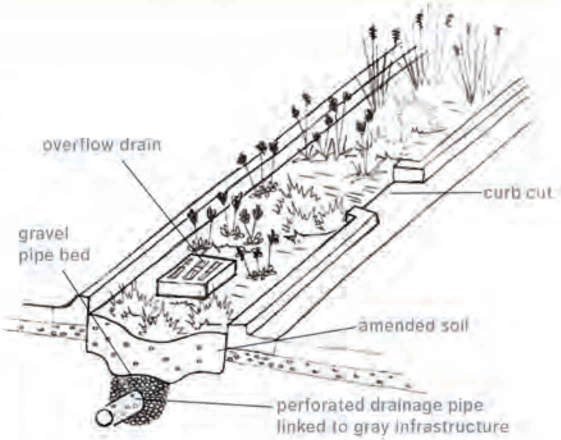
Contech Engineered Solutions, Greywater Action, The Groundwater Foundation, Interlocking Concrete Pavement Institute, LID Urban Design Tools, Maryland Department of Environmental Resources, Minnesota Stormwater Manual, National Association of City Transportation Officials, Philadelphia Water Department, Pioneer Valley Planning Commission, Seepage Control, Inc., Stormchambers, Stormwater Equipment Manufacturers Association, StormTech Subsurface Stormwater Management Chambers, Water Environment Research Foundation, and Whole Building Design Guide.

## BIOSWALE *Linear depressed vegetated swale that slows, cools, and filters stormwater runoff using native plants and soils.*

**Benefits**: Bioswales slow and remove pollutants from runoff while recharging the groundwater if soils permit infiltration. Bioswales typically incorporate hardy native plants that are tolerant of inundation and drought, sequester carbon in their roots, have lower maintenance requirements than non-native plants, and provide habitat for birds and pollinators.

**Application:** They are commonly used in parks and parking lots, along streets and near residential lawns. They can be integrated with curb extensions in streets, into medians, cul-de-sacs, and other public space or traffic calming strategies.

**Limitations:** Bioswales are not recommended in locations with low soil infiltration rates because standing water, localized flooding, and other issues can cause problems within the street and sidewalk in an urban environment.



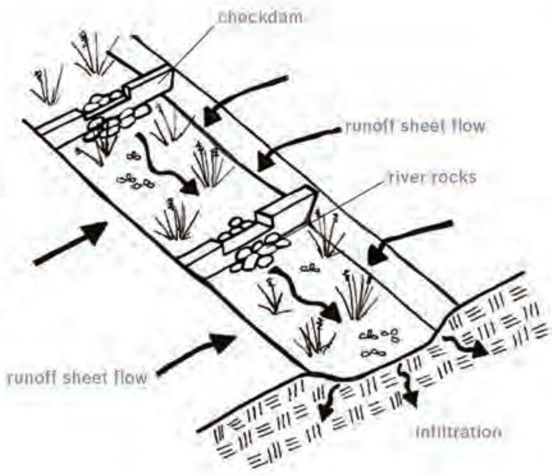

**Construction Details:** Bioswales must percolate 5–10 inches of rain water per hour and maintain a 5-foot clearance from the bottom of the bioswale to the top of high groundwater table. An overflow or bypass drain system is raised above the soil surface and connected to a gray infrastructure system. Side slopes should be 4:1, with a maximum of 3:1. For areas where curb cuts allow runoff to enter the bioswale, a minimum 2-inch drop in grade is required between the street and the bioswale. Curb cuts should be at least 18 inches wide and spaced 3–15 feet apart.

## BIOSWALE WITH CHECK DAMS *Bioswales (described above) used on steep slopes with dams running perpendicular that slow stormwater runoff.*

**Benefits:** Check dams slow stormwater, helping to prevent erosion and allowing sediment to settle as it is filtered and conveyed or infiltrated within the bioswale.

**Application:** Check dams are recommended for bioswales with longitudinal slopes exceeding 5%.

**Construction Details**: (see above) Check dams can be constructed using concrete, river rock, and sometimes logs.

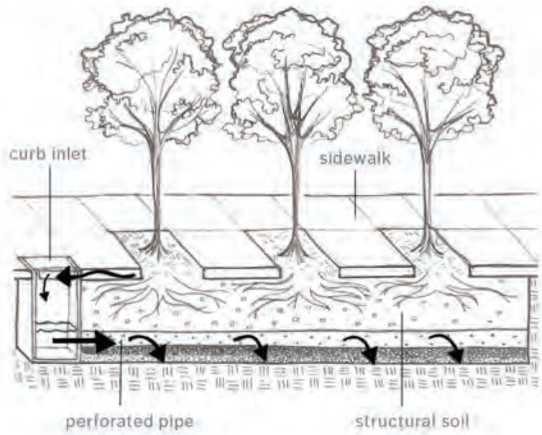


## FLOW-THROUGH PLANTER/TREE TRENCH

*Long rectangular sidewalk planters with underground trenches, a series of connected cells filled with soil that receive stormwater runoff from the road. Runoff is treated as it moves through the cells before overflowing into gray infrastructure.*

**Benefits:** Tree trenches filter out sediment, trash, and pollutants from stormwater. They detain and, where possible, infiltrate water below grade, thus maximizing space above grade. Tree canopy intercepts and slows rainfall, and roots absorb stormwater and reduce pressure on the stormwater sewer system. Compared to conventional street trees, trees in tree trenches are often healthier because there is more room for root growth and space for air and water within soil.

**Application:** They are best suited for urban streets and sidewalks and near parks, retail, or commercial areas where space around trees is needed for pedestrian circulation.




**Construction Details:** Tree trenches are filled with structural soil, layered over gravel, and planted with trees. An overflow drainage pipe connects to the stormwater sewer system. The planter is fed by curb-cut inlets along the road or direct connections to existing stormwater catchment basins. The size of the tree trench planter depends on the type of vegetation and the space available, however, they should be no less than 5x5 feet. Trees should be planted every 30' on center with soil media depth 3' and required drawdown time of 48 hours.

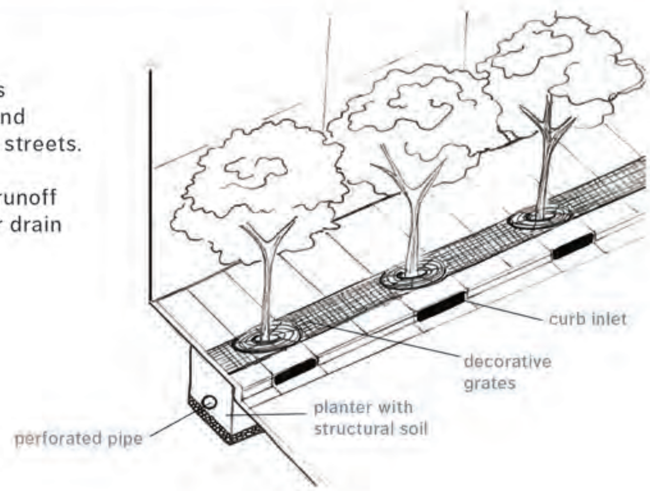
- Large Tree Trench (2 small deciduous trees): bottom surface area 420 sq ft.,
- Small Tree Trench (1 small deciduous tree): bottom surface area: 210 sq ft.

## COVERED TREE TRENCH

*Flow-through tree trench covered by permeable pavers or decorative grates that protect the planter from compaction and allow pedestrian access to streets.*

**Benefits:** The grates over the tree planters prevent soil compaction from foot traffic and allows pedestrian access to sidewalks and streets.

**Application:** They can be used to receive runoff from both curbs and sidewalks via inlets or drain runnels.

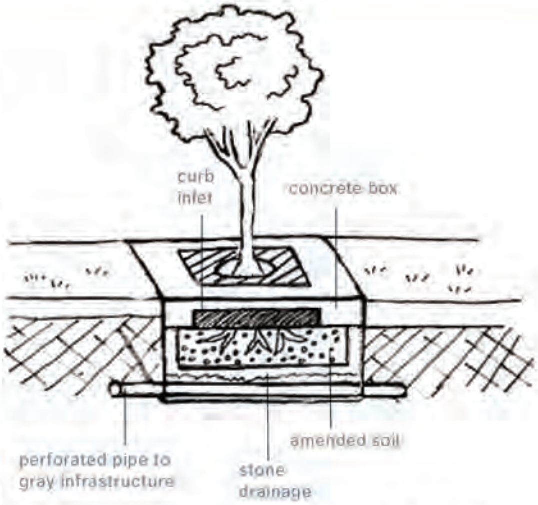


## TREEBOX FILTER *Concrete bioretention container planted with a tree or shrub that intercepts and filters stormwater runoff.*

**Benefits**: Treebox filters remove large quantities of pollutants from stormwater. Mulch intercepts and separates particulates and contaminants at the ground level while soil microbes and plants remove pollutants through phytoremediation. Treebox filters improve the urban environment by greening neighborhoods, enhancing habitats, and reducing urban heat island effects.

**Application:** They are ideal for small urban spaces where bioretention gardens are not feasible. They can be planted with trees, shrubs, ornamental grasses, and flowers. Treebox filters can be used to treat, detain, and/or store rainwater for later use.

**Construction Details:** The concrete bioretention container is filled with engineered soil and planted with a tree or shrub. Excess runoff percolates through rocks into a perforated pipe connected to the gray infrastructure system, additional green infrastructure system, or surrounding soil. Omission of bottom slab allows stormwater to infiltrate where appropriate soils exist.




**Limitations:** Treebox filters hold a fairly small volume of stormwater (100 - 300 gallons), but because of their compact size, many can be installed in a single drainage area to intercept larger runoff volumes. They can be used where other types of bioretention may not be feasible. Additional runoff flows can be intercepted by adding storage volume beneath the filter box with an outlet control device.

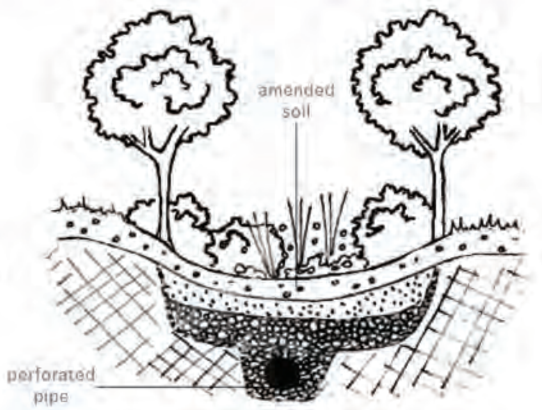
## BIORETENTION/RAINGARDEN *Depression in the ground planted with vegetation and designed to intercept, temporarily hold, and filter stormwater runoff.*

**Benefits:** Raingardens are simple to install requiring a small degree of excavation. Both small raingardens and larger bioretention areas are effective at intercepting and treating runoff. Native vegetation provides habitat for wildlife, is hardy to local climate and requires less water. Trees, shrubs, and grasses sequester carbon.

**Applications:** Larger bioretention areas are ideal for subdivisions or commercial lots already cleared of vegetation. Raingardens can be installed on small sites, such as residential properties.

**Construction Details:**
Site bioretention areas on the lowest point of a property, upland from inlets and outfalls, and near the source of stormwater runoff. They should be at least 10 feet from structures. Avoid siting near walkways to reduce soil compaction. Spatial criteria depends on drainage area, intentional percent of runoff detention, and the design storm.

To discourage mosquito habitat, raingardens and other bioretention basins must only hold water temporarily, infiltrating all water over 12-72 hours. A percolation test should be conducted to ensure adequate drainage. If infiltration is not possible, and overflow should be installed. Soil should be excavated 6-12 inches to create a pooling area. Sand and compost amendments can be added to existing soil to ensure proper drainage.




Rocks at both inlets and overflow outlets reduce erosion and slow channeled water. Adding mulch around the base of plants aids in denitrification, particularly in areas with high nutrient levels (especially nitrates) such as residential areas.

Large bioretention basins that allow stormwater to infiltrate into the ground should not contain filter fabric. Those that receive runoff from pollution hotspots should use an impervious liner to prevent infiltration.

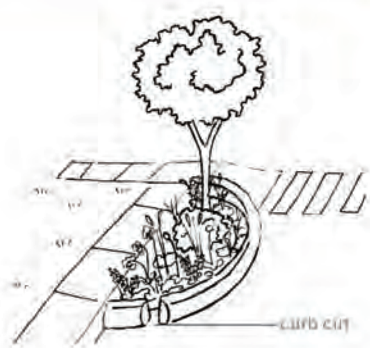
**Limitations:** In areas with a high water table, bioretention areas may be used to temporarily store stormwater, releasing it once peak runoff volumes and stress on the municipal storm system have subsided.

## BUMP-OUT/CURB EXTENSIONS *Sidewalk extensions that provide quicker, safer crossings for pedestrians and intercept, store, and filter stormwater runoff.*

**Benefits:** Bump-outs and curb extensions contain plantings, street trees, and occasionally public benches. They can be placed at the end of a bioswale or along existing sidewalks. They enhance street safety by shortening the time pedestrians are exposed to oncoming traffic and by slowing vehicles.

**Applications:** They are well suited for downtown and residential areas and can be sited mid-block, at intersections, and/or at bus stops.

**Construction Details:** Bump-outs are often the size of an on-street parking space or approximately 2 feet narrower. Curb extensions vary depending on ROW width. Both are suited for areas that have less than 6% slope.

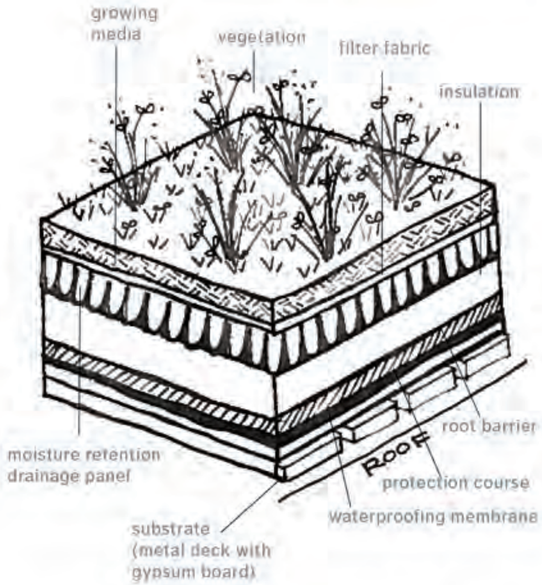


## VEGETATED ROOF (GREEN ROOF): *Structurally-sound flat or slightly pitched roof-tops planted with vegetation that intercept, retain, and treat stormwater before it reaches the street.*

**Benefits:** Vegetated roofs are an effective strategy for capturing, filtering, and evapotranspiring rainwater where space is limited for ground-level interventions. Vegetation absorb pollutants through their roots and soil filters-out particulates, improving water quality of roof runoff. Vegetated roofs also provide wildlife habitat, create gathering spaces, and mitigate the urban heat island effect. They add insulation that helps regulate building temperatures, reducing demands for energy, soundproofing indoor spaces, and increasing the roof's lifetime by protecting it from UV damage.

**Applications**: They are best suited for flat roofs and can be applied on a range of structures including industrial, commercial, institutional, and residential. They can be used in combination with solar panels.

**Construction Details:** Roofs must be able to bear weight of materials and plantings. Water holding capacity varies by materials. Vegetative roofs require engineered mineral soil resistant to freezing and thawing, irrigation during establishment, and specific vegetation able to withstand rooftop microclimates. They are best suited for roofs with a slope of 0-30 degrees, minimum ¼"/ft., and 1"/ft. is ideal for drainage without slippage of materials. Extensive Vegetated Roofs are <6" in depth, whereas Intensive Vegetated Roofs are much deeper and can support larger vegetation.




**Limitations**: Extensive vegetative roofs are more economical than intensive vegetated roofs. Initial costs can be high but savings can be achieved over time through increased building efficiency and reducing impact on stormwater management system. Bioswales and raingardens may be more economical options where ground space exists.

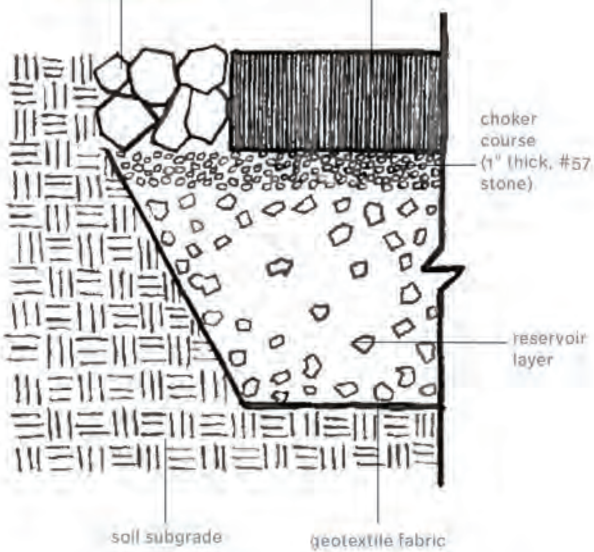
## POROUS ASPHALT *Asphalt with larger "voids" that allow water to infiltrate into a layer of stone where stormwater is temporarily stored.*

**Benefits:** Porous asphalt does not require any additional space because it can replace conventional asphalt. It decreases runoff temperatures, improves water quality by removing pollutants through coarse sand filtration, and speeds snow/ice melt, reducing the need for salt and sand. It is also more durable, resulting in fewer potholes.

**Application:** Porous asphalt is well-suited for roads, parking lots, alleys, and sidewalks.

**Construction details:** There should be 3-5' vertical separation from seasonal high groundwater table. It is best suited for sites that are 3' above water table and 2' above bedrock with slopes <5%.

**Limitations:** Porous asphalt has higher upfront costs, but lasts twice as long as conventional asphalt and has equivalent savings when considering reduction in stormwater infrastructure costs.

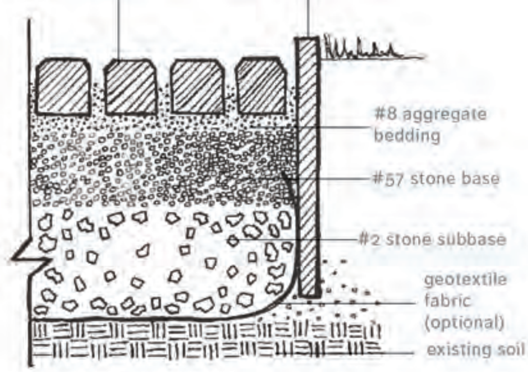



## PERMEABLE PAVERS *Concrete bricks or pavers that allow stormwater runoff to permeate into an infiltration area below.*

**Benefits:** Permeable pavers can replace conventional pavement. By cooling water and trapping pollutants from vehicles, they can improve the quality of stormwater infiltrating into the ground. Also, they reduce the amount of water entering the municipal storm system which can relieve stress during peak runoff.

**Applications:** Permeable pavers are optimal on sidewalks, driveways, parking lanes, and streets where speed limits are low. Site where locations are 3 feet above the water table and 2 feet above bedrock and on slopes <5%.

**Construction details**: Water infiltrates through gaps between pavers and is stored in voids until filtering into the soil. Yearly maintenance includes removing debris and replenishing aggregate as needed. Pavers require less road salt than other types of paving in winter. Sand should not be used for deicing because it can block permeability.



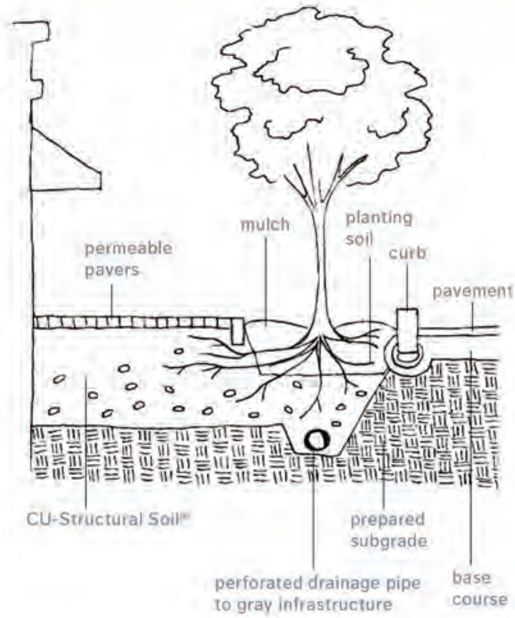

Areas with permeable pavers may be linked to underground stormwater chambers or other storage systems. They should have an infiltration rate: up to 50"/hr with maintenance, 3-4"/hr without maintenance.

## STRUCTURAL SOIL/BREAKOUT: STRUCTURAL SOIL (CU-STRUCTURAL SOIL®) *Licensed, engineered soil mixture that creates a compacted, load-bearing lattice of angular stone with pockets of soil and air penetrable by tree roots.*

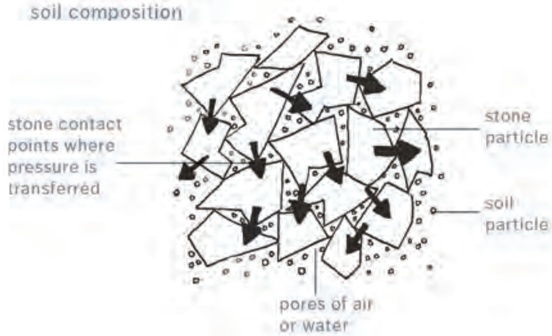
**Benefits:** Structural soil below sidewalks and/ or in breakouts allows trees roots to grow more than they would in a conventional urban tree pit because they have more room and can penetrate the structural soil profile. This results in healthier urban street trees. Furthermore, trees can be planted closer together and roots can grow without heaving sidewalks. Stormwater interception and infiltration rates increase when structural soil is used in conjunction with permeable pavers and asphalt.

**Applications:** Structural soil works best in areas with minimal vehicle traffic such as pedestrian malls, sidewalks, and parking lanes, and in urban areas with large amounts of pavement and minimal soil.

**Construction Details:** Soil depths should be 24-36". Trees should be planted that tolerate alkaline and well-drained soils. At the base of the planting area, a perforated drain should connect to the municipal storm system to prevent stormwater back-flow.



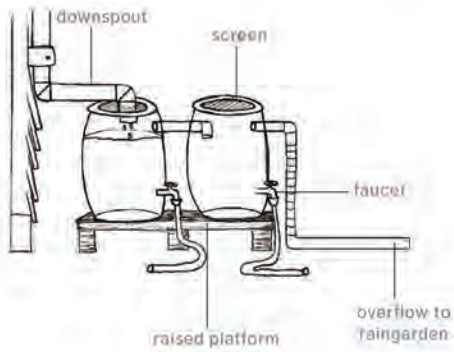

Detail of structural soil composition



## CISTERNS AND RAIN BARRELS

*Rainwater harvesting containers that can be attached to roof gutter downspouts that intercept, collect, and store stormwater runoff for later use.*

**Benefits:** Rainwater harvesting saves money and energy by decreasing demand for treated tap water. Rainwater harvesting effectively slows and diverts runoff before it reaches the catch basins, decreasing the impact of runoff on streams.



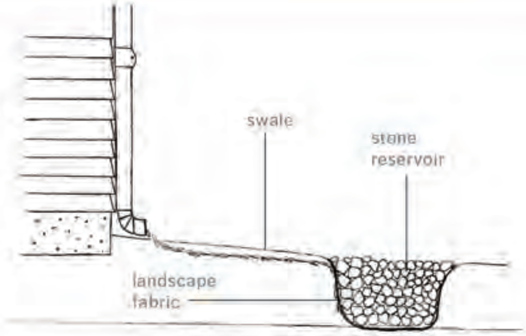

**Applications:** Best used on structures that have gutters. Harvested rainwater can be used for irrigating gardens, cleaning tools, washing cars, or a variety of other uses. For food-producing gardens, it is recommended that rainbarrels be used with metal roofs instead of asphalt shingles and a "first-flush" pollutant interception system be installed.

**Construction Details:** Rainwater from the gutter enters the rainbarrel which is covered by a screen, filtering leaves and debris and preventing mosquitoes from entering the reservoir. Tanks must be dark to prevent algae from growing. Rainbarrels have spigots near the bottom and can be elevated to increase water pressure using gravity. Rainbarrels must also have an overflow outlet which can be directed into a raingarden. Rainbarrels are often designed to hold 50 gallons of water but cisterns are available that can hold thousands of gallons. For greater runoff interception, multiple rainbarrels or cisterns can be linked. Rainbarrels can be installed under decks, along houses, or in unused spaces.

## DRY WELL

*Small excavated pits filled with gravel and stone that temporarily store stormwater runoff until it infiltrates into the soil.*

**Benefits:** Holding and infiltrating stormwater runoff reduces pressure on stormwater infrastructure, decreases flood impacts, improves water quality, and can recharge the groundwater supply.




**Applications**: Can be used in conjunction with or in place of a rainbarrel or raingarden to intercept overflow or runoff where percolation tests indicate soil conditions are suitable for infiltration.

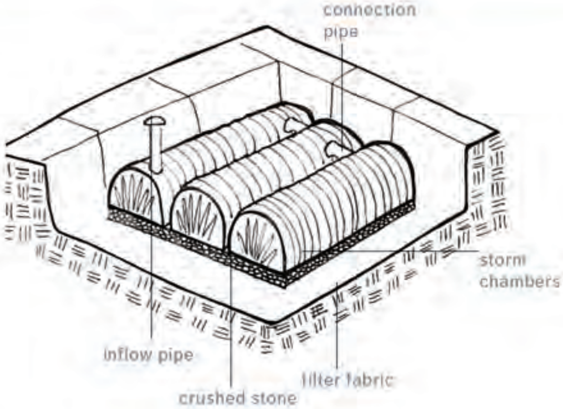
**Construction Details:**
Line a small excavated pit with landscape fabric and fill with gravel and stone. Alternatively, use a prefabricated perforated hollow chamber buried in the ground. Convey rooftop runoff to dry well via downspouts connected to underground pipes, French drains, or grassy swales. Leaf guards should be installed on gutters so pipes will not clog. Should be sized appropriately to rooftop and storm volume, with a safe overflow design that will not damage neighboring properties.
Dry well should be located at least 10' from homes and 25' from any down-slope buildings.

## STORMWATER CHAMBERS *Underground retention or detention of rainwater using buried prefabricated arch-shaped cisterns or perforated pipe and stone.*

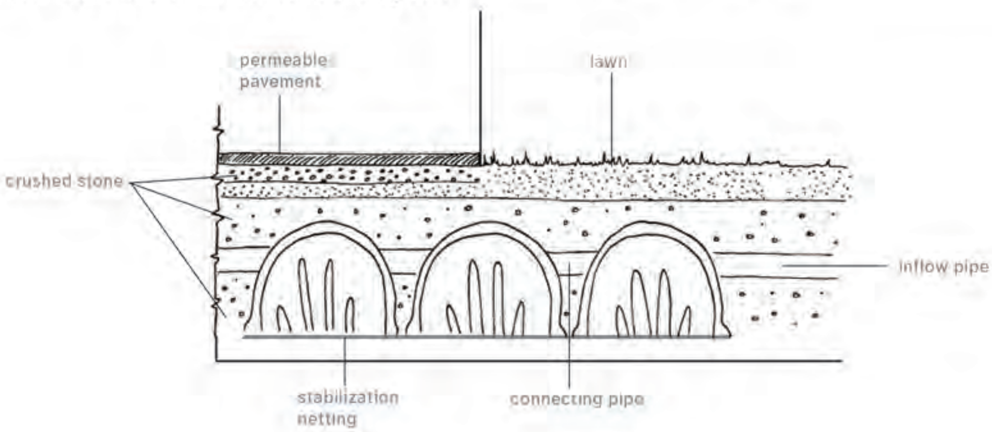
**Benefits:** Stormwater chambers decrease the volume of stormwater entering the municipal storm system during peak runoff, relieving stress and decreasing the likelihood of damage to these systems. They also enhance water quality by capturing sediment and removing pollutants, and recharge groundwater. When used in conveyance for ponds, stormwater chambers minimize algal blooms, sediment loading, and pond maintenance.

**Applications:** Stormwater chambers store stormwater runoff underground, below permeable parking, commercial land, parks, athletic fields, and urban green spaces. They are especially effective where there is not enough space for surface bioretention. Due to their ability to filter pollutants, installation should be considered near pollution hot spots.

**Construction Details:** Stormwater is channeled into bottomless underground chambers which function like a septic drain field, degrading nutrients and pollutants by percolating through filter fabric and stone into surrounding soil.




Water may be held temporarily during storm events and slowly released into aquifers, storm drains or waterways. Sizing of stormwater chambers depends on the supplier. Channels can be linked and stacked in alternating courses for maximum stormwater storage. Each chamber includes sediment traps that require periodic maintenance. Sediment may be removed by vacuum truck.

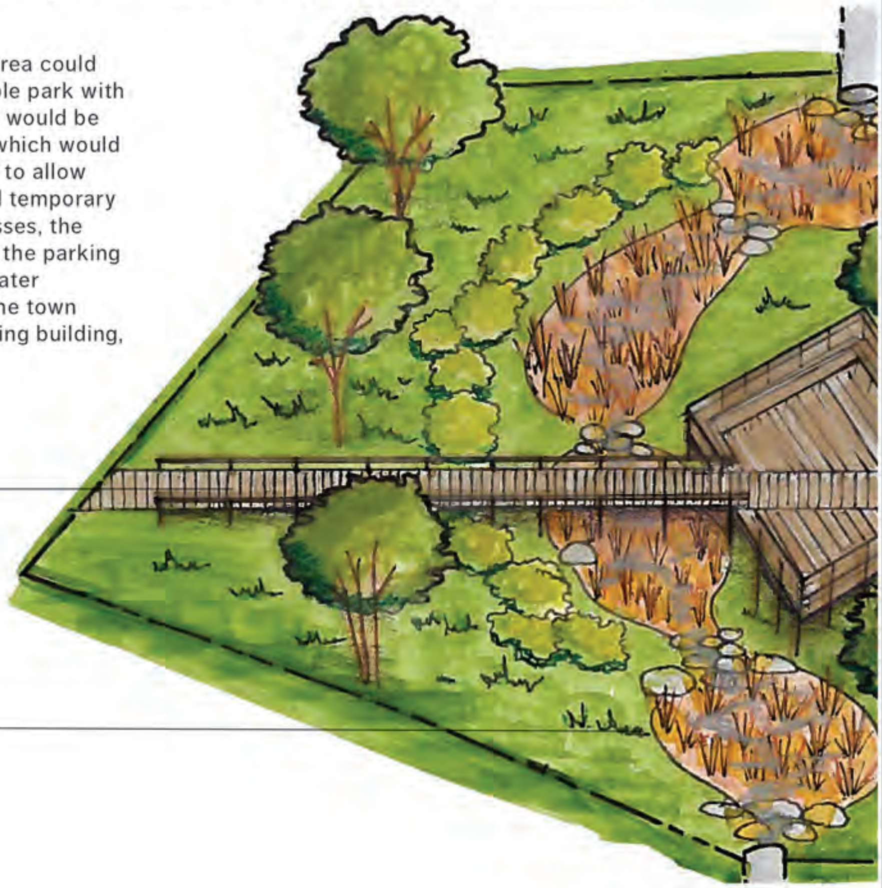


# Non-Residential Municipal Site: Fourth District Voting Hall

The former Fourth District Voting Hall is a 0.6-acre site owned by the town that is currently used only for occasional meetings and storage. This is a low-lying spot in a residential area where runoff pools from surrounding properties and the high-tide backflow from the stormwater catchment basin in the drainageway underlying the site. It was identified by the town civil engineer as one of several flood-prone sites in Mystic that currently has no official use and would be ideal for green infrastructure intervention. This site is large enough to accommodate several interventions and amenities designed to address flooding issues. Its downtown location makes it a potentially appropriate space for providing additional parking, which is a concern in the community during the tourist season.

In response to these conditions, this area could be potentially redesigned as a floodable park with a permeable parking lot. The property would be excavated and reshaped into a basin which would hold water after the culvert is opened to allow for controlled flooding of the park and temporary bioretention. After the peak storm passes, the park and stormwater chambers under the parking lot could drain into the town's stormwater management infrastructure. Should the town decide to keep and renovate the existing building, the same design principles can apply to the rest of the site.

Low-lying flood-prone sites exist throughout downtown Mystic. Designing these spaces to receive water and flood in a controlled manner will help address nuisance flooding on surrounding streets and properties. To prevent nuisance flooding, interventions in upland properties will help prevent runoff from accumulating in low-lying areas. Existing parks throughout the village can incorporate stormwater remediation and temporary storage during peak flood events using stormwater chambers and bioretention gardens. All impermeable parking areas can be repaved with permeable asphalt over structural soil and surrounded by bioswales for runoff treatment.

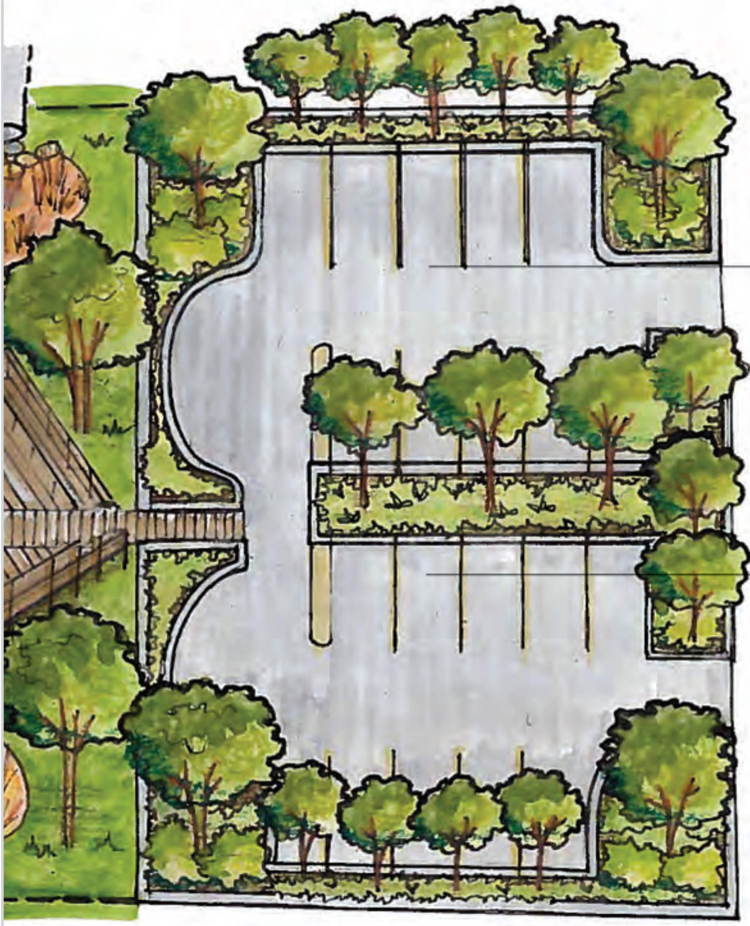


The boardwalk and platform area could include educational interpretive signs and provide opportunities for wildlife habitat observation.

Bioswales and gardens of trees, shrubs, grasses, and marsh areas would provide habitat and opportunity to absorb and treat stormwater. *(Toolbox, pp. 49 and 52)*

Fourth District Voting Hall (used for storage by the town of Stonington)

Flooding from an Extremely High Tide Coupled with Heavy Precipitation



Porous asphalt allows stormwater to infiltrate into the ground. *(Toolbox, p. 54)*

Underground stormwater storage chambers can be installed below the permeable parking lot and temporarily hold stormwater as it percolates through the parking area. *(Toolbox, p. 57)*

**Case Study:** Permeable Paving Materials and Bioretention in a Parking Lot, *see p. 75*

RECOMMENDATIONS | NON-RESIDENTIAL 69

# Non-Residential Commercial Site: Washington Street Bioremediation Pocket Park

Washington Street is a low-lying road subject to frequent flooding from both stormwater runoff and stormwater catchment drains backflowing from outfalls in nearby water bodies. Analyzing topography and runoff stream flow channels shows that the road forms a temporary stream during heavy rain events. Washington Street has multiple stormwater catchment basins with outfalls into the marsh and harbor. Because this is also a hotspot, flooding is of additional concern. It was identified by the community and the town engineer as a particularly vulnerable area and it sits within a high concentration of other pollution hotspots.

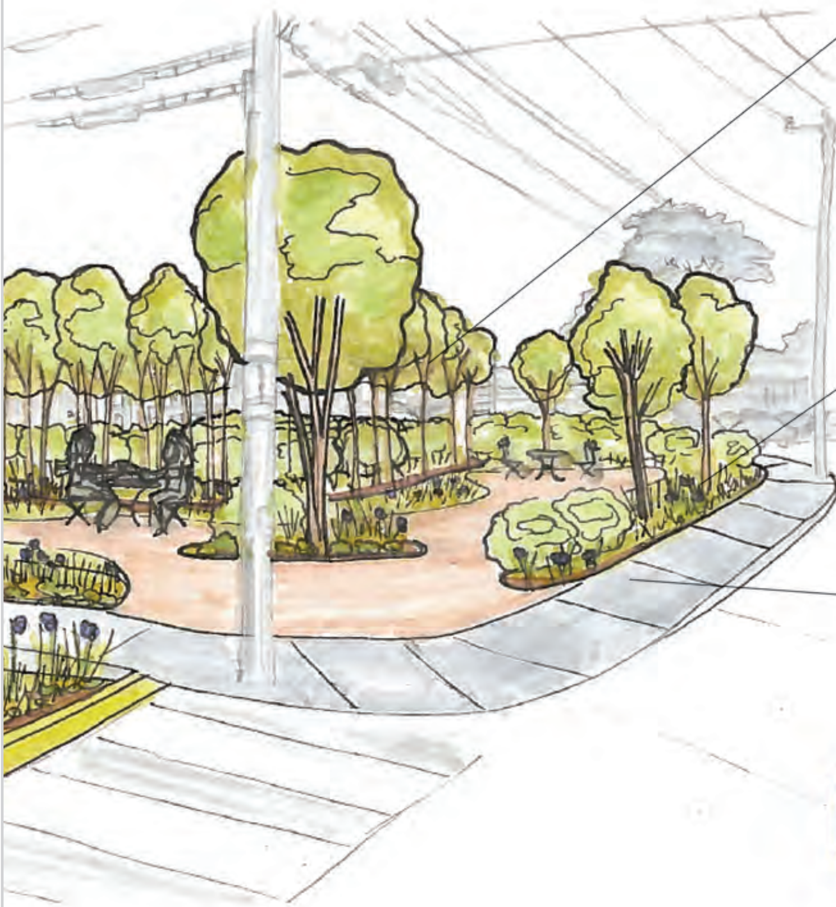
One of the pollution hotspots along Washington Street is a gas station with an adjacent vacant lot. This lot is located along a highly visible section of Main Street or Route 1, a well-traveled thoroughfare into downtown that was identified by the Stonington *Climate Resiliency Plan* as a potential "Green Corridor." This previously developed lot is currently a mowed field that is primarily flat with a low sidewalk around the perimeter. The neighborhood is a mixture of residential and commercial. While currently, the owner of the vacant property has development plans for this site, the following conceptual design provides a model how green infrastructure can be applied to contaminated undeveloped lots in Mystic.

Designing vacant lots into bioremediation parks throughout Mystic could add much needed community green space for gatherings and recreation, and complement the oceanside character of the community. Addressing climate change through interpretive green infrastructure in public spaces can help visitors and residents understand how these green spaces can help increase climate resilience. These interventions also provide initial stormwater treatment before runoff reaches a storm sewer system. There are several gas stations in the downtown area where polluted runoff could be intercepted and filtered by green infrastructure.

Interpretive signs can educate residents and tourists about how elements of the design intercept stormwater runoff, mitigate flooding, and treat pollutants. Signs can also suggest how these techniques might be replicated on other sites.

Vacant Lot on the corner of Washington Street and Route 1

Smaller interventions like filter strips and bioswales can be incorporated into the landscaping surrounding gas stations. Impervious surfaces such as gas station driveways and parking areas can be graded toward these smaller bioretention areas. Stormwater catch basins and drains could be installed in gas station pavement to direct runoff to green infrastructure systems depending on slope and how much stormwater flows on site.
*(Toolbox, p. 49)*



Tree trench treatment cells and an interception hedgerow can incorporate trees and shrubs in systems designed to break down pollutants; their canopy can filter air.
*(Toolbox, p. 50)*

Roads and gas station paving can be regraded to drain into curbcuts, inlets, and runnels that convey polluted runoff into bioswales and rain gardens.
*(Toolbox, p. 49 and 52)*

**Case Study:** Phytoremediation Treatment of Hydrocarbons, *see p. 75*

# Non-Residential Public Site: Mystic River Park

Mystic River Park was identified by the community as an opportunity for outreach and education about green infrastructure. Mystic River Park is important to the community because it is one of the few public spaces along the waterfront. Its boardwalk is a popular tourist destination for those leisurely enjoying the waterfront. The park often hosts large summer festivals, public events, and free concerts during the tourist season.

In this concept design, Mystic River Park retains its open grassy field as an important public riverfront gathering space. At the same time, a combination of several green infrastructure techniques filter and temporarily hold runoff along its perimeter.

The park is bordered by bioswales planted with native grasses and herbaceous perennial flowers endemic to coastal regions to help retain the historic character of Mystic. These bioswales have check dams to slow runoff while shrubs, grasses, and herbaceous perennials help to absorb stormwater while filtering sediment and pollutants. *(Toolbox p 49. )*

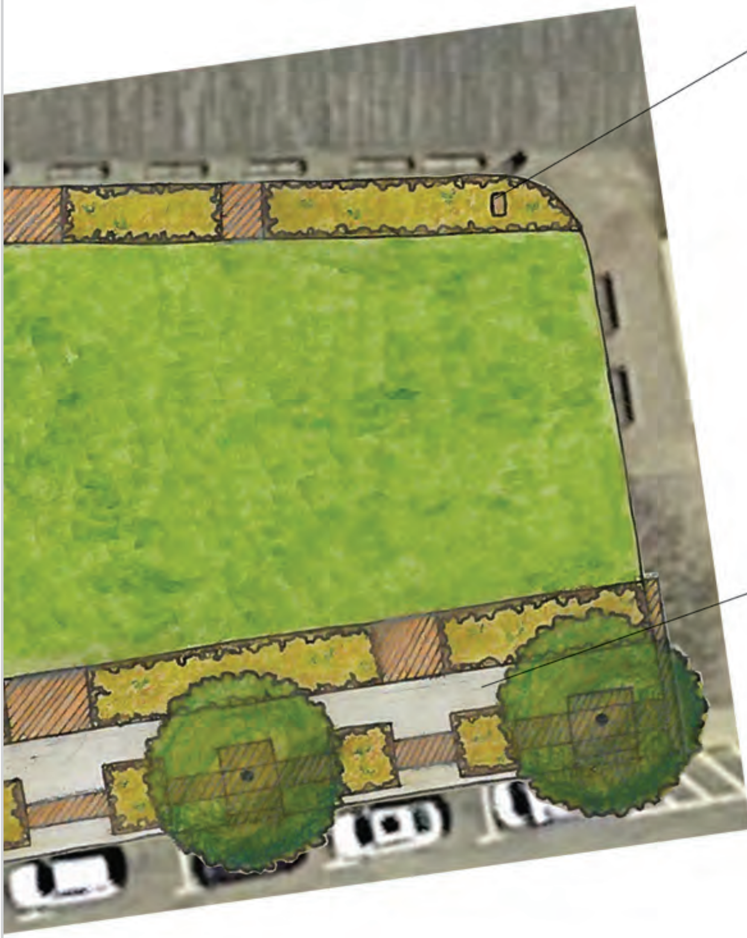
The park lawn is graded to drain into the bioswales that surround the park.

Stormwater treatment begins at Cottrell Street, where runoff is directed into catchment basins linked below ground to the tree trench and rain gardens for initial filtering. Runoff overflow from the tree trench percolates into an underground perforated pipe that channels excess stormwater into perimeter bioswales. *(Toolbox, p. 49)*

The tree trench and bioswales have crossings covered with a decorative grate to maintain pedestrian access between vehicles, gardens, and boardwalk. *(Toolbox, pp. 49 and 50)*

Mystic River Park and adjacent boardwalk

Educational signs located throughout gardens within the park interpret the design and functions of green infrastructure for residents and tourists.



A widened sidewalk along Cottrell Street in front of Mystic River Park includes space for gardens and street trees along the road that invite pedestrians into the park lawn and boardwalk. The sidewalk of permeable pavers is installed over structural soil to accept more runoff and allow for root expansion, supporting tree health and longevity. *(Toolbox, pp. 51 and 54)*

**Case Study:** Partnering with Colleges for Community Learning, *see p. 75*

# Residential Strategies to Reduce Stormwater Runoff and Improve Water Quality

## PLANT TREES

Trees intercept and store rainwater in their canopy and lift water out of the ground through their roots, thus significantly reducing the amount of stormwater runoff on a given property. They also shade surfaces underneath, cooling runoff moving across these surfaces.
*(p.43 )*

## PLANT RAIN GARDENS (SMALL BIORETENTION AREAS) & REDUCE GRASS TURF

Replacing grass turf with plants that have a high capacity to absorb water and do not produce and impervious layer of thatch can decrease the amount of stormwater leaving a site. Strategies include planting more shrubs, rain gardens, and bioswales. *(Toolbox p. 49)*

## AVOID CHEMICAL USE ON LAWNS

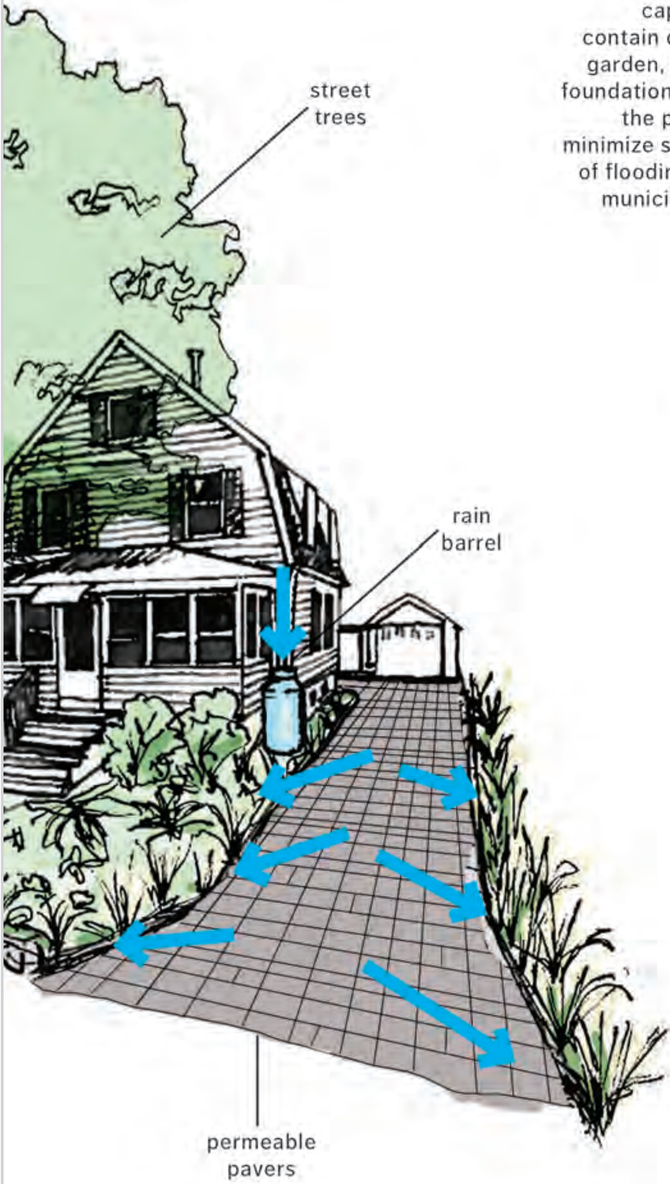
Avoiding the use of herbicides and pesticides helps to improve the water quality of residential runoff. Conducting a soil test will help determine any nutrient deficiencies for which organic fertilizers can help amend. Alternatively, choose plants that are tolerant of existing soil conditions. Additionally, picking up and properly disposing pet-waste can prevent harmful bacteria from entering nearby waterways.

## INSTALL CURB-CUTS AND REGRADE DRIVEWAYS AND ROADS

Manipulating existing impervious surfaces can help direct runoff into permeable areas. Techniques include curb-cuts and regrading driveways and streets to convey runoff from these surfaces into rain gardens.

## DISCONNECT GUTTERS AND CAPTURE/ STORE RAINWATER

Install or connect existing gutters to rain barrels or cisterns to capture rainwater from roofs. Storage containers should also contain overflow mechanisms that release excess water into a rain garden, bioswale, or french drain that directs water away from the foundation of the house. Delaying the release of stormwater reduces the peak runoff rate from a property at a given time, helping to minimize stress on the municipal system and decrease the likelihood of flooding. Residences that have gutters directly connected to the municipal stormwater system should consider disconnection and implementation of these techniques. *(Toolbox p. 56)*




## MAINTAIN VEHICLES

Performing regular maintenance on vehicles can reduce the likelihood of oil leaks. Additionally, because commercial car-washing facilities must obtain a permit for wastewater discharge and adhere to specific standards that protect the environment, washing cars in designated facilities instead of in residential driveways reduces the likelihood of phosphates from soap, hazardous chemicals, and heavy metals entering nearby waterways. Other strategies include recycling used motor-oil, using ground cloths or drip pans under vehicles in the event of a leak or during engine maintenance, and cleaning up immediately after a spill.

## INSTALL PERMEABLE DRIVEWAYS

Pervious pavement or permeable pavers can be used as a replacement for the traditional asphalt driveway. These strategies have the potential to reduce the amount of runoff leaving a property by allowing stormwater to filter into an underground stone reservoir and eventually into the ground. Because runoff from driveways can contain harmful chemicals from vehicles, reducing the amount that enters the municipal system improves water quality of nearby water bodies. *(Toolbox p. 54)*

# Green Streets

GREEN INFRASTRUCTURE STRATEGIES FOR STORMWATER MANAGEMENT ON MUNICIPAL AND STATE-OWNED RIGHTS-OF-WAY, INCLUDING PARKING LANES, SIDEWALKS, AND MEDIANS.

## WHY GREEN STREETS?

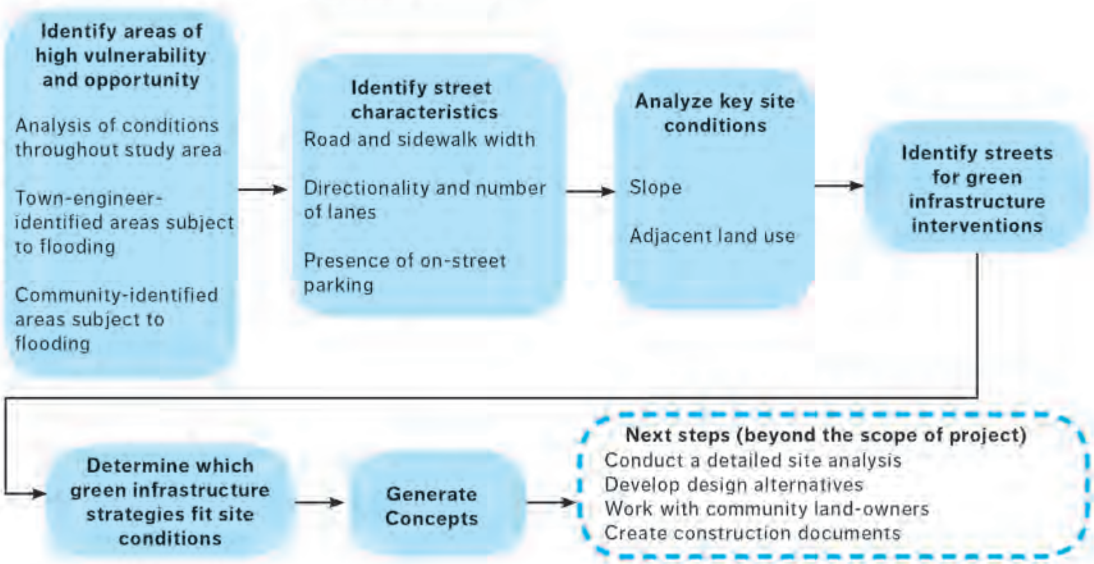
Green Streets are an approach to managing stormwater by using green infrastructure to treat runoff at the source. By replacing impervious surfaces with vegetation, soil and other permeable materials, stormwater runoff is slowed, filtered, and reduced. This can decrease the likelihood of flooding and improve the quality of downstream water bodies (U.S. EPA 2015). Green Streets can also create more beautiful urban streetscapes, reduce the heat island effect, and improve air quality. Using the Green Streets approach, Mystic has an opportunity to create a resilient urban environment, garner support for watershed health, and inspire similar coastal communities.

The 2017 *Coastal Resilience Plan* (CRP) noted that as sea levels rise and precipitation rates increase due to climate change, accessing important facilities such as hospitals, police stations, and emergency centers in Mystic may become challenging due to flooding along major roadways (Town of Stonington et al. 22). The CRP lists Route 27 and Route 1 as particularly vulnerable because of their tendency to flood and their value as commuter corridors (Town of Stonington et al. 16). Other streets identified by community members and Scot Deledda, the town engineer, as places that frequently flood include Church Street, Cottrell Street, and Washington Street. Flooding on streets can damage infrastructure and vehicles, and can lead to road closures—consequently impacting daily life and reducing tourist activity.

## DESIGN PROCESS

Street characteristics and site conditions inform the suitability and location of green infrastructure strategies. For example, strategies differ depending on the width of the right-of-way (ROW), lane directionality, presence of designated on-street parking, speed limit, slope, proximity to pollution hot-spots, and land use. For detailed information on spatial criteria and optimal site conditions for each green infrastructure technique, please refer to the Toolbox section of this book.

A six-step design process was developed to identify and illustrate Street Profiles that exemplify the range of street characteristics in Mystic and the diversity of green infrastructure techniques that can be applied. Streets were analyzed using GIS data from CT DEEP, CT ECO, the Town of Stonington's Geographic and Property Information Network, and Google Earth. Additionally, areas that experience frequent flooding were identified by community members and the Town Engineer, Scot Deledda. The existing municipal stormwater infrastructure was considered in the following conceptual designs; however, the location of other underground utilities was not. Therefore, further analysis is needed as underground utilities will likely impact the location and design of proposed strategies.



## STREET CHARACTERISTICS

The majority of streets in the village of Mystic are between 25' and 45' wide, with two-way directionality of travel, and speed limits between 25 and 35 mph. Most streets have on-street parking that is either delineated with striping or by the absence of "no parking" signs. With the exception of Mistuxet Avenue, School Street, East Church Street, and Reynolds Street, streets are generally flat with slopes <5%. Land use within the village of Mystic is primarily commercial and residential.

Based on these characteristics and conditions, and areas identified through the process of analysis and community feedback as highly vulnerable, five Street Profiles were created to show conceptual applications of green infrastructure techniques to a range of conditions in Mystic. Each Street Profile represents a distinct street in Mystic, but can be applied elsewhere where similar conditions exist.

Green infrastructure techniques applied to street profiles manage stormwater, increase canopy cover, and improve the aesthetic quality of a neighborhood. Preserving existing on-street parking was a major priority as city officials and community members noted concern about a lack of parking during peak tourist season.

Street Characteristics in the Village of Mystic


Local Flooding Impacts on Visitation to Downtown Districts

**Case Study: Annapolis, MD (Masters)**

A study in Annapolis, MD, analyzed data from parking meters and comments on Twitter from local businesses to understand the economic impacts of flooding. They reviewed 4,584 hours of parking meter records and found that when flooding occurred as a result of high tides and sea level rise, people avoided the downtown area altogether. Even after the flooding ended, there was more than a six-hour lag until visitation returned to its usual levels. This resulted in a 2% loss of visits (3,000 lost visits) to the historic downtown district, at a cost of $86,000 - $176,000 per year.

## Street Characteristics

### 1 COTTRELL STREET

Cottrell Street runs parallel to the Mystic River and abuts Mystic Harbor, making it particularly vulnerable to flooding from precipitation, storm surge, and sea level rise. Stormwater from nearby impervious surfaces is funneled into several catchment basins that line both sides of the street. Cottrell Street is in the heart of Mystic's commercial district and experiences heavy pedestrian and vehicle use. On-street parking is valuable and lines both sides of the street. The area is highly developed with structures encroaching on the right of way, and there is a large amount of impervious surface and minimal tree canopy cover.

### 2 CHURCH STREET

During heavy precipitation events, runoff from steep slopes to the east can collect on this section of Church Street and result in flooding. Additionally, high water levels in the Mystic River can cause water to back-flow through outfalls and up through catchment basins, which prevents stormwater from draining. The area is primarily residential, and the street abuts St. Patrick's Church, an important community asset. St. Patrick's Church has a large parking lot that drains to catchment basins along the north and south edges of Church Street.

### 3 EAST MAIN STREET

East Main Street is part of Route 1, a street identified in the 2017 *Coastal Resilience Plan* (CRP) as a location where green infrastructure may help to mitigate the impacts of flooding. Curbs funnel runoff into catchment basins, of which there are fewer compared to streets to the south and west. It is a main arterial road that connects the towns of Stonington and Groton, and runs through downtown Mystic Village. It is also frequented by pedestrians, with sidewalks lining both sides of the street. The CRP identified this area as high risk to flooding because of its location along the coastline and a priority for intervention because of its use as a major commuter corridor.

### 4 BROADWAY STREET

The southern section of Broadway Street is also part of Route 1. There are several gas stations within this section of Broadway Street and there is a high concentration of impervious surfaces. Thus, it is possible that runoff from this area may contain higher amounts of potentially harmful pollutants. There is minimal tree canopy cover. Curbs direct stormwater into catchment basins that line both sides of the street.

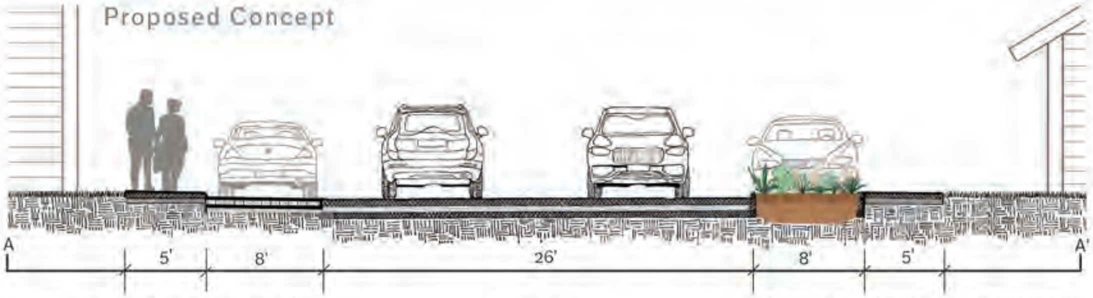
### 5 REYNOLDS STREET

Reynolds Street is one of the few streets in Mystic with a >10% slope. During heavy rain events, the road acts as a channel, transporting runoff from the higher elevations to low-lying areas. It is primarily lined with residential buildings and has minimal pedestrian and vehicle traffic. The right-of-way extends an additional 8-12 feet on either side beyond the paved road and is currently mowed grass. There is more tree canopy cover on Reynolds Street compared to the streets closer to the coastline.


2
3
1
5
4
Google Earth

# ① Street Profile: Cottrell Street

| Flood Risk | ROW Width | Speed Limit | On-Street Parking | Sidewalks | Adjacent Land Use | Slope |
|---|---|---|---|---|---|---|
| High | 52' | 25 mph | Yes (both sides) | Yes (both sides) | Commercial | <5% |




### GREEN INFRASTRUCTURE TOOLS

- Bump-out *(Toolbox p. 52)*
- Rain garden *(Toolbox p. 52)*
- Permeable pavers *(Toolbox p. 54)*
- Porous asphalt *(Toolbox p. 54)*

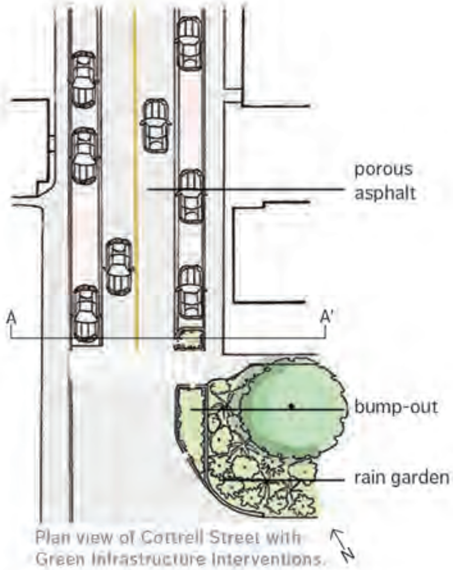
### ADVANTAGES AND LIMITATIONS

Filtering runoff from Cottrell Street, an area with high concentrations of impervious surfaces, can help maintain healthy water quality of nearby water bodies. This can be a challenge due to limited space; however, permeable pavers in parking lanes allow water to filter into the ground and preserves parking. Additionally, curb extensions at crosswalks slow and filter water, as well as shorten the time pedestrians are exposed to oncoming traffic while crossing the street. Finally, underutilized green space, such as that owned by the Town of Stonington at the southern end of Cottrell Street, can be used for small-scale stormwater detention in a rain garden.

Although these strategies can store some runoff on the surface and just below, larger volumes of underground storage may not be feasible due to soil percolation rates. While these strategies can improve water quality they may not significantly reduce flooding from back-flowing storm drains or during high precipitation events.

### ADDITIONAL CONSIDERATIONS

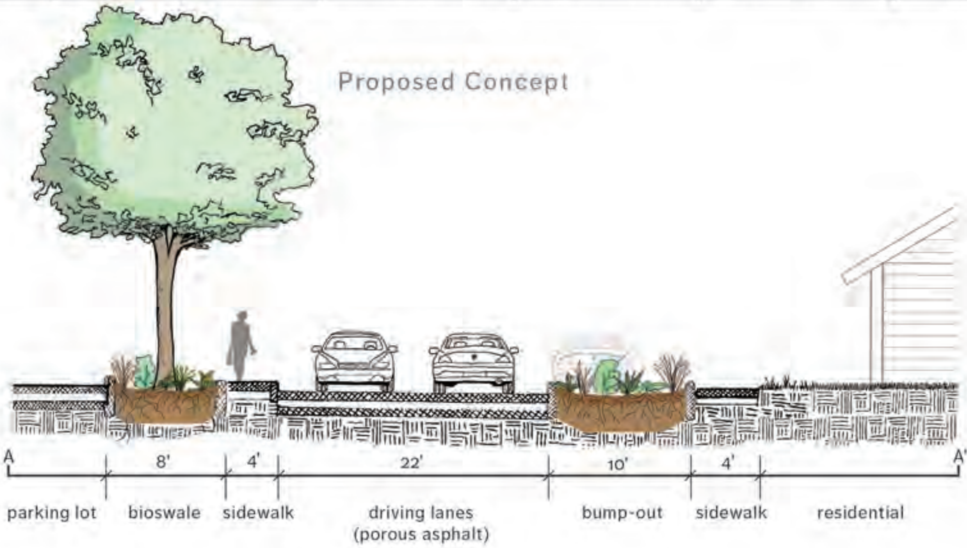
In areas with high pedestrian activity like Cottrell Street, green infrastructure can help educate and inspire community members and tourists about stormwater management and ecosystem and watershed health. The Town of Stonington is considering making Cottrell Street one-way, which would create space for additional green infrastructure strategies.




Plan view of Cottrell Street with Green Infrastructure Interventions.

## ② Street Profile: Church Street

| Flood Risk | ROW Width | Speed Limit | On-Street Parking | Sidewalks | Adjacent Land Use | Slope |
|---|---|---|---|---|---|---|
| High | 50' | 25 mph | Yes (one side) | Yes (both sides) | Commercial | <5% |




**GREEN INFRASTRUCTURE TOOLS**

- Bioswale *(Toolbox p. 49)*
- Bump-out *(Toolbox p. 52)*
- Porous asphalt *(Toolbox p. 54)*
- Street trees *(p. 43)*

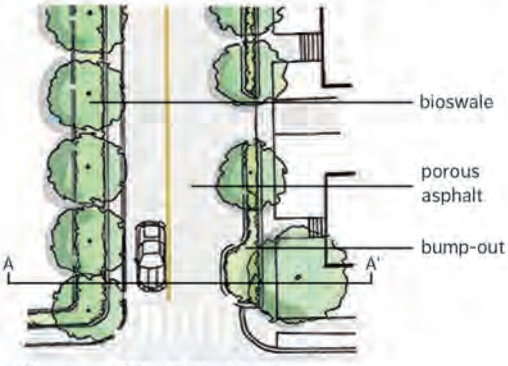
**ADVANTAGES AND LIMITATIONS**

Green infrastructure strategies that intercept runoff from the St. Patrick's Church parking lot and along the north side of Church Street have the potential to slow stormwater before it enters the municipal system and reduce the occurrence of nuisance flooding. Because so many vehicles use the parking lot, stormwater in this area may contain higher pollutant loads. Filtering stormwater from the parking lot can reduce pollution in water bodies into which runoff is channeled.

However, due to a high water table, these strategies may not significantly reduce flooding from back-flowing storm drains or during high precipitation events. While bump-outs slightly reduce parking availability, expanded parking is proposed in an adjacent lot. *(See page 68)*

**ADDITIONAL CONSIDERATIONS**

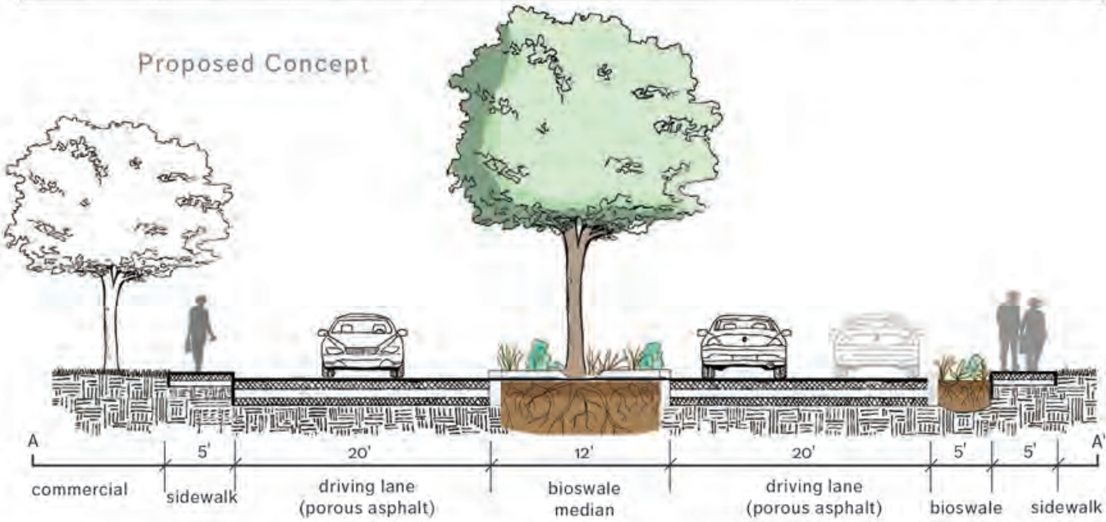
Partnering with and incentivizing community groups like St. Patrick's Church to reduce impervious surfaces and manage stormwater on-site can help the Town of Stonington build partnerships centered around watershed health and community resilience. Also, installing back-flow preventers at the nearby outfall may reduce flooding during high tides or storm surge.




Plan view of Church Street with Green Infrastructure Interventions.

# ③ Street Profile: East Main Street (Route 1)

| Flood Risk | ROW Width | Speed Limit | On-Street Parking | Sidewalks | Adjacent Land Use | Slope |
|---|---|---|---|---|---|---|
| High | 67' | 25 mph | Yes (one side) | Yes (both sides) | Commercial | <5% |




**GREEN INFRASTRUCTURE TOOLS**

- Bioswale in median *(Toolbox p. 49)*
- Bioswale *(Toolbox p. 49)*
- Street trees *(p. 43)*
- Porous asphalt *(Toolbox p. 54)*

**ADVANTAGES AND LIMITATIONS**

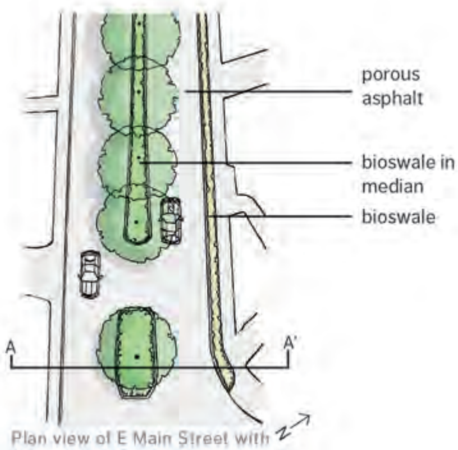
Trees and other plants tolerant of periods of drought and inundation that are planted in the existing median will intercept rain and reduce the amount of runoff entering the municipal system. Additionally, street trees provide shade for parked cars and pedestrians and improve the aesthetics of the road.

In order for stormwater to enter the bioswales, curbs must be cut so that they are level with existing road.

While they offer some storage, due to a high water table, these strategies may not significantly reduce flooding from back-flowing storm drains or during high precipitation events.

**ADDITIONAL CONSIDERATIONS**

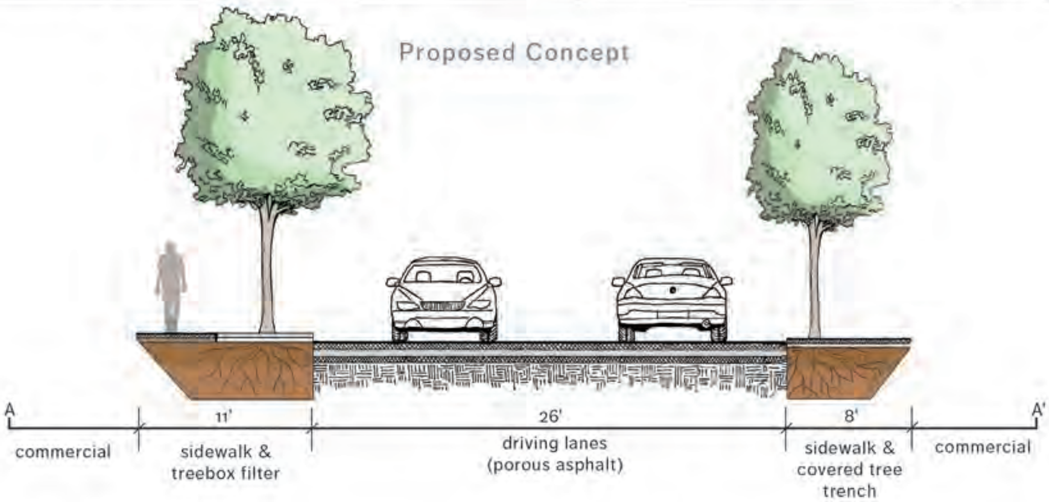
Route 1 is managed by the CT Department of Transportation. Standards for green infrastructure and maintenance may differ on the state level. Further investigation of design standards is needed.




Plan view of E Main Street with Green Infrastructure Interventions.

# ④ Street Profile: Broadway Street (Route 1)

| Flood Risk | ROW Width | Speed Limit | On-Street Parking | Sidewalks | Adjacent Land Use | Slope |
|---|---|---|---|---|---|---|
| Medium | 45 | 25 mph | No | Yes (both sides) | Commercial | <5% |




**GREEN INFRASTRUCTURE TOOLS**

- Treebox filter *(Toolbox p. 51)*
- Covered tree trench *(Toolbox p. 50)*
- Porous asphalt *(Toolbox p. 54)*

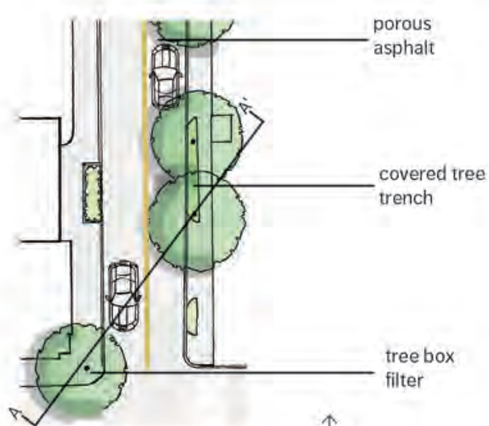
**ADVANTAGES AND LIMITATIONS**

This section of Broadway Street (Route 1) has a high concentration of impervious surfaces as well as several nearby gas stations identified as pollution hot spots. Treebox filters and covered tree trenches filter water before it enters the municipal system. Additionally, they help to increase tree canopy cover in an area that is currently sparse. They also provide shade for parked cars and pedestrians and improve the aesthetics of the road.

These boxes will provide a degree of storage, though due to a high water table, they will not significantly reduce flooding from back-flowing storm drains or during high precipitation events.

**ADDITIONAL CONSIDERATIONS**

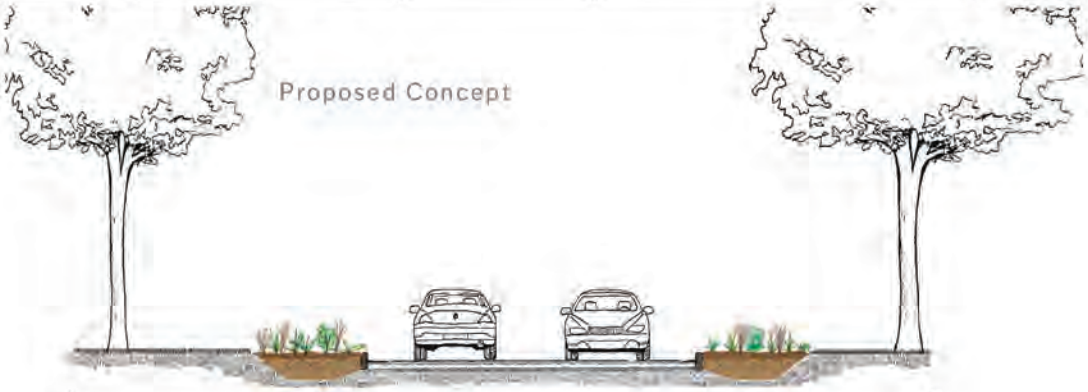
Route 1 is managed by the CT Department of Transportation. Standards for green infrastructure and maintenance may differ on the state level, so further investigation of design standards is needed before implementation.




Plan view of Broadway Street with Green Infrastructure Interventions

# ⑤ Street Profile: Reynolds Street

| Flood Risk | ROW Width | Speed Limit | On-Street Parking | Sidewalks | Adjacent Land Use | Slope |
|---|---|---|---|---|---|---|
| Low | 42' | 25 mph | No | No | Residential | >10% |




**GREEN INFRASTRUCTURE TOOLS**

- Bioswale with check-dams *(Toolbox p. 49)*
- Porous asphalt *(Toolbox p. 54)*

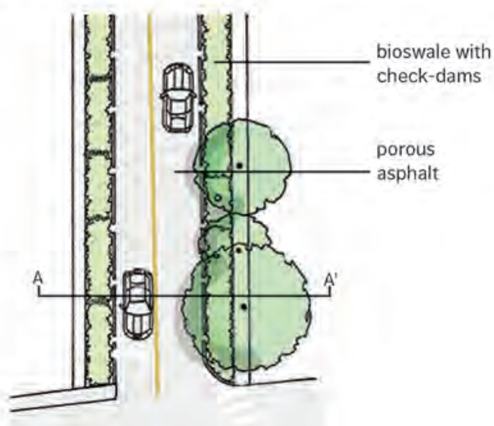
**ADVANTAGES AND LIMITATIONS**

Intercepting runoff from streets with steeper slopes and at higher elevations has the potential to significantly reduce flooding in lower-lying areas. The water table may be lower further up hill on Reynolds Street than it is underneath streets at lower elevations. Larger volumes of water may infiltrate into the ground. By regrading and using curb-cuts to direct water into bioswales, stormwater is directed away from impervious surfaces and into vegetated channels. This strategy also filters water through vegetation and soil, subsequently improving water quality.

Bioswales along the southern side of the street are especially important because they can overflow or connect directly to the storm drain at the bottom of the hill. However, they will need to be spaced accordingly so that they do not interfere with existing telephone poles.

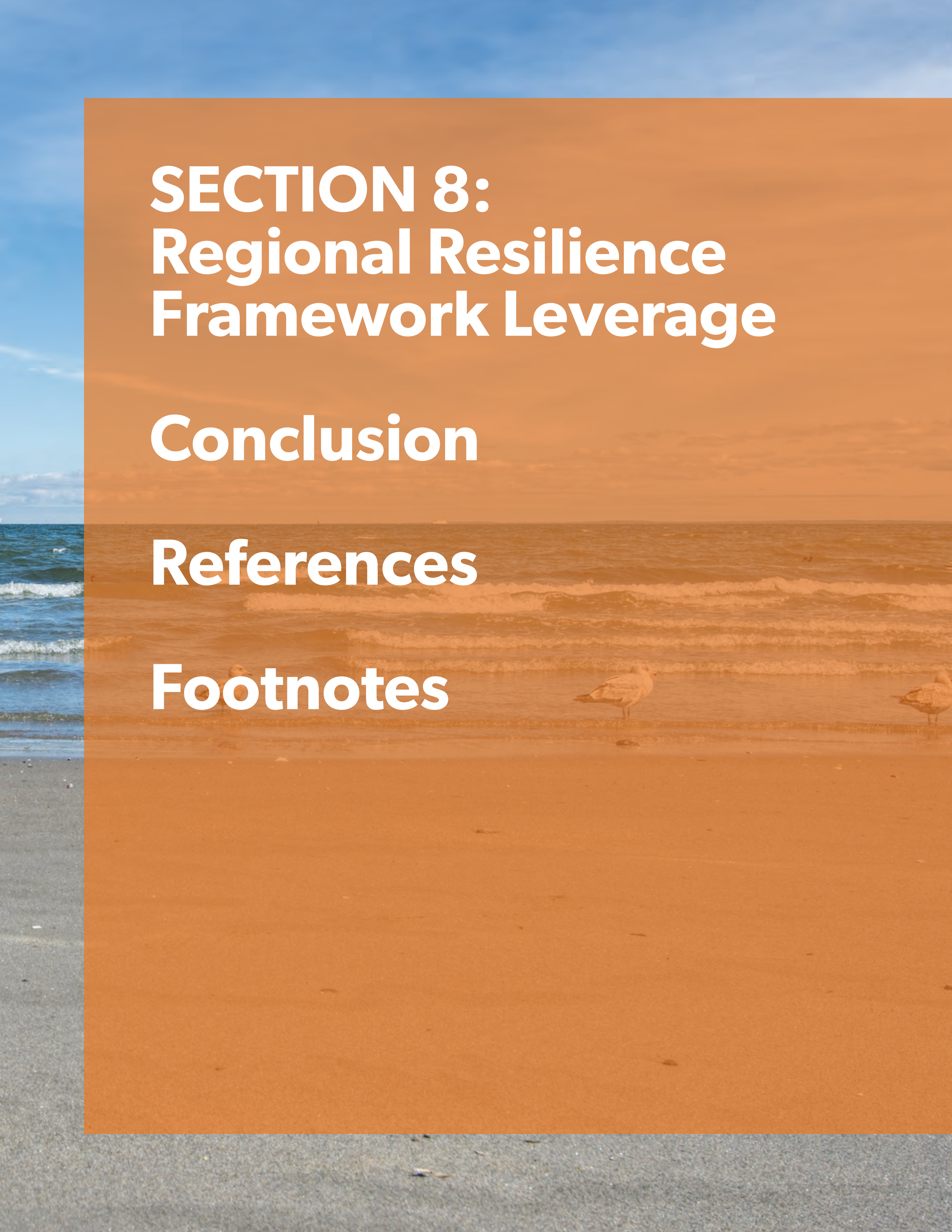
**ADDITIONAL CONSIDERATIONS**

Green infrastructure along residential streets can reduce the impacts of stormwater on private properties and inspire residents to implement additional strategies within their yards. Furthermore, it can help improve property value and add to the aesthetics of a neighborhood.




Plan view of Reynolds Street with Green Infrastructure Interventions.


PHOTO CREDIT: Susan Rubinsky



# SECTION 8: Regional Resilience Framework Leverage

# Conclusion

# References

# Footnotes

# Regional Resilience Framework Leverage

## 2015-2017

In 2015, The Nature Conservancy's Connecticut Chapter received funding from The Community Foundation of Eastern Connecticut to continue resilience work in southeastern Connecticut. This investment allowed TNC to capitalize on a decade of community resilience building efforts working to conserve ecosystems and protect people and property in cities, towns, and villages across Connecticut from extreme weather and a changing climate. In early 2016, TNC enlisted the support of SCCOG and seCTer. This Core Team subsequently formed the backbone of a regional resilience visioning process. After a series of intensive, information-gathering interviews with municipal staff, the Core Team gathered a larger planning team comprised of land use and economic development planners to help further define what they hoped to gain from a regional resilience visioning exercise. Current concerns, knowledge gaps, and who they wanted to include in the larger resilience dialogue were identified. The nine municipalities engaged included East Lyme, Groton (City and Town), Montville, New London, Norwich, Ledyard, Salem, Stonington, and Waterford. These initial meetings created common understanding of current and future risks alongside high priority challenges and potential solutions for each of the municipalities. This information served as the bedrock upon which the subsequent community resilience building efforts were structured.

The planning team and Core Team eventually landed on six planning sectors of concern that came up regularly in conversation including water, food, ecosystem services, transportation, energy, and the regional economy. These planning sectors provided the framework for the regional resilience workshops that followed. These workshops were followed by further engagement with the planning team to further refine the solutions and foster collaborative ownership going forward.

## 2017-2019

The Nature Conservancy's initial engagements and the visioning workshops helped the Core Team to expand relationships and solidify trust in the region. The Regional Resilience Working Group is an excellent example of how the past workshops have laid the groundwork for committed individuals to carry the conversation forward. The Working Group brought together economic development professionals, environmental professionals, and an emergency manager who had not worked together before. While selecting meeting topics, the team regularly consults the findings from the visioning workshop and CEDS for a more complete picture of regional concerns and aspirations.

Through the visioning effort, the Core Team also formed relationships with municipal officials that have aided in the creation of the project database. Representatives from each municipality had an opportunity to review project lists before and after site visits.

Finally, the 2015-2017 engagement efforts opened the door for collaborative project design. These projects include the Lake George Washington Park Wetland Enhancement, the Esker Point Parking Lot Retrofit, and the Village of Mystic Resilience Planning.

## 2019-beyond

Many exciting coastal development and adaptation projects are well underway across this southeastern Connecticut region. In addition to resilience and adaptation plans developed in Stonington, Groton, and Waterford, several coastal development projects provide an opportunity for TNC to assist with living shoreline, green stormwater infrastructure, and environmental restoration components. These include the Mago Point redevelopment in Waterford, Fort Trumbull redevelopment in New London, Poquonnock Bridge redevelopment in Groton, and the Seaport Marina in Mystic. Having put in the time to form strong relationships in these communities, the Core Team is poised to assist with the natural infrastructure aspect of these high-profile projects. Such a project would signal a meaningful commitment to resilience in the region and elevate climate adaptation among Connecticut's development community.

## Statewide Leverage

The work TNC's Community Resilience Building Program has pursued in southeastern Connecticut with this Regional Resilience Framework has already increased the impact and profile of resilience work across the state. With the completion of the Southeastern Connecticut Resilience Project Catalog, the Connecticut Resilience Project Catalog now spans 85% of the state's coastline and a number of inland communities. This geospatial database, hosted on a public-facing website (www.CoastalResilience.org), allows broad access to foster multi-jurisdictional and cross-organizational collaboration.

Furthermore, the three Regional Resilience Frameworks created by TNC and many partners (Southeastern, Southern, Southwestern) are not only the first in Connecticut but also among the few examples nationally of multi-municipalities planning together to increase the effectiveness and efficiency of actions to reduce risk and improve resilience to extreme weather and climate change.

## Conclusion

Southeastern Connecticut is a collection of communities each with its own individual identity and history. However, the fate of each community is closely tied to the social, environmental, and economic health of the whole region. Therefore, the challenges facing southeastern Connecticut are best tackled collectively with multiple towns, organizations, associations, institutions, foundations, neighborhoods, and businesses working together. Our sincere hope is that the projects database, Regional Resilience Working Group, conceptual designs, and Final Report can help communities build greater clarity on the common challenges they face while providing a positive vision for continued dialogue, resource sharing, and forward-thinking leadership needed for community resilience building here in Connecticut and beyond.

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# Footnotes

## Executive Summary

1 - White and Whelchel 2017a., 2017b.
2 - Whelchel et al. 2017a., 2017b.

## Section 1

3 - Whelchel et al., 2017a.
4 - Whelchel et al., 2017b.

## Section 2

5 - Johnson, 2009
6 - CT DEEP
7 - Johnson, 2009
8 - Stone et. al., 2005
9 - Lewis, 1997
10 - Rozsa, 1995
11 - Ryan and Whelchel, 2014, 2015a., 2015b., 2015c.
12 - Hoover and Whelchel, 2015
13 - Pardo and Whelchel, 2013a., 2013b.
14 - Rozsa, 1995
15 - Rozsa, 1995
16 - Johnson, 2009
17 - Johnson, 2009
18 - Johnson, 2009
19 - United States Army Corps of Engineers, 2015

## Section 4

20 - Whelchel et al., 2017a., 2017b.
21 - Titus, 2011
22 - Whelchel et al., 2015

## Appendix A

23 - White and Whelchel, 2017c.
24 - Whelchel and Ryan, 2015

PHOTO CREDIT: iStockPhoto

# APPENDICES

PHOTO CREDIT: Susan Rubinsky

# APPENDIX A: Document Review and Initial Scoping Meetings

This appendix contains the background document review, research, and record of meetings that generated the majority of the information presented in this report. In addition to the initial scoping meetings presented herein, TNC Core Team participated in stakeholder communications (e.g. emails, phone calls, in-person site visits, local and regional visioning exercises, etc.) that surfaced additional projects and project details that are integrated into the Regional Resilience Project Catalog in the main body of this report. The following information is categorized by municipality.

# Project Scoping Process

All projects selected for the resilience projects database were shared for feedback at least twice during the project. After reviewing local plans, the Core Team developed a preliminary list of candidate projects and shared them with local officials in the municipal planning departments who shared these lists with their colleagues in engineering, public works, or other departments. Once the Core Team secured the municipality's go-ahead on the list, the project coordinator scheduled a site visit and invited the municipal official and any other local stakeholders. The descriptions of these meetings are below. After the site visits, the Core Team drafted project descriptions for each site. These descriptions combined the base information collected from the planning documents, as well as additional facts relayed by the municipal officials, and the Core Team site observations. Opportunities to incorporate natural infrastructure into the project were noted. Once the Core Team completed the draft descriptions, the project coordinator shared them with the municipal partners and stakeholder for additional feedback.

## Review of Existing Reports, Studies, Plans, and Assessments

The resources listed below were reviewed to compile an initial list of potential or existing resilience projects.

### Watershed Management Plans:

- Baker Cove Track Down Survey and Abbreviated Watershed-Based Plan (2011)
- Flat Brook Abbreviated Watershed-Based Plan (2013)
- Niantic River Resilience Vision: Natural Solutions for Community Resilience Building in the Lower Niantic Watershed (2017)[23]

### Environmental Studies, Reports and Asssements:

- RMC Restoration Workplan – Long Island Sound Study (2017)
- Tidal Wetlands Habitat Restoration Workplan – Long Island Sound Study (2017)

### Natural Hazard Mitigation Plans:

- Eastern Connecticut Risk and Vulnerability Assessment Workshop (2012)
- Hazard Mitigaton Plan Annex for the Town of Groton - SCCOG (2005)
- Southeastern Connecticut Multi-Jurisdictional Natural Hazard Mitigation Plan – SCCOG (2017)
- Southeastern Connecticut Multi-Jurisdictional Natural Hazard Mitigation Plan Update – SCCOG (2012)

### Plan of Conservation and Development (POCD):

- Town of East Lyme Plan of Conservation and Development (2012)
- Town of Waterford Plan of Conservation and Development (2012; 2015 supplement)
- City of New London Plan of Conservation and Development (2017)
- City of Groton Plan of Conservation and Development (2008)
- Town of Groton Plan of Conservation and Development (2016)
- Town of Stonington Plan of Conservation and Development (2014)
- Town of Salem Plan of Conservation and Development (2012)
- Town of Montville Plan of Conservation and Development (2010)
- City of Norwich Plan of Conservation and Development (2013)
- Town of Ledyard Plan of Conservation and Development (2003)

### Other Municipal Plans:

- Town of Stonington Coastal Resilience Plan (2017)
- Town of Waterford Climate Change Vulnerability, Risk Assessment, and Adaptation Study (2017)
- Preparing for Climate Change in Groton, Connecticut: A Model Process for Communities in the Northeast (2011)
- City of Norwich Waterfront Vision (2011)
- Waterford Community Resilience Building Summary of Findings (2014)[24]
- New London Community Resilience Building Summary of Findings (2018)
- City of Groton Community Resilience Building Summary of Findings (2019)
- Adapting to Coastal Storms and Flooding: Report on a 2014 Survey of Waterford Residents

# Site Visit Meeting Memos

## Norwich Site Visits

| | | |
|---|---|---|
| **DATE:** | **January 24, 2018** | **ATTENDEES:**<br>**Cary White, TNC**<br>**Patrick McLauglin, Norwich City Engineer** |
| **PROJECT:** | **Regional Framework for Coastal Resilience in Southeastern Connecticut** | |
| **SUBJECT:** | **Norwich Coordination** | |
| **LOCATION:** | **Upper Falls Dam** | |

Cary White and Norwich City Engineer, Patrick McLauglin, met on January 24th, 2018 at the Upper Falls Dam to discuss projects appearing in the recently updated Hazard Mitigation Plan. These projects included the Upper Falls Dam, improvements to the Sherman Street Bridge, and the expansion of the Heritage Trail in the floodplain. The initial interest for removing the Upper Falls Dam arose while planning to elevate the upstream Sherman Street Bridge. The aim was to lower the water levels to allow easier access during construction. While funders supported the overall bridge reconstruction, they did not allocate monies for the dam removal. The dam sits just upstream from the Indian Leap Falls and therefore its removal would likely not have significant fish passage benefits. Likewise, the Sherman Street Bridge project presents little opportunity for green infrastructure as the footings sit directly on ledge and do not face erosion challenges. Patrick also alerted Cary to a water quality and erosion control project planned for the parking lot immediately North of Viaduct Road.

## City of Groton Site Visits

| | | |
|---|---|---|
| **DATE:** | **January 31, 2018** | **ATTENDEES:**<br>**Cary White, TNC**<br>**Tim Umrysz, City of Groton Director of Public Works** |
| **PROJECT:** | **Regional Framework for Coastal Resilience in Southeastern Connecticut** | |
| **SUBJECT:** | **City of Groton Coordination** | |
| **LOCATION:** | **Various** | |

Cary White and City of Groton Engineer, Tim Umrysz, met on January 31st, 2018 near Shenecossett Beach to discuss projects appearing in the recently updated Hazard Mitigation Plan. These projects included, improving drainage of the Duck Ponds near Shenecossett Beach, elevating Shenecossett Road East of Avery Point, and improving drainage near Bayberry Lane. Tim explained to Cary how the Duck Pond immediately north of Avery Point did not drain properly and could flood that section of Shenecossett Road. The poor drainage was likely due to sediment build up in the culvert that runs under Shenecossett Road. At this point, both Cary and Tim were unclear whether the sediment came from the upstream wetland and Duck Ponds or from marine sources.

Tim alerted Cary to a funded seawall repair project he is working on across Shore Avenue from the golf course. Erosion around the wall base presented the main challenge to the wall's future resilience. The beach below the wall is narrow and likely faces permanent inundation from sea level rise this century. Cary suggested planting beach grass or building out a restored salt marsh as a temporary stopgap to future erosion challenges.

Tim next brought Cary to a past channel and culvert reconstruction project on Pine Island Road. Tim believed that this was what the Bayberry Lane project referred to in the Hazard Mitigation Plan. Tim continues to be concerned about this area, and in particular regarding the culvert collapsing. He pointed out a private fill property adjacent to the tidal creek that is currently used for boat storage. He believes that regrading the fill to the level of the creek would increase water storage and reduce strain on the culvert.

Finally, Tim brought Cary to Washington Park to show him a project that appeared in the Baker Cove Watershed Management Plan. The City previously levelled a low spot in the park to create a seasonal skating rink. Public Works cut linear channels in the wetland to help maintain proper water levels. However, due to generally warm winters, the wetland rarely freezes over for skating. Additionally, the eroding banks of the channels are clogging downstream pipes. Cary and Tim discussed options for slowing down water through the wetland and replanting steep banks as a means of reducing erosion and downstream sedimentation.

## Stonington Borough Site Visits

| | | |
|---|---|---|
| **DATE:** | **February 14, 2018** | **ATTENDEES:**<br>**Cary White, TNC**<br>**Jeff Callahan, Stonington Borough Warden** |
| **PROJECT:** | **Regional Framework for Coastal Resilience in Southeastern Connecticut** | |
| **SUBJECT:** | **Stonington Borough Coordination** | |
| **LOCATION:** | **Various** | |

Cary White and Stonington Borough Warden, Jeff Callahan, met on February 14th, 2018 at the Wadawanuck Club to discussed proposed projects appearing in the recently completed Town of Stonington Coastal Resilience Plan. Cary was interested in learning more about a multi-part recommendation to raise the rail line north of Stonington Harbor and construct living shoreline-reinforced levees where the rail bed tied into the coastline. Jeff expressed concern regarding this proposal. While raising the rail line would protect the neighborhoods to the north in Lamberts and Quanaduck Cove, the plan did not examine if the altered hydrology would increase flooding south of the levee in the Borough.

Jeff then directed Cary an ongoing project to restore the jetty protecting Stonington Harbor. Superstorm Sandy heavily damaged the jetty, and, given the number of businesses, public space, and fishing vessels housed behind the wall, Borough officials helped secured funds for its repair. The jetty itself is very old and the Borough wishes to restore it as closely as possible to its historic design.

Lastly, Jeff brought Cary to the Dodge Paddock and Beal Preserve. He mentioned some of the issues that Avalonia Land Trust has faced with drainage and invasive plants on the site. He suggested Cary reach out to the Land Trust directly for further information.

## Town of Waterford Discussion

| | | |
|---|---|---|
| **DATE:** | **March 5, 2018** | **ATTENDEES:**<br>**Cary White, TNC**<br>**Abby Piersall, Town of Waterford Director of Planning**<br>**Maureen Fitzgerald, Environmental Planner** |
| **PROJECT:** | **Regional Framework for Coastal Resilience in Southeastern Connecticut** | |
| **SUBJECT:** | **Waterford Coordination** | |
| **LOCATION:** | **By phone** | |

Cary White spoke with Waterford Director of Planning, Abby Piersall, by phone on March 5, 2018 regarding projects included in the Town's recent Hazard Mitigation Plan and its Climate Vulnerability, Risk Assessment and Adaptation Study. Cary alerted Abby that he would be visiting several pump stations in the town, and she relayed the message to Waterford's Public Works Director. Abby expressed concern that projects included in the resilience projects database may give viewers the idea that all projects were approved by the Towns. In particular, the recommendations from the Climate Adaption Study have not been approved by Waterford, and she urged that all relevant project descriptions reflect this.

On April 18th, after reviewing the draft project descriptions, Abby and Maureen Fitzgerald, called Cary to ask that the descriptions not be included in the final database. Abby and Maureen reiterated their concern that the Town had not endorsed the recommendations from the Study. Instead, the three agreed to provide a single data point in the town that referenced the full study.

## Town of East Lyme Site Visits

| | | |
|---|---|---|
| **DATE:** | **March 9, 2018** | **ATTENDEES:**<br>**Cary White, TNC**<br>**Gary Goeschel, Town of East Lyme Director of Planning** |
| **PROJECT:** | **Regional Framework for Coastal Resilience in Southeastern Connecticut** | |
| **SUBJECT:** | **East Lyme Coordination** | |
| **LOCATION:** | **Various** | |

Cary White and East Lyme Director of Planning, Gary Goeschel, met on March 9th, 2018 to discuss projects identified in the Town's recently updated Hazard Mitigation Plan. These projects included pursuing home elevations on Atlantic Street and removing a small dam south of Rt. 1 on Latimer Brook, said to be causing flooding on the road. Gary first showed Cary a recently completed culvert, draining the wetland north of Atlantic Street out on to the beach. He expressed concern that the elevation of the outfall might render the culvert useless as sea levels continue to rise. Gary explained that the Atlantic Street homes in between McCooks Park and Crescent Beach were highly vulnerable to coastal storms. While a few homeowners had elevated their houses, others seemed slow to follow and none sounded amenable to a buyout at this time. Gary also brought up a climate vulnerability study the Town is currently working on. Part of the hope, Gary explained, was that more accurate sea level rise projections may allow the Town to amend its freeboard requirements and give additional leverage when engaging with home-owners about elevations.

Next Cary and Gary went to the Latimer Brook dam, which Gary did not think was causing flooding on the road. Instead, Gary brought Cary to Darrow Pond where a road bed crosses the outlet and forms a dam. Gary explained that the Town engineers and DEEP had expressed concern over the structural integrity of the dam, classifying it as High Hazard. A dam failure would likely flood downstream homes as well as a stretch of 161.

## Dodge Paddock and Beal Preserve Site Visit

| | | |
|---|---|---|
| **DATE:** | **April 3, 2018** | **ATTENDEES:**<br>**Cary White, TNC**<br>**Victoria Hoyland, TNC**<br>**Beth Sullivan, Avalonia Land Conservancy**<br>**Juliana Barrett, CT Sea Grant** |
| **PROJECT:** | **Regional Framework for Coastal Resilience in Southeastern Connecticut** | |
| **SUBJECT:** | **Dodge Paddock and Beal Preserve Site Visit** | |
| **LOCATION:** | **Stonington Borough** | |

Cary White and Victoria Hoyland met Beth Sullivan (Avalonia Land Conservancy) and Juliana Barrett (CT Sea Grant) at the Dodge Paddock and Beal Preserve on April 3rd, 2018. Beth led the tour of the site and explained the project history. To reduce mosquito and phragmities populations on the parcel, ALC attempted to improve drainage and tidal exchange by way of a drain pipe on the eastern shore. Superstorm Sandy filled in this pipe and whipped up a gravelly dune, which prevented any drainage. DEEP excavated and created a drainage swale on the South side of the property first with a plastic liner and later with coir logs after the liner was undermined. Juliana has currently secured LISS funding to support a coastal engineer assessment of the site. This will inform future storm protection efforts to ensure drainage and potential marsh migration. Beth and Juliana also touched on the existing stone wall on the eastern shore. Removal of this could possibly provide alternative means of draining the site; however, as it is a historic structure, the land trust is not allowed to remove it.

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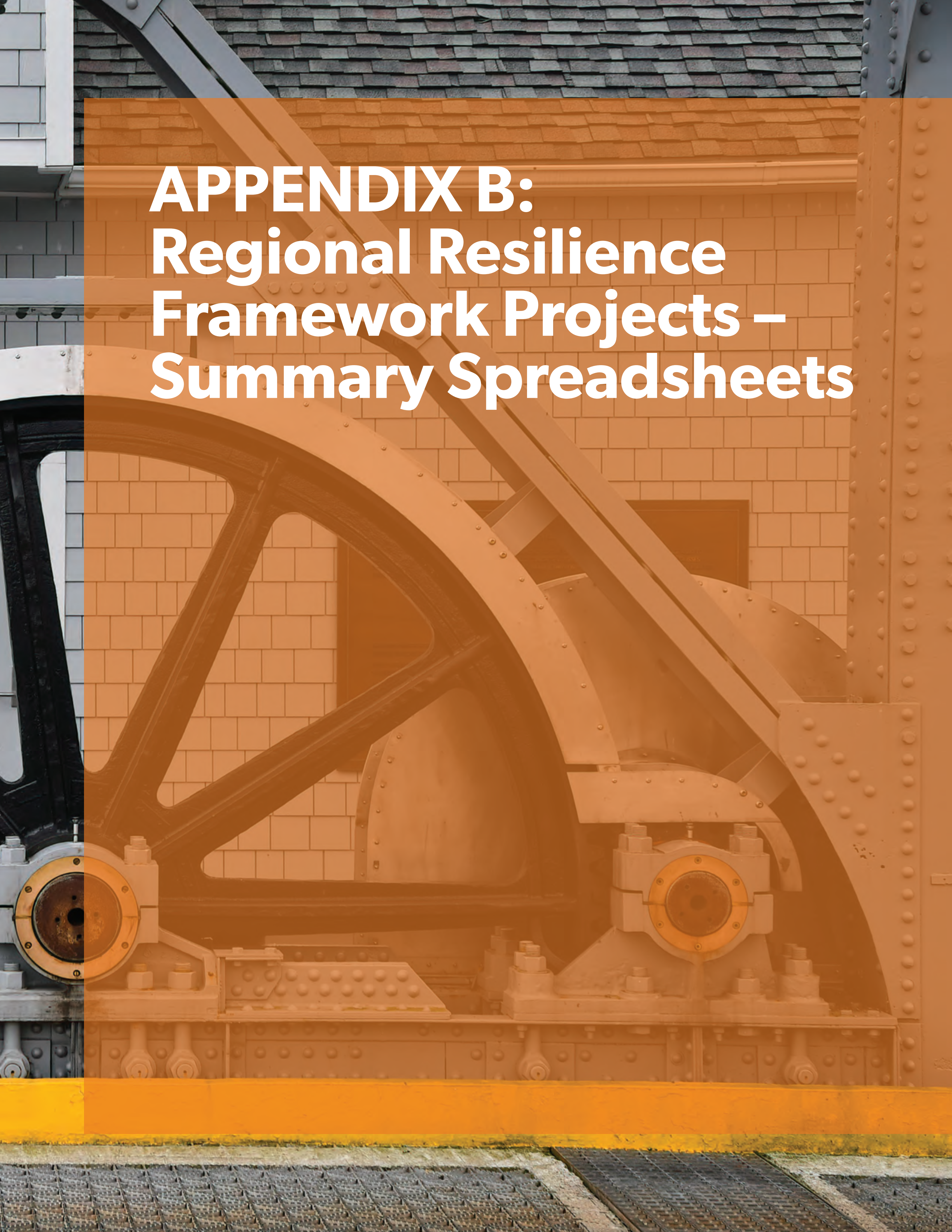


# APPENDIX B: Regional Resilience Framework Projects – Summary Spreadsheets

# GIS Database Development

After the initial go ahead from municipal officials, each project was entered through a customized form using ESRI's Survey123 app. This form collected site photos, descriptions, and additional field observations and contextual information. Once data entry was completed in Survey123, the Core Team exported the project database to ArcMap 10.3 and conducted an overlay analysis to append the following additional grant-pertinent information to the project entries: the Connecticut Department of Energy and Environmental Protection's Natural Diversity Areas, the Federal Emergency Management Agency's flood zone and base flood elevation, the United States Department of Housing and Urban Development's low-to-moderate income percentage (within block group), and the United States Geological Survey's watershed (HUC-12). The intent of including this information was to enhance project-screening for potential funding sources and facilitate inclusion of projects in grant applications.

# Municipal Summaries

## TYPE LEGEND

CNI - Coastal Natural Infrastructure
HI - Hard Infrastructure
INI - Inland Natural Infrastructure
O - Other
SI - Shoreline Infrastructure
SM - Stormwater Management

## STRATEGY LEGEND

B - Beach
Bu - Building
BP - Bank Protection
FPS - Flood Protection System
LS - Living Shoreline
R - Road
RG/B - Rain Garden/Bioswale
S - Seawall
SR - Sedimant Removal
SC - Stream Channel
SI - Stormwater Infrastructure
TG - Tide Gate
TM - Tidal Marsh
U - Undetermined

## ACTION LEGEND

A/D - Acquire/Demolish
C - Create
CF - Create Floodplain
E - Elevate
En - Enhance
E/M - Enchance/Modify
IC - Increase Capacity
M - Modify
N - Nourish (Managed)
NA - New Area
O - Other
R - Restore
R(D) - Restore (Direct repair)
RO - Remove Obstruction
RwO - Replace with Other
U - Undetermined

# EAST LYME

| East Lyme Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (") | LMI (%) | HUC12 |
| Atlantic St Residential Elevations - 28 | SI | B | M | Atlantic St | 2017 Hazard Mitigation Plan | Buildings | Public Access | Y | AE | 11 | 0.387 | Coastal drainages-Niantic River to Griswold Point |
| Darrow Pond Dam Removal - 29 | HI | R | U | Mostowy Rd | 2017 Hazard Mitigation Plan | Roads | Private Property | N | 0.2 PCT ANNUAL CHANCE FLOOD HAZARD | -9999 | 0.1627 | Niantic River |

# NEW LONDON

| New London Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (") | LMI (%) | HUC12 |
| Fort Trumbull Wastewater treatment plant - 26 | HI | U | U | Smith St | 2017 Hazard Mitigation Plan | Critical Facility | Town Property | N | X | -9999 | 0.358 | Thames River-Frontal New London Harbor |
| Fort Trumbull Development Phase III Infrastructure Project - 27 | HI | B | NA | Smith St | 2017 Hazard Mitigation Plan | Buildings | N/A | N | X | -9999 | 0.358 | Thames River-Frontal New London Harbor |

# GROTON

| Groton Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (') | LMI (%) | HUC12 |
| High Rock Infiltration Swales - 17 | SM | RG/B | C | D, G, H Streets | Baker Cove Track Down Survey and Abbreviated Watershed-Based Plan | Ecosystems | N/A | N | AE | 11 | 0.0949 | Coastal drainages-Pawcatuck Point to Eastern Point |
| Washington Park/Lake George Stormwater retrofit - 18 | SM | SR | E | Washington Park | Baker Cove Track Down Survey and Abbreviated Watershed-Based Plan | Sewer System | Ecosystems | Y | X | -9999 | 0.2674 | Coastal drainages-Pawcatuck Point to Eastern Point |
| Shore Ave Drainage Improvements - 19 | SI | R | E/M | Shore Ave | 2012 Hazard Mitigation Plan | Roads | Private Property | Y | AE | 10 | 0.2552 | Thames River-Frontal New London Harbor |
| Shore Ave Seawall Repairs - 20 | SI | S | M | Shore Ave | Public Works | Roads | N/A | N | AE | 10 | 0.2552 | Thames River-Frontal New London Harbor |
| Mumford Cove tide Gate - 38 | HI | TG | C | Mumford Cove | 2017 Hazard Mitigation Plan | Buildings | Critical Facility | Y | N/A | N/A | 0.3231 | N/A |
| South Rd Underpass - 39 | HI | R | M | 165-257 South Rd | 2017 Hazard Mitigation Plan | Roads | N/A | Y | X | -9999 | 0.3712 | Poquonock River |
| Tower Ave Railroad crossing - 40 | SI | R | E/M | 60-58 Tower Ave | 2017 Hazard Mitigation Plan | Roads | Critical Facility | Y | AE | 9 | 0.0949 | Coastal drainages-Pawcatuck Point to Eastern Point |
| Groton Long Point Bridge - 41 | SI | R | E/M | Groton Long Point Rd | 2017 Hazard Mitigation Plan | Roads | N/A | Y | VE | 13 | 0.3231 | N/A |
| Fort Hill Neighborhood Redevelopment - 45 | HI | B | A/D | Midway Oval | 2017 Hazard Mitigation Plan | Buildings | Town Property | N | 0.2 PCT ANNUAL CHANCE FLOOD HAZARD | -9999 | 0.1984 | Coastal drainages-Pawcatuck Point to Eastern Point |

| Groton Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (") | LMI (%) | HUC12 |
| Bluff Point parking lot marsh restoration - 49 | CNI | TM | R | 100 Depot Rd | 2017b Tidal Wetlands Habitat Restoration Workplan | Ecosystems | N/A | Y | VE | 11 | 0.3231 | Poquonock River |

# STONINGTON

| Stonington Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (") | LMI (%) | HUC12 |
| Mystic Village Marsh Restoration - 21 | CNI | TM | A/D | Washington St | 2017 Stonington Resilience Plan | Ecosystems | Private Property | N | AE | 10 | 0.2298 | Mystic River |
| Mystic Green Infrastructure Corridor - 22 | SM | RG/B | E/M | E Main St | 2017 Stonington Resilience Plan | Buildings | Ecosystems | N | AE | 9 | 0.2298 | Coastal drainages-Pawcatuck Point to Eastern Point |
| Harbor Breakwater restoration - 23 | HI | S | R(D) | Water St | N/A | Buildings | Town Property | Y | VE | 15 | N/A | N/A |
| Stonington Borough Adaptation - 24 | HI | FPS | E/M | Water St | 2017 Stonington Resilience Plan | Roads | Private Property | Y | VE | 12 | 0.2414 | N/A |
| Mystic River Park Natural Buffer - 25 | CNI | LS | U | 28 Cottrell St | 2017 Stonington Resilience Plan | Ecosystems | Roads | Y | AE | 9 | 0.2298 | Mystic River |
| Pawcatuck River Hurricane Barrier - 33 | HI | FPS | C | 257 River Rd | 2017 Stonington Resilience Plan | Buildings | Roads | N | N/A | N/A | N/A | Lower Pawcatuck River |

| Stonington Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (") | LMI (%) | HUC12 |
| Bishops Cove Neighborhood Egress - 34 | HI | R | C | Canberra St | 2017 Hazard Mitigation Plan | Private Property | N/A | N | X | -9999 | 0.7233 | Coastal drainag-es-Pawca-tuck Point to Eastern Point |
| Masons Island Causeway Elevation - 35 | HI | R | E/M | Masons Island Rd | 2017 Stonington Resilience Plan | Roads | Ecosys-tems | Y | VE | 13 | 0.2674 | N/A |
| Donahue Park Conversion - 36 | CNI | LS | E/M | 17 Com-merce St | 2017 Stonington Resilience Plan | Public Access | Ecosys-tems | N | AE | 10 | 0.451 | Lower Pawcatuck River |
| Dodge Pad-dock and Beal Preserve - 42 | CNI | LS | E | 32 Wall St | N/A | Ecosys-tems | Build-ings | Y | VE | 13 | N/A | Coastal drainag-es-Pawca-tuck Point to Eastern Point |
| Mystic Railway Elevation and Tidal Control Measures - 50 | SI | FPS | M | Village of Mystic | 2017 Stonington Resilience Plan | Build-ings | Town Property | N | AE | 10 | 0.2298 | Coastal drainag-es-Pawca-tuck Point to Eastern Point |
| I-95 Tide Gate - 51 | HI | TG | M | I-95 | 2017 Stonington Resilience Plan | Private Property | Roads | Y | AE | 9 | 0.2298 | Mystic River |

# SALEM

| Salem Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (') | LMI (%) | HUC12 |
| Floodproofing Measures Behind Salem Four Corners Plaza - 5 | HI | B | U | 1 New London Rd | 2017 Hazard Mitigation Plan | Build-ings | Private Property | Y | AE | -9999 | 0.1301 | East Branch Eightmile River |
| Culvert Improvements Harris Brook at Rt 82 - 6 | HI | R | E/M | 38-52 E Haddam Rd | 2017 Hazard Mitigation Plan | Roads | Build-ings | Y | AE | -9999 | 0.1301 | East Branch Eightmile River |
| Bridge Improvements East Branch Eightmile at Rt 82 - 7 | HI | R | M | 301 E Haddam Rd | 2017 Hazard Mitigation Plan | Roads | Ecosys-tems | Y | AE | -9999 | 0.1301 | East Branch Eightmile River |
| Culvert Improvements Darling Rd and White Birch Rd - 8 | HI | R | M | 99 White Birch Rd | 2017 Hazard Mitigation Plan | Roads | Private Property | N | X | -9999 | 0.1301 | East Branch Eightmile River |
| Culvert Improvements Harris Brook at Rt 85 - 10 | HI | U | U | 9 Hart-ford Rd | 2017 Hazard Mitigation Plan | Roads | N/A | Y | AE | -9999 | 0.2 | East Branch Eightmile River |
| Culvert Improvements Witch Meadow Road at Big Brook - 12 | INI | R | E/M | 26-50 Witch Meadow Rd | 2017 Hazard Mitigation Plan | Roads | Public Access | N | X | -9999 | 0.1301 | East Branch Eightmile River |

# MONTVILLE

| Montville Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (") | LMI (%) | HUC12 |
| Culvert Replacements Old Colchester Rd at Fair Oaks - 9 | HI | SC | E/M | Fair Oaks Swamp | 2017 Hazard Mitigation Plan | Roads | Private Property | N | A | -9999 | 0.5714 | Stony Brook |
| Drainage Improvements Rt 32 at Jerome Ave - 11 | HI | N/A | U | Jerome Ave | 2017 Hazard Mitigation Plan | Roads | Buildings | N | X | -9999 | 0.1418 | Stony Brook |
| Bridge Replacement Pink Row at Oxoboxo Brook - 52 | HI | R | U | 12-42 Pink Row | 2012 Hazard Mitigation Plan | Roads | Buildings | N | 0.2 PCT ANNUAL CHANCE FLOOD HAZARD | -9999 | 0.1418 | Stony Brook |

# NORWICH

| Norwich Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (") | LMI (%) | HUC12 |
| Sherman Street bridge raising - 14 | HI | R | E/M | Yantic Swamp | 2017 Hazard Mitigation Plan | Roads | Private Property | N | AE | -9999 | 0.5108 | Yantic mainstem |
| Upper Falls Dam Removal - 15 | INI | SC | RO | Sherman St | 2017 Hazard Mitigation Plan | Ecosystems | Roads | N | AE | -9999 | 0.5108 | Yantic mainstem |
| Vianduct Parking Lot - 16 | SM | RG/B | E/M | Railroad Landing | N/A | Ecosystems | N/A | N | AE | -9999 | 0.7349 | Shetucket mainstem |

# LEDYARD

| Ledyard Summary | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | TYPE | STRATEGY | ACTION | ADDRESS | PLAN REFERENCE | RISK - PRIMARY | RISK - SECOND | NDDB | FLOOD ZONE | BASE FLOOD ELV (') | LMI (%) | HUC12 |
| Town Farm Road bridge improvements – 13 | HI | R | CF | 80-98 Town Farm Rd | 2017 Hazard Mitigation Plan | Roads | Public Access | N | AE | -9999 | 0.2669 | Mystic River |
| Baldwin Hill Rd Stream Channel Restoration – 53 | INI | SC | E | 1392-1398 Baldwin Hill Rd | Flat Brook Abbreviated Watershed-Based Plan | Roads | N/A | N | AE | -9999 | 0.295 | Thames River-Frontal New London Harbor |

PHOTO CREDIT: Susan Rubinsky

# APPENDIX C: Regional Resilience Framework Projects – Municipal-Based Maps

# REGIONAL RESILIENCE FRAMEWORK PROJECTS
## Municipal-Based Maps

The projects of greatest importance to each of the nine municipalities within the Southeastern Connecticut Regional Framework for Coastal Resilience service area (Map 1) are presented in the following municipal-based maps. The projects are spatially presented and organized by type (see Box 2 above for terminology definitions). For additional detail on each project please refer to Section 5, Appendix B as well as the Regional Resilience Project Application (see APPENDIX H for user guide) on Coastal Resilience (www.coastalresilience.org).

# East Lyme

29 Darrow Pond Dam Removal
28 Atlantic Street Residential Elevations

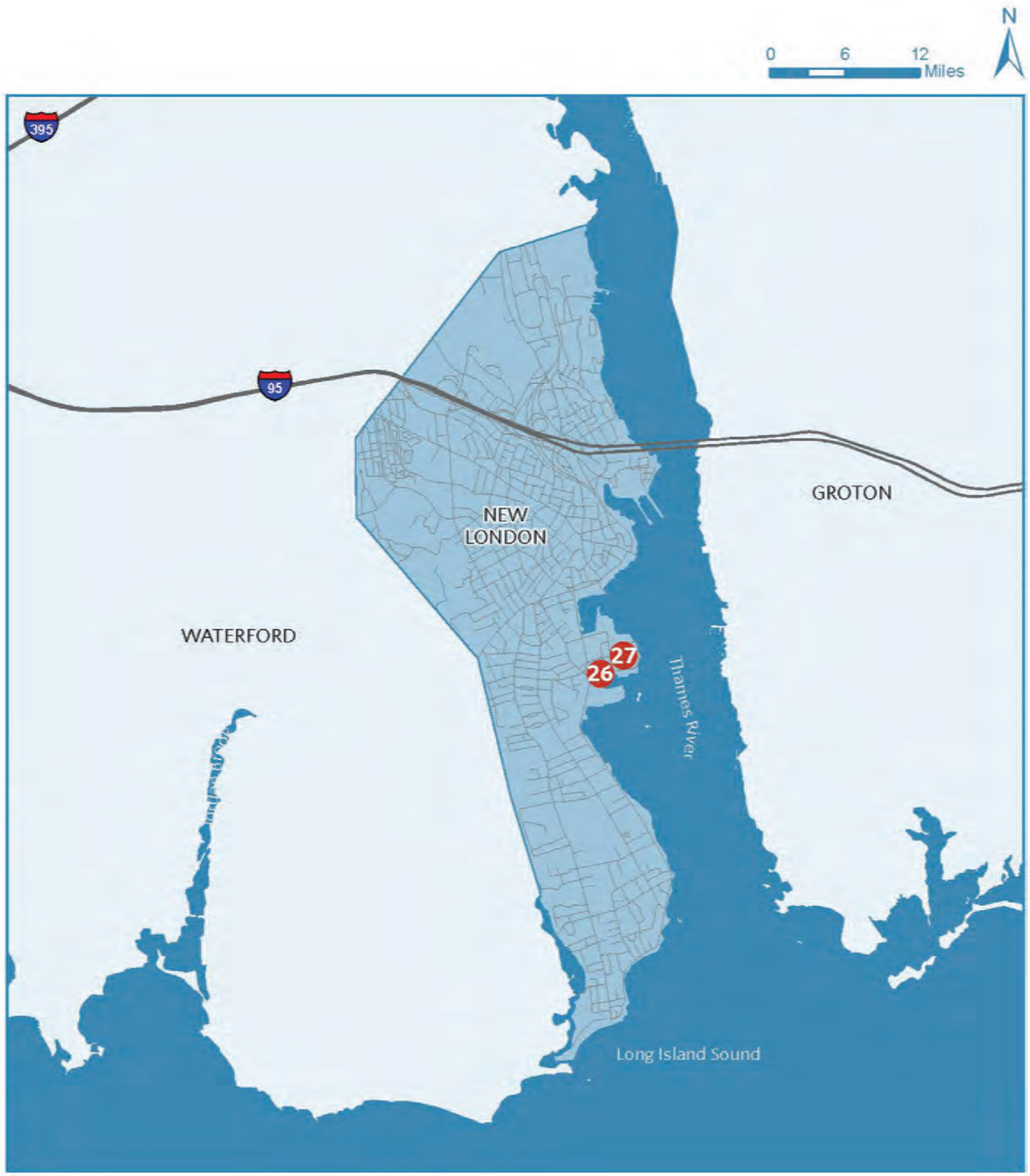

# Waterford

54 Waterford Climate Change Risk Vulnerability, Risk Assessment, and Adaptation Study


# New London

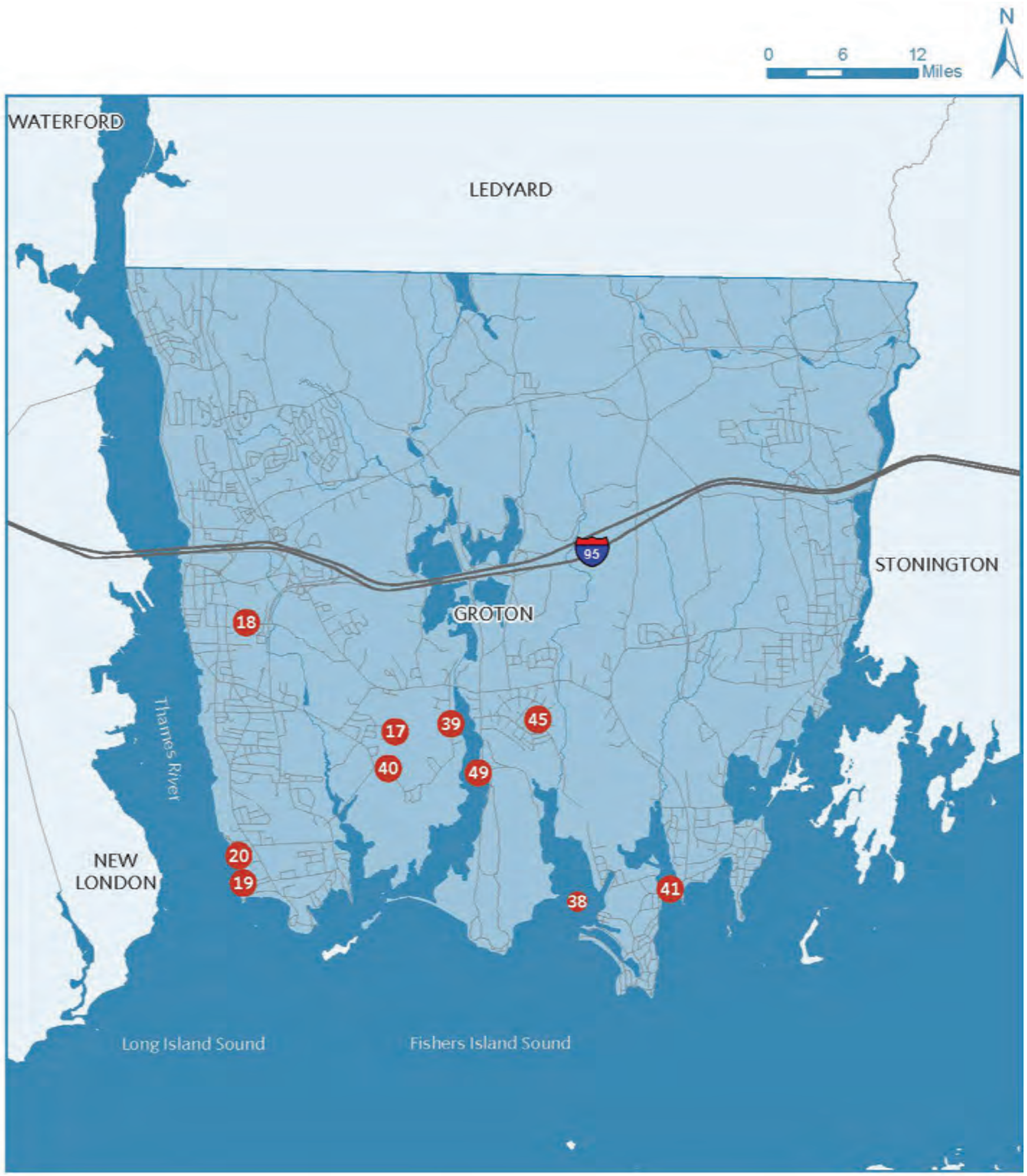
26 Fort Trumbull Wastewater treatment

27 Fort Trumbull Development Phase III



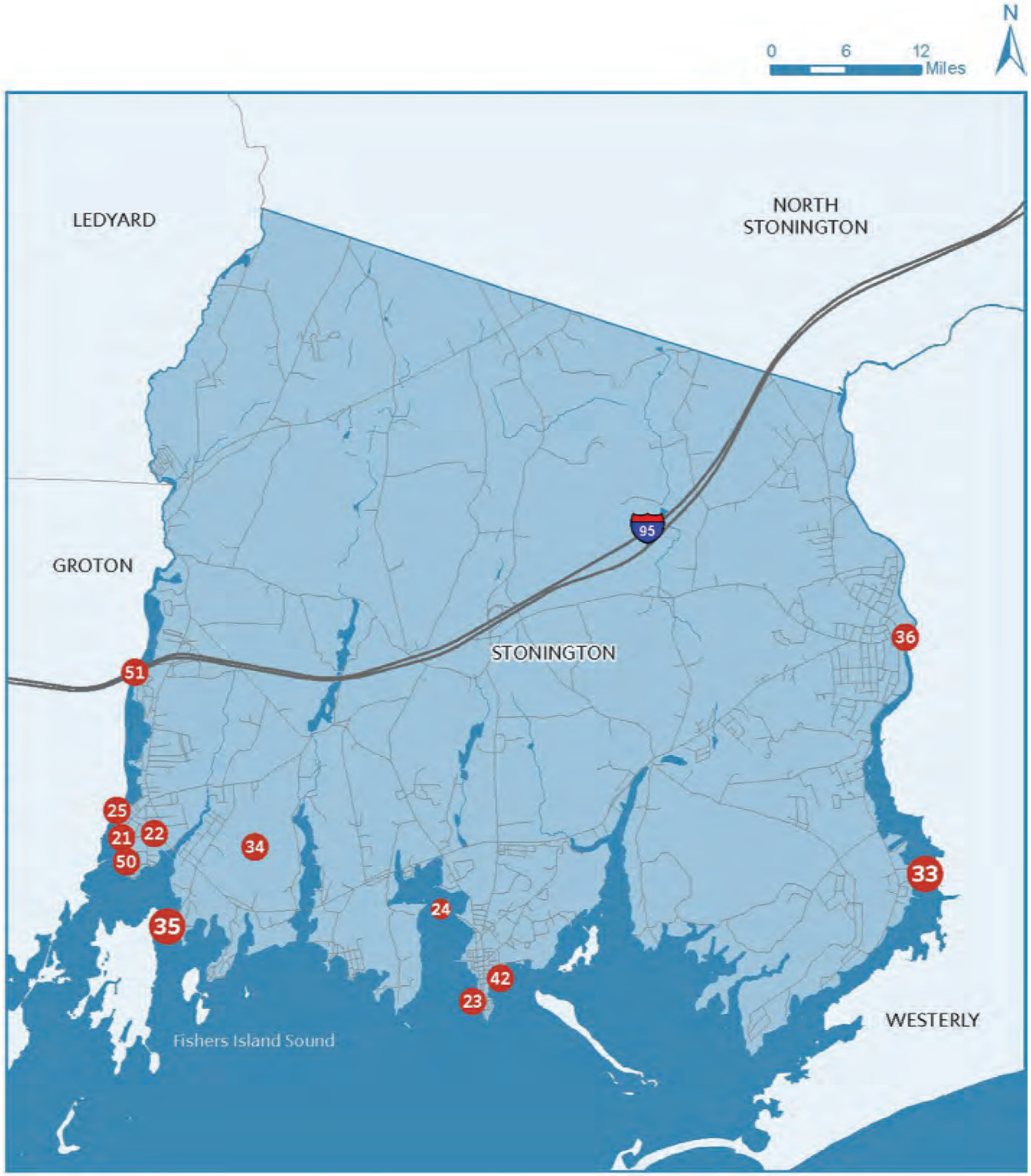

# Groton

- **18** Washington Park/Lake George Stormwater Retrofit
- **40** Tower Avenue Railroad Crossing
- **39** South Road Underpass
- **20** Shore Avenue Seawall Repairs
- **19** Shore Avenue Drainage Improvements
- **17** High Rock Infiltration Swales
- **41** Groton Long Point Bridge
- **45** Fort Hill Neighborhood Redevelopment
- **49** Bluff Point Parking Lot Marsh Restoration

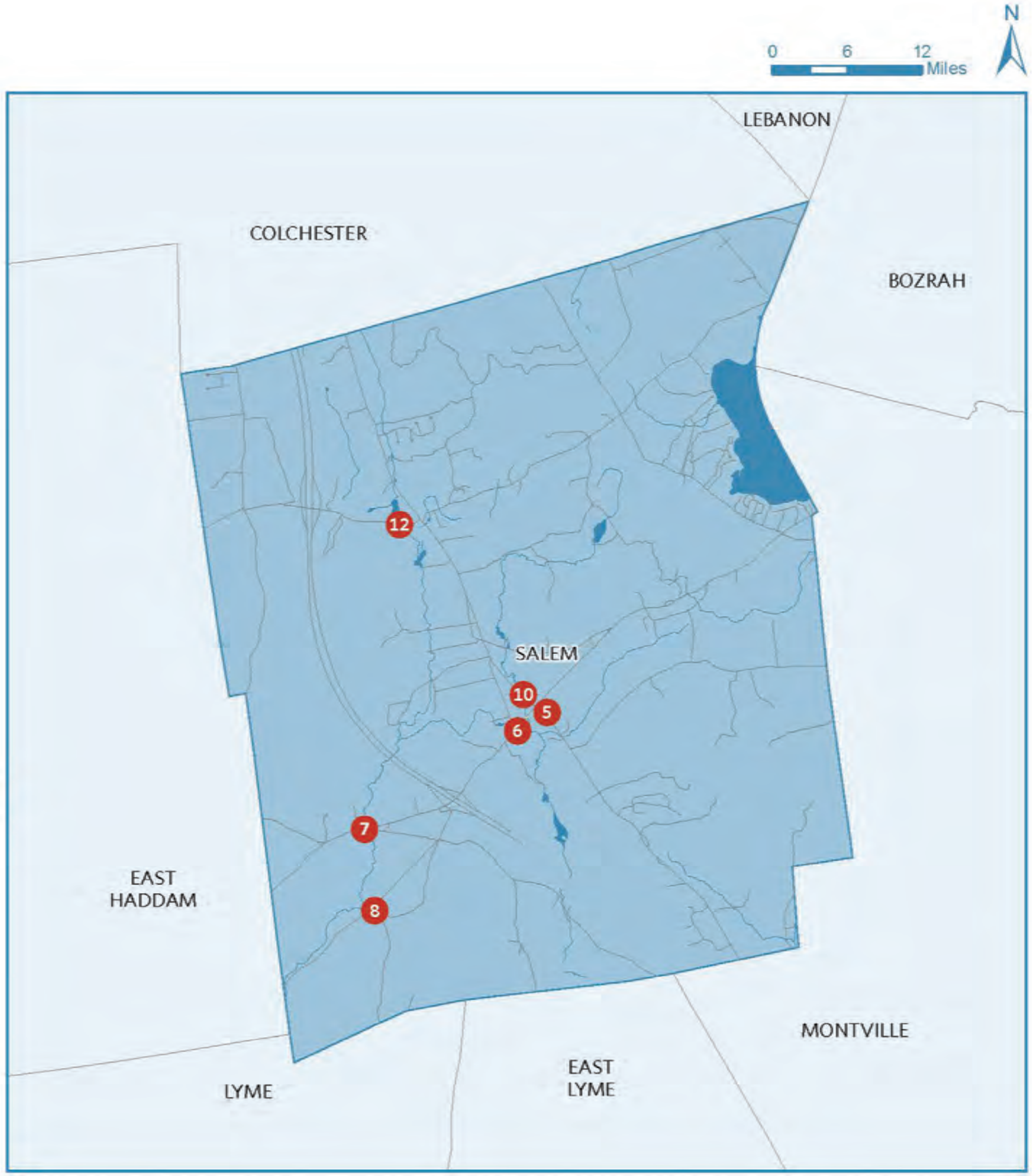
# Stonington

- 21 Mystic Village Marsh Restoration
- 25 Mystic River Park Natural Buffer
- 50 Mystic Railway Elevation and Tidal Control Measures
- 22 Mystic Green Infrastructure Corridor
- 51 I-95 Tide Gate
- 23 Harbor Breakwater Restoration
- 36 Donahue Park Conversion
- 42 Dodge Paddock and Beal Preserve
- 34 Bishops Cove Neighborhood Egress
- 35 Mason's Island Causeway Elevation
- 33 Pawcatuck River Hurricane Barrier

# Salem

- 5 Floodproofing Measures Behind Salem Four Corners
- 12 Culvert Improvements Witch Meadow Road at Big Brook
- 10 Culvert Improvements Harris Brook at Route 85
- 6 Culvert Improvements Harris Brook at Route 82
- 8 Culvert Improvements Darling Road and White Birch Road
- 7 Bridge Improvements East Branch Eightmile at Route 82

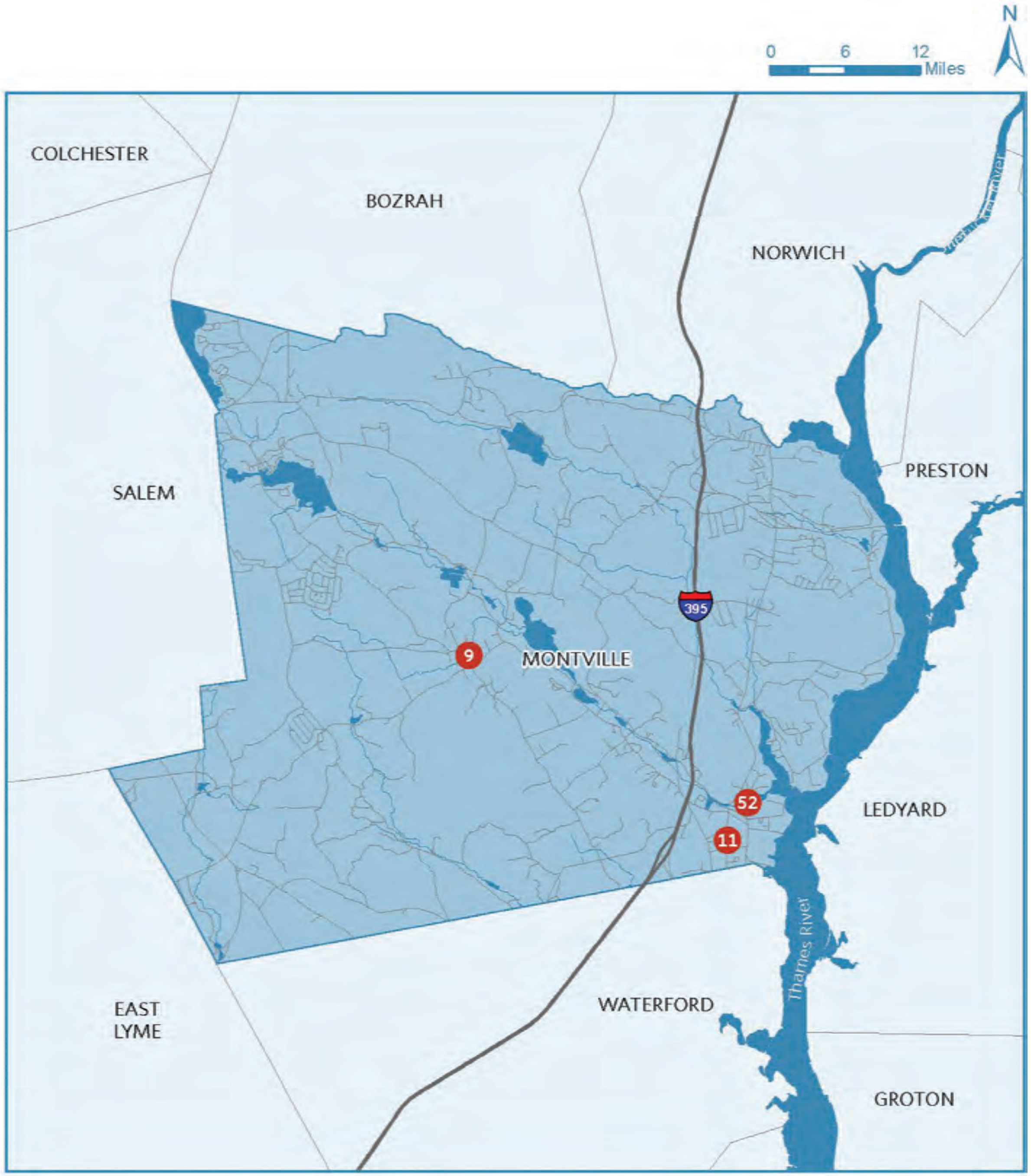



# Montville

11 Drainage Improvements Route 32 at Jerome Avenue

9 Culvert Replacements Old Colchester Road at Fair Oaks

52 Bridge Replacement Pink Row at Oxoboxo Brook

# Norwich

- 16 Vianduct Parking Lot
- 15 Upper Falls Dam Removal
- 14 Sherman Street Bridge Raising


# Ledyard

- 13 Town Farm Road Bridge Improvements
- 53 Baldwin Hill Rd Stream Channel Restoration

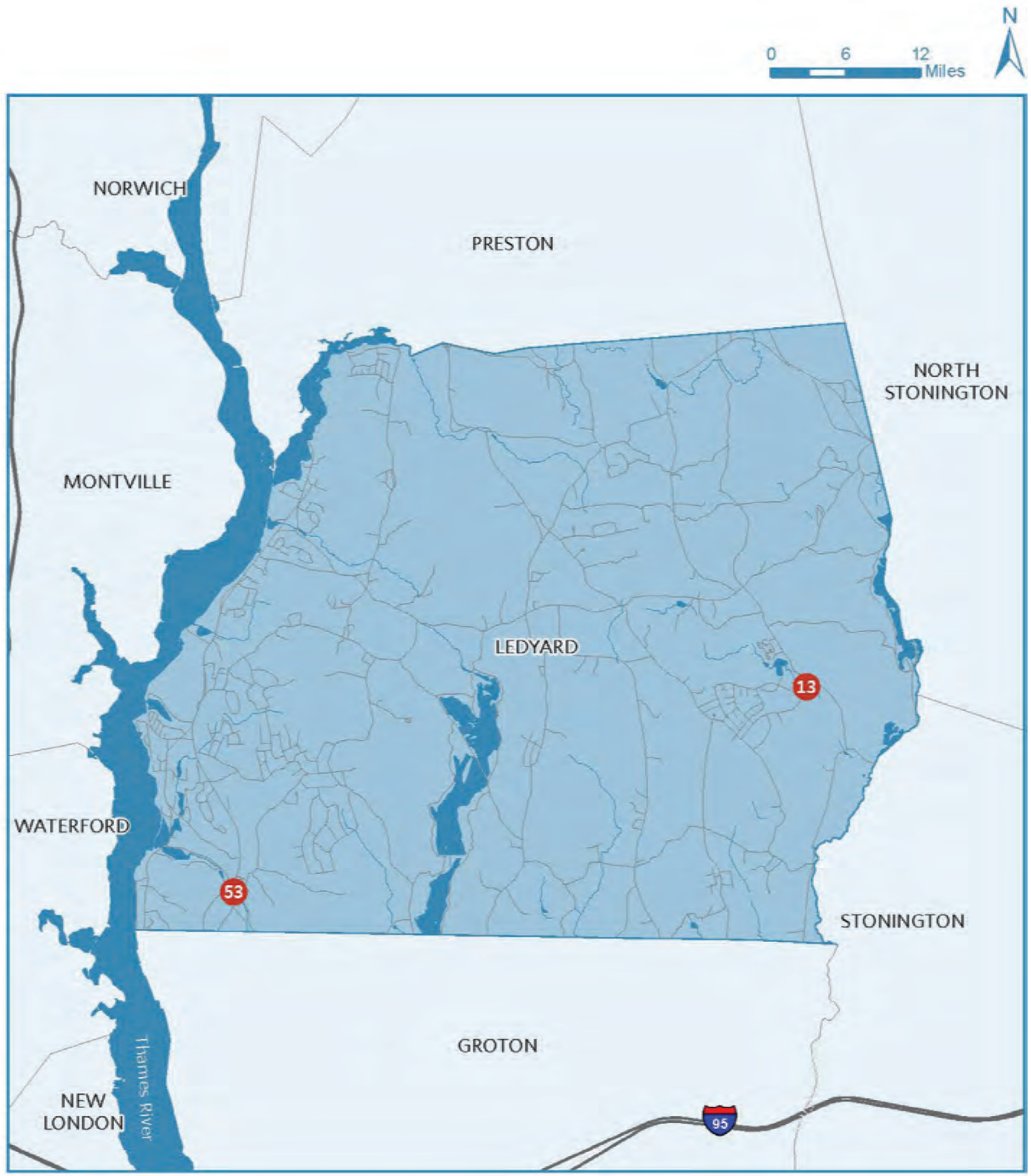


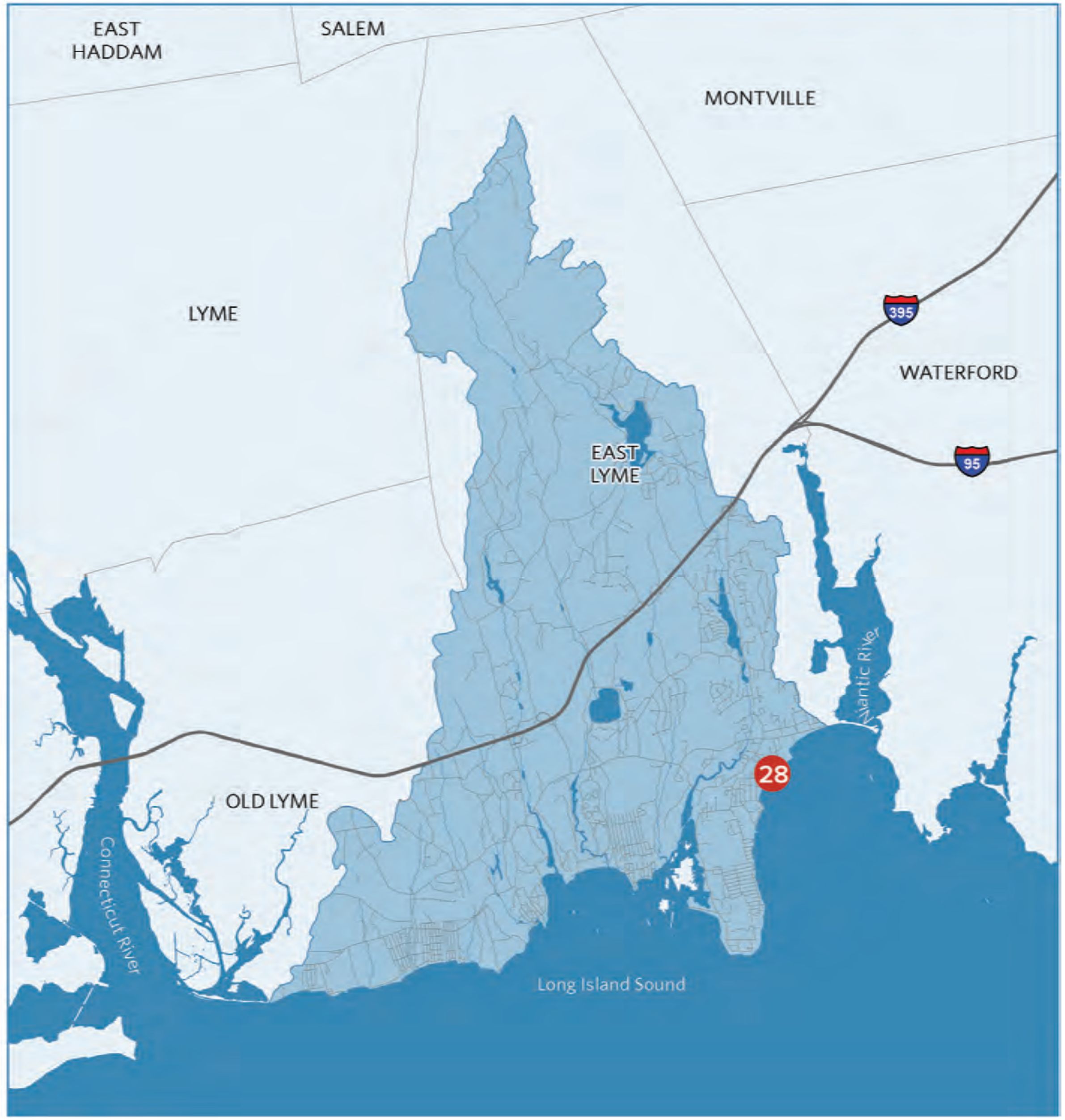

PHOTO CREDIT: Susan Rubinsky

# APPENDIX D: Regional Resilience Framework Projects – Watershed-based Maps

# REGIONAL RESILIENCE FRAMEWORK PROJECTS
## Watershed-Based Maps

The projects of greatest importance across a suite of individual watershed within the Southeastern Connecticut Regional Framework for Coastal Resilience service area (Map 2) are presented in the following watershed-based maps. The projects are spatially presented and organized by type (see Box 2 above for terminology definitions). For additional detail on each project please refer to Section 5, Appendix B as well as the Regional Resilience Project Application (see Appendix H for user guide)  on Coastal Resilience (www.coastalresilience.org).

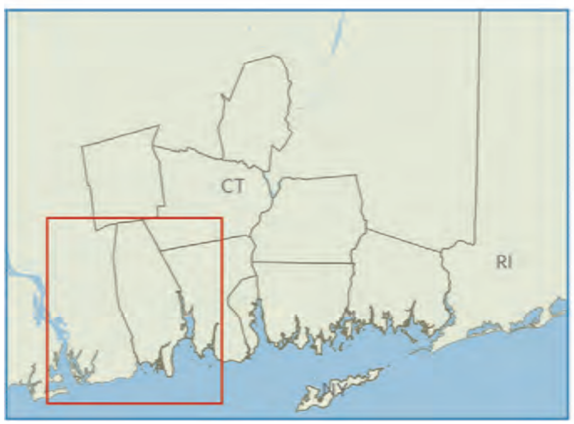
# Coastal drainages-Niantic River to Griswold Point




0 6 12 Miles

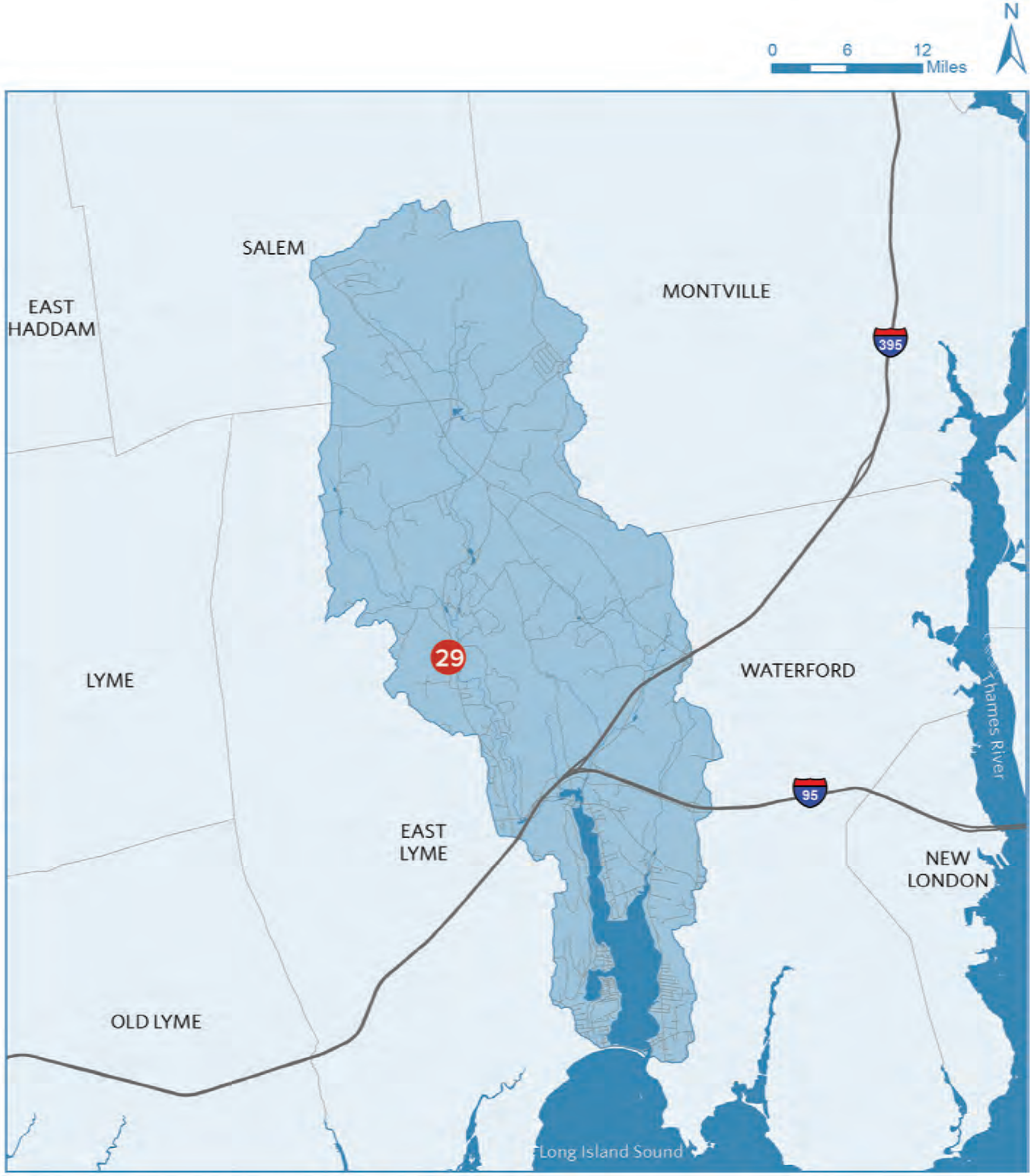
N

28 Atlantic Street Residential Elevations



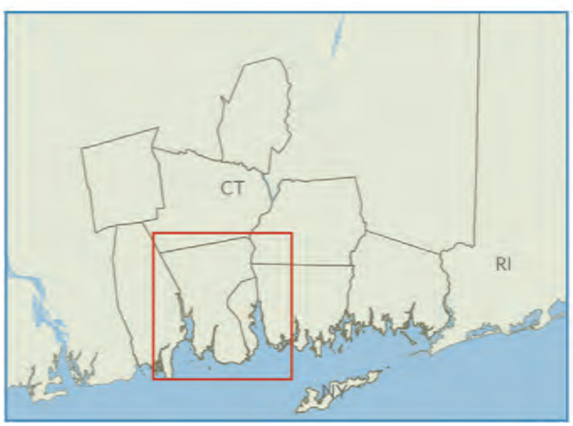
# Niantic River

29 Darrow Pond Dam Removal



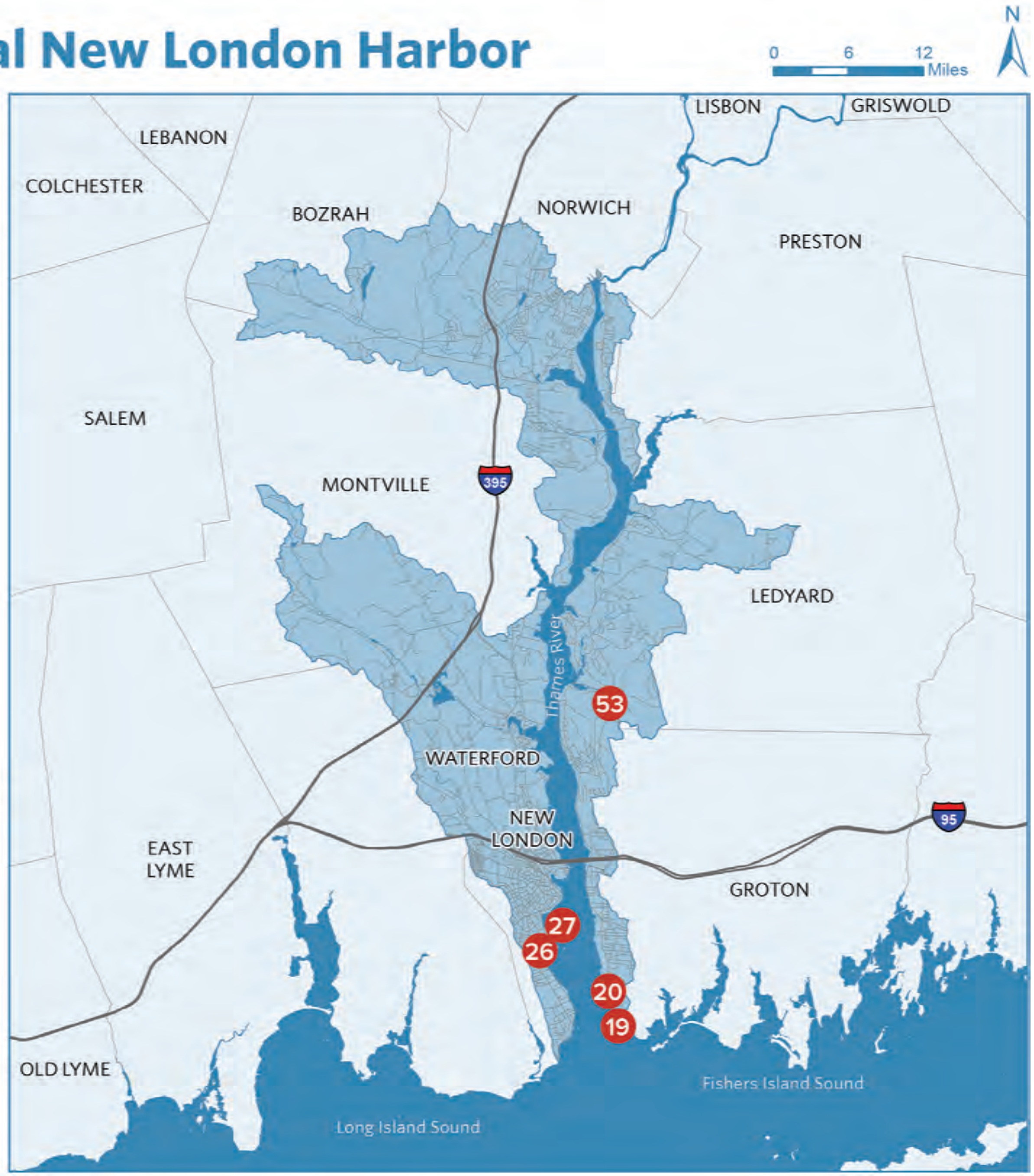

# Coastal drainages-Long Rock to Niantic River


54 Waterford Climate Change Risk Vulnerability, Risk Assessment, and Adaptation Study



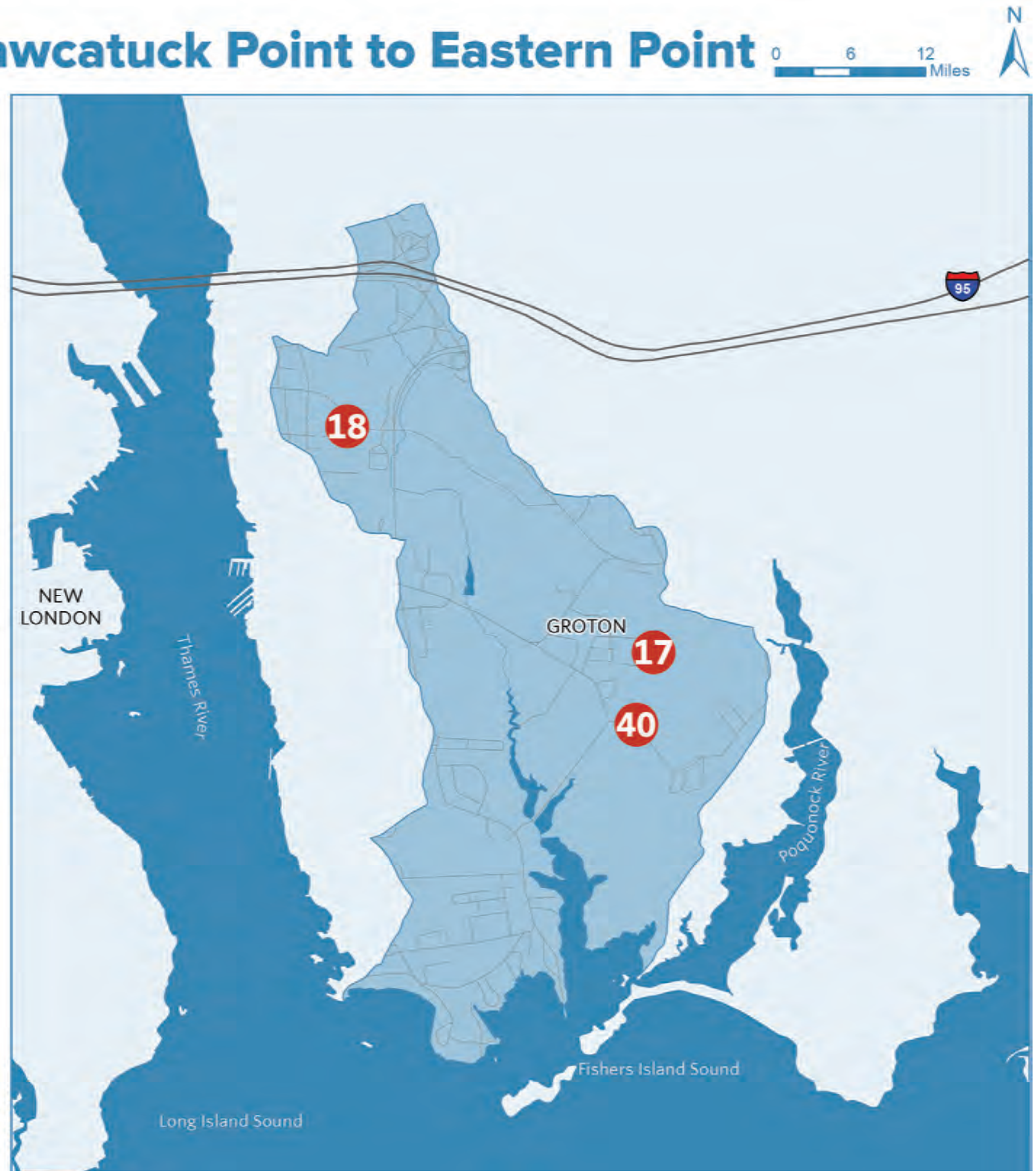
# Thames River-Frontal New London Harbor

- 20 Shore Avenue Seawall Repairs
- 19 Shore Avenue Drainage Improvements
- 26 Fort Trumbull Wastewater treatment plant
- 27 Fort Trumbull Development Phase III Infrastructure Project
- 53 Baldwin Hill Rd Stream Channel Restoration

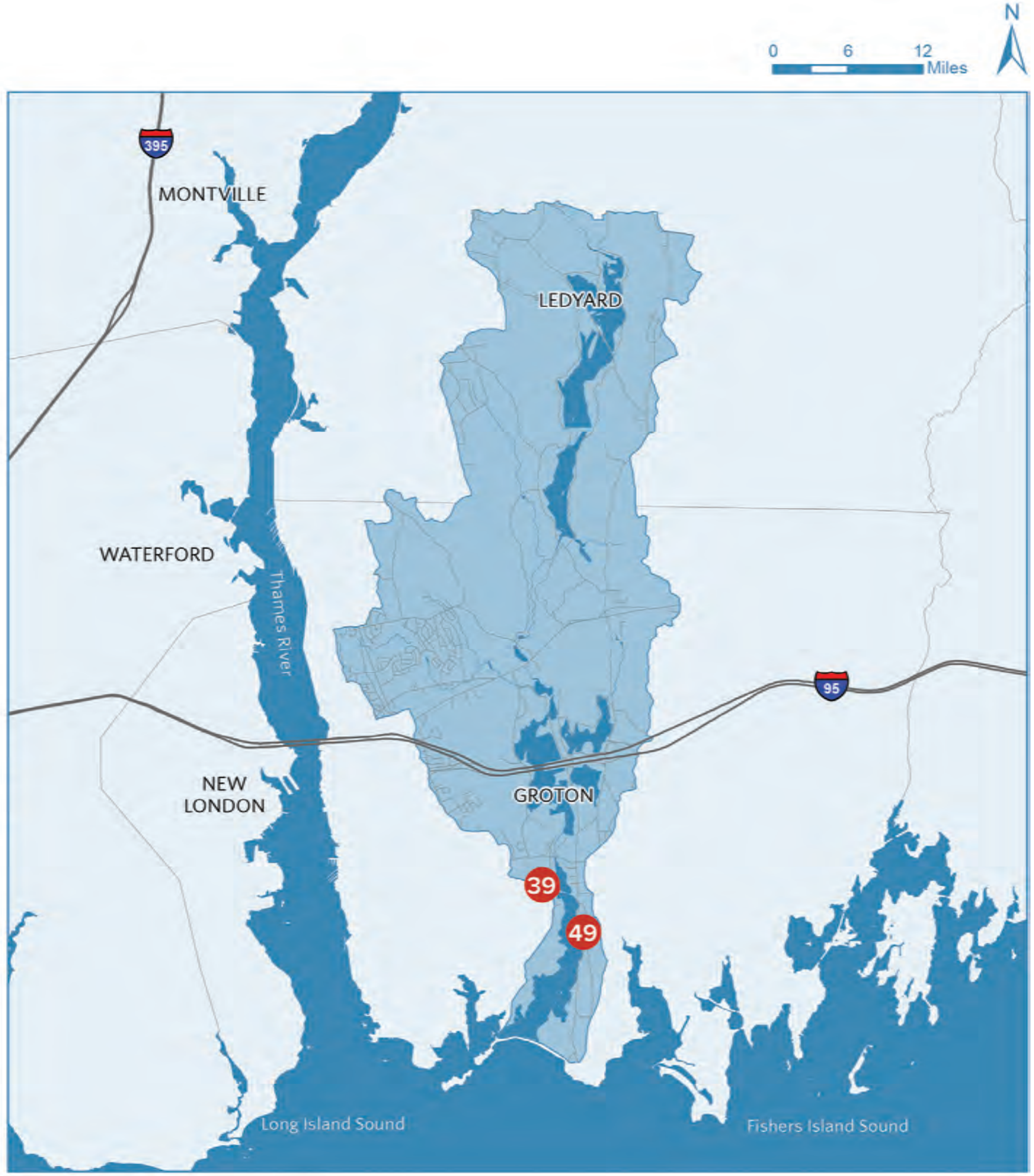
# Coastal drainages-Pawcatuck Point to Eastern Point

- 18 Washington Park/Lake George Stormwater retrofit
- 40 Tower Avenue Railroad crossing
- 17 High Rock Infiltration Swales

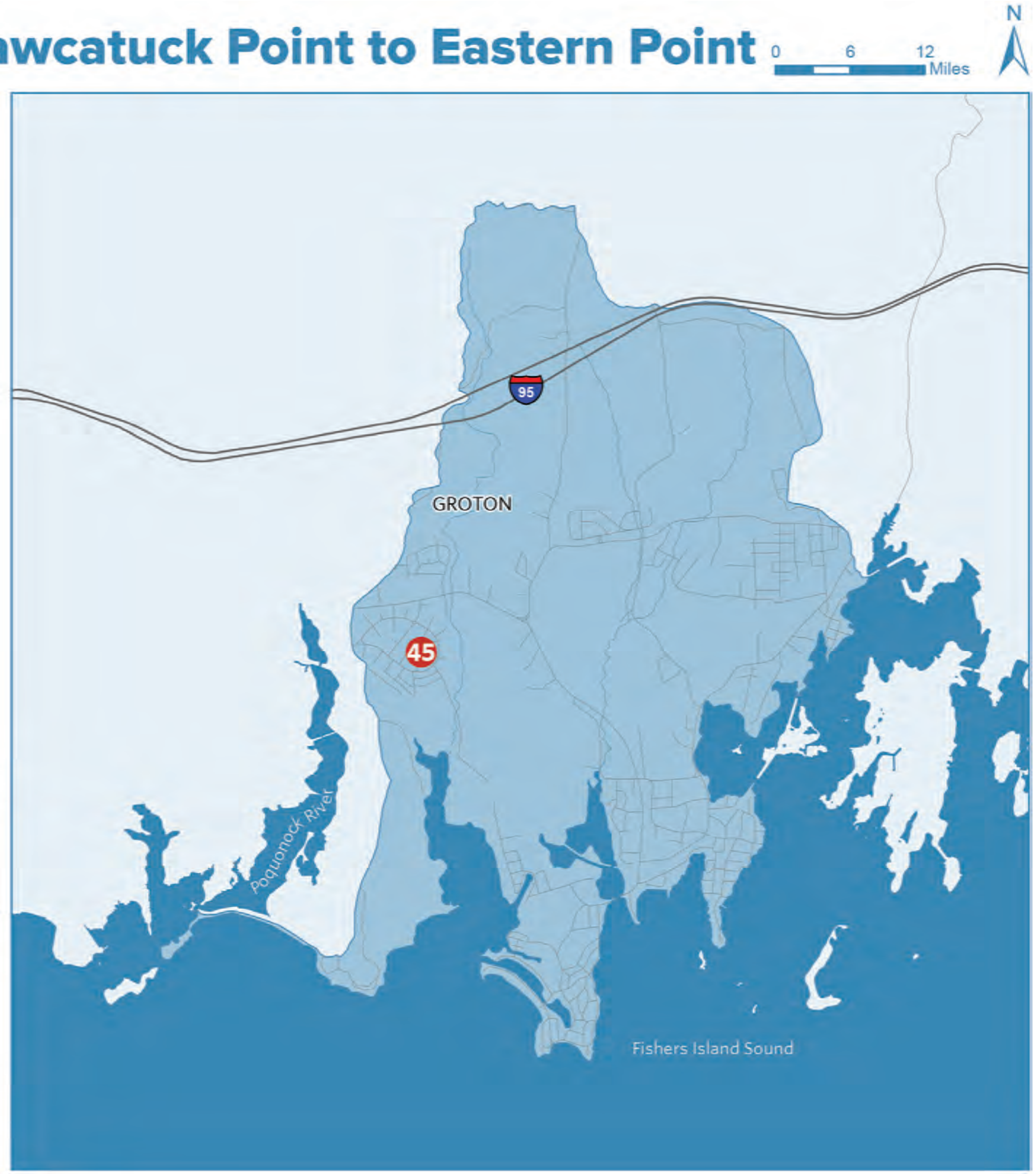



# Poquonock River

- 39 South Road Underpass
- 49 Bluff Point Parking Lot Marsh Restoration



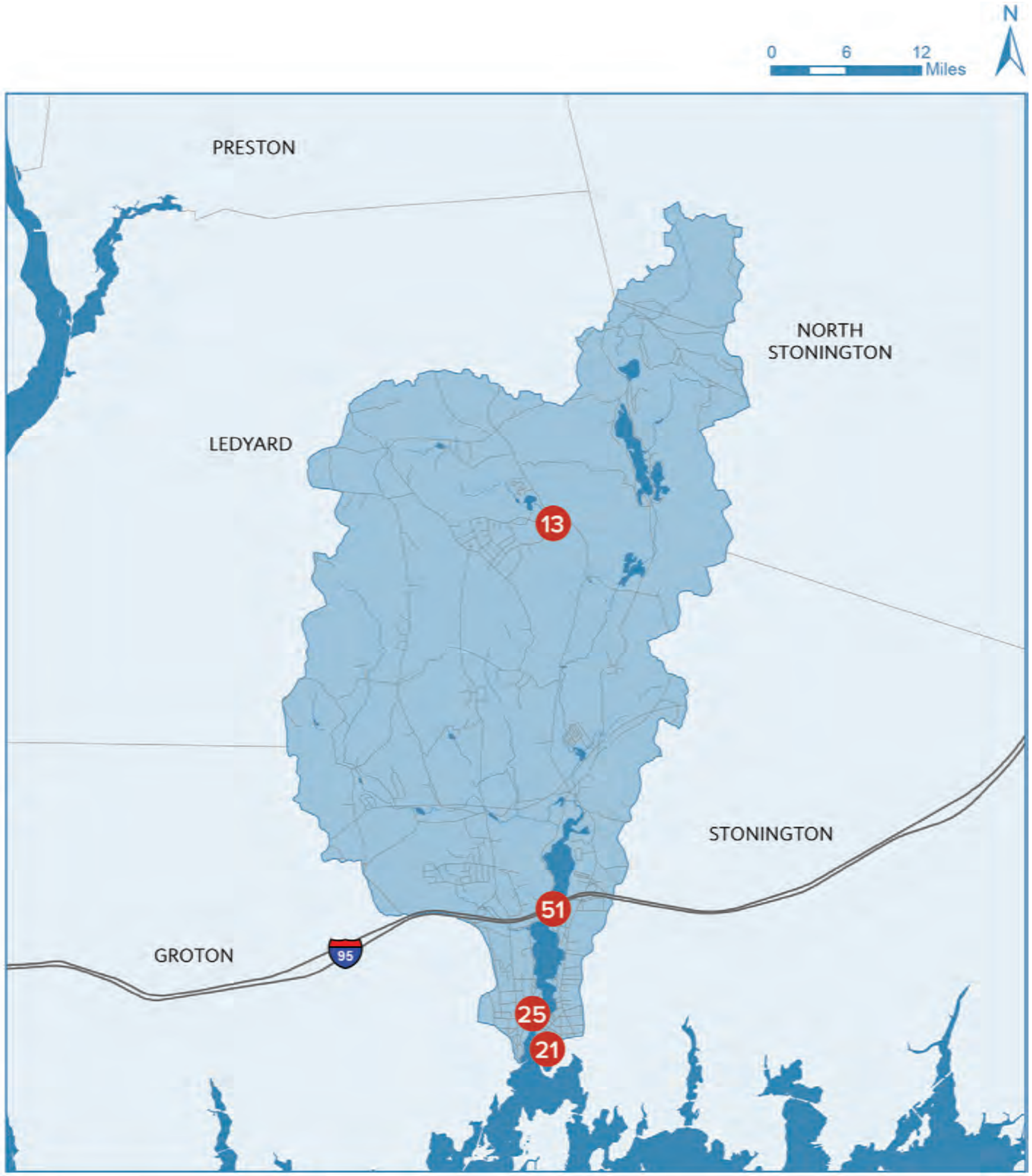

# Coastal drainages-Pawcatuck Point to Eastern Point




45 Fort Hill Neighborhood Redevelopment

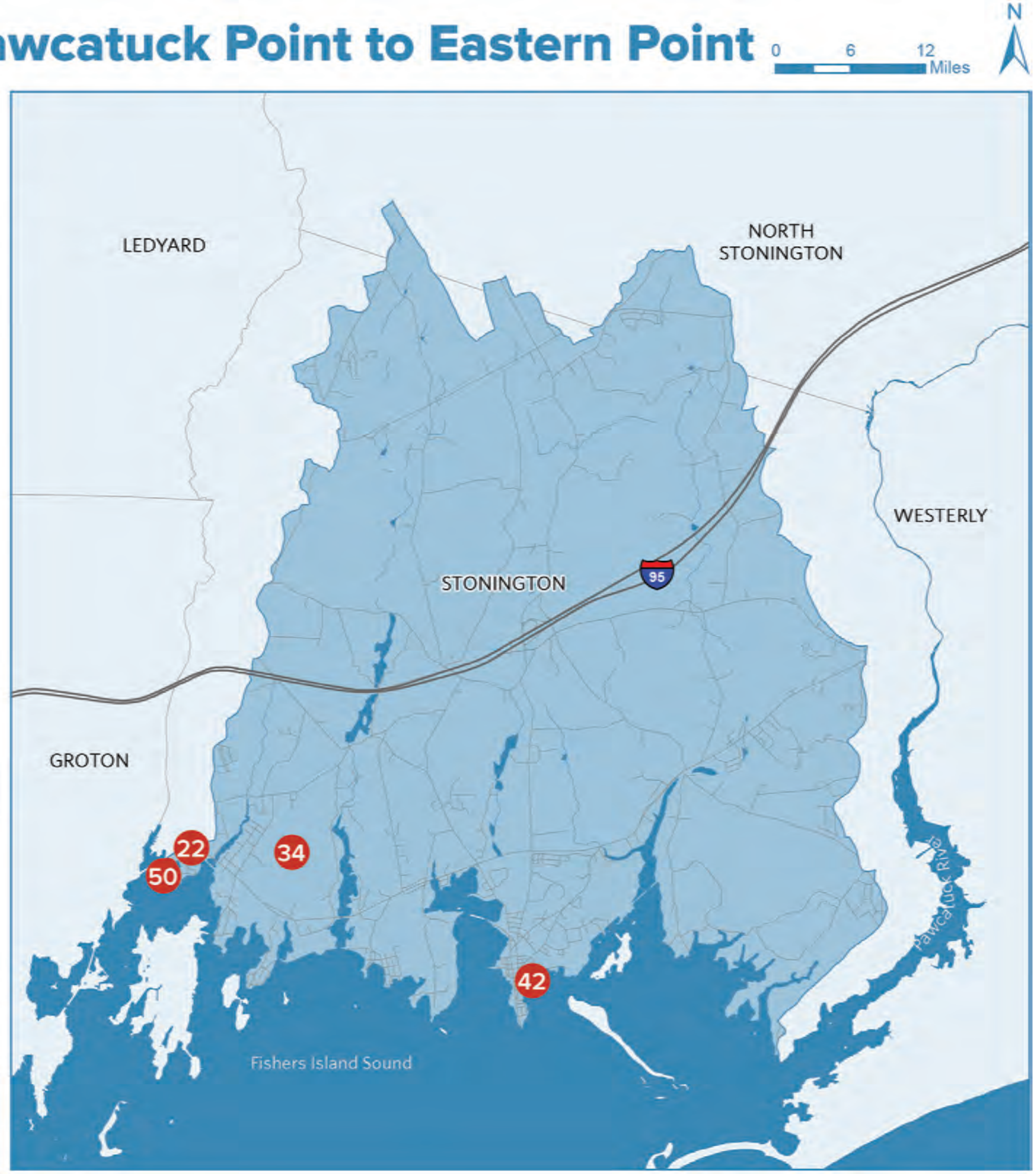
# Mystic River

- 13 Town Farm Road Bridge Improvements
- 21 Mystic Village Marsh Restoration
- 25 Mystic River Park Natural Buffer
- 51 I-95 Tide Gate

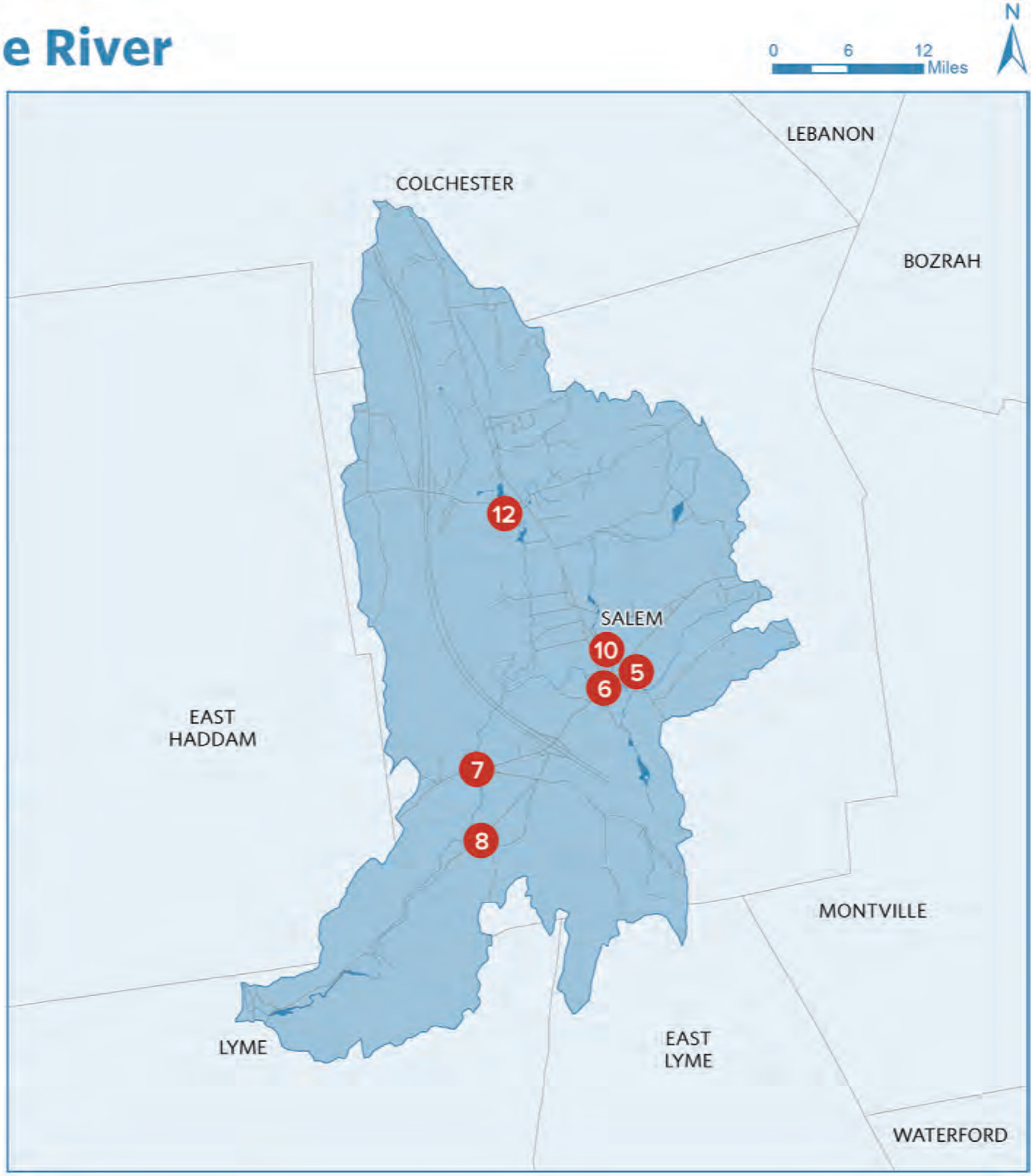
# Coastal drainages-Pawcatuck Point to Eastern Point

- 50 Mystic Railway Elevation and Tidal Control Measures
- 22 Mystic Green Infrastructure Corridor
- 42 Dodge Paddock and Beal Preserve
- 34 Bishops Cove Neighborhood Egress



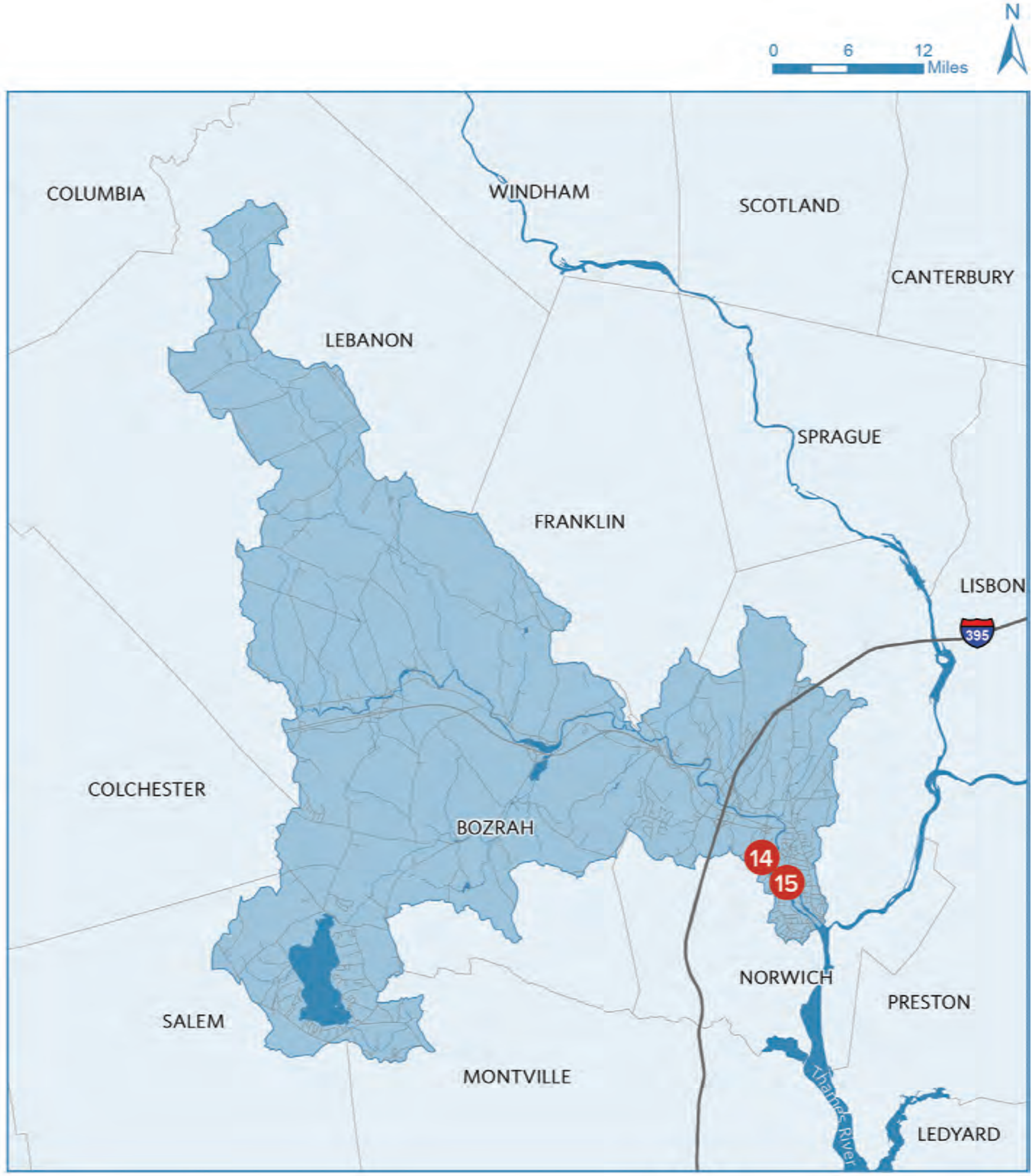

# East Branch Eightmile River

- 5 Floodproofing Measures Behind Salem Four Corners Plaza
- 12 Culvert Improvements Witch Meadow Road at Big Brook
- 10 Culvert Improvements Harris Brook at Route 85
- 6 Culvert Improvements Harris Brook at Route 82
- 8 Culvert Improvements Darling Rd and White Birch Rd
- 7 Bridge Improvements East Branch Eightmile at Route 82




# Yantic mainstem

15 Upper Falls Dam Removal
14 Sherman Street Bridge Raising



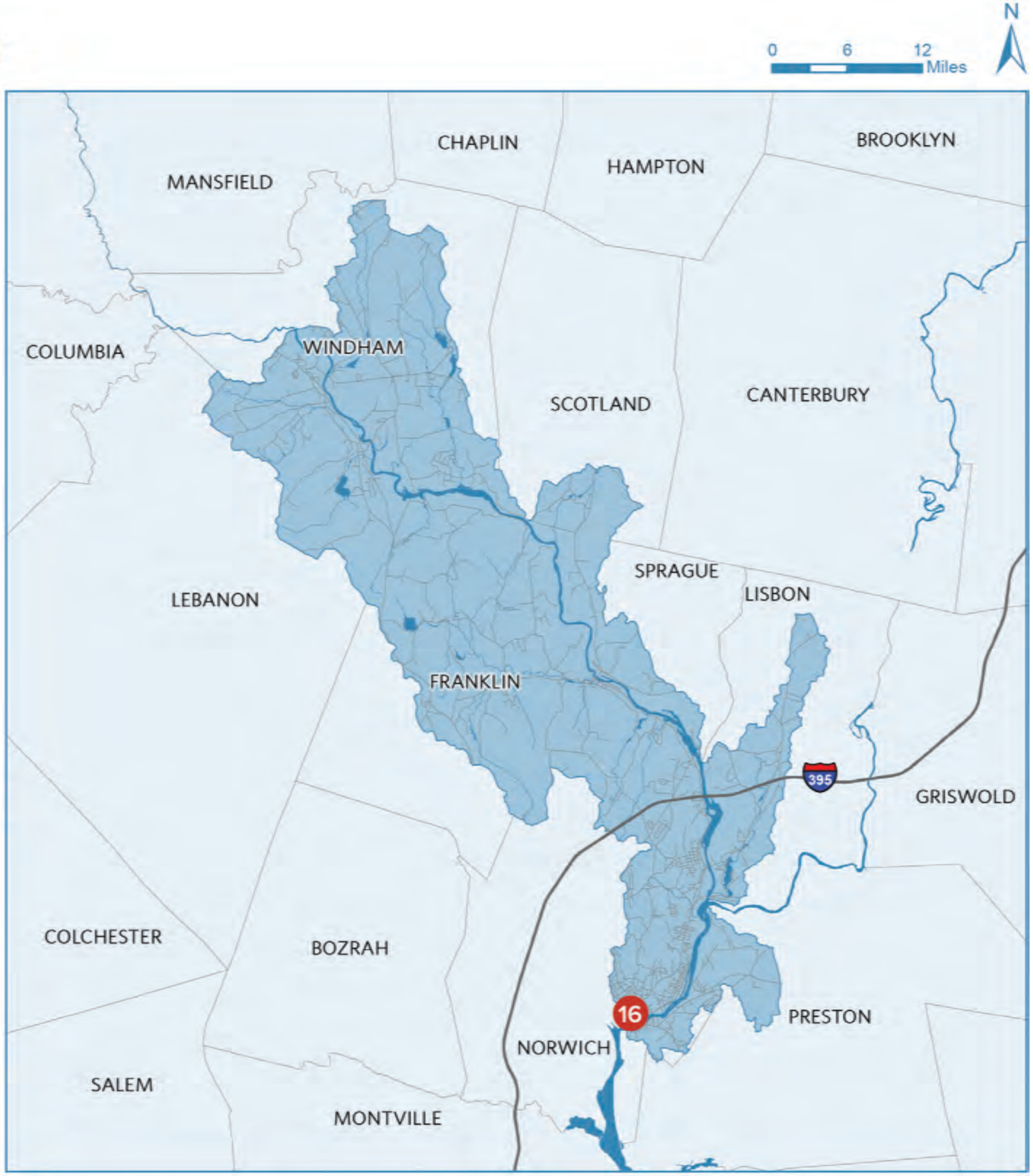

# Lower Pawcatuck River

33 Pawcatuck River Hurricane Barrier

36 Donahue Park Conversion


# Shetucket mainstem

16 Viaduct Parking Lot




# Stony Brook

- **11** Drainage Improvements Route 32 at Jerome Ave
- **9** Culvert Replacements Old Colchester Rd at Fair Oaks
- **52** Bridge Replacement Pink Row at Oxoboxo Brook

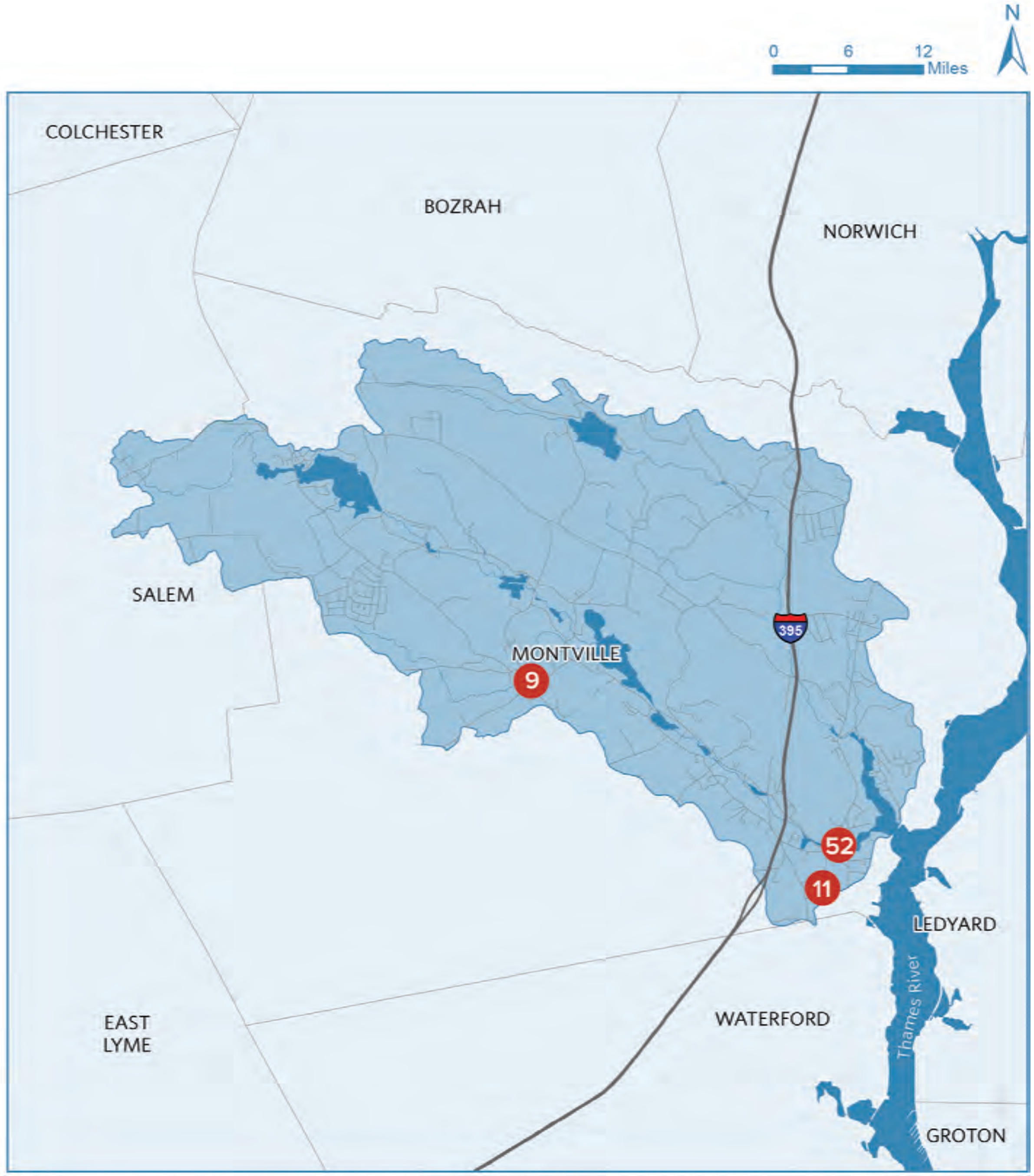
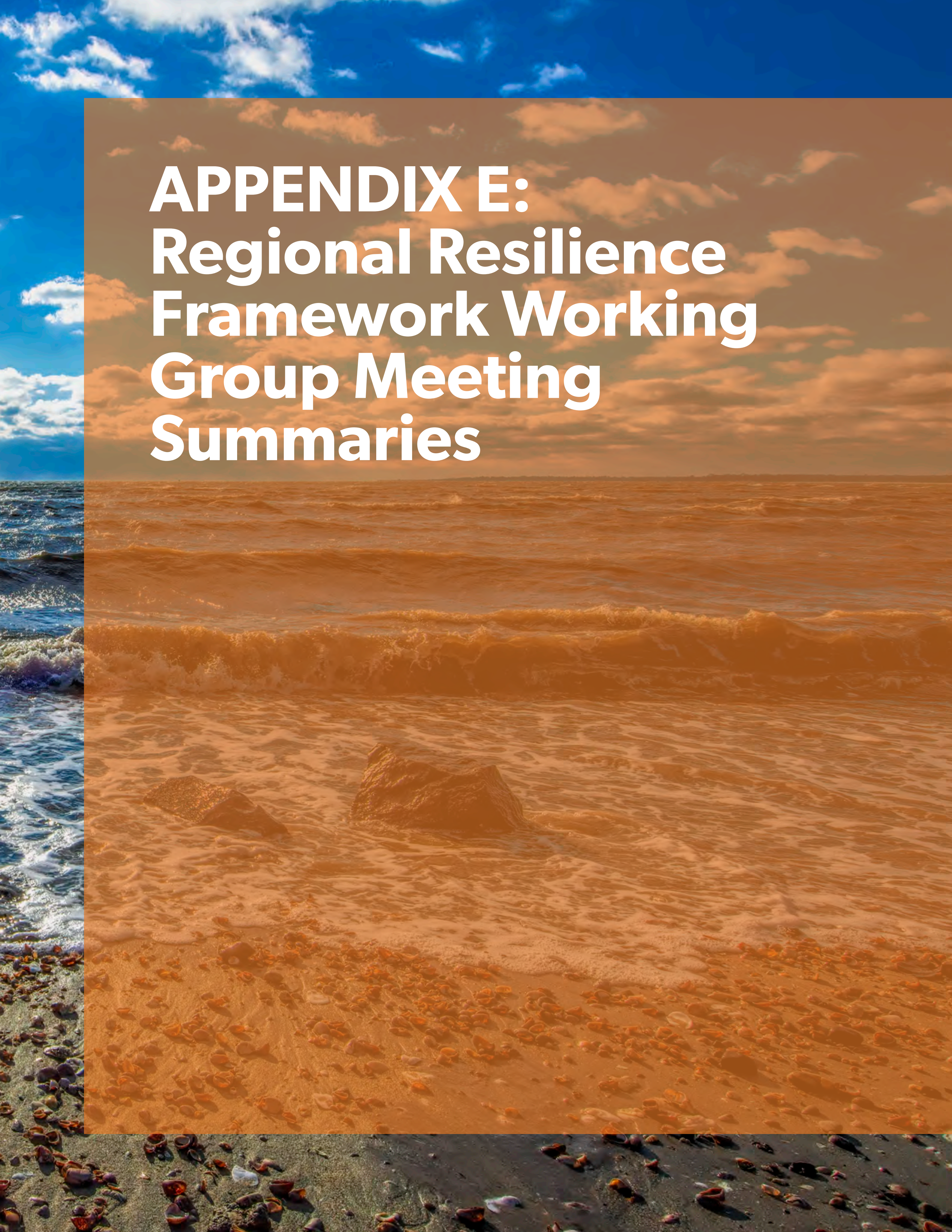



PHOTO CREDIT: Susan Rubinsky

# APPENDIX E: Regional Resilience Framework Working Group Meeting Summaries



In 2017, TNC entered into a partnership with the Southeastern Connecticut Enterprise Region (seCTer) to plan and host a Regional Resilience Working Group. This group met quarterly to advance topics relevant to resilience of businesses, communities, and natural systems.

# Possible Focus Area Pathways

Prior to convening the first Working Group meeting, the Core Team developed a suite of possible action areas. The Core Team intended the projects and goals to arise from the group participants; however, they deemed it necessary to begin with a general outline of focus areas to stimulate discussion.

Address largest regional transportation vulnerabilities

- Meet with regulators, engineers, local property owners, etc. to examine feasibility of different adaptation strategies (relocation, repair, improvements, etc)
- Propose steps address vulnerabilities

Address water supply vulnerabilities

- Meet with utilities, experts, etc. to assess the possibility of future water shortages
- Complete a watershed protection and restoration action plan (Points available in Sustainable CT)
- Draft Drought Restriction Ordinance (Points available in Sustainable CT)
- Draft Drought Communications Plan (Points available in Sustainable CT)

Encourage sustainable development and land use

- Create model ordinance for sustainable development; checklist to streamline permitting (Points available in Sustainable CT)
- Identify unique aspects of POCDs that may be vulnerable to climate change (Points available in Sustainable CT)
- Create model ordinance that integrates natural infrastructure into zoning codes
- Catalog financial mechanisms and incentives for property owners to construct and steward livings shorelines and green stormwater infrastructure
- Identify opportunities to improve infiltration capacity regionally at large scale
- Assist municipalities with MS4 permitting requirements

Improve business resilience

- Support development of business continuity plans
- Develop regional or municipal business recovery plan
- Develop mutual aid agreement between P/Z departments to assist with post-disaster permitting

Enhance local agriculture

- Map regional food shed and identify areas to encourage agriculture near development centers
- Build connections between local businesses and farmers
- Create model ordinance to mandate open space subdivisions and cluster housing. (Points available in Sustainable CT
- Develop TDR Program

Make the case locally for climate adaptation

- Conduct fiscal impacts study of natural disaster in major commercial areas

Further prioritize and plan out recommendations from guidebook and CEDS

- Create “Resilience Index” for different strategies
- Assist TNC with development of resilience projects database in region

# Regional Resilience Working Group Meetings

## Regional Resilience Working Group Session 1

| | | |
|---|---|---|
| **DATE:** | **April 10, 2018** | **ATTENDEES:**<br>Cary White, TNC<br>Adam Whelchel, TNC<br>Nancy Cowser, SeCTer<br>Melinda Wilson, SeCTer<br>Juliet Hodget, Town of North Stonington<br>Tammy Daugherty, Ferncroft LLC<br>Jason Vincent, Town of Stonington<br>Justin LaFountain, SECCOG<br>Sam Eisenbeiser, Town of Groton |
| **PROJECT:** | **Regional Framework for Coastal Resilience in Southeastern Connecticut** | |
| **SUBJECT:** | **Regional Resilience Working Group Session #1** | |
| **LOCATION:** | **SeCTer Office, City of Groton** | |

Working group members convened at the Southeastern CT Enterprise Region office in Groton City on April 10, 2018. Following an agenda drafted between TNC and SeCTer staff, Nancy kicked off the meeting, explaining how the work fit in with the goals of both SeCTer's Comprehensive Development Strategy (CEDS) and TNC's Regional Resilience Guidebook. She explained how the deliverables from this working groups session could feed into larger outreach efforts to businesses around resilience. Adam first led the group in an exercise to define the top actions for business owners to take before and after a natural disaster. The following is a list of the ideas that the group surfaced:

### Better Businesses Actions: Pre-Disaster

- Conduct inventory of merchandise and equipment (i.e. photos and written).
- Pre-arrange with suppliers the process to ensure pre- and post-disaster supply availability.
- Assess need and opportunities to secure back-up power (generators; micro-grid, etc.)
- Contact information of all employees written down and available before emergency.
- List of upcoming appointments with clients – call to reschedule before disaster
- Ensure all important insurance policy information is stored and available electronic and paper copies.
- Pre-determine and secure cooperative space for businesses with power and electricity. Develop reciprocal agreements between private sector in coordination with municipal and state emergency management operations.
- Conduct stress test of risk assessment of business to various types of hazards (i.e., hurricanes, heat waves, Nor'easters, etc.).
- Develop protocols in response to specific triggers or categories of risk (i.e. highway closure, temporary versus longer-term power outages, etc.)
- Craft model ordinances to help speed up business recovery needs and actions (i.e. permitting).
- Distribute or alert businesses to state list of licensed and bonded contractors prior to disasters.
- Explore opportunities to provide working capital or additional credit lines to business in advance of disasters to accelerate recovery and continuity post-disaster.
- Provide tools to businesses to calculate the daily closure cost during recovery in advance of disasters to assist with financial planning for expenses (i.e. payroll).

*Footnote: Actions need to be tailored or made specific to certain types of business (grocery versus toy store).

### Better Businesses Actions: Post-Disaster

- Utilize the states licensed and bonded contractor list when selecting contractor to fix damage to facilities and structures.
- Have a network of suppliers beyond region notified and available to make delivers of goods as appropriate during recovery.
- Conduct damage assessment quickly and estimate length of closure. Look to notify customers and clients of that estimate.
- Participate in educational opportunities to full understand the recovery steps required with insurance and FEMA.
- Keep copies of essential forms, documents, and statements needed during recovery offsite in a secure and retrieval location.
- Connect with available business support network (i.e. Chambers).
- Maintain routine communications with employees.
- Activate financing to maintain pay roll distributions (i.e. stop loss insurance).

After discussing business actions, Cary led the group on a participatory mapping exercise to identify the important business corridors most vulnerable to natural hazards. He reiterated how identifying these corridors could help SeCTer and other working group members target outreach efforts to vulnerable businesses. Below is the result of that exercise. While participants identified many important corridors in green, they ultimately agreed upon a few areas (shown in orange) that were both highly important to the region and vulnerable to natural hazards. These corridors were downtown New London, the City of Groton's military infrastructure, Gales Ferry, Mohegan Sun, Foxwoods Resort Casino, Backup Hospital, and Downtown Mystic. Considering that many of these places are dominated by a single large business that likely already has a strong hazard mitigation protocol, the group discussed how an outreach strategy may be more appropriate with the more diversified and smaller scale corridors such as Gales Ferry and Mystic.

After the mapping exercise, Nancy led the group in a conversation about how best to engage the business community around hazard mitigation and recovery. The group discussed how larger locally based business could provide a template or assistance for other businesses. Existing materials such as the RESF7, FEMA risk mitigation app, Insurance Institute for Business and Home Safety could all be used in outreach efforts to avoid "recreating the wheel." The group also discussed existing processes such as PTAP and other loan applications, zoning permits, and other instances where businesses had to interact with a governing body. The working group could work with these bodies to see if hazard mitigation and emergency management planning could piggyback on their processes.

The group adjourned after finally discussing next steps. While the group set no date for next meeting, the participants did discuss what would be required to move the outreach process forward. The group agreed that the participants needed a greater awareness of of the existing toolkits available to businesses. The group also asked how much time and energy it would take for a business to create a hazard mitigation and emergency protocol, and if the group could realistically help with this. Nancy agreed to get more clarity on the contact data available for an outreach effort.

# Regional Resilience Working Group: Session 2 (June 13, 2018)
# Location: seCTer office, 19-B Thames St, Groton, CT

**Purpose:** Review possible resources and for business recovery; align on next steps for business engagement; review projects database; discuss database and potential applications

| Time | Action Sequence and Steps |
|---|---|
| 10:30 | Arrival and get situated |
| 10:40 | Welcome and recap of working group goals and direction |
| 10:45 | Presentation of business recovery resources<br>3 resources (3-5 minutes each) |
| 11:00 | Discuss next steps for business outreach |
| 11:15 | Begin projects database review |
| 11:45 | Discuss projects database |
| 11:55<br>Nancy | Wrap up<br>Next steps from today's exercise<br>Foreshadow next session's focus<br>Any updates on tomorrow's TVSCI symposium and Sustainable CT<br>Plant seed for input on future session focal points/issues |
| 12:00 | Thank you! Lunch! |

# Regional Resilience Working Group Session 3
# Location: seCTer office, 19-B Thames St, Groton, CT

**Purpose:** Business Resilience next steps; Review POCDs for secondary climate change impacts

| Time | Action Sequence and Steps |
|---|---|
| Time | Action Sequence and Steps |
| 12:00 | Arrival and get situated |
| 12:05 | Welcome and refresher on working group goals |
| 12:10 | Round-robin; participants share a project they are working on |
| 12:30 | Business Resilience Next Steps<br>Review use of toolkit by SeCTer<br>Discuss strategies for outreach campaign |
| 12:50 | Begin POCD resilience review; Lunch arrives<br>Explain relation of exercise to the Southeastern CT Regional Resilience Visioning Process and Sustainable CT action 4.4.2<br>Hand out POCDs and checklists; allow participants to use computers to search documents<br>On checklists, each participant marks if and where connections are made; add notes to expand what isn't covered |
| 1:15 | Reflect on exercise<br>What were some surprising inclusions? Omissions?<br>Next steps: Coordinating team will scan, compile, and share results |
| 1:30 | Wrap up<br>Share update on final projects database<br>What does group want to focus on for FY19?<br>Who's missing from group? |
| 1:40 | Thank you! |


PHOTO CREDIT: iStockPhoto

# APPENDIX F: Natural/Green Infrastructure Resource Guides

# Review of Available Resources About Promoting Resilience through Green Infrastructure, Nature-Based Solutions, and Living Shorelines

The number of resources available for promoting nature-based solutions to risk reduction, green infrastructure, and living edges/shorelines (in the broad sense of the term) for advancing coastal resiliency has been growing at a hastening pace since about 2011. A selection of resources is discussed below chronologically in hopes of enhancing awareness amongst the region served by this project in southeastern Connecticut and beyond.

### Living Shorelines in New England: The State of the Practice

Prepared for The Nature Conservancy by the Woods Hole Group in 2017, this report details the varying techniques, case studies, and state regulatory frameworks applicable to living shoreline design and construction in New England. The report also includes design guidelines in the form of profile drawings for common living shoreline types in the region.

### Living Shoreline Engineering Guidelines

Prepared for the New Jersey Department of Environmental Protection in 2016, this document outlines living shoreline guidance for engineers and regulators. The document includes a description of the critical design parameters as well as methods for selecting the appropriate project parameters.

### Southeastern Connecticut Regional Resilience Guidebook

The precursor to this Regional Framework Report. This Guidebook provides a broad contextual overview of resilience planning in southeastern Connecticut and compiles findings from the two regional resilience workshops conducted in Fall 2016.

### Future of our coasts: The Potential for Natural and Hybrid Infrastructure to Enhance the Resilience of our Coastal Communities, Economies and Ecosystems

This article briefly described U.S. policy for coastal resilience, provides examples of natural and built infrastructure, summarizes knowledge about coastal protection benefits associated with natural and built infrastructure, and outlines the limitation and research needs. This article is one of the early narratives that concisely describe "hybrid" solutions to coastal protection.

### Living Shorelines – From Barriers to Opportunities

The report Living Shorelines – From Barriers to Opportunities was released by Restore America's Estuaries in June 2015. The report's focus is to identify and assess barriers that prevent broad use of living shorelines in the U.S. A definition of living shoreline presented in the report is:

- Any shoreline management system that is designed to protect or restore natural shoreline ecosystems through the use of natural elements and, if appropriate, manmade elements. Any elements used must not interrupt the natural water/land continuum to the detriment of natural shoreline ecosystems.

This definition differs slightly from the DEEP definition but is consistent with many of the examples discussed below in this report. The report also notes that a "management system that breaks the water/land continuum is not considered a living shoreline.... This choice is based on the belief that any manmade break in the water/land continuum will eventually become a de facto hardened structure functioning essentially like a bulkhead or revetment."

## Natural and Structural Measures for Shoreline Stabilization

NOAA and the USACE collaborated through their "Systems Approach to Geomorphic Engineering" ("SAGE") practice to publish materials in 2015 including *Natural and Structural Measures for Shoreline Stabilization*. This reference guide and manual promotes coastal risk reduction through use of living shorelines. The three goals of living shorelines are cited as:

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

One of the highlights of the SAGE publications is the graphical display of the range of green and soft techniques to gray and hard techniques, with the following depicted in clear graphics:

- Vegetation only
- Edging
- Sills
- Beach nourishment
- Beach nourishment and vegetation on dune
- Breakwater
- Groin
- Revetment
- Bulkhead
- Seawall

The SAGE resources also described anticipated benefits of living shorelines, challenges, and costs. The SAGE resources were helpful during the planning and design phases of the Regional Framework for Coastal Resilience timeline.

## Urban Coastal Resilience: Valuing Nature's Role – Case Study: Howard Beach, Queens, New York

TNC published Urban Coastal Resilience: Valuing Nature's Role – Case Study: Howard Beach, Queens, New York in July 2015. The report considers the use of natural infrastructure to address flood and other climate change–induced risks in an urban area (specifically, New York City). The report had three stated objectives: to evaluate the relative merits of various approaches to climate change resilience using a case study; to propose an innovative approach to quantifying ecosystem functions and services; and to establish replicable methods for making decisions about using natural infrastructure in this context.

The report discusses how a cost-benefit analysis can account for environmental benefits that are often difficult to quantify and discusses the application of a Habitat Equivalency Analysis to consider the benefits of natural infrastructure such as wetlands, beaches, berms, and shellfish reefs. Five alternative sets of protective infrastructure were considered for both their flood protection efficacy and their ecosystem services co-benefits, which when combined contribute to resilience. The five sets of alternatives included (in varying measures) restored marshes, hard toes of mussel shells, berms, breakwaters, groins, floodwalls, and flood gates.

The study found that when ecosystem functions and services are included in a cost-benefit analysis, hybrid infrastructure (combining nature and nature-based infrastructure with gray infrastructure) can provide the most cost-effective protection from sea level rise, storm surges, and coastal flooding.

## Community Resilience Planning Guide for Buildings and Infrastructure Systems

The guidebook Community Resilience Planning Guide for Buildings and Infrastructure Systems (NIST Special Publication 1190, 2015) was developed to help communities address resilience through a practical approach that takes into account community social goals and their dependencies on the built environment (buildings and infrastructure systems). The guide defines Community resilience as the ability of a community to (1) Prepare for anticipated hazards, (2) Adapt to changing conditions, and (3) Withstand and recover rapidly from disruptions.

### Performance of Natural Infrastructure and Nature-based Measures as Coastal Risk Reduction Features

The Environmental Defense Fund published Performance of Natural Infrastructure and Nature-based Measures as Coastal Risk Reduction Features in September 2015. The report is a narrative review of nature-based risk reduction methods based on workshops and literature reviews prepared by the authors. The various techniques addressed in the report include beach nourishment, vegetated dunes, edging and sills (living shorelines), oyster reefs, and coastal wetlands. For each method of risk reduction, the report outlines the strengths, weaknesses, uncertainties, suitable conditions, limitations, etc.

### Natural Defenses in Action – Harnessing Nature to Protect Our Communities

The National Wildlife Federation, Allied World, and ASFPM collaborated on the report Natural Defenses in Action – Harnessing Nature to Protect Our Communities (2016). The report is essentially a handful of case study examples for nature-based solutions to risk reduction. The report notes that "Constructing engineered features designed to mimic natural features and functions can be an effective approach for reducing risks. Nature-based features can include such things as engineered dune complexes to buffer coastal communities, and living shorelines that use mostly native materials (biological and physical) to stabilize shorelines. Engineered reefs, built from or serving as substrate for oysters or corals, are another focus of active experimentation with potential wave attenuation and shoreline protection benefits." The report also noted that "Because many traditional ecological restoration efforts require engineering, design, and construction, restoration of purely natural systems and construction of nature-based features are probably best viewed as occurring on a continuum, and any given project may have elements of both."

Furthermore, the report states that "Increasingly, practitioners are identifying opportunities to blend green and gray approaches to risk reduction. In some places the protective functions of a structural feature can be augmented with those provided by a natural or nature-based feature—such as dunes, marsh, or natural floodplain—creating multiple lines of defense. Creating such green–gray hybrids, where ecologically appropriate, can soften the impacts of the structural feature and provide other environmental benefits typically associated with natural infrastructure. Integrating natural, nature-based, non-structural, and structural approaches recognizes that risk reduction needs and opportunities are highly site specific and depend very much on the geophysical and ecological setting as well as the type and sensitivity of the assets to be protected. Given the traditional reliance on structural measures in most heavily populated areas, opportunities to promote and expand the use of natural and nature-based features will often involve incorporating them into such integrated, hybrid risk reduction systems."

Because the case studies in the report vary widely in geography, some are not directly applicable to Connecticut. However, the example from Cape May highlights the benefits of wide beaches and robust dune systems, stating that "After Hurricane Sandy, Cape May communities that had participated in U.S. Army Corps of Engineers dune and beach nourishment projects, starting in 1989 with Cape May City, had relatively little storm and flooding damages in places where wider beaches and deeper dune systems provided adequate buffers."

### Coastal Wetlands and Flood Damage Reduction

TNC, Wildlife Conservation Society, U.C. Santa Cruz, and Lloyd's Tercentenary Research Foundation collaborated on the report Coastal Wetlands and Flood Damage Reduction (October 2016). This report presents one of the most recent concise yet compelling arguments for protecting or restoring tidal wetlands (marshes) for storm surge and flood risk reduction. In the past, most reports speak of tidal wetlands "absorbing" storm surges or attenuating wave energy without presenting direct evidence. For this paper, modeling was conducted by the authors to demonstrate that the roughness associated with tidal wetlands will, in some cases, reduce the elevation of floodwaters caused by storm surges. However, the modeling also demonstrated that in some locations (especially at the leading edge of expansive marsh systems), the roughness of marshes may increase flood levels. The report calls this is a "piling up" of water."

Overall, flood damage reduction (in dollars) was found to be negligible for Connecticut's shoreline when compared to the other states in the study (Massachusetts to Virginia). This is a function of the setting and tidal wetland characteristics along the Connecticut shoreline rather than a direct measure of the importance of tidal wetlands in Connecticut.


PHOTO CREDIT: iStockPhoto

# APPENDIX G: Southeastern Connecticut Regional Resilience Vision

In 2015, TNC's Connecticut Chapter received funding from the Community Foundation of Eastern Connecticut to continue resilience work in southeastern Connecticut. This investment allowed TNC to capitalize on a decade of community resilience building efforts working to conserve ecosystems and protect people and property in cities, towns, and villages across Connecticut from extreme weather and a changing climate. However, for this project the Core Team sought to apply the notion of resilience at a regional scale as well as integrate the implications of shifts in socio-economic conditions. This expansion serves to represent a more relevant, meaningful, and holistic representation of regional resilience in southeastern Connecticut; and likely elsewhere nationally and internationally.

The following year, TNC enlisted the support of SCCOG and SeCTer. This Core Team subsequently formed the backbone of the regional resilience visioning process. After a series of intensive, information-gathering interviews with municipal staff, the Core Team gathered a group of landuse and economic development planners to help further define what they hoped to gain from a regional resilience visioning exercise. Current concerns, knowledge gaps, and who they wanted to include in the larger resilience dialogue were identified. The nine municipalities engaged included East Lyme, Groton (City and Town), Montville, New London, Norwich, Ledyard, Salem, Stonington, and Waterford.

Greater awareness of risks from extreme weather and climate change across the nine municipalities was advanced through direct and routine community engagement efforts. This engagement involved between two to four individual listening and scoping meetings with each municipality. These initial meetings created common understanding of current and future risks alongside high priority challenges and potential solutions for each of the municipalities. This information served as the bedrock upon which the subsequent community resilience building efforts were structured. The resulting information encompassed extreme weather and climate change and shifts in social and economic conditions across southeastern Connecticut.

After these initial discussions and an exhaustive review of all other previous work on hazard mitigation and resilience in the region, the Core Team gathered a larger municipal-based team comprised of planners from all nine municipalities and regional entities (approximately 25 professionals). This larger planning team then served as the nucleus for a series of scoping sessions to further refine the shared values, context and intent for the Regional Resilience Vision. The larger planning team and Core Team eventually landed on six systems of concern or planning sectors that came up regularly in conversation including water, food, ecosystem services, transportation, energy, and the regional economy. These planning sectors provided the framework for subsequent dialogues in the regional resilience workshops; Challenges and Solutions. The total number of participants at these two workshops reached one hundred with additional stakeholders contacted in post-workshops interviews. These workshops were followed by further engagement with the municipal-based planning team to further refine the solutions and foster collaborative ownership going forward.

Workshop participants were selected from a wide range of organizations across the region. In addition to planners and economic development professionals, public and private utility representatives, state agencies, community non-profits, academic institutions, public health departments, and major regional employers were engaged among others. Interestingly, many of these groups—especially those with more resources—already had staff tasked with helping their organization adapt to natural hazards and a changing climate. This suggested that the human capital is rapidly embracing a more regional planning perspective that is receptive to risk and resilience considerations.

Organizations that participated in the process included representatives from SCCOG, SeCTer, nine municipalities (East Lyme, Groton (City and Town), Montville, New London, Norwich, Ledyard, Salem, Stonington, and Waterford), Ledge Light Health District, Avalonia Land Conservancy, UConn CLEAR, UConn NEMO, Connecticut College, Millstone Environmental Laboratory, New London Homeless Hospitality Center, Uncas Health District, New London County Food Policy Council, FRESH New London, Eastern Connecticut State University Institute for Sustainable Energy, Thames River Basin Partnership, Norwich Public Utilities, Groton Utilities, Eversource Energy, Norwich Community Development Corporation, Renaissance City Development Corporation, Pfizer, Connecticut Department of Public Health, Connecticut Department of Energy and Environmental Protection, Connecticut Department of Transportation, Connecticut Department of Emergency Management and Homeland Security Region 4, Community Foundation of Eastern Connecticut, and the Eastern Connecticut Conservation District. The Connecticut College Arboretum, the Southeastern Connecticut Council of Governments, Spark Makerspace, and Foundry 66 thankfully provided space to hold meetings and workshops.

# Findings

Planning for extreme weather, a changing climate, and shifting social and economic conditions is an inherently interdisciplinary endeavor. Therefore, the collective planning team felt it was important to cast a wide net when initiating these conversations. In a series of two workshops—one focused on regional challenges and the next on solutions to those challenges—the Core Team facilitated dialogues between a wide array of stakeholders as mentioned above. During the challenges workshop dialogues, participants were first asked to brainstorm all relevant challenges that fell within each of the six planning sectors and identify those challenges which were most important to address for community resilience building across the region. At the solutions workshop, participants were given the top challenges generated from the previous workshop and asked to articulate possible solutions to these challenges as specifically as possible. At the end of these discussions, participants were then asked to come to consensus on a set of "overarching solutions" that can be applied to individual and multiple challenges and across planning sectors. Highlights of these conversations are found below:

## Water

### Challenges

- Impacts of nonpoint source pollution on the health of the region's surface and ground water
- Insufficient capacity of aging and outdated stormwater systems to handle current and future precipitation and sea level rise Important infrastructure vulnerable to storm surge, riverine flooding, and sea level rise
- Rising sea level intruding into aquifers, drinking wells, and septic systems
- Lack of clear policies in place to equitably manage water shortages across industry, agriculture, and ecosystems

### Solutions

- Assess current public and private water supply and distribution capacity
- Build upon past projects and foster future opportunities across the region to utilize green infrastructure and improve gray infrastructure to enhance capture and infiltration of runoff
- Develop a regionally specific decision support process to help municipalities assess and plan for flooding, efficient water use/reuse, and nonpoint source pollutions, simultaneously

## Food

### Challenges

- Regulatory hurdles faced by producers; particularly new, smaller scale enterprises
- Limited processing infrastructure for producers and distributors
- Competition for farmland with other, more profitable landuses such as development
- Limited food access for some communities; particularly in parts of Groton and Norwich
- Uncertain future environmental conditions present challenges to local and regional agriculture

### Solutions

- Explore cooperative funding, sourcing, and distribution models to meet demands for local foods among area residents, schools, and other institutions
- Scope feasibility of large-scale municipal composting, regional processing facility, and cooperative distribution system
- Look to streamline regulatory requirements across multiple state agencies
- Create greater housing opportunities in currently developed areas and take steps to promote agricultural careers among the next generation
- Explore ways to accommodate the uncertainty of future environmental conditions in farm planning
- Reduce flood risk to farmers through dam removal, soil erosion control measures, and watershed management
- Conduct a food-shed mapping effort across the region to determine sources and quantities of locally produced food

# Ecosystems

## Challenges

- Effects of reduced water quantity and quality on natural resources and the derived services and co-benefits for residents
- Reduction in ecosystem services such as coastal and riverine flood protection and water purification in forested watersheds
- Lack of ecosystem service value integration in existing and future development projects
- Need to integrate natural resources and green infrastructure to redefine smart, balanced, and resilient development

## Solutions

- Strengthen collaborative leadership that champions the benefits of ecosystem services from municipal to regional scale
- Catalogue financial mechanisms and incentives for property owners to maintain and enhance natural infrastructure and associated services
- Monetize services provided by natural assets when making economic growth and development decisions across the region
- Define ways to incorporate ecosystem services directly into permitting requirements for MS4 and other initiatives
- Integrate natural infrastructure into zoning codes to reduce conflicts between development and community resilience
- Conduct outreach and education for residents and business owners on where and what natural alternatives could be considered alongside standard hard engineering approaches

# Transportation

## Challenges

- Flood vulnerability to critical transportation centers such as New London
- Primary arterial roads are vulnerable to flooding, tree falls, and ice impacts
- Unreliable emergency transportation for transit-dependent communities to shelters and employment centers
- Aging infrastructure including roads, rail, and bridges

## Solutions

- Prioritize state and local funding for infrastructure improvements that contribute to overall community resilience
- Collaborate on largest regional transportation vulnerabilities and share planning, engineering, and monetary resources across municipalities to enhance regional resilience
- Integrate green infrastructure and natural assets into transportation upgrades and retrofits through design standards and codes
- Establish mutual aid agreements with nearby urban centers (Hartford, Worcester) to reduce risk to transit-dependent residents during emergencies

# Energy

## Challenges

- Preparedness and capacity to recover from flooding and high wind events
- Communications disconnect between energy consumers and providers leading to potential misunderstandings
- Uncertainty surrounding the future of local energy production and supply may hinder further investment in local energy resilience infrastructure such as solar and micro-grid technology

## Solutions

- Identify steps to further strengthen and possibly redesign the distribution system in partnership with municipalities
- Improve communications among stakeholders within the energy system
- Target and incentivize consumer behavior to improve overall regional energy resilience
- Routinely update state building codes with energy efficiency standards
- Update existing response plans with a specific emphasis on speeding up the recovery of energy infrastructure

# Economy

## Challenges

- Short and long-term effects of flooding and power outages on business continuity and economic recovery
- Post-storm complications limit access to food, transportation, and shelter particularly in lower income neighborhoods
- Limited preparedness training for municipalities and social service organizations
- Effects of coastal hazards on municipal grand list - vulnerability of tax base
- Negative effects of natural resource degradation on economy, especially tourist sector

## Solutions

- Conduct fiscal impact study of extreme weather and sea level rise scenarios to strengthen commitments from community leaders and elected officials
- Improve coordination of disaster recovery between public and private stakeholders
- Reduce long-term over-reliance on high-value, residential property for tax revenue
- Prioritize compact mixed-use areas by infilling downtown and village centers outside of flood hazard areas
- General diversification of the economy to increase collective revenue streams and reduce the demands on local ecosystems

# Cross-Sector Resilience

## Challenges

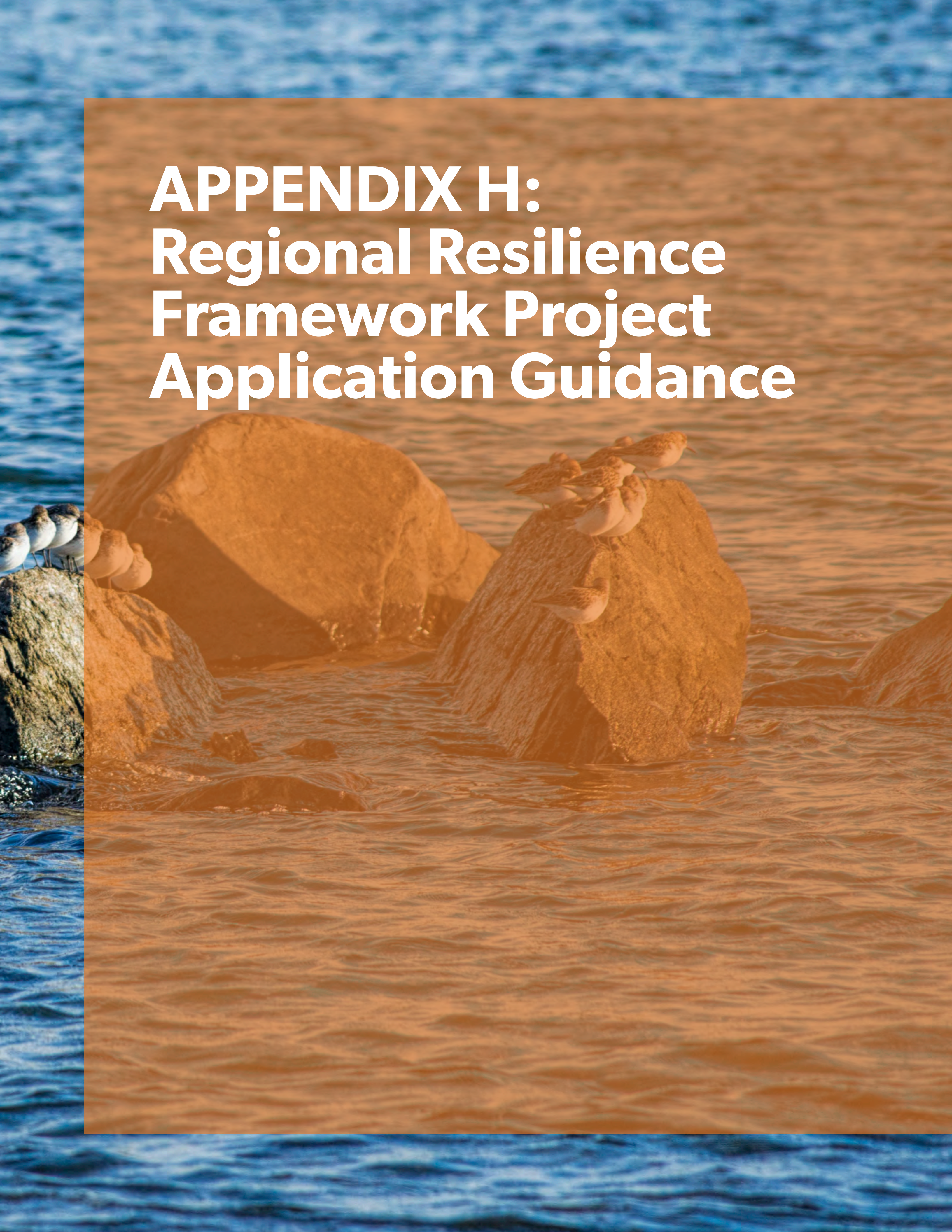
- Rising sea level intrusion into aquifers, drinking wells, and septic systems
- Effects of drought on water quantity and quality for natural resources and the derived services and co-benefits for residents
- Flood vulnerability of critical transportation centers such as New London
- Preparedness and capacity to recover quickly from flooding and high wind events
- Short and long-term effects of flooding and power outages on business continuity and economic recovery
- Insufficient capacity of aging and outdated stormwater systems to handle current and future precipitation and sea level rise
- Limited processing infrastructure for food producers and distributors
- Lack of ecosystem service value integration in existing and future development projects
- Aging infrastructure including roads, rail, bridges, and other public infrastructure
- Uncertainty surrounding the future of local energy production and supply may hinder further investment in local energy resilience infrastructure such as solar and micro-grid technology

## Solutions

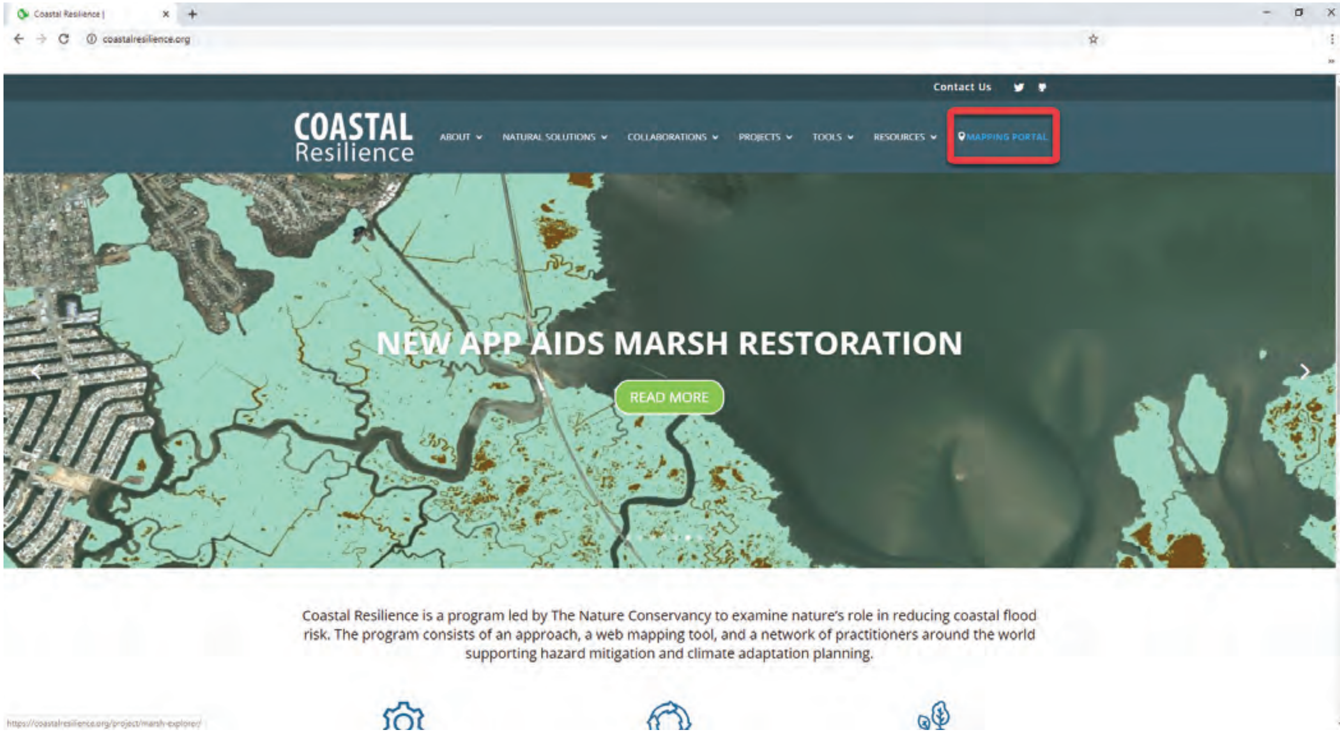
- Develop a regionally specific decision support process to help municipalities assess and plan for flooding, efficient use/re-use, and nonpoint source pollution, simultaneously
- Integrate natural infrastructure into zoning codes to reduce conflicts between development and community resilience
- Collaborate on largest regional transportation vulnerabilities and share planning, engineering, and monetary resources across municipalities to enhance regional resilience
- Conduct fiscal impact study of extreme weather, drought, and sea level rise scenarios to strengthen commitments from community leaders and elected officials
- Build upon past projects and foster future opportunities across the region to utilize green infrastructure and improve gray infrastructure to enhance capture and infiltration of runoff
- Conduct a food-shed mapping effort across the region to determine sources and quantities of locally produced food
- Monetize services provided by natural assets when making economic growth and development decisions across the region
- Prioritize state and local funding for infrastructure improvements that contribute to overall community resilience across the region
- Identify steps to further strengthen and possibly redesign energy distribution system through partnerships across multiple municipalities

PHOTO CREDIT: Susan Rubinsky

# APPENDIX H: Regional Resilience Framework Project Application Guidance

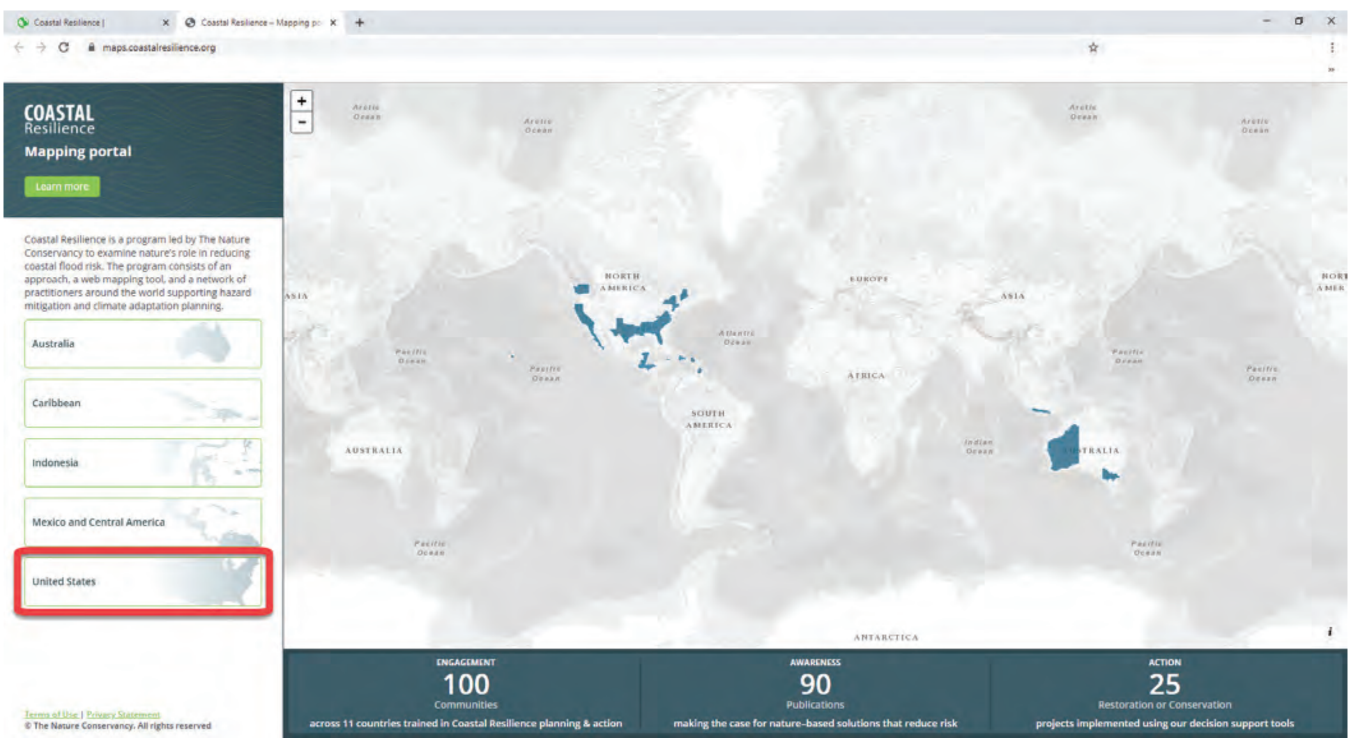


## Step 1



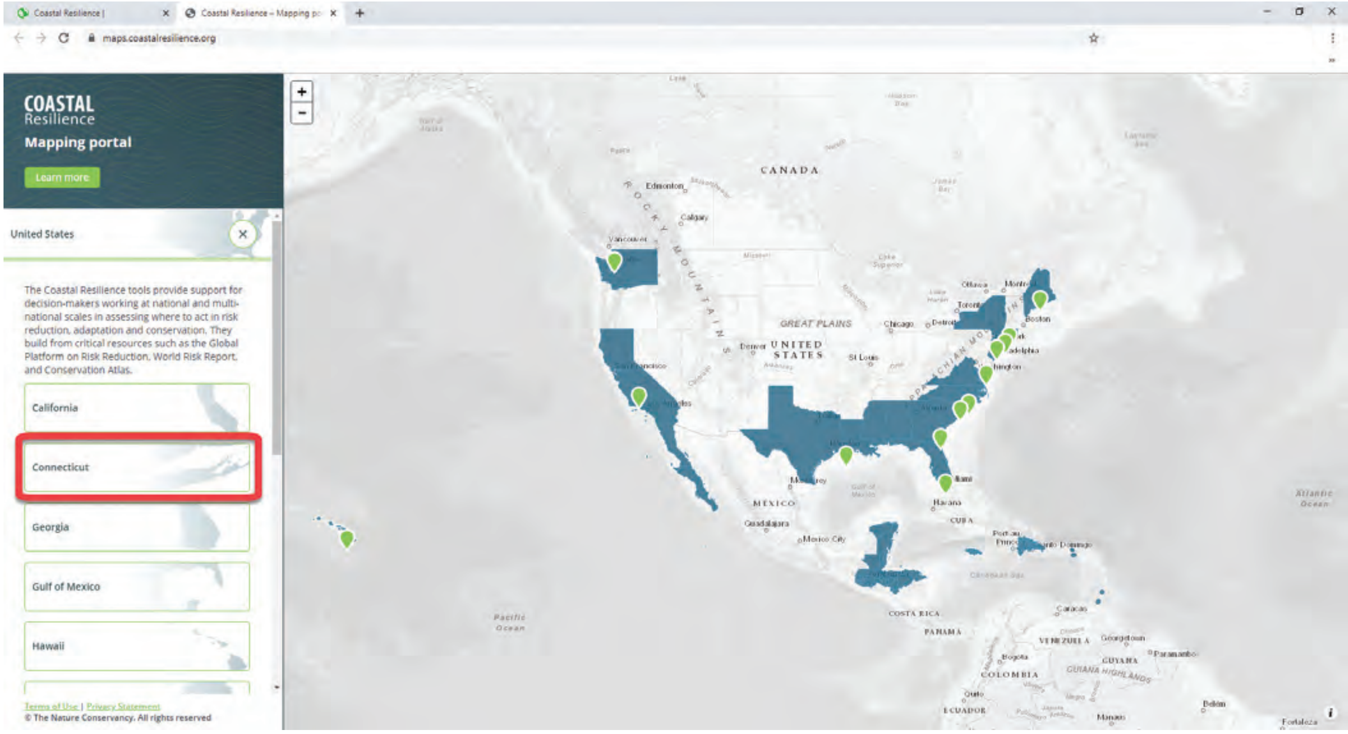

Log on to Coastal Resilience – www.CoastalResilience.org – and click on "Mapping Portal" from the upper horizontal toolbar.

## Step 2




Select "United States" and then "Connecticut" from left vertical toolbar and "Open Map".

# Step 3


COASTAL Resilience
Mapping portal
Learn more
United States
The Coastal Resilience tools provide support for decision-makers working at national and multi-national scales in assessing where to act in risk reduction, adaptation and conservation. They build from critical resources such as the Global Platform on Risk Reduction, World Risk Report, and Conservation Atlas.
California
Connecticut
Georgia
Gulf of Mexico
Hawaii
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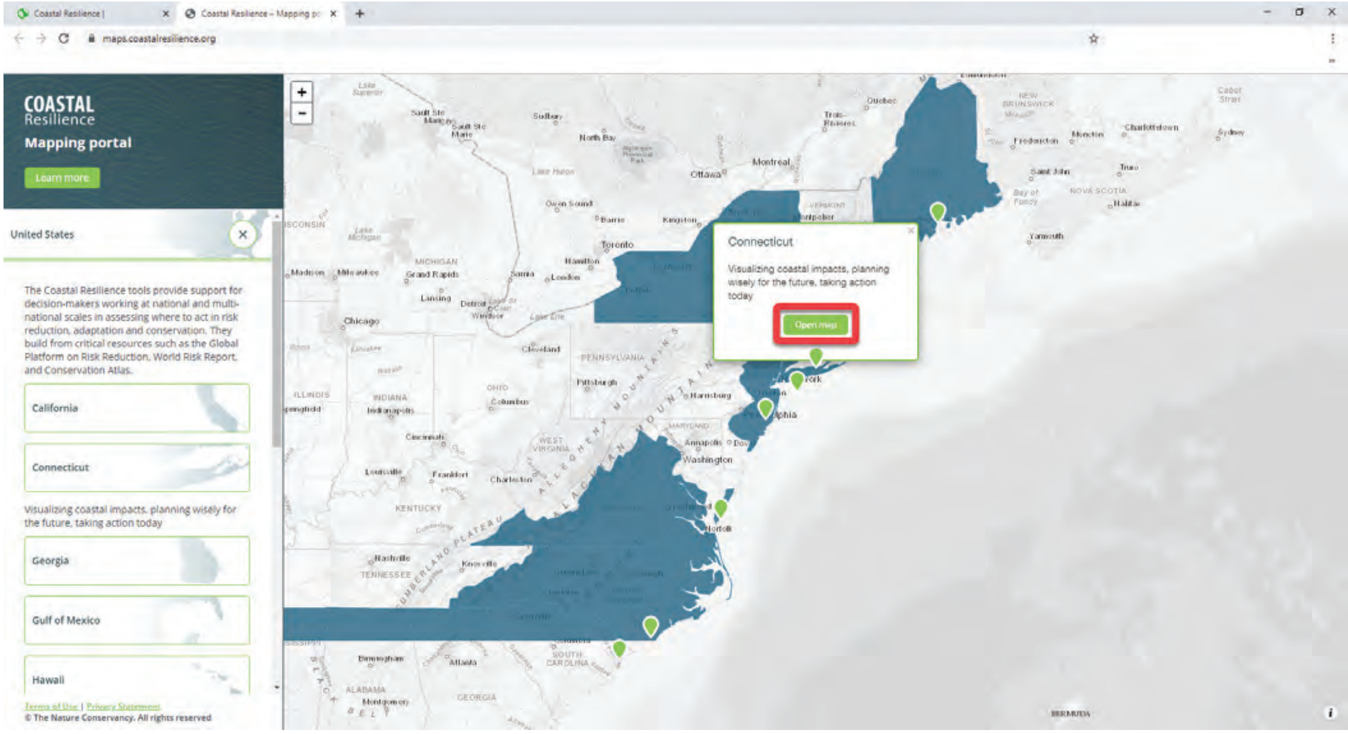
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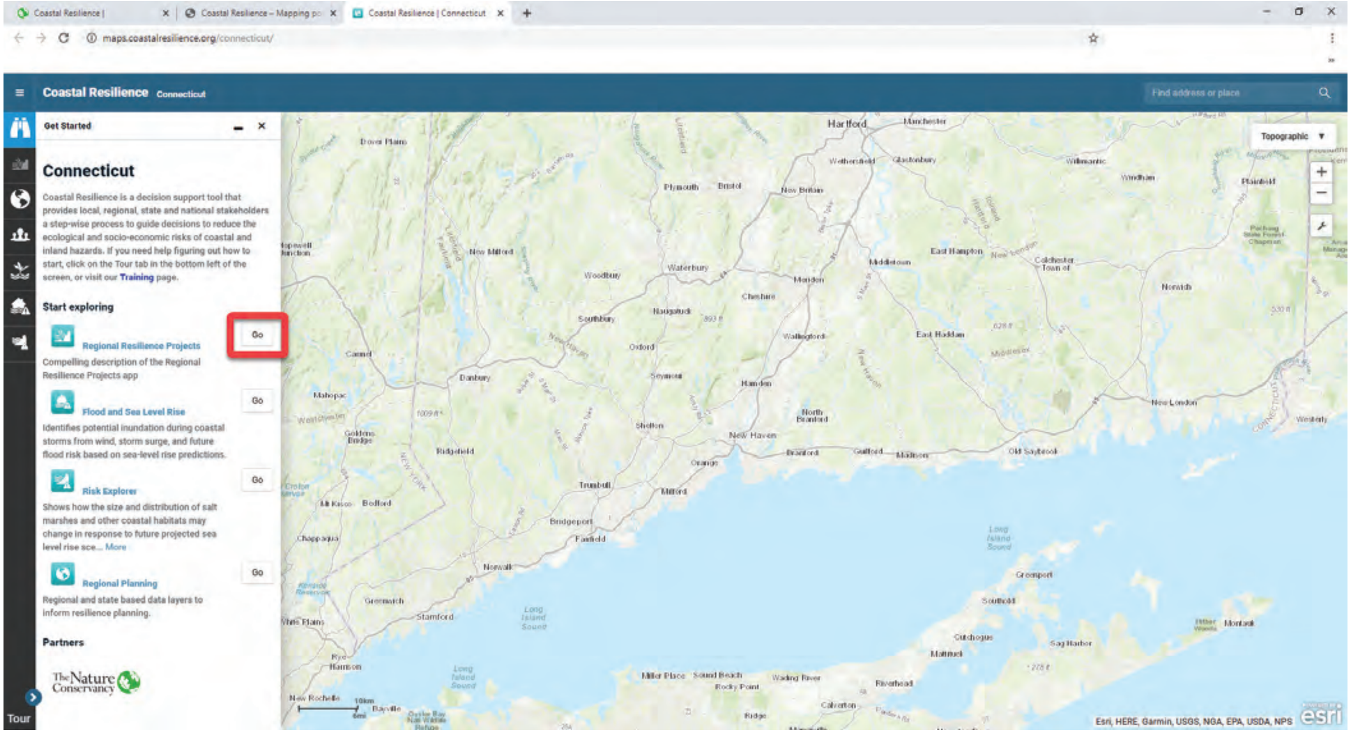
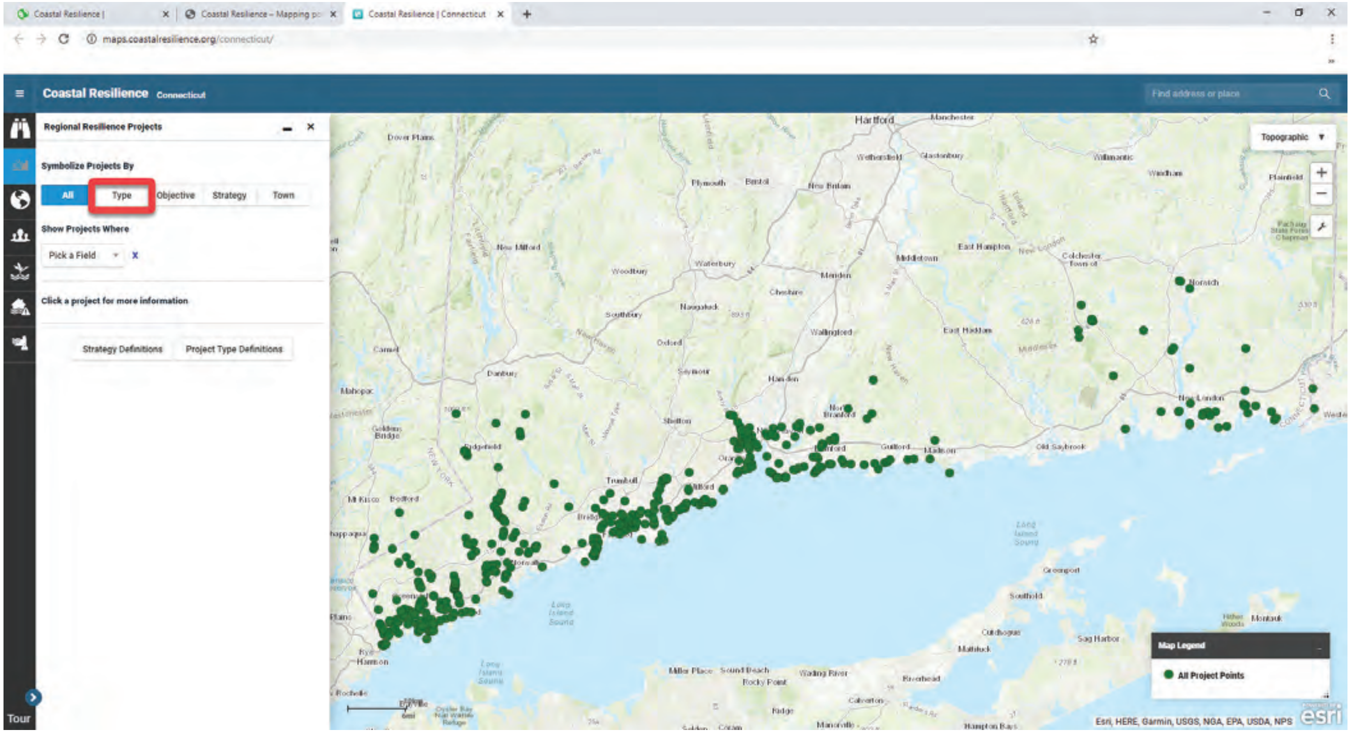
California
Connecticut
Visualizing coastal impacts, planning wisely for the future, taking action today
Georgia
Gulf of Mexico
Hawaii
© The Nature Conservancy. All rights reserved
Connecticut
Visualizing coastal impacts, planning wisely for the future, taking action today
Open map



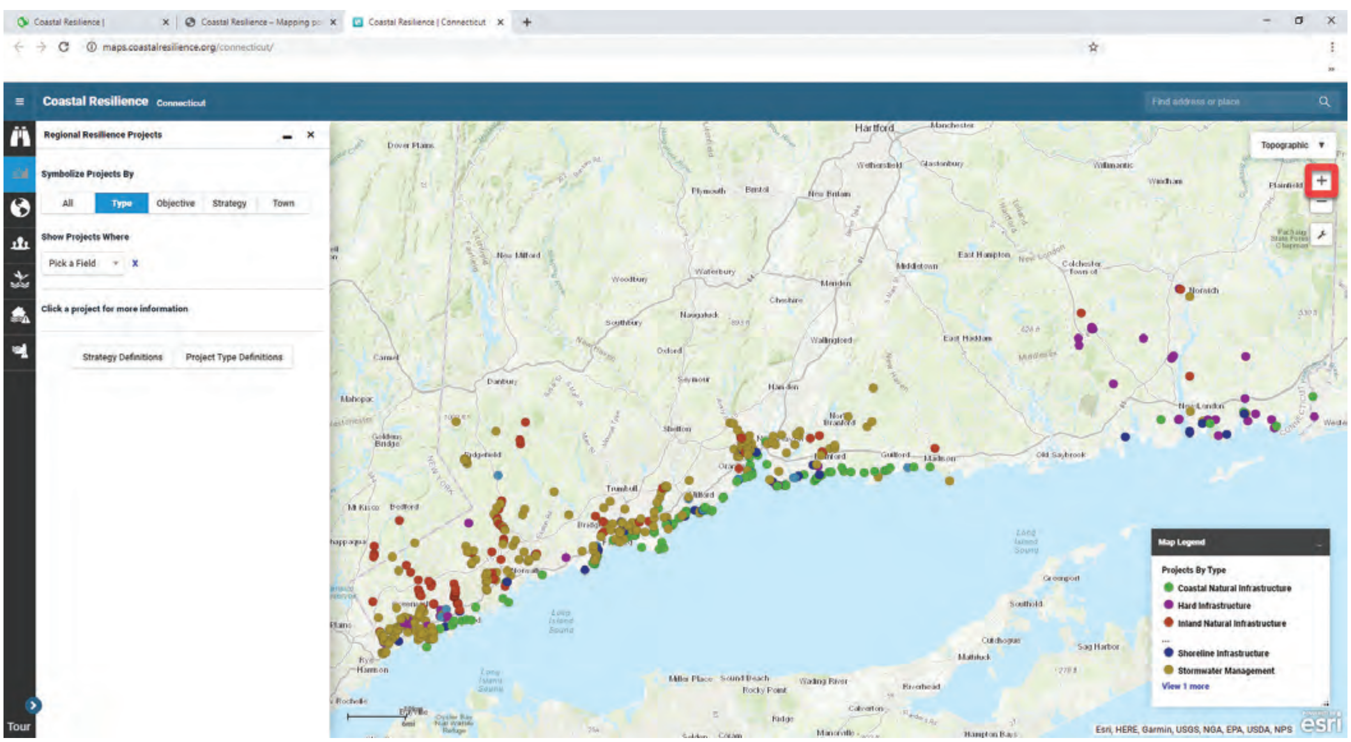

Click on “Regional Resilience Project App” in left vertical toolbar.

## Step 4



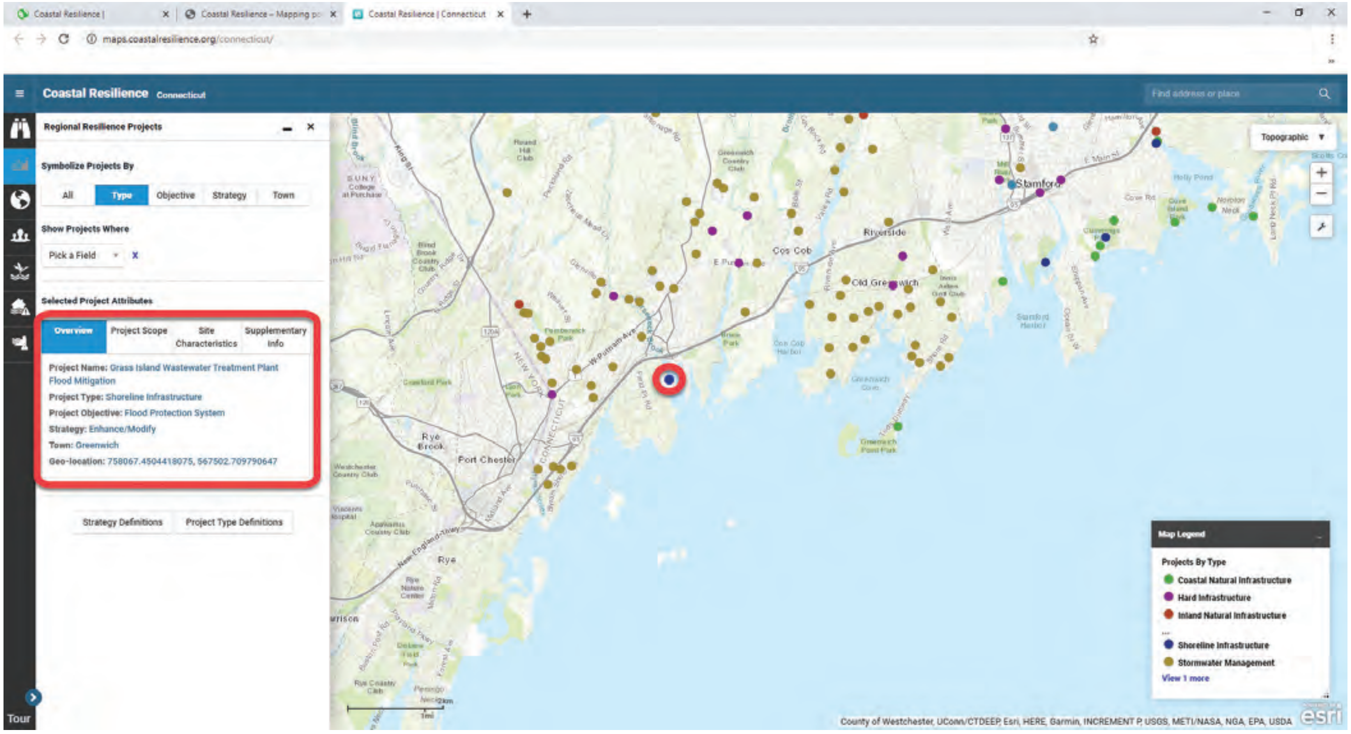

Review Regional Resilience Projects across the southeastern and the rest of the Connecticut coastal areas. Zoom “In” and “Out” and move around the site (click, drag, release). Click on Strategy and Project Type Definitions for a refresher. Create then “export” maps for meetings and reports.

## Step 5



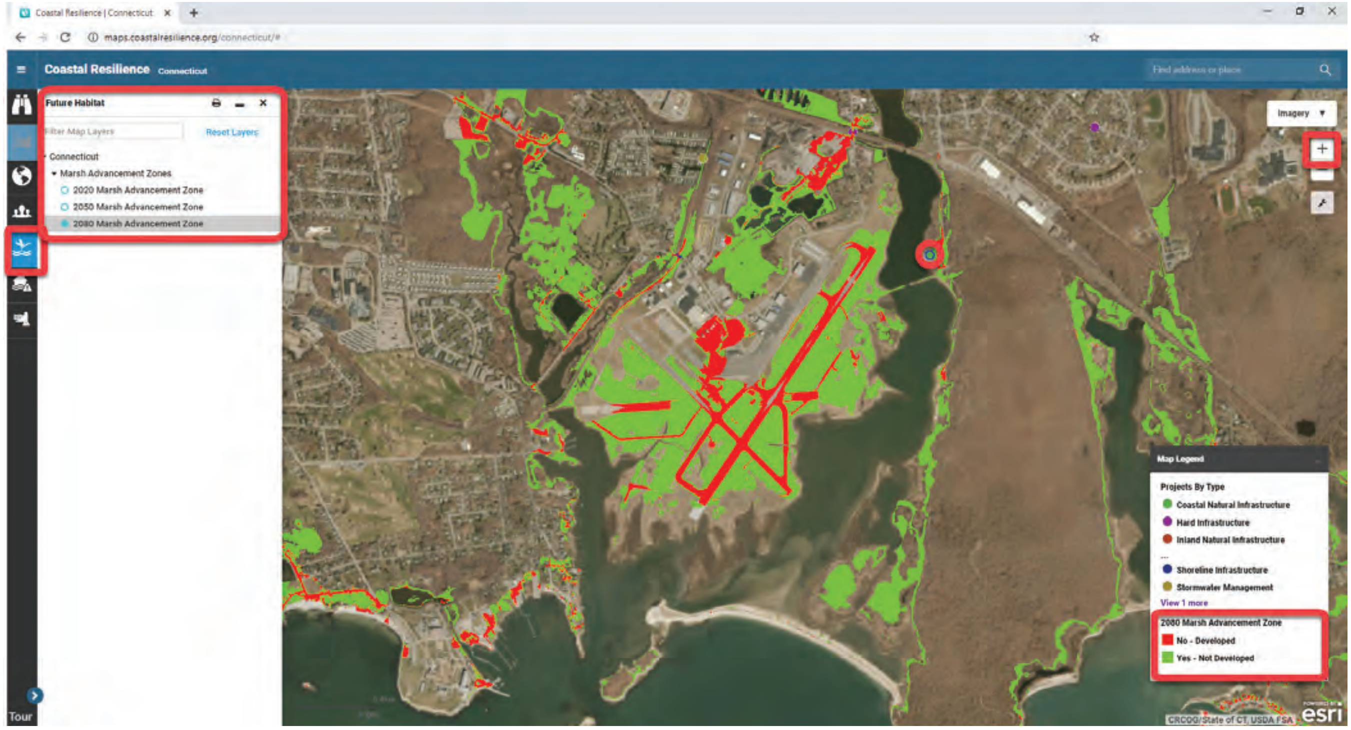

Begin sorting projects by selected “Project Type” in the tool bar menu.

## Step 6



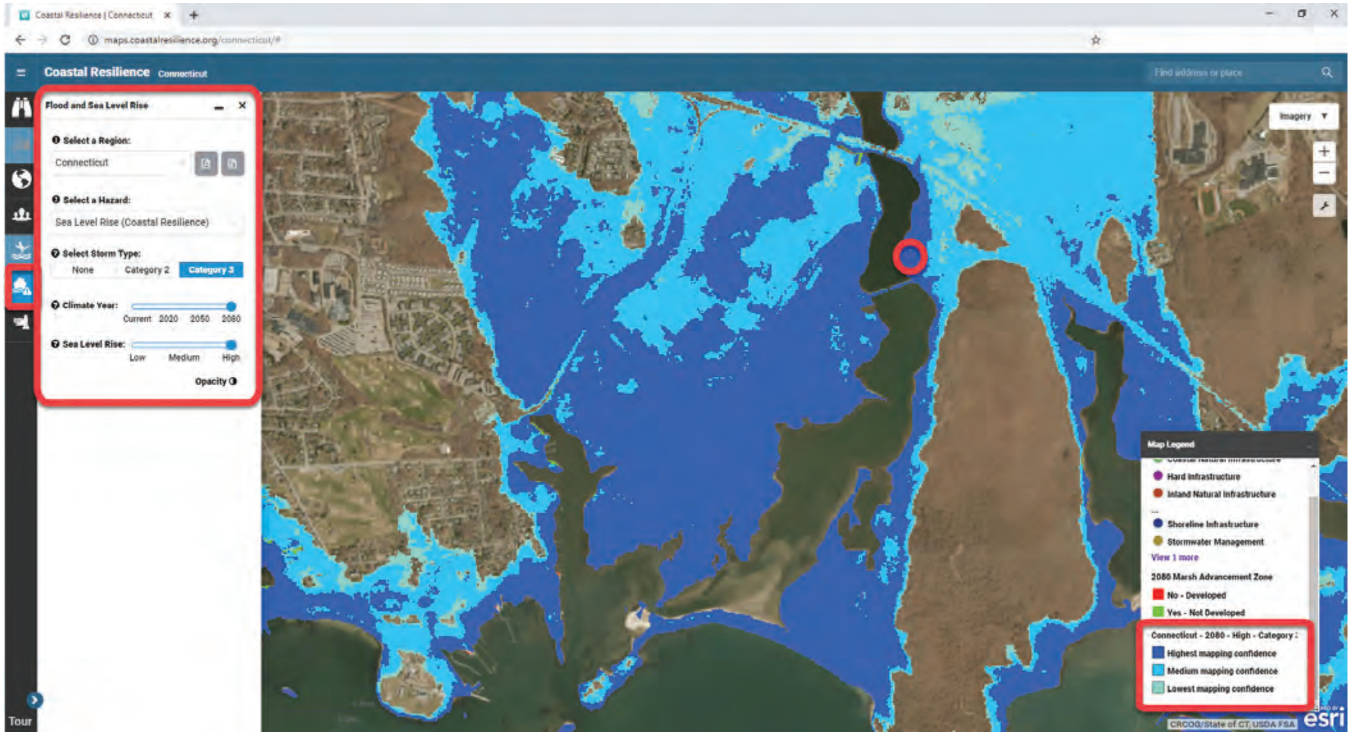

Zoom into area of interest to see project locations by "Project Type", "Objective", "Strategy", and "Town". Click on individual project dots to bring up "Overview", "Project Scope", "Site Characteristics", and "Supplementary Info". As seen above for example zoomed in and clicked open – Project Type: Coastal Natural Infrastructure; Objective: Tidal Marsh; Strategy: Restore; Town: Groton – Bluff Point Parking Lot Marsh Restoration.

# Step 7




Explore intersection of other geospatial layers on Coastal Resilience including Salt Marsh Advancement Zones in proximity to identified regional resilience project.

# Step 8




Continue exploration of intersection of other geospatial layers on Coastal Resilience including storm surge extent with and without downscaled sea level rise scenarios that may impact the design and implementation of identified regional resilience project.

## ABOUT THIS PROJECT

This endeavor was supported through a grant from The Community Foundation of Eastern Connecticut. Without this continued support, this important community resilience building work within and across the communities of southeastern Connecticut would not have been possible.

Southeastern Connecticut is a collection of communities each with its own individual identity and history. The fate of each community is closely tied to the social, environmental, and economic health of the whole region. The challenges facing southeastern Connecticut are best tackled collectively with multiple towns, organizations, agencies, departments, associations, institutions, foundations, and businesses working together to advance this Southeastern Connecticut Regional Framework for Coastal Resilience. Our sincere hope is that this Regional Resilience Framework development process and Final Report helps communities build greater clarity on the common challenges and strengths they face and have while providing a positive vision for continued dialogue, resource sharing, and forward-thinking leadership needed for community resilience building here in Connecticut and beyond.