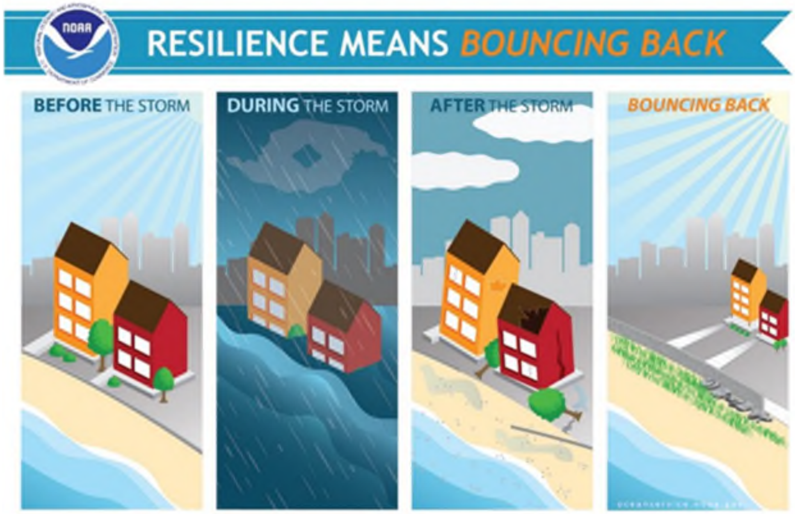
Attachment 1: Approach and Methodology

Resilience and Adaptation



"Resiliency is the ability of a community to "bounce back" after hazardous events such as hurricanes, coastal storms and flooding." (NOAA)

Coastal resiliency is the ability to recover quickly from coastal flood events such as nor'easters and hurricanes. It can be achieved through a combination of: 1) zoning and building codes that require buildings to be protected from flooding; 2) public outreach and education; 3) appropriate emergency response capabilities; 4) the fostering of strong social networks; and 5) physical shoreline protection and flood mitigations measures (such as structural and natural and nature-based features), that work together to reduce the short-term effects of flooding.

However, the frequency and intensity of coastal floods will increase in the future, primarily as a result of sea level rise. Over the last 100 years the, sea level within Long Island Sound has risen about 0.8 foot. Over the next 100 years sea levels are projected to rise, with a reasonable probability, another 4 to 6 feet and may increase as much as 15 feet. During the next 100 years, regardless of the actual amount of sea level rise, the rate of sea level rise will steadily increase. The on-going, incremental effects of rising sea levels will require that communities adapt. And the successful communities will those that proactively develop the social and economic capacity to adapt.

Study Approach

This Study is part of an on-going process that the Town has embarked on to proactively reduce coastal flood risk and prepare for the effects of sea level rise. The Study used:

- Industry-accepted "State-of-the-Science" sea level rise projections that are also consistent with current State of Connecticut guidance.
- A "risk-based" approach, including defining coastal flood hazards in terms of probability of occurrence, consistent with methods currently being used by state and federal agencies.
- High resolution, hydrodynamic computer flood modeling to supplement flood hazard analyses performed by FEMA and the US Army Corps of Engineers (USACE).
- ESRI ArcGIS geographic information system (GIS) software, also used by the Town.
- Resilience and adaptation strategies, actions and measures that are consistent with Old Saybrook's current vision and plans for development.

Study Methodology

The preparation of the Study included:

Step 1: Characterization of the Coastal Flood Hazards

Step 2: Assessment of the Vulnerability of Town Infrastructure, Neighborhoods, Buildings, and Natural Resources

Step 3: Identification of Coastal Resilience and Adaptation Strategies, Actions and Measures

Step 4: Public and Stakeholder Outreach

Step 5: Identification of steps to implement the Study

Terminology

The Study uses flood terminology consistent with that used by FEMA. Flood hazard areas identified on the FEMA Flood Insurance Rate Maps (FIRMs) are identified as a Special Flood Hazard Area (SFHA). SFHAs define the limits of flood inundation associated with floods that have: 1) a 100-year recurrence interval (aka 1% annual exceedance probability); and 2) a 500-year recurrence interval (aka 0.2% annual exceedance probability). The 100-year recurrence interval flood elevation is a flood elevation that has, in any given year, a 1 in 100 chance of being met or exceeded. The FEMA 100-year recurrence interval flood is also referred to as the base flood and the associated water level is the base flood elevation (BFE). Similarly, the 500-year recurrence interval flood elevation is a flood elevation that has, in any given year, a 1 in 500 chance of being met or exceeded.

Other FEMA terminology includes:

- Floodplain: FEMA defines any land area susceptible to being inundated by water from any source as the "floodplain".
- AE Zones: AE flood hazard zones are areas within the 1% percent annual chance (base) flood, with waves of 1.5 feet or less in height. Coastal AE zones are areas within the 1% percent annual chance (base) flood, with waves between 1.5 and 3 feet height. These are areas that will be exposed to both flood, moderate wave forces and other wave effects.
- VE Zones: VE flood hazard zones are areas within the 1% percent annual chance (base) flood, with waves greater than 3 feet in height. These areas are subject to storm-induced high velocity wave currents and significant wave forces.
- LiMWA: The Limit of Moderate Wave Action (LiMWA) is the demarcation between areas with waves greater and lower than 1.5 feet height.

Figure 1-1 graphically illustrates the FEMA SFHAs.

Step 1: Coastal Flood Hazards

Coastal flood hazards include tides, storm surge, waves, high winds and coincident precipitation (rain or snow). The coastal flood hazards at Old Saybrook were characterized using several methods and sources of information:

1. The effective (2013) FEMA Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) for Old Saybrook. The FEMA FIS and FIRMs present Old Saybrook's flood hazard as determined by FEMA for purposes of the National Flood Insurance Program (NFIP). The FEMA Base Flood shown on the FIRM is also referenced in State and local building codes.

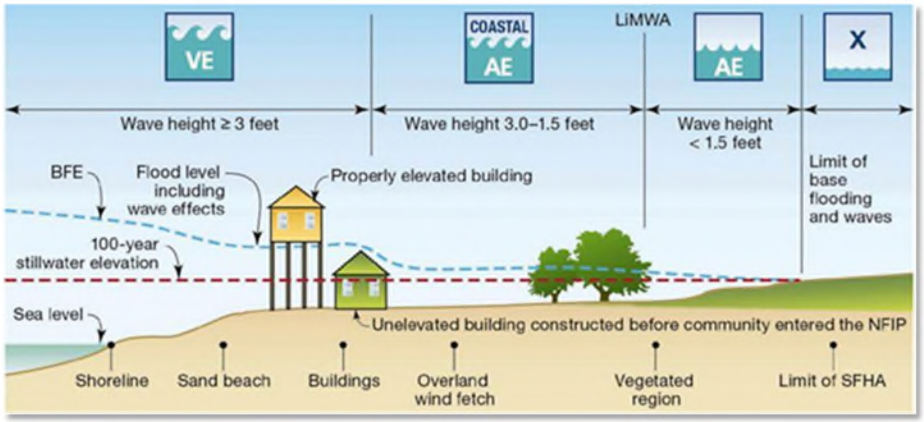


Figure 1-1: FEMA Coastal Flood Hazard Zones

2. Statistical analyses of the NOAA New London tide gage historical water level data. The New London tide gage monitors water level and has an approximately 79-year period of record. Statistical analysis of the tide gage data provides an estimate of flood elevation versus probability (i.e., likelihood of occurrence).
3. The North Atlantic Coast Comprehensive Study (NACCS). This study was performed by the USACE after Hurricane Sandy to characterize coastal flood hazards in areas impacted by Hurricane Sandy (from the Chesapeake Bay to New Hampshire) for use on federal projects. The study performed statistical analysis and computer modeling of storm surge and waves on a coarse resolution. The USACE has made the information available for public use. The NACCS presents nearshore flood hazard data at a number of locations along the Old Saybrook shoreline.
4. Sea level rise projections used by the USACE and the National Oceanic and Atmospheric Administration (NOAA) were used to predict the effect of sea level rise on coastal flooding in the future. The projections are available on-line for the NOAA tide gage station locations using the USACE "Sea Level Rise Calculator".
5. High resolution LiDAR topographic data and NOAA bathymetry were utilized to develop ground surface elevations nearshore and throughout the Town limits. Shoreline features (such as beaches, wetlands, man-made structures) were identified.
6. Flood inundation observed during Hurricane Irene and Superstorm Sandy. Available information about the effects of these storms at Old Saybrook includes photographs, anecdotal information and documented limits of flood inundation and elevation.

7. Computer modeling of storm surge and waves. GZA performed high resolution, numerical hydrodynamic modeling of tides, storm surge and waves to supplement analyses performed by FEMA and the USACE. GZA also performed non-hydrodynamic modeling of tides and storm surge.

GZA Coastal Flood and Wave Modeling

GZA modeled the tides, storm surge and waves at Old Saybrook using the ADvanced CIRCulation Model (ADCIRC) storm surge model and the Simulating Waves Nearshore (SWAN) wave model. ADCIRC is a two-dimensional, depth-integrated, barotropic, hydrodynamic circulation model. SWAN is a third-generation model developed at Delft University that computes wind-generated waves in coastal regions and inland waters. Both models are used by federal agencies such as FEMA and the USACE, including the NACCS.

GZA developed a high-resolution model mesh and local model domain to represent the detailed topographic and bathymetric features at Old Saybrook (Figure 1-2) in the flood models. The model mesh covers all coastal areas of the Town, Long Island Sound and tidal portions of the Connecticut River. The model extends about 3 miles offshore of the Old Saybrook coast into Long Island Sound. The resolution of the model in Old Saybrook is as fine as 10 meters.

The results of the NACCS (the flood-frequency curves) were used as input to GZA's high resolution model simulations. GZA also developed synthetic hydrographs, representative of typical Connecticut hurricanes and nor'easters to characterize storm duration in the model simulations. GZA's model simulations of Hurricane Sandy were compared to the observed conditions to check the model accuracy.

GZA's flood simulations were performed for both astronomical tidal conditions (Mean Sea Level and High Tide) and for storm surge (the 100-year and the 500-year recurrence intervals floods). To capture the effects of sea level rise, model simulations of tide and storm surge were also performed for several time horizons. In addition to the current time, flood model simulations were performed for the years 2041, 2066 and 2116.

GZA's model simulations are intended to supplement, not replace, the effective FEMA Flood Insurance Rate Maps. They are only intended to be used to support resilience and adaptation planning and are not intended to be used for establishing the flood hazard at any specific location and for any other purpose.

Step 2: Flood Vulnerability Assessment

The vulnerability of Old Saybrook to coastal flooding was evaluated by:

1. Inventoring all assets and organizing by category;

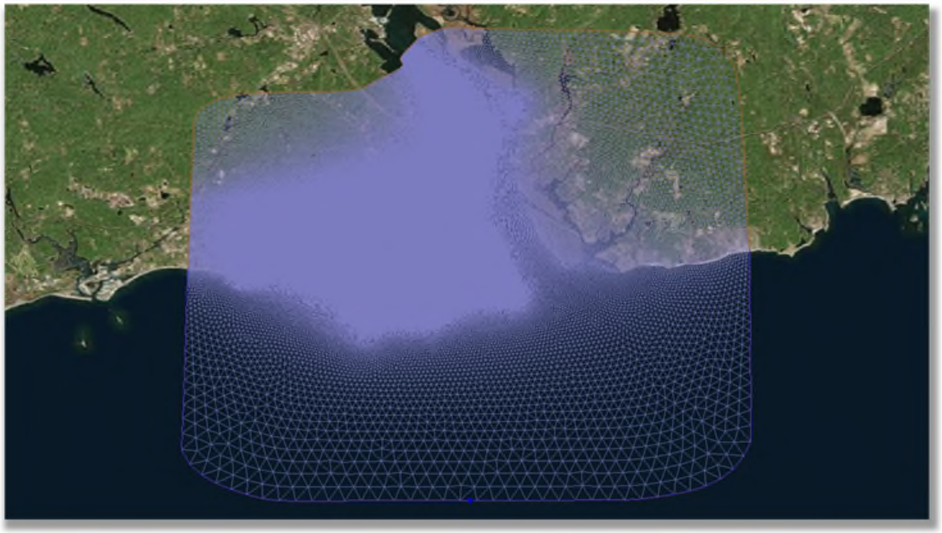


Figure 1-2: GZA High Resolution Computer Model Domain

2. Evaluating the flood vulnerability of each asset and asset category based on:
   a. Review of FEMA Flood Insurance Studies and Flood Insurance Rate Maps;
   b. Supplemental computer modeling to simulate flood inundation due to floods associated with different probabilities of occurrence, ranging from astronomical tide conditions to the 500-year recurrence interval flood. Flood depths were assessed by comparing flood elevations to ground surface elevations. Computer modeling of waves was also performed to identify areas vulnerable to large waves and wave-induced loads;
   c. Evaluation of economic loss using the FEMA Hazus software; and
   d. Area and asset-specific risk profiling.

Sea level rise was predicted base on both the USACE 2013 and the NOAA 2017 projections. The effects of sea level rise was determined based on additional flood simulations for different future time horizons.

Asset Inventory

The first step of the vulnerability assessment was to create a detailed inventory of Town assets. These assets were categorized consistent with criteria used by federal agencies for hazard management and the building code.

Categories	ASCE 7-10	ASCE 24-14	Other
Essential Facilities	Occupancy Category IV	Flood Design Class 4	
Lifeline Utility Systems	Occupancy Category IV	Flood Design Class 4	
Transportation Systems	-	-	AASHTO
High Potential Loss Facilities	-	-	FERC, USACE, NRC
Hazardous Material Facilities	Occupancy Category III & IV	Flood Design Class 3 and 4	
Support, High Occupancy and Vulnerable Population Facilities	Occupancy Category III	Flood Design Classes 2 to 3	
Neighborhoods	Residential	Flood Design Class 2	
Natural Resources			

Table 1-1: Old Saybrook Asset Inventory Categories

The definitions of the asset categories are:

- Essential Facilities are essential to public safety and welfare and include buildings and other structures that provide services (such as emergency response and recovery) that are intended to be available in the event of extreme environmental loading from flood, wind, snow, or earthquakes.
- Lifeline Systems are those public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during and after a flood.
- Transportation Systems generally refer to those key roadways, rail, etc. that are necessary for evacuation and emergency response.
- Hazardous Material Facilities are buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.
- High Potential Loss are those facilities, such as dams, whose failure can result in catastrophic loss of human life. Old Saybrook does not have any High Potential Loss facilities.
- Support, High Occupancy and Vulnerable Populations are those facilities that represent a substantial hazard to human life in the event of failure such as schools, assembly areas, jails and detention facilities and other areas where a large number of people congregate.
- High Density Development Areas and Neighborhoods are developed areas.
- Natural Resources, at Old Saybrook, include beaches, wetlands, salt marshes, tidal flats, etc.

Table 1-1 Notes: 1) ASCE 7-10 and ASCE 24-14 are American Society of Civil Engineers guidance documents that are incorporated by reference in the State Building Code. 2) FERC indicates Federal Energy Regulatory Commission. USACE indicates U.S. Army Corps of Engineers. NRC indicates Nuclear Regulatory Commission, AASHTO indicates American Association of State Highway and Transportation Officials, and EPA indicate Environmental Protection Agency.

Loss Estimation

The consequences from coastal flooding include damage to buildings and infrastructure, displacement of people, disruption of services and damages to natural resources. Economic loss and displacement of people were evaluated using the FEMA United States Multi-Hazards (HAZUS-MH) software. HAZUS-MH is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods and hurricanes.

Economic losses were characterized based on an "Average Annualized Loss" basis. The results of this analysis were used to predict potential current losses at a census block level.

Impacts to Natural Resources

The Town's coastal natural resources include extensive tidal marshes and a coastal shoreline fronting on both Long Island Sound and the Connecticut River. The effect of sea level rise on the tidal marshes was performed using the "Application of the Sea Level Affecting Marsh Model to Coastal Connecticut" simulation results. To evaluate the long-term shoreline change, GZA used the results of the University of Connecticut "Analysis of Shoreline Change in Connecticut" results in GIS. GZA also performed a statistical wind and wave analysis, including numerical wave modeling of prevailing conditions, to infer sediment transport/littoral drift. GZA also performed numerical wave modeling of the 100-year recurrence interval flood to qualitatively evaluate the potential for cross-shore beach erosion under storm events.

Risk Level

The Study uses a "risk-based" approach; specifically, the methodology "Risk-Informed Decision Making". "Risk-Informed Decision Making" is the process of making decisions that are informed by an understanding of risk, where risk is defined as:

Risk = Hazard Probability X Vulnerability

and:

- *Hazards* are events that have the potential to cause harm or loss. Coastal flood hazards principally include flood inundation, flood depth and waves, including the resulting hydrostatic and hydrodynamic loads from currents and wave action. Flood hazards can also include rain, intense winds and salt spray that often accompany coastal flooding.

- *Hazard Probability* is the likelihood (or chance) that the hazard will occur.

Asset vulnerability is characterized by Risk Level where:

High: indicates a high probability of occurrence and a significant consequence.

Low: indicates either a low probability of occurrence and/or a consequence of less significance.

Moderate: indicates either a high probability of occurrence and a consequence of minor significance, a moderate probability of occurrence and a moderate consequence, or a low probability of occurrence and a significant consequence.

Flood Probability

Just like flipping a coin, the probability of flooding is an expression of chance. Each time a coin is flipped, there is a 50% chance that it will be heads. If the coin is flipped multiple times in a row, the chance of getting a heads at least once increases (in ten consecutives flips, there will be nearly a 100% chance that at least one of the flips will be heads).

The probability of flooding is characterized in a similar manner. Flood probabilities are described in the Study (and by FEMA and other State and federal agencies) in terms of the "recurrence interval" or "annual exceedance probability". Each of these terms characterize the probability of experiencing a specific flood (i.e., flood elevation, inundation limits, waves) in any given year. As noted previously,

- the 100-year recurrence interval flood (1% annual exceedance probability) has, in any given year, a 1 in 100 chance of being equaled or exceeded.
- the 500-year recurrence interval flood (0.2% annual exceedance probability) has, in any given year, a 1 in 500 chance of being equaled or exceeded.

Other flood probabilities considered in the Study include:

- the 2-year recurrence interval flood (50% annual exceedance probability) has, in any given year, a 1 in 2 chance of being equaled or exceeded.
- the 10-year recurrence interval flood (10% annual exceedance probability) has, in any given year, a 1 in 10 chance of being equaled or exceeded.
- the 20-year recurrence interval flood (5% annual exceedance probability) has, in any given year, a 1 in 20 chance of being equaled or exceeded.

The chance of experiencing a given flood at least once increases over a time period of interest. For example, the 100-year recurrence interval flood has a 25% (1 in 4) chance of being equaled or exceeded at least once in any 30 year period.

The risk of coastal flooding will also increase due to climate change, in particular as a result of sea level rise. As the average water level of Long Island Sound (e.g., the mean sea level) increases over time due to sea level rise, the elevation of an equivalent storm surge will be higher in the future than it is today. For example, the 100-year recurrence interval flood today will occur with much greater frequency (say, a 10-year recurrence interval) in the future. The implication is that coastal flooding will become more frequent, and for a given probability of occurrence the effect of the flood (i.e., flood elevation, inundation limits, etc.) will become worse.

Step 3: Resilience and Adaption Strategies, Actions and Measures

A range of coastal resiliency strategies, actions and measures, appropriate for Old Saybrook, were evaluated. The strategies, actions and measures are consistent with those used in other State and federal coastal resilience plans and programs, and previously approved for State and Federal funding. They are also consistent with current regulatory codes. The USACE's September 2013 publication *Coastal Risk Reduction and Resilience: Using the Full Array of Measures* (CWTS 2013-3) provided valuable guidance for selection of the strategies, actions and measures.

The Study approach was also to select resiliency strategies, actions and measures that can support and be integrated into future updates of relevant Town plans such as the upcoming update of the Natural Hazards Mitigation Plan Update scheduled for 2019 and the current Local Plan of Conservation and Development.

Resilience and Adaptation Strategies

Resilience and adaptation strategies include:

Retreat: Managed withdrawal from coastal areas, most often accompanied by adaptive land use and managed relocation.

Protect: A range of interventions designed to hold back flooding from inundating developed areas and preventing erosion and loss of land.

Accommodate: Allowing inundation to occur, but protecting infrastructure, property and natural resources from damage through permanent and interim measures implemented on an on-going basis.

Resilience and Adaptation Actions and Measures

Resiliency actions and measures fall into three categories: 1) Non-Structural; 2) Structural; and 3) Natural and Nature-Based Features.

Nonstructural:

Non-structural measures reduce human exposure or vulnerability to a flood hazard without altering the nature or extent of the flooding. Plans, Policies and Regulations that regulate flooding are considered non-structural measures.

Structural:

Structural measures are designed to protect (i.e., prevent flooding) and are consistent with a resiliency strategy of Protection. Specifically, they decrease shoreline erosion and/or reduce coastal risks associated with wave damage and flooding.

Natural and Nature-Based Features:

Natural features are features that are created and evolve over time through the natural actions of physical, biological, geological and chemical processes. Nature-Based Features are features that "mimic" natural features but are created by human design, engineering and construction to provide specific services such as coastal risk reduction. Nature-based features are acted upon by the same physical, biological, geological and chemical process that effect natural features, and therefore will need maintenance to reliably perform.

Accreditation by FEMA

While each of the resilience and adaptation actions and measures presented above will reduce the Town's flood risk, most will not be recognized by FEMA for their classification of special flood hazard zones. The only flood mitigation measures accredited by FEMA for hazard mapping purposes are: 1) elevated structures; 2) dry and wet floodproofed structures; and 3) levees that are constructed and managed in accordance with 44CFR§65.10.

Levees are defined as "a man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water in order to reduce risk from temporary flooding." The NFIP regulations define a levee system as "a flood protection system which consists of a levee, or levees, and associated structures, such as closure and drainage devices, which are constructed and operated in accordance with sound engineering practices." Non-accredited levees may be provisionally considered by FEMA in concert with local authorities.

Natural primary sand dunes are considered by FEMA during flood mapping. Beach nourishment and engineered dunes may be considered by FEMA under specific circumstances. FEMA takes beach nourishment and dune projects into consideration only when the project is significant (i.e., has the dimensions necessary to affect 1-percent-annual-chance flood hazards) and with guarantees for maintenance and management.

Step 4: Public and Stakeholder Outreach

The Town organized and facilitated a series of resiliency team meetings and workshops, and two public meetings. The resiliency team meetings and workshops included presentations to inform the resiliency team and public of the interim Study findings and to receive feedback throughout the planning process. The study team gathered and documented input at each public meeting through an interactive discussion followed by questions and answers.

The study team conducted a survey during the 2nd resiliency team meeting to document the community's observations of vulnerable areas of Town impacted by Hurricanes Sandy and Irene as well as areas that will need resiliency improvements in the future.

The two public meetings were conducted upon completion of the following two project milestones.

- June 7, 2017 – Public Meeting on the Vulnerability and Risk Assessment
- November 15, 2017 – Public Meeting on the Draft Study

Several additional meetings were held with Town commissions and department heads to discuss the findings and recommendations and to receive Town input.

Neighborhood Studies

In addition to the Town-wide public meeting, a series of neighborhood workshops were performed to evaluate needs, concerns and options at the neighborhood level. Two neighborhoods were identified including: 1) Chalker Beach, which is representative of the Low Beach Communities; and 2) Route 154 and surrounding area between Saybrook Point and Town Center, which is representative of a common coastal flood condition throughout Old Saybrook – flooding of a major arterial, impacting resident ingress and egress, limiting the Town's capability to provide emergency services and disrupting business for commercial activities.

Step 5: Implementation

The Study recommends Action Items to implement the steps to create resilience and adapt to the effects of sea level rise. The existing Town plans were reviewed in the context of the proposed coastal resilience and adaptation strategies.