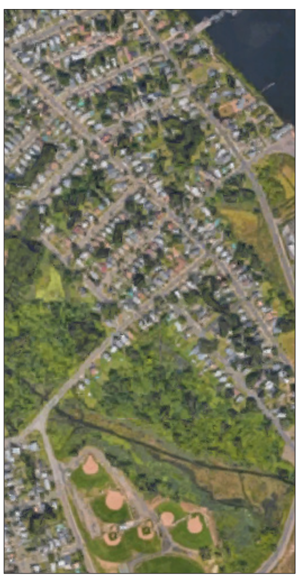
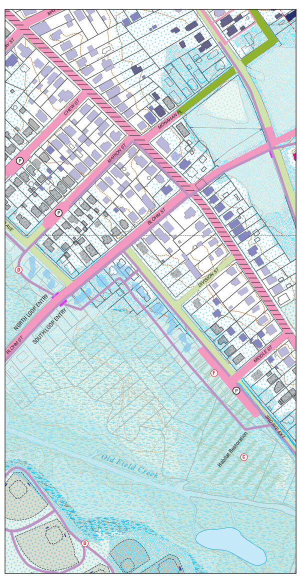
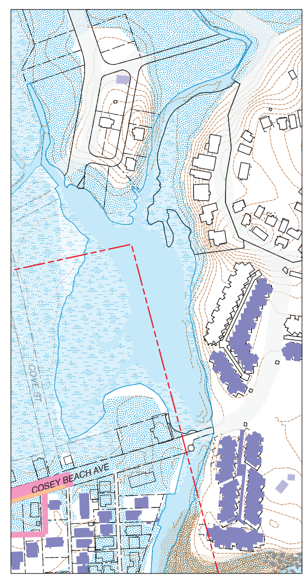
Design and Technical Guide

For Implementing Innovative Municipal Scale Coastal Resilience In Southern Connecticut



UED LAB Yale ecopolitan design

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The mission of the Connecticut Institute for Resilience and Climate Adaptation (CIRCA) is to increase the resilience and sustainability of vulnerable communities along Connecticut's coast and inland waterways to the growing impacts of climate change on the natural, built, and human environment.

More information about CIRCA can be found at circa.uconn.edu.

Design and Technical Guide

For Implementing Innovative Municipal Scale Coastal Resilience in Southern Connecticut

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Executive Summary

The Design and Technical Guide For implementing Innovative Municipal Scale Coastal Resilience (Guide) was made possible through a Connecticut Institute for Resilience and Climate Adaptation (CIRCA) Grant. The project advances the analysis completed as part of The Nature Conservancy (TNC) Coastal Adaptation Project, in which Principal Investigators evaluated near, mid-, and long-term plans for the coastal communities of East Haven and West Haven.

The Principal Investigators in the TNC Coastal Adaptation project sought to integrate infrastructure analysis and risk management with urban design strategies including social and ecological goals and investment for resilience. This was a complementary effort to the Regional Framework for Coastal Resilience in Southern CT Project. The Southern Connecticut Regional Framework for Coastal Resilience (Regional Framework) is a partnership between SCRCOG, Metro COG, and The Nature Conservancy, and was funded through the Superstorm Sandy Coastal Resiliency Competitive Grant Program administered by the National Fish and Wildlife Foundation. The main objective of the Regional Framework was to comprehensively assess and advance resilience opportunities to reduce risk to the 591,000 residents across ten coastal municipalities and increase the viability of natural ecosystems along a significant portion of the Connecticut coastline.

The project integrates economic analysis with landscape architecture and planning tactics, focusing on critical scales of decision-making and action within municipalities. The strategies address land use changes and innovations in housing, landscapes, and habitats, roadways and utilities, towards a cohesive transformation of an urban coastline, over time. The three scales that we focus on for this report include: municipal-wide scale planning, a scalable boundary that we define as 'zones of shared risk,' designating sub-populations of homeowners facing similar risks, and the individual property homeowner scale. These scales were the most relevant when connecting economic analysis to planning.

The two selected locations analyzed in this Guide, East Haven and West Haven, are at different stages in planning for and adaptation to evolving coastal risks. Each location has a specific settlement density and habitat typology, and distinctive patterns of hydrology, erosion, and waves. The analysis for the two diverse locations included a range of flexible and integrative approaches to coastal adaptation. These approaches can guide other Northeastern coastal communities facing similar challenges.

Building on these experiences and findings, we propose to translate the innovative but practical near-, mid- and long-term plans developed collaboratively with municipalities into targeted implementation strategies. In particular, we compare the costs of these more innovative approaches with traditional practices. The project team included a landscape architect and economist from Yale University connected with an advisory group including regional planners, a land use attorney, and town engineers. A main goal was refining initial design proposals and leveraging an economic analysis to guide the planning process and inform municipal planning.

Through a process of quantitative economic analysis and qualitative design thinking and outreach with municipal leaders, we sought to create a phased project that positions the municipality to achieve viable long-term coastal adaptation strategies. Building on municipal meetings, we identified priority areas and refined the selection of particular locations as targets for economic analysis of resiliency options. We evaluated the benefit of wall building, road raising, tide gates, inland protection and no action, based on the costs and the potential to mitigate storm impacts. Leveraging the economic model, we evaluated a grade of grey to green armoring interventions at selected locations to reduce risks of probabilistic storm events. We analyzed results iteratively, within the context of alternative time horizons, and their influence on choices for protection and prioritizing projects, to plan and educate homeowners about how to chart paths of incremental change towards realizing collective benefits.

The details for the economic model were defined during meetings with the municipalities and advisors. The goal was to align the economic analysis and ecological planning with municipal and homeowner interests to create an economic model that can serve as a decision-making support tool. Models were made that predicted sea level rise and storm surge inundation before being used to predict property damage. A design framework was established to prioritize projects based on their ecologic and economic factors. Alternatives were considered that minimize property loss and damage to wetlands. The economic model was developed to assess the impacts of alternative strategies by measuring their benefits and costs, with the goal of assisting in the decision-making process for coastal planning.

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The Design and Technical Guide is intended to be a prototype serving as a toolkit for municipal planning. The comparable options based on economic analysis still required additional interpretations regarding existing infrastructure investments, ecological considerations, and considerations of social demographics. The tool is intended ultimately to provide a guide for the transition from towns driven by hard infrastructure, road transportation and developer-driven housing to spaces created with equity, human health, ecosystem function, and climate change as drivers of planning and design. The East Haven and West Haven coastal resilience redesign is the focus of the document, however, the thought process presented poses possible design considerations for a number of future locations. Though site-specific planning should be factored for a number of future locations, this guide is a framework for possible solutions and presents an economic prioritization tool that, once calibrated for new locations, will be influential in many coastal redevelopment efforts.

Acronym List

BPJ Voting Matrix
FILL IN HERE

CIRCA
Connecticut Institute for Resilience and Climate Adaptation

CJL
Coastal Jurisdiction Line

DEEP/DEP
Department of Energy and Environmental Protection

EGS
Ecosystem goods and services

FEMA
Federal Emergency Management Agency

F&ES/FES
Yale School of Forestry and Environmental Studies

FIRM
Flood Insurance Rate Map

GEV
Generalized Extreme Value

GIS
Geographic Informational System

HUD NDR
U.S. Department of Housing and Development National Disaster Resilience

HAZUS
Hazus is a nationally applicable standardized methodology developed by FEMA that contains models for estimating potential losses from earthquakes, floods, hurricanes, and tsunamis.

LIDAR
Light Detection and Ranging

LISS
Long Island Sound Study

MEA
Millennium Ecosystem Assessment

MHHW
Mean High High Water

NAVD 88
North American Vertical Datum established in 1988

NNBF
Natural and nature-based

NOAA
National Oceanic and Atmospheric Administration

SCRCOG
South Central Regional Council of Governments

SLR
Sea level rise

SRTG
Self Regulated Tide Gates

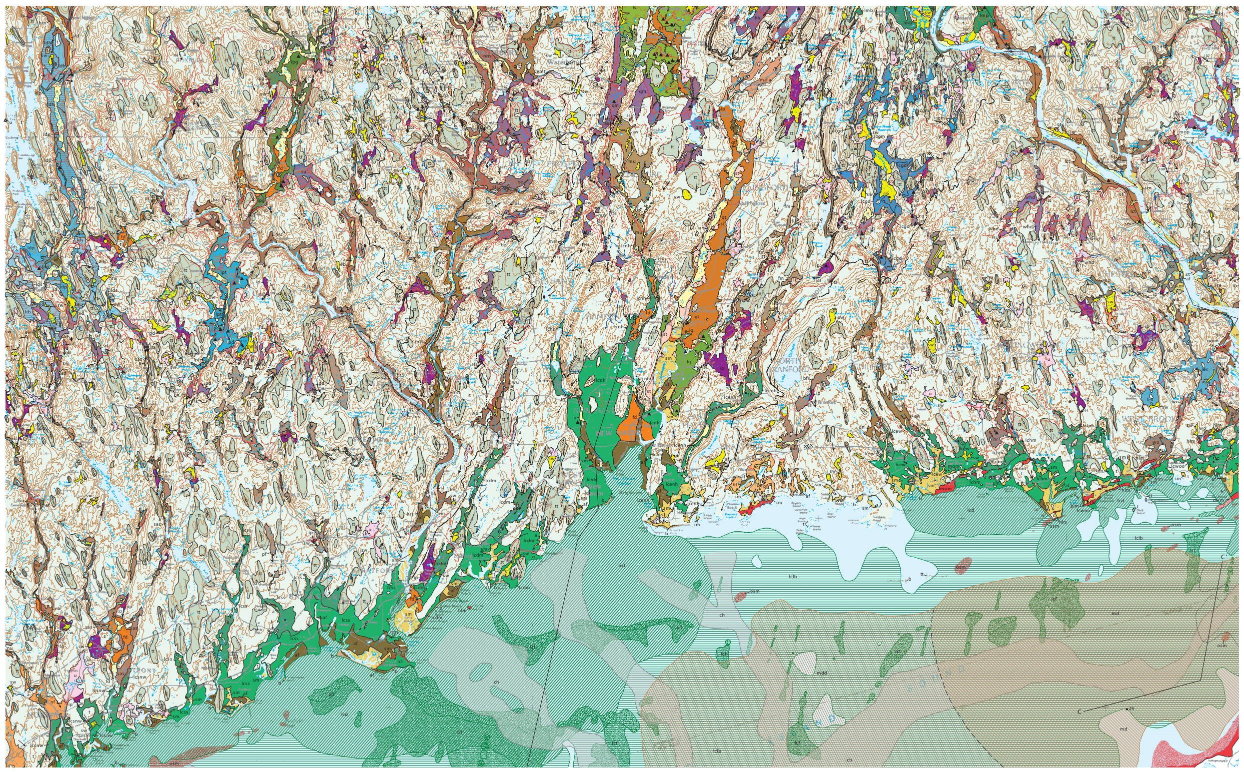
TES

TNC
The Nature Conservancy

UCONN
University of Connecticut

UEDLAB
Urban Ecology and Design Laboratory

OVERVIEW



Quaternary Geologic Map of Connecticut and Long Island Basin, 2005[1]

Overview

Flooding and Urbanization Challenges

Recent flood events, including Superstorm Sandy and Hurricane Irene, have caused considerable damage and threatened extensive areas of the Connecticut coast. These risks, and the uncertain impacts associated with climate change and sea level rise, are pushing municipl leaders to reconsider their position on how to manage housing and infrastructure within the floodplain. Compounding these risks from flooding is a broad change in federal policies concerning subsidizing flood insurance. The new policies will force homeowners to pay a much higher price for insurance if they fail to reduce these risks. Municipal leaders are, therefore, increasingly recognizing the need to shift from maintaining the status quo (a common default position) to a more proactive position on preparing their towns for flooding. Municipal leaders are now recognizing the consequences of inaction in the face of flooding that pose threats to infrastructure, housing and residents and their quality of life.

As municipalities engage in planning efforts to protect their coastal resources and inhabitants, there is also a growing awareness that coastal protection is expensive and complicated by issues including property ownership, infrastructure legacy, and uncertainty around flood risks, and, thus, demand careful consideration. Funding constraints and prohibitive costs make it difficult for municipalities to execute projects effectively. While some adaptation efforts are underway, efforts are complicated by the financial pressures, regulatory constraints, local government politics and the disproportionate distribution of risks. The National Oceanic and Atmospheric Administration (NOAA) Technical Report OAR Global Sea Level Rise Scenarios for the United States National Climate Assessment suggested planning for a range from 0.2 to 2m, a factor difference of 10.[2] This analysis was based on aggregated data for the Intergovernmental Panel on Climate Change (IPCC) version 4 which created a consensus global sea level trend that included hundreds of parameters such as ocean circulation patterns, temperature in air on sea growth, temperature effects on ice melt and changing wind pattern as the global temperature changes. These projections incorporated a range of reasonable values for each of the processes that they were assessing. Scientists agreed on four scenarios based on over a hundred model runs. Each run had a prediction for global sea level, global winds, and global temperature, projecting how sea level would change. These global models are then downscaled for different regions, but this process increases the uncertainty. The number of options and the wide ranges fuel debate. In addition, the regulatory framework and differences at the local, state and federal level create challenges for navigating and prioritizing responses. All of these factors create an uneven understanding of impacts and adaptation options and thereby impede stakeholders and the ability for municipal leaders to conceptualize the problems. There is a need, now more than ever before, for a deeper analysis of alternative choices and more dialogue between interested parties.

There is a need to evaluate the outcomes both quantitatively and qualitatively so that institutions and engaged citizens can comprehend the consequences of their choices. Of course, people and institutions will weigh some consequences as more important than others. Conflicts associated with making these choices are inevitable.

The purpose of this analysis is to clarify the economic impacts of different adaptation options and to understand the individual consequences to homeowners and segments of towns on a broader, more accessible level. Communication helps people understand how collective actions affect others and themselves individually.

Connecticut Coast

With over 96 miles of coastline, including bays, harbors and coves with many salt-water influenced waterways, Connecticut is second only to Florida in terms the fraction of land that sits within the floodplains. Naturally, the coast is also where a significant portion of the development, density, economic vibrancy and infrastructural corridors in the state have formed, in large part because of Connecticut's proximity to water. In addition, coastal communities contain 60% of the state's population. With the second highest exposure of vulnerable coastal assets on the eastern seaboard, and more than $542 billion at risk to coastal storms, Connecticut must develop an economy that is resilient to climate change. At the same time, it should be noted, the topography in Connecticut creates flood risks in small patches in between areas of higher ground along the Sound. Thus, some Connecticut homeowners face risks while many others adjacent can live on the coast with little concern. While the risks that Connecticut faces differ from the homogeneous and overwhelming risks faced in the Outer Coastal Plain of New Jersey, the Outer Banks of North Carolina, and the New Orleans sand levees, the heterogeneous condition along the Connecticut coast invites a wider variety of ecological management techniques under targeted site-specific and replicable conditions. Connecticut provides a strong research and design test bed for future coastal resilience strategies and solutions, nationally and internationally, at a block, neighborhood, or district scale.

The Impact of Superstorm Sandy

Northeast coastal communities are heavily settled and vulnerable to sea level rise and increasingly severe and frequent storm surges. Critical infrastructure, ecosystems, and human safety in these towns are under threat.[3] These vulnerabilities were felt acutely following Tropical Storm Irene (2011) and Hurricane Sandy (2012), including in the two coastal communities within the project area (East Haven and West Haven). New Haven and Fairfield Counties were designated by HUD as the most impacted and distressed counties in the State of Connecticut, due to Superstorm Sandy. 2,853 single-family homes in Fairfield County and 1,165 in New Haven County were damaged during Superstorm Sandy. Unmet recovery needs totaled more than $158 million from housing ($135,789,167) and infrastructure ($22,360,508), including eight (8) public housing properties totaling 815 units in the 100-year floodplain. Additional unmet need would reach into the hundreds of millions of dollars. More than 32,000 homes lie in the 100-year floodplain.

Since Superstorm Sandy, the State of Connecticut remains vulnerable to future storm events, an exposure that will be exacerbated by climate change. Estimating a sea level rise of up to approximately 12” by 2050[4], coastal communities remain vulnerable to a changing shoreline and flooding due to more frequent and intense storm events.

QUANTITATIVE ECONOMIC MODEL

Quantitative Economic Model

Overview

Our economic prioritization template and decision-making tool couples economic theory with science to yield a methodology to assess the costs and benefits of a wide set of alternative planning scenarios. These scenarios have been developed collaboratively with academic practitioners and municipal engineers. The approach combines a decade of direct experience working with coastal communities on resiliency planning including the development of the first coastal resilience plan in the State of Connecticut, working with Guilford, along with an economic theory and model of coastal defense planning, first developed by Ou, Albis, and Mendelsohn (2017), that views coastal defenses as a resource allocation challenge. The approach also builds on the concept of zones of shared risk, developed as part of the Guilford Coastal Resilience Plan (2015). The approach recognizes that the coast is composed of heterogeneous segments each of which includes sub-populations facing different risks and rewards to protection so that they should be managed differently. This approach looks at the costs and benefits of taking actions to manage housing in each segment of the floodplain through a combination of protection and adaptation and no action. For East Haven, we focused on a municipal-wide consideration of the risks and opportunities and developed an economic model that the municipal officials can consider as a guide for planning. We compared this municipal-wide strategy with different approaches in the eastern and western parts of the town. For West Haven, we focused on a particular area (Old Field Creek) that includes a large inland wetland and adjacent wastewater treatment system and a perimeter (coastal) road. This is a fairly common land use configuration in coastal areas of Connecticut. The economic analysis explores alternative scenarios that address the multiple factors at play.

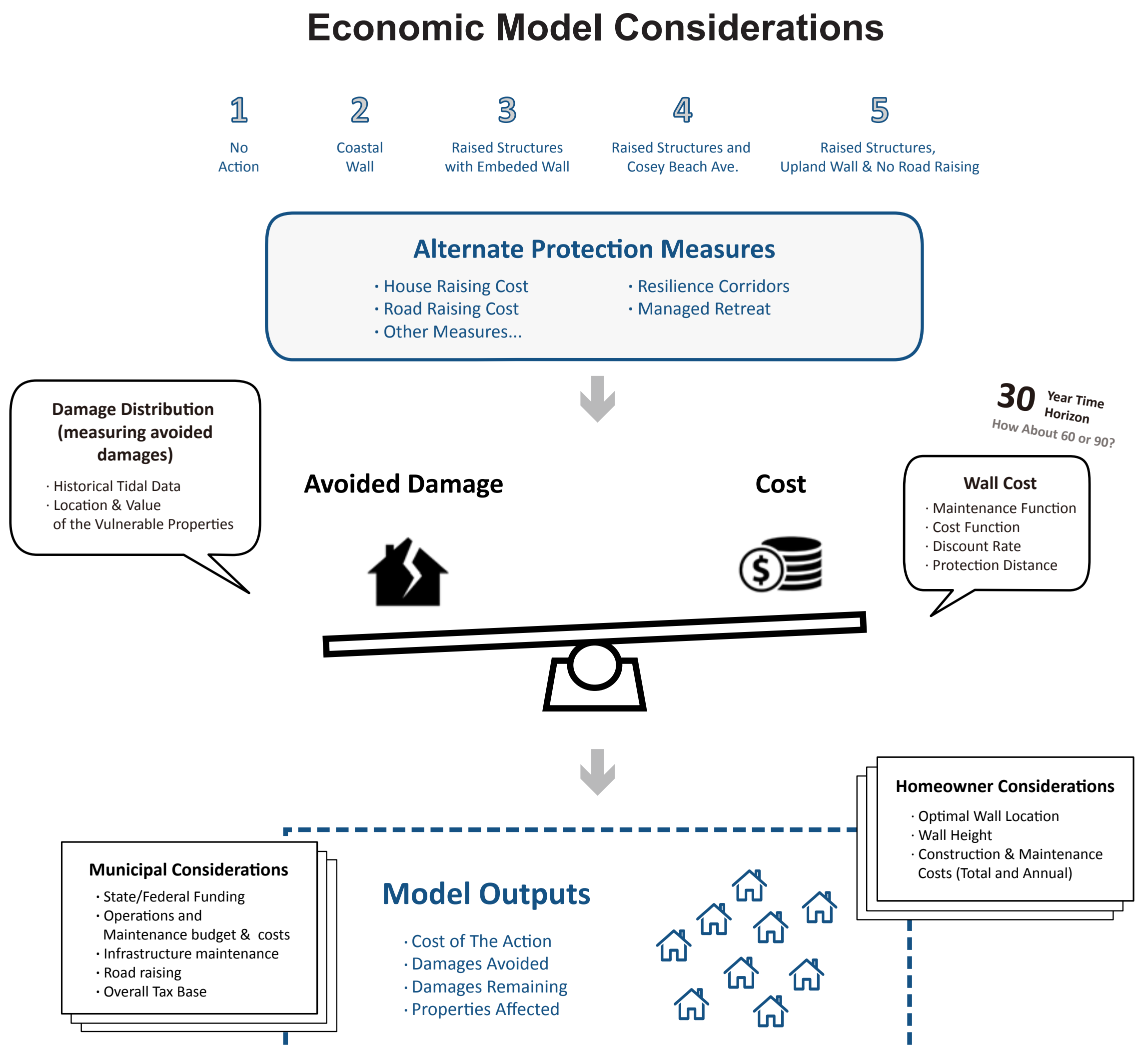
$$t(x) = \left[1 + k\frac{(x-\mu)}{\sigma}\right]^{-\frac{1}{k}}$$

$$F(x{:}\,\mu,\sigma,k) = e^{-t(x)}$$

$$f(x{:}\,\mu,\sigma,k) = \frac{1}{\sigma}t(x)^{k+1}e^{-t(x)}$$

This equation calculates the Storm damage. The steps include: (1) calculating the probability density function of storm intensity, (2) calculating flood height for each property by storm intensity, (3) calculating flood damage at each property, and (4) calculating probability density function of total damage in each area.

Fundamentally, this analysis seeks to minimize the sum cost of protection and the expected remaining damage from storm surge and sea level rise. The probability of storm surge is calculated from NOAA tidal data.[5] This same data set also provides an estimate of near term sea level rise. In order to measure vulnerability, a census of structures in the low lying areas in each segment are determined using Geographic Information Systems (GIS) tools, elevation maps, and town data. This establishes which properties are vulnerable to flooding. Finally, a damage function is taken from Federal Emergency Management Agency (FEMA) Hazus program (HAZUS) to predict what damage would occur from a flood to each building. Combining this data allows the model to measure the benefits of coastal protection specifically for housing. Existing infrastructure was identified through discussions with the municipal engineers and considered as part of the planning process. Ecosystems, such as wetlands and floodplains, were also taken into account as part of the planning process, but not incorporated into the economic model. The benefit of each action is the reduction in damage that it causes. The quantitative cost is simply what a town or its citizens would have to spend to implement a specific plan. Qualitatively, the team explored issues of



Economic Model: focuses on five possible actions and possible measures. The model compares costs of actions to avoided damages with the goal of minimizing the sum of the wall cost for protection of developed property against the potential damage based on historical tidal data, and location and property value. The model reveals that the cost of barriers are propositional to the square of the height times the coastal length. Damage depends on both SLR and storm damage. Storm damage is death and destruction from temporary flood/SLR damage is permanent lost land and capital. Based on this analysis municipalities and homeowners have several considerations listed above.

aesthetics, floodplain management and ecosystem function through alternative planning scenarios.

This tool can then be used to evaluate alternative strategies to protect the coast including taking no action, road raising, building walls, lifting houses, or anticipatory retreat. The tool reveals the relative merits and trade-offs of alternative plans focusing on the cost and benefit to housing. For example, wall building may minimize the sum of the cost of action and damage, but it may also reduce the ability of wetland areas to migrate. Lifting houses may be a good strategy to address properties that cannot be protected by walls and may allow floodplains to co-exist but may make providing infrastructure more complicated and reduce the aesthetics of the neighborhoods. Raising streets may provide viable egress routes and may support infrastructure maintenance while also allowing for economic development, establishing elevated finished floor elevations to match the height of the raised road in future housing. Raised streets, in some circumstances, may act as walls. Anticipatory retreat condemns housing in advance of a storm while reducing issues with repetitive flood loss homes and re-establishing areas of the floodplain for flood management. While these houses are no longer damaged when a storm strikes, it is relatively expensive to buy out housing. One example is currently underway in West Haven as part of the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) - Emergency Watershed Protection (EWP) buyout program. The study will examine a variety of planning and design scenarios, including a range of economic defined 'optimal' and 'sub-optimal' plans and their associated compromises, so that decision makers in the towns and the residents can see the range of possibilities and associated trade-offs to determine the most desirable options for moving forward.

Generalized Extreme Value Equation Parameters

x	5
k	0.1748803
σ	0.1336775
μ	1.5910596

t(x)A	6.09173E-05
CDF	0.999939085
PDF	8.34623E-05

Damage Function Parameters

100% Damage Upper Bound	7
0% Damage Lower Bound	-2

Scenario for data informing Storm damage through the Generalized Extreme Value Equation Parameters

Damage

The model applies an empirically-derived function from NOAA tidal data measuring the frequency of storm surge of different magnitudes. The model also uses an empirically derived rate of sea level rise from local NOAA tidal data. The vulnerability of each coastal segment is derived from town data that describes the number and value of properties at different elevations along the coast. Combining the frequency of storms at each storm surge height and the flooding damage at each property from each storm surge height, one can estimate the damage each storm causes to each property. Aggregating this data across vulnerable properties, one can calculate the aggregate damage of each storm. Combining this with the frequency of each storm, one can calculate the annual expected storm surge damage from storms.

More specifically, the model estimates the likelihood of storm events of different magnitude using NOAA tidal data. This analysis reveals that tides often exceed Mean High High Water (MHHW) but the higher the surge, the less frequently it occurs. Very high surges are consequently rare in Connecticut. Using this tidal data, the model computes a Generalized Extreme Value (GEV) function, which measures the frequency of tides above MHHW along the CT coastline.

To translate floods into damage, the model uses the empirical damage function in HAZUS that predicts the damage at a property given the value of the structures on the property and the height of each flood relative to the elevation of the properties first floor.[6] Damage is proportional to building value. The proportion increases linearly from -1 m (-3 feet) to 7m (21 feet) whereupon the entire structure is destroyed. Coastal flooding is particularly destructive because of the corrosive effect of salt water which ruins walls and electrical systems.

In order to compute the vulnerability of each coastal segment, the model uses GIS to identify the properties that will flood with each surge height. The elevation data is derived from LIDAR measurements made by the State of Connecticut.[7] The elevation of the centroid of each property is calculated from this data. The model uses a relatively simple calculation that compares the elevation of each possible storm surge to the elevation of properties nearby the sea. The model calculates which properties would be affected at each surge height. The model, however, does not compute how quickly the flood water would rise, so there remains a possibility that properties, which are far inland, would not be reached by a brief storm surge. Using GIS based data, we include information about the value of structures on each affected property.

Combining the GIS data, with the GEV probability function of storm surge, and the HAZUS damage function, it is possible to calculate the damage from each storm surge height for each property. One product of the model is that it identifies the actual expected damage at each property so that property owners can better understand their risks.

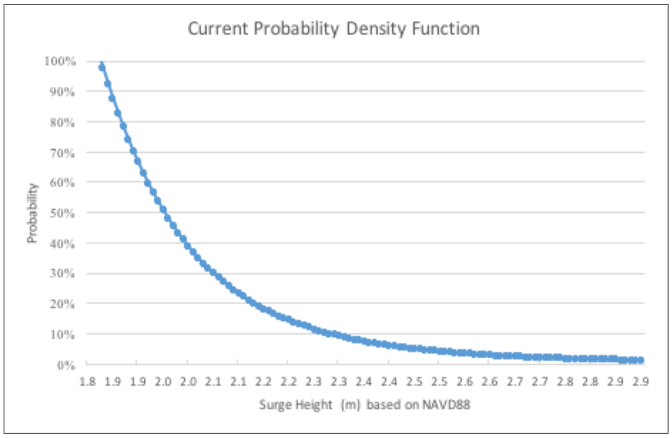
The aggregate damage within each coastal segment for each storm surge height is the sum of the damage of all the affected properties. The marginal damage associated with each storm height is the expected additional damage from a storm of that height each year. This expected marginal damage is the product of the actual damage when such a storm occurs times the probability that it would happen each year. The marginal damage is calculated for each storm surge height (in two centimeter increments) starting at MHHW (5 feet) and rising to 15 feet.

Findings

The results reveal that marginal expected damage falls as storm surge height increases. Although the actual damage from a storm rises with higher storm surge, the expected marginal damage falls because the probability of higher storm surges falls rapidly. The results also reveal that each coastal segment has a slightly different marginal damage function. There are many reasons for this. The probability of storm surge can vary by segment. This does not

B	C	D	E	F	G	H	I	J	K
STREET	**HOUSE NUMBER**	**ACRES**	**ZONING**	**SCRCOG LAND USE**	**LAND VALUE**	**OUTBUILDING VALUE**	**STRUCTURAL VALUE**	**TOTAL VALUE**	**SQUARE FOOTAGE**
COSEY BEACH AVE	392	0.13	R-3	Residential	1300	0	0	1300	0
COSEY BEACH AVE	390	0.13	R-3	Residential	409860	0	217345	627205	1964.688251
COSEY BEACH AVE	388	0.14	R-3	Residential	342760	28026	183991	554777	2386.089264
COSEY BEACH AVE	384	0.14	R-3	Residential	360800	0	251852	612652	2112.970301
COSEY BEACH AVE	380	0.14	R-3	Residential	288640	0	0	288640	1517.038294
COSEY BEACH AVE	376	0.16	R-3	Residential	369600	0	274561	644161	2236.009334
COSEY BEACH AVE	372	0.16	R-3	Residential	351120	13430	187094	551644	3643.869195
COSEY BEACH AVE	368	0.16	R-3	Residential	388080	6481	382699	777260	2846.45036
COSEY BEACH AVE	360	0.14	R-3	Residential	378840	11556	148509	538905	2220.42229
COSEY BEACH AVE	358	0.14	R-3	Residential	378840	6883	222671	608394	1944.90392
COSEY BEACH AVE	356	0.14	R-3	Residential	378840	0	360207	739047	0
COSEY BEACH AVE	354	0.14	R-3	Residential	360800	0	326704	687504	1638.309132
COSEY BEACH AVE	352	0.14	R-3	Residential	360800	11522	252871	625193	2407.478496
COSEY BEACH AVE	350	0.14	R-3	Residential	342760	12712	245857	601329	2444.870428
COSEY BEACH AVE	346	0.18	R-3	Residential	280500	0	0	280500	0

For housing data inputs, we used automated work flow for property selection in ArcGIS



Current probability density function graph

change a great deal within the CT coastline, but it varies significantly across the United States. But a more important reason that values vary across Connecticut is that each coastal segment has a different amount of low lying property value. Some coastal segments have either many properties or highly valued properties in these low-lying areas. They have much more vulnerability to storms and so have a much higher marginal expected damage function. That is, the benefits of protecting these segments are much higher.

The benefit of eliminating flood risk is equal to the flood damage prevented by taking an action. For example, if a property is removed from the flood plain, the benefit is the expected flood damage that is now gone. The annual value is the entire expected annual flood damage to that property. If a structure is lifted to a higher elevation, the benefit is the elimination of all the flood risks up to the new elevation of the structure. For example, a 12 foot flood would still strike a building raised from 6 to 11 feet, but the height of the flood at the property would only be 1 foot whereas it would have been 6 feet before the lifting.

Cost

In addition to measuring the benefit of each action, the model also calculates the cost. The cost rises proportionately with the extent of the action. For example, cost rises proportionately with the length of a wall, with the number of houses that are lifted, and the number of houses that are purchased for removal. Cost also rises with the intensity of the action. Cost tends to rise with the square of the height of a wall and proportionately with the height a house is lifted or the height a road is raised. The marginal cost of an extra foot of height in a wall consequently rises as the wall gets taller. But the marginal cost of an extra foot of road or an extra foot a house is lifted tends to be relatively constant.

Maximizing Net Benefit

The economic model evaluates alternative locations of walls and alternative heights to build walls, alternative heights to raise buildings and roads, and alternative choices about the extent of purchasing homes for removal or alternative homes to lift. The economic model identifies which strategy leads to the highest net benefit for the town in terms of housing value. But the model also calculates the net benefit of other choices so that everyone can see the overall consequences of each choice. What is best for the town will not necessarily be the best choice for each individual.

Furthermore, what is best from an economic standpoint can conflict with ecological goals (such as floodplain management) and public values (such as public access). It is also true that some factors may not have been taken into account in the analysis. By comparing the net benefits of different choices, one can see what one loses in measured net benefits versus what one may gain in other unquantified dimensions.

The net benefit of each action is the total benefit (the damage avoided) minus the cost of the action. The cost of most actions considered in coastal defense is taken at once. For example, the largest cost of the wall is the construction cost to build it. However, the analysis also takes into account maintenance cost that will be spread out over the lifetime of the wall. In contrast, the benefits of most actions are spread out over the lifetime that the action will be in place. When one removes a vulnerable structure, the benefit will extend indefinitely. However, building walls, raising roads, or lifting houses will only last the lifetime of the structure. In this analysis, we assume these structures will have a practical lifetime of 30 years, although this could be adjusted when appropriate.

In order to make both immediate costs and benefits versus streams of costs and benefits comparable, we convert everything into annual costs and benefits. For example, the benefits of reducing storm damage for 30 years is converted into the annual value of that stream. The annual value is what one would pay every year for that specific stream of benefits. Similarly, the construction cost is converted into an annual payment over 30 years that is equal in value to the immediate cost. The model is therefore comparing equivalent annual payments over 30 years for both costs and benefits.

Quantified Decisions

The economic model evaluates several important decisions to make with respect to each intervention. One decision is where the intervention should take place. With walls, one must decide where to place the wall. In this analysis, we have assumed that no wall would be built below the Coastal Jurisdiction Line (CJL), which typically falls above MHHW.[8] One concern for this is that such a wall would require state approval since the State of Connecticut is responsible for all land below MHHW. A second concern is that a wall below MHHW would be vulnerable to wave action which would substantially increase the maintenance cost of the wall. So the closest wall to the ocean that we consider occurs at or above CJL. A third concern is that coastal walls may block views and access to the water. In some instances, it makes sense to move walls back from the coast to protect inland properties. The cost of the wall may also be lower further inland because the topography is likely to be higher. Furthermore, inland walls increase the availability of land within the floodplain, allowing for marsh migration. Since protection is based on the elevation of the top of the wall, the actual wall height (base to top) can be shorter with inland walls. Third, the inland wall is likely to face less pressure than a wall along the coast because wave action and flood depth is lower further inland. The inland wall does not have to be fortified to the same extent as a wall along the coast, making it less expensive. The farther inland a wall is built, however, the more existing homes are outside the protection of the wall. These considerations also depend on the availability and elevation of egress routes.

There are several details that are not yet taken into account in the economic analysis. The analysis does not yet quantify the effect of sea level rise. Coastal walls also trap water behind them and require outlets and areas for storage behind the wall. This has not yet been included in the cost of the wall. Walls also create barriers preventing easy access to the sea. A system of steps or storm gates should be designed into the wall to allow access. This has also not yet been included in the cost of the wall.

Location is important for all of the strategies. If one is buying homes to remove them, it makes sense to buy the homes with the highest expected damage/value first. That is, the home purchase program should focus on the homes at the lowest elevation that are subject to repeated flooding first. The same logic applies to bans on new construction in the flood plain. The first place to ban is the lowest elevation land with consideration for existing ecosystems and the potential for habitat expansion. Lifting homes also depends on the risk to the home and its value. Lower elevation homes are at greater risk and so there is a larger benefit by lifting them. Dry egress is an additional consideration, and depends on the existing topography and housing locations. Because there is a large fixed cost to raising a home, the home must have a relatively large minimum value before it makes sense to lift it. The spatial extent of every decision is one of the parameters the model examines.

In addition to the wall location, another design decision concerns the height of the action. The higher the wall, the more flooding events that will be prevented. However, simultaneously, a higher wall will be more costly and eventually prohibitive. There is a trade-off between spending ever more on the wall cost to prevent ever smaller risks of flooding. One must build a very high wall to prevent very small risks from happening at all. At some point, each community would not want to pay more for the small remaining risk to be eliminated. In many cases where walls are warranted, each community may prefer a more modest wall that prevents most storms, accepting the small risk of a very large storm. It is this small risk of a large storm that is best handled by flood insurance. The economic model computes the height that minimizes expected cost and damage. To calculate the wall height at which construction is economically efficient, the model computes the wall height for which the marginal wall cost equals the expected marginal benefit of reduced parcel property damage. Developed to supplement an integrative design process, the model also shows alternative heights and residual risks.

Height must also be considered for lifting homes. In many municipalities there are restrictions on the maximum height of structures to properties to control blocking views and changing the character of the neighborhood. These constraints often restrict options for homeowners. While new construction is being regulated in terms of heights, homeowners also face the question of how high. The marginal cost of a slightly higher lift is relatively small compared to the overall cost of lifting a home at all. So it can make sense to lift a home higher than one would want to build a wall. However, it helps to make the lifting process a joint decision in a neighborhood. Partly, it helps to have all homes lifted to the same height to support infrastructure such as road access. Choosing uniform lifting rules for a neighborhood can lead to a more aesthetic appearance which would enhance property values

Wall Cost Parameters

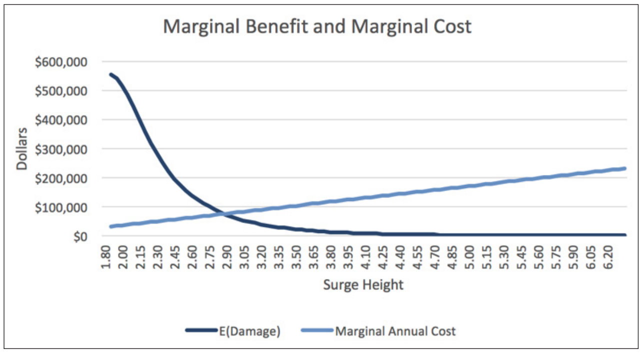
Wall base height (H)	1.13
Wall length (L) (meters)	1500
Discount Rate	0.04
Wall Useful Life (years)	30
Annual Maintenance CapEx	0.02

Wall Altitude	3.87
Wall Total Cost	$87,197,009
Wall Marginal Cost	$45,063,054
Wall Discounted Annual Cost	$4,991,201
Annual Maintenance CapEx	$1,743,940
Total Annual Wall Cost	$6,735,142

Using the economic model, we calculated the optimal wall height and length based on our assumptions. The wall length depends on the area deemed financially worth protecting. The wall height depends on the cost and expected value of property protected. We equated the marginal cost to the expected marginal damage. This maximizes net benefits. Note that rare large storms will still overtop the wall ($p<1/100$).

in the neighborhood. Special coastal zoning areas is one creative way to manage all of these issues.

Because most storms not only threaten with coastal storm surge, but also increased precipitation, one of the difficulties in building coastal walls concerns fresh water flooding behind the wall. Tide gates that block sea water from entering but open when fresh water accumulates provides one option for draining accumulated water. Maintaining green infrastructure behind the wall is also necessary. In some cases, the community will want to utilize nearby wetlands as a place to store temporary flood waters. In other cases, the community will have to consider expensive pumping alternatives.



The graph above illustrates an optimal elevation for the wall at Cosey Beach around 2.9 meters where the estimated damage interests with the marginal costs.

Results

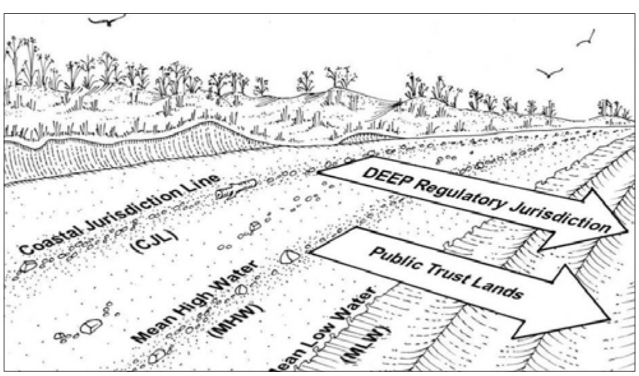
Efficient Wall Height (meters)	2.85
Total Expected Damage	$6,961,209
Expected Remaining Damage	$832,561
Expected Damage Reduction	$6,128,648
Total Annual Wall Cost	$1,330,398
Net Annual Gain	$4,798,249

Wall Total Cost	$17,224,101
Annual CapEx	$334,482
Wall Lifetime Reduced Damages	$4,991,201

Annual Damage at Efficient Wall Height

Total Land Damage	$14,510,140
Total Building Damage	$13,385,965

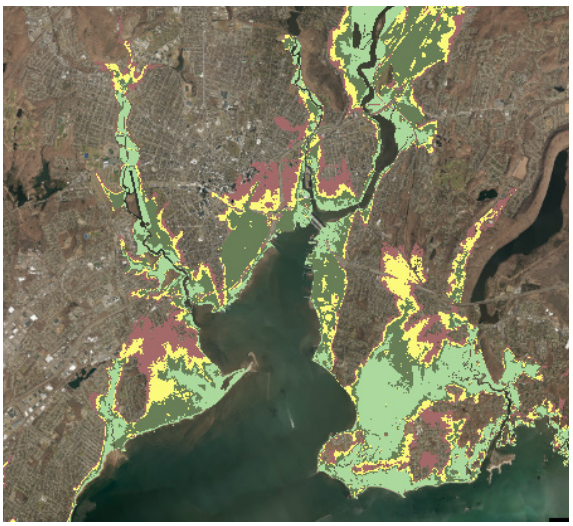
The table above focuses on Cosey Beach in East Haven. Based on the assumptions in the model, it indicates that the efficient wall height would be 2.85 meters with a net annual gain of approximately $4.8 million.



There are jurisdictional overlaps between DEEP and municipalities.

ECOLOGICAL DESIGN MODEL

Coastal Risks



Current Storm Surge

With the second highest exposure of vulnerable coastal assets on the eastern seaboard, and more than $542 billion at risk to coastal storms, Connecticut must more strongly develop an economy that is resilient to climate change. With over 60% of the state's population living in coastal communities and over $542 billion in assets (64% of properties) at risk, the State of Connecticut remains vulnerable to future storm events, an exposure that will be exacerbated by climate change. The State of Connecticut incurred an estimated $70 billion in damages following Hurricane Sandy.

Future Sea Level Rise and Storm Surge

With sea level rise and increased storm intensity, an increasing number of coastal homes will be exposed to flooding. Actions taken in the near term address current storm risks can also be designed to address future seal level rise (SLR). Recognizing the exacerbating risks of SLR on coastal properties, it is imperative to communicate with homeowners and to move collectively towards proactive solutions.

Ecological Planning Options

Risks and Considerations

Northeast coastal communities are heavily settled and vulnerable to sea level rise and increasingly severe and frequent storm surges. Critical infrastructure, ecosystems and human safety in these towns are under threat.[19] These vulnerabilities were felt acutely following Tropical Storm Irene (2011) and Superstorm Sandy (2012), including in the two coastal communities within the project area (East Haven and West Haven).

It is imperative to initiate proactive planning and consider all options. Planning options for coastal municipalities are dependent on site-specific conditions including the topography, development patterns, history and culture along with the predicted risks of flooding and sea level rise. Project considerations must include the conditions of existing infrastructure, and the presence of private property and its interface with existing local ecosystems. Dry egress and existing flood risks as well as future exacerbated risks are critical to consider. There are also several challenges to transition from planning to implementation, which range from lack of communication and decision-making tools, gaps in valuing urban ecosystem services, a peripheral role for ecologists in the creative design process, and a mismatch of the objectives recognizing that the socio-economic and mounting environmental pressures upon built environments.

We explored an integrative approach to planning that utilizes economic theory as a tool for evaluating and prioritizing options combined with environmental planning as a way of combining our analysis with smart development practices. Using coastal adaptation strategies applied to selected projects, this proposal integrates economic analysis with ecological and development goals. The strategies address land use changes and innovations in housing and protection strategies along with managed retreat, design and habitat restoration. Taken together, the piecemeal strategic adaptations seek a thoughtful and economically viable transformation of an urban coastline over time.

A main goal was to establish a set of initial design proposals and to evaluate each using an economic model looking more in depth at assessed values and the impact of potential flood risks as a tool for informing municipal planning.

Municipal Tools Overview

Having examined the practical application of the various strategies, we developed an "Economic Analysis and Decision Making Support Tool." The tool exemplifies an approach to prioritized projects with cost estimates as a decision-making framework to refine the planning and implementation process. This approach allows municipalities to prioritize projects and identify near-term opportunities that feed into long term planning. The prioritized projects can inform ways of applying these coastal adaptation strategies more broadly to municipalities across the coast. The tool was evaluated through municipal staff and an advisory team with legal and engineering expertise. We applied a prioritization approach to a location in each specific municipality in order to illustrate how the Design and Technical Guide can be utilized and integrated into the municipal planning process.

These tools are intended ultimately to provide a guide for the transition from municipalities driven by hard infrastructure, road transportation and developer-driven housing to spaces created with equity, human health, ecosystem function, and climate change as drivers of planning and design.

This technical guide approaches the challenge of responding to storms and sea level rise using two distinct frameworks, an economic approach and a landscape architectural approach. Each of these approaches assume distinct timeframes focusing on flood risk differently. As a team, we explored the outcomes of each approach and sought to hybridize the methodologies as a benefit to town planning and local decision-making and implementation. The economic approach assumes a 30 year time horizon as the duration over which the responses to distinct probability flood events and costs are calculated. The assumption is that future inhabitants will be in a better position and with an updated understanding of the risks to make decisions about flood risk for future populations. For coastal adaptation from a landscape architecture perspective, we approached the site first from a long-term flood risk and predicted sea level rise perspective. We further developed a 90 year ecologically based design vision. This approach allowed us to envision the long-term future risk and to assume a precautionary approach about how development investments might support future predicted SLR and storm events. We then worked backwards to a mid-term (60 year) and near-term (30 year) time horizon to ensure that choices we make over the next 30 years do not curtail long term planning.

Planning Considerations

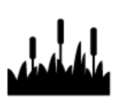

Cost


Private Property


Socioeconomic Factors


Political Dimensions


Infrastructure Legacy


Environmental Influences

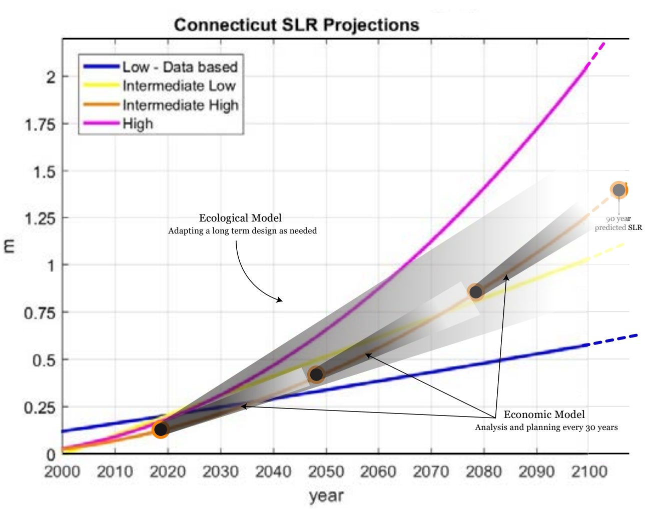
As high tide levels continue to rise, increasing numbers of coastal homes are exposed to sea water. Coastal marshlands can expand to accommodate additional water, but they soon flood, overtaking inland homes near unmanaged rivers.

Hybridizing these approaches within the short-term, mid-term and long-term planning strategies help determine the project's effectiveness in different time spans and allow for a comparison of various intervention measures over their effective lifetimes. The graphs to the right show a flood-prone coastline in East Haven, CT along Cosey Beach Ave. The graphs shows the threat of flooding to coastal residences and a proposed intervention in present day as well as after 30, 60 and 90 years.

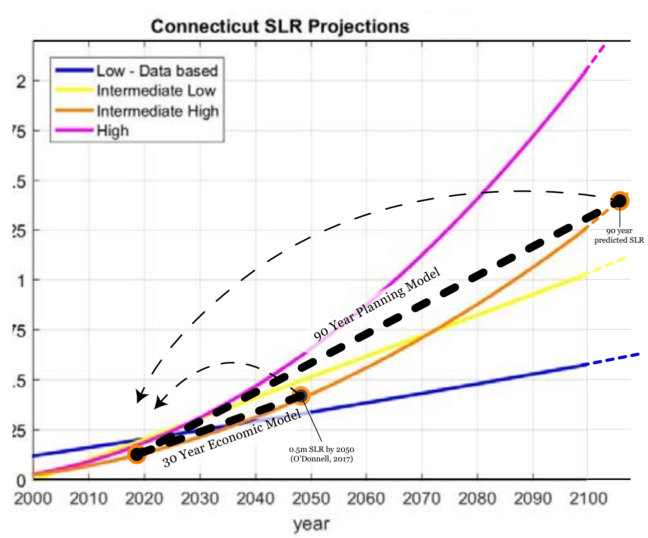
In the process of creating and evaluating effective designs, this project has utilized two trains of thought. One, stemming from the economic model, involves looking at 30 year predictions of sea level rise (SLR) and storm events and designing solutions that will be effective in that period. Another, prioritizing the protection of coastal marshland ecosystems, utilizes a 90 year prediction model as a basis of informing the near-term (30 year) and mid-term (60 year) strategies. The long-term model proposes an intervention that could extend beyond the lifespan of the initial engineered solution. The diagram below this text to the left illustrates this by comparing the two time frames and their respective reference points.

Since the economic model involves a shorter time scale, it offers more practical and digestible solutions in the short term and suggests that the design be reevaluated every 30 years. In the diagram on the right, this is illustrated in a series of 3 narrower planning scales, each taking the next 30 years of possible variance in expected sea level rise and flooding possibilities into account. Designs based solely on economic principles run the risk of inadvertently setting land management precedents that are unsustainable in the long term. In contrast, the broader, ecologically-based, planning scale proposes design solutions that may not be acceptable to occupants today, and may suggest larger investments that are difficult to convince people and may not practical. Establishing the long term vision and incorporating observations into the near term planning process encourages design decisions that can be nested within defined constraints, but that can also be altered when needed without reevaluating the entirety of the project. The predicted project scope of this strategy is broader because it involves planning over a longer time frame and considering a transitioning process for the near and mid term.

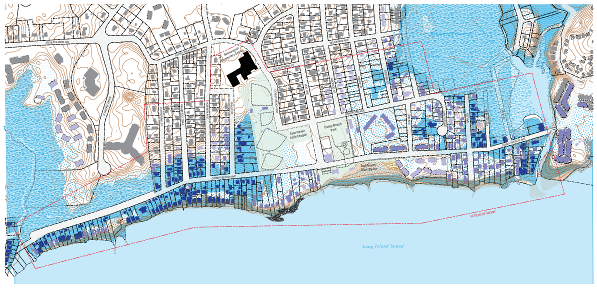
This technical guide seeks to work across both models. To ensure effective floodplain management and to support a transition into more coastally resilient municipalities, with investments that reduce the loss of additional property in subsequent design efforts, we provide a prioritization tool that relies on the economic model to do an initial evaluation of the costs and benefit of selected projects. We also illustrate a specific planning process for a selected location to show how distinct techniques can be applied under a particular set of circumstances both as a near term 30 year solution and given the longer term planning and precautionary approach of the 90 year time frame.



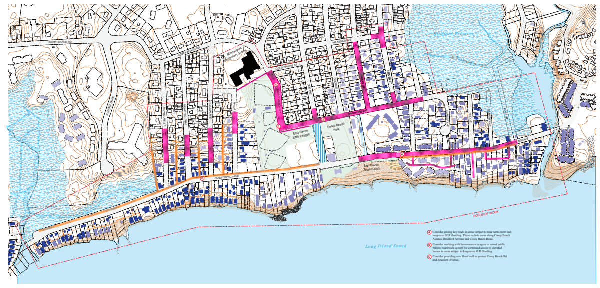
This graph illustrates the 30 year incremental decision making framework used for the economic model superimposed on a longer term predictive model of sea level rise with low, intermediate low, intermediate high, and high estimates based on predictions



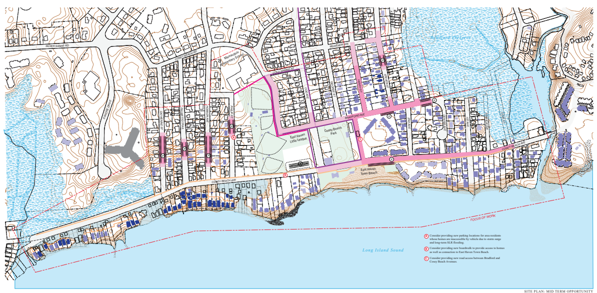
This graph superimposes the reflective decision making framework using a 30 year interval alongside a longer 90 year perspective illustrating the combined approach utilized in this technical guide of combining these approaches for planning purposes.



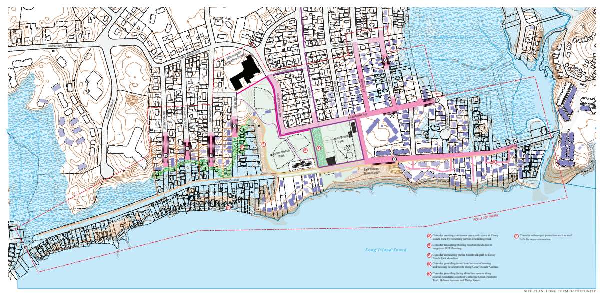
Current



Near term



Mid term



Long term

Strategic realignment approach with raised roads in pink and proposed raised parking structures to facilitate access to coastal properties, which could be raised individually. This approach allows the municipality to raise roads while avoiding paying for an extensive wall. The raised road strategies allow for the wetland to be maintained and to expand over time.

In order to address the complex site specific challenges within each municipality, it is useful to focus on planning efforts that will make the most impact while considering the local challenges to the community and the ecology. Possible solutions include constructing coastal or inland walls (either complete or segmented), raising houses and roads, installing tide gates in heavy flood areas and developing strategic realignments and in certain cases to take no action. All of the strategies suggested in this proposal are based on a series of design elements listed below.

Barrier walls are hardened structures that protect homes from an inland or coastal position. They are also costly and create a disconnected wetland system that will fail to accommodate increasing flood levels, overlooking the provision of ecosystem services in the coastal regime.

Self regulating tide gates (SRTGs) are inland infrastructure elements that block waterways during flood events to prevent further inundation, but remain open most of the time to allow normal water flow.

Tide gates are barriers that can regulate the flow of water in and out of marshlands to reduce flooding in residential areas. However, these gates require substantial maintenance and are costly in the short term. In the long term, as sea levels rise and tide gates remain closed for larger durations of time, these gates may restrict marsh migration and act as dams.

Upland walls can be smaller and less costly, but fail to protect all coastal residents. Yet this planning option involves significant cooperation from the community and may result in the loss of some properties nearest to the coast.

Raised homes are protected from storm events and can survive over water, but do not protect the surrounding areas unless a wall is embedded beneath.

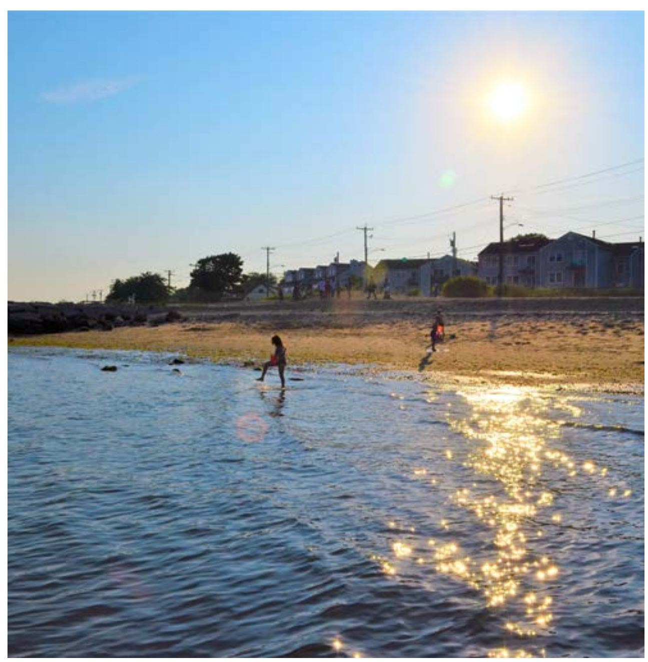
Embedded walls occur upland of coastal areas within neighborhoods. In these upland areas, the walls are typically lower and less costly. However, they may require more negotiations with private landowners and may create conflicts with other urban uses. Embedded walls can be integrated into housing.

Raised roads are based on existing infrastructure and utilize the height of the road as the physical barrier as well as ensuring egress.

Green streets are an environmentally friendly solution that propose greening strategies to manage the transition zone between houses and areas that flood. The green streets are highly reliant on the ability of marshes to act as a sponge and soak up flood waters, meaning they are not an option if marshlands are cut off from the sea or are detrimentally affected to the point of collapse.

Strategic Realignments also known as managed retreat, are usually anticipatory approaches focusing on repetitive flood loss homes. They include buyout programs and abandoning properties to facilitate adaptation solutions.

No action, in certain cases, is valuable. Municipalities can avoid pressures by establishing policy that limits development, road raising or home raising for example.



Cosey Beach, East Haven. Photograph by Paurush Singhal

A combination of strategies can be used in strategic locations to reduce overall cost and negative impact on the environment while minimizing residential flood risks.

Below we review the prioritization tool for each municipality and go into detail on a particular site illustrating five adaptation strategies, highlighting the value and trade offs:

(1) Self Regulated Tide Gates (SRTGS)

Tide gate is a tool to avoid building upland wall.

1. East River Flooding
2. Historical Tide Gate
3. Dashed line indicates the length of coastal wall that may or may not be built.
4. Coastal Wall

(2) Coastal Wall

There are several options for where the wall/ raised road can be built.

1. Options for wall construction
2. End of the coastal wall where it tie in to the uplands
3. Coastal wall

(3) Raised Houses with Embedded Wall

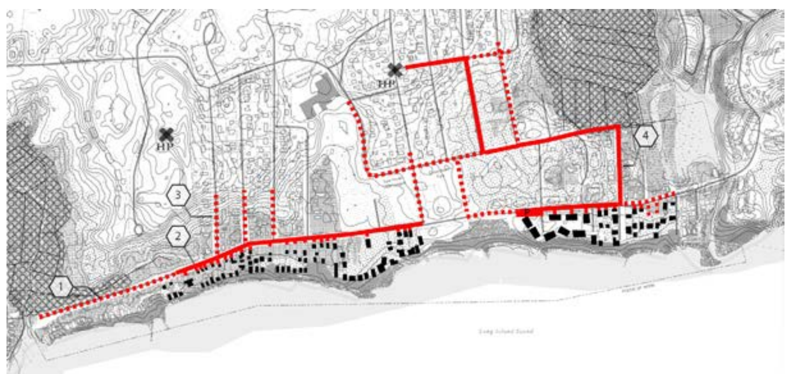
The wall can be embedded and be part of the raised structure.

1. Options for wall construction
2. End of the coastal wall where it tie in to the uplands
3. Raised houses with embedded wall

(4) Raised Houses and Raised Road (Cosey Beach Ave.)

There are several options for where the raised road can occur.

1. Dotted line indicates length of road that may or may not be raised.
2. Each paired homes will include a shared parking area linked to the raised road.
3. The connection of the raised road to the upland areas will tie in depending on the topography



(5) Raised Structure and Upland Wall

1. Boardwalk network
2. Inland wall provides flood management without raising houses

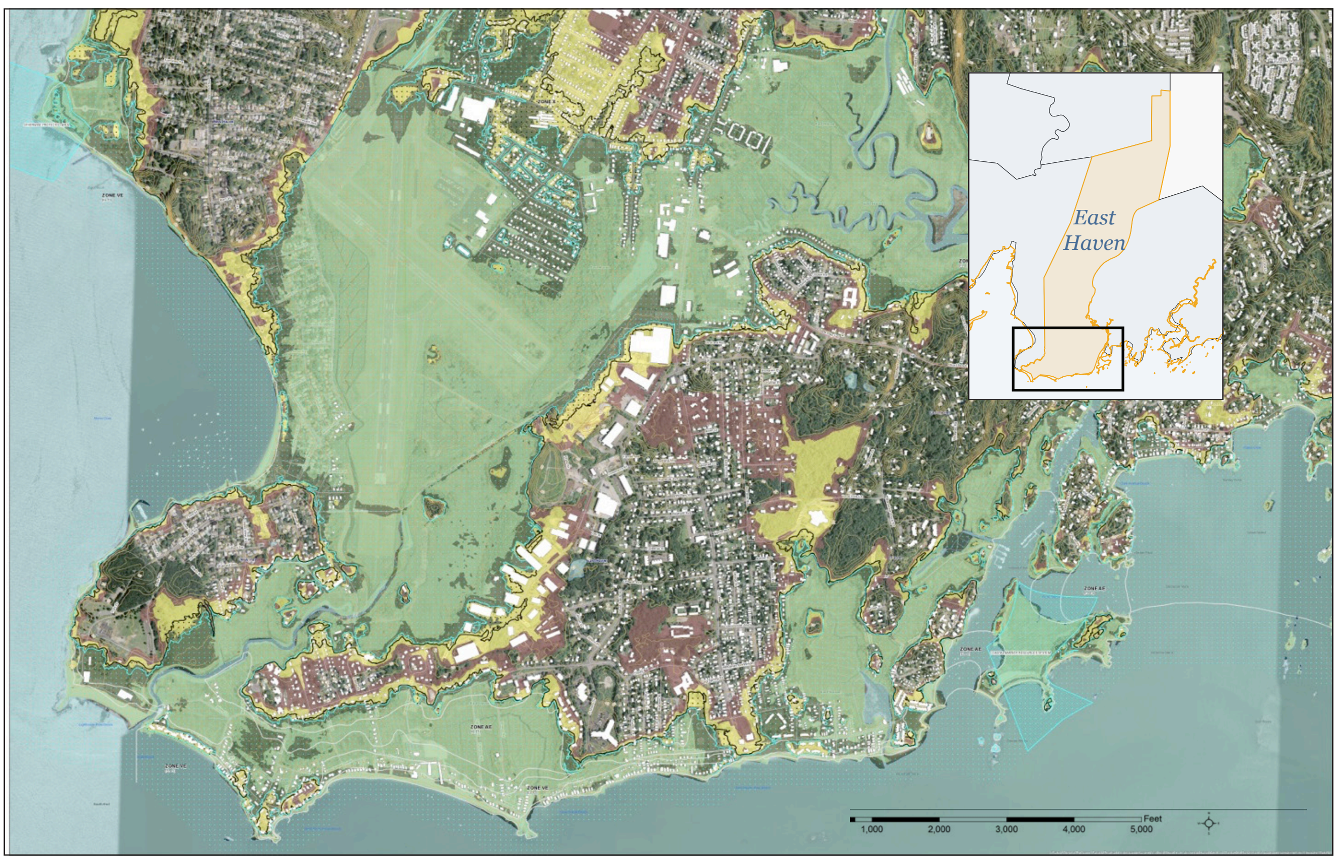
ECONOMIC ANALYSIS AND DECISION MAKING SUPPORT TOOL

EAST HAVEN

A survey of ecosystem services in East Haven highlights the abundance of marsh and wetlands in the town, totaling 112 acres (5.34%) within, intersecting, or immediately adjacent to the town borders. 263 acres (3%) of town land are in the 500-year floodplain and 1,948 acres (22.7%) are within the 100-year floodplain. Similarly, West Haven has ample ecological assets, with 20 acres (0.3%) of marsh and wetlands, 15 acres (0.2% total) of which are tidal, within, intersecting, or immediately adjacent to its borders. Also within or immediately adjacent to West Haven’s borders are 119 acres (1.69%) of tidal, mud, sand, or gravel flats in open water. The town has 996 acres (14.1%) of land within the 100-year floodplain, and 343 acres (4.9%) are within the 500-year floodplain.

Results of the Economic Analysis

The analysis below represents the outcomes of the economic analysis. These outcomes provide a coarse assessment of comparable options based on selected factors focusing on the quantitative assessment of risk and the current regulations around floodplain development. Following this section, we go into greater detail on specific planning options. The planning options also allow for the integration of a variety of more qualitative analyses including: aesthetics, such as the impact of wall height on visibility and access, neighborhood quality, issues of dry egress, existing infrastructure, and environmental considerations.



This map shows East Haven with the overlay of the FIRM map from 2016 as well as the SLOSH model analysis from 2016.

Municipal Wide/Site Specific Solutions

The analysis of East Haven's coastline reveals that the town is predominately low-lying with very few naturally elevated sections. An elevated point area near the Village at Mariners Point divides the East Haven coastline into a short western section and a longer eastern section. As an idealized or optimized economic strategy, one might explore a single strategy for coastal defense. With the high point at Mariners' Point, the town has the option of choosing distinct strategies, addressing each independent coastal segment. Our adaptation solution starts with an optimized or idealized economic analysis of these two options: a uniform strategy for the entire East Haven coastline, and a separate strategy for the eastern and western segments. We recognize the potentially prohibitive cost of such a proposal from a regulatory, financial and negotiating perspective across homeowners, however, one of the values of our tool is to explore economic solutions first on their own, and to allow comparability across options, which can then be contextualized.

The economic analysis examines a coastal wall, lifting homes, planned retreat, and no action. We use no action as the baseline approach. In this case, the town makes no effort to address coastal defense and each homeowner is left to their own devices subject to existing laws and regulations. The benefit and cost of each of the other strategies is made in comparison with no action.

The wall strategy considered in East Haven was the construction of a hardened structure at MHHW along the 4,832 m of coastline. Alternative heights for this wall were considered in the analysis. The benefit of additional reduced storm damage was considered versus the higher cost of building and maintaining a taller wall. One problem with a wall at MHHW is that there are several unprotected properties in front of the wall. In order to address this shortcoming, we also separately examine lifting the structures in front (on the coastal side) of the wall.

The results of the uniform policies for the entire East Haven coastline are shown in Table 1. The analysis reveals that the optimal wall elevation that maximizes net benefit is 3.6 m (12 ft) at the top of the wall. Given that the base of the wall is at MHHW (1.74 m or 5.7 ft), the actual height of the wall is 1.9 m (6 ft). The wall protects against all storms with a return rate of 126 years or less. There remains a small expected annual net loss of $110,000 to the properties behind the wall from rare large storms. The net benefit of this wall the entire length of the coast is about $22 million per year. The benefit to cost ratio is almost 5 to 1.

One drawback of the coastal wall is that some homes built below MHHW lie in front of the wall. These homes get no protection from the wall. In order to address these homes, we consider a policy of lifting homes. The annual expected flood damage to these low lying homes is $10.5 million. Lifting these homes to a 3.6 m (12 ft) elevation would lead to an annual cost of $0.7 million but this effort eliminates extensive frequent flooding damage. The net benefit of lifting low elevation homes in front of the wall is $10 million. The benefit of lifting these homes far exceeds the cost.

A final strategy is strategic realignments, which may include planned retreat. Instead of dealing with properties that are repeatedly flooded and damaged, which tends to create anxiety amongst existing homeowners and future home buyers, for homes located in front of the location where the economic analysis suggests building the wall, the town could buy them out in advance. The property value of all property below MHHW in East Haven is $55 million. The annual rental value of all of this property is $3.2 million. The expected storm damage eliminated is $10.5 million. The net benefit of this policy is $7 million. Although buying out homes before they are damaged can lead to an orderly withdrawal, it is often more expensive than lifting homes.

While a singular uniform strategy for the entire East Haven coastline is useful as an exercise to consider economies of scale, such singular solutions are often costly and rarely implementable. It is essential to work locally and determine ways of integrating solutions with economic development opportunities and investment capacity within municipalities. Building on the notion of focusing on segments between high points as an incremental strategy, in East Haven there is the option of choosing a different strategy for the eastern versus western portions of the coastline. Table 2 reveals the relative benefits and costs of building a wall and lifting homes below MHHW.

The eastern segment of East Haven is relatively densely populated with structures whereas the western portion has a strip of homes near the coast many of which are under MHHW. The eastern section accordingly has more property value that is vulnerable to storm surge than the western portion. The analysis suggests that a wall in the eastern part of East Haven segment has high priority whereas a wall in the western part does not. The proposed elevation of the eastern wall remains at 3.6 m (12 ft) but the proposed elevation of the western wall is just 2.74 m (9 ft). Given the elevation of the base remains at MHHW (1.74 m), the actual height of the western wall is 1 m (3 ft), whereas the eastern wall is almost 1.8 m (6 ft). The western wall is 1,700 m long whereas the eastern wall is 3,043 m long.

One of the striking results of Table 2 is that the majority of the benefits of building a coastal wall in East Haven come entirely from building the wall along the eastern segment. This is because the benefit of protecting the eastern portion from storm surge is much higher than the western portion. A wall along the western segment might still make sense but the height and the net benefit of the western wall is much lower. The greater density of homes in the eastern segment justifies the coastal wall with a benefit to cost ratio of 7 to 1. The western segment has a wall with just a 2 to 1 benefit to cost ratio.

There are several details that are not yet taken into account in the East Haven analysis. The analysis does not quantify the effect of sea level rise. The sea is rising at 3mm/year in East Haven which implies that the benefit of protection is rising as well. This is not yet taken into account in the analysis.

One problem with coastal walls is that they trap water behind them. The design of the wall must include outlets that let fresh water escape while preventing salt water from entering. This has not yet been included in the cost of the wall. It is also true that the wall is a barrier preventing easy access to the sea. A system of steps or storm gates should be designed into the wall to allow access.

Table 1: Uniform Strategy for **East Haven** coast

	Wall	Structure
Desired Elevation	3.6 m	3.6 m
Annual Cost (million)	$5.7	$0.7
Annual Expected Benefit (million)	$28.1	$10.5
Net Gain (million)	**$22.4**	**$9.8**

Table 1: Uniform Strategy for East Haven Coast

Table 2: Annual Benefit and Cost for **Eastern and Western Segments of East Haven**

	Eastern	Eastern	Western	Western
	Wall	Structure	Wall	Structure
Elevation	3.6 m	3.6 m	2.7 m	3.6 m
Cost (million)	$3.2	$.42	$0.5	$0.48
Benefit (million)	$23.3	$5.2	$1.0	$5.3
Net Gain (million)	**$20.1**	**$4.8**	**$0.5**	**$4.8**

Table 2: Annual Benefit and Cost for Eastern and Western Segments of East Haven

Cosey Beach Storm Surge Maps

Storm Surge Map at three (3) feet

Storm Surge Map at nine (9) feet

Storm Surge Map at six (6) feet

Storm Surge Map at twelve (12) feet

EAST HAVEN LOW LYING AREAS OF RISK

Kenneth Street area
Low lying isolated neighborhood built on fill over a wetland, adjacent to the airport with egress flood issues.

Commerce Street
Industrial roadway in East Haven supporting the airport. It could serve as a future raised road connector.

Morris Creek Area
Morris Creek has an existing tide gate that manages flooding onto the airport grounds.

Cosey Beach Avenue
Low-lying beach front community with limited egress.

Caroline Road
Low-lying beach front community with no egress.

Shell Beach Road
Low-lying beach front community with no egress.

Hemmingway Avenue

Low lying isolated neighborhood built adjacent to a wetland.

Farm River near Coe Avenue

Coe Avenue is main corridor and egress with a low lying area currently being raised 2 feet with flood risks from the farm river.

Farm River near the Coast

Low lying housing along the Farm River corridor

Bradford Preserve and Atwater Street

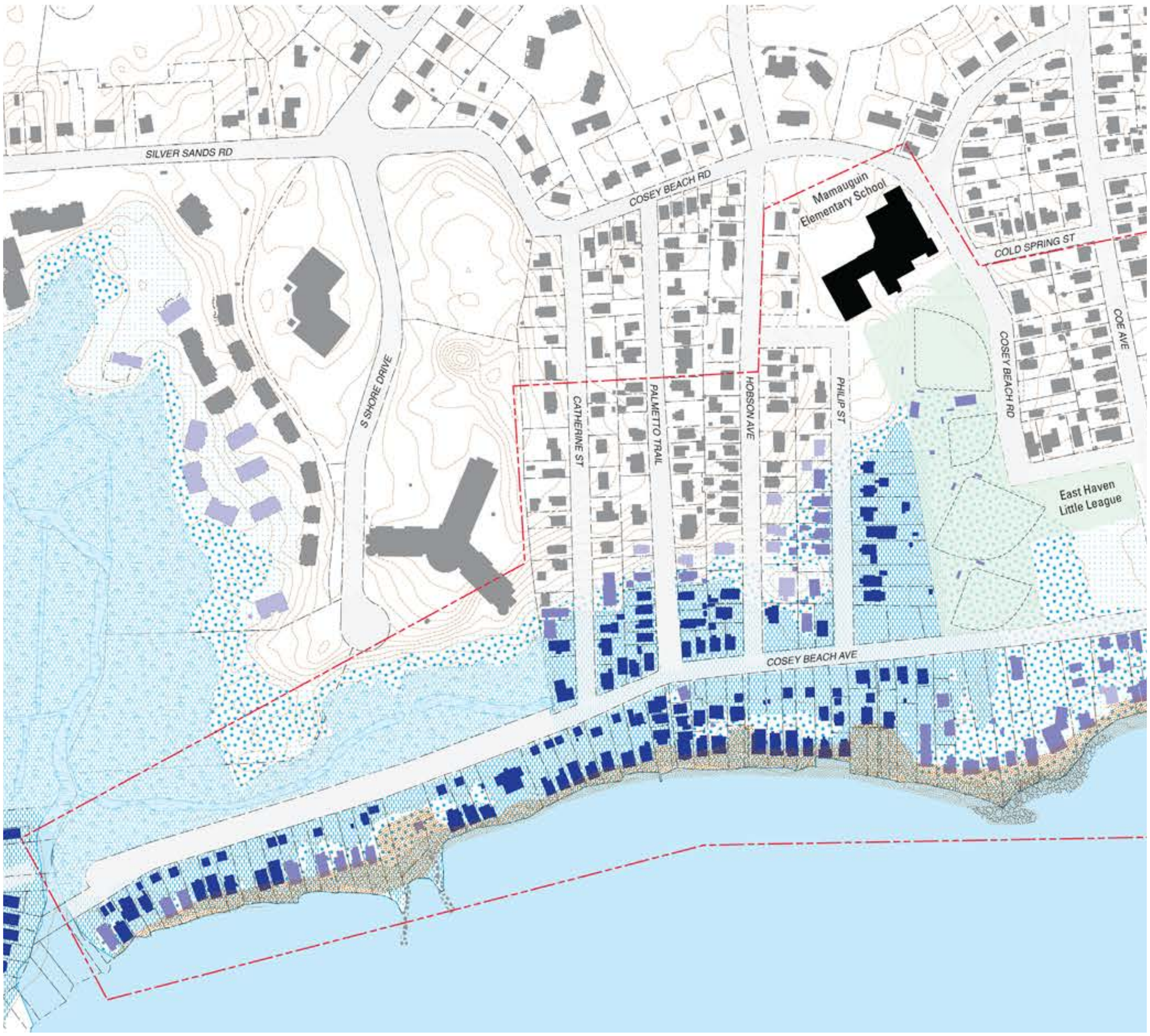
Inland tidal marsh with peripheral housing that floods

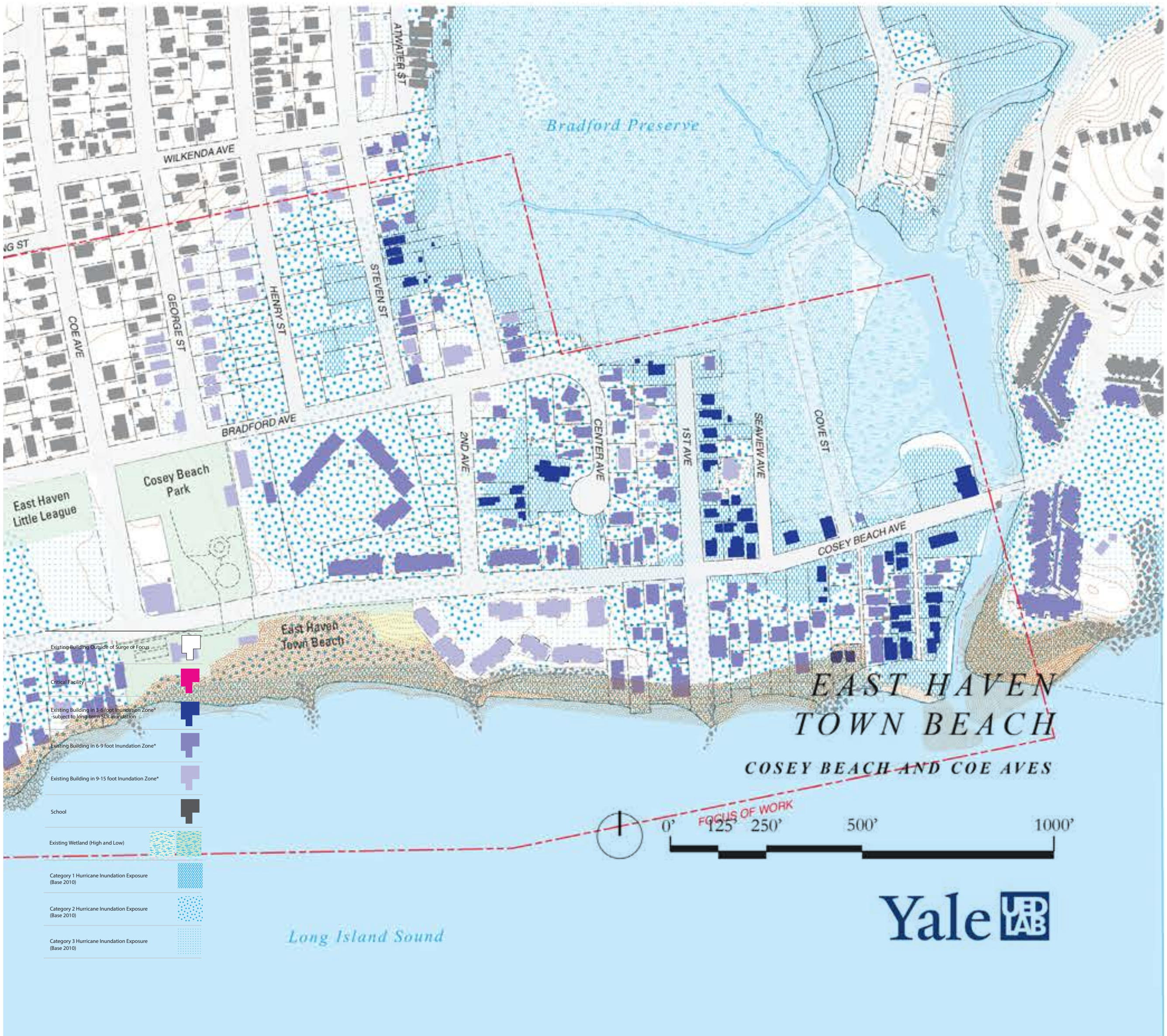
Mansfield Point

High point that is an island with condominiums and limited access

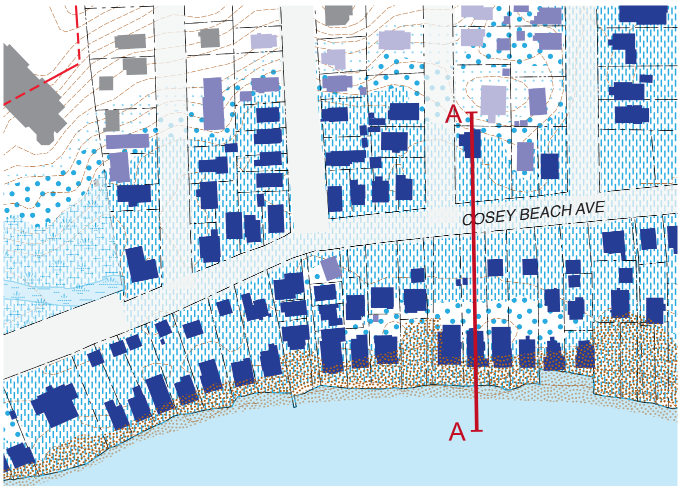
Design and Technical Guide
Site Priortiziation Plans

Current Condition; No Action - Storm Surge Exposure



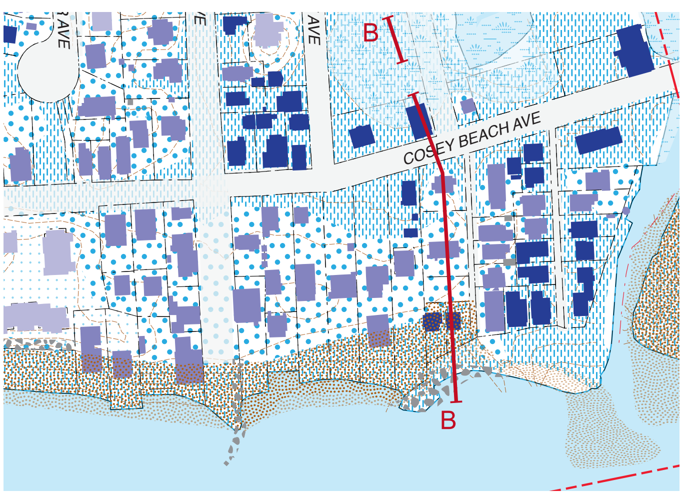

Bradford Preserve
WILKENDA AVE
ATWATER ST
STEVEN ST
HENRY ST
GEORGE ST
COE AVE
BRADFORD AVE
2ND AVE
CENTER AVE
1ST AVE
SEAVIEW AVE
COVE ST
COSEY BEACH AVE
Cosey Beach Park
East Haven Little League
East Haven Town Beach
EAST HAVEN
TOWN BEACH
COSEY BEACH AND COE AVES
FOCUS OF WORK
0'
125'
250'
500'
1000'
Long Island Sound
Existing Building Outside of Surge or Focus
Critical Facility
Existing Building in 3-6 foot Inundation Zone*
-subject to long-term SLR inundation
Existing Building in 6-9 foot Inundation Zone*
Existing Building in 9-15 foot Inundation Zone*
School
Existing Wetland (High and Low)
Category 1 Hurricane Inundation Exposure
(Base 2010)
Category 2 Hurricane Inundation Exposure
(Base 2010)
Category 3 Hurricane Inundation Exposure
(Base 2010)
Yale UD LAB

Sections Illustrating Cosey Beach Road Scenarios



Showing Existing Conditions

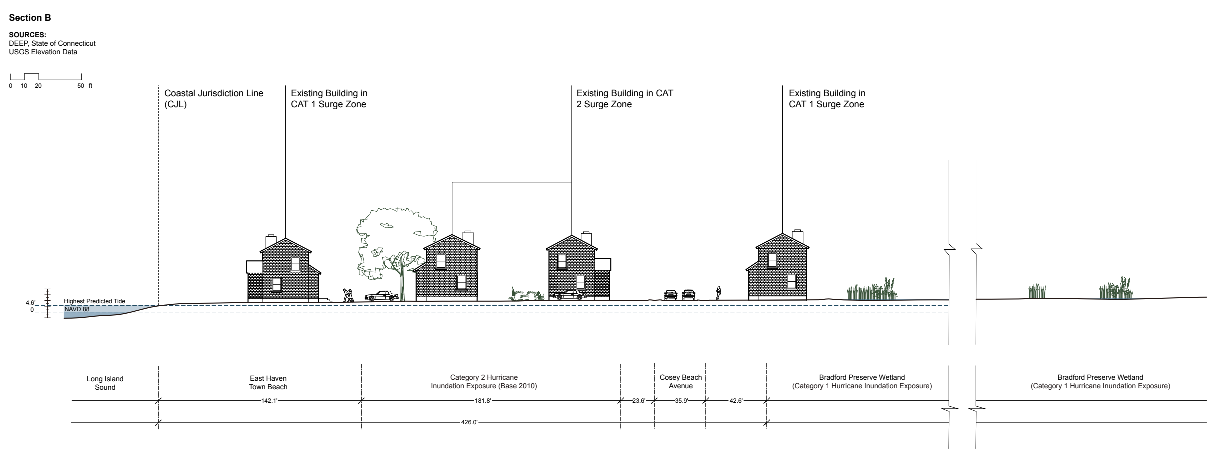
The relationship of housing to beach along Cosey Beach.



Showing Existing Conditions

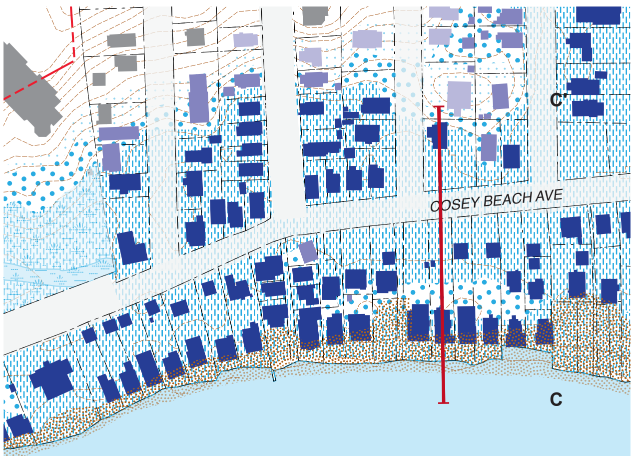
Tidal inlet where a storm gate could be constructed.

Existing Conditions - Cross Section A-A'



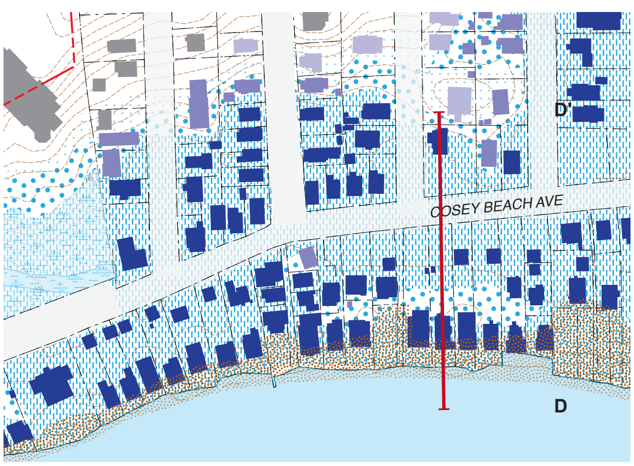
Existing Conditions Cross Section B-B'

Sections Illustrating Cosey Beach Road Scenarios



Showing seawall at the CJL

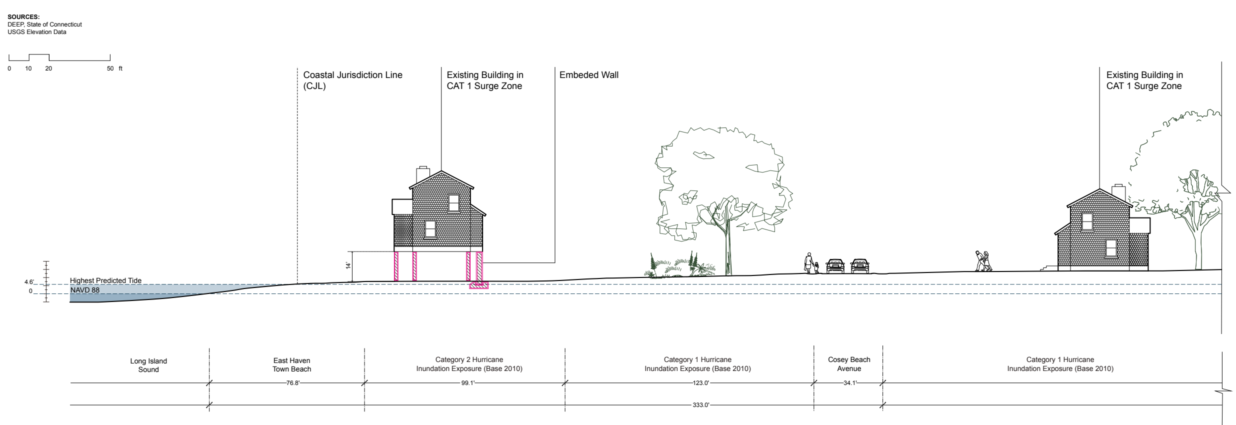
An existing seawall built on the upland portion of the beach in front of existing raised multi-family housing.



Showing a seawall under existing structures and embedded in raised homes

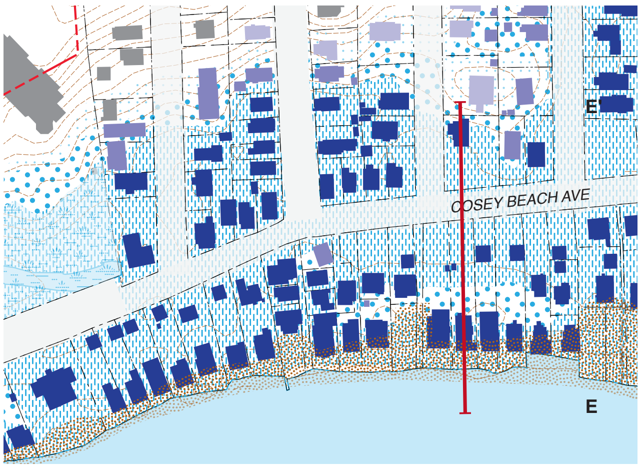
Buildings with a semi-integrated seawall and raised structures

Cross Section C-C' showing seawall at the CJL



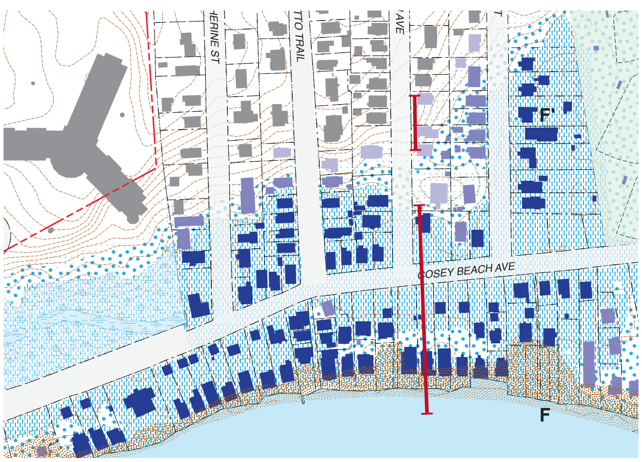
Cross Section D-D' showing a seawall under the existing structures and embedded structures in raised homes

Sections Illustrating Cosey Beach Road Scenarios



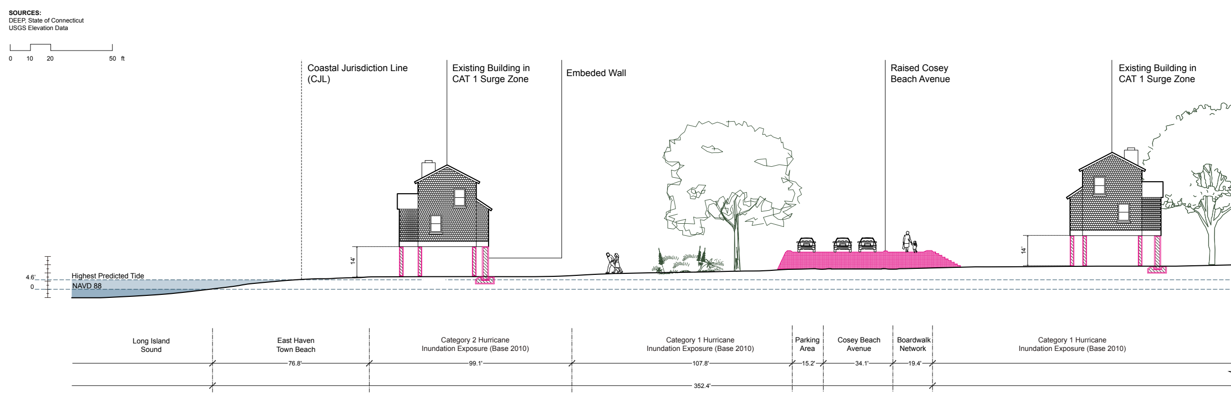
Showing a raised road berm with raised housing


Moving the wall back allows for full beach access

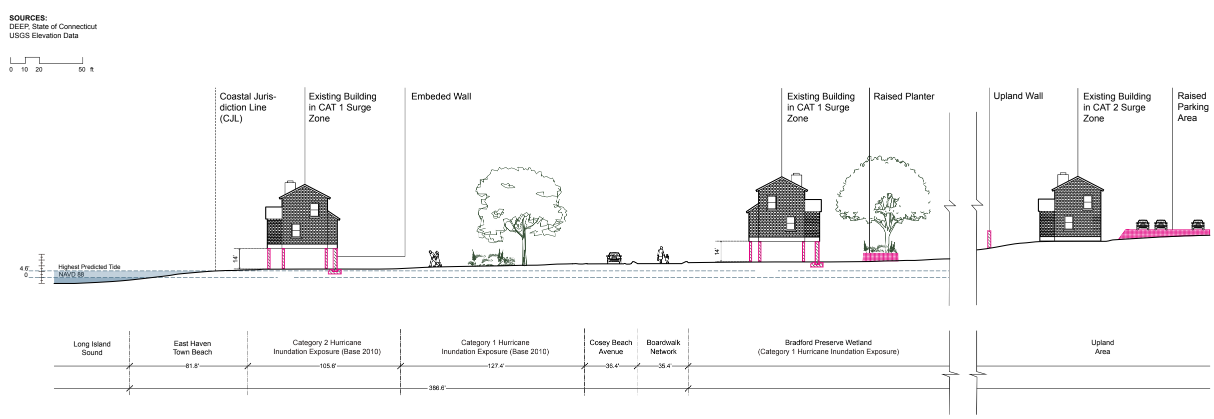


Showing a raised inland wall, raised planter and raised parking area


Raised housing along a barrier beach



Cross Section E-E' showing a raised road berm with raised housing



Cross Section F-F' showing a raised inland wall, raised planter and raised parking

ECONOMIC ANALYSIS AND DECISION MAKING SUPPORT TOOL

WEST HAVEN

This map shows East Haven with the overlay of the FIRM map from 2016 as well as the SLOSH model analysis from 2016.

West Haven

Incremental Site Specific Approaches

We focus the West Haven analysis on the coastal flooding surrounding Old Field Creek and the New Haven harbor along the eastern edge of West Haven. Applying a coarse economic evaluation for comparison to the area, we can identify three choices to address this problem. They can build a coastal wall by raising Beach Street and First Avenue along with a self-regulating tidal gate of Old Field Creek at Beach Street. They can build an interior wall to contain the flooding of Old Field Creek. They can buyout the low lying properties along Old Field Creek.

Raising Beach and First Avenue involves about 6,000 m of street. West Haven estimates that this would cost $8 million. Annualizing this cost and adding maintenance leads to an annual cost of $618,000. Building the self-regulating tide gate would cost about $1.5 million. Annualizing this cost and adding maintenance suggests an additional annual cost of $115,000. The total annual cost of this option is therefore $734,000.
Building a 3,100 m interior wall that is 3.2 m in final elevation (1.2 m high) crossing Old Field Creek would have an annual cost of about $1.6 million. Lifting the 154 homes in front of this wall to an elevation of 3.6 m (12 ft) would have an annual cost of $4.7 million. The total annual cost of the interior wall and lifting homes is $6.3 million. The final third option is to buyout the 405 low lying properties in this area. Given the average price of homes in West Haven of $270,000, the annual cost of such a buyout would be about $6.3 million.

The expected benefit of nearly eliminating the flooding in eastern West Haven is expected to be about $9 to $10 million. All of the proposed actions are worth taking. Each action is designed to have about the same final effect (total benefit). However, the least costly action is to raise Beach Street and First Avenue and to place a self-regulating tide gate on the Beach Street crossing of Old Field Creek.

The benefit to cost ratio of this option is over 10 to 1.

The advantage of raising Beach Avenue and First Avenue is that it protects a large number of modestly priced homes. Although raising these homes is technically feasible, the high cost of raising homes makes this an unattractive option for a homeowner. There is no net benefit to raising these homes for a homeowner. There was initially a concern that raising First Avenue was going to be too expensive because of peat under the road. However, it appears that replacing the peat with fill leads to cost effective road construction.

Old Field Creek is a functional wetland. West Haven plans to design the road to allow tidal flows underneath the road. A storm gate will be put in place, however, to prevent storm flooding. The wetland will help serve as a storage device during periods of high rainfall.

WEST HAVEN LOW LYING AREAS OF RISK

Main Street and Kelsey

This area includes proposed transit oriented development zones adjacent to the train station. The area floods from the Cove River.

Painter Drive

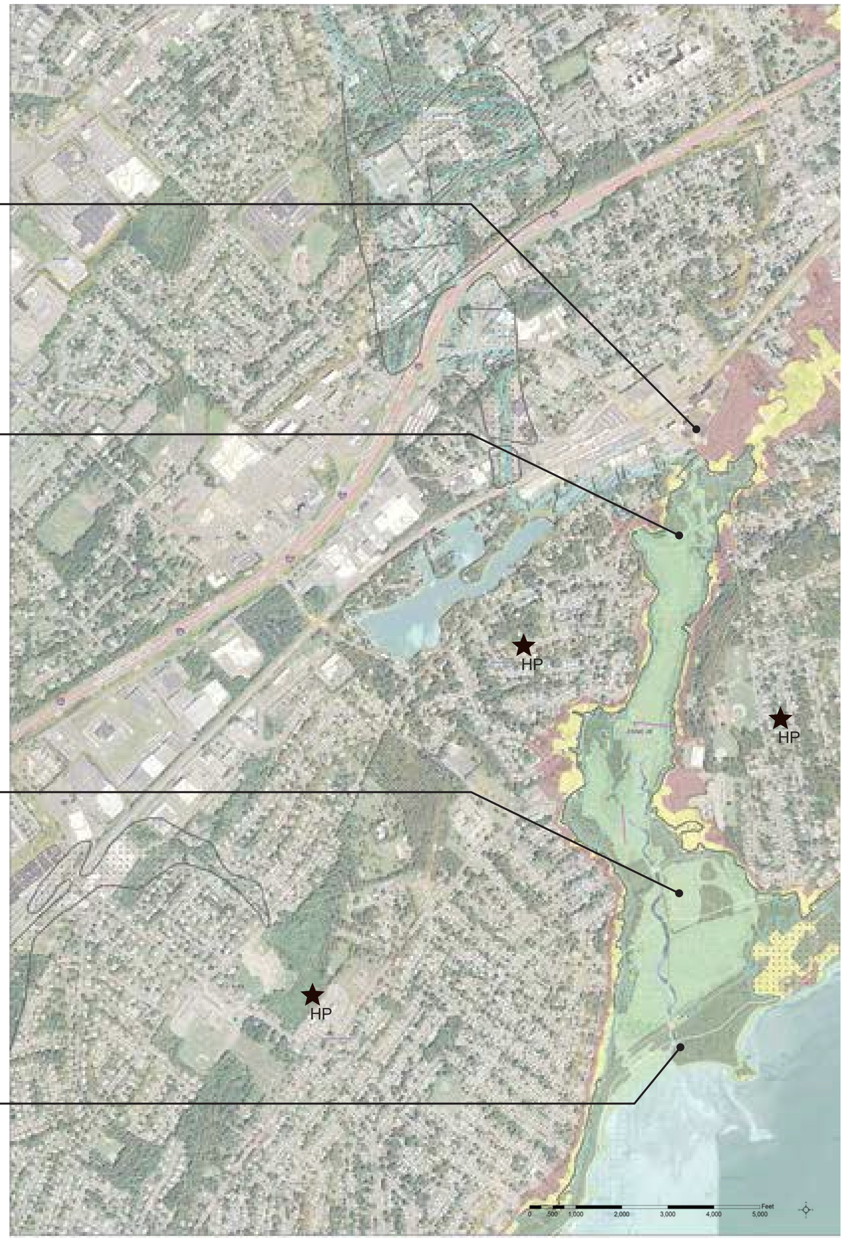
Road that floods. Needs walls and raised homes.

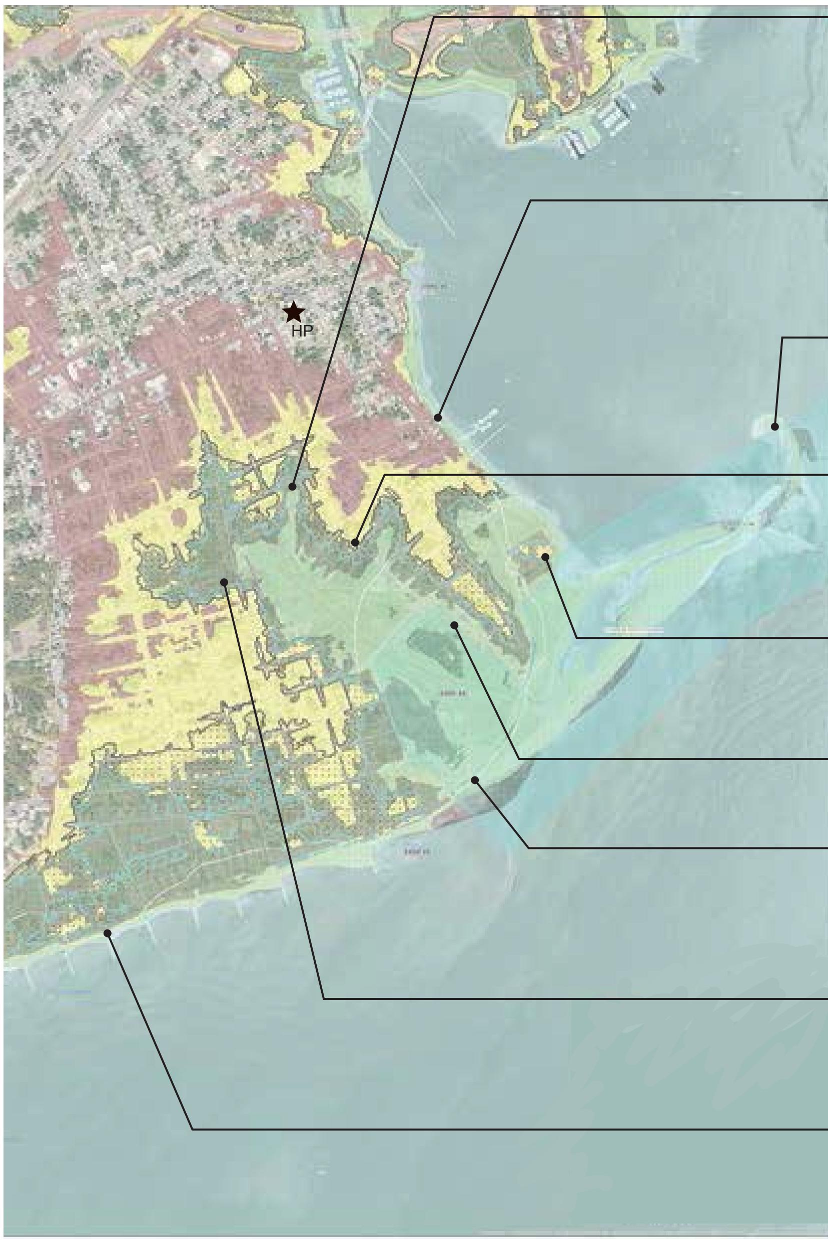
West Haven HS

Sports fields that flood and Painter Avenue.

Tide Gate

Potential location for a self-regulated tide gate designed as a management tool to control flooding.





Flooding Streets
Consider house raising, road consolidation and inland walls of White and Marshall to Brown Street.

First Avenue
Proposal to raise for dry egress to the Treatment Plant.

Sandy Beach Outfall
Pinch point at treatment plant outfall pipe.

Flooding Streets
Consider raised homes, separate parking and walls on Jones and May St at 3rd Ave.

Waste Water Treatment
Infrastructural building requires berming.

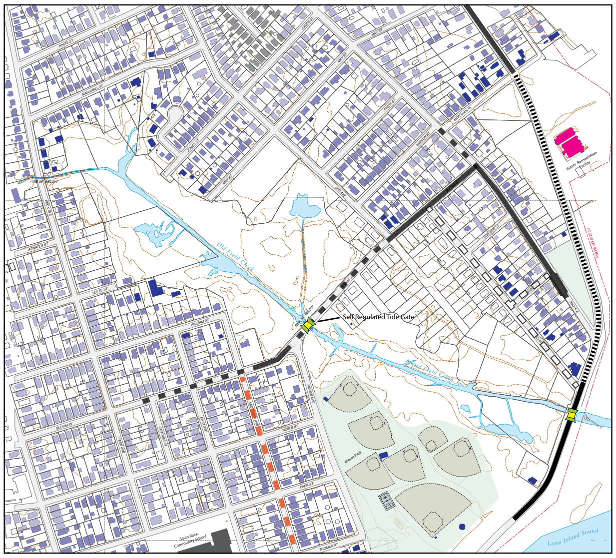
Flooded Homes
NRCS Buyout program

Beach Street #1
Considering raising but peat underneath makes this proposal a costly venture.

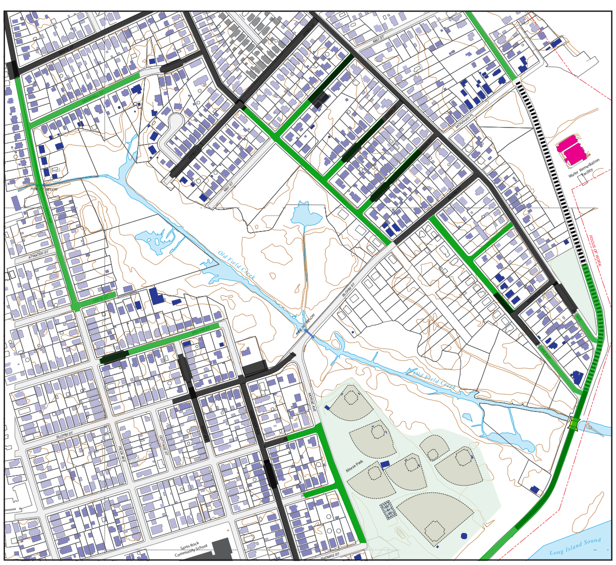
Pike Street
Area floods and requires bigger culvert and raised roads.

Beach Street #2
Beach erosion and flood management risks coastal properties flood.

Design and Technical Guide
Site Priortiziation Plans

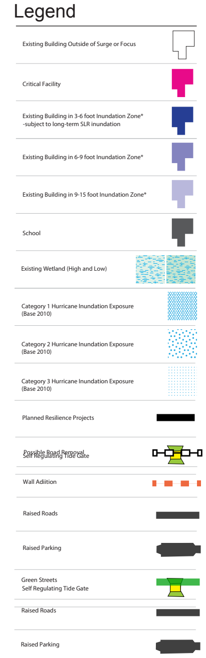


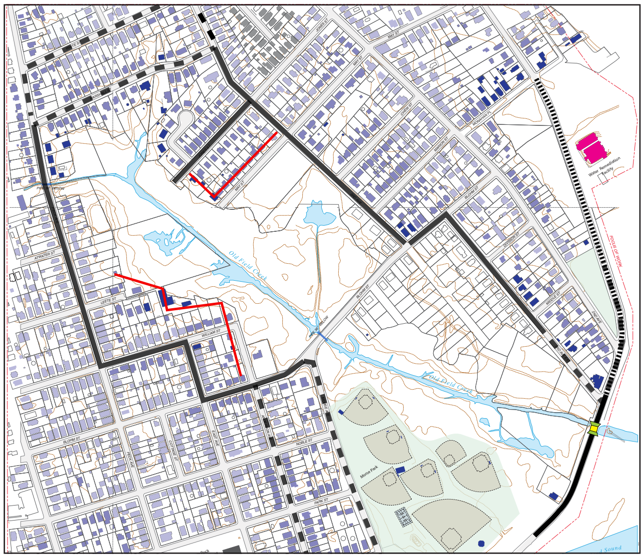
Tide Gate Strategy



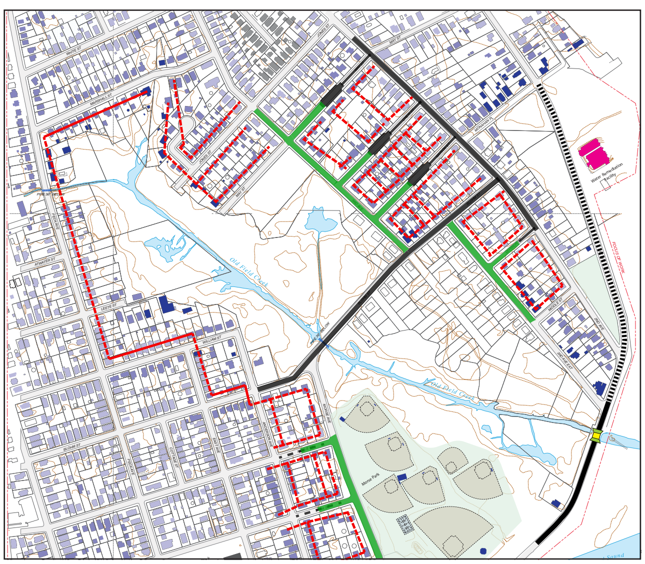
Green Streets and Road Raising

Legend

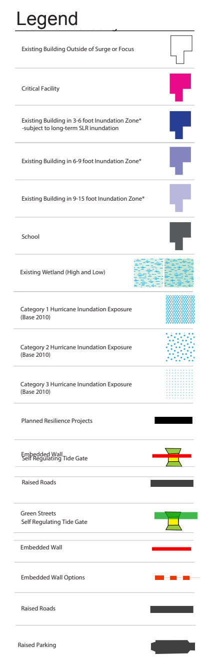


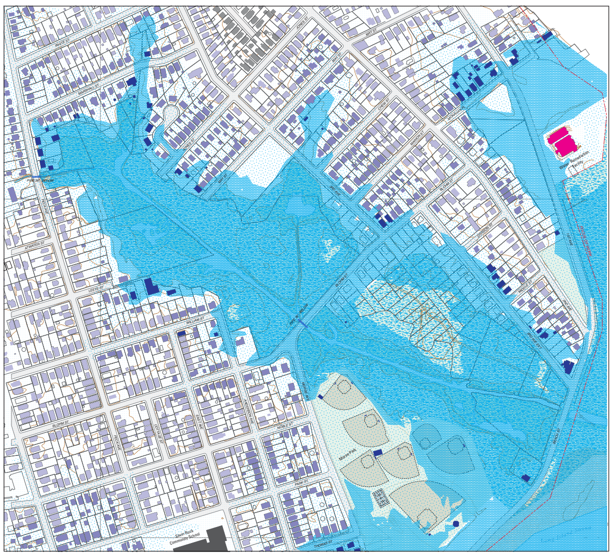


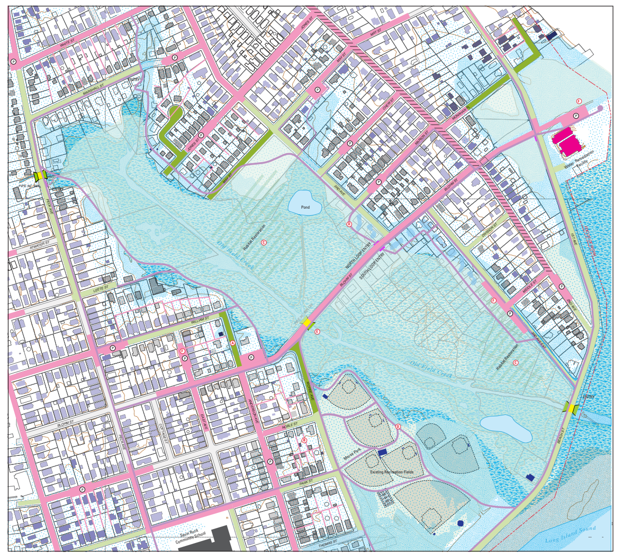
Inland Wall



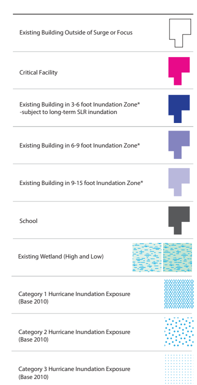
Green Streets, Raised Homes and Embedded Walls

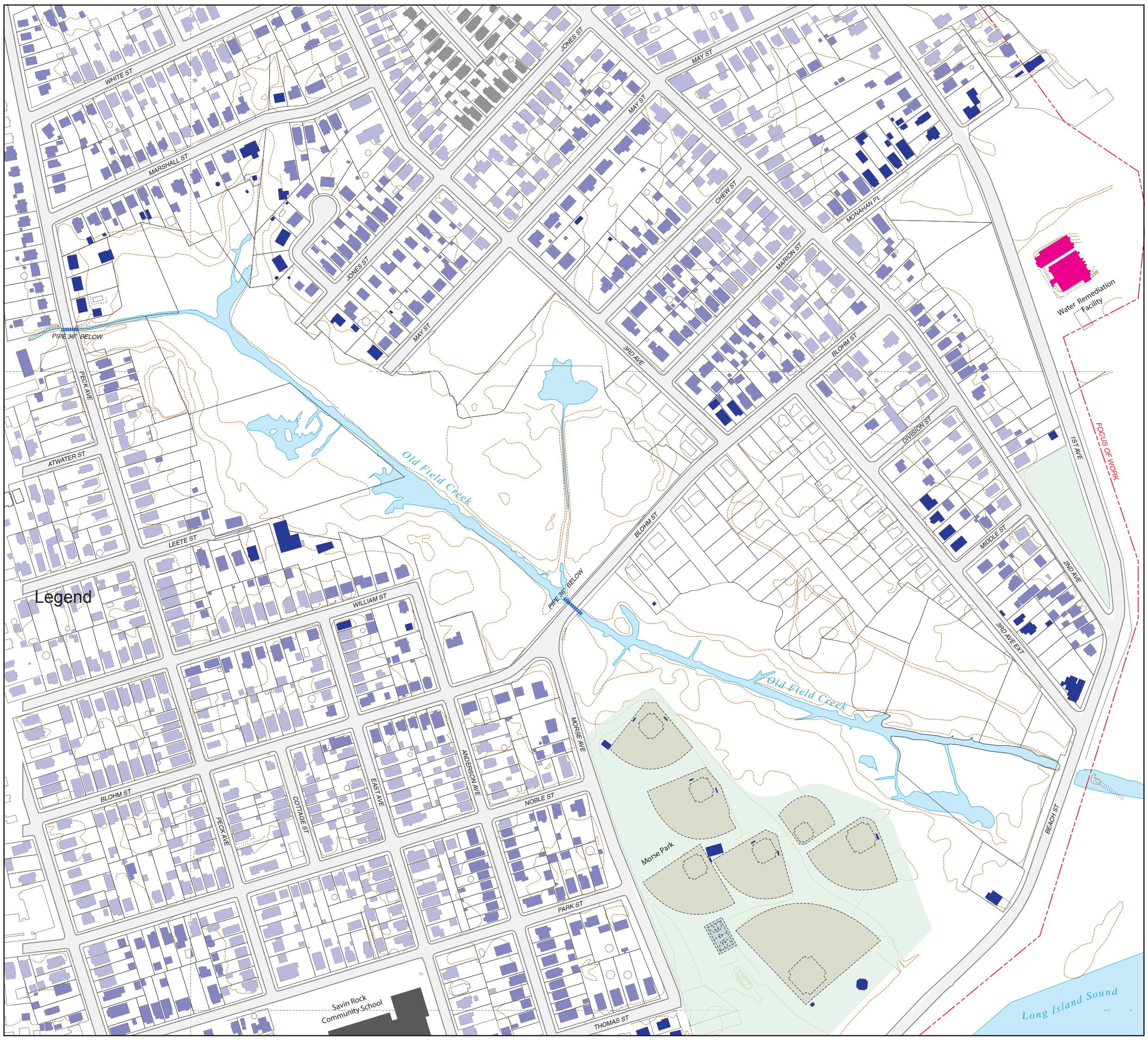






A variety of options are being explored for addressing flood risks in West Haven's Old Field Creek. On the left we illustrate the potential for a coastal wall. On the right we explore a series of raised road strategies while allowing Old Field Creek to flood.





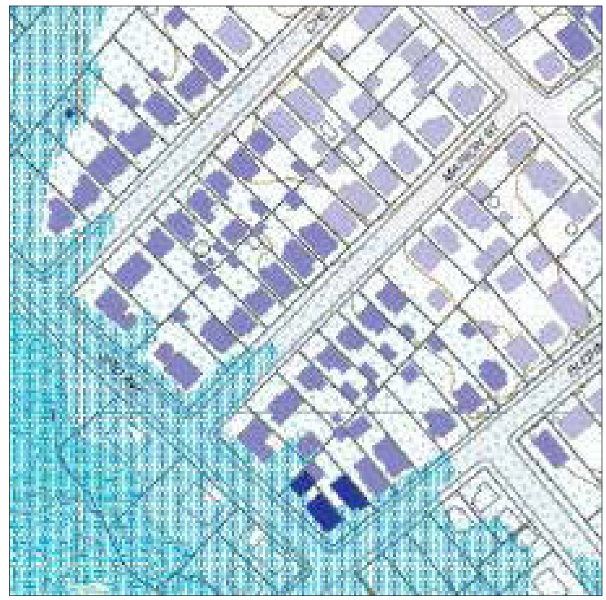
Current Condition / No Action / Storm Surge Exposure

'No change' plan and section in Marion St.

In the following sections, Marion Street and Blohm Street have been selected as targeted sites to represent the 4 design strategies in West Haven town.

Here, we depict the current condition with flood risk assuming no action.

Showing a commercial establishment directly adjacent to Beach Street in West Haven. Photograph by Paurush Singhal, 2018



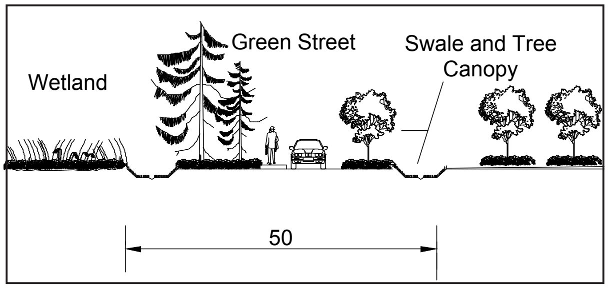
Marion Street Map

No Action - Existing Condition Section

West Haven's Beach Street showing the direct adjacency of the beach to the roadway. Photograph by Paurush Singhal, 2018

Raised Homes with Embedded Wall - Green Streets

In this strategy, Second Avenue and a part of Marion Street are raised and a parking lot is constructed for the houses in the area. Green street urban renewal design will be implemented over time from Marion Street to Third Avenue. Houses in green streets are raised with an embedded wall.



This roadway cross section illustrates a strategy for adding vegetation and pervious surfaces on greens streets for infiltration and ecosystem function.

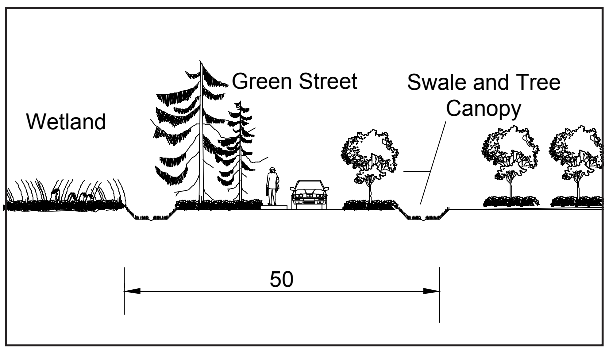
Marion Street Map

Embedded Wall and Green Streets Section

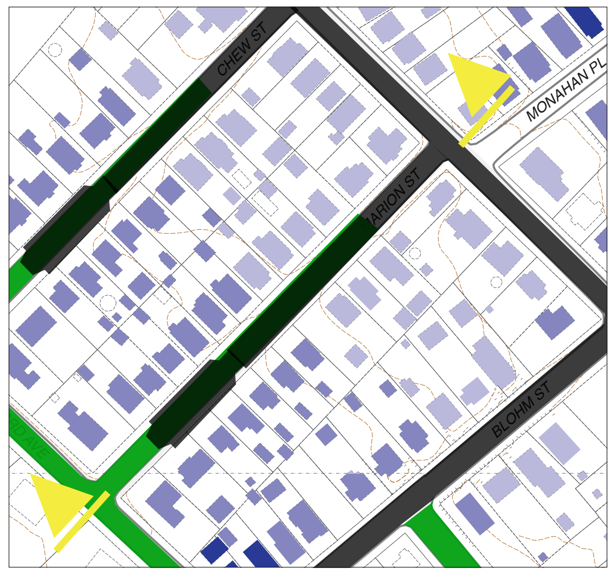
Housing along Old Field Creek wetland area. Photograph by Paurush Singhal, 2018

Green Street Road Raising

Coordinated road raising strategies with a central spine (resilience corridor) create a long term evacuation route for dry egress. Houses can be raised in blocks over the next few decades.



This roadway cross section illustrates a strategy for adding vegetation and pervious surfaces on green streets for infiltration and ecosystem function.



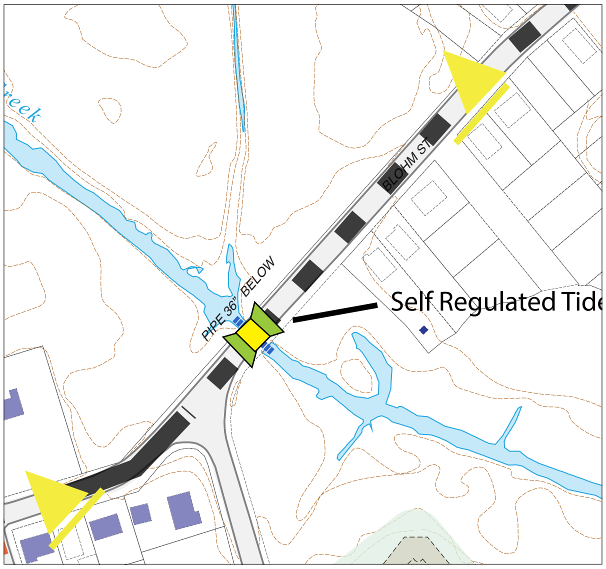
Marion Street Map

Green Streets Road Raising Section

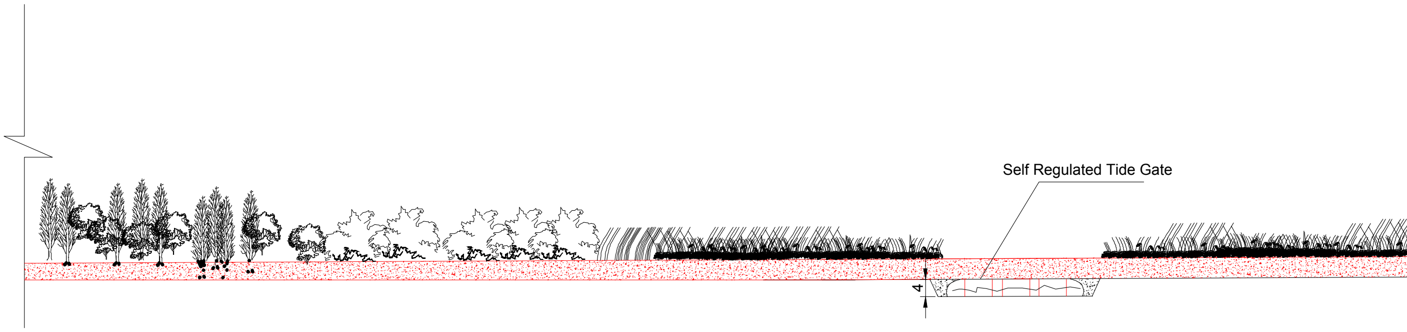
The beach along Beach Street with adjacent housing that is at risk of flooding. Photograph by Paurush Singhal, 2018

Self-Regulated Tide Gate

In this flood management strategy, constructing a self regulated tide gate on Old Field Creek could be closed during large storm events to control flooding and protect the area behind it while remaining open at other times to allow normal water flow during non-flood periods. The use of SRTGs as combined flood and ecosystem management tools still requires additional testing and development to ensure its viability. It will require re-evaluation and tinkering over time with sea level rise.

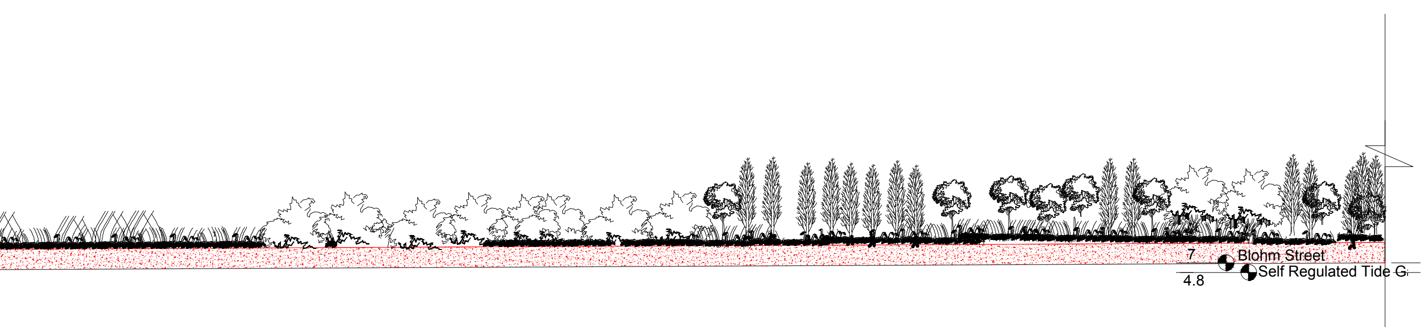


Blohm Street Map



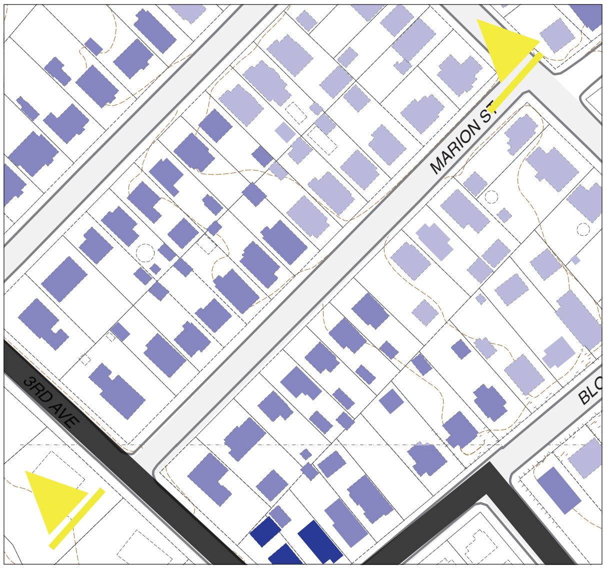
Tide Gate on Blohm Street Section

Tide gates such as this one on the West River have been installed on multiple waterways in Connecticut over many decades to control flooding and manage water flow. The ecological impacts of tide gates are a concern and require further analysis. Regulations on tide gate installations exist in Connecticut. The flood management benefits depend on the tide gate height, and operations. More advanced tide gates include remote capacity for opening and closing the gates, or self regulated tide gates. Increased operability can also lead to operational failures. Photograph by Kevin Lubey



Protective Road Raising

One option is to raise Third Avenue to protect the houses behind it. To manage flood water behind the raised road, green infrastructure strategies are proposed to facilitate storage, infiltration, and prevent flooding in Marion Street.



Marion Street Map

Protective Road Raising Section

Here you can see the limited grade change between the beach, road and adjacent commercial buildings and housing.

CONCLUSIONS

This study provides a prioritization tool for municipalities faced with extensive flood risk and the challenge of balancing property/ homeowner interests, with town scale concerns including the tax base and investment priorities and infrastructure maintenance and failure. Specifically, we focused on two coastal locations, East Haven and West Haven. In East Haven, we were able to look at the whole coastline. In West Haven, we focused on Old Field Creek, and impounded marsh area where buyouts have occurred and funding is going towards road raising.

This study combines two approaches to coastal adaptation and climate change risk mitigation: a quantitative economic model and an ecological-based design model. The economic analysis tool is preliminary and provides a snapshot of the value of housing at risk and the benefits of protection. The planning approach was streamlined. We met twice with the city engineers and planners to explore ongoing projects and incorporate feedback into the design.

While ecosystem services were not integrated into the economic model, the planning efforts explore options that take into account ecosystem services alongside economic drivers. We also met with DEEP officials and discussed the outcomes of this plan. Each of the proposed plans and economic recommendations will require further investigation and discussion with DEEP around issues of permitting and impacts related to encouraging redevelopment in the floodplain.

The proposals here are intended to illustrate the value of assessing flood risks using a combined economic assessment with an ecologically sensitive planning approach. The hybrid strategy includes assessing the risks across 30 years, with the intention that planners in 30 years can revisit the situation with a better understanding of the circumstances, as well as a long term planning strategy, looking at 2100 and identifying future predicted conditions to inform near term practices and particularly to avoid making choices that lead to poor choices for long term resilience measures.

The outcomes of this hybrid analysis are that solutions are heterogeneous. In certain instances it may be highly beneficial to consider building a wall in front of a series of houses, in other cases, raising homes and roads are a better solution, in additional cases, building walls further back, or taking no action, with the intention of eventually retreating make the most economic sense. The wall heights are based on optimizing investment into the wall in relation to avoided damages to properties. It does not address all storm events. Additionally, while this study does not consider the source of funding or the financing mechanisms for the recommended projects, we recognize this is a critical consideration for municipalities.

We hope other towns along the Connecticut coastline will benefit from this analysis and explore ways of applying this hybrid approach to their own neighborhoods. By identifying zones of shared risk and working toward a more resilient and cost effective set of solutions, we can reduce the risk of future superstorm events and help strengthen the collaboration of municipal leaders, subject matter experts, and local residents toward shared solutions. While the economic assessment reveals that there is practical way of protecting each and every house or investing unconditionally in infrastructure, this approach allows for science-based solutions that make the most of municipal investment and engage multiple stakeholders toward shared solutions.

ENDNOTES

References

1: Stone, JR; Schafer, JP; London, EH; DiGiacomo-Cohen, ML; Lewis, RS; Thompson, WB; Quarternary Geologic Map of Connecticut and Long Island Sound Basin; United States Geological Survey; 2005.

2: National Oceanic and Atmospheric Administration; Global Sea Level Rise Scenarios for the United States National Climate Assessment: NOAA Technical Report OAR CPO-1; United States Department of Commerce; 2012. 1

3: FitzGerald, D. M., M. S. Fenster, B. A. Argow, and I. V. Buynevich. 2008. Coastal impacts due to sea level rise. Annual Review of Earth and Planet Science 36: 601–47.

4: R. E. Kopp, R. M. Horton, C. M. Little, J. X. Mitrovica, M. Oppenheimer, D. J. Rasmussen, B. H. Strauss, and C. Tebaldi (2014). Probabilistic 21st and 22nd century sea-level projections at a global network of tide gauge sites. Earth's Future 2, 287–306, doi:10.1002/2014EF000239.

5: https://tidesandcurrents.noaa.gov/stations

6: https://www.fema.gov/hazus/

7: cteco.uconn.edu/data/lidar/index.htm

8: https://www.ct.gov/deep/cwp/view.asp?a=2705&Q=511544&deepNAV_GID=1622

9: Grimm, Nancy B., Elizabeth M. Cook, Rebecca L. Hale, and David M. Iwaniec. 2016. "A Broader Framing of Ecosystem Services in Cities: Benefits and Challenges of Built, Natural, or Hybrid System Function." In Handbook on Urbanization and Global Environmental Change, edited by K.C. Seto, W.D. Solecki, and C.A. Griffith, 203–12. Routledge.

10: Redman C, Morgan Grove J and Kuby L 2004 Integrating social science into the Long-Term Ecological Research (LTER) Network: social dimensions of ecological change and ecological dimensions of social change Ecosystems 7 161–71.

11: Ahern, Jack & Cilliers, S & Niemelä, Jari. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. Landscape and Urban Planning. 125. 10.1016/j.landurbplan.2014.01.020.

12: Erik Gómez Baggethun and David N Barton. 2013 Classifying and valuing ecosystem services for urban planning. Ecological Economics. (86):235-245.

13: https://www.millenniumassessment.org/documents/document.356.aspx.pdf; pgs. v.

14: De Groot, Rudolf S. "A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services." Ecological Economics 41, no. 3 (2002): 393-408. ScienceDirect.

15: Fisher, Brendan. "Defining and Classifying Ecosystem Services for Decision Making." Ecological Economics 68, no. 3 (January 2009): 643-53. ScienceDirect

16: Elliff, Carla I. "The Ecosystem Service Approach and Its Application as a Tool for Integrated Coastal Management." Abstract. Natureza & Conservação 13, no. 2 (2015): 105-11. ScienceDirect.15:

17: Diane E. Pataki et al.,"Coupling Biogeochemical Cycles in Urban Environments: Ecosystem Services, Green Solutions, and Misconceptions,'" Frontiers in Ecology 9 (2011): 27–36.

18: Bridges, T. S., Wagner, P. W., Burks-Copes, K. A., Bates, M. E., Collier, Z., Fischenich, C. J., Gailani, J. Z., Leuck, L. D., Piercy, C. D., Rosati, J. D., Russo, E. J., Shafer, D. J., Suedel, B. C., Vuxton, E. A., and Wamsley, T. V. 2014. Use of natural and nature-based features (NNBF) for coastal resilience. ERDC SR-15-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

19: FitzGerald, D. M., M. S. Fenster, B. A. Argow, and I. V. Buynevich. 2008. Coastal impacts due to sea level rise. Annual Review of Earth and Planet Science 36: 601–47.

APPENDIX

Project Overview

Summary and Scope of Work

We have prepared the following technical memorandum to summarize our efforts to date for Tasks 1-3 and to complete Task 4. During this period, we worked across academic and professional partnerships at Yale University and Ecopolitan Design. We employed several graduate and undergraduate students at Yale to generate our economic analysis and site evaluation techniques. Ecopolitan Design also met with municipalities, experts, and members of SCRCOG.

Summary of Task Efforts

Over the period from July 01, 2017 to August 31, 2018, we worked with graduate and undergraduate students at Yale University to generate the site evaluation, economic analysis and planning documents. We met with town engineers and town planners, from both East Haven and West Haven*, and with local experts and members of SCRCOG.

Task 1: Review the completed coastal resilience plans for two sites across two towns and gather feedback on select projects.

For this task, Ecopolitan coordinated the kickoff meeting and held working meetings with each municipality, gathering information about the priorities of the town and sharing our initial approach to solicit feedback. We discussed ways of evaluating distinct time horizons for the town and the ways the condition of homeowners' structures and land, as well as the town's tax base, shift and evolve over these time scales. We reviewed cost assessments and met with GZA Engineering to discuss our approach toward risk evaluation. We met with the executive director of CIRCA, James O'Donnell, to review our economic model and our approach to using probabilities and basic elevations, in relation to the approach at CIRCA, as an alternative to CREST and WAVE. In meeting with Jim to review our methodology, we were able to analyze and review the validity of our economic model and soundness of our overall methods while ensuring the project adhered to the HUD NDR intent. We are capitalizing on the efforts already made in each municipality through the existing resilience plans developed as part of the Regional Framework for Coastal Resilience in Southern Connecticut with the SCRCOG and The Nature Conservancy.

Task 2: Develop prioritization and decision making tools and refine the target projects

Building on our meetings with the town engineer and planner, we identified priority areas and refined the selection of particular locations as targets for economic analysis of resiliency options. We evaluated the benefit of wall building, road raising, tide gates, inland protection and no action, based on the costs and the potential to mitigate storm impacts. Leveraging the economic model, we evaluated a grade of grey to green armoring interventions at selected locations to reduce the risks of probabilistic storm events. We analyzed results in the context of alternative time horizons and their influence on choices for protection and ways of prioritizing projects, iteratively adjusting our target options in an analytical feedback loop. Concurrently, we are exploring innovative ways of planning and educating homeowners about how to chart paths of incremental change towards realizing collective benefits. Through this process of quantitative economic analysis and quantitative design thinking and outreach with town engineers, we seek to create a phased project that positions the municipality to achieve viable long-term coastal adaptation strategies.

We identified locations where coastal walls could be placed to reduce the damage of storm events. We identified a series of target options through the initial discussion with the town, including considerations on the impact of alternative time horizons on choices for protection and ways of prioritizing projects. Near-term projects that have long-term values will be prioritized, especially projects with high benefit to cost ratios.

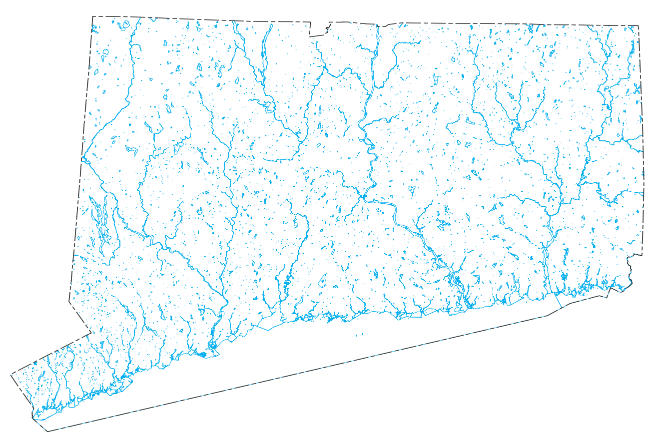
Task 3: Review the economic analysis decision making tool with the municipal staff and the advisory consultant team

The details for the economic model were defined during meetings with the municipalities and advisors. Models were made that predicted sea level rise and storm surge inundation before being used to predict property damage based on the information provided by municipalities. Discussions with municipalities brought forth specific concerns about possible property and infrastructure losses near the coast. From these concerns and others on coastal zoning, it was possible to determine a list of practical scenarios for East Haven and West Haven's coastal development. A design framework was established to prioritize projects based on their ecologic and economic factors. Alternatives were considered that minimize property loss and damage to wetlands. The economic model was developed to assess the impacts of alternative strategies by measuring their benefits and costs, with the goal of assisting in the decision making process for coastal planning.

Task 4: Develop a Design and Technical Guide – Decision Making Support Economic Tool and Memorandum

The technical guide combines economics with practical decision making, planning and ecological design. The model was developed in response to comments and input from municipalities and the State. It provides guidance to design efforts for site-specific planning. Designs are proposed and presented in the format specified in the original scope of the project, and additional information has been added in order to fully contextualize all decision making and design strategies. The East Haven and West Haven coastal resilience redesign is the focus of this document, however, the thought process presented poses possible design considerations for a number of future locations. Though site-specific planning should be factored into future projects, this guide is a framework for possible solutions and presents an economic prioritization tool that, once calibrated for new locations, will be influential in coastal redevelopment efforts.

Map of New Haven and adjacent cities



Bodies of water in Connecticut

Project Schedule and Budget Summary (30 June 2017)

Detailed project description and workplan

1. Project description (include project name and project address);

Title: Design and technical guide for implementing innovative municipal scale coastal resilience in Southern Connecticut

Project locations: West Haven - Old Field Creek and East Haven - Cosey Beach

Project Description: Northeast coastal communities are heavily settled and vulnerable to sea level rise and increasingly severe and frequent storm surges. Critical infrastructure, ecosystems and human safety in these towns are under threat (FitzGerald 2008). These vulnerabilities were felt acutely following Tropical Storm Irene (2011) and Hurricane Sandy (2012), including in the two coastal communities within the project area (East Haven and West Haven).

The Yale Urban Ecology Design Lab (UEDLAB) evaluated the selected sites and developed municipal near-, mid- and long-term plans as part of a coastal adaptation project funded by The Nature Conservancy. In each project the UEDLAB sought to integrate infrastructure and risk management with urban design strategies including social and ecological goals and investment for resilience. This was a complementary and coordinated effort to the Regional Framework for Coastal Resilience in Southern CT Project. The Regional Framework for Coastal Resilience is a partnership between SCRCOG, MetroCOG and The Nature Conservancy, funded through the Hurricane Sandy Coastal Resiliency Competitive Grant Program administered by the National Fish and Wildlife Foundation. The main objective of the Regional Framework for Coastal Resilience was to comprehensively assess and advance resilience opportunities to reduce risk to the 591,000 residents across ten coastal municipalities and increase the viability of natural ecosystems along a significant portion of Connecticut's coastline.

The two selected locations in this project are at different stages in planning for and adapting to the evolving risks. Each is also distinct in settlement density, hydrology, erosion and wave patterns, and types of habitat. Working with these two diverse sites, we will analyze a range of flexible and integrative approaches to coastal adaptation that can inform other Northeastern coastal communities facing similar challenges. Building on these experiences and findings, we propose to translate the innovative but practical near-, mid- and long-term plans developed collaboratively with municipalities into targeted implementation strategies and particularly comparing the costs of these more innovative approaches with traditional practices. To do so, we propose working closely with a landscape architect and economist from Yale University connected with an advisory group including regional planners, a land use attorney, and town engineers. A main goal is refining initial design proposals and leveraging an economic analysis to guide the planning process and inform municipal planning.

Coastal adaptation and resilience planning at the municipal scale face multiple challenges. Town planners are concerned with the tax base that coastal inhabitants represent, and, therefore, they seek solutions that preserve the existing configurations. This goes against the pressures of increased sea level rise and storm surges. There are several challenges to transition from planning to implementation, which range from lack of communication and decision tools, gaps in valuing urban ecosystem services, a peripheral role for ecologists in the creative design process, and a mismatch of the objectives and timelines across the different disciplines.

This proposal seeks to overcome some of these challenges that practitioners, planners and policymakers encounter, with the recognition that more than ever before the socio-economic and mounting environmental pressures upon built environments particularly in urban areas demand careful assessments to inform innovative actions. Using coastal adaptation strategies applied to selected projects, this proposal will build on exemplary projects that integrate social, ecological and economic goals. The strategies address land use changes and innovations in housing, landscapes and habitats, roadways and utilities, towards a cohesive transformation of an urban coastline, over time.

Having examined the practical application of the strategies, this proposal is to work with municipalities to prioritize projects and identify choice near-term opportunities that feed into long term planning through the use of a decision making support tool. Each of the prioritized projects are intended to inform a broader state level set of lessons learned and ways of applying these coastal adaptation strategies more broadly to climate change adaptation. Each of the prioritized projects will be vetted through the application of the Economic Analysis/Decision Making Support Tool to refine the implementation process. The outcome of this process will be a Design and Technical Guide based upon the evaluation of the Economic Analysis/Decision Making Support Tool by municipal staff and an advisory team with Legal and Engineering expertise. The Design and Technical Guide will serve as a toolkit to be integrated into the municipal planning process. They are intended ultimately to provide a guide for the transition from towns driven by hard infrastructure, road transportation and developer-driven housing to spaces created with equity, human health, ecosystem function, and climate change as drivers of planning and design.

Workplan (including major phases, deliverables, project dates, permitting process (if applicable), project team members and roles);

1. Review the completed coastal resilience plans for two sites across two towns for feedback and select projects

Description: Coordinate a kickoff and working meeting with each municipality (2 total) to provide feedback on the near-, mid- and long-term plans and cost assessments and engineering guidance. Plans were developed as part of the Regional Framework for Coastal Resilience in Southern Connecticut. The team will capitalize on the established communication channels between the SCRCOG and municipalities, to improve the existing maps. The team will leverage the value and investments already made in each municipality through the existing resilience plans to extend our work with the towns and develop technical and implementation documents to support intelligent near-to long-term adaptations. The team will work closely with CIRCA to review the proposals prior to meeting with the towns in relation to the current modeling analysis through CREST and Wave.

Scope of Services: **a. Internal meeting with CIRCA.** This meeting is to review current modeling information and CREST maps for the existing mapped locations and near-to long-term proposed land use changes. **b. Kickoff meeting with town representatives in each municipality.** Meet with town planners, engineers and other selected town representatives to vet the near-to long-term planning process. The meetings organized by SCRCOG will include AFLA, Yale, municipality representatives, and selected experts. We seek critical information about the current plan proposals, including site characteristics and concerns, additional threats from sea level rise and other constraints and opportunities for the furthering the design and moving towards implementation of the project for the municipal representatives. In addition, we will review alternative strategies and obtain cost assumptions and implications from the selected options. **c. Select projects that carry over from near-, mid- and long-term plans.** Based on the meetings, each municipality will select a set of near-term to long-term projects to develop preliminary economic assessments towards supporting choices regarding implementation steps and cost implications. These projects will serve as focal areas for this scope to be developed further in terms of design and implementation. **d. Engage with targeted stakeholders.** Work with the town to identify a select group of stakeholders based on discussions with the municipalities, and coordinate an outreach and communication meeting to inform the project. **e. Modify the existing plans.** Based on feedback, the team will modify existing plans. **f. Establish channels for communication to the public about the findings.** Working with CIRCA, the team will establish a communication approach to get feedback from local stakeholders regarding the near-to long-term plans.

Deliverable for Phase 1: 2 meetings (one with each town) Memoranda summarizing the meetings and revised plans for 2 project sites.

Time Frame: 8 weeks

Participants: SCRCOG, CIRCA, AFLA and students from the UEDLAB, municipality, stakeholder

2. Develop prioritization and decision making tool and refine target projects

Description: Together with municipalities, the team will review options illustrated in the planning documents for specific near term projects. The team, working with each municipality will develop a set of decision-making criteria to select a series of phased projects to position the municipality to achieve a viable long term coastal adaptation solution. Near-term projects that have long-term values will be prioritized especially where they shift towns away from short-sighted solutions with long term negative impacts. The team will identify target projects through a prioritization process. The team will coordinate with each municipality to develop a series of project options, including prioritization, information gathering, stakeholder perspectives, and gaps in understanding.

Scope of Services: **a. Evaluate options through a land use assessment and comparable economic analysis.** Building on the communication with municipalities around the planning process, and based on relevant documents for each municipality including hazard mitigation plans and the Plans of Conservation Development, Zoning Regulations, Inland Wetlands, and municipal code of ordinances, the team will develop a preliminary economic and land use change assessment for 2-4 comparable options. **b. Coordinating materials and inform an economic prioritization template and decision making tool.** The core team will evaluate feedback from the original meetings with towns and evaluate the proposed projects to develop prioritization criteria to evaluate project options with municipalities. The preliminary tool will support municipalities in evaluating the tradeoffs and uncertainty and define particular metrics for social, economic and ecological services. **c. Prioritization and Decision Making Tool** – An outcome as part of this process is to generate a prioritization and decision making chart for use in guiding municipality decisions moving forward.

Deliverable for Phase 2: Economic analysis and template prioritization and decision making tool.

Time Frame: 10 weeks

Participants: Yale Rob Mendelsohn and Alex Felson through the UEDLAB will be responsible for developing the prioritization tool to inform decision making. Input will be provided through an advisory team including Town Engineer, Land use Lawyer, SCRCOG, municipality Planners, other stakeholders

3. Review economic analysis and decision making tool with municipal staff and advisory consultant team

Description: Working with CIRCA and municipal staff, we will evaluate the proposed land use scenarios translated into near-to long-term modifications and studying the impacts from an ecosystem valuation and ecosystem-based assessment. The team will investigate the prioritized projects and develop revised design steps indicating the regulatory and permitting process, sizing and scaling, and public coordination, ecosystem service benefits and overall logistics for construction. Additional review and input will be provided by a consultant team of engineering and legal advisors

Scope of Services: **a. Engage with CIRCA researchers.** We will identify valuable existing mapping and modeling to inform land use alternatives and cost evaluation. We will be identifying opportunities for improvements. Determine inundated areas during normal, storm, and future sea level rise conditions. **b. Land use, Policy and Economic assessment of municipal coastal resilience options.** Overlapping the risk assessment and environmental stewardship opportunities with viable land development options based on feedback from the municipality and/or modeled scenarios based upon town planning and land development practices. **c. Linking ecosystem-based management to future development scenarios.** Management of coastal real estate and structures (building codes, freeboard, zoning overlays), shoreline protection and management of coastal and near-shore lands (living shorelines, hard and soft protections), roadway alterations (elevation, abandonment, secondary egress), and protection or replacement of water supply wells and septic systems (on-site retrofits, extension of water and sewer systems, development of community systems). Working with local officials and with economic experts we will evaluate the impact of the proposals on homeowner property value and on the overall town tax base.

Deliverable for Phase 3: Memorandum summarizing the discussion and findings

Time Frame: 12 Weeks

Participants: Team member focusing on modeling land use change. Alex Felson and the UEDLAB will develop the proposed scenarios. SCRCOG will serve as project manager. Economist will assess various options and outcomes over time including property values and the town tax base in the face of future risks. Yale students will be involved in multiple stages.

4. Develop Design and Technical Guide – Decision Making Support Economic Tool and Memorandum

Description: Working with the team to develop an implementation guide based on the economic analysis and decision making support tool and memorandum with drawings. The two projects sites will be used to highlight the applicability of the guide.

Scope of Services: **a. Work with team to synthesize information.** The team will generate and present a final memoranda building on the planning documents developed prior to the scope, and developing these into conceptual design proposals for selected sites, using the Economic Analysis and Decision Making Support Tool. **b. Provide final materials.** Materials will be provided in hard copy and electronic format to the municipality and other stakeholders, in a single meeting. Final conceptual designs based on the economic analysis will include: (1) broader and (1) zoomed in plan view (shown at 3 time frames), (1) cross-section for each location, and (1) overall conceptual diagram and design rendering all in Adobe pdf presentation format with individual separate image files.

Deliverable for Phase 4: Design and Technical Guide based on Economic Analysis and Decision Making Support tool highlighting the two project sites.

Time Frame: 6 Weeks

Participants: Team member focusing on modeling land use change. Alex Felson and the UEDLAB will develop the proposed scenarios. SCRCOG will serve as project manager. Economist will provide guidance. Yale students will be involved in multiple stages.

2. Resumes for team members:

See attached.

3. Permits required and plan for acquisition, if applicable, including all drawings and plans to be submitted during the permitting process;

The development of projects will inform economic analysis and plan drawings for additional funding.

4. Partner roles and responsibilities (if applicable);

TOWNS: Provide direct feedback on the proposed near to long term plans; prioritize projects options based on a set of established criteria and objectives; provide support materials to inform the process of design and planning; provide feedback in a timely manner for an interim deliverable.

SCRCOG (Eugene Livshits, Rebecca Andreucci): Management of communication and information exchange along with meetings with towns; participation in meetings; participation in developing technical memos.

AFLA (Alex Felson): Lead the planning and design and lead the meetings; oversee the development of the decision tool and technical manual; coordinate the deliverables.

YALE UNIVERSITY (Alex Felson, Robert Mendelsohn & Students): Ecosystem service assessment with students for the decision making tool; analysis of urban ecosystems; ecosystem service assessment; economic comparisons.

LAND USE/LEGAL (Chuck Andres): Evaluate policy and land use options; inform decision making tool.

POLICY (TBD): Evaluate regulatory/policy considerations; inform decision making tool.

ENGINEERING/CONTRACTING (TBD): Evaluate implementation considerations (cost estimation, development strategies) to inform decision making tool

CIRCA: Provide existing modeling information/maps for selected sites; participate in meetings depending on availability and provide input into the process; provide feedback on coastal systems; review technical memos evaluating engineering and ecology

6. Sources of leverage and amounts (if applicable);

Work previously done through the Regional Framework for Coastal Resilience in Southern Connecticut will be leveraged.

7. How project will advance mission of CIRCA;

This project will increase the resilience and sustainability of vulnerable communities along Connecticut's coast and inland waterways to the growing impacts of climate change. The CIRCA mission will be advanced through the development of technical memos and a decision support tool which will be applied to two sites, with the intention that the design and technical guide can be used across Connecticut's entire coastline.

8. Define collaboration with CIRCA (if applicable);

CIRCA will be involved in discussions regarding their modeling data in Phase 1, during the study of land use alternatives and cost feasibility in Phase 3, in analyzing sea level rise projections in Phase 3, and will be provided with final deliverables in Phase 4. CIRCA is also encouraged to attend any of the municipal meetings in Phase 1.

9. Description of how project satisfies a priority area of CIRCA, indicating which priority area(s) and, if applicable, demonstrated use of one or more of CIRCA's research products

The project area we will target is: "Foster resilient actions and sustainable communities – particularly along the Connecticut coastline and inland waterways – that can adapt to the impacts and hazards of climate change"

10. Description of acknowledgement;

CIRCA will be acknowledged as the funding source on all final deliverables.

11. Letters of support (if applicable).

N/A

12. Statement affirming that applicant participated in the September 19, 2016 webinar or reviewed the recording.

Rebecca Andreucci watched the live webinar on September 19th. The other team members reviewed the recorded webinar on October 24, 2016.

SCRCOG CIRCA MRGP Detailed Budget	
Organization	**Budget**
Yale University (Yale)	
Alex Felson	$8,250.00
Robert Mendelsohn	$10,750.00
Graduate/Undergraduate Students	$14,000.00
Total Yale:	**$33,000.00**
Alex Felson Landscape Architect (AFLA)	
Hiring a designer and project manager	$13,000.00
Engineering	$0.00
Land use lawyer	$0.00
Cost Estimator	$0.00
Legal/Engineering Advisors	$4,000.00
Total AFLA:	**$17,000.00**
Total Project Budget	**$50,000.00**

Framing of Critical Considerations

Notes GZA Engineering Firm
June 9th, 2017

Participants: Dan Stapleton, Alexander Felson, Robert Mendelsohn, Alyssa Lustig, Ou Lun

(1) Integrating risks that have probabilities and consequences into action

- Because risks have probabilities and consequences. So consensuses have a probability associated with them. Risks should inform decision-making.
- When you look at SLR you are understanding a cumulative distribution of all of these problems and the approach is to look at the area within that.
- This tells you the probability of associated hazards and translates this into consequences.

(2) Defining the probability of the event

- To move forward, one needs to define the probability of the event.
- One can stress the system itself to see how it responds and what the consequences are.
- So, by taking a municipality and breaking it up into discrete assets one can see how they fall into discrete categories and/or get categorized. This fits into the National FEMA FIRM for hazard risk.
- Categorizations are intended to reflect how those assets may be treated from a regulatory perspective versus socioeconomic perspective. Every asset from people neighborhoods, police stations. Etc. fall into categories.
- They collectively make the system. So it is essential to study the system. One can consider a programmatic approach that lets you evaluate and apply options

(3) Developing a system response curve

- Developing a system response curves.
- Takes an asset and assigns a system response to it. Note that some are proprietary.
- Develop system response curves and you get system response.
- This is a background way of categorizing properties that towns may use.
- Categories are applied through the building code. Natl flood insurance regulations ASE24
- These inform design flood elevation.
- FEMA based flood elevation – flood that has an annual probability of 1:100
- Communities can by law establish their own flood elevations.· Flood risk and regulatory conditions.
- Certified wall – barrier. Takes you out of the system
- For Municipalities it is 15% permitting regulation and 85% for construction
- Resiliency bonds – they may allows municipalities to bond these projects. But hard to finance.

(4) Example of Old Saybrook Beach Revetment

- Low probability storm- it works.
- But for a 10-20 year return period the natural processes are working.
- So it doesn't completely break down the function.
- Shoreline protection structures - related to mitigating erosion, scour and other factors.
- Walls – we are talking about flood protection. Seawall or flood wall.
- Extrapolate to insurance rate map – levee.
- Has to be a required levee to get accretion. Difficult to achieve.
- By pure elevation. You have to be base level 3 feet above. 13 NAVD (structure is 16)
- Very robust flood regulations. Coupled with community establishing their own design elevation let things take its course.
- Creating resilience in the form of accommodation.

(5) Flood regulation and mapping analysis

approaches
- 1970s flood regulations were intended to protect the tax payers of the US.
- Army Corp decision making using an algorithm approach. The approach is scalable. Tides to 500 years. Each flood level has a probability associated with it (plus wind and waves)
- Inundation mapping from tidal conditions. Storm water systems that are affected to a 500 year flood.
- Publicly available data to get 1 year, 2, year 10 year, 100 year 500 year.
- Risk analysis – need to understanding things in terms of a probability event.
- Tropical cyclone –hurricane.
- Looking for probability of floods from 0-500 on LIS you have a Nor-easter and a tropic system.
- Hurricane – and different categories. Water levels that cumulatively result from all of those events create the flood. Looking at an 80 year return period. Still seriously contributed by extra tropical storms.
- Two types of storms creating risks, and all cumulatively create your final risk.
- One issue is that there are no established probability associated with it.
- Slosh display program – open to the public. They take a certain category storm. Solely wind intensity.
- But doesn't take into account track landfill radius of storm.
- FIRM - mandate is only to look at base flood. 100 year return.

(6) Seeking broader approaches to evaluate the whole suite of risks
- Base flood – it is a probability.
- It is a cumulative probability. It is met or exceeded.
- North Atlantic Coast Comprehensive Study
- Modeling efforts- typical of what FEMA would do today.
- Mixture of statistical analysis and meteorological storm parameters coupled with storm modeling.
- Aggregated with joint probability method. Did it for waves and flood.
- FEMA_ interpolates between data points.
- The underlying concept of risk analysis. Let's say you have a 1 year flood and a certain associated economic loss. 10 year flood higher loss. 100 year flood higher loss 1 in a 100 x a million. Cumulative effective costs is each of those. The higher cost at bigger events the lower probability. Only work on those with high risk moments.
- Living shorelines work well in a high probability flood event – 1 -10 year. But no value in higher like 100 or 500 year. Usually use hydrodynamics studies to understand dynamics.
- RI has taken North Atlantic coastal data and have done assessment across them. You get point data. Save points.
- FEMA (statistics) vs ACOE (Geophysical)
- Topographical maps
- SLAMM Coastal Engineering Geo tool

CIRCA MEETING NOTES
June 23, 2017

Participants: James O'Donnell, Alexander Felson, Robert Mendelsohn, Alyzza Lustig, Ou Lun, Connor Duwan

(1)Calculating flood risk
- Function for probability from local tide heights and storm risk for extreme probabilities
- Different areas have differently sloped responses for sea level rise and extreme flooding events.
- Marginal cost of wall increases as height increases, but marginal benefit (avoided summed costs) decreases, & the economically-optimal intersection may exist.
- How can long-term visions influence initial 30-year decisions?
- If we decide to protect and then later abandon, should we have just abandoned in the first place? - actually, not necessarily
- Lines show the 95th percentile of modeled SLR outcomes - tolerable risk of 5%
- Idea of regulating to 2050 (2100 is too uncertain - in the future we will have better

scientific data and more insight on global political directions)
- Recommendation: towns regulate 1% flood risk in relation to 2050 intermediate flood risks. Ref number - 50 cm by 2050
- Veil of ignorance for mapping? It is better to not allow homeowners to see whether their own specific home is impacted (more of a communally shared risk mindset)

(2) Overtopping calculators
- Overtopping calculators (EurOtop) for how much flooding occurs when storm surges surpass wall height
- Hedonic analysis is being used.
- Looking at Surge Height Probability Density Function in 2110
- Effect of sea level rise.
- Risk of flooding will increase a lot and impacts will have reactions far sooner than SLR.
- 25cm will lead to increased frequency of flooding.
- 1 m at time 0.4 m
- Talk about the per year risk.
- Concept of the return interval is based on things that are not changing.
- 1% risk zone vs. the 100 year flood zone.
- Think about what the 1% risk zone in 2050.
- Areas impacted – by every storm in the probability distribution.
- Sum up the damage and define damage to the community.
- Preventing people from losing their value. Vs. telling them to move.

(3) Proposed timescale for decisions - sequential 30 year timelines
- Goal: minimize sum of (cost of protection plus damages)
- Cost of barriers: proportional to height squared times coastal length
- Damage depends on storms (death, property destruction) and SLR (permanent losses to land and abandoned capital - either depreciated by owners in advance or lost fully if they wait too long)
- 30/60/90 strategy works well with phasing strategies (no regrets, setup for future adaptation)

(4) People are not as insured as they think
- People are ensured for depreciated value. 250k. Perception is that they are insured but they really are not.
- It is not replacement value.
- People think they're insured but it only really covers depreciated values, limited things below the first floor, only up to $250,000 from National Flood Insurance program, and other restrictions

(5) Will tax value of coastline be eliminated, or be made up with a new coastline?
- Economists disagree (Gary Yohe – says that tax value will be maintained by new coastline)
- Give up housing on the shoreline that the town will lose tax base. But next layer may be added value /You get a new one.

(6) Ecological considerations
- Future work will also account for ecological perspectives
- How to value ecosystem services?
- Need to devise an approach and incorporate it into the model

(7) Random Fluid Dynamics stuff about advanced modeling
- Channels for where the water goes restricts how external flooding (e.g. Long Island Sound) affects the level of flooding further inland - can't always just extend level horizontally
- Take into account that effects on different neighborhoods may be very different
- Reinforces the idea of patch solutions
- Hurricane will cause a major storm surge but will only be high for 2-3 hours. For the water to get in behind the body into the marsh it has to go through a different channel. Goes up in LIS and than up in the marsh. Down in LIS and down in the marsh. The portal Acts as a filter.

- Elevation and duration were both impacts on the LIS.
- Projections are good for planning.
- Using models to evaluate the elevations in marsh.
- What happens in one neighborhood is geomorphologically influenced compared to another.

(8) Regulations rollback
- Trade-offs between saving property and critical infrastructure and maintaining the status of protected environments (e.g. marshes and wetlands)
- Retracting environmental regulations (DEP) to preserve housing may be a tough fight
- Do you back up off the regulations now to save some houses ? or do you keep the regulations.
- If you do not do anything the marsh itself may be destroyed by SLR.'
- Offset the negative impacts of restricting sediment by adding dredge or sediment to accrete.
- Could offset it by adding sediment. But what are the costs.
- Political costs. Do people want it.
- Transaction value – if you can sell it that is the transaction value.
- But how do you value the generational value-
- How emotional you are going to be.

(9) Atlantic hotspot
- The highest levels of mean global sea level change will occur off the Atlantic coast
- However, this is also the area with the greatest uncertainty regarding changes due to the difficulty predicting the actions of the Gulf Stream.

EAST HAVEN MEETING NOTES
July 24th, 2017

- From the Nature Conservancy - lots of economic questions at homeowner, patch, town scale
- Recognizing multiple benefits - protection, ecological improvements, place-making
- Three feet raised property - 75% off flood insurance
- Irene winds pushed the water house wards
- Sea level rise - one of the challenges is thinking about the small difference in 30 years in contrast to the huge difference in 100 years
- When analyzing options, look at economic value as well as quality of space
- Additional work needed for rivers to prevent surges traveling upstream
- East Haven is discussing grant money to insert floodgates (historically effective). Due to flooding from rivers, these become larger town-wide impacts.
- Focus on larger hydrological strategies instead of repetitive flood-loss homes
- Most people outside of wall have raised houses, while those inside haven't
- Place to the left - "gold coast" with year-round residents
- Infrastructure-tied improvements much easier to implement
- Cosey Beach wall - save $30 in value for every $1 on wall (3m wall)
- Some things can't be costed out easily - ecological and social benefits
- Town would only be interested in a $30 million project with state or federal grants (even 5%)
- Glen Vizzano (tied to the senate) has properties that would be severely impacted, so it becomes a political issue
- Saving only 30 houses in an area that will continually flood in the future
- Insurance reductions only come from FEMA-certified flood walls
- East Haven has lots of underutilized assets (park, development potential)
- Important benefits for homeowners - flood insurance reduction
- Farm River has lower-income housing and more political sympathy for action

WEST HAVEN MEETING NOTES
July 20th, 2017

- Future steps: graph surge height against damage for West Haven segments
- Assess risk potential with economic value to help prioritize projects
- Non-considered factors: ecological value and low-income housing needs
- 4 zones of shared risk
- Area near marsh needs to be reconfigured to drain water from storm events
- Birding in marsh areas is very important for town community and tourism
- Some lots more valuable to city as passive nature and flood managements than as development
- Idea of shifting value - houses behind those sold increase in value
- Priority area - Beach Street as economic development potential
- New development area - intersection at lower right corner of Old Field Creek
- Shorter commercial timelines make more sense than residential ones
- Access corridors can provide values to homes behind and use development as access
- Offer lots of different things so everyone gets something (roads, marshes, parking, etc.)
- Parking restrictions during breeding season, tracking on birding visitation, etc. - to investigate
- Ongoing project: elevate Beach Street segments
- NRCS only focuses on properties connecting to water flow areas
- Properties are also disqualified for any type of contamination, no matter how light

MEETING NOTES
June 18th, 2018

*from Chuck Andros Notes:

- Push-back under Hurricane Irene
- Detriments of structural solutions, portraying this to all parties
- Largely administrative, need to get many naysayers on board
- Advisory brought before local zoning commission
- Possibility to sue if there was something wrong
- Westport
- People will fight to protect their water views
- Important to raise structures, but at what cost?
- Need to raise to get above MHW mark
- Zoning is usually final, no wiggle room
- Zoning commission’s decision
- Variances come from exceptions
- Very rarely made
- Describe hardship
- Hard to establish need
- Installing a deck is not hardship
- Major discrepancy in theory and practice
- Maybe new zone? Coastal Resident Zone?
- Increase height
- Zoning on property by property basis
- Not shared zoning by neighborhood, by individual property
- Neighborhood standard, few properties that are treated uniquely?
- Tension in the law
- Appellate court often involved
- Proper permits
- Lots of discretion on actual plans
- Within zoning regulations

MEETING NOTES
June 18th, 2018

- Identified opportunities for zoning and land use change focusing on municipal land use law.
- One of the challenges with this is the Federal ability to take land. There is no taking without

compensation. But the minute you hint at moving in this direction people become concerned.

- A critical question is whether you are regulating in a way to warrant a legal condemnation issue? Is it an impediment? Enough to warrant a takings Claim?
- In terms of restrictions, there is the Coastal Area Management zone (CAM). The area below MHHW. Where locals are raising houses. Usually there is a zoning height limit. There are efforts to raise the lower levels. But there are also concerns about blocking views.
- Detriments of structural solutions, portraying this to all parties
- Largely administrative, need to get many naysayers on board
- Adding a wall typically requires an easements through Connecticut Coastal Zone Management Act (CCMA) (22A 22) administered by the Department of Energy and Environmental Protection (DEEP) and is approved by NOAA (National Oceanic and Atmospheric Administration) under (Section 22a-90 through 22a-112 of the Connecticut General Statutes), the Structures Dredging and Fill statutes (Section 22a-359 through 22a-363f) and the Tidal Wetlands Act (Section 22a-28 through 22a-35).
- Development of the shoreline is administered at the local level through municipal planning and the zoning boards and commissions under the policies of the CCMA, with technical assistance and oversight provided by Program staff.
- One can get a lot of push back with storm event such as Irene where there is a lot of damage and a compelling argument for easements and protection.
- Below mean high water (Deep has direct oversight). Above mean high water (DEEP advises local P&Z commission.
- These zoning regulations are administered by the zoning commission. So you can potentially get a variance and show hardship. You have to show something that is unique to you.
- Advisory brought before local zoning commission
- Possibility to sue if there was something wrong. (E.g. Westport)\
- Harder to say no to the town when you are on the commission.
- The policies are embedded in the municipality (and politics of the town) For example, in East Haven Lynn Fasano has some impact.
- People will fight to protect their water views
- Important to raise structures, but at what cost?
- Need to raise to get above MHW mark
- Currently there are no property rights to views. Such as a views easement that you can purchase. One question is what height do you want (a higher height). One can typically to get a variance. E.g. going from 35’ height limit to get it to 40’ or greater.
- Zoning is usually final, no wiggle room
- Zoning commission’s decision
- Variances come from exceptions
- Very rarely made
- Describe hardship
- Hard to establish need
- Installing a deck is not hardship
- Major discrepancy in theory and practice
- Maybe new zone? Coastal Resident Zone?
- Increase height
- Zoning is not on a property by property basis but variances work property by property.
- Not shared zoning by neighborhood, by individual property
- Neighborhood standard, few properties that are treated uniquely?
- A good way to create a new zone e.g. coastal residence zone. (Branford Summer cottages)
- One can create as zone in a proper area map it. Such as an Overlay zone or planned development districts
- Not a single property vs. spot zoning
- Requires a legislative act to apply to property for permits -- goes a lot to P&Z commission
- Cases on supreme court (judge Berger)
- Hardened structures vs zones too close to the sea. Vs zoning policy
- Large (anticipatory legal issues)
- Small (spot zoning claim) Stony Creek Association design review board

- With Zoning overlay zoning height is an issue
- West Haven affected housing in urban areas. Height restrictions
- Privatized coast (Taking)
- Easement
- To title to the land?
- Fee?
- Access and maintenance issues
- Roads are easement
- Old suburbs (property owners - owns to center of the road)
- Deep concern over structural
- If shared by a lot of properties - flood risk that could damage lower housing.
- Looking for groups of houses to identify a set of houses to raise. They can help each other.
- Tension in the law
- Appellate court often involved
- Proper permits
- Lots of discretion on actual plans
- Within zoning regulations
- Difference in theory and practice
- Exceptions to the rule
- Reducing non- conformity in one area increases in another (legal base)
- Market forces why spread money on private land (issue)

WEST HAVEN MEETING NOTES
June 21st, 2018

- Presented plans and info about economic feasibility of five plans
- Explained economic analysis and benefits of multiple planning scales
- Discussion of peat location and possible piling installation for Beach vs Blohm
- Expanding Old Field Creek into park complex with access from all sides
- Presented green streets plan that could revitalize area
- Need to focus on attractive solutions
- Houses near coast are largely low value, make redevelopers raise new houses without gentrifying neighborhoods
- Introduced idea of back-to-back neighbors and importance in embedded wall strategies
- Discussion of coastline as economic zone, will need to shift inland or inundation will occur

New Info:
- West Haven is interested in raising 1st Ave
- 4.5 Million dollar grant to install SRTGs and a culvert along Coe River
- Blohm has too much infrastructure to raise, possibility of raising Beach instead
- Water treatment plant above 100yr flood risk but no access during large flood events

Photograph by Paurush Singhal

Table: Example Strategies for Acquiring Land

Acquisition Option	Details	Challenges	Opportunities
Buyout at fair market value	• Purchase targeted property at fair market value • Example: Plainville, Connecticut 2012 T 2014	• Availability of funds • Consent of property owner • Mismatch between appraised vs. market value • Possible loss of local tax base due to relocation	• Market-based comparatively less contentious • Comparatively fewer legal obstacles • Can proceed as quickly as consent and availability of funds allows • Guaranteed acquisition
Buyout at fair market values with incentives	• Incentivize sale at fair market value with bonus payment. • E.g. NY Rising Buyout and Acquisition Programs offering 5-15% incentives above fair market value for purchase of homes in storm-damaged targeted buyout areas, contingent on resettlement within the same county	• Availability of funds • Consent of property owner • Mismatch between appraised vs. market value	• Market-based comparatively less contentious • Comparatively fewer legal obstacles • Can proceed as quickly as consent and availability of funds allows • Incentivize preservation of local tax base • Guaranteed acquisition
Targeted information campaign on long term costs and risks of remaining in vulnerable area	• Encourage willingness to sell with information campaign. • E.g. Community education; mandated disclosure of property risks for sellers of real estate	• Information changing rapidly • Information open to interpretation • Comparatively slow • Does not guarantee acquisition • Possible loss of local tax base due to relocation • May generate confusion or unintended backlash	• Comparatively lower cost • Builds public awareness about challenges • Consent resides with property owner
Strategic zoning	• Use down-zoning to limit post-storm reconstruction, as well as other zoning tools, such as overlay zones with setback and height restrictions	• Requires sequence of plan development and approvals • Comparatively slow • May be susceptible to legal challenges • Does not guarantee acquisition	• Comparatively low cost • Allows for timed phasing of physical risks and shifts in tax base

Acquisition Option	Details	Challenges	Opportunities
Tax Incentives	• De-incentivize development by basing property tax assessment on current use value instead of fair market value in certain conservation areas • Encourage relocation through tax credits	• Availability of funds (i.e. reduction in tax revenue) • Mismatch between appraised vs. market value • Does not guarantee acquisition	• Consent resides with property owner • Can include incentive for no net loss to local tax base
Transferable Development Rights	• Guide development from 'sending' to 'receiving' zones through market-based exchange of development rights	• Requires adequate 'receiving zone' within local tax jurisdiction • Uncertain timing • Comparatively slow • May require regulatory framework, including zoning changes • Does not guarantee acquisition	• Enables an increased availability of viable, risk-reduced properties • Incentive for no net loss to local tax base • May accomplish development goals with minimal public cost • Consent resides with property owner
Conservation Easements	• Limit development in target areas by acquiring, encouraging, or incentivizing conservation easements, may include education about federal tax benefits • CT Example: too numerous to list	• Requires sequence of plan development and approvals (if municipality purchases easements) • Consent of existing property owners • Comparatively slow • May only achieve partial limits on development • Availability of funds (if municipality purchases easements)	• Comparatively lower cost, particularly if easements are donated • Allows for timed phasing of physical risks and shifts in tax base.

*Note: While not represented in this table, it is noted that eminent domain, whether outright or through conditional lease, remains a legal means of property acquisition for public purposes (CGS Title 48). However, multiple aspects of eminent domain make it the least desirable alternative. Legal justification, lack of owner consent, public dissatisfaction and backlash, availability of funds, and susceptibility to ongoing legal challenges associated with this means of acquisition. Therefore, the range of acquisition options described above in the table are more ideally suited for addressing the challenges of coastal adaptation over the next multiple decades.

ECOSYSTEM SERVICES: A QUALITATIVE ASSESSMENT

Ecosystem Service Benefits and Disservices

Overview

Indispensable to formulating a holistic plan for coastal resilience and complementary to an economic comparison of adaptation strategies, we consider an ecosystem services assessment to be the second pillar of a decision-making tool tailored to municipal scale resilience planning.[9] Mirroring the economic model in its integration of social and cultural assets—as the economic model enables policymakers to focus on specific geographic regions with heightened vulnerability, ecosystem services, or “natural capital,” encompass ecosystem contributions to human welfare and thus necessitate the wedding of ecological and socioeconomic or sociocultural objectives.[10]

Ecosystem services are defined as ecological processes and functions that benefit people, including the natural benefits provided to humans by a healthy and functioning natural system.[11] Municipal coastal resilience, where development coincides with floodplains and river ways, is a complementary analysis of ecosystem services integrated with the planning process in combination with the economic modeling to support smart adaptation strategies.[12] The ecosystem services assessment is framed as the second pillar of our decision-making tool tailored to municipal scale resilience planning.

Ecosystem services applied to coastal management include regulating services, provisioning services, cultural services and supporting habitat services.[13] In the last decade, researchers have devised new schemes for classifying ecosystem goods and services (EGS), grouping EGS by ecosystem sub-functions (e.g. climate regulation, water regulation, raw materials, recreation)[14] or by spatio-temporal category, whether a service is delivered in-situ, directionally, or omnidirectionally.[15] Although there is little consensus on a single classification typology, precedents for assessing ecosystem services have proliferated, and many studies concentrate specifically on a marine, coastal, or riverine context. Advocating for an integrated coastal management strategy,[16] conform to the Millennium Ecosystem Assessment (MEA) framework in citing examples of ecosystem services delivered in coastal areas; relevant to Connecticut, these services include food provision by fisheries and aquaculture (provisioning), flood and storm protection through wave energy attenuation (regulating), nutrient cycling (supporting), and boating, tourism, or other recreational activities (cultural).[16]
For coastal areas in Connecticut, where Long Island Sound meets the land, the ecosystem services and human benefits are interlocked. Regulating services include waste decomposition, buffer zones and natural hazard mitigation, and water supply regulation and filtration, among many others. Supporting habitat services include a range of aquatic and terrestrial biologically mediated habitats and biodiversity conservation areas, nutrient cycling and primary production. Cultural services include recreation, tourism, views and aesthetics, science and education. Floodplains and wetlands in particular supply disproportionately high ecosystem services in relation to their area. Because floodplains are ecologically rich and heavily developed ecosystems, it is crucial to understand the trade offs associated with further investments in contrast to the ecosystem services they provide and to consider how management decisions will impact ecosystem services. Floodplains are already recognized as critical components of flood mitigation and ecosystem health by policymakers, particularly through the Department of Energy and Environmental Protection (DEEP). Municipal officials often feel pressured to keep homeowners where they are and to maintain the property base while valuing the ecosystem service benefits of floodplains is often a lower priority. This tension plays out in multiple venues between municipalities and the state. As ecosystem services are being documented,

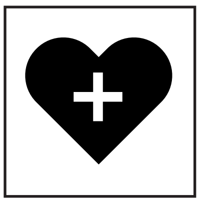
there is also a growing recognition of ecosystem disservices, with efforts to document and analyze disservices and the trade-offs associated with them.[17]

Building an inventory of ecosystem goods and services in East Haven and West Haven forms the backbone of an assessment of those services. To weave an ecosystem services assessment into municipal planning, policymakers must engage stakeholders to identify the ecosystem services of highest priority. A recent report by the US Army Corps of Engineers (USACOE) on the use of natural and nature-based (NNBF) adaptation interventions has relied on an expert elicitation exercise, engaging 78 experts in ranking ecosystem goods and services in order of importance as part of a stakeholder workshop. The USACOE study, which defined 21 ecosystem-based goods and services and 72 quantitative performance metrics, proposes the use of a BPJ voting matrix of ecosystem services and planning options to refine stakeholder preferences. This matrix invites stakeholders to compare ecosystem services associated with each option and the suite of NNBF or grey infrastructure solutions it entails.[18]

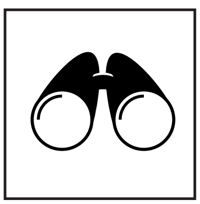
The metric-based approach elaborated on in USACOE study developed performance metrics by (i) determining the components, such as soil and vegetation type, of each NNBF, (ii) using causal pathways as a filter to link the ecosystem functions associated with each component to a particular good or service, (iii) defining benefits from each good or service and the most suitable metric to measure that benefit. For instance, the structural diversity, rooted vegetation, and macrotopographic complexity (components) of a dune/swale complex (feature) provide for erosion stabilization (ecosystem service) through the attenuation of erosive processes (ecosystem process) and thus decrease erosion, which can be readily quantified by measuring vegetative cover. The exact impact of the benefits, from ecological (e.g. TES species protection) to socioeconomic (e.g. environmental stewardship), is extremely site- and project-specific, and the USACOE's metric-based approach constitutes just one method for assessing benefits. Methods do exist to determine a dollar-value for floodplain-based ecosystem services. For instance, the Nature Capital Project's Integrated Valuation of Ecosystem Services and Trade-offs model (InVEST) maps and values ecosystem goods and services monetarily (e.g. net present value of carbon sequestered), non-monetarily (e.g. low to high recreational activities available), or biophysically (e.g. tons of carbon sequestered). The benefit transfer approach to economic valuation values ecosystem services by scaling an estimated per area service value for a given ecosystem or green or grey infrastructure feature by the area of that ecosystem or feature. Other methods that monetize ecosystem service delivery span from contingent valuation (e.g. willingness to pay) to direct market valuation (e.g. exchange value) or indirect market valuation (e.g. avoided cost, hedonic pricing).

Alongside the USACOE study, which demonstrates how planning can be directly inserted in an ecosystem services assessment, The Nature Conservancy's "Guide for Incorporating Ecosystem Service Valuation into Coastal Restoration Projects" employs an ecosystem services approach as a point of departure for increasing the uptake of living shoreline projects. The guide suggests other modes of quantifying ecosystem goods and services, including. Similar to the USACOE and other ecosystem goods and services studies, the guide details how ecological production functions are used to translate the biophysical outcomes of ecological data collection or modeling into ecological endpoints, or changes in the delivery of ecosystem goods and services. The guide introduces a five-step process for ecosystem services valuation studies, a process that, taking a novel angle, centers on a set of socioeconomic goals (e.g. community resilience to erosion, community resilience to flooding, general economic development) defined by a

Watersheds
Watershed scale planning provides an integrated approach to address a multitude of issues including human activities and terrestrial and water resource management. Watershed scale ecosystem services provides practical and tangible metrics to guide land use practices for coordinating management of nutrient and pollutant loading. Land management practices can address water quality concerns impacting the ecosystem health of riparian systems.

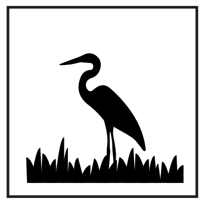


Public Health
A coastline protected by wetlands means a protected built environment and protected human infrastructure. The ecosystem services provided by wetlands and marshes help to protect coastal homes from storm surge and flash flooding, keep roads clear for egress and emergency vehicles, and protect critical facilities such as power plants, water treatment plants, airports, and hospitals.



Cultural Value and Recreation
Floodplains provide multiple spaces for recreation including boating, fishing, birding, and hiking. Beaches are popular tourist attractions and provide a space for large community events. Coastal communities benefit significantly from proximity to beaches and water-based recreation areas.
Important Considerations
Given the unique topography, hydrology, ecology and land development patterns along the Connecticut coastline, it is essential to focus on site specific conditions across each municipality to inform ecosystem services and planning. Connecticut's coastline was uniquely formed by glaciers 13,000 years ago. Low lying areas and ridge lines create flood risks in patches in between areas of higher ground. As a result, some Connecticut homeowners face risks while others, nearby or adjacent, can live on the coast with little concern. The heavy investments and diverse conditions along the Connecticut coast invite a wide variety of economic and ecological informed management techniques.

Marsh Migration
Where marshes are not bordered by developed land or steep elevation increases, they can more easily migrate landward to accommodate sea level rise. Marsh restoration should take migration potential into account because they are a rare commodity that can prevent storm and flood damage. For this reason, recognizing where marsh migration can occur and integrating this into planning choices is essential for the coastal ecosystem health.



Floodplain and Upland Habitat
Tidal marshes and other floodplain and upland ecosystems provide habitat for many plant and animal species. They also help to buffer against coastal flooding and sea level rise, reduce coastal erosion, and filter nutrients from runoff, keeping them out of larger water bodies. Mud flats are similarly home to many animal species and to eelgrass, and they also provide prey for larger species. Like marshes, mudflats filter out contaminants from runoff.

Storm water and Wastewater Management
Storm and wastewater treatment systems are networks of costly above and below ground infrastructure. They typical work by gravity with limited pumping and discharge at low points along the coast. Given the interconnected nature of this infrastructure, buffers are increasingly necessary for avoiding sewage discharge during storm events. Sea level rise is exacerbating this near term risk. Green infrastructure and other projects that facilitate flooding using green and grey infrastructure can encourage infiltration where water lands and can alleviate pressure on the downstream wastewater treatment systems or storm water systems.

*Note: these are specific to coastal dwellings given project team through rapid stakeholder assessment. For each tabulated goal, the guide synthesizes and summarizes final metrics to monetarily or non-monetarily measure that goal, prescribes methods for data collection and analysis, and recommends tips and tricks to decision-makers, effectively serving as a resource for project managers to clarify and gauge the achievement of their project's goals.

Wetlands, marshes, and floodplains, found both inland and on the coast, can buffer the built environment from flooding. Thus wetlands are part of the solution to flooding problems along the coast. However, tidal creeks can also carry storm surge deep into towns and cause substantial inland flooding. The ecosystem analysis in this project is seeking to balance the need to maintain normal salt water flow to wetlands while at the same time finding a solution to harmful storm surge flooding. The analysis specifically looks at alternatives to handle tidal creek flooding of interior developed areas.

Analysis

There are several alternative approaches to managing tidal creek flooding. One approach is a strategic realignment or planned retreat of the interior homes adjacent to wetlands. In this strategy, interior homes nearby wetlands are bought out in advance of flooding events. A second approach is to build walls between the wetland and these developed areas. These walls would lie in the interior and prevent storm water traveling from the wetlands into homes. A third approach is to construct smart storm gates that would close when a storm approaches but would remain open at all other times. The smart gates would be managed with the goal of maintaining normal saltwater flows in to the wetland while periodically limiting storm surge. We would seek to avoid blocking salt water from entering wetlands completely, as this could heavily impact wetland hydrology and floodplain ecology.
We consider the cost and benefit of taking action versus doing nothing at all. Wetlands that border vulnerable properties, where flood risk exists taking action versus doing nothing is the preferred alternative. In this analysis, we focus on Old Field Creek in West Haven and on the Farm River on the eastern border of East Haven. Both municipalities have extensive developed property adjacent to the wetlands associated with each waterway.

The Farm River potentially floods homes adjacent to the mouth of the river. However, the flooding that we analyzed in this study is in two neighborhoods bordering the Farm River that are further north and west. One lies between Meadow Street and Vista Drive north of Route 142 and the other is south of Main Street and east of Hemingway Avenue.

The specific alternatives facing East Haven are to place a smart gate near the Shoreline Greenway Trail that would limit storm surge beyond that point, build a wall along the edge of the Farm River wetlands from the Shoreline Trail to Coe Avenue and south of the East Lawn Cemetery, or to buy out the low lying homes in both neighborhood. The smart gate is estimated to have an annual cost $77,000-115,000 and would effectively block storm surge above this point in East Haven. The top of the wall would need to be about 3 m with a total length of 6500 feet. Given that the base of the wall is about 2m, the actual wall height would be 1 m (3 feet). The annual cost of this wall would be $1.9 million. Removing the low- lying properties in these two neighborhood would have an annual cost of about $812,000.

The aggregate annual flood damage in these two neighborhoods is estimated to be about $2 million/year. It therefore is beneficial to engage in an active policy that would reduce flooding up the Farm River. The least expensive action is to construct the self-regulating tide gate where the Shoreline Trail crosses the Farm River.
The benefit to cost ratio of the smart tidal gate is about 20 to 1. This proposal would require

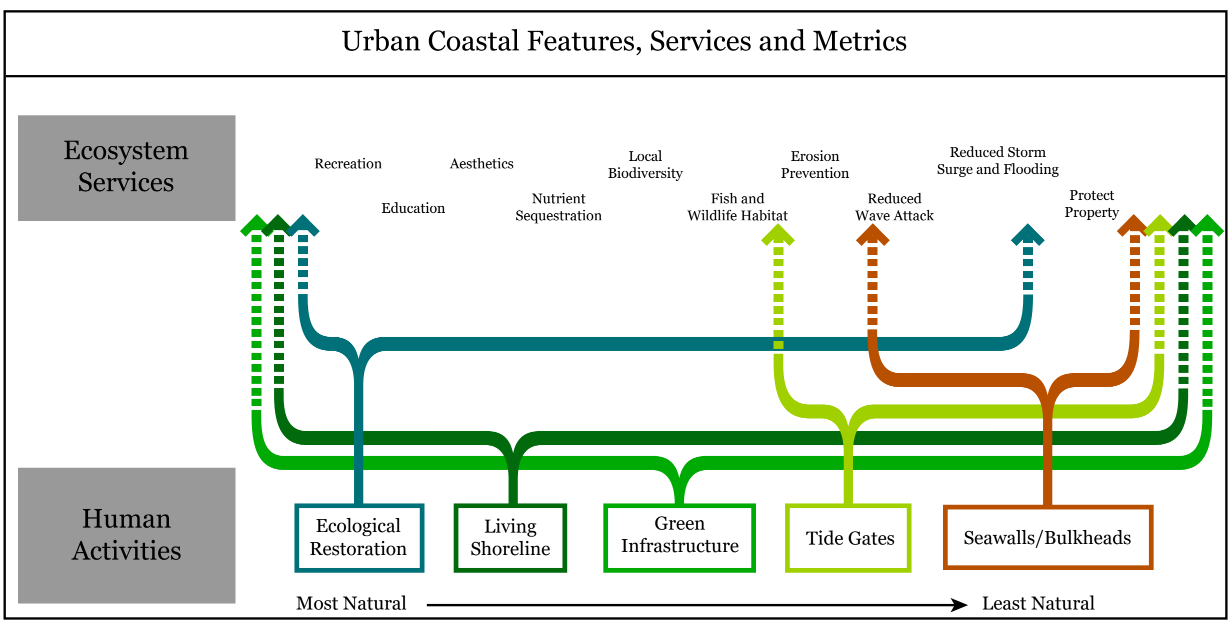
additional analysis to ensure that the smart guides could be managed to allow for viable river functions from a hydrology and ecosystem functioning perspective.

The West Haven analysis comes to a similar conclusion. An interior wall enclosing Old Field Creek coupled with either lifting homes or buying them out can solve the flooding problem associated with the tidal creek. But a coastal wall coupled with a self-regulating tide gate offers a much less expensive alternative. As with the East Haven example, the self-regulating tide gate could be used as a tool to protect the wetland and also eliminate the bulk of the expected flooding damage. Again, this will require further study to ensure the system will function and can be adapted periodically over time

Design

The economic analysis provides comparative analysis and economies of scale providing guidance on coastal defense strategies. It argues which general strategy is likely to be the most beneficial. It indicates efficient wall heights and positioning to start the dialogue around solutions. It also illustrates which properties may need to be lifted or purchased. It prioritizes which actions have the largest benefit to cost ratios (greatest return).

Building on the economic model, there are many details that need to be addressed and that still must be answered before effective planning can take place. The solutions should embrace a combination of landscape architecture and hard infrastructure that combine economic development, creation and enhancement of public amenities, and ecological restoration strategies to achieve multi-functional landscape solutions. Alongside the construction of raised roads, raised railroad beds, berms and tide gates, one can explore alternative land use strategies with boardwalks, marine loading facilities, habitat creation and even sealed buildings. The precise shape and form of these hybrid soft and hardened structures can be designed in many ways. Therefore design is a critical step



Additional Ecosystem Services indentified by ACOE Nature Based Features For Coastal Resilience Report (2015):
Scientific opportunities, reduced peak flood height, maintained land elevation, clean water provisioning, suspended sediment, reduced hazardous materials, cultural heritage protection, raw material and healthy groundwater supply

in the transition from quantitative analysis to implementation.

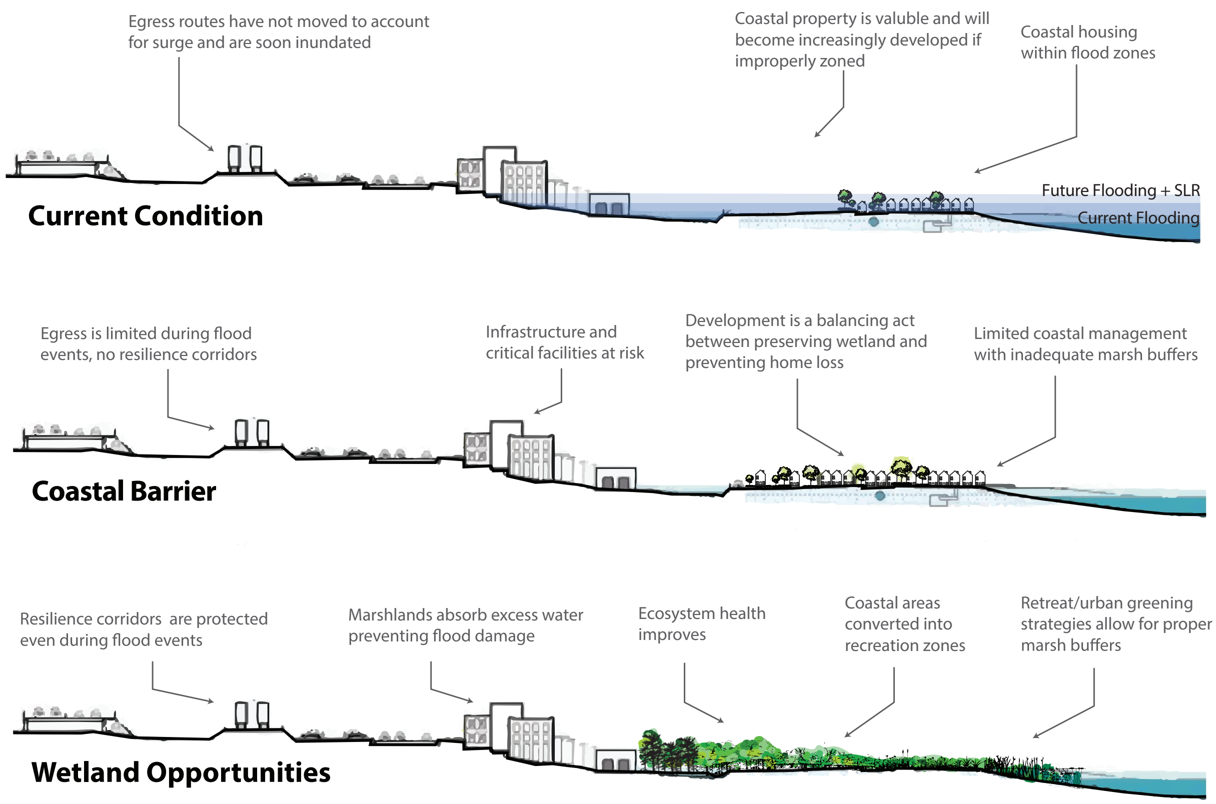
Design goes beyond the selection and sizing of a proposed strategy. Walls, for example, can be integrated into parks or buildings. They can be retaining walls or vegetated berms. Likewise, raised roads can be bermed or include storm water management gardens and walking paths. Reclaimed coastal areas can be left wild and barren or provide a public ecological retreat with visual and functional value. Additionally, the formal and material selection impacts longevity and palatability. It is clear that design decisions have both functional and aesthetic consequences, affecting cost, effectiveness and appeal. Design can influence is a proposed project's adaptability to future change. Adaptability and aesthetics are critical to a project's short term and future successes. Design can also serve as a negotiating tool between different interest parties to foster win-win solutions and to negotiate around political obstacles.

The New York Highline is an interesting example that highlights the role of aesthetics in the urban/ecological environment. A goal of this project was to revitalize the Lower West Side area by redeveloping a derelict, overhead rail line and providing a public park amenity. The proposal is balanced in its ecological and urban function and integrates these concepts into a visually pleasing urban park. Because of its functional and aesthetic success, it became a model for other cities in the world to imitate. Sydney's The Goods Line, Seoul's Seollo Skygarden, Rotterdam's Hofbogen Viaduct, and Chicago's 606: The Elevated Park, are just some example projects that have followed this model. Additionally, its success led to intense gentrification of the neighborhood to its benefit and detriment. Estimates for the Highline suggest approximately $900 million in returns on a $260 million cost put forth by the city, and private individual and business donors (well above the $250 million revenue estimates). This provides a significant boon for the city and the local area, but what makes this project particularly interesting is that the project has been so successful that gentrification and tourism displaced the existing community residents such that a majority of the users are now no longer residents of the neighborhood or city. As such, effective design often includes trade offs and requires a careful balance of goals.

Limitations

As hinted in the above example and although an important issue, the economic analysis tool in this work offers no suggestion about who should pay for future coastal defense. Naturally, the immediate property owners who will enjoy a reduced risk of flooding are the primary beneficiaries, but the public will share in the gains from protected infrastructure such as roads and utilities. Municipalities will gain by holding onto a valuable property tax base and by communicating that they are coastally adapted. The number of repetitive flood loss properties will also be reduced. In the long run, with sea level rise, the number of property owners that will be affected will only increase. So even if property owners only a face a future risk, they nonetheless should care about the precedent set by current policy. The state also has a stake in the decision-making because they are responsible for prosperity in the state, the health and safety of citizens when storms strike, and for protecting state ecosystems.

The model outcomes are intended to provide comparable analyses across locations to inform a municipal officials' choices about coastal adaptation and to educated homeowners and provide alternative scenarios to consider. Other critical factors such as political issues, constituency interests, and past projects, as well as environmental factors are not part of the model but are brought in through environmental planning. These issues will need to be considered throughout this analysis.



Urban Ecological Cross Section showing different relationships over time

New York City Highline seen from eye level; nycgovparks.org

Chicago 606 Trail as seen from eye level

Can a project effectively grow or expand to accommodate additional protections or social benefits?
Can a project be appropriately phased to balance the environmental, social and economic goals?

Conclusion

This document develops an economic analysis to assist local coastal planning and reviews opportunities and trade-offs associated with protecting the urbanized floodplain and wetlands simultaneously. The analysis helps communicate critical scientific data revealing the risks of climate change on coastal communities. The analysis reviews trade offs exist in alternative approaches that municipal officials can take to address risks. The economic model reveals that some actions are more beneficial than others. This suggests that coastal planning should allow local flexibility because the ideal actions in one place may not be ideal in another. In some cases, a wall would be effective, in other cases houses need to be lifted, or a self-regulating tidal gate needs to be constructed. But every coastal segment appears to benefit from some additional coastal defensive action.

One of the goals of the project was to let decision makers see a range of choices that they can make and to prioritize which actions should come first. There are clear indications that some projects have very high benefit to cost ratios. These high return projects should be seriously considered and where possible prioritized. The list of projects that need to be undertaken is too long to accomplish all at once. Towns need to realize and plan for a series of coastal defense projects for the next few decades.

Approaching adaptation with a one size fits all approach or in a piecemeal fashion to design may address individual problems or a range of problems poorly instead of solving the most pertinent ones well. The systems being modified include economic, social, physical, and ecological ones. By understanding these systems, a more holistic, sustainable, and reliable solution can be found. For Connecticut, the areas at risk do not often follow municipal boundaries, neighborhoods, or districts
Given the unique topography, hydrology, land development patterns and ecology along the Connecticut coastline, it is essential to focus in on areas or patches or risk and economic opportunities. Heterogeneous land uses are at risk. Officials need to determine the best course of action segment by segment. Designers and planners should experiment with alternative protection measures and develop site specific approaches to protect and adapt both coastal ecosystems and neighborhoods.

This document is intended to serve the decision-makers in East and West Haven with the choices that they face. We hope that this document will also serve a much broader community and improve future coastal planning decisions.

Design and Technical Guide

For Implementing Innovative
Municipal Scale Coastal Resilience
In Southern Connecticut
2018