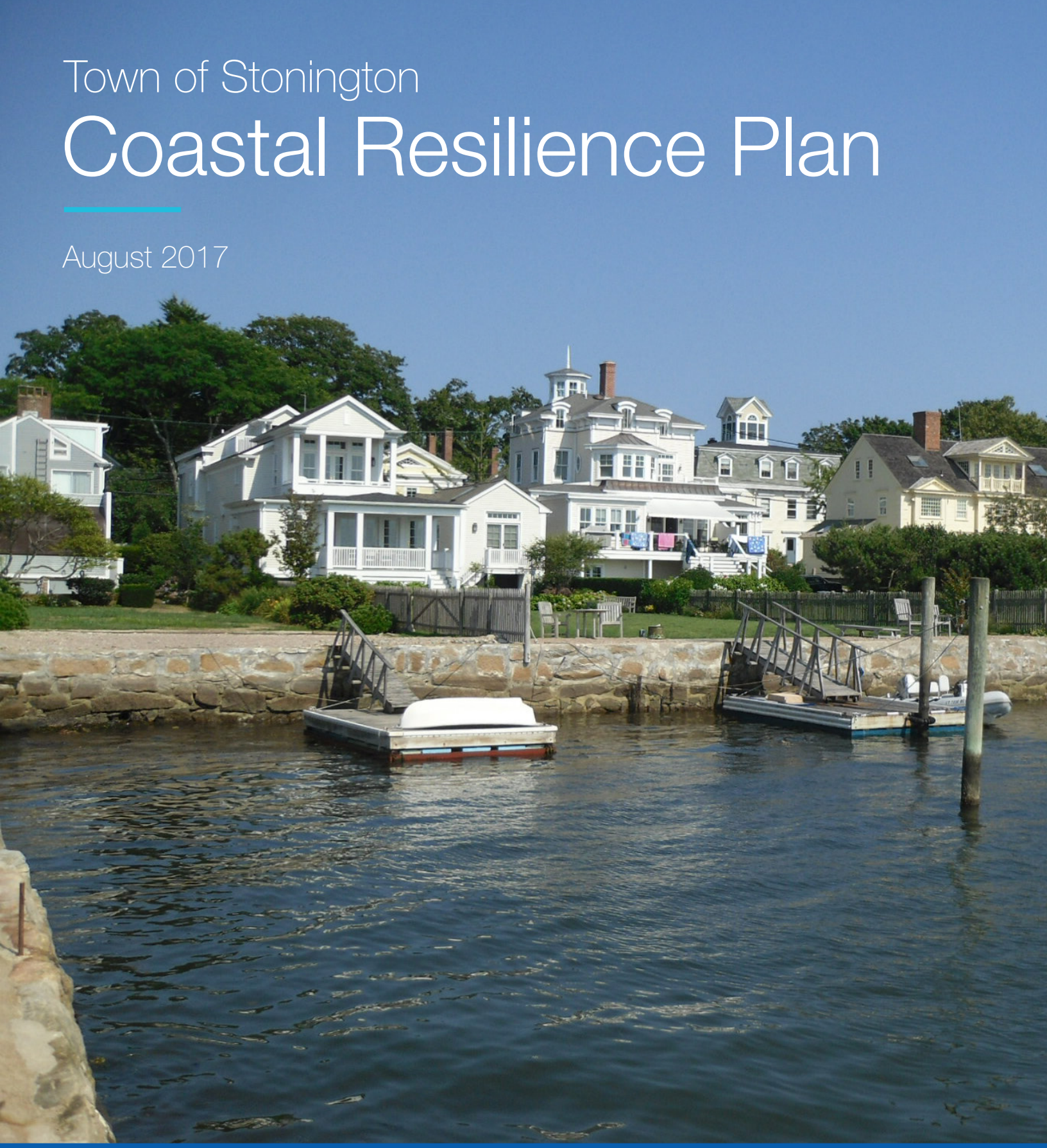
Town of Stonington

Coastal Resilience Plan

August 2017



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The Town of Stonington would like to acknowledge the following contributors and advisors for the Coastal Resilience Plan.

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A special thank you to all of the residents of Stonington who attended the public input meetings and provided valuable comments and feedback that helped shape this plan.

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Executive Summary

Project Overview

The Town of Stonington is largely characterized by its relationship with the sea. As a coastal community, much of Stonington's unique character, history, and economy are defined by its location along the waterfront. However, such a coastal location comes with both benefits and risks: the coastal resources that can drive the economy and provide a high quality of life for the Town's residents can also present unique threats. Many of Stonington's community resources, assets, and residential properties are at significant risk from coastal flooding. The Town, and much of the Northeastern United States, became acutely aware of this flood risk when Superstorm Sandy made landfall in New York on October 29, 2012. While Stonington was not in the direct path of Superstorm Sandy, the Town still experienced significant flooding and storm damage as a result of the storm, including damage to the Town Dock and Masons Island Causeway.

With four historic coastal villages and over 1,400 properties located in the present-day 100-year

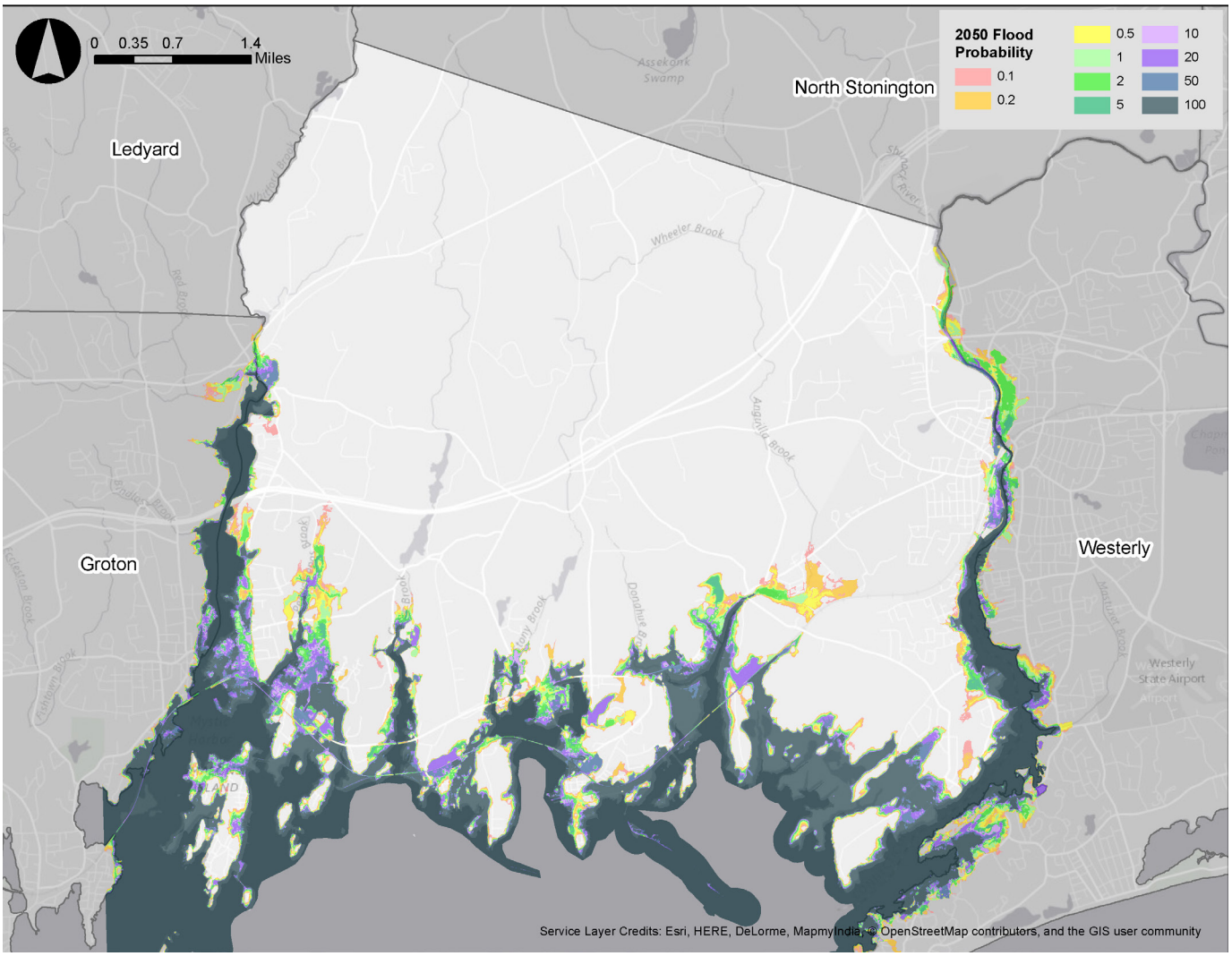


Figure 1: 2050 Flood Probability in Stonington

floodplain, Stonington faces increasing risk to its residents, infrastructure and critical assets. Moreover, Stonington's economy relies heavily on tourism generated by the Town's waterfront; this tourism economy could be significantly impacted by future coastal flooding events. While providing economic benefits from coastal tourism, Stonington's location presents significant risk to its built infrastructure and environmental, economic, and social systems. As a result, the Town of Stonington received Community Development Block Grant – Disaster Recovery (CDBG-DR) funding to complete this Coastal Resilience Plan. The Plan is intended to develop a comprehensive understanding of Stonington's coastal flood risk by assessing the vulnerability of key critical assets and infrastructure and developing potential resilience solutions for the Town's most at-risk resources. This coastal resilience plan is the first step towards creating a safer and more secure future for the Town of Stonington and its residents.

Risk Assessment

Coastal risk is the potential for an asset or system to be impacted by a future coastal flooding event. Coastal flood risk was evaluated based on three main factors: hazard, exposure and vulnerability. These factors were used to calculate a risk score for each community asset, using the following formula:

Risk = Hazard x Exposure x Vulnerability

Hazard is a measure of the likelihood of a future storm event impacting the asset. Coastal modeling scenarios were developed to assess future flood scenarios for the Town of Stonington. These scenarios assessed the probability of a coastal flood event (and the associated extents of that flooding) in the years 2030 and 2050. Probability, in this case, is defined as the percent annual chance of flooding. Figure 1 shows the potential future flood scenarios for the Town of Stonington in the year 2050 and Figure 2 details the risk assessment scoring methodology for the various hazard types:

Figure 2: Hazard Scores for Risk Assessment

Hazard Type	Hazard Score
Present-day 1% storm or FEMA AE/VE Zone	3
2030 1% or 0.1% Storm	2
2050 1% or 0.1% storm	1

Exposure refers to the depth of flooding that may be experienced by the asset during a given storm event. Because flood depths vary depending on the intensity of the storm event, the exposure scores were standardized across all assets by using the depth of flooding at each asset during the 2050 0.1% storm event (or the 1000-year storm). The 2050 1000-year storm event was chosen for the exposure analysis because it is the most intense storm analyzed as part of this assessment. Figure 3 shows the exposure scores associated with each category of flood depths:

Figure 3: Exposure Scores for Risk Assessment

Depth of Flooding	Exposure Score
> 10	4
5.01-10 ft	3
2.01-5 ft	2
0-2 ft	1

Vulnerability is a measure of the impact to the community if the asset is damaged in a flood event. Vulnerability was assessed according to four factors: criticality of the facility; community impact; economic impact based on replacement cost; and, impact to the tourism economy/historic resources. The vulnerability score is an average of these four factors for each asset.

Figure 4 details the critical facility scores:

Figure 4: Critical Facility Scores

Critical Facility	Critical Facility Score
Critical Facility by FEMA's definition	3
Other essential assets	2
Non-critical and non-essential assets	1

FEMA Critical Facilities:

- Structures or facilities that produce, use or store highly volatile, flammable, explosive, toxic and/or water-reactive materials.
- Hospitals, nursing homes and housing likely to have occupants who may not be sufficiently mobile to avoid injury or death during a flood.
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for flood response activities before, during and after a flood.
- Public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during and after a flood

Community impact is a function of the redundancy of the asset and the percentage of Stonington residents affected by failure of or damage to the asset. Figure 5 details the community impact score:

Figure 5: Community Impact Scores

Impact by %	Community Impact Score
67-100%	3
34-66%	2
0-33%	1

Economic impact is a function of the value of the asset. Facilities with important and valuable infrastructure and equipment are considered high economic value and would have a high replacement cost if damaged during a storm event. Figure 6 displays the economic impact scores:

Figure 6: Economic Impact Scores

Impact by %	Economic Impact Score
High = important infrastructure equipment	3
Medium = other buildings	2
Low = open space and recreation areas	1

Based on this calculation of risk and local knowledge of the importance of various community facilities, we identified the top 5 and top 25 most at-risk assets in the community. These assets were carried into the next phase of the assessment: developing potential resilience solutions.

For each of the top 5 assets, we developed potential resilience solutions. Those solutions include building-scale solutions, such as elevation of the building and/or mechanical and electrical systems, implementation of green infrastructure, and installation of temporary flood barriers, among others. Proposed resilience solutions were developed for:

- Apple Rehab Mystic
- Masons Island Causeway
- Mystic Wastewater Treatment Facility
- Village of Mystic
- Models for a typical single-family home and a typical mixed-use building

A higher-level analysis was completed to identify potential resilience solutions for the top 25 assets, as identified in Figure 7.

Figure 7: 25 Most At-Risk Assets in Stonington

Top 25 Assets		
Masons Island Causeway	Mystic Bridge Historic District	State Highway 1
Mystic Wastewater Treatment Facility	Rossie Velvet Mill Historic District	Cutler St. Electrical Substation
Boulder Avenue Pump Station	Stonington Borough Historic District	Mystic Train Station & Rail Line
River Road/Mary Hall Road Pump Station	Apple Rehab Mystic	Barn Island Management Area
Stonington Wastewater Treatment Facility	Mystic Seaport	Mystic Fire Department
Greenmanville Avenue Electrical Substation	Town Dock	Mystic River Park, Cottrell Street
Stonington Community Center (COMO)	State Highway 27	Lords Point neighborhood
Quiambaug Fire Department	Donahue Park	Murphy's Point neighborhood
Mechanic Street Historic District		

Community Vulnerability

While this study was largely focused on assessing the vulnerability and risk of key community facilities and assets, it is important to understand Stonington's vulnerability on a larger-scale. On a community-wide scale, 27% of the total land area is anticipated to be impacted by the 1000-year coastal flood event in 2050; this accounts for approximately 5,800 acres of land. The parcels in the impact area account for 53% of Stonington's total tax base, which represents approximately $2 billion worth of property value. Therefore, a flood event of that scale would have a significant impact on the Town's residents, and its economy.

In addition to the built environment and physical infrastructure vulnerabilities identified during the risk assessment, Stonington's transportation network, natural resources, and historic resources may all experience impacts as a result of climate change.

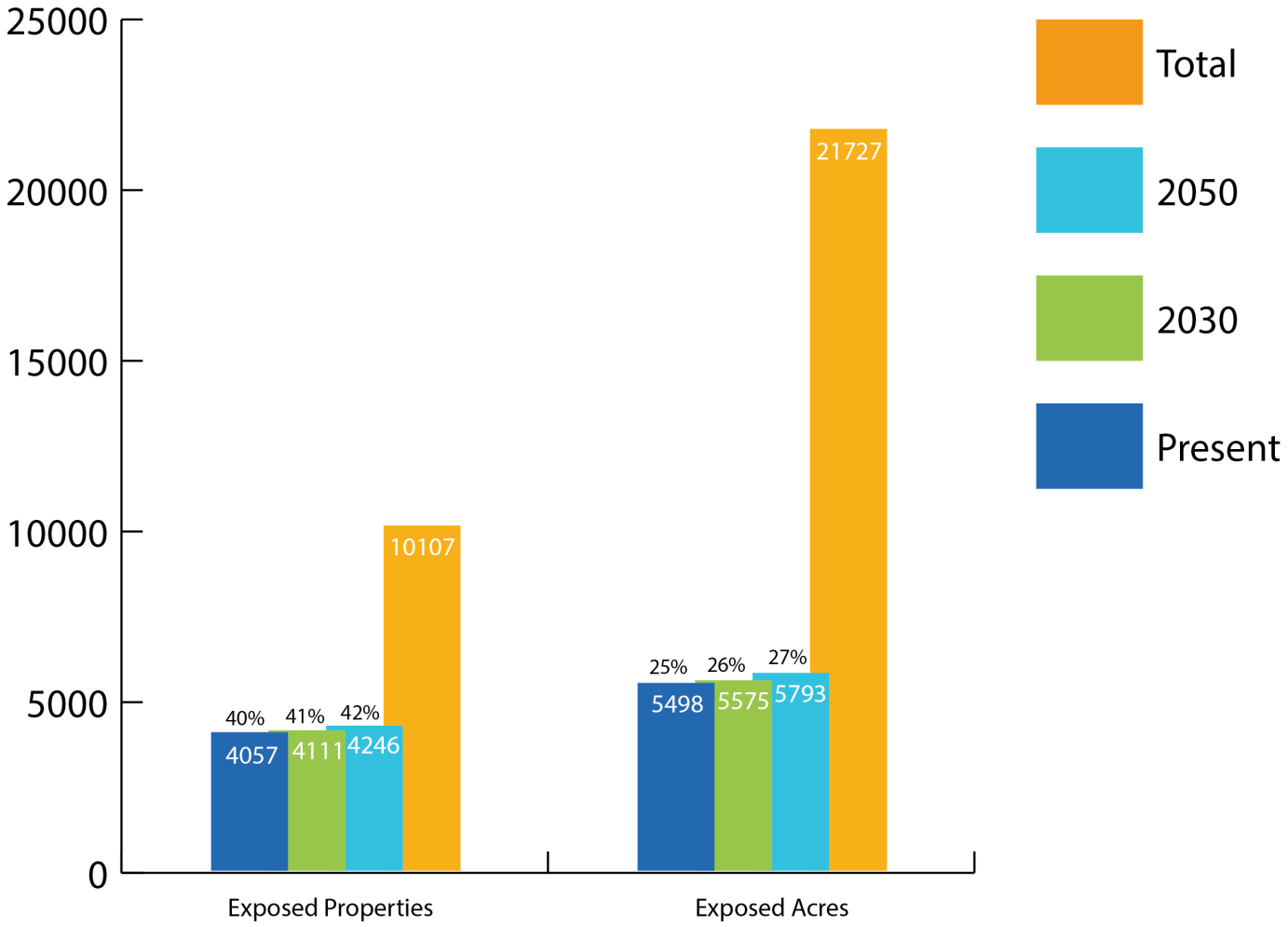
Transportation

The Town has already experienced significant flood impacts to Mason's Island Causeway during Superstorm Sandy and other past flood events. Additional impacts from coastal flooding may affect Route 27, as it extends down through Stonington Borough, and Route 1, which runs in close proximity to the coast of Stonington between Mystic and Pawcatuck. In addition to roadways, the Northeast Corridor railway is highly vulnerable to flood impacts in Stonington. The rail line runs along the coast throughout Stonington and is expected to experience significant flood impacts. With over 260 million annual passenger trips along the Northeast Corridor, and 25,704 annual trips through Mystic amounting to $1,292,097 in annual station revenue, flooding and damage along this railway would have significant impacts to Stonington and cascading impacts throughout the region.

Natural Resources

Sea level rise and storm surge can negatively impact natural resources by damaging or killing trees, plants and grass as a result of salt water inundation and causing flood damage to recreational facilities. The most vulnerable open space in Stonington is the Barn Island Management Area. Barn Island Management Area is a particularly valuable resource; with over 1,000 acres, it is Connecticut's largest, most diverse, and ecologically significant coastal wildlife management area. In addition to that significant protected open space, Mystic River Park and Donahue Park are also expected to experience significant flooding.

Figure 8: Potential Property and Land Flood Vulnerability in the Town of Stonington



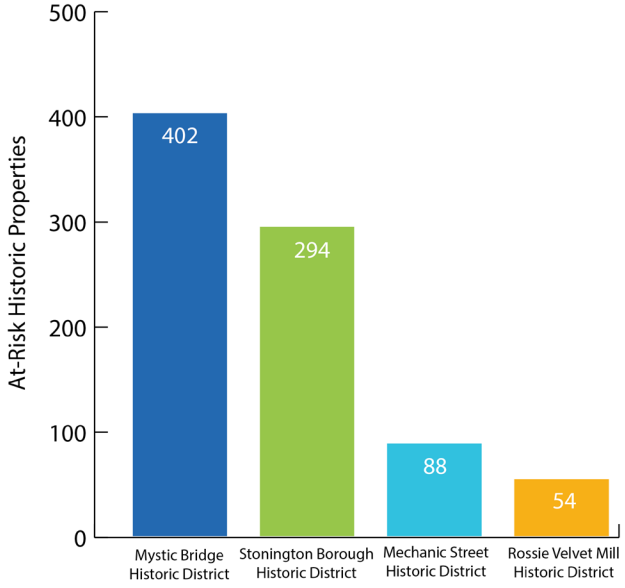
Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

Stonington's shoreline is also experiencing significant changes due to the advancement of salt marsh from the coast into upland areas of Town, as a result of sea level rise. In total, Stonington is expected to see approximately 2000 acres of salt marsh advancement by 2080; 13% of that advancement is expected to affect land areas that are not suitable for advancement, because they are currently developed with buildings and associated infrastructure. In particular, the Village of Mystic is particularly vulnerable to salt marsh advancement, which could result in negative impacts to Stonington's economy and tourism industry, historical resources, and property values.

Historic Resources

Stonington's historic resources are essential to the character of the community and are important drivers for the Town's tourism economy. The Town has 854 historic properties that are vulnerable to coastal flooding by 2050. Of those, 838 are located in the Town's four largest historic coastal districts: Rossie Velvet Mill Historic District, Mystic Bridge Historic District, Ston-

Figure 9: 2050 At-Risk Historic Properties in Stonington



ington Borough Historic District, and Mechanic Street Historic District. While all four districts are vulnerable to coastal flood impacts, the Mystic Bridge Historic District is the most vulnerable to coastal flooding and has the greatest number of at-risk historic homes in Stonington (see Figure 9).

Resilience Solutions

Potential resilience solutions were developed for each of the most at-risk assets in Stonington, including Apple Rehab Mystic, Mystic Wastewater Treatment Facility, model single-family and mixed-use buildings, the Village of Mystic, and Masons Island Causeway.

In addition to asset-level resilience solutions, regional resilience concepts were also developed as part of this planning effort. These concepts include larger-scale infrastructure projects that could protect large portions of Stonington from future coastal flooding. Four main regional solutions were proposed, including:

- Tide gates beneath the I-95 crossing at the Mystic River.
- A hurricane barrier across the Pawcatuck River, at the constriction point south of Westerly Yacht Club.
- A multi-element intervention consisting of an elevated railway, tidal control gates, a living shoreline, and green infrastructure in the areas of Lamberts Cove and Quannaduck Cove where the railway crosses from Wamphassuc Neck to Stonington Borough.
- An elevated railway and tidal control gates along the railroad tracks crossing from Groton to Mystic to Latimer Point.

The regional intervention crossing from Groton through Mystic to Latimer Point is likely to have the most impact in Stonington as it would protect the majority of historic resources and tourism assets in the Village or Mystic; therefore, protecting Stonington's unique character and it's tourism industry.

Funding and Financial Considerations

While there are a variety of grants and other funding sources available that the Town should pursue, it is important that the Town recognize the need to contribute its own funding to these solutions. With the current political climate, it is likely that many of the government-supported funding opportunities may become unavailable. In addition, the federal government is taking steps to encourage states and cities to take on more responsibility for resilience. Some potential town funding mechanisms may include:

- Town budget and capital improvement plans – The town should advocate for the inclusion of coastal flood protection and climate adaptation measures as an annual line item in the town budget and capital improvement plan. This could begin as a small allocation in the annual budget and increase over time as the Town's flood protection priorities become clearer.

- Tax Increment Financing (TIF) districts and impact fees to support flood protection infrastructure.
- Public-Private Partnerships (P3) – P3 allows for cost sharing between the Town and private entities and many communities are beginning to use P3 funding for large-scale infrastructure improvements.

Next Steps

In the short term, the Town should work to implement the following resilience options:

1. Renew Stonington's participation in the Community Rating Systems (CRS) program.
2. Implement a targeted floodplain buyout and relocation program.
3. Continue to educate and cultivate active engagement from the residents of Stonington on coastal resilience issues.
4. Implement additional regulatory measures to encourage resilient development practices in floodprone areas.
5. Leverage current projects as a means for furthering the Town's resilience goals.

Over the longer-term, the Town should consider the following actions:

1. Performing a stormwater modeling analysis to understand the impact of the increased frequency and intensity of rainfall on Stonington's flood risk. This may be completed as a town-wide analysis or separated by neighborhoods.
2. Forming working partnerships with locals, state and federal actors, community stakeholders, and nonprofit institutions that also have a vested interest in reducing flood risk in Stonington and the region, as a whole.
3. Pursuing grant funding and implementing the various town funding mechanisms, such as TIF districts, P3 opportunities, and town budgeting and capital improvement plans.
4. Conducting a feasibility analysis for the potential regional adaptation solutions in order to understand the costs and benefits of these types of interventions.

Section 1: Project Overview

Stonington is a coastal community bounded on 3 sides by water. The Town's history is based upon its relationship to the sea and as such, many of its most developed areas are located near the water. Those coastal developments include four historic villages, each with its own unique character. Over the years the Town has also seen the development of waterfront communities such as Lords Point, Latimer Point and Masons Island as well as commercial areas adjacent to its highway interchanges. In contrast to the coastal neighborhoods, Stonington's upland areas consist of historic farms, scenic rural roads, and low density residential development.

The Town is fortunate to possess a combination of natural and man-made scenic resources that has attracted residents and visitors for generations. Visitors and are drawn to Stonington's National Register Historic Districts and tourist attractions such as Mystic Seaport and Mystic Aquarium. However, such a coastal location comes with both benefits and risks: the coastal resources that can drive the economy and provide a high quality of life can also provide unique threats. Many of Stonington's important assets and attractions are at-risk of increased flooding from sea level rise and storm surge. The Town witnessed this coastal flood risk on October 29, 2012 when Superstorm Sandy made landfall in New York. Superstorm Sandy was the second most costly hurricane in U.S. history, causing approximately $50 billion worth of damage. The damage associated with Superstorm Sandy is second only to Hurricane Katrina, which caused over $100 billion worth of damage in 2005.[1] While Connecticut was largely spared a direct hit from the storm, the state still suffered millions of dollars in damage and received $71.8 million of federal Community Development Block Grant – Disaster Recovery (CDBG-DR) funding from the Department of Housing and Urban Development (HUD). A portion of that funding was allocated to assist communities with local planning efforts to repair public facilities and infrastructure and increase community resilience against future storm events. As part of that allocation, the Town of Stonington received funding to complete this Coastal Resilience Plan to assess the vulnerability of key critical assets and infrastructure to coastal flood events and develop targeted resilience solutions for the most at-risk assets in the Town.[2]

In recent years, many communities have started to assess their risks to climate change and develop adaptation plans. However, Superstorm Sandy instilled a sense of urgency throughout the Northeastern United States and motivated many communities to take a more proactive stance on climate change. This collective action is vital to protecting the livelihood of the region given that losses from major coastal flooding and storm events are anticipated to increase in the coming years as climate change impacts worsen. Those impacts will be compounded by the increasing investment in valuable, yet vulnerable, coastal real estate. From 2011-2015, the annual average of billion-dollar weather-related disasters has more than doubled from 5.2 events per year in the previous decades to approximately 10.8 events per year in the last five years.[3] That trend toward more costly and more damaging storm events is expected to continue throughout the century: in Stonington approximately $1.9 billion of coastal property could be at-risk of flooding by 2050.

In the Northeast region of the United States specifically, heavy downpours and increasing sea level rise pose growing challenges that are likely to compromise the region's aging infrastructure and increase the vulnerability of vital environmental, social, and economic systems.[4] Over the last century, sea levels in the Northeast rose approximately one foot, which is 50% greater than the global

Water Street commercial district, Stonington, CT (Author: Pi.1415926535, Wikimedia Commons)

average of eight inches. Sea level rise, combined with more frequent storm events and a projected increase in extreme precipitation events, poses an increasing threat to Connecticut and the surrounding states in the Northeast region.[5]

While Stonington was not in the direct path of Superstorm Sandy, the Town still suffered significant damage from the storm. In the wake of Superstorm Sandy, Stonington received over $280,000 of reimbursement funding from the Federal Emergency Management Agency (FEMA) to repair damage to the Town Dock, Masons Island Causeway, and other damaged sites. At only six feet above sea level, Masons Island Causeway is a particularly vulnerable asset in Stonington; as the only means of egress for more than 800 residents living on Masons Island, many residents of Stonington face significant risk as a result of coastal flood impacts to the Causeway.

Many of Stonington's residential properties are also vulnerable to coastal flood impacts; since 1978, Stonington residents have received over $4.5 million of flood insurance payouts. Significant storms in July 2009 and March 2010 resulted in significant damage to the Town. In 2009, two dams were overtopped during a nor'easter. In March 2010, the Route 184 bridge was destroyed, several roadways were damaged, and serious basement flooding impacted many homes and a few town-owned properties, including Stonington Town Hall.

Historically, Stonington is a community characterized by its proximity to and relationship with the coast. With four historic coastal villages and over 1,400 properties located in the present-day 100-year floodplain, Stonington faces increasing risk

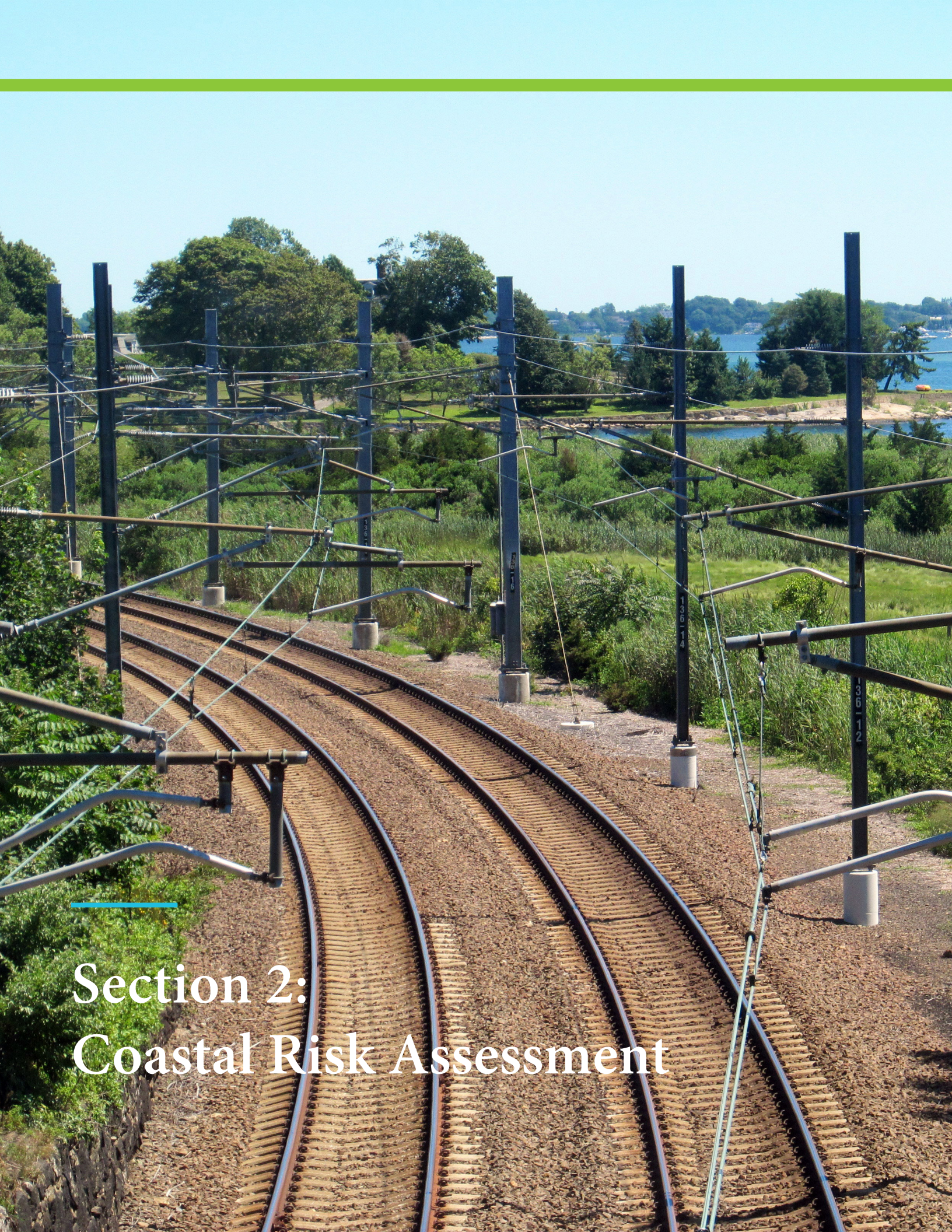
Mystic Seaport (Author: Gregory Moine, Wikimedia Commons)

to its residents, infrastructure and critical assets. Moreover, Stonington's economy relies heavily on tourism generated by the Town's waterfront; this tourism economy could be significantly impacted by future coastal flooding events. While providing economic benefits from coastal tourism, Stonington's location presents significant risk to its built infrastructure and environmental, economic, and social systems.

Stonington acknowledges the risks related to its coastal location. To date, the Town has implemented several new programs, policies, and regulations to try to minimize risk to coastal flooding within the community, including:

- Zoning regulations that restrict development in the 100-year floodplain and require elevation of new construction above base flood elevation (BFE);
- Past participation in the Community Rating System; and
- Construction, maintenance, and on-going improvements to flood control structures.

Importantly, the Town does not currently have a comprehensive understanding of its risks. This understanding is vital to developing effective coastal mitigation and adaptation strategies and increasing the resilience of the community, its people and its infrastructure. This coastal resilience plan is the first step towards creating a safer and more secure future for the Town of Stonington and its residents.



Section 2: Coastal Risk Assessment

Methodology

Coastal risk is the potential for an asset or system to be impacted by a future coastal flooding event. This coastal risk assessment focused on important community assets and systems, as defined by the Town of Stonington and the Climate Change Task Force. The community facilities were organized into four main categories:

- Community Facilities;
- Historic Resources;
- Transportation; and,
- Drainage and Utilities.

Community facilities in these categories, also known as assets, were ranked according to their coastal flood risk, in order to determine the most at-risk community assets. Coastal flood risk was evaluated based on three main factors: hazard, exposure and vulnerability. These factors were used to calculate a risk score for each community asset, using the following formula:

Risk = Hazard x Exposure x Vulnerability

Hazard is a measure of the likelihood of a future storm event impacting the asset. Coastal modeling scenarios were developed to assess future flood scenarios for the Town of Stonington. These sce-

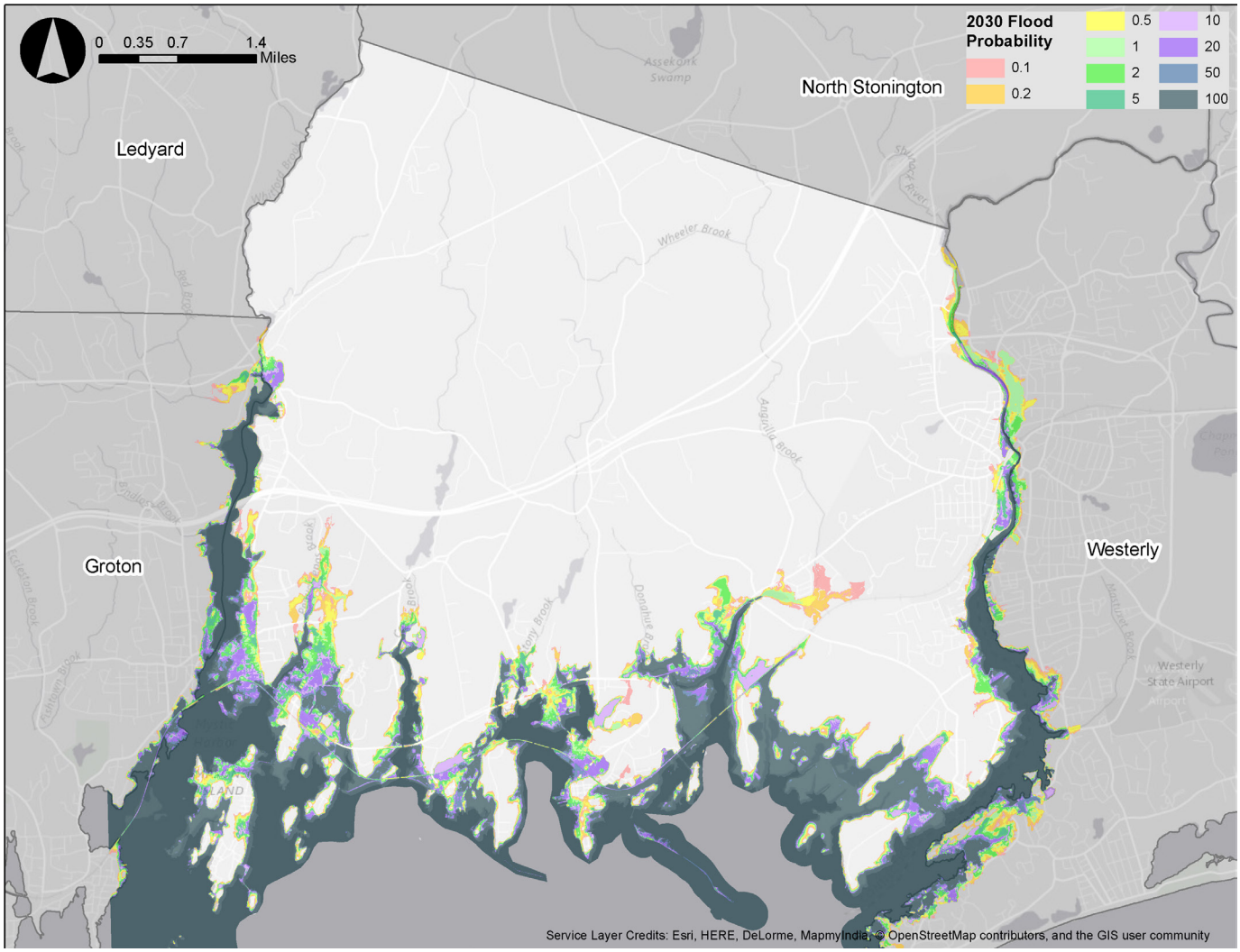


Figure 10: 2030 Flood Probability in Stonington, CT

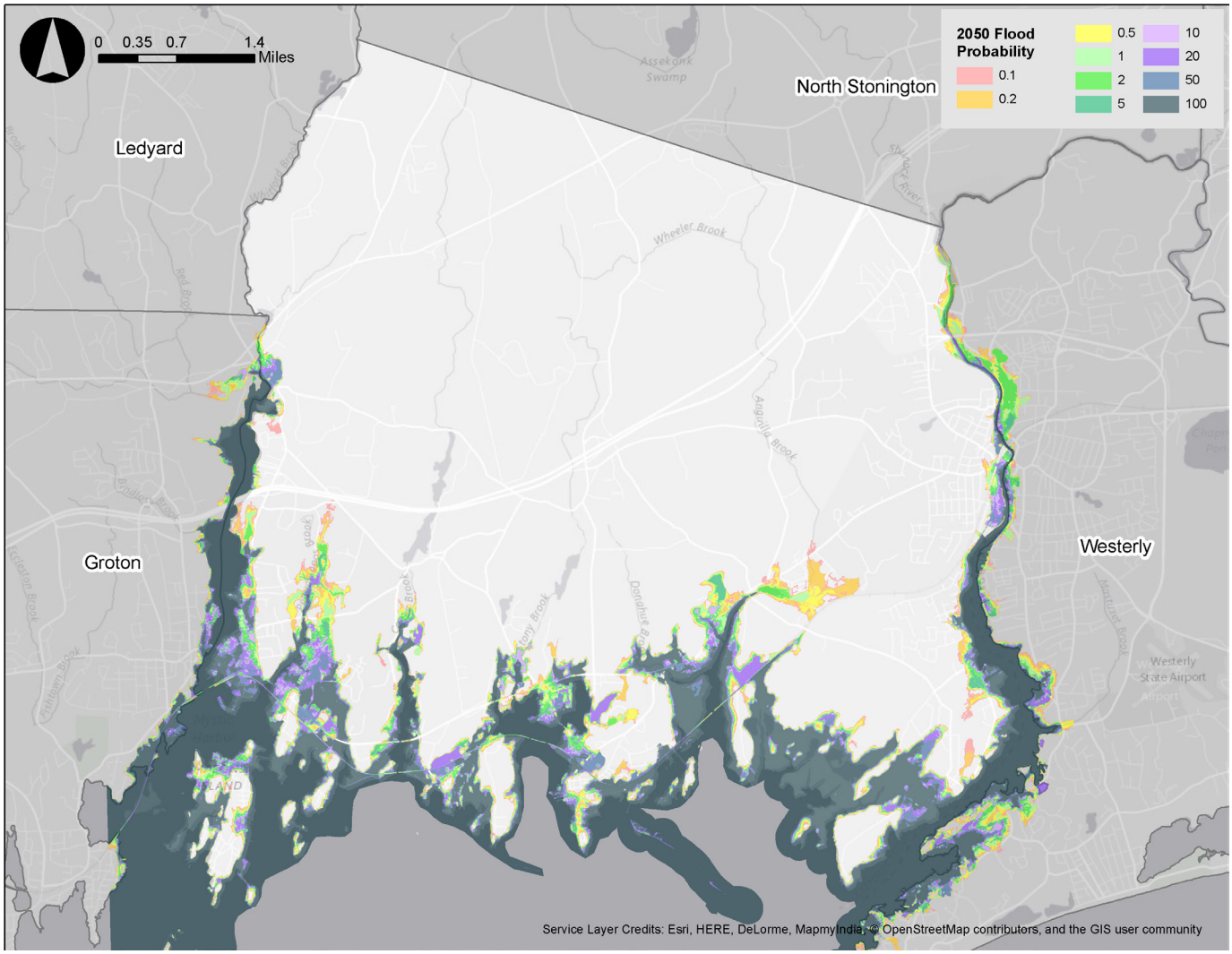


Figure 11: 2050 Flood Probability in Stonington, CT

narios assessed the probability of a coastal flood event (and the associated extents of that flooding) in the years 2030 and 2050 based on future sea level rise assumptions.

Global sea levels have risen approximately eight inches since 1880. Since 1992, that rate of sea level rise has almost doubled compared to the prior century and there is consensus in the scientific community that sea level rise will continue to increase throughout the 21st century. The acceleration, probability, and volume are difficult to predict. Sea levels are rising faster in the Northeast United States compared to the global average, largely as a result of land subsidence. The National Climate Assessment predicts that sea levels will rise an additional one to four feet by the end of the century. Therefore, it was important to use conservative (i.e. leaning towards overestimation) scientific projections of sea level rise in order to analyze potential coastal flood impacts to Stonington.

The rate of sea level rise used in this study accounts for expected future increases in sea level rise and is consistent with the projections detailed in the National Climate Assessment. By 2030, sea levels are estimated to rise approximately 0.55

feet and by 2050, sea level rise may increase by 1.69 feet over present-day sea levels, under the highest emissions scenario. While projections are not certainties, planning ahead requires paying attention to the highest risk scenarios. For more detail on the sea level rise assumptions used for this study, please refer to Appendix F.

Based on these sea level rise scenarios, probability is defined as the percent annual chance of flooding. Figure 10 displays the probability of flooding in 2030 and Figure 11 displays the probability of flooding in 2050. Between 2030 and 2050, it is important to note that the extent of flooding in Stonington does not change significantly (see Figure 18). The more significant change is an increase in the depth of flooding in certain areas of town, as displayed in Figures 14-17. Figure 12 details the risk assessment scoring methodology for the various hazard types:

Figure 12: Hazard Scores for Risk Assessment

Hazard Type	Hazard Score
Present-day 1% storm or FEMA AE/VE Zone	3
2030 1% or 0.1% Storm	2
2050 1% or 0.1% storm	1

Exposure refers to the depth of flooding that may be experienced by the asset during a given storm event. Because flood depths vary depending on the intensity of the storm event, the exposure scores were standardized across all assets by using the depth of flooding at each asset during the 2050 0.1% storm event (or the 1000-year storm).

The 2050 1000-year storm event was chosen for the exposure analysis because it is the most intense storm analyzed as part of this assessment. The storm has the largest flood extents and will impact the most community assets; therefore, by using the flood depths associated with this storm, each community asset that is likely to be impacted by a future storm can be included in the exposure assessment. In addition, recent studies show that the frequency of major storm events is likely to increase throughout the century. By 2100, there could be an increase of 17 times the current frequency of major Sandy-like storm events, resulting in a powerful storm approximately once every 20 years.[6] Figure 13 shows the exposure scores associated with each category of flood depths:

Figure 13: Exposure Scores for Risk Assessment

Depth of Flooding	Exposure Score
> 10	4
5.01-10 ft	3
2.01-5 ft	2
0-2 ft	1

Key Terms

Sea Level Rise Assumptions
The following assumptions were made to estimate future sea level rise in Stonington. These assumptions are based on data from the National Coastal Assessment.

By 2030, sea levels are expected to rise approximately 0.55ft.

By 2050, sea levels are expected to rise approximately 1.69ft.

FEMA Flood Mapping
FEMA flood maps are based on current and historic flood-related data, including: hydrology, infrastructure, hydraulics, land use, and existing floodplain and base maps.

100-year Storm: The 100-year storm event is a storm that has a 1% annual chance of occurring in any given year.

1000-year Storm: The 1000-year storm event is a storm that has a 0.1% annual chance of occurring in any given year.

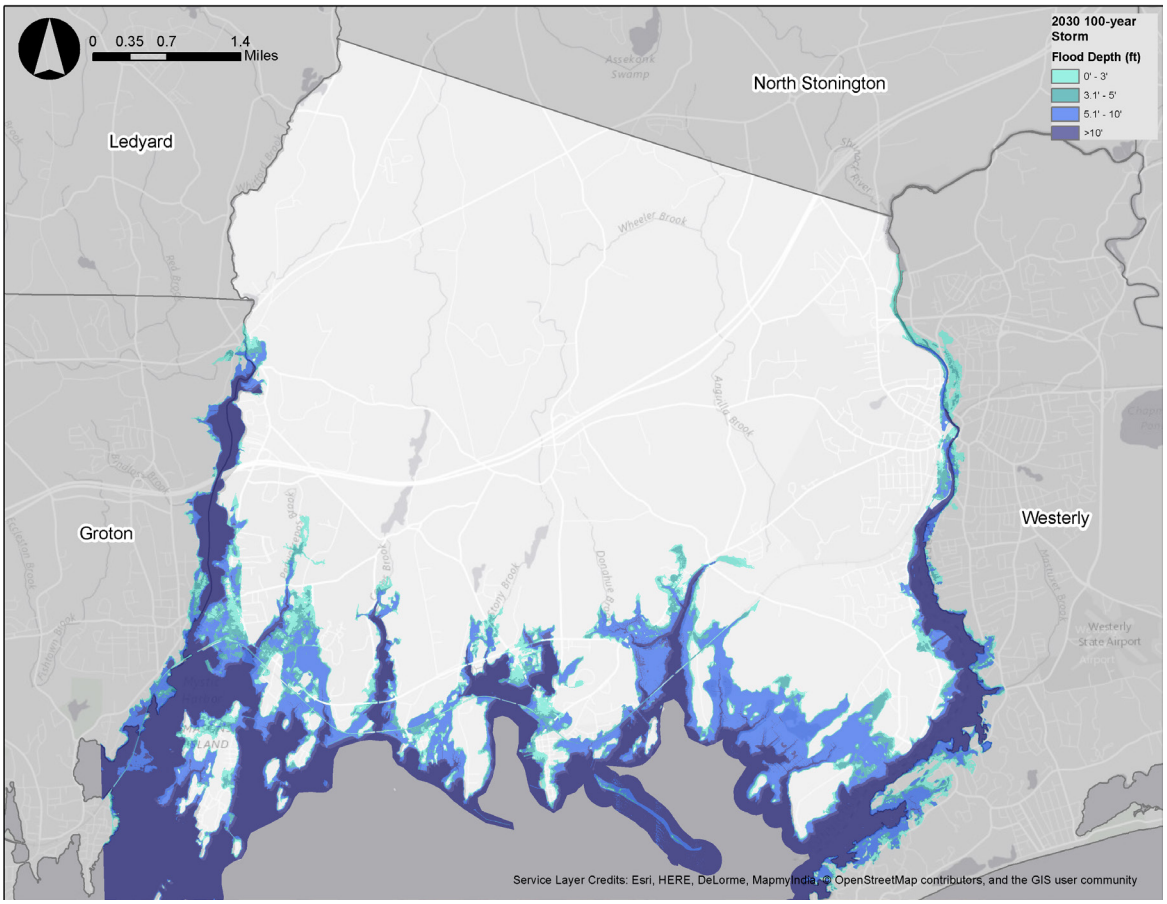


Figure 14: Estimated Flood Depths for a 100-year Storm Event (1% Annual Chance of Flooding) in 2030

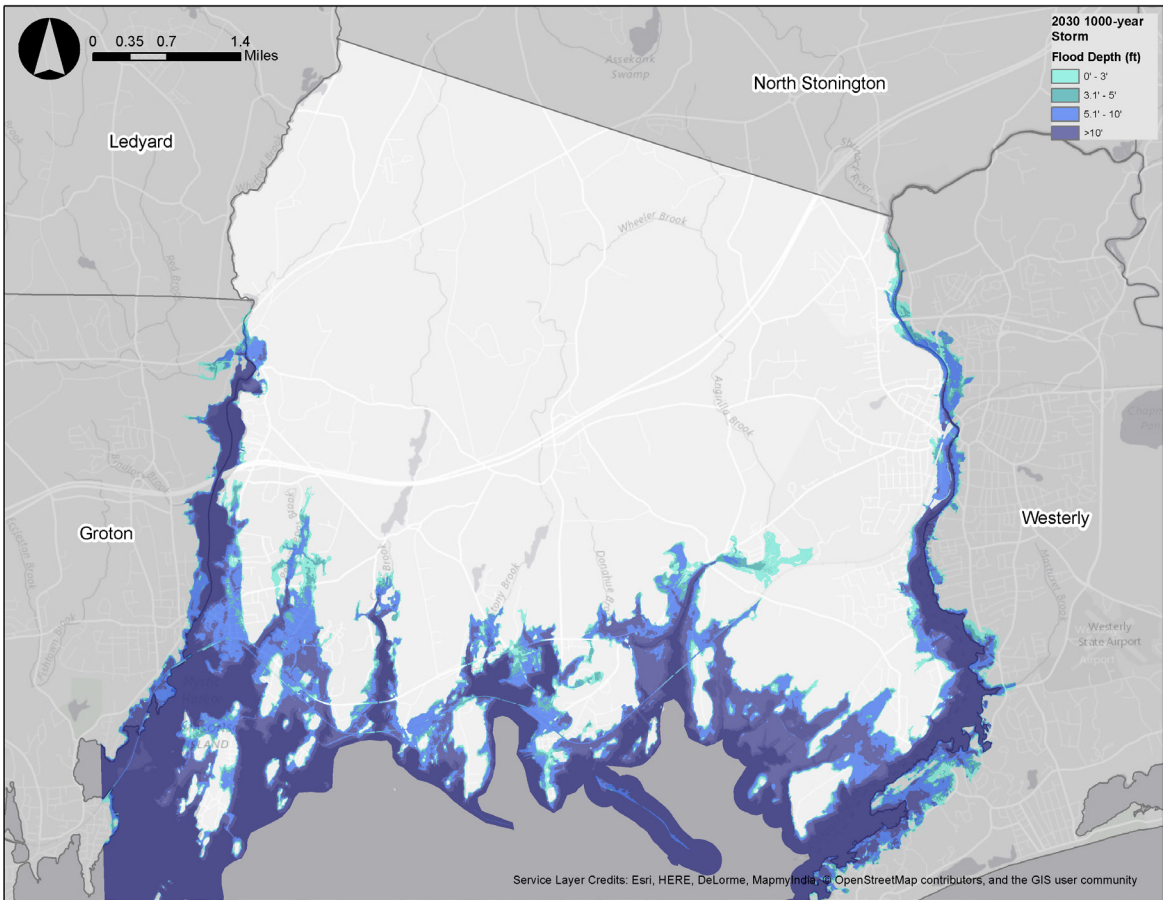


Figure 15: Estimated Flood Depths for a 1000-year Storm Event (0.1% Annual Chance) in 2030

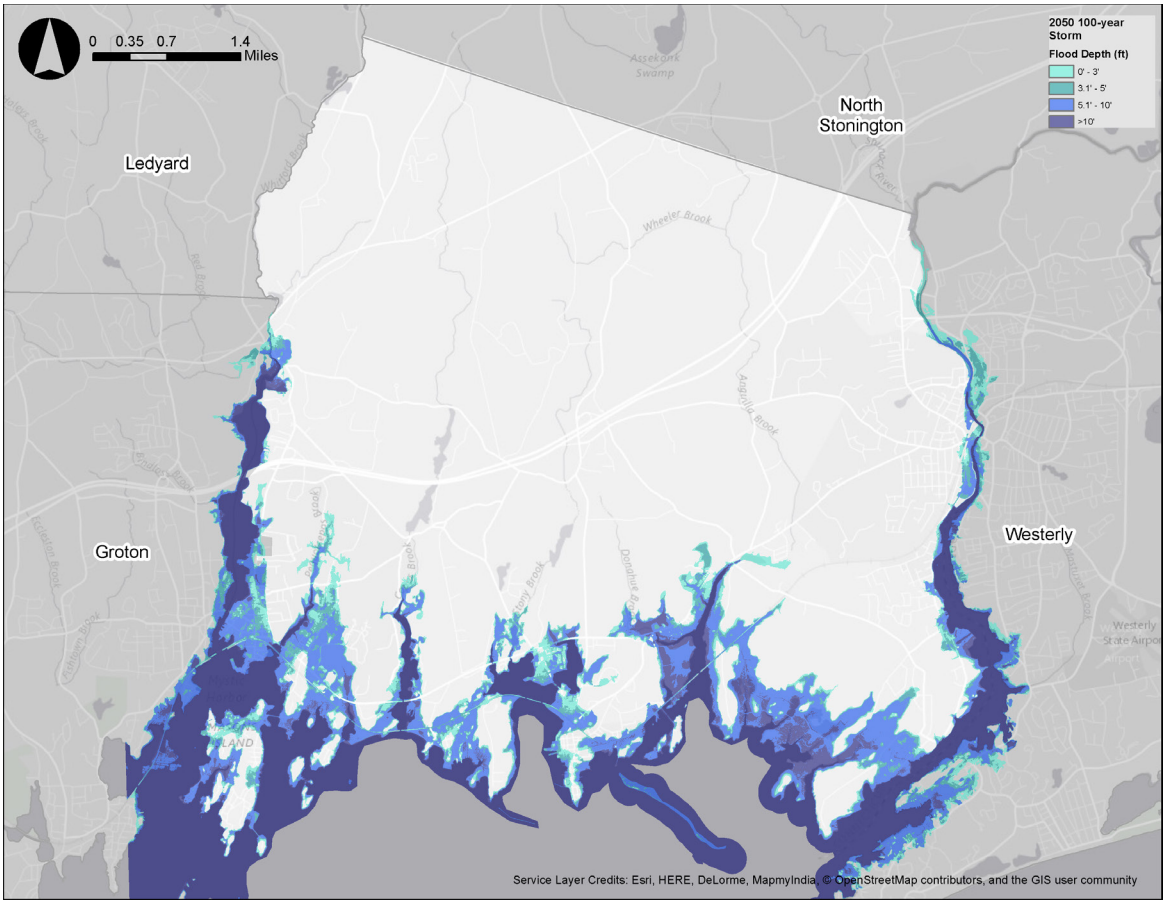


Figure 16: Estimated Flood Depths for a 100-year Storm Event (1% Annual Chance) in 2050

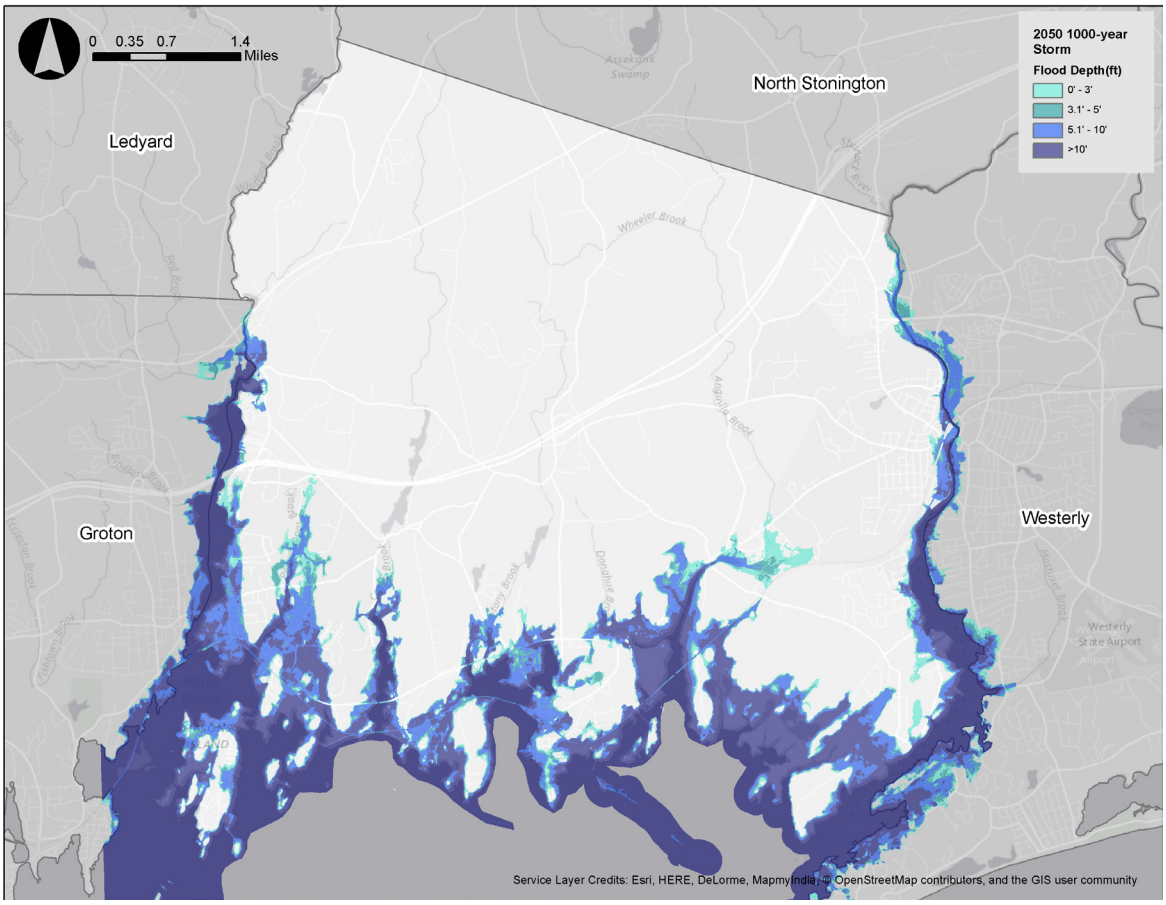


Figure 17: Estimated Flood Depths for a 1000-year Storm Event (0.1% Annual Chance) in 2050

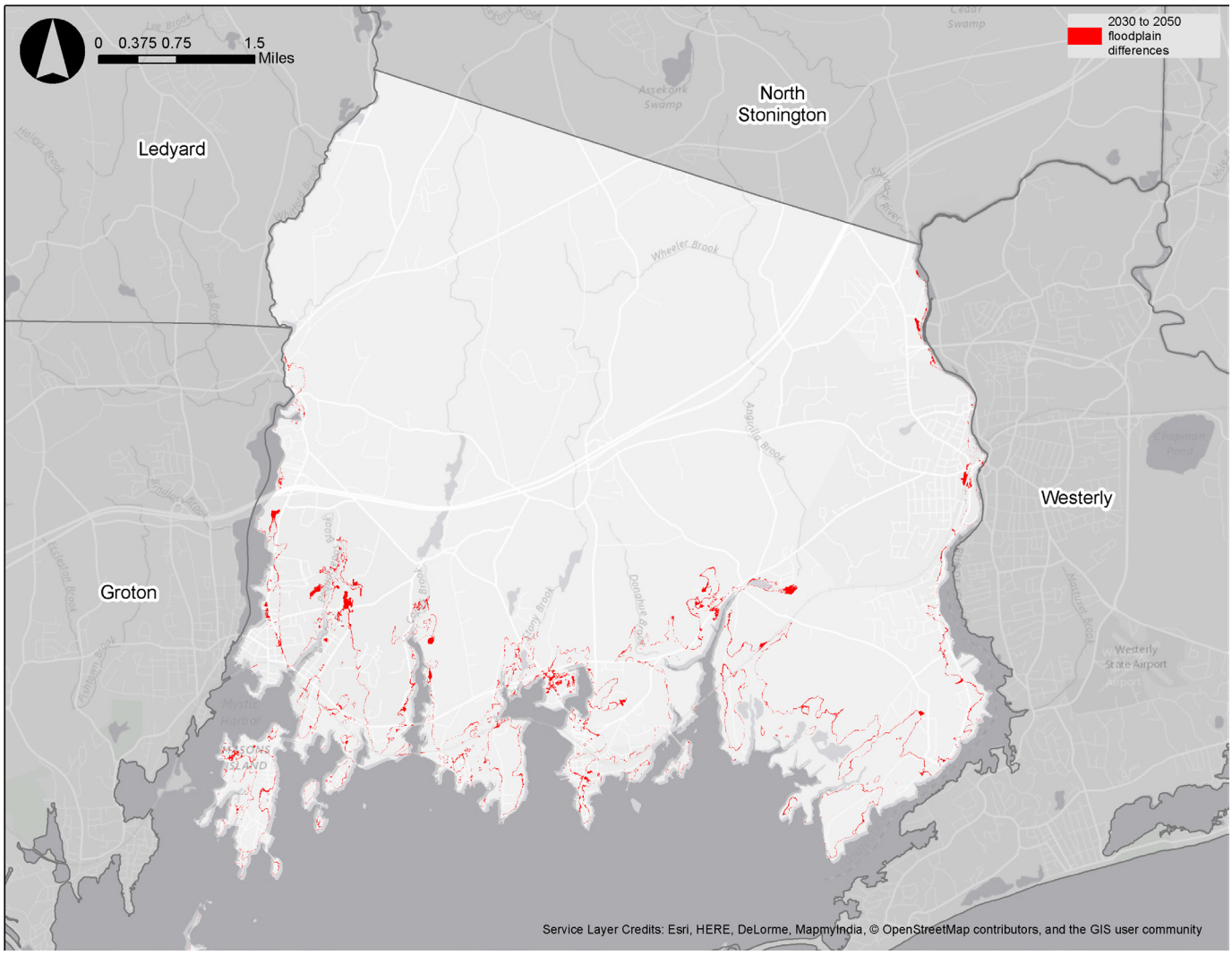


Figure 18: Difference in Flood Extents between 2030 and 2050

Vulnerability is a measure of the impact to the community if the asset is damaged in a flood event. Vulnerability was assessed according to four factors: criticality of the facility; community impact; economic impact based on replacement cost; and, impact to the tourism economy/historic resources. The vulnerability score is an average of these four factors for each asset. A critical facility is defined by the FEMA definition: "FEMA defines four kinds of critical facilities:

- Structures of facilities that produce, use or store highly volatile, flammable, explosive, toxic and/or water-reactive materials.
- Hospitals, nursing homes and housing likely to have occupants who may not be sufficiently mobile to avoid injury or death during a flood.
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for flood response activities before, during and after a flood.

- Public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during and after a flood."[7]

Figure 19 details the critical facility scores:

Figure 19: Critical Facility Scores

Critical Facility	Critical Facility Score
Critical Facility by FEMA's definition	3
Other essential assets	2
Non-critical and non-essential assets	1

Community impact is a function of the redundancy of the asset and the percentage of Stonington residents that would be impacted by failure of or damage to the asset. Figure 20 details the community impact scoring based on the percentage of residents impacted.

Figure 20: Community Impact Scores

Impact by %	Community Impact Score
67-100%	3
34-66%	2
0-33%	1

Economic impact is a function of the value of the asset. Facilities with important and valuable infrastructure and equipment are considered high economic value and would have a high replacement cost if damaged during a storm event. Figure 21 displays the economic impact scores:

Figure 21: Economic Impact Scores

Economic Importance	Economic Impact Score
Important buildings and infrastructure	3
Other community buildings	2
Open space and recreation areas	1

Lastly, a high-level analysis was conducted to capture the impact of a flood event on the tourism economy and historic character of Stonington. Because we do not have detailed statistics on the value of tourism on Stonington's economy, we conducted a high-level assessment to identify important tourism assets and districts. Tourism and historic resources in the Town seem to be closely correlated, as the most important historic districts also seem to be the most popular tourist destinations. Any asset or district identified by the Town as an important historic district or tourist destination was given a score of three, including Mystic Seaport, Mechanic Street Historic District, Mystic Bridge Historic District, Rossie Velvet Historic District, and Stonington Borough Historic District.

The vulnerability score was determined by taking an average of the critical facility, community impact, economic impact, and tourism/historic resources impact scores. The final risk score is a function of the combined hazard, exposure, and vulnerability scores.

Risk Ranking

Using this methodology, we created a risk score for each of the important community facilities and resources in the Town of Stonington in order to help the Town identify and prioritize Stonington's most at-risk resources. Figure 22 and Figure 23 show the final risk ranking for Stonington's community facilities, separated by ownership. The following abbreviations are used for each of the asset classes in Figures 22 and 23:

CF	Critical Facilities
T	Transportation
HR	Historic Resources
D&U	Drainage & Utilties

For more detail on the methodology and the full risk ranking, please refer to Appendix B.

Figure 22: Risk Ranking for Town and Borough-Owned Assets

Asset	Asset Class	Ownership	Hazard	Exposure	Vulnerability	***Risk***
Masons Island Causeway	CF	Town	3	4	2.00	***24***
Mystic Wastewater Treatment Facility	CF	Town	3	4	1.75	***21***
Mechanic Street Historic District	HR	Private and Town	3	4	1.75	***21***
Mystic Bridge Historic District	HR	Private and Town	3	4	1.75	***21***
Rossie Velvet Historic District	HR	Private and Town	3	4	1.75	***21***
Stonington Borough Historic District	HR	Private and Town	3	4	1.75	***21***
Boulder Avenue Pump Station	D&U	Town	3	4	1.50	***18***
Diving Street Pump Station	D&U	Town	3	4	1.50	***18***
River Road/Mary Hall Road Pump Station (Pump Station No. 3)	D&U	Town	3	4	1.50	***18***
Wolcott Avenue Pump Station	D&U	Town	3	4	1.50	***18***
River Road/Mechanic Street	T	Town	3	4	1.50	***18***
North Main Street	T	Town	3	4	1.50	***18***
Elm Street	T	Town and Borough	3	4	1.50	***18***
Flanders Road	T	Town	4	3	1.50	***18***
Cutler Street	T	Town	4	3	1.50	***18***
Town Dock	CF	Town	3	3	1.75	***16***
Catchbasins	D&U	Town	3	4	1.25	***15***
Outfalls	D&U	Town	3	4	1.25	***15***
Hewitt Road Pump Station	D&U	Town	3	3	1.50	***14***
Mechanic Street (Pump Station 1)	D&U	Town	3	3	1.50	***14***
Willow Street	T	Town	3	3	1.50	***14***
Water Street	T	Borough	3	3	1.50	***14***
Donahue Park	CF	Town	3	4	0.75	***9***
Ensign Lane Pump Station	D&U	Town	3	2	1.50	***9***
Former 4th District Voting Hall	CF	Town	3	3	1.00	***9***
Mystic River Park	CF	Town	3	4	0.75	***9***
Borough Hall	CF	Borough	3	2	1.25	***8***
Old Mystic Playground	CF	Town	3	3	0.75	***7***
Stonington Police Department	CF	Town	3	1	2.25	***7***
Stonington High School & Emergency Shelter	CF	Town	3	1	2.00	***6***
Borough Fire Station	CF	Borough	3	1	1.75	***5***
Old Mystic Pump Station	D&U	Town	3	1	1.50	***5***
Lindbergh Road Pump Station	D&U	Town	1	1	1.50	***2***
Spellman Park	CF	Town	1	1	0.75	***1***

Figure 23: Risk Ranking for Assets not owned by the Town or Borough

Asset	Asset Class	Ownership	Hazard	Exposure	Vulnerability	***Risk***
Apple Rehab Mystic	CF	Private	3	4	2.00	***24***
Mystic Seaport	CF	Private	3	4	1.75	***21***
Greenmanville Ave Electrical Substation	D&U	Private	3	3	2.25	***20***
Cutler St Electrical Substation	D&U	Private	3	3	2.25	***20***
Amtrak Rail Line	T	Private	3	4	1.50	***18***
East Main Street	T	State	3	4	1.50	***18***
Greenmanville Avenue	T	State	3	4	1.50	***18***
North Water Street	T	State	3	4	1.50	***18***
Roosevelt Avenue	T	State	3	4	1.50	***18***
State Highway 27/Denison Avenue	T	State	3	4	1.50	***18***
Stonington Road	T	State	3	4	1.50	***18***
West Broad Street	T	State	3	4	1.50	***18***
Williams Avenue	T	State	3	4	1.50	***18***
Mystic Train Station	CF	Private	3	3	1.75	***16***
Mystic Fire Department	CF	Fire District	3	3	1.75	***16***
Quiambaug Fire Department	CF	Fire District	3	3	1.75	***16***
Alpha Avenue	T	State	3	3	1.50	***14***
Broadway Avenue	T	State and Town	3	3	1.50	***14***
Liberty Street	T	State	3	3	1.50	***14***
Westerly Bypass	T	State	3	3	1.50	***14***
Ocean Community YMCA	CF	Private	3	3	1.25	***11***
Stonington Community Center	CF	Private	3	3	1.25	***11***
Old Mystic Post Office	CF	Private	3	3	1.00	***9***
Dubois Beach	CF	Private	3	4	0.75	***9***
Barn Island Management Area	CF	State	3	4	0.75	***9***
Mystic Post Office	CF	Federal	3	3	1.00	***9***
Avalonia Land Conservancy (Ram Point)	CF	Private	3	4	0.75	***9***
Paffard Marsh Preserve	CF	Private	3	4	0.75	***9***
Denison Pequot Nature Center (Greenmanville Ave)	CF	Private	3	4	0.75	***9***
Denison Pequot Nature Center (Pequotsepos Rd)	CF	Private	3	4	0.75	***9***
Cottrell Marsh (owned)	CF	Private	3	4	0.75	***9***
TNC Gallup Salt Marsh (easement)	CF	Private	3	4	0.75	***9***
TNC Mason Island Company (easement)	CF	Private	3	4	0.75	***9***
South Broad Street	T	State	3	2	1.50	***9***
Whitehall Avenue	T	State	3	2	1.50	***9***
Pawcatuck Neighborhood Center	CF	Private	3	2	1.25	***8***
La Grua Center	CF	Private	3	2	1.25	***8***
Denison Pequotsepos Nature Center, Inc.	CF	Private	3	3	0.75	***7***

Mystic Reservoir	D&U	Private	3	1	2.00	***6***
Pawcatuck Fire Station	CF	Fire District	3	1	1.75	***5***
Borough Post Office	CF	Federal	3	1	1.00	***3***
Anguilla Preserve	CF	Private	3	1	0.75	***2***
Avalonia Land Conservancy (N. Stonington Rd)	CF	Private	3	1	0.75	***2***
Avalonia Land Conservancy (North Main Street)	CF	Private	3	1	0.75	***2***
Pawcatuck Little League	CF	Private	3	1	0.75	***2***
Stonington Soccer Club	CF	Private	3	1	0.75	***2***

Based on this ranking and local knowledge of the importance of community facilities, we identified the top 5 and top 25 most at-risk assets in the community. These assets were carried into the next phase of the assessment: developing potential resilience solutions (see Section 3: Resilience Solutions). For each of the top 5 assets, we developed a detailed assessment of potential resilience solutions for each asset. Those assets include:

- Apple Rehab Mystic
- Masons Island Causeway
- Mystic Wastewater Treatment Facility
- Village of Mystic
- Models for a typical single-family home and typical mixed-use building in Stonington

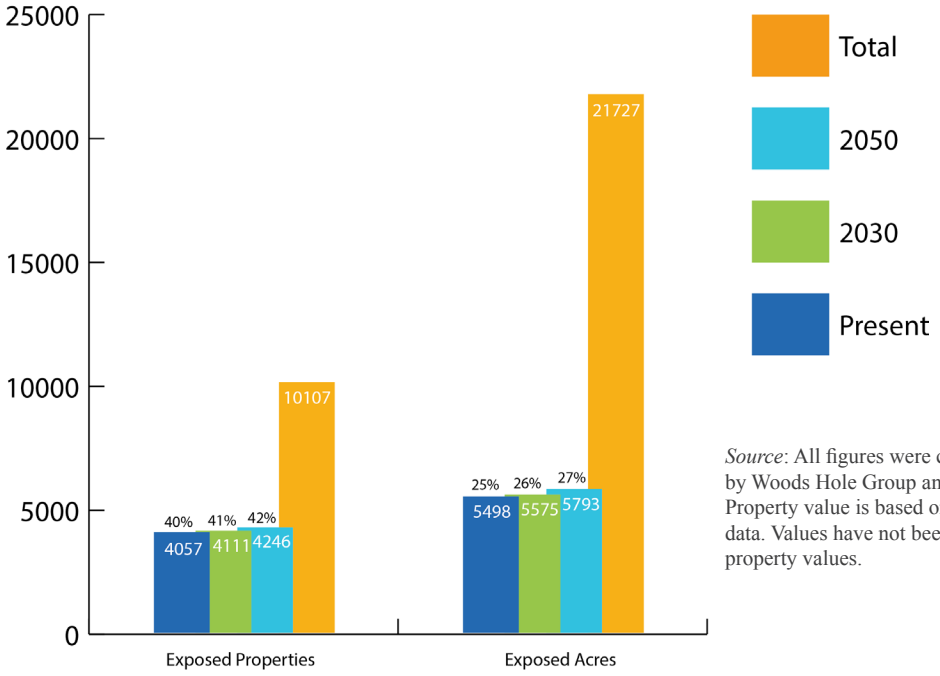
While single-family homes and businesses were not part of the initial risk assessment, feedback from the community indicated that residents were very interested in strategies for protecting their homes and businesses. Therefore, a typical single-family home and mixed-use building were included as part of the detailed resilience solutions. Inclusion of typical buildings seeks to assist residents in understanding how to make their properties more resilient. In addition, there was interest in understanding the resilience solutions that could be employed on a neighborhood and regional scale. As such, a study of the Mystic neighborhood was also included in the resilience solutions as an example of how to develop neighborhood-scale resilience strategies.

For the top 25 assets, a higher-level analysis was completed to identify potential resilience solutions for the Town to further investigate as it continues its coastal resilience planning efforts. Figure 24 displays the top 25 most at-risk assets.

Figure 24: 25 Most At-Risk Assets in Stonington

Top 25 Assets		
Masons Island Causeway	Mystic Bridge Historic District	State Highway 1
Mystic Wastewater Treatment Facility	Rossie Velvet Mill Historic District	Cutler St. Electrical Substation
Boulder Avenue Pump Station	Stonington Borough Historic District	Mystic Train Station & Rail Line
River Road/Mary Hall Road Pump Station	Apple Rehab Mystic	Barn Island Management Area
Stonington Wastewater Treatment Facility	Mystic Seaport	Town Dock
Stonington Community Center (COMO)	Mystic Fire Department	Mystic River Park, Cottrell Street
Greenmanville Avenue Electrical Substation	State Highway 27	Lords Point neighborhood
Quiambaug Fire Department	Donahue Park	Murphy's Point neighborhood
Mechanic Street Historic District		

Figure 25: Potential Property and Land Flood Vulnerability in the Town of Stonington



Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

Community-wide and Neighborhood Vulnerability

While this study was largely focused on assessing the vulnerability and risk of key community facilities and assets, it is important to understand Stonington's vulnerability on a larger-scale. On a community-wide scale, 27% of the total land area is anticipated to be impacted by the 1000-year coastal flood event in 2050; this accounts for approximately 5,800 acres of land. The parcels in the impact area account for 53% of Stonington's total tax base, which represents approximately $2 billion worth of property value. Therefore, a flood event of that scale would have a significant impact on the Town's residents, and its economy.

> 27% of the total land area in Stonington is anticipated to be impacted by the 1000-year coastal flood event in 2050.

This plan focuses on the assets that are vulnerable to coastal flood impacts. However, it is important to document the areas and assets in Stonington that are not vulnerable to coastal flooding. Identifying these locations and facilities can ensure that they are leveraged for planning, response and recovery functions during future flooding events. All of Stonington's schools are located outside of flood-prone locations, which is important both from the perspective of protecting the children in the community as well as serving as a community gathering space and shelter during an emergency event.

It is also important to assess dependencies between assets that have higher and lower vulnerability. For example, if the Town's emergency shelter is protected from flooding, but the roads leading to the facility are flooded the Town is still exposed to significant risk during a flood event. Therefore, we looked at the vulnerability of Stonington, as a community, and assessed that vulnerability as it relates to the Town's critical assets, transportation systems, historic resources, and natural resources.[8]

Built Environment and Physical Infrastructure

The built environment and physical infrastructure incorporated into this assessment include community assets and infrastructure, critical resources, and key physical assets and systems that are important to the community and the daily operations of the Town. Several utilities and infrastructure facilities may be vulnerable to flood impacts, including the Mystic and Stonington Wastewater Treatment Facilities, the Boulder Avenue and River Road Pump Stations, and the Greenmanville Avenue and Cutler Street Electrical Substations. Each of these facilities are critical to the efficient operations of the Town; therefore the Town should ensure that appropriate measures are taken to protect these facilities from flood impacts and ensure redundancy of critical operations within and between the facilities.

Additional vulnerable community facilities include the Town Dock, Mystic and Quiambaug Fire Departments, the Apple Rehab Mystic facility, and the Mystic Seaport. Impacts to any of these facilities could have significant implications for the Town. The Town Dock is an important economic resource for the Town and if the dock is not able to continue its daily operations, due to flood damage to the structure, there could be cascading implications throughout Stonington's economy. The Mystic and Quiambaug fire stations are important to the Town's daily operations and emergency response; flood impacts to these facilities or the surrounding roadways may impact public health and safety and limit the ability of first responders to effectively respond to an emergency. Apple Rehab Mystic is one of the only medical facilities within Stonington and may be vital for providing medical support during an emergency event. Lastly, Mystic Seaport is one of the key economic drivers within the Town, as it attracts more than 250,000 visitors each year and Mystic, as a whole, accounts for approximately 29% of the total traveler spending in Connecticut.[9] Thus, each of these facilities provides a critical resource for Stonington and is essential to both the daily functionality of the Town and the operations of the Town during an emergency event.

Additional community facilities that may be impacted by coastal flood events include: several additional pump stations, Borough Hall, the Stonington Police Department, Stonington High School, the Mystic, Old Mystic, and Pawcatuck Post Offices, and several important community centers (including the La Grua Center, Stonington Community Center, the Former Fourth District Voting Hall, Pawcatuck Neighborhood Center, and the Ocean Community YMCA). While these facilities are less vulnerable than some of Stonington's other physical assets, impacts to each of these facilities would negatively impact the quality of life and daily operations of Stonington.

Transportation

Stonington's transportation network may also be impacted by coastal flooding. The Town has already experienced significant flood impacts to Mason's Island Causeway during Superstorm Sandy and other past flood events. Additional impacts from coastal flooding may affect Route 27, as it extends down through Mystic, and Route 1, which runs in close proximity to the coast of Stonington between Mystic and Pawcatuck. These three roadways are the most vulnerable to flooding in Stonington. While Mason's Island Causeway is not a major commuter corridor, it is the only means of access to and egress from the island. Therefore, flooding of the causeway will significantly impact residents of Mason's Island, limiting their ability to get on or off the island and causing significant health and safety concerns during an emergency event, given the lack of access to food and healthcare facilities on the island.

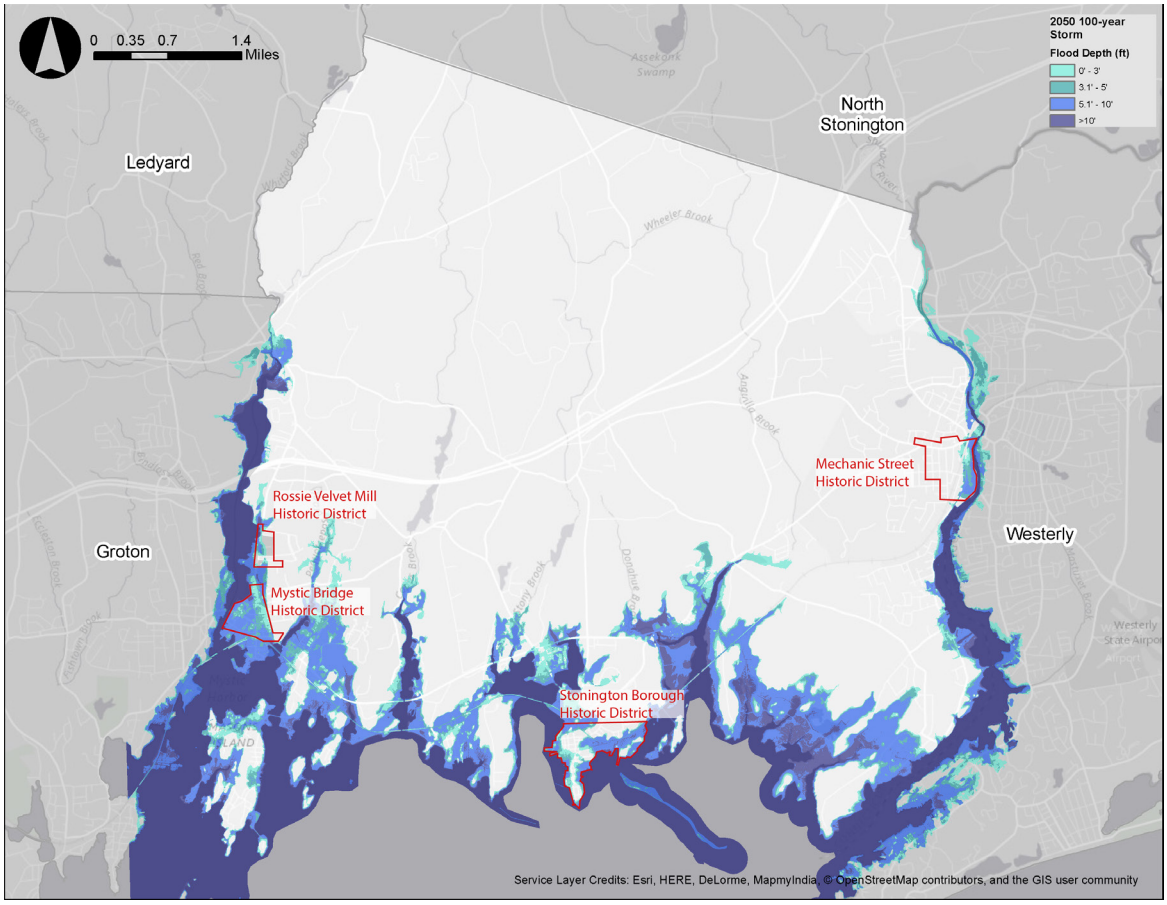


Figure 26: 2050 At-Risk Historic Structures in Stonington by Historic District

Route 27 and Route 1 are both major roadways in Stonington; therefore, flooding along these roadways may impact the mobility of Stonington residents, including their daily commutes to work.

In addition to roadways, the Northeast Corridor railway is highly vulnerable to flood impacts in Stonington. The rail line runs along the coast throughout Stonington and is expected to experience significant flood impacts. With over 260 million annual passenger trips along the Northeast Corridor, and 25,704 annual trips through Mystic amounting to $1,292,097 in annual station revenue[10], flooding and damage along this railway would have significant impacts to Stonington and cascading impacts throughout the region. Impacts to the railroad infrastructure and Mystic train station would likely result in a decrease in tourism and would impact commuters who rely on the train for their daily commute in and out of Stonington. Similar impacts would be likely to effect the surrounding Towns, resulting in cascading impacts to Connecticut's economy.

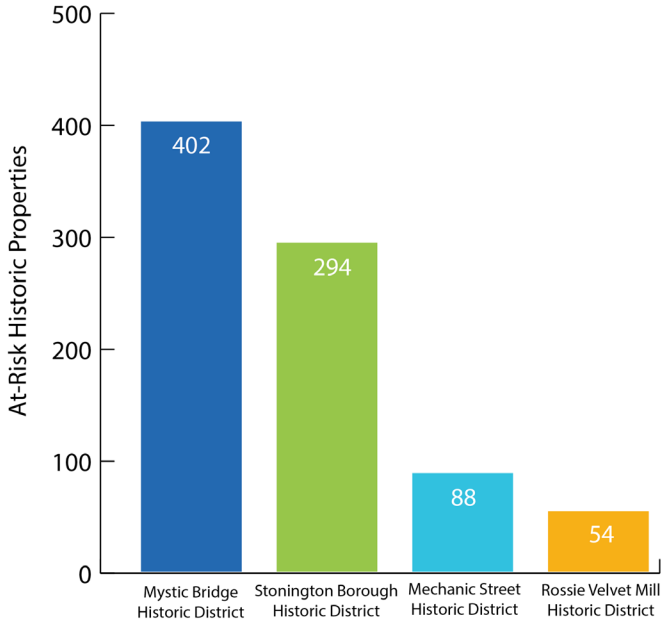


Figure 27: 2050 At-Risk Historic Properties in Stonington

Smaller roadways within Stonington may also see significant flood impacts, but those roadways are less likely to significantly impact the Town, its residents, and the economy. See Figures 22 and 23 for the minor roadways that may be impacted.

Historic Resources

Stonington's historic resources are essential to the character of the community and are important drivers for the Town's tourism economy. The Town has 854 historic properties that are vulnerable to coastal flooding by 2050. Of those, 838 are located in the Town's four largest historic coastal districts: Rossie Velvet Mill Historic District, Mystic Bridge Historic District, Stonington Borough Historic District, and Mechanic Street Historic District. While all four districts are vulnerable to coastal flood impacts, the Mystic Bridge Historic District is the most vulnerable to coastal flooding and has the greatest number of at-risk historic homes in Stonington (see Figure 18). Historic resources are particularly important assets to protect, because the assets are often irreplaceable and damage to these assets will also diminish the community's character and quality of life. The physical damages sustained by historic buildings can be more expensive to repair, and losses of historic structures can impact the tourism attractiveness of the neighborhood.

These historic districts are largely comprised of historic buildings; therefore, working with the State Historic Preservation Office and local historic societies to implement building-scale resilience improvements is important. Some building-scale improvements will not be feasible, because they will alter the historic nature of the building; as a result, it is important that the Town and historic commissions work together to maintain the character of the structure while also protecting the asset from future flood impacts.

Natural Resources

Natural resources are an important part of any community; they contribute to the character of the Town and quality of life of its residents while also providing important flood mitigation benefits. Sea level rise and coastal flooding will have a significant impact on these natural resources if they are not properly protected. Approximately 45% of the Town's current land area is either vacant land,

Figure 28: Benefits of Green Infrastructure and Open Space

ENVIRONMENTAL BENEFITS	ECONOMIC BENEFITS	SOCIAL BENEFITS
Improved Visual Amenity	Increased Property Prices	Encouraging Physical Activity
Enhanced Urban Microclimate	Increased Land Values	Improving Childhood Development
Improved Air Quality	Faster Property Sales	Improved Mental Health
Reduced Flood Risk	Encouraging Inward Investment	Faster Hospital Recovery Rates
Better Water Quality	Reduced Energy Costs via Microclimate Regulation	Improved Physical Health
Improved Biodiversity	Improved Chances of Gaining Planning Permission	Improved Workplace Productivity
Reduced Ambient Noise	Improved Tourist and Recreation Facilities	Increasing Social Cohesion
Reducing Atmospheric Co_2	Lower Healthcare Costs	Reduction in Crime

managed or committed open space, or agricultural land; therefore, almost half of the Town's current land area provides an environmental benefit to the community. Trees, parks, and open space are valuable resources that provide significant environmental, social, and economic benefits to a community, as demonstrated in Figure 28.

Sea level rise and storm surge can negatively impact natural resources by damaging or killing trees, plants and grass as a result of salt water inundation and causing flood damage to recreational facilities. The most vulnerable open space in Stonington is the Barn Island Management Area. Barn Island Management Area is a particularly valuable resource; with over 1,000 acres, it is Connecticut's largest, most diverse, and ecologically significant coastal wildlife management area.[11] In addition to that significant protected open space, Mystic River Park and Donahue Park are also expected to experience significant flooding. Additional at-risk open space includes the properties listed below. More detail on the risk ranking for these assets can be found in Figures 22 and 23.

- Dubois Beach
- Avalonia Land Conservancy (Ram Point)
- Paffard Marsh Preserve
- Denison Pequot Nature Center (Cottrell St)
- Denison Pequot Nature Center (Pequotsepos Rd)
- Cottrell Marsh (owned)
- TNC Gallup Salt Marsh (easement)
- TNC Mason Island Company (easement)
- Denison Pequotsepos Nature Center, Inc.
- Old Mystic Playground
- Mystic Reservoir
- Anguilla Preserve
- Avalonia Land Conservancy (N. Stonington Rd)
- Avalonia Land Conservancy (North Main Street)
- Pawcatuck Little League
- Stonington Soccer Club
- Spellman Park

In addition to the impact of flooding on the Town's environmental resources, Stonington's shoreline is experiencing significant changes

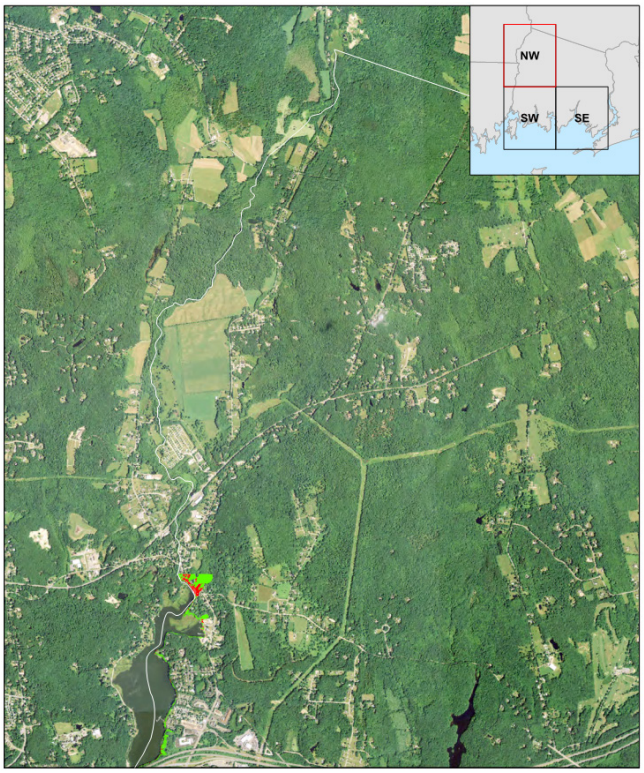


Figure 29: Anticipated Salt Marsh Advancement in NW Stonington by the 2080s

Figure 30: Anticipated Salt Marsh Advancement in SW Stonington by the 2080s

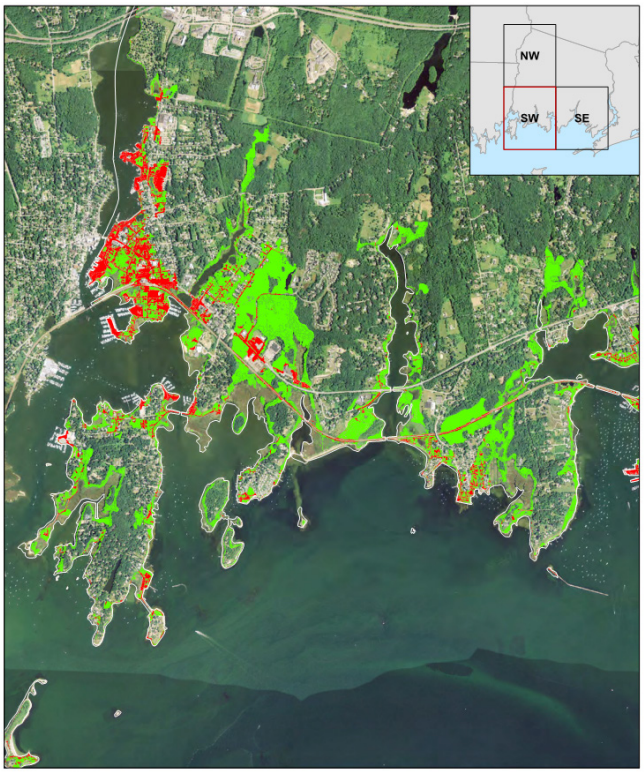


Figure 31: Anticipated Salt Marsh Advancement in SE Stonington by the 2080s

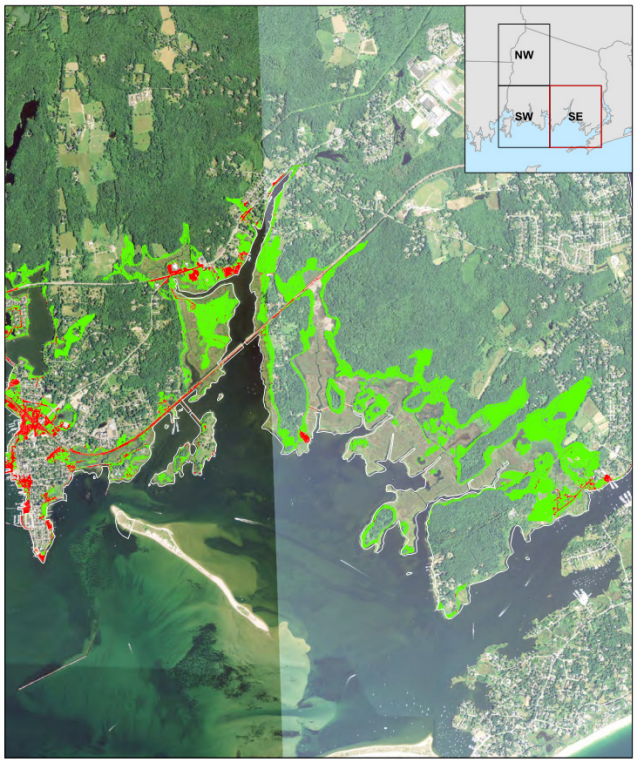
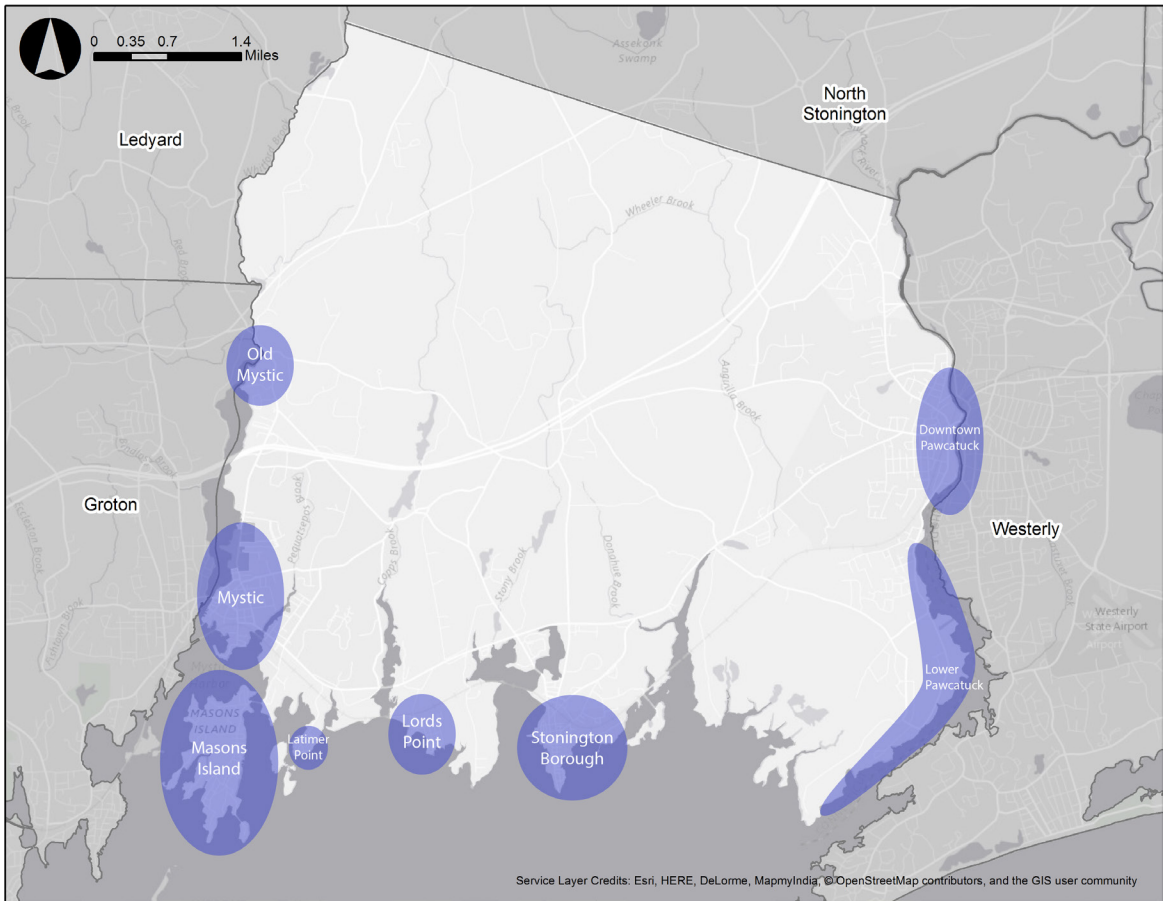


Figure 32: Stonington Neighborhoods Analyzed as part of the Neighborhood-Level Analysis



due to the advancement of salt marsh from the coast into upland areas of Town, as a result of sea level rise.[12] In total, Stonington is expected to see approximately 2000 acres of salt marsh advancement by 2080; 13% of that advancement is expected to affect land areas that are not suitable for advancement, because they are currently developed with buildings and associated infrastructure. Thus, it is important that the Town protect the 87% of identified land area that is currently open space and therefore, suitable for salt marsh advancement. This will allow the Town to maintain its wetland resources into the future. In addition, the Town must work with property owners whose land will be in direct conflict with the salt marsh advancement in order to protect those properties from impacts associated with this advancement. The Village of Mystic is particularly vulnerable to salt marsh advancement, which could result in negative impacts to Stonington's economy and tourism industry, historical resources, and property values (see Figure 30).

In addition to an overview of the Town's vulnerability, we looked at the vulnerability of seven distinct neighborhoods within Stonington, as identified in Figure 32.

Old Mystic

Portions of Old Mystic are highly vulnerable to flooding; however, the neighborhood, as a whole, is less vulnerable to coastal flooding than many of the other neighborhoods throughout Stonington. By 2050, 252 properties and 334 acres of land will be vulnerable to coastal flooding. This amounts to approximately, 18% of the properties in Old Mystic and 6% of the total land area. In addition, approximately 28% of the property value in Old Mystic, amounting to $150 million, is at risk from flooding by 2050. In addition, several

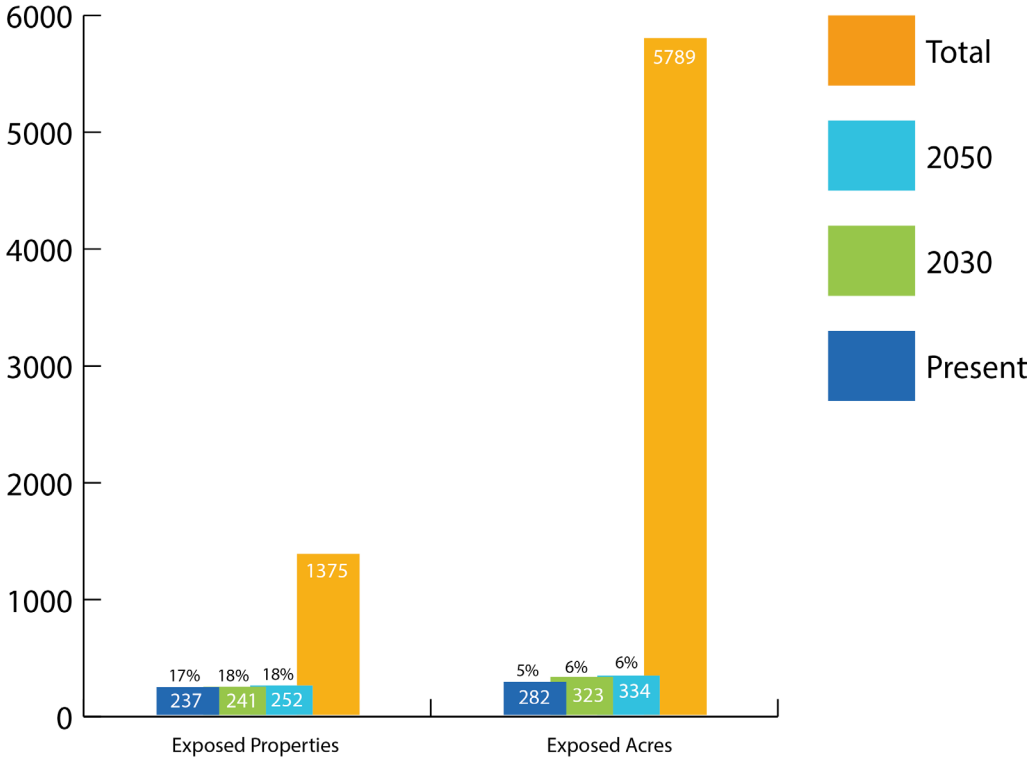


Figure 33: Potential Property and Land Flood Vulnerability in Old Mystic

Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

major roadways may experience significant flooding, including portions of Pequot Trail, Whitehall Avenue, Main Street and North Stonington Road. While the Old Mystic Fire Department is not technically vulnerable to flooding, impacts to these major roadways would significantly impact access to and egress from the fire station during a flood event. Additionally, the Old Mystic Post Office is highly vulnerable to flooding, both the facility itself and the surrounding roadways that would allow access to the facility. While the nearby pump station facility is not vulnerable, it is likely to see a greater volume of water flowing through the facility during a storm event and should be further assessed to understand the capacity of the facility and the potential impacts from projected flooding. It is likely that any flood event would also be accompanied by increased precipitation, which would also impact the pump station's ability to operate effectively.

There are a variety of solutions that could be implemented to protect Old Mystic from the impacts of coastal flooding. On the neighborhood scale, the I-95 Regional Adaptation and the Mystic Regional Adaptation, detailed in Section 3:

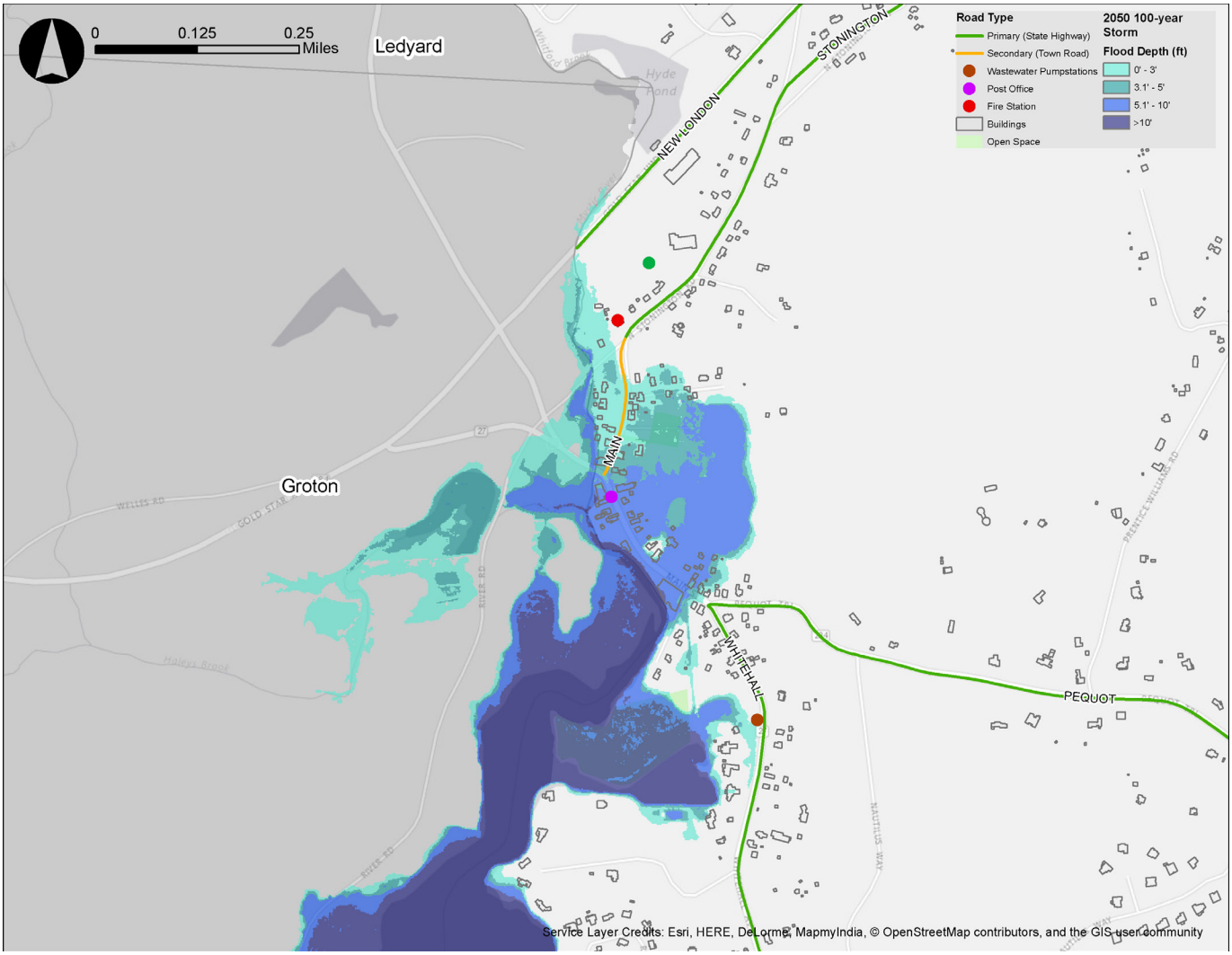


Figure 34: Old Mystic Flood Vulnerability (2050 100-year Storm)

Resilience Solutions, would both provide significant flood protection for Old Mystic. In addition, targeted green infrastructure solutions along Route 27, Pequot Trail, Main Street and North Stonington Road could provide beneficial flood mitigation. At the asset level, at-risk single-family homes and businesses in Old Mystic should consider implementing the building-scale solutions suggested for the typical single-family home and mixed-use business in Stonington, detailed in Section 3: Resilience Solutions. These solutions include elevation of the building and/or critical mechanical and electrical systems, temporary flood barriers, and landscaping solutions to reduce flood impacts. For more detail on these potential solutions, please refer to the Resilience Solutions Memorandum in Appendix C.

Mystic

The Village of Mystic is a highly vulnerable village within Stonington, not only from the physical impacts of flooding on the community's assets and properties, but also as a main driver of tourism and as home to one of the Town's most important historic districts. On the asset level, Mystic Post Office, Apple Rehab Mystic, Mystic Fire Station, Mystic Train Station, Mystic Wastewater Treatment Facility, the Amtrak Rail Line, Mystic Seaport, the Greenmanville Electrical Substation and the wastewater pump station are all vulnerable to the impacts of flooding. In addition, there will be limited access to each of these facilities as a result of the flooding along some of the main roadways, including East Main Street, Broadway Avenue, Williams Avenue, and Denison Avenue. By 2050, 889 acres of land and 1,259 properties, amounting to approximately $472 million in property value, will be at risk from coastal flooding. From a statistical perspective, these numbers account for 71% of total land area, 76% of parcels in Mystic, and 77% of the property value in Mystic

As one of the main historical neighborhoods in Stonington, damage to the buildings located here may be more costly than damage to a typical single-family home. The physical damages sustained by historic buildings can be more expensive to repair, and losses of historic structures can impact the tourism attractiveness of the neighborhood. Both the Mystic Bridge Historic District and the Rossie Velvet Mill Historic District area located in Mystic. Within these districts, approximately 450 structures are at risk from coastal flooding by 2050, with the majority of the buildings dating to the mid-to-late 1800s.

Damage to cultural assets such as the Mystic Seaport will have a significant impact on the tourism economy. In addition, coastal flood impacts to one of the region's critical transportation links – the

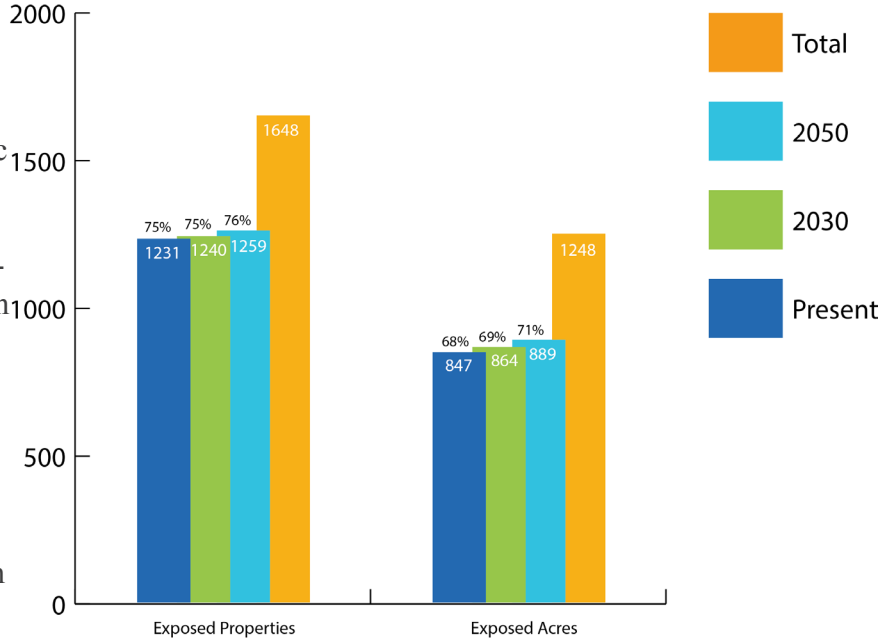


Figure 35: Potential Property and Land Flood Vulnerability in Mystic

Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

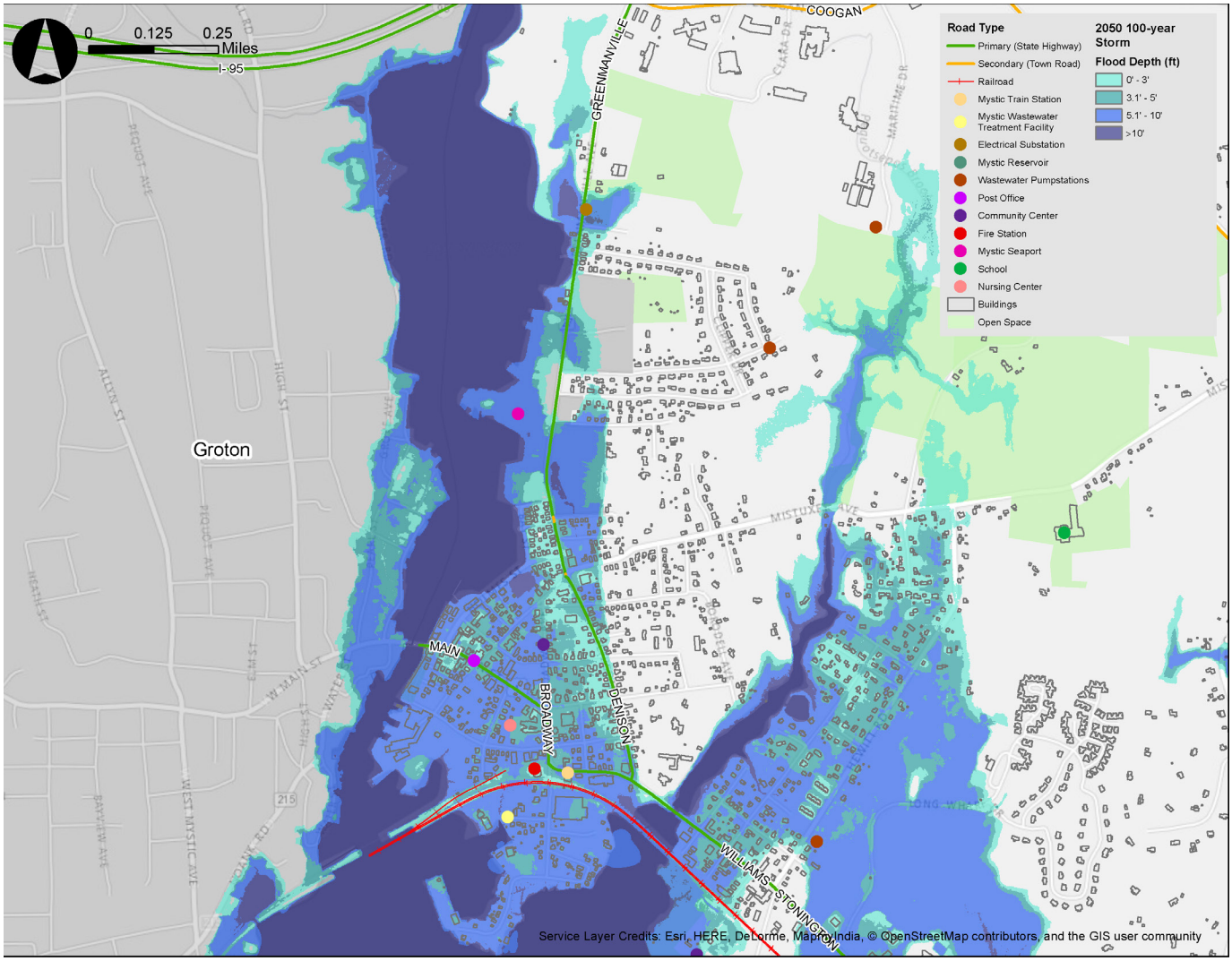


Figure 36: Mystic Flood Vulnerability (2050 100-year Storm)

northeast regional Amtrak service – as well as the Mystic Train Station could have a significant impact on regional mobility and tourism accessibility. For details on potential resilience solutions for Mystic, refer to Section 3: Resilience Solutions.

The Village of Mystic has significant value to the economy of Stonington due to its value as a tourist destination and the significant cultural resources in the neighborhood; therefore, the village would benefit from a comprehensive regional scale solution, as detailed in the Mystic Regional Adaptation in Section 3: Resilience Solutions. It would be difficult to protect all of Mystic's valuable and irreplaceable assets without a more holistic resilience solution. However, individual asset-level solutions should also be considered as a complementary effort to any regional-scale solutions. Suggested solutions for the Mystic Wastewater Treatment Facility, Apple Rehab Mystic, and neighborhood-scale solutions for the Village of Mystic are detailed in Section 3: Resilience Solutions. These solutions include a targeted green infrastructure corridor along Route 1, a living shoreline, and hard infrastructure solutions along the coast. For more detail on these potential solutions, please refer to Resilience Solutions Memorandum in Appendix C.

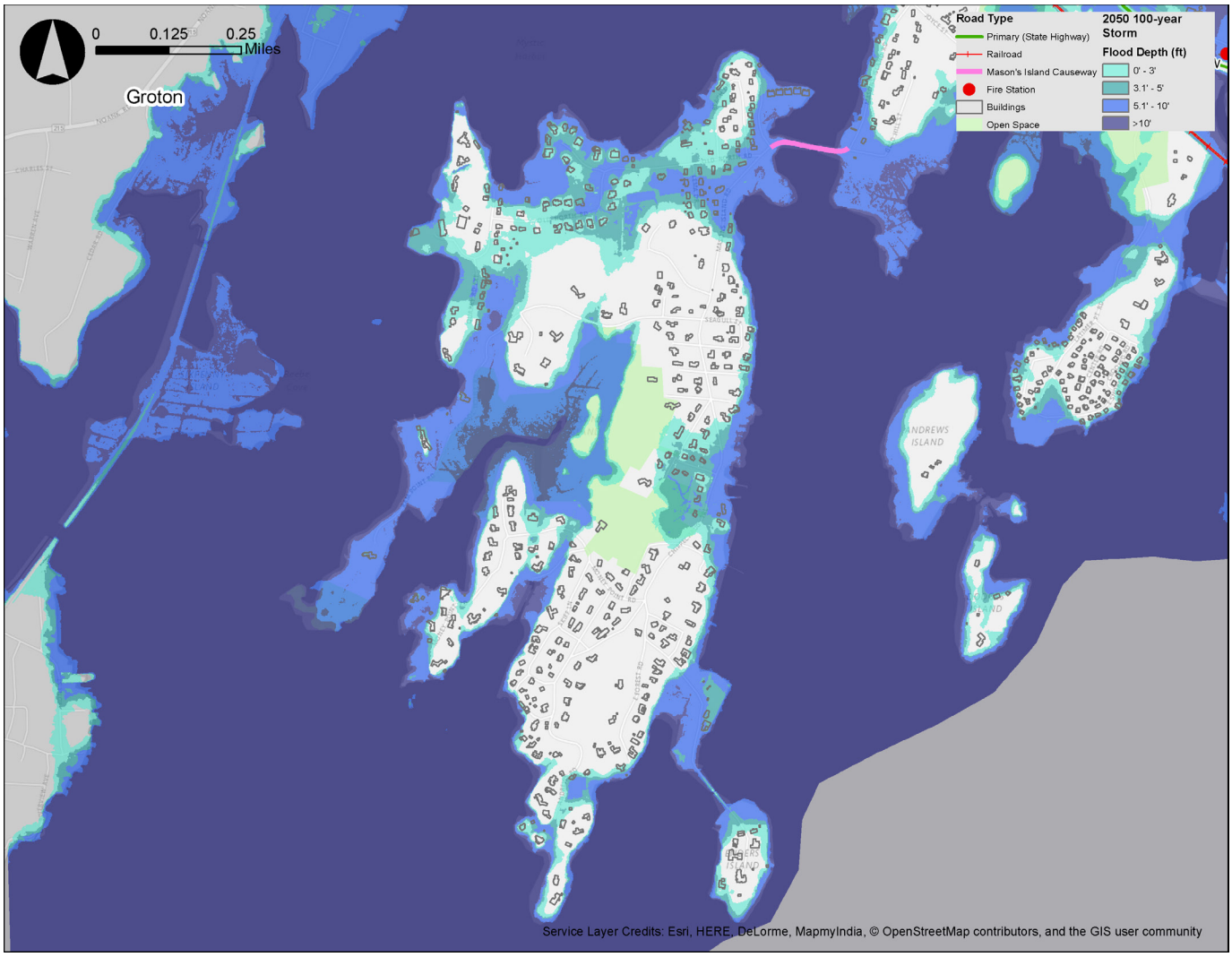


Figure 37: Masons Island Flood Vulnerability (2050 100-year Storm)

Masons Island

Masons Island is a particularly vulnerable neighborhood in Stonington, largely because of the vulnerability of Masons Island Causeway. The Causeway is susceptible to flooding in the present-day and was one of the community assets most impacted during Superstorm Sandy in October 2012. In addition to the Causeway, residents of Masons Island could experience additional mobility issues due to significant flood impacts to some of the roads running throughout the island, including Ram Point Road, Old North Road, and portions of Chippechaug Trail.

In the present-day, 319 of the 412 total parcels on the island may be impacted by a flood or storm event; these parcels account for approximately 87% of the land area on Masons Island and 83% of the total property value (approximately $240 million). While there is a slight increase in vulnerability by 2050, the increase is limited: approximately, five additional properties and two additional acres of land are vulnerable to flood impacts by 2050. Figure 38 displays the change in vulnerability between present-day, 2030, and 2050. These residential areas will be significantly vulnerable during a storm event, since Masons Island Causeway is the only means of access to

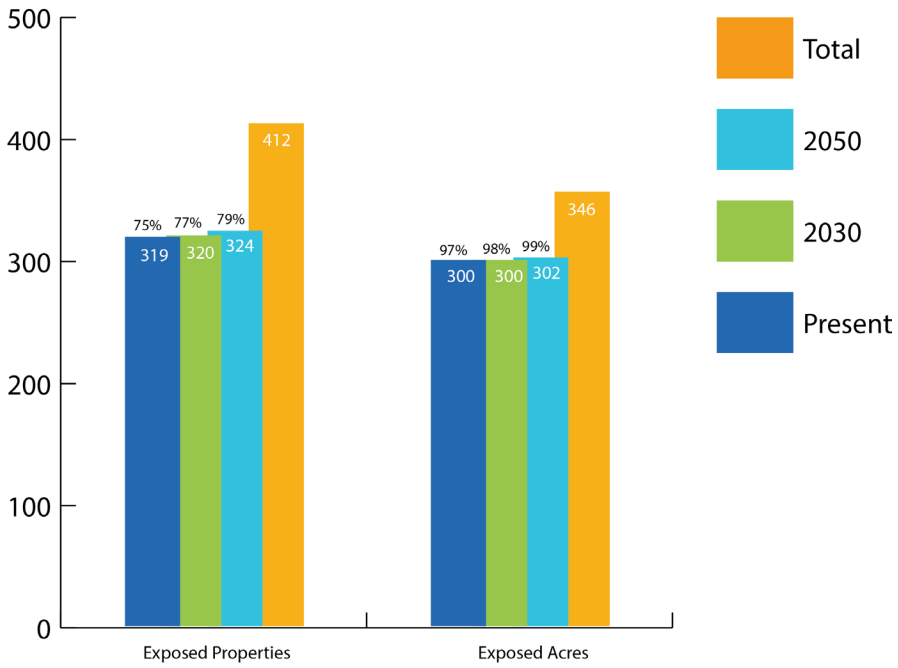


Figure 38: Potential Property and Land Flood Vulnerability on Masons Island

Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

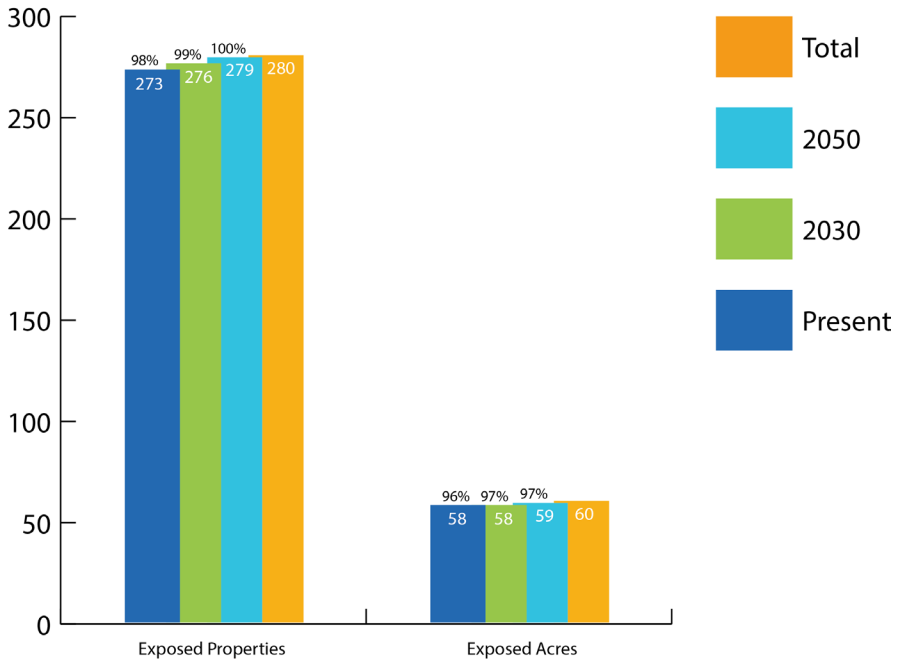


Figure 39: Potential Property and Land Flood Vulnerability in Lords Point

Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

and egress from the Island. Therefore, the biggest concern for Masons Island is that without significant investment in protecting the causeway, any residents of Masons Island would effectively be stranded during any flood event that impacts the causeway. For more information on the vulnerability of Masons Island Causeway and the potential resilience strategies, see Section 3: Resilience Solutions.

The most important solution for Masons Island is the suggested implementation of a bridge in place of the existing Masons Island Causeway. However, the homes on Masons Island are also at significant risk to flood impacts and individual homeowners should consider elevation as well as the other resilience solutions for single-family homes detailed in Section 3: Resilience Solutions. Masons Island could also be a good candidate for a targeted floodplain buyout or acquisition program, given the significant risk to the homes on the island as well as the access and egress issues caused by the low elevation of the existing causeway.

Lords Point

Lords Point is arguably one of the most vulnerable neighborhoods in Stonington, with nearly every parcel experiencing flood impacts by 2050: 59 of the 60 acres in the neighborhood may see some level of flooding in 2050 and approximately 279 of the 280 total properties will similarly be impacted, amounting to approximately $104 million in

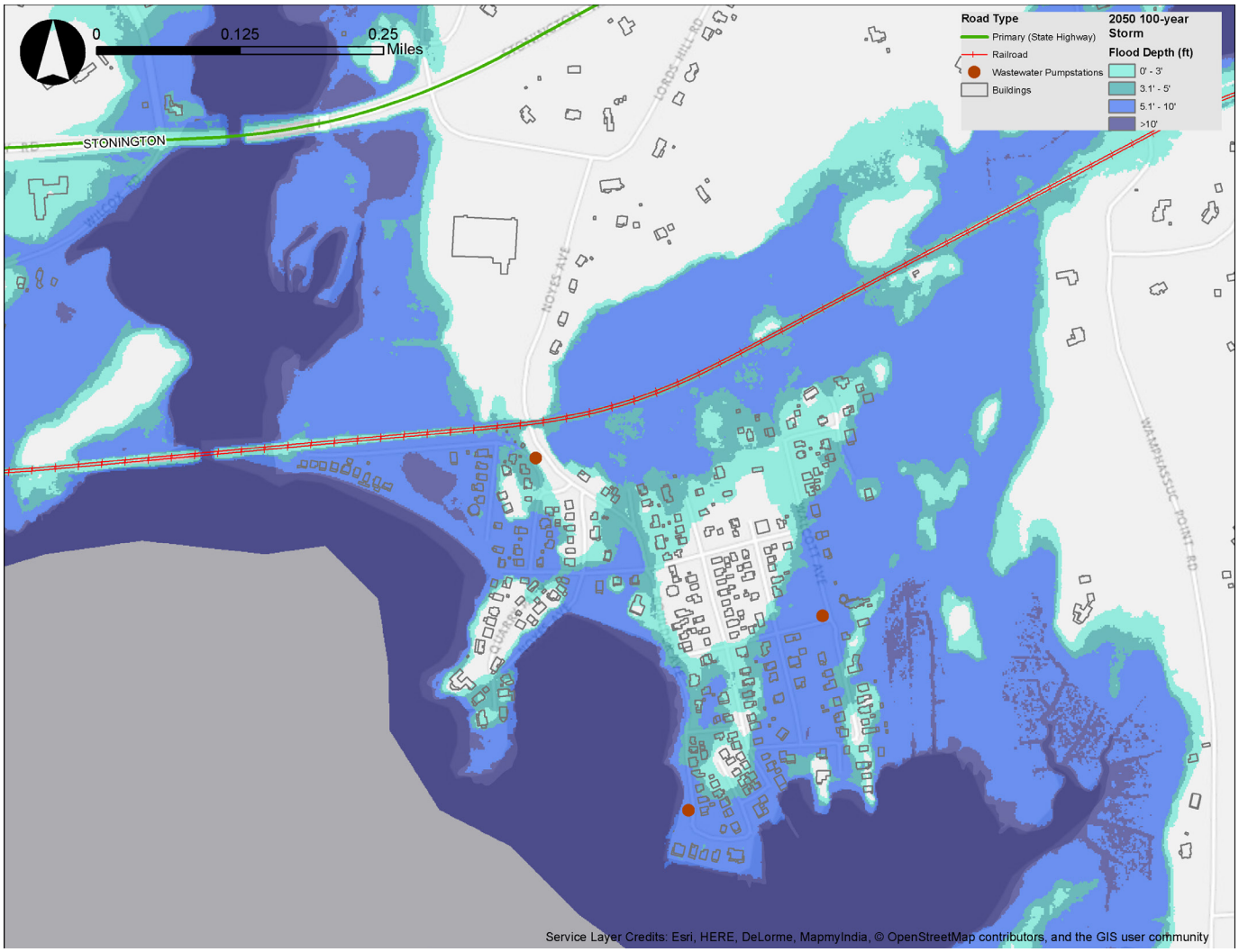


Figure 40: Lords Point Flood Vulnerability (2050 100-year Storm)

property value. These figures are only slightly higher than the present-day vulnerability of 273 properties (98% of total parcels), 58 acres (96% of total land area), and $102 million of property value (95% of total property value) experiencing some level of vulnerability to flood impacts. In addition to the property vulnerability, it is important to note that the Amtrak rail line and all three major pump stations are expected to be impacted by the 2050 100-year storm event. The impacts to these pump stations could be further exacerbated by increased precipitation accompanying a coastal flooding event. If these pump stations are not able to handle the capacity, the result could be more severe flooding as well as significant public health and environmental concerns resulting from the release of untreated sewage.

Lords Point may also be a good candidate for a targeted floodplain buyout or relocation program, due to the significant vulnerability of the properties in the neighborhood. In the absence of a comprehensive buyout program, elevation of individual homes may be particularly important in this neighborhood. In addition, the portion of the Northeast Corridor rail line running through Lords Point is highly vulnerable to flood impacts and may benefit from targeted green infrastructure solutions along the rail corridor in addition to potentially raising the rail line.

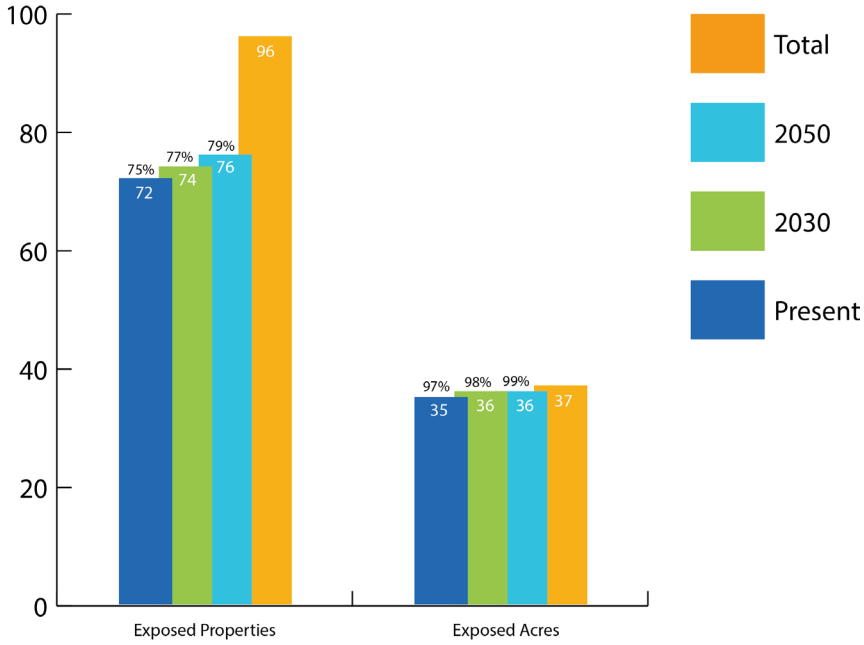


Figure 41: Potential Property and Land Flood Vulnerability in Latimer Point

Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

Latimer Point

Latimer Point is also a highly vulnerable neighborhood. The Quiambaug Fire Station (and access roads to the fire station), the Amtrak rail line, and portions of Stonington Road are all expected to be impacted by coastal flooding under the 2050 100-year storm scenario. In addition, access to and egress from Latimer Point is likely to be restricted as a result of significant potential flooding across Latimer Point Road, which is the only roadways extending across Latimer Point and connecting it to the rest of Stonington. Approximately 76 properties and 36 acres of land in Latimer Point (79% of the total properties and 99% of the land area) will be exposed to flooding in 2050. This accounts for approximately 88% of the property value ($42 million) in that neighborhood. As shown in Figure 38, access to the neighborhood is also likely to be difficult under the 100-year storm scenario, with portions of Latimer Point Road experiencing greater than five feet of flooding.

Latimer Point is comprised of a lot of valuable marshland, open space and trees; the Town should investigate ways to utilize these natural systems to provide more comprehensive natural flood retention in this area. It may be a good candidate for a living shoreline or other green infrastructure solution. In addition, Latimer Point Road is highly vulnerable to flooding and as the only means of access to the homes on Latimer Point, implementing resilience solutions to protect this road would be valuable. Homes on Latimer Point should investigate the feasibility of elevation of the home, elevation of critical systems and filling the basement, and other flood protection mechanisms, including temporary flood barriers and landscaping solutions to reduce flood impacts. For more detail on these potential solutions, please refer to the Resilience Solutions Memorandum in Appendix X.

Stonington Borough

Several important community facilities are vulnerable to coastal flooding in Stonington Borough, including the Wastewater Treatment Facility, the Borough Fire Station, the Cutler Street Electrical Substation, the pump station, Amtrak rail line, and several important roadways. Access to the Borough and emergency egress may be difficult during a storm event as well since all major roadways are expected to experience some level of flooding, including Water Street, Cutler Street, Alpha Avenue, and Main Street. Overall, 602 properties and approximately $370 million in property value could be impacted by coastal flooding under the 2050 storm scenarios. This amounts to 88% of the properties and approximately 91% of the proper-

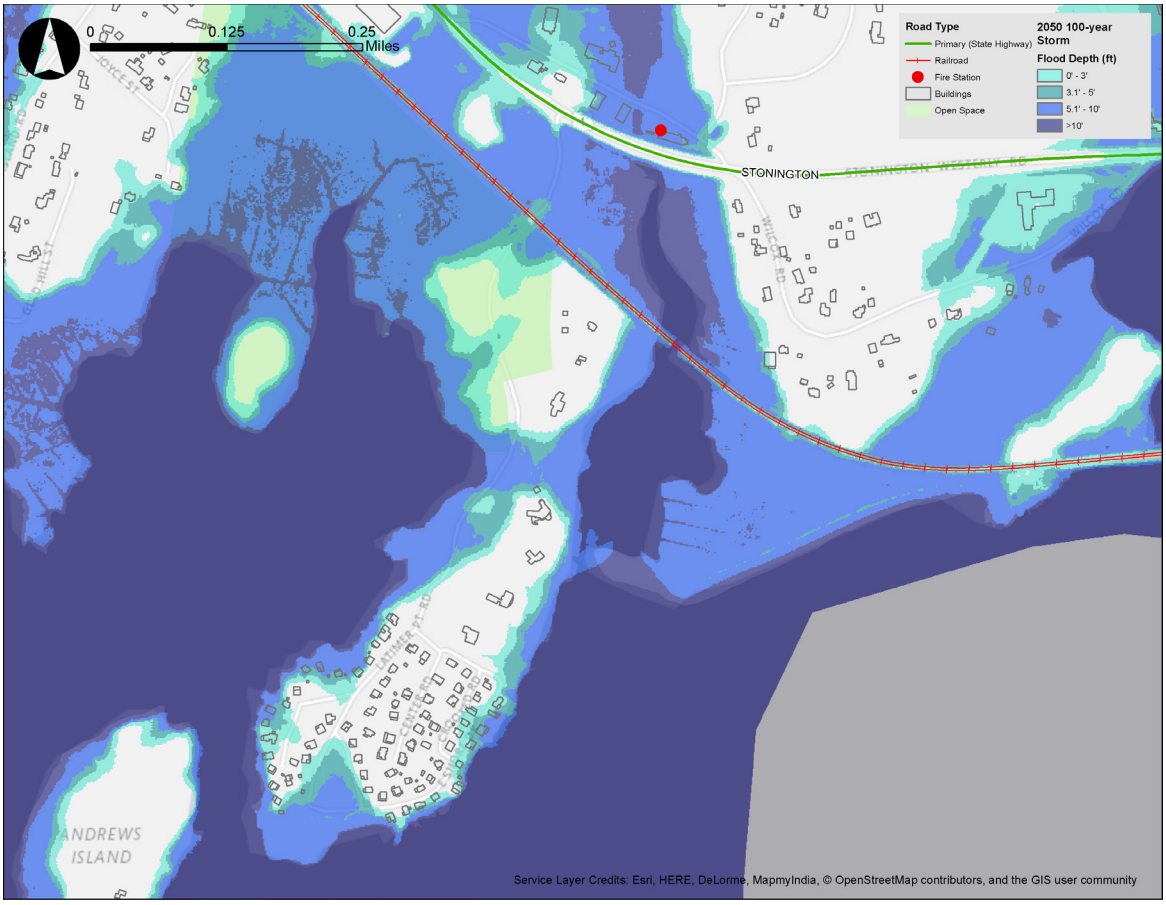


Figure 42: Latimer Point Flood Vulnerability (2050 100-year Storm)

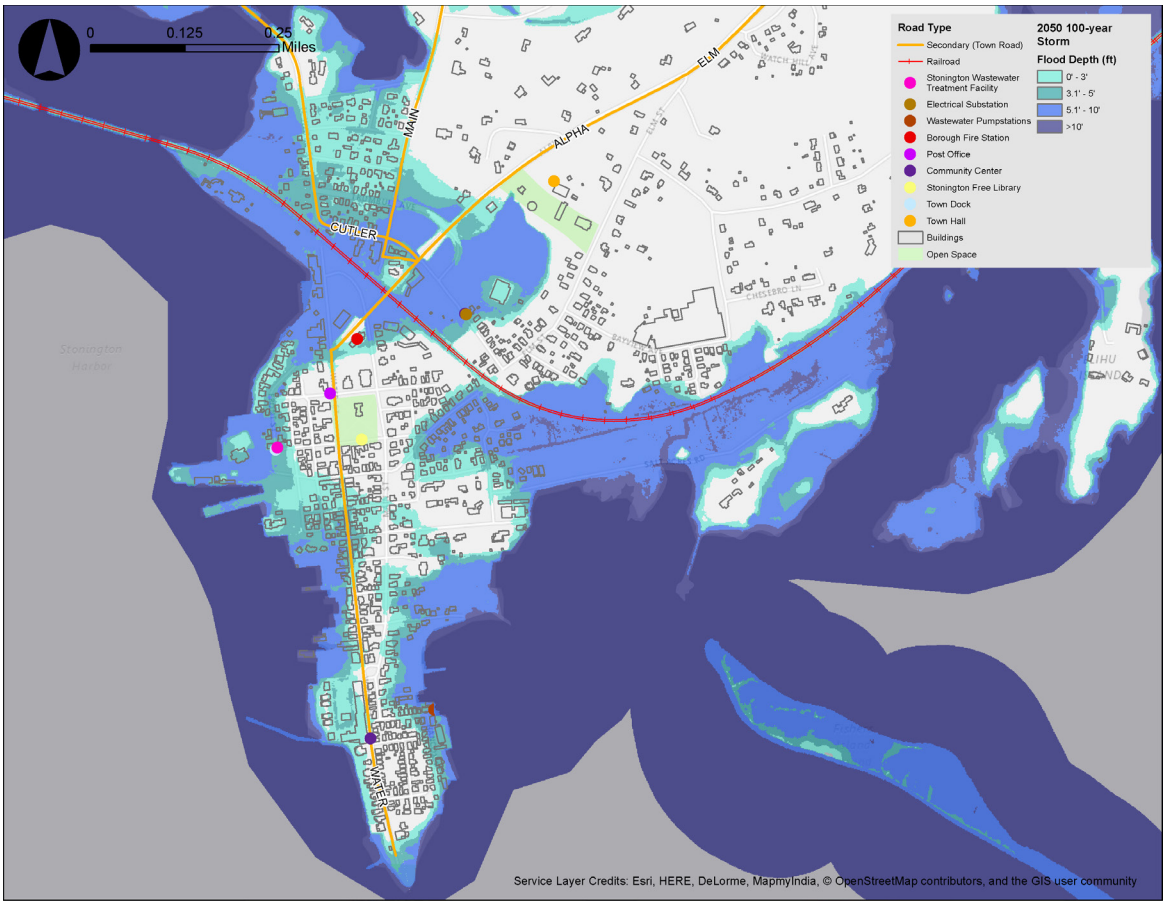


Figure 43: Stonington Borough Flood Vulnerability (2050 100-year Storm)

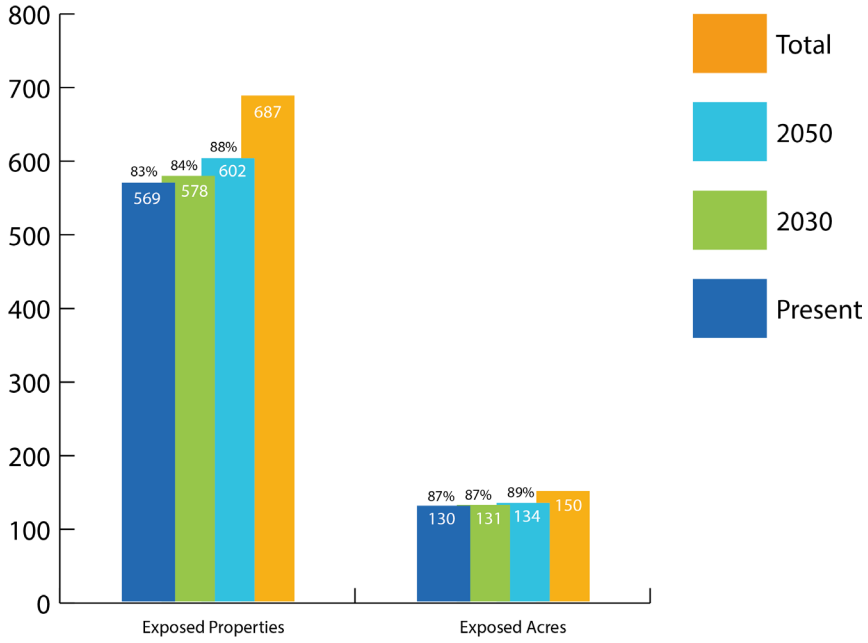


Figure 44: Potential Property and Land Flood Vulnerability in Stonington Borough

Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

ty value in Stonington Borough. In addition, 134 acres of land may be vulnerable to flood impacts, amounting to 89% of the land area in the Borough.

As the Town already experienced during Superstorm Sandy, the Town Dock is also likely to be impacted by coastal flooding and may sustain damage equal to or greater than what occurred during Superstorm Sandy, which could result in detrimental effects on the portion of the Town's economy that stems from fishing if the dock is not operational.

The Stonington Borough Historic District is also likely to be impacted by coastal flooding, with approximately 294 historic buildings at risk from flooding by 2050. These buildings are some of the oldest in Stonington, with the majority constructed in the mid-1850s.

Stonington Borough is a particularly important, and particularly vulnerable, neighborhood in Stonington. Therefore, a variety of solutions will need to be implemented to protect the Borough's critical assets and resources. While the Stonington Borough Regional Adaptation will protect a portion of the Borough, most the critical resources in the Borough will still be exposed to a significant amount of flooding; therefore, a combination of green and grey infrastructure solutions may be needed to protect the Borough. These solutions may include sea walls and offshore breakwaters as well as green infrastructure solutions along Water Street and other vulnerable roadways. At the asset level, at-risk single-family homes and businesses should consider implementing the building-scale solutions suggested for the typical single-family home and mixed-use businesses in Stonington, detailed in Section 3: Resilience Solutions. These solutions include elevation of the building and/or critical mechanical and electrical systems, temporary flood barriers, and landscaping solutions to reduce flood impacts. For more detail on these potential solutions, please refer to the Resilience Solutions Memorandum in Appendix C.

Pawcatuck

While many of the assets in Pawcatuck are located outside of the flood-prone areas, several wastewater pump stations are vulnerable to flood impacts. As mentioned in previous neighborhood analyses, this flood vulnerability could be further exacerbated by increased precipitation during a coastal flood event. Further analysis of the potential combined coastal flooding and stormwater flooding should be completed in order to understand the

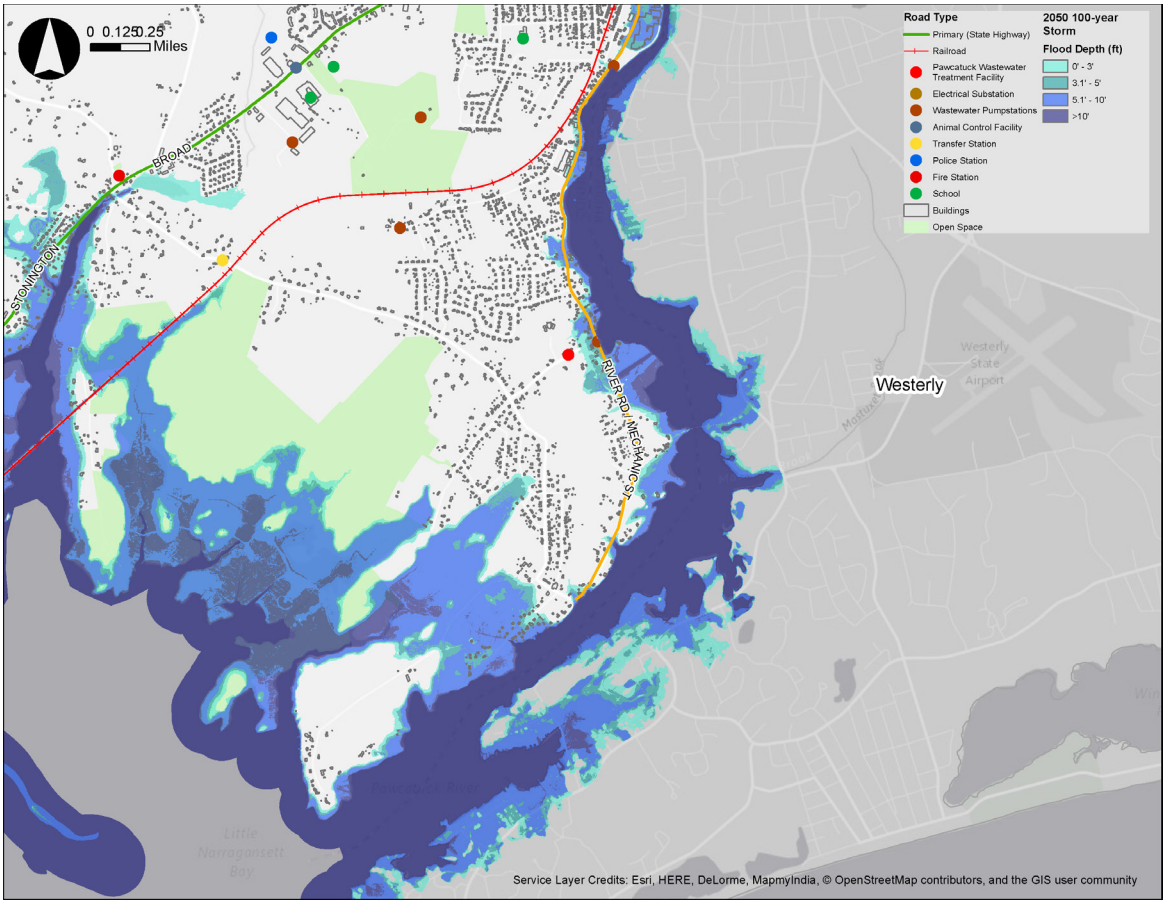


Figure 45: Lower Pawcatuck Flood Vulnerability (2050 100-year Storm)

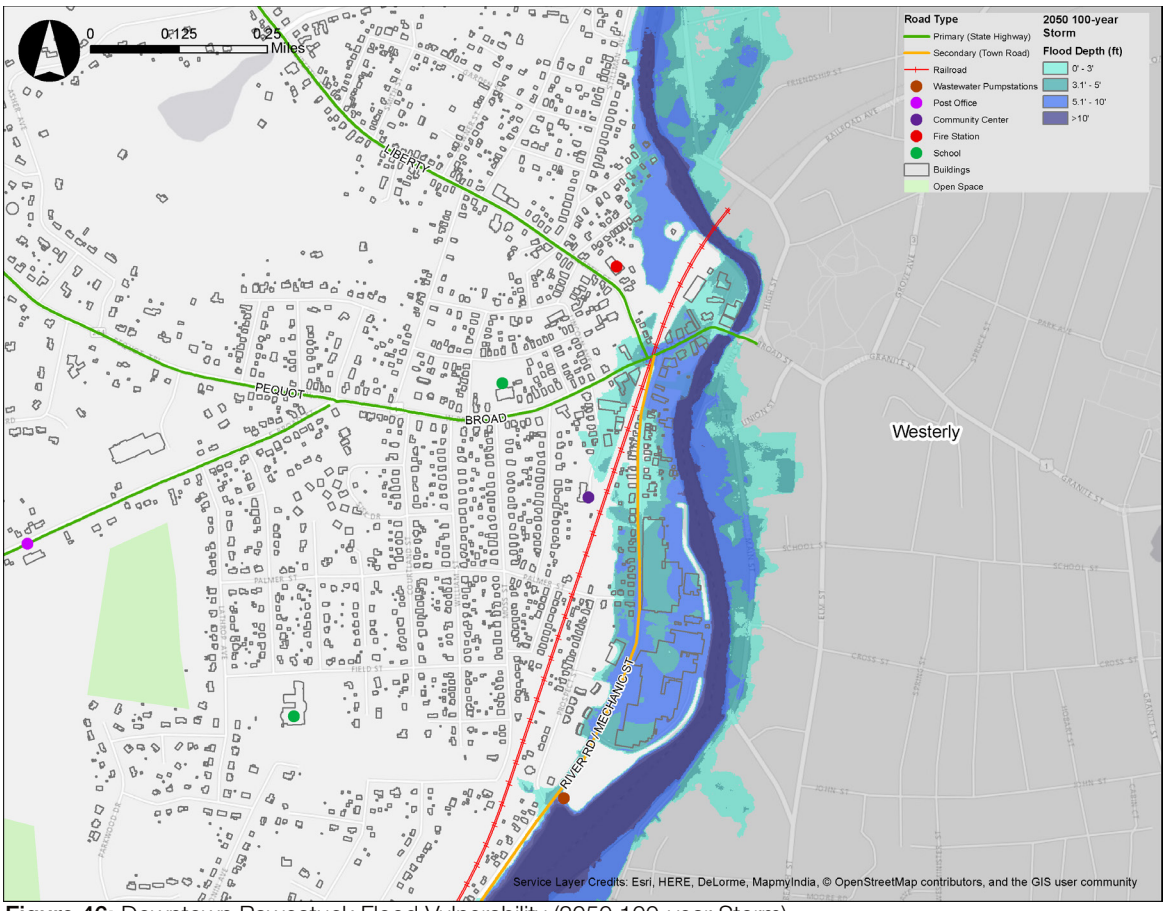


Figure 46: Downtown Pawcatuck Flood Vulnerability (2050 100-year Storm)

full vulnerability of the stormwater management system. In addition to the pump stations, River Road, Mechanic Street, and portions of Broad Street could all experience flood impacts. Specifically, a significant amount of flooding extends across Osbrook Point and is likely to cause access and egress issues along the roadway, extending down into Pawcatuck Point. However, impacts to these roadways would not cause the same level of access and egress issues as other neighborhoods may experience, because there are additional travel options within the neighborhood.

Pawcatuck is also home to the Mechanic Street Historic District, which encompasses over 400 historic buildings, including a large mill complex with seven major historic industrial mill buildings. The mill buildings were constructed between 1855 and 1920 while the historic homes were constructed between 1830 and 1920. Within this district,

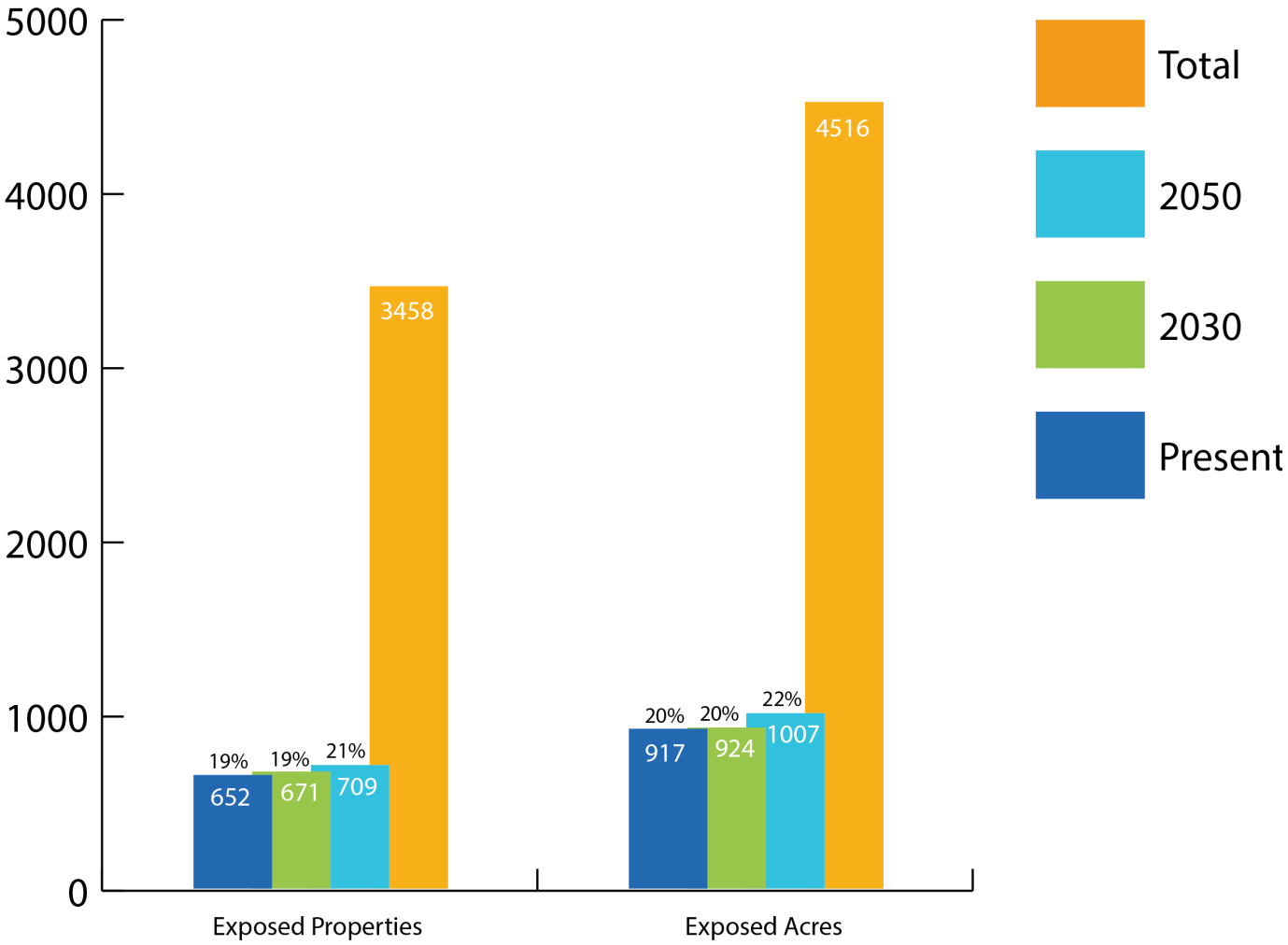


Figure 47: Potential Property and Land Flood Vulnerability in Pawcatuck

Source: All figures were calculated using flood scenarios produced by Woods Hole Group and 2016 Town of Stonington Assessor's data. Property value is based on values from the 2016 Stonington Assessor's data. Values have not been adjusted for inflation or future changes to property values.

approximately 88 structures, with an average building construction date of 1870, are exposed to flooding.

While Pawcatuck has several valuable assets and cultural resources that should be protected, statistically, it is one of the least vulnerable neighborhoods in terms of percentage of assets and land area impacted, with only 21% of properties, 22% of land area, and 27% of total property value in vulnerable flood locations. However, Pawcatuck is the largest neighborhood; therefore, the total numbers of impacted properties in land area is actually one of the highest in Stonington, with 1007 acres of land, 709 properties, and $251 million of property value potentially at-risk from flooding by 2050.

Due to the size of the Pawcatuck neighborhood and its geographic location within Stonington, several larger-scale regional solutions may be beneficial in Pawcatuck. A portion of the Village of Pawcatuck is currently protected by a flood control structure constructed by the U.S. Army Corps of Engineers in the 1960s. The levee and fate system was constructed to protect the manufacturing core of Pawcatuck from flooding. This structure is still operational today and provides significant flood protection to downtown Pawcatuck; however, the structure was never accredited by FEMA and thereofre, does not provide relief from FEMA's federal flood hazard regulations. Although the flood protection impacts of this structure have not been analyzed as part of this report, the Town of Stonington recently allocated funding to conduct an in-depth study this flood control structure and the lack fo accreditation.

Additional flood control structures that could be constructed to protect the Village of Pawcatuck are detailed in Section 3: Resilience Solutions. One of those solutions, the Pawcatuck River Regional Adaptation, could provide significant protection to the neighborhoods in Pawcatuck. In addition, Pawcatuck's natural coastline may make it a good candidate for natural solutions and green infrastructure, including the potential for the implementation of a living shoreline. The significant green and open space in Pawcatuck should be utilized for green infrastructure solutions to flood mitigation. While the Barn Island Management Area provides significant opportunity for implementing a living shoreline and other natural solutions near Pawcatuck, it is also home to valuable ecosystems and habitats that will need to be protected from the negative impacts of coastal flooding and saltwater inundation. Impacts to these valuable environmental resources should be considered as part of any potential flood mitigation solutions in the area. As with each of the other neighborhoods, at-risk single-family homes and businesses in Pawcatuck should consider implementing the building-scale solutions suggested for the typical single-family home and mixed-use business in Stonington.These solutions include elevation of the building and/or critical mechanical and electrical systems, temporary flood barriers, and landscaping solutions to reduce flood impacts. For more detail on these potential solutions, please refer to the Resilience Solutions Memorandum in Appendix C.

Section 3: Resilience Solutions

Overview of Resilience Strategies

The following table details a wide variety of potential resilience strategies with an overview of the strategy, the benefits of implementing the strategy and the regulatory and cost constraints that the Town should consider for each of these strategies.

Resilience Solution	Description	Benefits	Regulatory Constraints	Cost
PROTECTION				
"Hard" Solutions	Engineering solutions may include bulkheads, seawalls, levees or revetments, constructed out of stone or concrete, to protect exposed shorelines for erosion and coastal flooding.	Can protect the largest area of the Town with one solution, which reduces the need for individual building adaptations.	High	$$$-$$$$
Living Shoreline	Living shorelines are comprised of a system of green infrastructure and natural solutions that create a buffer along the water's edge to minimize erosion and absorb wave action.	Provide flood protection along the shoreline and the least damaging solution to surrounding environmental resources.	High	$$$-$$$$
Tide Gates	Tide gates are deployable floodgates that can control water flow and prevent flooding. They can vary in size and are typically installed as part of a larger flood control system.	Can protect a large area of the Town without causing significant impact to environmental resources.	High	$$$-$$$$
Floodplain Buyout and Acquisition Programs	Floodplain buyout and acquisition programs are voluntary programs where homeowners in at-risk flood areas can sell their homes to the government. The government will either remove those properties from the floodplain and return the land to nature or redevelop those properties in a more flood resilient manner.	Provide a long-term solution to protecting private property by removing the structures from the floodplain or ensuring that they are better protected. Could remove the need for an expensive engineering solution to protect the shoreline.	High	$$-$$$
Relocation	Relocation refers to the process of relocating structures outside of the floodplain.	Provide a long-term solution to protecting private property by removing the structures from the floodplain. Could remove the need for an expensive engineering solution that protection the shoreline.	High	$$-$$$

Cost Legend	
$	< $100,000
$$	$100,000 - $1,000,000
$$$	$1,000,000- $10,000,000
$$$$	> $10,000,000

Raised Streets	Roadways that are prone to flooding can be raised to effectively elevate the roadway above the flood elevation.	Solves access and egress issues during flood events by protecting roadways from flooding.	Medium	$$$
Wet Floodproofing	Wet floodproofing is the practice of allowing floodwaters to enter and exit a building during a flood event. Typically, that means using flood-resistant building materials and elevating mechanical and electrical systems about the design flood elevation (DFE).	Lowers risk of structural damage from flooding and can be cheaper than dry floodproofing. It also will not alter the exterior appearance of the structure.	Low	$-$$
Dry Floodproofing	Dry floodproofing is the process of making a structure watertight below the design flood elevation (DFE), so that floodwaters do not enter the structure. Some elements of dry floodproofing include installing backflow preventers and watertight shields and sealing walls with watertight coatings.	Several floodproofing measures can be combined to protect a structure from flooding and does not require additional land because solutions are applied to the building. Minimal alteration to the external appearance of the structure.	Low	$
Floodplain Policies and Regulations	Floodplain policies and regulations can be amended to include flood resilience considerations for new construction or renovations. Innovative financing policies, such as tax increment financing (TIF) can also be employed to help fund community resilience projects.	Updating policies and regulations is entirely within the Town's control and these strategies can be used to require investment in resilience, rather than relying on voluntary participation.	Medium	$
Offshore Breakwaters	Offshore breakwaters are stone or concrete structures constructed off the coast to absorb wave energy before the waves reach the shore.	Reduce the need for sea walls and other solutions along the shoreline and could protect a large area of the Town.	High	$$$-$$$$
Hurricane Barriers	Hurricane barriers are permanent barriers typically constructed across a harbor or other water opening, extending across the water to the land on either side.	Reduce the need for sea walls and other solutions along the shoreline and could protect a large area of the Town.	High	$$$-$$$$
Temporary Flood Barriers	Temporary flood barriers are barriers that can be constructed prior to a flood event and deconstructed after the event. They can range significantly in cost and construction effort, from sandbags to deployable barriers that rise automatically as floodwaters rise.	Can provide effect flood protection, are reusable and easy to deploy, and do not require building or site modifications.	Low	$-$$

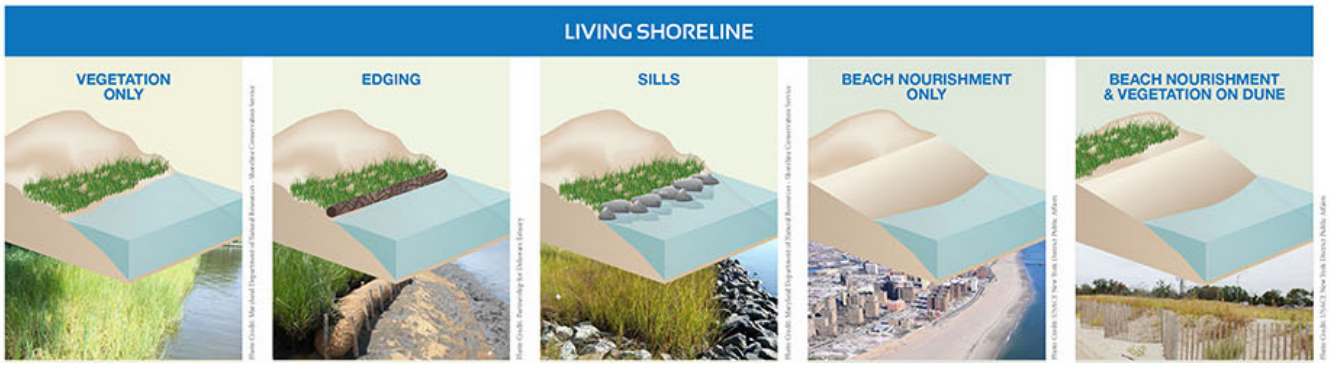


Figure 48: Examples of Living Shoreline Strategies

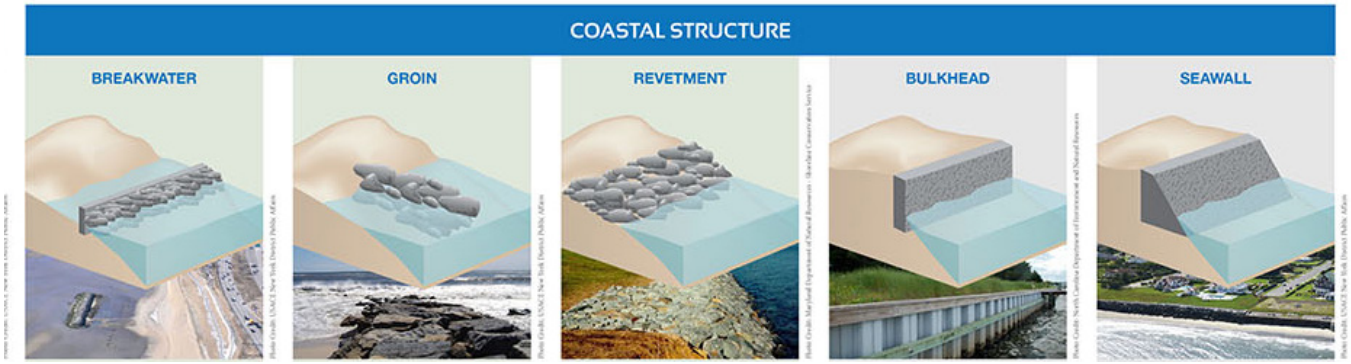


Figure 49: Examples of "Hard" Engineering Solutions

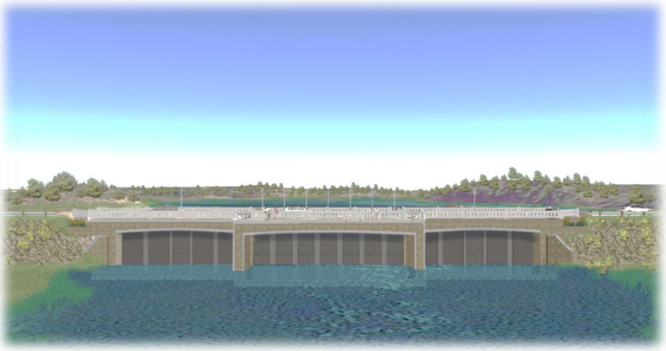


Figure 50: Example of a Tide Gate at the Herring River Restoration Project in Wellfleet, MA

Figure 51: Example hurricane barrier from New Bedford, MA

Figure 52: Example of a Breakwater in Stonington, CT

Figure 53: Example of a Temporary Flood Barrier along the Thames River

Figure 54: Example of a Raised Street in Miami, FL

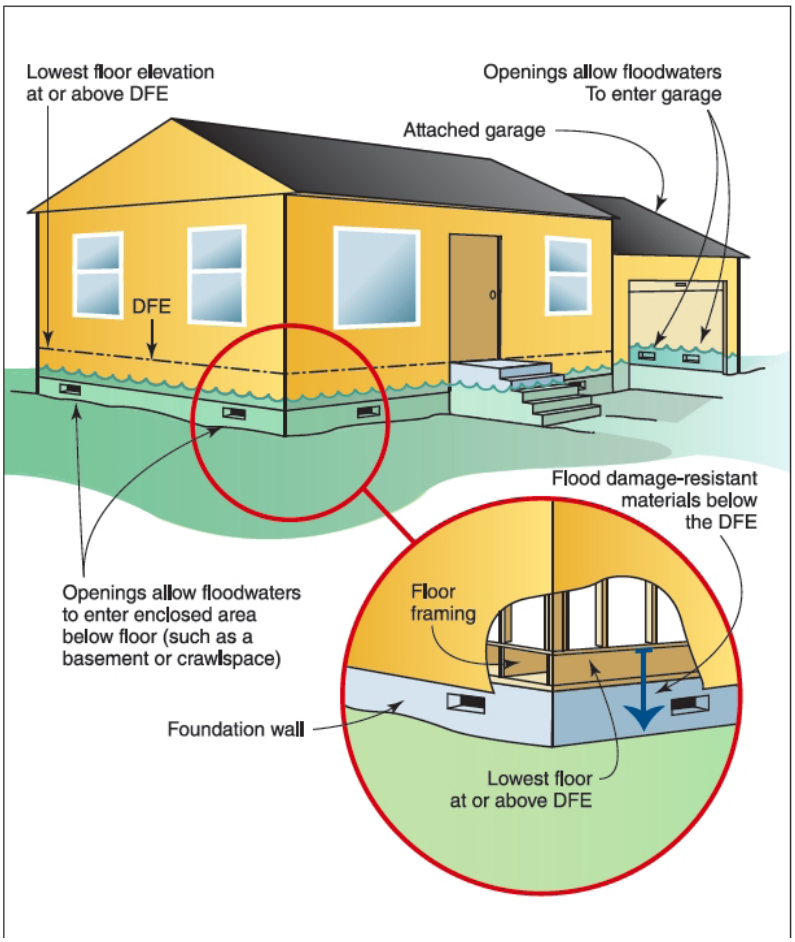


Figure 55: Wet Floodproofing Strategies

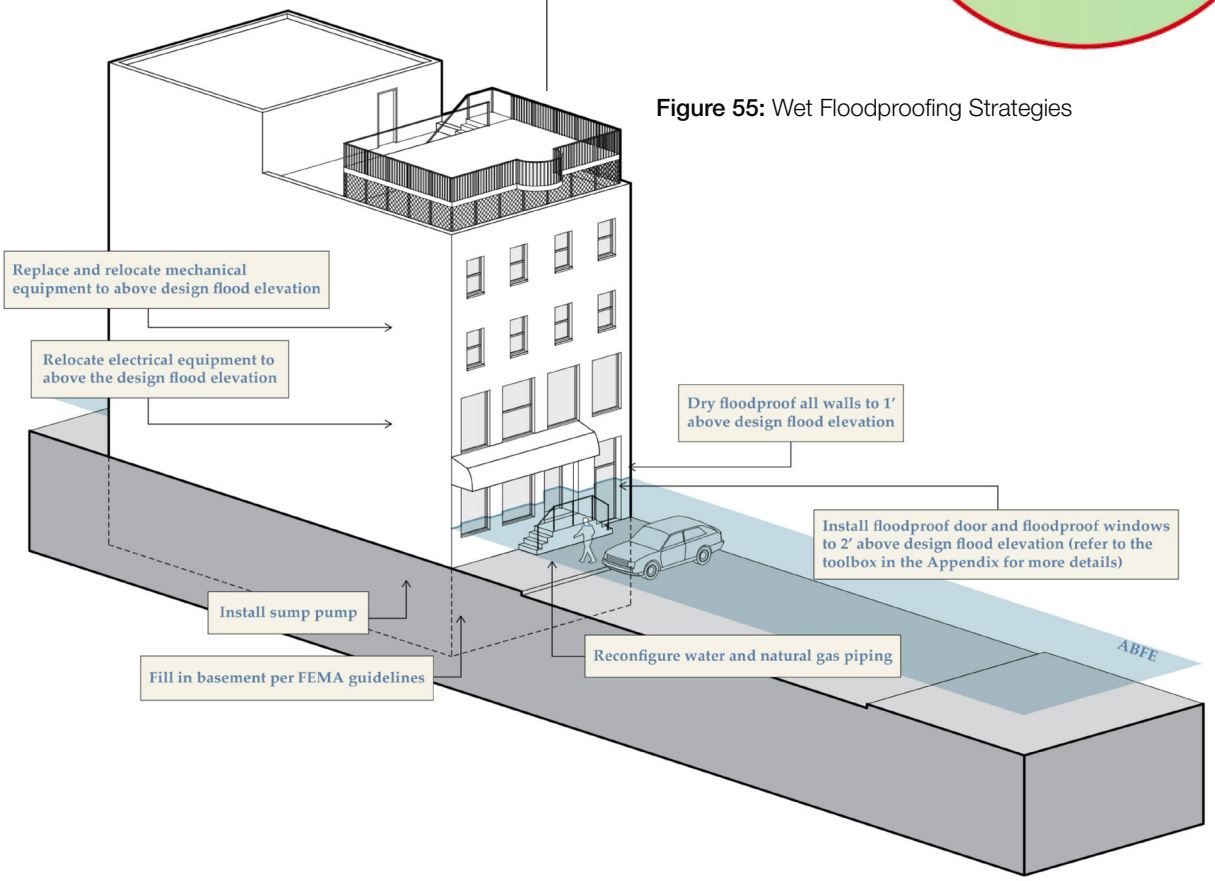


Figure 56: Dry Floodproofing Strategies

ADAPTATION				
Buoyant Architecture	Buoyant architecture allows buildings to rise and fall in response to changing water levels, either by constructing buildings on floating barges or constructing buildings on the ground with an amphibious foundation that will allow the structure to float as necessary.	Can contribute to waterfront development and responds dynamically to rising sea levels and storm surges.	Medium	$$
Elevation	Structures can be elevated on piles in order to raise the structure about the design flood elevation. Other methods of elevation may include modifying the topography of the site or abandonment of the first floor.	Protects buildings from wave action and flooding and often helps reduce flood insurance premiums.	Medium	$-$$
Protecting and Elevating Critical Mechanical and Electrical Systems	Mechanical and electrical systems are typically located in the basement of a building, the area most vulnerable to flooding. Elevating critical equipment about design flood elevation or relocating equipment to a higher floor will protect these critical systems from flood impacts.	Protects critical infrastructure from flooding and allows for the building to maintain functionality during a flood event.	Low	$-$$
Backflow Preventers	During a flood event, pipes may get inundated with flood waters, resulting in the unwanted flow of water in the reverse direction. A backflow valve will prevent the backflow of these contaminated waters into a building.	Protects buildings and potable water sources from contaminated flood waters. Reduces public health concerns during flood events.	Low	$
Sump Pumps	Sump pumps are used to discharge unwanted flood waters that may enter a building during a flood event. These pumps are generally used in conjunction with other floodproofing techniques.	Allows for quick drainage of water that enters a building and can be combined with other floodproofing measures.	Low	$
Basement Fill	Filling the basement of a property is often an effective flood protection measure if all critical equipment has been relocated from the basement and the first floor of the property is above the design flood elevation.	Protects building and critical systems from flood damage and can be more cost-effective than elevating the structure.	Low	$
Operable Windows	Making sure that all windows can be opened and closed is important as the windows may be used as emergency evacuation routes during a flood event.	Provide passive ventilation and temperature control, minimize urban heat island impacts, and provide a method of evacuating buildings during flood events.	Low	$

Figure 57: Example of Buoyant Architecture

Figure 58: Example of an Elevated Home in Lindenhurst, NY

Figure 59: Example of Protecting and Elevating Critical Equipment

Figure 60: Example of a Backflow Preventer

Figure 61: Example of Green Infrastructure

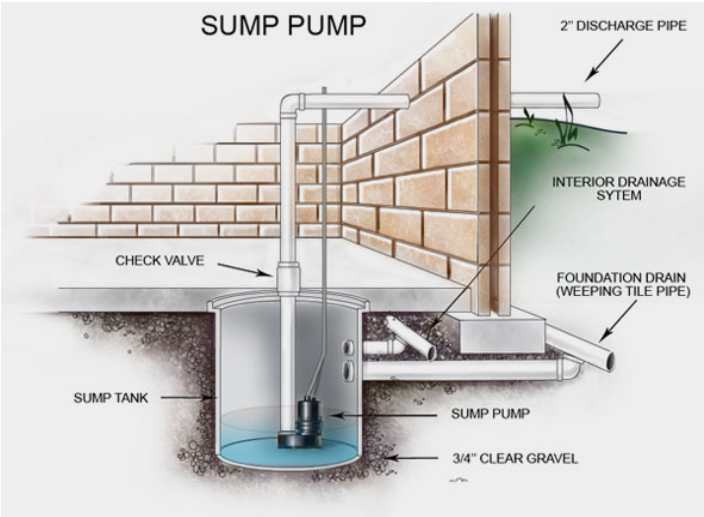


Figure 62: Diagram of a Sump Pump

Underground Power Lines	Building power lines underground instead of the traditional above-ground power lines can provide more reliable service and reduce power outages.	Less prone to physical deterioration and damage from storms, high wind, and downed trees, which all contribute to reduced service reliability.	High	$$$
Green Infrastructure	Green infrastructure is a small improvement that can reduce flood impacts while also providing co-benefits to the community. Some examples include: permeable paving, green roofs, bioswales and rain gardens, and rainwater harvesting.	Reducing flood impacts, beautifying the community, improving air quality, providing more outdoor space, and reducing urban heat island impacts. Solutions can also be scaled to the site constraints and budget.	Low	$
Securable and Removable Equipment	In some cases, equipment may not need to be elevated. If it is acceptable for equipment to get wet, making sure that the equipment is fully secured and anchored to prevent flotation in flood waters is important. In other cases, investing in equipment that can be removed prior to a flood event, may be a valuable investment.	Protects equipment and critical systems from damage from flood events.	Low	$
BACKUP				
Microgrid	Microgrids are small-scale electric grids that can provide power to a certain site or neighborhood. They operate independently of the main power grid.	Allows for power continuity when the larger grid is experiencing outages and is often more energy-efficient.	Medium	$$$
Backup Power	Backup power can be implemented through the use of batteries or generators.	Provide redundancy and maintain critical functionality during power outages. Batteries may be connected to solar photovoltaics, which decreases reliance on fuel delivery and reduces energy bills.	Low	$$
Emergency Charging Stations	Designated community emergency charging stations are important for residents who are without power for an extended period of time.	Allows for greater communication and continuity of business operations during an emergency.	Low	$
Renewable Energy Supply	Renewable energy, such as solar and wind power, can increase resilience by reducing dependence on the larger electrical grid and reducing dependence on fuel delivery.	Reduces greenhouse gas emissions (GHG), reduces energy bills, and provides backup power during an emergency event.	Medium	$

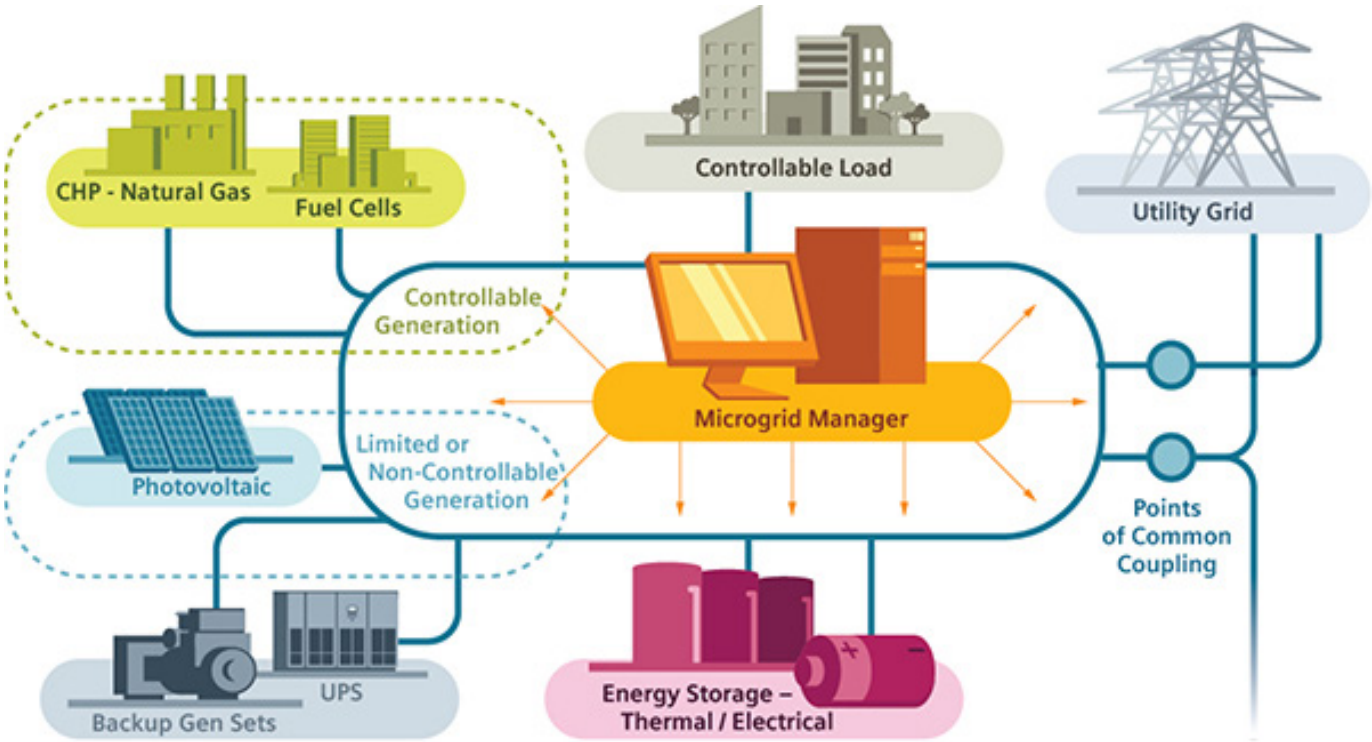


Figure 63: Diagram of a Microgrid

Figure 64: Example of a Generator (Elevated to Protect Against Flooding)

Figure 65: Example of Renewable Energy (Solar Panels)

Figure 66: Example of Renewable Energy (Wind Turbines)

Figure 67: Example of Emergency Charging Stations

COMMUNITY RESILIENCE				
Community Assistance Centers	Community assistance centers are central locations that can provide residents with information on resilience and preparedness and can also be a refuge and a place to get information during and after a disaster event.	Help educate the public on flood risks and ways to be protect themselves and their properties. Also provide a central location for refuge and assistance.	Low	$
Business Continuity Program	Business continuity planning ensures that businesses have the capability to maintain essential functions during potential emergency events.	Maintains business functionality during emergency events, by ensuring that business owners understand their risks and have taken steps to mitigate those risks.	Low	$
Public Education Program	Educating the public on flood safety, adaptation and mitigation measures, and emergency management plans is one of the most cost-effective strategies for resilience.	Ensures that the community understands the risks, takes steps to mitigate those risks and protect themselves and their properties, and understands proper emergency management procedures during a major event.	Low	$
Community Rating System (CRS)	FEMA's Community Rating System (CRS) is a program designed to encourage community-wide floodplain management activities. CRS floodplain management activities are designed to enhance public safety, reduce property damages and human suffering, protect public infrastructure, minimize economic losses, and protect the environment.	Provides an incentive for the community to invest in resilience by reducing flood insurance rates pursuant to the community's resilience efforts.	Medium	$
Building Community Ties	In the event of disaster, neighbors and community institutions and leaders often become the "first responders," assisting with providing resources, support, and information. Communities with strong social ties and important community institutions have been proven to better weather storm events.	Protect residents during emergency events and reduce injury and/or loss of life by providing resources and assistance during an emergency.	Low	$
Emergency Shelters	Locating emergency shelters in areas that are accessible during a storm event and equally distributed throughout the community is important to providing refuge during a flood event	Protect residents during emergency events and reduce injury and/or loss of life.	Low	$
Stormwater Modeling	Coastal flooding and rainfall events often occur simultaneously. As a result, understanding the capacity of the stormwater drainage system to handle coastal floodwaters as well as stormwater from a storm event will be important to understanding Stonington's flood vulnerability.	Help the Town understand the complete picture of the community's flood vulnerability and can identify areas of particular concern during storm events.	Low	$$

For more detail on each of the resilience strategies and the associated costs, please refer to Appendix C.

Proposed Solutions for Highest Risk Assets

The following section details the potential solutions for a selection of the Town's highest risk assets These strategies are intended to help focus Stonington's future resilience efforts and provide a path forward in investigating potential solutions; however, the Town will need to undertake additional research and analysis (including feasibility and cost-benefit analyses) prior to implementation of any of these strategies.

Boulder Avenue Pump Station & River Road Pump Station

Using the flood projections in this report (and any future stormwater modeling), the Town should complete a more detailed risk assessment that looks at the location of critical systems and infrastructure within the station, the service area of the pump station and the potential consequence of failure, including residences and critical facilities that would be impacted. Likely adaptation measures would include elevating critical systems, installing backup power to ensure redundancy, implementing wet or dry floodproofing strategies, and protecting the site with flood walls or green infrastructure.

Stonington Wastewater Treatment Facility

The Stonington Wastewater Treatment Facility would benefit from a variety of resilience strategies. A more detailed review of the current location of key critical equipment in the facility would be needed in order to provide comprehensive design solutions. Once that review is completed, the Town should consider some of the following resilience solutions: installing backup power to ensure redundancy and make sure the facility can still operate during a power outage, investigate the use of temporary or permanent flood barriers, elevating critical equipment or installing removable equipment, and better anchoring equipment that can be flooded.

Town Dock

The Town Dock was significantly impacted during Superstorm Sandy, demonstrating the vulnerability of the asset. Many of the proposed regional solutions (hurricane barriers, tide gates, and offshore breakwaters) could protect the Town Dock from future flood impacts during extreme weather events, but other resilience considerations should include: investigating the potential of elevating the dock and/or reinforcing the structure with stronger materials, such as steel.

Mystic Fire Department

Mystic Fire Department is located in an extremely vulnerable area of Mystic. Both the station and access to the station could be significantly impacted during a flood event. Potential strategies to protect the station and ensure that the Town's fire department can respond in the event of an emergency include: relocation of the fire department to an area of Mystic that is outside the areas vulnerable to flooding, investigating wet and dry floodproofing alternatives, installing backup power and ensuring redundancy of critical systems.

Quiambaug Fire Department

Quiambaug Fire Department is located in an extremely vulnerable area of Latimer Point. Both the station and access to the station could be significantly impacted during a flood event. Additionally, if both Mystic Fire Department and Quiambaug Fire Department are impacted by a flood event, the town's emergency response efforts could be significantly impacted. Potential strategies to protect the station and ensure that the Town's fire department can respond in the

event of an emergency include: relocation of the fire department to an area that is outside the areas vulnerable to flooding, investigating wet and dry floodproofing alternatives, installing backup power and ensuring redundancy of critical systems.

Mechanic Street Historic District, Rossie Velvet Mill Historic District & Stonington Borough Historic District

Historic districts are particularly vulnerable to flooding, because the historic resources are often irreplaceable and if damaged by flooding, cannot be rebuilt or replaced. It is important to employ a variety of strategies to make sure these assets are well-protected. Resilience strategies in historic districts may include: adjusting floodplain policies and regulations as well as historic preservation regulations to all for resilience modifications to historic structures, installing temporary or permanent flood barriers in the district, using green infrastructure to help mitigate the impacts of flooding, elevating buildings (if possible), filling the basement to prevent floodwater inundation, and relocating key mechanical and electrical systems as well as any moveable artifacts and resources that can be placed above the design flood elevation. In some instances, it may be worthwhile to investigate the feasibility of relocating the entire historic structure outside of the floodplain or regrading the site so that the structure is out of the floodplain. In addition, historic districts are ideal for public education programs around sea level rise and coastal flooding and should be leveraged to educate the public on the risks and the potential solutions for protecting property from flooding.

Mystic Seaport

The Mystic Seaport is a particularly important and particularly vulnerable asset in Stonington. While relocation of the structures and historic vessels may not be an option, there may be an opportunity to move important exhibits and historical resources to areas that are less vulnerable to flooding, either by relocating the resources to higher floors within the same building or moving them to a different building that is outside the floodplain. Additional considerations for protecting the seaport may include: installing backup power and wet or dry floodproofing buildings, elevating certain structures (where feasible), and using temporary or permanent flood barriers to protect these vital resources. In addition, many of the regional solutions will provide protection to the Village of Mystic and the Mystic seaport. The Seaport may also be used as a public education mechanism for teaching people about coastal resilience.

Greenmanville Avenue Electrical Substation

The electrical substation on Greenmanville Avenue in Mystic is highly vulnerable to flood impacts and is a critical resource for the supply of electricity in Stonington. Further investigation is needed to understand the level of redundancy built into the power grid and the various substations in order to get a comprehensive view of the substation's vulnerability. Some potential resilience solutions for this asset may include: elevation of the building and/or critical mechanical and electrical systems within the building; installing sump pumps and backflow preventers; ensuring adequate redundancy is in place between the various substations and within the substation, including installing backup power; and looking into the potential for underground transmission lines that will protect the lines from wind and other storm damage.

Cutler Street Electrical Substation

The electrical substation on Cutler Street in Stonington Borough is highly vulnerable to flood impacts and is a critical resource for the supply of electricity in Stonington. Further investigation is needed to understand the level of redundancy built into the power grid and the various substations in order to get a comprehensive view of the sub-

station's vulnerability. Some potential resilience solutions for this asset may include: elevation of the building and/or critical mechanical and electrical systems within the building; installing sump pumps and backflow preventers; ensuring adequate redundancy is in place between the various substations and within the substation, including installing backup power; and looking into the potential for underground transmission lines that will protect the lines from wind and other storm damage.

Highway 27

Route 27 is one of the main roadways running along the Mystic River. The roadway is vulnerable to flooding in several locations. Detailed engineering studies should be completed to investigate the feasibility of elevating the roadway. In addition, installing green infrastructure along the roadway could provide significant flood mitigation benefits.

Highway 1

Route 1 is one of the main roadways running along the coast, from Mystic to Pawcatuck. The roadway is vulnerable to flooding in several locations. Detailed engineering studies should be completed to investigate the feasibility of elevating the roadway. In addition, installing green infrastructure along the roadway could provide significant flood mitigation benefits.

Donahue Park

Donahue Park is in a vulnerable coastal location along the Pawcatuck River. The park does not currently have any buildings or equipment that would be negatively impacted from flooding, so flooding to the park is unlikely to cause significant damage. However, the Town should consider implementing green infrastructure solutions in the park to help mitigate flooding to the surrounding Village of Mystic. In addition, the park could be leveraged as an opportunity to create public awareness around sea level rise and to build community ties by having community events in that location.

Barn Island Management Area

Barn Island Management Area is an extremely important resource within Stonington; it is the largest coastal wildlife conservation property in the State of Connecticut. While the area is largely open space and does not have a lot of important buildings or infrastructure to protect, the Town should work with CT DEEP to understand the impacts of flooding on the ecosystems and wildlife habitats within the management area. Potential solutions in this area may include a variety of green infrastructure and/or living shoreline interventions that can mitigate flooding without impacting the important habitats and ecosystems on the land.

Mystic River Park

Mystic River Park is in a vulnerable coastal location along the Mystic River. The park does not currently have any buildings or equipment that would be negatively impacted from flooding, so flooding to the park is unlikely to cause significant damage. However, the Town should consider implementing green infrastructure solutions in the park to help mitigate flooding to the surrounding areas in Pawcatuck. In addition, the park could be leveraged as an opportunity to create public awareness around sea level rise and to build community ties by having community events in that location.

Mystic Train Station & Rail Line

Amtrak has undertaken an extensive visioning process for the Northeast Regional Corridor over the last several years. Stonington should engage with Amtrak regarding the risk to the Mystic Train Station and the Northeast regional rail line. Raising the rail line above flood elevation is one potential solution in Stonington. This solution could provide multiple co-benefits by providing

the town with the opportunity to install flood gates and other flood protection infrastructure below the raised rail line. Additional solutions that could protect the rail system include raising critical infrastructure, installing renewable energy supplies and backup power, and elevating at-risk stations, such as Mystic Train Station. Additionally, the resilience solutions implemented could be used as an opportunity to educate the public on the region's flood risk, given the large number of commuters and tourists that utilize the services of the Northeast Regional Corridor.

Stonington Community Center (COMO)

The Stonington Community Center is vulnerable to flooding, but also an important resource for ensuring community resilience to flooding. Protecting the COMO from flooding will serve multiple co-benefits for creating a resilient community. Potential resilience strategies for the physical protection of the COMO include: elevating the building, installing backup power, elevating critical systems, investigating the use of both wet and dry floodproofing techniques, protecting the asset with temporary or permanent flood barriers and installing green infrastructure solutions. The COMO can also be leveraged as a community assistance center where residents can learn about climate change risk and potential resilience solutions; it can be used as a location for hosting public education programs and other events; and, can be used for building community ties and fostering relationships and forming a network within the community. In addition, in the event of a disaster the community center could be used to assist residents by providing charging stations and other necessities that they may not be able to access during an emergency.

Lords Point Neighborhood

Lords Point is one of the most vulnerable neighborhoods in Stonington. The neighborhood is almost entirely residential in character and as a result, may be a good candidate for investigating the potential of relocating homes outside the floodplain, either through implementing a voluntary floodplain buyout and acquisition program or investigating other alternatives for incentivizing homeowners to relocate. In the absence of relocation, other potential resilience strategies may include hardening the shoreline with sea walls and other flood barriers, creating a living shoreline, and installing offshore breakwaters. If a large-scale neighborhood-wide solution is not possible, individual homes may be protected by filling the basements or elevating the homes, elevating critical infrastructure and systems within the homes, using temporary flood barriers, and installing green infrastructure on individual properties and along roadways. Using renewable energy and investigating the feasibility of installing a microgrid in the neighborhood would be beneficial in maintaining power in the neighborhood during a flood event. Additionally, the neighborhood may benefit from identifying a location for a community assistance center and holding events to build community ties and educate the neighborhood on coastal risk and resilience.

Murphy's Point Neighborhood

Murphy's Point is one of the most vulnerable neighborhoods in Stonington. Many of the regional solutions proposed in this plan may not provide protection to the Murphy's Point neighborhood; therefore, the neighborhood may be a good candidate for investigating the potential of relocating homes and businesses outside the floodplain, either through implementing a voluntary floodplain buyout and acquisition program or investigating other alternatives for incentivizing relocation. In the absence of relocation, other potential resilience strategies may include hardening the shoreline with sea walls and other flood barriers, creating a living shoreline, and installing

offshore breakwaters. If a large-scale neighborhood-wide solution is not possible, individual homes may be protected by filling the basements or elevating the homes, elevating critical infrastructure and systems within the homes, using temporary flood barriers, and installing green infrastructure on individual properties and along roadways. Using renewable energy and investigating the feasibility of installing a microgrid in the neighborhood would be beneficial in maintaining power in the neighborhood during a flood event. Additionally, the neighborhood may benefit from identifying a location for a community assistance center and holding events to build community ties and educate the neighborhood on coastal risk and resilience.

Most At-Risk Assets

Through the risk assessment, the Town identified its most at-risk assets. The following section provides a detailed discussion of the resilience solutions developed for each of Stonington's top six most at-risk assets.

Apple Rehab Mystic

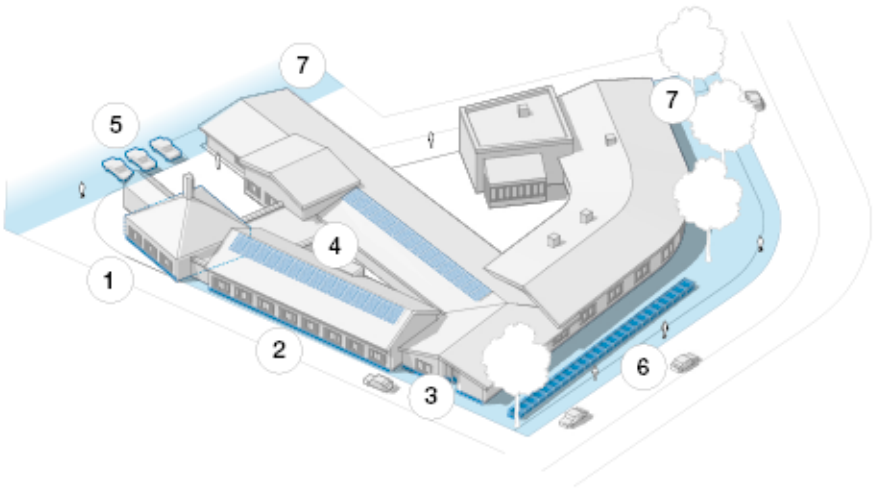
As both a significant economic driver for the community, and home to an elderly population that may be at particular risk during storm events, Apple Rehab Mystic was identified as a priority asset for protection during emergency events. Resilience strategies for the facility involve both physical protections and operational procedures put in place to mitigate the impact of a flood event. While the strategies suggested here are considered specifically for the Apple Facility, many of these strategies are applicable to other large facilities within the Town of Stonington.

Project Elements

Potential project elements include temporary or permanent flood barriers, landscaping, floor shields and other dry flood proofing measures to be implemented in the case of an emergency. Because the facility is not immediately adjacent to the water, large-scale permanent flood barriers such as flood walls may not be appropriate. However, impermeable walls, flood wraps, waterproof membranes, sprays and other sealants that protect the ground floor can be quickly deployed in the case of anticipated flooding. Given the size of the facility, it may be necessary to prioritize a limited number of buildings or rooms, retrofitted with waterproofing applications such as sealants and waterproofed walls. Additionally, emergency measures such as gravel filled containers, sandbags and water-filled barriers can reduce the impact of any storm surges. In the medium-term, alternative energy sources, including additional solar panels mounted on the facility's roof, can provide electricity when and if outside sources are temporarily disabled. Because the facility serves a vulnerable population that relies on electric-operated medical equipment and may be particularly vulnerable to prolonged exposure to heat or cold, ensuring an adequate supply of electricity is especially critical.

Another strategy entails the introduction of green infrastructure on to the site. Apple rehab sits adjacent to four small parking lots and Broadway Avenue, and may be vulnerable to flooding due to the high proportions of impermeable paving. Efforts to mitigate the impact of flooding, in both normal rainfall events and longer-term flood impacts, could include the introduction of green infrastructure, native plantings, trees and permeable paving materials for the parking facilities and along Broadway Avenue.

Depending on surrounding infrastructure enhancements, a longer term strategy may include investigating relocating the facility to a less vulnerable location. If significant infrastructure improvements are made to reduce flooding vulnerability, elevation of the building may still be considered.



1 **COMMUNICATION CENTER**
If it is infeasable to protect a large building complex, one or several areas dedicated to communicating and managing disaster responses should be prioritized, using waterproofing applications or waterproofed walls (e.g. using CMU block).

2 **IMPERMEABLE WALLS**
Sealants or wraps can protect the lower stories of a property. Applications include waterproof membranes, flood wraps, spray applied sealants on the positive side and fiber-reinforced polymer wraps on the negative side.

3 **FLOOD SHIELDS**
Flood shields and other dry floodproof measures can help protect windows and doors from rising waters. These are temporary, watertight barriers built of metal (aluminum, stainless steel) or plastic, often using rubber or similar materials to seal the barrier.

4 **ENERGY SUPPLY**
Alternative energy sources, such as roof solar panels can provide electricity if traditional energy sources are temporarily made unavailable. Solar energy is a one attractive option because it is naturally elevated and at low risk of flooding.

5 **PROVISIONS & STORAGE**
Especially for vulnerable populations, the facility should ensure adequate stockpiles of critical goods, including food and water, and medical supplies such as first aid kits, antibiotics, medications, sanitation supplies, mobility aids, age-appropriate clothing, etc. These should be packaged and stored in dry, protected areas.

6 **EMERGENCY BARRIERS**
As a last resort, emergency measures such as gravel-filled containers, sandbags and water-filled containers can reduce or eliminate the impacts of floodwater.

7 **GREEN INFRASTRUCTURE**
Landscaped berms, rain gardens, street trees and plantings can reduce, divert or retain floodwater and storm surges and provide a range of urbanistic and ecological benefits.

Figure 68: Apple Rehab Mystic, potential strategies

A range of operational strategies should complement the protections described above. These include well-rehearsed emergency evacuation procedures with clearly-delineated responsibilities, information dissemination and adequate disbursement of key supplies in the case of an emergency. Storing food, medical equipment, clothing, blankets, and other emergency supplies in dry, elevated or otherwise protected areas within the facility is also critical.

Community Benefits

These risk reduction strategies should focus on protection of human life, reducing damage from floodwaters, ensuring that the building functions adequately during the event, and establishing quick recovery after an emergency. Unlike assets described elsewhere in this report, it may not be feasible to evacuate large numbers of residents, who may have limited mobility. The facility should therefore prioritize protective measures that allow at least some areas within the building to continue functioning even in the midst of a disaster event.

Ensuring that residents are safe and well-cared for in the event of an emergency delivers a clear social good to the community, including residents

and their family members and friends. Helping the facility recover quickly and resume operations soon after an event may also carry ancillary economic benefits to the town. Additionally, green infrastructure measures that bolster the attractiveness of the streetscape and reduce the amount of impervious surface in the neighborhood will result in reduced flood risk during typical rain events and extraordinary flooding.

Potential Costs

Developing a comprehensive and rehearsed operational plan for preparing for storm events – including communication and evacuation procedures, and storing and protecting food, water and medical supplies – will incur minimal financial costs. Procuring and storing temporary floodproofing measures such as flood shields, waterproof membranes and other sealants are more expensive, and emergency barriers carry a higher cost that includes procurement, training and storage expenses. Additional landscaping that introduces elevation changes to the site, and new alternative energy supplies will incur additional costs. The cost of additional solar panels will be defrayed by cost savings during normal times, however.

Implementation

Unlike other resilience measures that require buy-in from multiple stakeholders, strategies for Apple Rehab Mystic can be implemented unilaterally by the facility in consultation with residents. The engineered solutions proposed here are not overly complex – solar panels and landscaping may require some engineering consultation, but other proposed measures can be implemented largely in consultation with product manufacturers. As a result, the single largest barrier to implementation may be cost, as well as the training required to instruct staff on new operational procedures. Strategies may be implemented over the short and medium term.

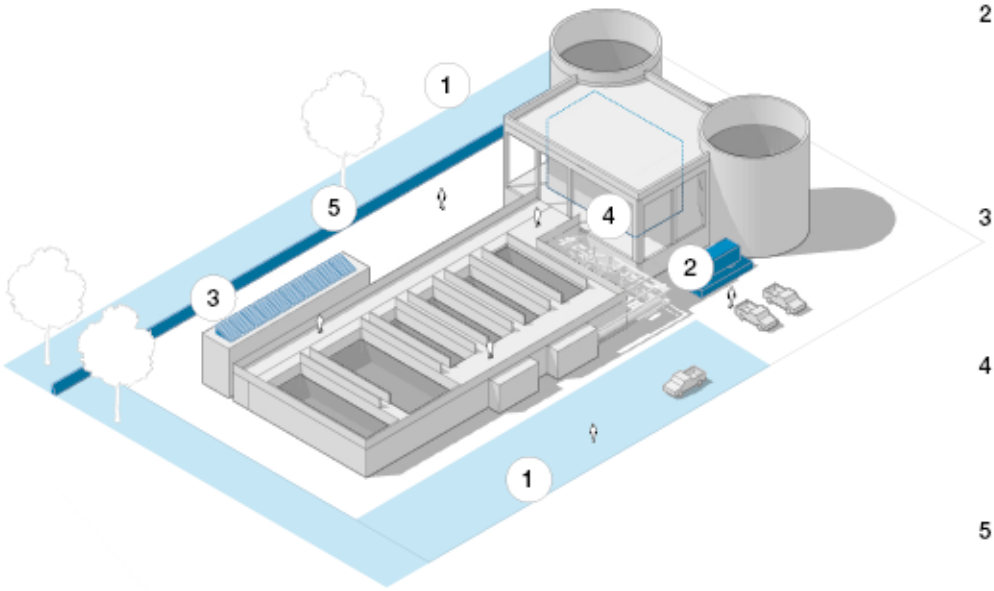
Mystic Wastewater Treatment Facility

The Town of Stonington is responsible for three sanitary sewer systems and related wastewater treatment facilities, the oldest of which is the Mystic Wastewater Treatment Plant. The Mystic plant, which receives higher flows and loads than either the Pawcatuck and Stonington Borough plants, has been in service for over 40 years and lies directly adjacent to Mystic Harbor, immediately south of downtown Mystic. Due to its proximity to the village, its vulnerability to flooding and its criticality to the overall sanitary system, the treatment facility was deemed a high priority asset.

Project Elements

The facility, which is located on the harbor, is particularly vulnerable to coastal flood events. Additionally, all of the surrounding roads, including Edgemont Street and Broadway, are vulnerable to significant flooding, which would prohibit access to the facility during a flood event. Potential project elements include a range of measures to prevent water from entering the facility, as well as strategies to protect key equipment from being damaged by floodwaters. Although the tanks and equipment are elevated, an additional layer of protection would include flood barriers such as walls or berms surrounding the facility. Landscaping that provides additional elevation, and plantings that reduce the flow or intensity of water along the water's edge will also reduce the force and elevation of flooding.

Another layer of protection exists in the combination of operational and physical measures that protect key equipment, including electrical controls, computers and records. These materials may reside in elevated or flood-proofed areas. The plant may also invest in capacity to temporarily remove and store vulnerable components in anticipation of a flood event.



1 **GREEN INFRASTRUCTURE**
Native plant species can divert or reduce the impact of flooding, stabilize soils and provide protection against wind erosion. Landscaped swales may provide a natural buffer to rising waters. Additionally, where hard surface are necessary, permeable paving can reduce pooling and speed recovery.

2 **ELECTRICAL EQUIPMENT**
All electrical equipment, inlcuding electrical controls, computers and records, should be elevated or relocated. An emergency generator should be elevated above the DFE. Additionally, the treatment facility can work with the local power utility to ensure a reliable connection to its power source; for example, it might install a substation or dedicated feeder expressly for the facility.

3 **ENERGY SUPPLY**
Alternative energy sources, such as roof solar panels can provide electricity if traditional energy sources are temporarily made unavailable. Solar energy is a particularly attractive option because it is naturally elevated and at low risk of flooding.

4 **SECURABLE & REMOVABLE EQUIPMENT**
If necessary, critical equipment such as tanks should be secured to prevent floatation if flooded. During upgrades or design of new equipment, the plant may invest in capacity to temporarily remove and safely store vulnerable components when there is advanced warning of a flood.

5 **FLOOD BARRIERS**
Permanent barriers built to DFE should be installed along the facility's perimeter. Anchored flood barriers may include flood walls, berms and levees, prevent floodwaters from reaching critical facilities. These can be built using a variety of natural and synthetic materials. Such measures are specially appropriate to protect critical infrastructure in isolated, non-public areas, where the negative impact of permanent barriers is minimal.

Figure 69: Mystic Wastewater Treatment Plant, potential strategies

Alternative energy sources – including wind and solar power, backup generators and substations to power the plant – will also be critical to operate equipment in the event of a power outage or other impact to the energy supply. In some cases, pumping systems and channel or culvert systems may be used to collect and divert flood water from the facility.

Community Benefits
Given its vulnerable location, there exists significant risk to the Mystic Wastewater Treatment Plant, and severe consequence if it fails. The strategies described above are intended to achieve two key aims of, first, reducing or eliminating the risk of sewage overflow into the harbor and, second, resuming normal operations immediately after a flooding event.

Protecting the treatment facility has clear and significant impact on the village of Mystic, which relies on the treatment plant to process all waste for the village. Additionally, allowing untreated waste to enter the harbor would bring significant ecological harm to the area, and negatively impact the town's economy which relies heavily on tourism and recreational activities.

Potential Costs
Because of the plant's proximity to Mystic Har-

bor and due to the complexity of the equipment involved, strategies to mitigate flood impacts on the plant may be more expensive than for other assets identified. Specifically, high costs may be involved in developing the required mix of permanent flood barriers, equipment relocation, and alternative power sources. Electrical infrastructure, including substations, backup generators, solar panels or wind turbines that reduce dependency on the electrical grid will carry significant costs. However, the facility is critical to the functioning of the town, both on a daily basis and following a storm event.

Implementation

Upgrades to the wastewater treatment facility are the responsibility of the town and do not directly impact private landowners. The greatest obstacle to implementation is, therefore, the significant funding required to install the various mitigation strategies described above.

Model Single-Family Home

Stonington is a highly residential community and, as such, there is a lot of interest in understanding what individual homeowners can do to protect their own properties. This set of solutions is intended to provide a range of solutions that homeowners can consider implementing on their properties. Understanding the geography of the site, the character of the neighborhood, the expected intensity and frequency of flooding on the site, and the homeowner's budget and appetite for risk will all be key considerations for determining which solutions are best suited for each property.

Project Elements

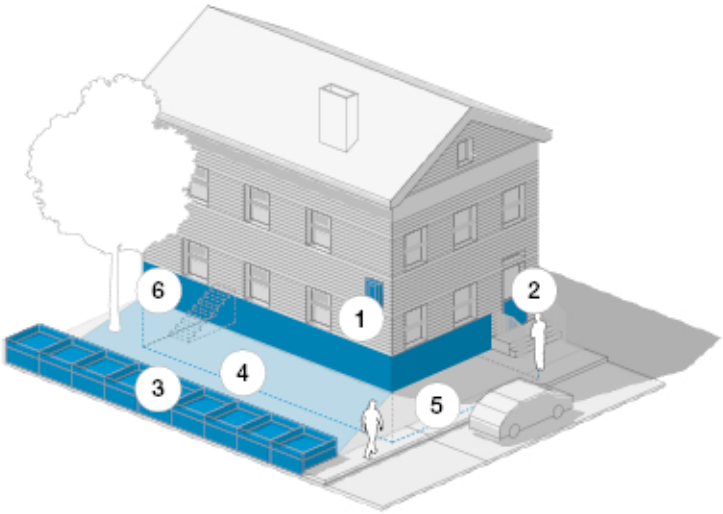
There are a variety of protection and adaptation strategies that homeowners can implement on their own properties. These strategies include landscaping and green infrastructure to capture stormwater runoff and protect the house from flood waters. Many homeowners likely already use sandbags to protect their property during a known flood event. Sand bags are a low-cost protection solution. There are several alternative types of emergency barriers, such as floor shields, that can also be used as a flood protection mechanism. Additionally, elevation of the property or filling the basements to prevent entry of floodwaters are some of the more complex flood protection solutions. Some additional adaptation measures include installing a sump pump, ensuring that electric wiring is in either protected from floodwaters or installed in such a way that it can be easily replaced if damaged, and installing a generator to maintain power in the event of an emergency. In some cases the Town and the most vulnerable residential neighborhoods may start planning for relocation or buyout/acquisition programs as longer term adaptation measures.

Community Benefits

Stonington is a largely residential community. As a result, if each individual property owner takes action to protect their property, those actions could have a large impact on the resilience of the community, as a whole. Additionally, if homeowners start taking action to protect and adapt their properties, other property owners are likely to take notice. These efforts might influence neighbors or nearby business owners to take steps to protect their own properties and also help educate the public on coastal flooding and resilience.

Potential Costs

For homeowners, costs can vary widely. Resilience measures such as landscaping and using sand bags, can often be implemented at relatively low cost to the homeowner. However, the most intensive resilience measures, such as elevation, often come at a high upfront cost to the homeowner and many homeowners may have difficulty implementing these measures without additional



1 **ELECTRICAL WIRING**
Electrical wiring in flood-prone areas should be installed so that it can be easily replaced or cleaned and then reused. Cable systems are easy to replace if damaged.

2 **FLOOD SHIELDS**
Flood shields and other dry floodproof measures can help protect windows and doors from rising waters. These are temporary, watertight barriers built of metal (aluminum, stainless steel) or plastic, often using rubber or similar materials to seal the barrier.

3 **EMERGENCY BARRIERS**
As a last resort, emergency measures such as gravel-filled containers, sandbags and water-filled containers can reduce or eliminate the impacts of floodwater.

4 **LANDSCAPING**
Terraced front yards with plantings provide additional elevation, protecting the house from rising floods. Organic material can diminish the impact of flood waters and absorb water during and after a flood event.

5 **IMPERMEABLE WALLS**
Sealants or wraps can protect the lower stories of a property. Applications include waterproof membranes, flood wraps, spray applied sealants on the positive side, and fiber-reinforced polymer wraps on the negative side.

6 **BASEMENT**
When structures are built on solid foundation walls or have other enclosures below the Design Flood Elevation (DFE), foundation walls should have openings that permit the automatic entry and exit of floodwater. Battery powered sump pumps can be relied on to remove water in the case of flooding.

Figure 70: Model Single-Family Home, potential strategies

funds. Overall, there are strategies that can be implemented across all income levels and each homeowner will take a different approach to resilience. By combining a variety of different strategies, homeowners can tailor their resilience solutions to their own income levels and risk appetites.

Implementation

Overall, implementation of these strategies is typically dependent on the income of the homeowner and whether they have the funds to take action. However, if funds are readily available, many of these strategies are relatively easy to implement when compared to large-scale engineering solutions. Implementation of these strategies may require cooperation from the Town. Often homeowners will need to acquire building permits for implementing these strategies. In addition, some strategies may be in conflict with current zoning requirements or other town regulations. Therefore, the homeowners will need to work with the Town for the appropriate variances or waivers to those requirements. One common issue is that homeowners that want to elevate their homes often have difficulty because the elevation would cause

their home to be raised above the height restrictions for the community.

Model Mixed-Use Building

Stonington has a variety of mixed-use and commercial buildings in the downtown areas of Stonington Borough and the villages. Similar to the single-family property solutions listed above, there was a great deal of interest in understanding what resilience solutions are available to property owners for mixed-use and commercial structures throughout Stonington. A combination of building-specific strategies as well as green infrastructure and landscaping along the streetscapes can provide significant protection from coastal flooding. When implementing strategies in these commercial districts, it is important to understand how different strategies will change the character and feel of the streetscape. For example, elevation of all of the buildings would inhibit the fluid interaction between the pedestrians on the street and the businesses and thus, negatively impact the user experience. Therefore, a variety of strategies should be employed to reduce any negative impacts to the tourism experience and the general look and feel of the downtown corridors.

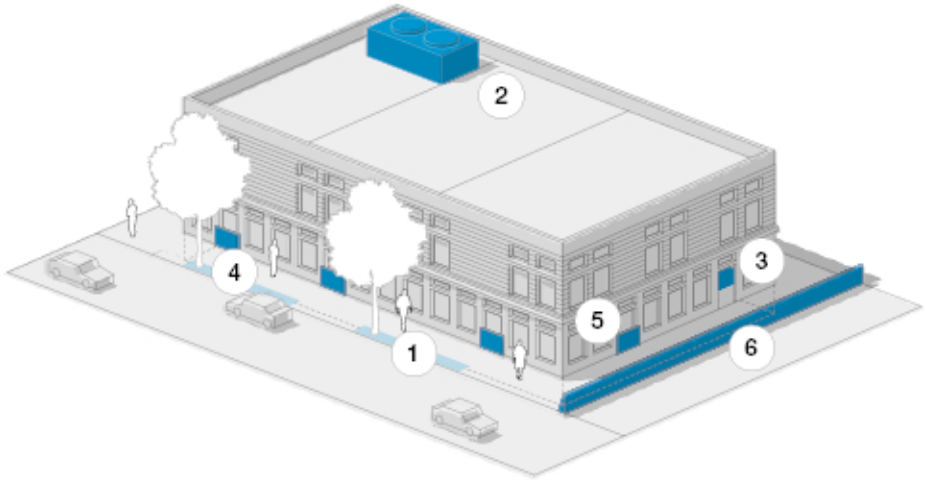
Project Elements

Strategies for protecting and adapting the building include elevation, where appropriate, as well as a mix of protection and adaptation strategies. In the example above, elevation may be difficult because of the size of the structure; however, there are some free-standing structures in some of these downtown locations, where elevation is a potential option. In lieu of elevating the entire building, property owners may consider elevation of mechanical and electrical systems, filling basements to prevent infiltration of flood waters, installing temporary floodproofing measures like floor shields and sandbags, and using materials that are flood-resistant. More expensive protection measures include retrofits of interior spaces to waterproof interior walls and install impermeable coatings for core areas (either structurally critical spaces, or areas used for protecting key equipment). Interior raised floors may also be introduced into ground floor retail spaces without negatively impacting internal uses, or changing the opening to the street. In addition, property owners should consider installing generators and other forms of backup power and investigate the potential of renewable energy, such as solar panels.

Additional strategies should be employed along the streetscape. Some of those strategies may include flood barriers, such as flood walls, berms and levees along the coast that prevent floodwaters from reaching critical facilities. These permanent measures have proven to be highly effective elsewhere, but require greater financial investment than temporary alternatives, and may negatively impact the local streetscape. In order to maintain Stonington's unique and historic character, green infrastructure may be a more appropriate solution along these downtown streetscapes, as they often enhance the aesthetic of the area and also provide stormwater management solutions. Some potential strategies include street trees, rain gardens, impermeable paving, bioswales and plantings.

Community Benefits

In addition to the intended flood mitigation benefits, these strategies can provide long-term economic benefits and cost savings. On an individual level, business owners that consider switching to renewable energy sources may see long-term cost savings. On a community level, small businesses and the character of these downtown, mixed-use corridors are essential to Stonington's economy, both from the revenue generated by the businesses themselves and the tourism generated by the historic nature and character of the Stonington.



1 **GREEN INFRASTRUCTURE**
Landscaping elements such as street trees, plantings and rain gardens will reduce the impact and absorb floodwaters. These measures also improve the quality of local streetscape during normal conditions, and provide a range of other ecological benefits.

2 **CRITICAL EQUIPMENT**
Critical equipment, including utilities and electrical facilities should be located above Design Flood Elevation (DFE). Where this is not possible, electrical wiring in flood-prone areas should be installed so that it can be easily replaced and even reused.

3 **INTERIOR PROTECTION**
In addition to waterproofing interior walls and installing impermeable core areas (for instance, using CMU walls or cast-in-place concrete), groundfloor users can introduce interior steps to elevate wares above ground level.

4 **BASEMENTS**
Where possible, existing basements can be abandoned and filled with sand, gravel or concrete to reduce the impact of flooding. Critical infrastructure should be moved from basements to higher ground areas wherever possible.

5 **FLOOD SHIELDS**
Flood shields and other dry floodproof measures can help protect windows and doors from rising waters. These are temporary, watertight barriers built of metal (aluminum, stainless steel) or plastic, often using rubber or similar materials to seal the barrier.

6 **FLOOD BARRIERS**
Anchored flood barriers, which may include flood walls, berms and levees, prevent floodwaters from reaching critical facilities. These may be built using a variety of natural and synthetic materials. Permanent barriers require maintenance and may impact the local streetscape, but provide greater protection in case of emergency.

Figure 71: Model Mixed-Use Building, potential strategies

Protecting these assets from flood vulnerability is important to protecting Stonington's future economy.

Potential Costs

The financial costs ranged drastically depending on the solutions that the Town and the business owners choose to implement. Planting street trees and using sandbags as flood protection measures are fairly low cost. Some of the more permanent solutions, such as elevation of critical equipment and installing flood barriers would come at a greater cost. In addition to immediate financial costs associated with each of these measures, implementation should be careful to consider potential negative effects of such strategies on the local streetscape, as discussed above.

Implementation

Because decisions about mixed-use properties involve multiple landowners, tenants and users, implementation will require aligning the interests of a range of stakeholders and ensuring that the character of Stonington is not negatively impacted by these flood mitigation strategies. Choosing what strategies are best-suited for particular areas will necessitate a broad conversation about community priorities – what areas are most in need of public dollars, and what areas carry the largest benefit to the larger community. However, strategies in these locations may be phased – those solutions that can be implemented at the discretion of the business owner may be implemented in an earlier phase than those that require community buy-in. Stonington should review the suggested strategies and

create a phased plan that accounts for budget, ease of implementation, and which strategies are most effective for the location.

Village of Mystic

The Village of Mystic is an important historic and economic development area, located in both Groton and Stonington, CT. The village is situated along the Mystic River and the portion of the village located in Stonington is home to many historic resources and tourist destinations. As such, the village is an important part of both the character and the economy of Stonington. Historically, the village was home to one of the area's most important seaports; that seaport is now home to one of the nation's leading maritime museums and is an important tourism destination in the Town of Stonington. The portion of the village that is located in Stonington is also home to the Mystic Aquarium, the Mystic Train Station (and Amtrak rail line), a multitude of historical resources located in the Mystic Bridge Historic District, the Mystic Wastewater Treatment Plant, and a variety of residential properties, businesses, parks, and roadways.

Project Elements

In order to develop a comprehensive strategy to protect the neighborhood, as a whole, and its key assets, a variety of resilience solutions must be considered. Due to the historic character of the neighborhood and its important relationship with the coast, strategic retreat is not a popular option; therefore, flood prevention and protection will be critical. A comprehensive approach to neighborhood-scale resilience will require a combination of green and grey infrastructure as well as individual asset-level solutions and larger neighborhood-wide protection. At an individual asset level, detailed solutions have been provided for Apple Rehab Mystic and the Mystic Wastewater Treatment Plant. Similarly, the strategies provided for the typical single-family home and mixed-use business provide detail on how individual homeowners and business owners in Mystic can implement resilient solutions on their own properties. Many of these strategies are also applicable to other building assets. On a more neighborhood-wide scale, a variety of temporary and permanent strategies can be used in commercial, residential, and mixed-use zones and, specifically, along pedestrian-friendly corridors located in downtown areas. While more natural solutions are typically the preferred option, a combination of both grey infrastructure – hardscapes and engineered solutions – and green infrastructure – such as trees, plantings and landscaping – may be needed in Mystic. Potential measures may include a green corridor along Route 1, preserved green and open space throughout the neighborhood, and a combination of living shorelines and coastal flood barriers along the coast.

Both green and grey solutions can provide additional community benefits, including more beautification of the neighborhood, additional green space that can be accessed and used by the residents, and new access points to the waterfront. Additional strategies should include regulatory considerations, such as a waterfront overlay zone that may restrict the types of uses in those zones and also enforce alternative building methods. These strategies are intended to work together as one cohesive whole, rather than implementing a variety of strategies separately without consideration of how they will interplay with each other.

Community Benefits

Beyond their value as flood mitigation measures, these measures may carry a range of other positive benefits. In particular, green infrastructure that introduces new green space to the local streetscape brings both ecological benefits and additional social benefits. Reducing the amount of permeable paving in downtown areas, for instance, can

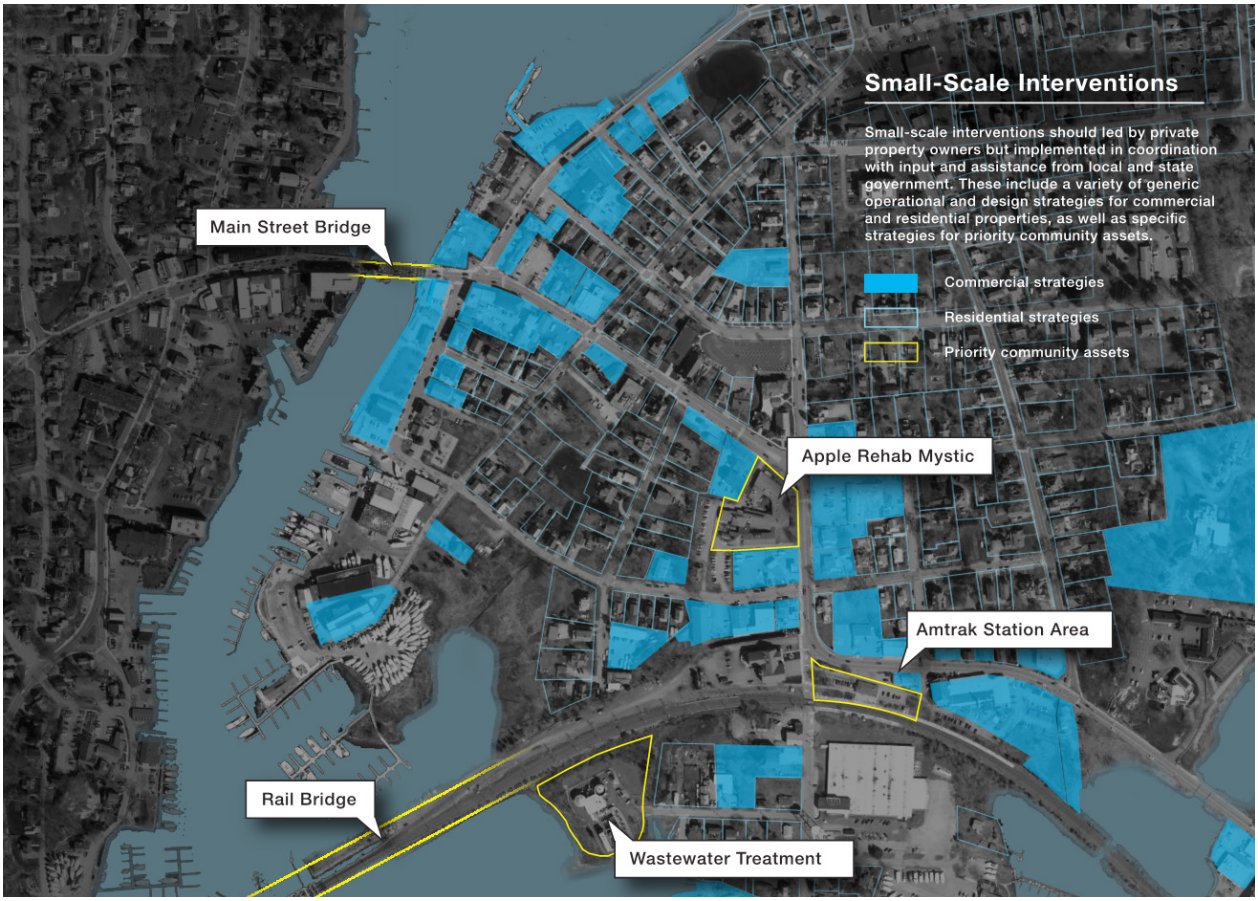


Figure 72: Mystic, potential small-scale strategies

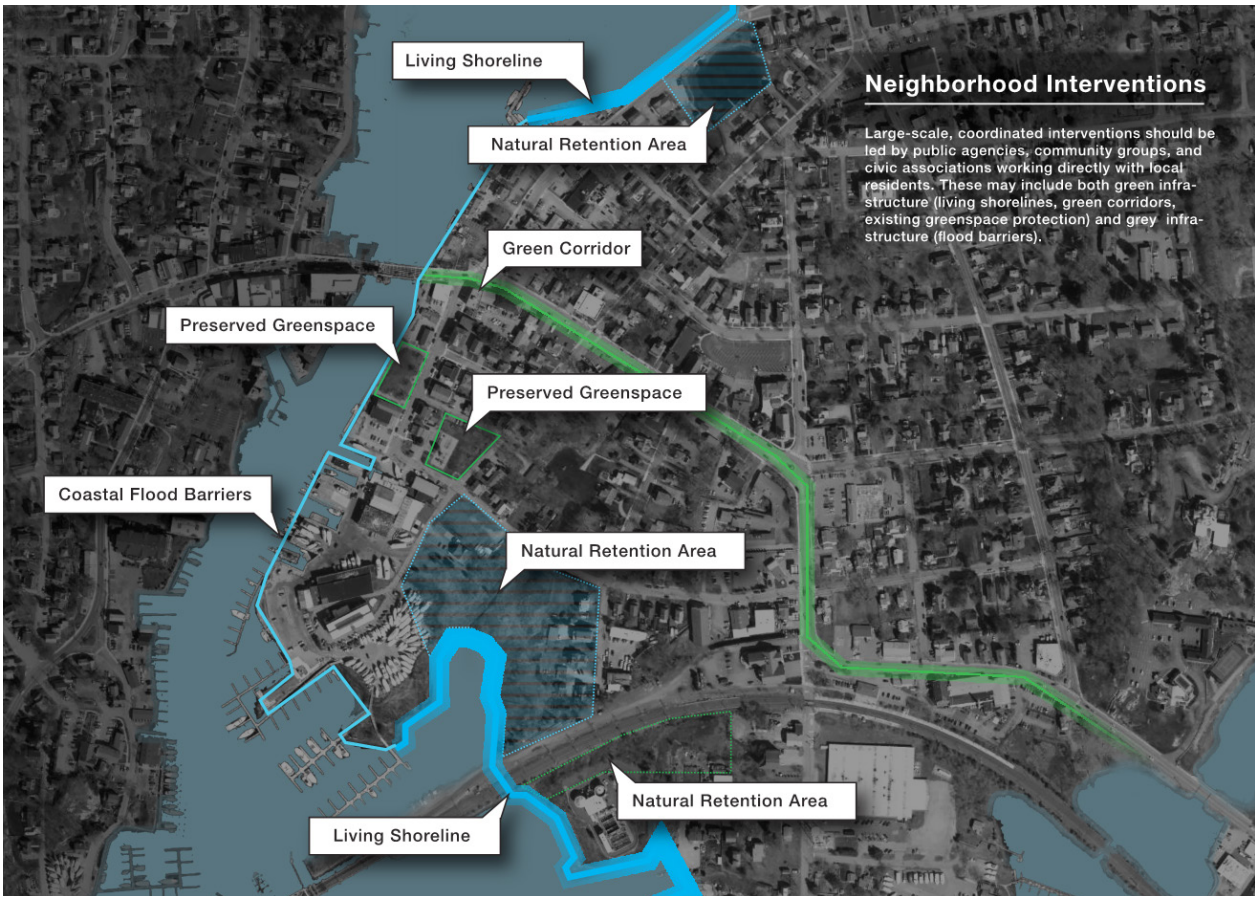


Figure 73: Mystic, potential neighborhood-scale strategies

reduce flooding during typical rainfall events. New plantings reduce the impact of the 'urban heat island effect' and new street trees provide shade on hot summer days. Flood barriers have the potential to reduce or limit access to the water if designed poorly, but may actually highlight or channel pedestrian activity to the waterfront if designed carefully and with an eye to minimizing disruption to natural pedestrian movement.

When implemented in a manner that is sensitive to the needs of the community, local property owners, and users, these strategies can provide flood protection while also improving the look and feel of the neighborhood. Unlike many of the other strategies proposed for the town, these strategies will inherently involve multiple stakeholders, including not only the people who live and work in affected areas, but also those who frequent these areas as shoppers, tourists, or otherwise as part of their regular routine. As such, the process of negotiating what strategies are appropriate where, and who assumes responsibility for financing, building, and maintaining key infrastructure, will involve substantial effort to ensure that all stakeholders are heard and that costs and benefits are distributed fairly.

Potential Costs

In addition to immediate financial costs associated with each of these measures (which vary widely depending on the solutions that the Town chooses to implement), implementation should be careful to consider potential negative effects of such strategies on the local streetscape. The downtown Mystic area is currently a vibrant, walkable area. Implementing these measures should consider how each measure interacts with the local streetscape. For instance, while protecting ground floor commercial land uses is of high priority, any new flood protection measure should take care to maintain a strong connection with the street, through easy access and attractive facades. New green infrastructure should be planned to minimize costs associated with streetscape changes, such as widening sidewalks or digging up pavement to accommodate new plantings.

Implementation

Because decisions about mixed-use properties involve multiple landowners, tenants and users, implementation will require aligning the interests of a range of stakeholders. Choosing what strategies are best-suited for particular areas will necessitate a broad conversation about community priorities – what areas are most in need of public dollars, and what areas carry the largest benefit to the larger community. Additionally, all strategies must balance flood mitigation demands with the needs of local users; store owners may be reluctant to disrupt normal retail activity to prepare for the uncertainty of a future storm event. While there are no easy answers to these questions, open conversations about available resources and shared priorities, viewed in light of risk assessments provided elsewhere in this report, will help begin a process of implementing these strategies. Strategies may be implemented over the short and long term, with immediate investigations into the availability of temporary measures, and longer term considerations of more complex and permanent solutions such as flood barriers and green infrastructure.

Masons Island Causeway

Masons Island is an approximately 600-acre island containing three marinas, a yacht club, a 47-acre nature preserve, and numerous residential homes. Masons Island also provides the only land-based access to Enders Island. Since the Masons Island Causeway is the only land-based access to the island, its long-term usability is an important component for emergency planning and climate change adaptation in Stonington.

Figure 74: Proposed elevation of Masons Island Causeway

Figure 75: Current Image of Masons Island Causeway

Masons Island Causeway and the adjacent access roads have high probabilities of coastal flood impacts. The Causeway itself has a relatively low elevation and is already susceptible to flood events, in the present-day. The annual probability of flooding for the Causeway is only expected to increase throughout the century, with annual flood probabilities ranging from:

- 10% to 20% in the present day,
- 10% to 50% by 2030,
- 20% to 100% by 2050, to
- 100% by 2070.

A 1% probability event can flood the Masons Island Causeway and access roads under present-day conditions. Under future scenarios, the extent and depth of this flooding will increase.

Project Elements

The Masons Island proposed regional adaptation, displayed above, is comprised of the following elements:

- Masons Island Bridge
- Elevating portions of Masons Island Road north of Shaffer's Boat Livery
- Hybrid shoreline treatment with rising gate for Shaffer's Boat Livery vicinity
- Green infrastructure solution (berm and living shoreline) for portion of Gled Hill Street east of bridge
- Green infrastructure solution (marsh creation, living shoreline, natural berm) for portion of Masons Island Road south of bridge
- Elevating portion of Masons Island Road south of bridge
- Elevating Dubois Drive north of bridge

These elements may be strategically phased over time to distribute capital investment and implement adaptive management, while providing the necessary level of protection against the combined effects of future sea level rise and storm surge. The priority element for the Masons Island regional adaptation project should be the replacement of the causeway with a suitably elevated bridge. The figure below provides a rendering of the proposed Masons Island Bridge. While a bridge is recommended, other alternatives, including raising the causeway could also be considered. The proposed bridge alternative also promotes improved tidal exchange and flushing throughout Mystic Harbor and may have ancillary ecological benefits for the region.

Near term accessibility of the bridge during storm conditions will be insured if additional elements (in addition to the bridge or elevation of the causeway) are constructed contemporaneously. On the mainland, implementing green infrastructure along Gled Hill Street and a proposed hybrid shoreline treating at Shaffer's Boat Livery will prevent inundation of the mainland approach to the bridge and address access issues at Shaffer's created by the bridge approach. On the island, elevating Dubois Drive and installing green infrastructure (e.g., living shorelines, expanded salt marsh, berms) along Masons Island Drive will prevent inundation of the island approach to the bridge and reduce the probability of flooding in northern portions of Masons Island. These road raising, green infrastructure, and nature-based solutions would need to be developed and designed more fully in a subsequent phase of work.

Community Benefits

The proposed solutions for Masons Island Causeway could have significant community benefit to Stonington and its residents. The proposed solutions will not only help protect the 600+ residents of Masons Island, both during storm events and nuisance flooding, but they will also help to minimize flooding in neighboring areas of Stonington. In addition, given the vulnerability of the Causeway to flood events, there is likely to be increased maintenance costs associated with future flooding to the Causeway. By constructing a bridge, the Town can minimize those future impacts and maintenance costs.

While these adaptation elements will maintain access to Masons Island and provide some regional reductions in flood vulnerability over the approximate design life of the project, the project-

Figure 76: Masons Island Causeway, potential strategies

ed flooding for 2070 (and beyond) presents severe challenges to maintaining safe and reliable access to Masons Island during storms. While the proposed Masons Island regional adaptation project should provide for long-term daily access to the island in non-storm conditions, decisions will have to be made in the future regarding the emergency management planning for Masons Island (e.g. preemptive evacuation).

Potential Costs

The components of this project range greatly in cost. There is likely to be significant costs from feasibility, planning, design, and construction phases associated with the proposed Masons Island Bridge project, as well as the potential raising of Masons Island Road. Some of the green infrastructure solutions are likely to be less costly and have quicker implementation timeframes than the proposed "hard" solutions.

Implementation

The strategy for Masons Island Causeway is a phased solution, with the top priority being the construction of the proposed Masons Island Bridge and complementary green infrastructure solutions along Gled Hill Street and at the Shaffer's Boat Livery, in the near-term. By 2030, a second phase of elements may become necessary to protect access to the bridge. These elements include elevating both mainland and island portions of Masons Island Road, and tying them into the existing green infrastructure and hybrid shoreline treatments on either side of the bridge.

These construction of a proposed Masons Island Bridge along with potential future elevation of portions of Masons Island Road will require significant time to implement. These are larger infrastructure projects and therefore, will need stakeholder buy-in and agreement within Town management that these projects are necessary.

In addition, due to the high cost of these types of projects, the Town will need time to identify funding sources or build the project into the Town's budget and capital improvement planning process. And lastly, the planning, design, approval, and construction process for the bridge will take a significant amount of time to complete. In order to navigate the potential roadblocks to implementation, the Town will need to conduct a more extensive study of the feasibility of such a solution and the benefits to the Town.

Regional Solutions

In addition to the local, facility-based adaptations that are intended to improve resiliency of an individual facility, structure, or asset, there are also potential regional adaptations that can be implemented to protect a larger area from flood risk. Typically, these regional adaptations focus on renovation at flood entry points, where a larger upland area is flooded by water arriving from a vulnerable section of the coastline. In many cases, these regional solutions can be more cost effective than local adaptations by protecting a larger upland area consisting of numerous buildings, facilities, homes, and roads that encompass multiple asset types and stakeholders. As such, in many cases the overall cost of the adaptation can then be shared across stakeholders. The challenges with regional adaptations typically involve coordination, communication, and agreement between various stakeholders, all of whom may have different agendas or needs for protection. However, if these challenges can be overcome, regional adaptations usually provide the most cost-effective resiliency option, while also providing ancillary benefits beyond just protection of an individual structure. For example, while a local adaptation may reduce flooding to a structure, a regional solution may also maintain access to the structure by protecting the surrounding area and transportation services.

In order to assess potential viable regional adaptations, the flood risk maps were evaluated for each climate change scenario to identify key flood entry points and flood pathways within Stonington. While there are other flood entry points and flood pathways that may be viable sites for regional adaptations, the locations identified here were targeted to protect critical community assets. Additionally, Stonington's geographic landscape limits the amount of focused and nonexpanding flood entry points. Most of Stonington's shoreline consists of wide flood entry locations where flood waters inundate the land over large areas, thereby limiting potential cost effective, targeted regional solutions.

These solutions are intended to provide a range of potential options aimed at protecting Stonington's key critical assets as well as the largest amounts of land area; these adaptation options are not the only possible alternatives and they may not be the best possible alternatives. But rather, the intent was to provide some initial concept designs for regional adaptation solutions. A more detailed analysis would need to be completed in order to fully evaluate all of the possible alternatives and to understand the costs and benefits of each solution as well as the feasibility of implementation.

One important component of that more detailed analysis is an assessment of downstream impacts. When a flood adaptation option is designed to keep water out of a certain area, property, or structure, the flood water that would normally have advanced and filled that site may be redirected to another area. This can occur at both a local scale and a regional scale. Therefore, resiliency designs need to consider potential impacts from redirected flood waters to neighboring areas or parcels. On a local scale, the volume of re-directed water is typically relatively small. As such, there will be insignificant increases in the total water surface

elevation for the surrounding region and increased flooding will not occur. However, while local scale adaptations rarely increase the water level, potential designs can sometimes redirect water in a way that changes local flow velocities and pathways. For example, if a flood wall is constructed around a building, water that would normally have flooded that structure may now be redirected through a narrower pathway increasing velocity through an area. This is usually a localized problem and does not typically occur for a majority of adaptations. Even if it does occur, it may not be problematic.

Likewise, regional scale options that protect larger areas, such as those considered for Stonington, may also redirect flood waters into adjacent areas. For example, blocking off the upstream portion of the Mystic River at the I-95 bridge crossing would inhibit a volume of water from advancing upstream, forcing the water to remain in downstream areas. For a vast majority of these areas, there is no increase in downstream water surface elevation since the downstream area (typically the harbor, ocean, or bay) is significantly larger than the upstream area. The volume of water inhibited from flowing upstream is simply spread over a larger downstream area (i.e., the volume of the ocean is huge) and as such there is no increase in water surface elevation. For example, hurricane barriers, like those in Stamford, CT or New Bedford, MA, do not create increased flooding downstream during storm events since the redirected water is simply redirected to a much larger water body. Analyses completed for numerous flood adaptation designs indicate that the volume of water blocked from flooding large upland areas does not result in increased flooding for areas downstream of the proposed barrier. Similar results would be expected for most of the regional adaptations proposed in Stonington, where the downstream water bodies are much larger than the upstream areas protected. The one exception would be the Upper Mystic River adaptation at the I-95 crossing where the downstream area is on the same order of magnitude (volume wise) as the upstream blocked area. In these cases, similar to dams placed on a river, the constricted riverine areas may result in downstream impacts due to the obstructed flood adaptation.

Regardless of the adaptation being considered on either a local or regional scale, the potential redirection of flood waters is typically conducted as part of the design process for any adaptation solution. Therefore, when conducting the engineering design of the potential coastal or resiliency design, the potential impact of the proposed solution on neighboring properties should be evaluated.

I-95 Regional Adaptation

The vulnerability and risk assessment, completed as part of this project, indicates that storm surge could inundate portions of the Upper Mystic River basin under present day and future conditions. The probability that the banks of the Upper Mystic River could be overtopped by flood waters, resulting in subsequent inundation of roads and residential areas is, as shown in Figure 77, up to:

- 20% (or approximately every 5 years) under present day conditions,
- 20% (or approximately every 5 years) by 2030,
- 50% (or approximately every 2 years) by 2050, and
- 100% (annual flooding) by 2070.

Potential inundation in this region of Stonington would affect large segments of Route 27, developed areas along Main Street in Old Mystic, and developed areas along Whitehall Avenue. Although storm surge can also cause inundation

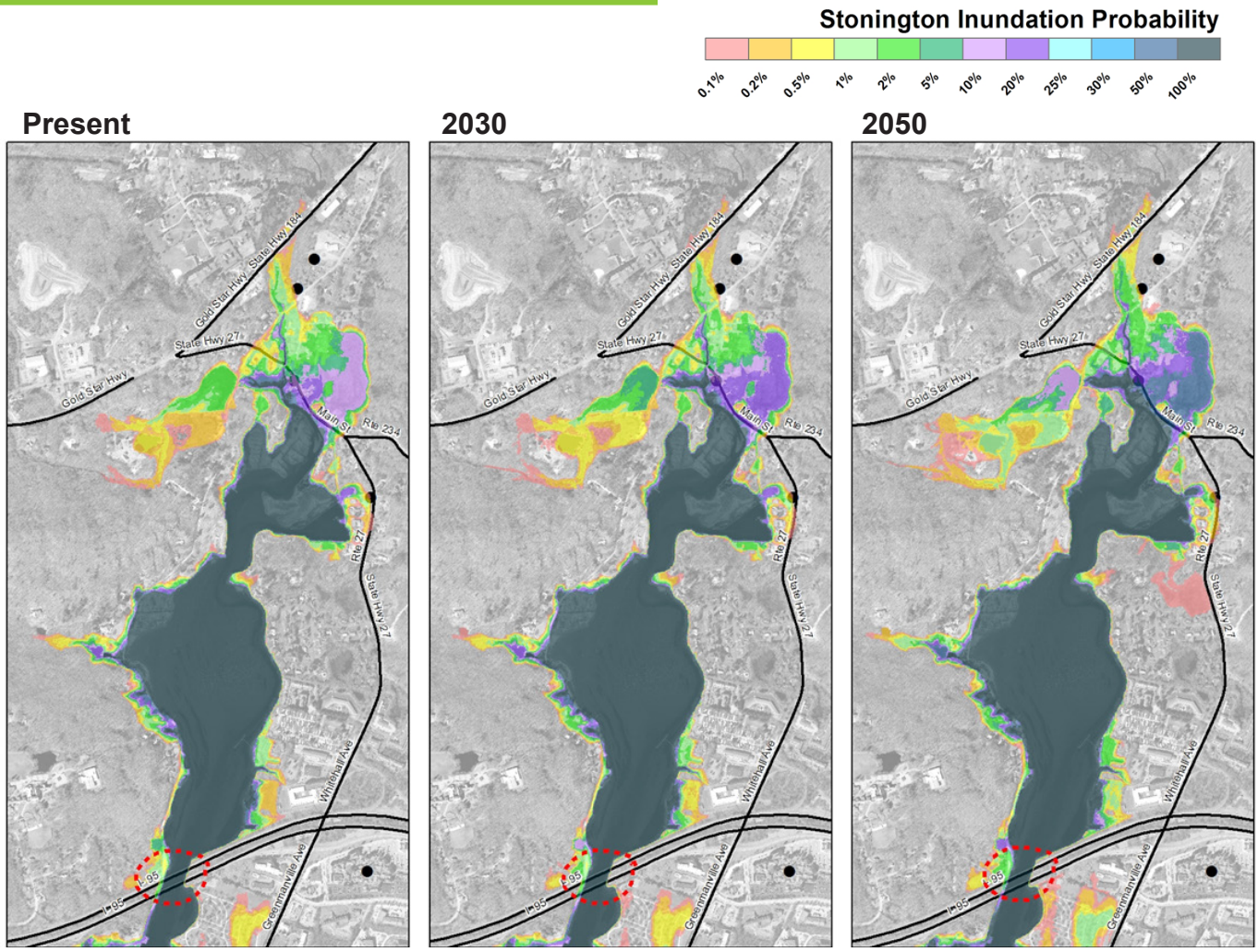


Figure 77: Coastal Flood Exceedance Probability (CFEP) for the Upper Mystic River Basin. The red dashed circle shows the potential location of an I-95 adaptation.

along the western banks of the Mystic River, topography and development patterns in Groton result in less vulnerability.

The bermed area created by the I-95 crossing at the Mystic River provides an opportunity for a regional intervention. Retrofitting one of the I-95 bridges with an array of adjustable tide control gates underneath the bridge to prevent storm surge from propagating further upriver could prevent storm surge inundation in the Upper Mystic River basin. These tide gates would be adjustable so that most of the time they would be open to allow tidal exchange, but would be able to be closed in the case of an impending storm event. Such a regional adaptation could prevent up to:

- 113 acres of present day inundation,
- 121 acres of inundation by 2030,
- 141 acres of inundation by 2050, and
- 159 acres of inundation by 2070.

The proposed I-95 Regional Adaptation would be redundant (or the need for it would be greatly reduced) if the Mystic Regional Adaptation (discussed later) is implemented downstream. Therefore, this solution may not be the most beneficial for Stonington; the other alternatives discussed in this section may be more effective at protecting a larger area of Stonington.

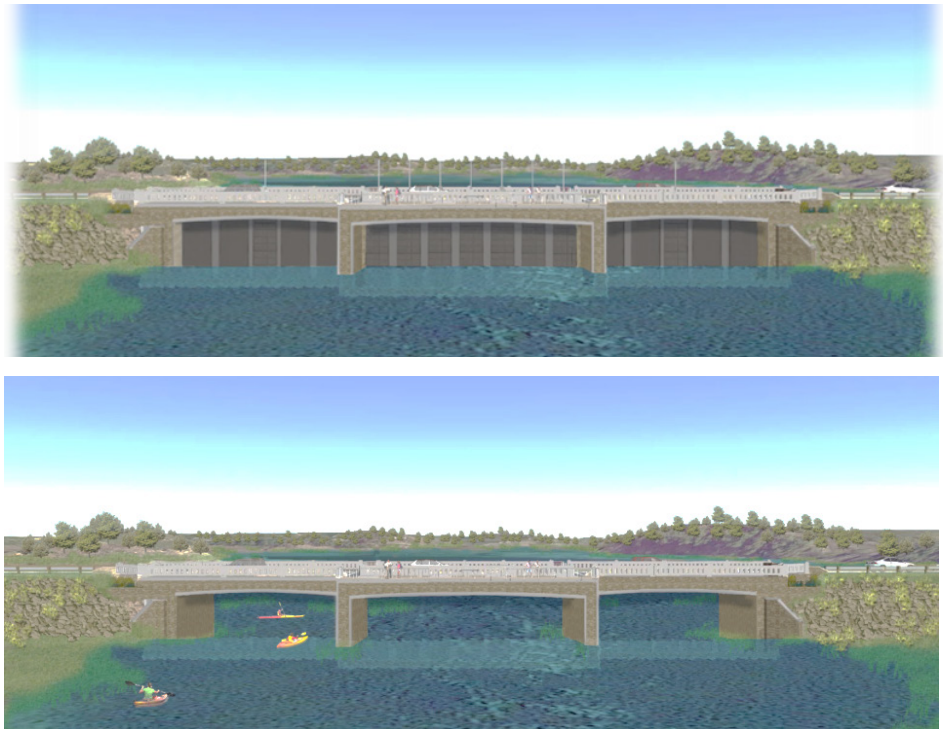


Figure 78: Example of a Tide Gate at the Herring River Restoration Project in Wellfleet, MA

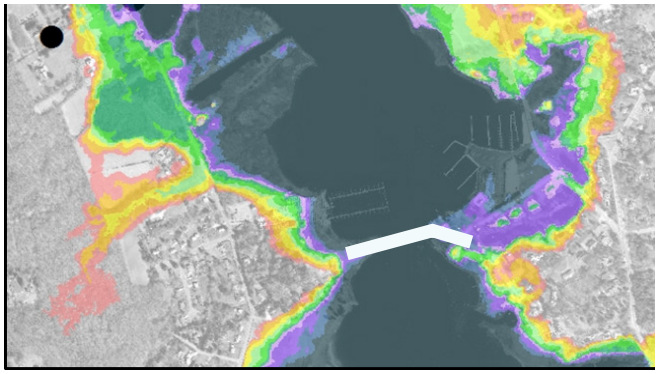


Figure 79: Potential location for a hurricane barrier in the Pawcatuck River Basin (in white)

Figure 80: Example hurricane barrier from New Bedford, Massachusetts

Pawcatuck River Regional Adaptation

Storm surge could inundate portions of the Pawcatuck River basin under present day and future conditions. The probability that the banks of the Pawcatuck River could be overtopped by flood waters, resulting in subsequent inundation of roads and developed areas is, as shown in Figure 81, up to:

- 20% (or approximately every 5 years) under present day conditions,
- 50% (or approximately every 2 years) by 2030,
- 100% (annual flooding) by 2050, and
- 100% (annual flooding) by 2070.

Potential inundation in this region of Stonington would affect segments of River Road and adjacent residential areas, segments of Mechanic Street, and developed areas in Pawcatuck and Westerly. The constriction and adjacent elevated area on the Pawcatuck River, south of the Westerly Yacht Club and Stonington on the River, provides an opportunity for a regional intervention. A hurricane barrier (Figure 80) at this location to prevent storm surge from progating further upriver could prevent storm surge inundation in the Upper Pawcatuck River basin. Similar to adjustable tide gates, the hurricane barrier would be open a majority of the time, but could be closed to protect the upstream basin during an impending coastal storm event. It is estimated that such a regional adaptation could prevent up to:

- 422 acres of present day inundation,

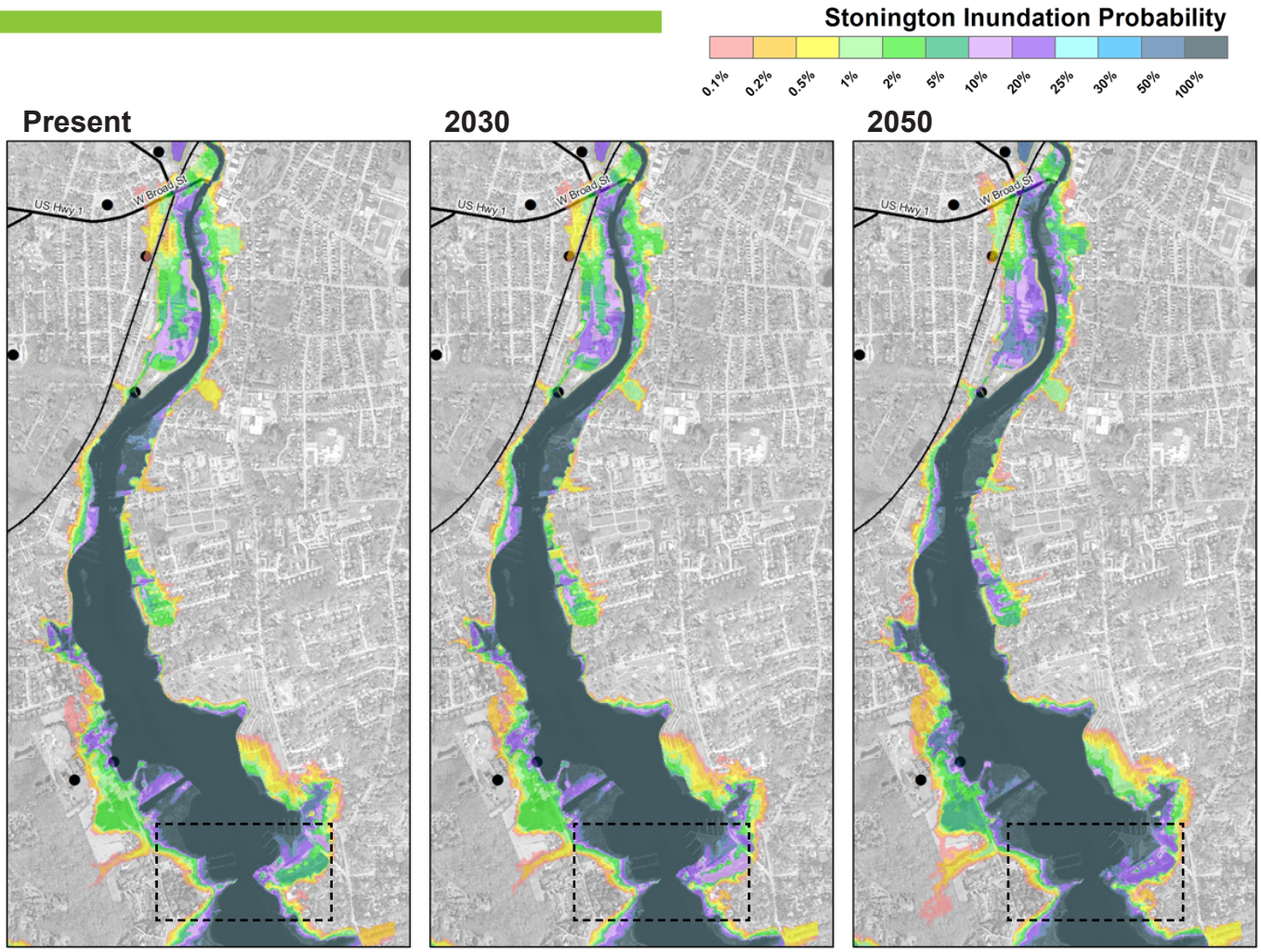


Figure 81: Coastal Flood Exceedance Probability (CFEP) for the Pawcatuck River Basin. The black dashed square shows the potential location of a regional adaptation.

- 443 acres of inundation by 2030,
- 490 acres of inundation by 2050, and
- 562 acres of inundation by 2070.

Stonington Borough Regional Adaptation

Storm surge could inundate portions of the upland areas surrounding Lamberts Cove and Quannaduck Cove under present day and future conditions. The probability that the railroad tracks across Stonington Harbor could be overtopped by flood waters, resulting in subsequent inundation of roads and developed areas to the north is, as shown in Figure 83, up to:

- 20% (or approximately every 5 years) under present day conditions,
- 20% (or approximately every 5 years) by 2030,
- 50% (or approximately every 2 years) by 2050, and
- 100% (annual flooding) by 2070.

Potential inundation in this region would affect segments of Wamphassuc Point Road, Route 1, Route 1A, North Main Street and Alpha Avenue, and adjacent residential and commercial areas. The linear berm of the railroad tracks may provide an opportunity for a regional intervention. A multi-element intervention (consisting of elevating railroad tracks from Noyes Avenue to the Wadawanuck Club, a living shoreline treatment at the top of Wamphassuc Neck, tidal control gate arrays at each railroad bridge, and a green infrastruc-

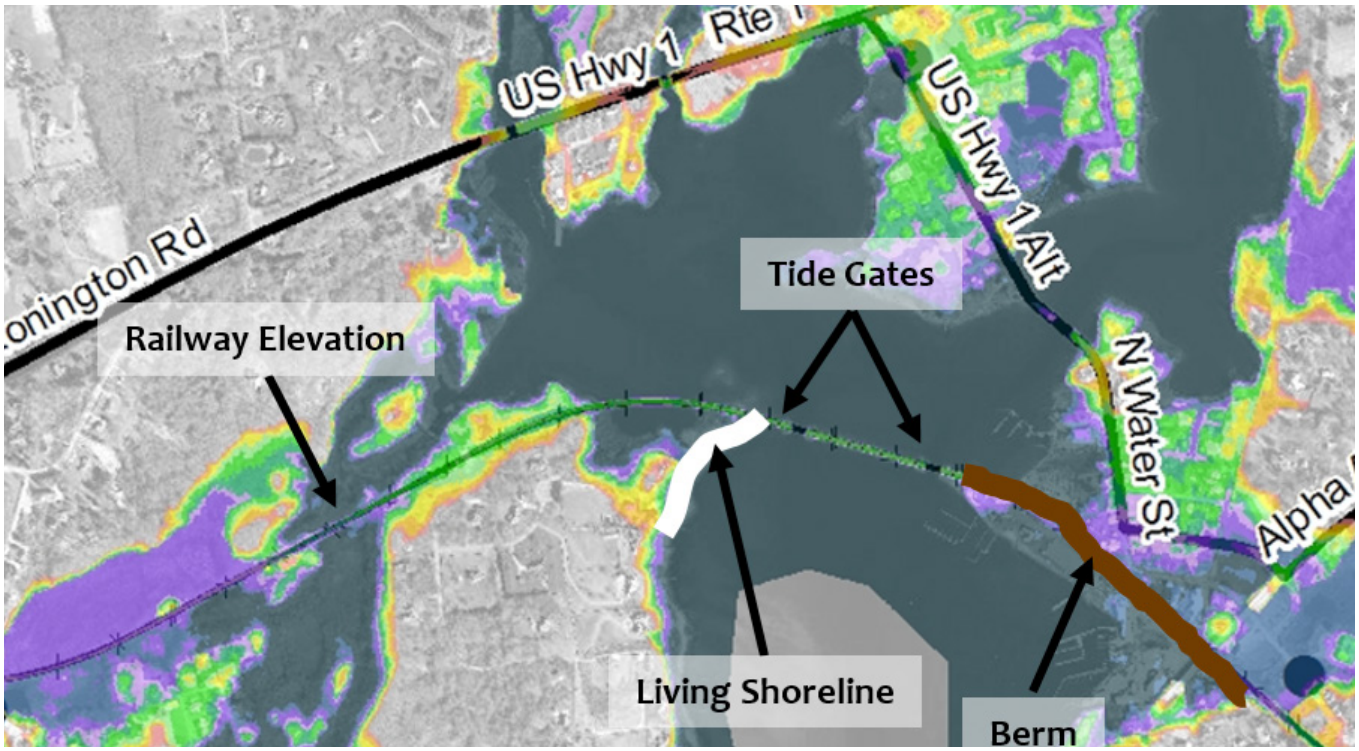


Figure 82: Elements of potential regional protection approach for the Stonington Borough area.

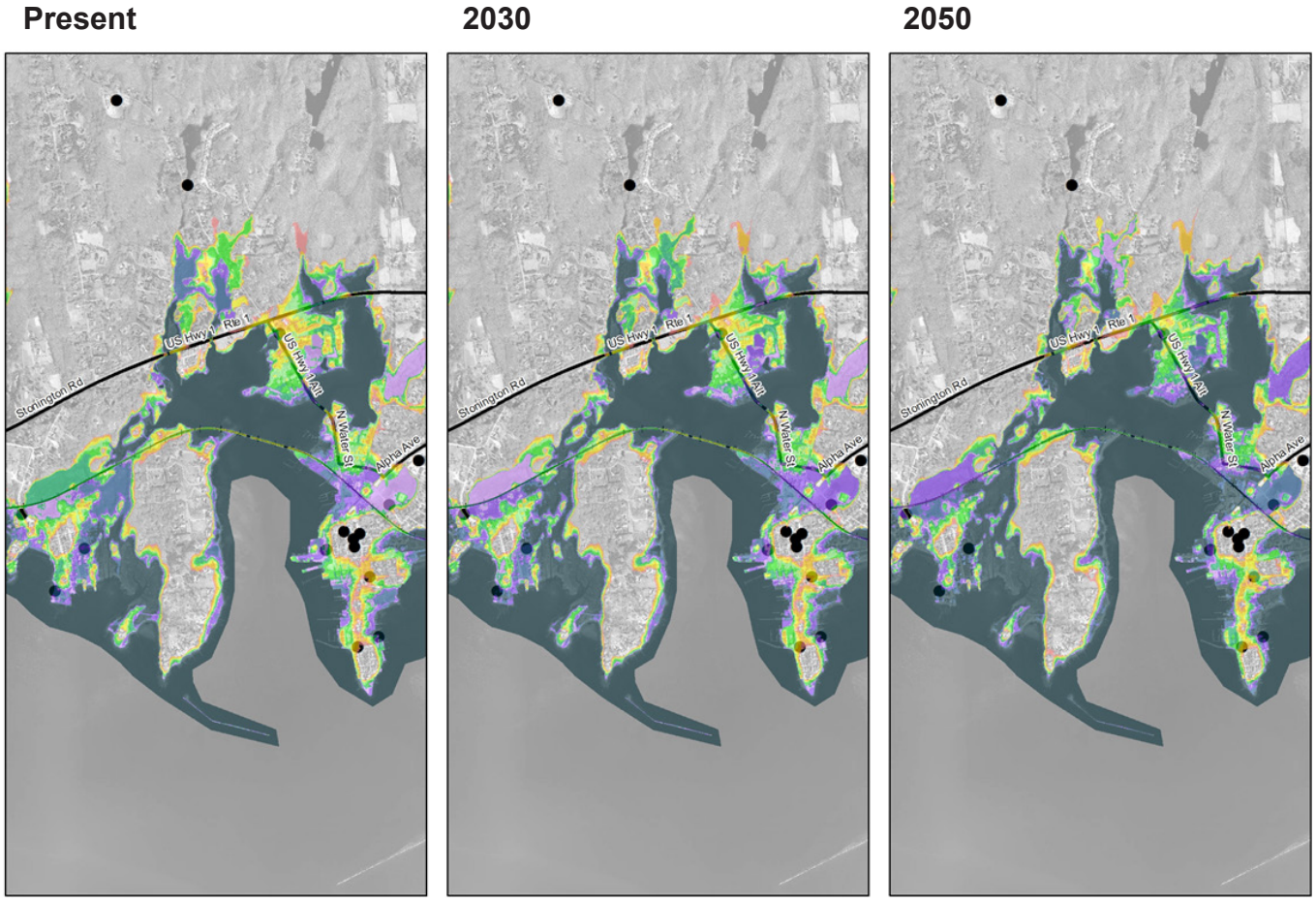
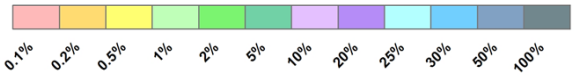


Figure 83: Coastal Flood Exceedance Probability (CFEP) for the Stonington Borough area.



ture berm from the Wadawanuck Club to the Elm Street pedestrian railroad overpass) could prevent storm surge inundation in the areas around Lamberts Cove and Quannaduck Cove. Depending on the target elevation, the adaptation project may also require modifications to roadways that cross or pass over the railroad (Noyes Avenue, Wamphassuc Point Road, and Alpha Avenue). Elements of this potential regional protection approach are shown in Figure 82. It is estimated that such a regional adaptation could prevent up to:

- 252 acres of present day inundation,
- 261 acres of inundation by 2030,
- 278 acres of inundation by 2050, and
- 302 acres of inundation by 2070.

Mystic Regional Adaptation

Storm surge could inundate portions of the upland areas surrounding the Mystic River, Pequotsepos Brook, and the cove east of Latimer Point under present day and future conditions. The probability that the banks of these water bodies could be overtopped, resulting in subsequent inundation of roads, residential, and commercial areas is, as shown in Figure 85, up to:

- 100% (annual flooding) in the present-day,
- 100% (annual flooding) by 2030,
- 100% (annual flooding) by 2050, and
- 100% (annual flooding) by 2070.

Potential inundation in this region of Stonington would affect large portions of downtown Mystic, areas in the Mystic River basin north of I-95, as well as Route 27, Route 1, Hewitt Road, and Mistuxet Avenue. These areas contain dense residential, commercial, and industrial development, as well as a number of critical assets.

Again, the linear berm of the railroad tracks provides an opportunity for a regional intervention. A multi-element intervention (consisting of elevating railroad tracks from Fort Rachel Marina to the Wilcox Road and tidal control gate arrays at each railroad bridge and culvert) could prevent storm surge inundation in the areas around the Mystic River, Pequotsepos Brook, and the cove east of Latimer Point. Depending on the target elevation, the adaptation project may also require modifications to roadways that cross or pass over the railroad (Broadway Avenue, Masons Island Road, and Latimer Point Road). Elements of this proposed regional resiliency option are shown in Figure 86. It is estimated that such a regional adaptation could prevent up to:

- 706 acres of present day inundation,
- 734 acres of inundation by 2030,
- 795 acres of inundation by 2050, and
- 869 acres of inundation by 2070.

Figure 84: Example of a Raised Rail

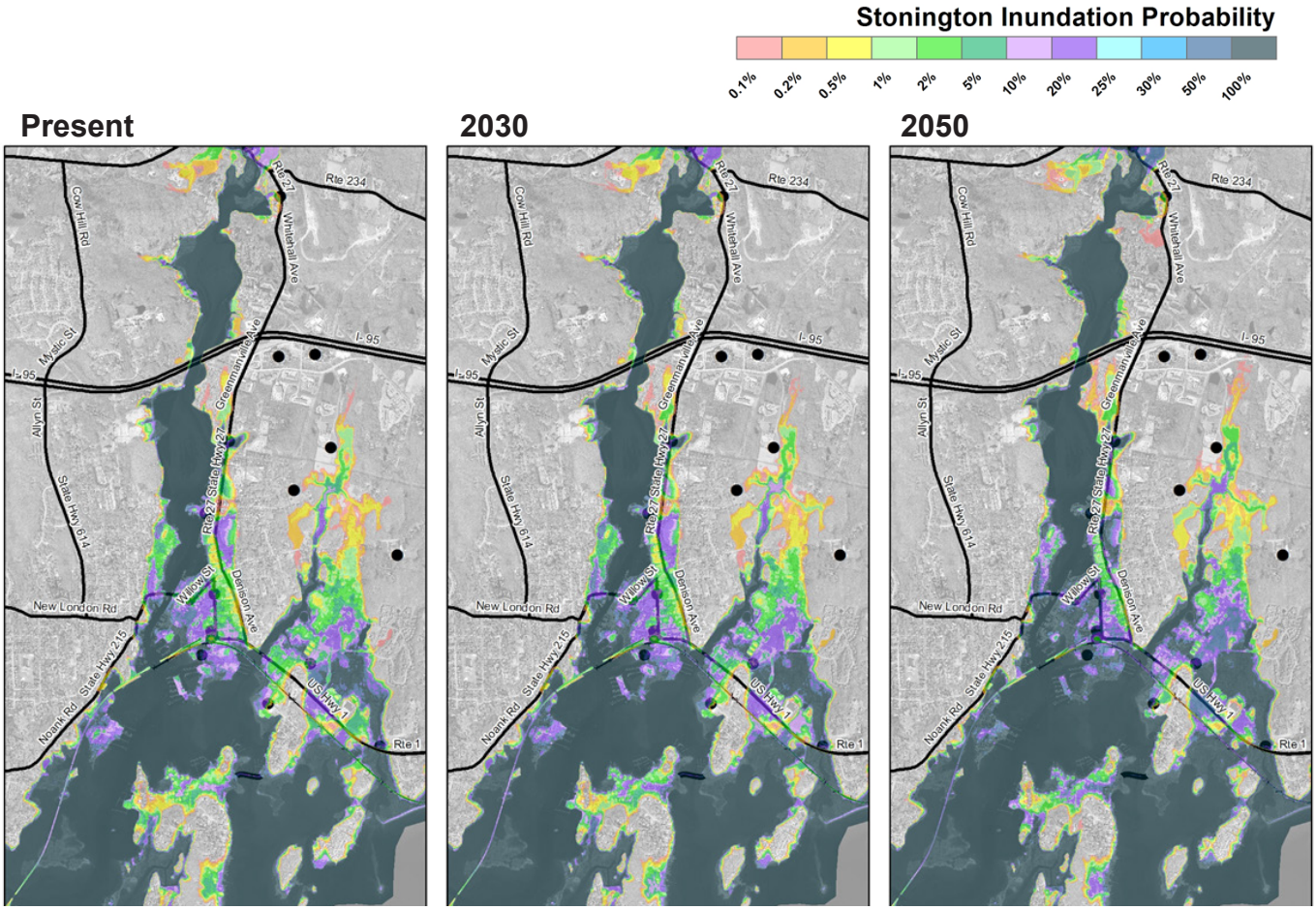


Figure 85: Coastal Flood Exceedance Probability (CFEP) for the Mystic Region.

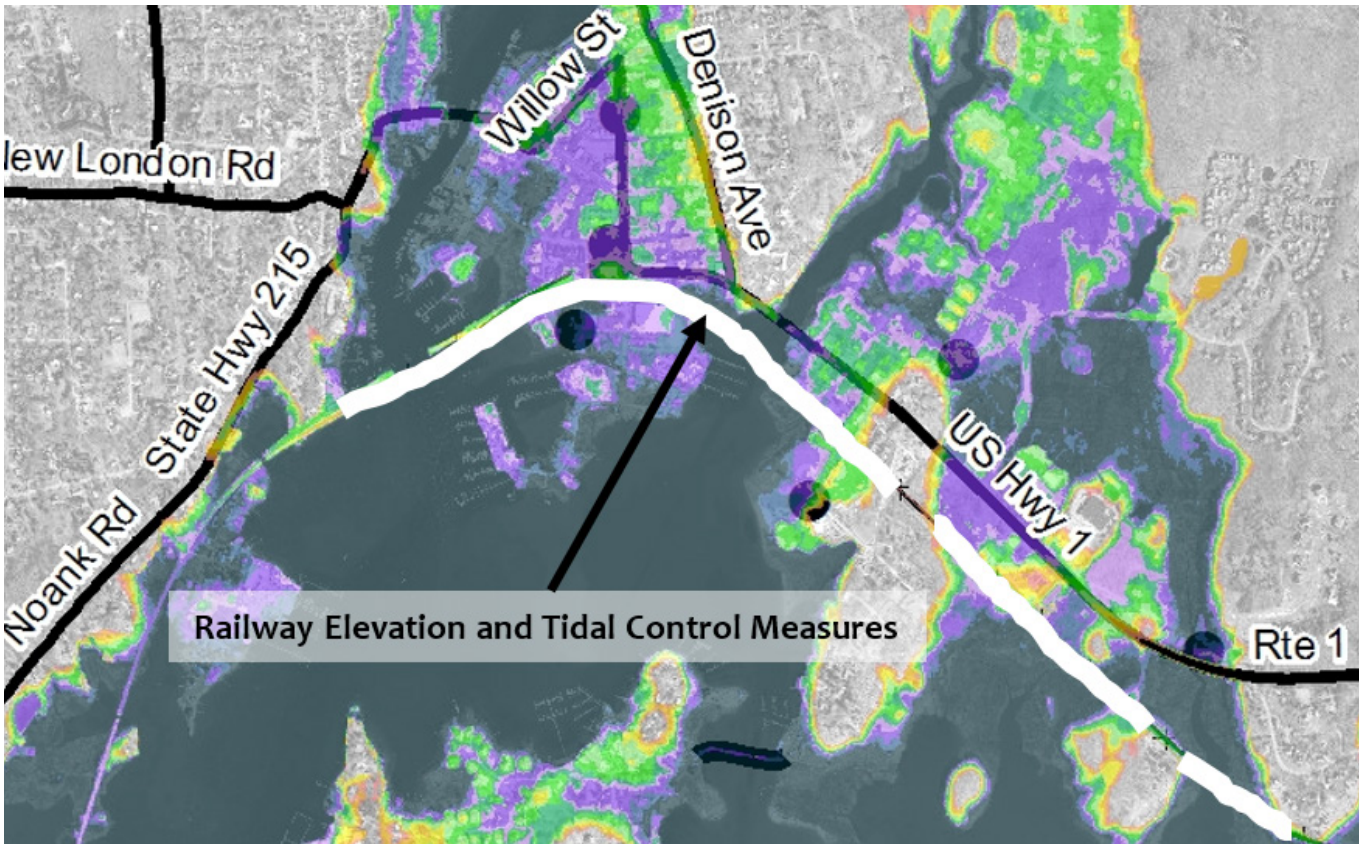
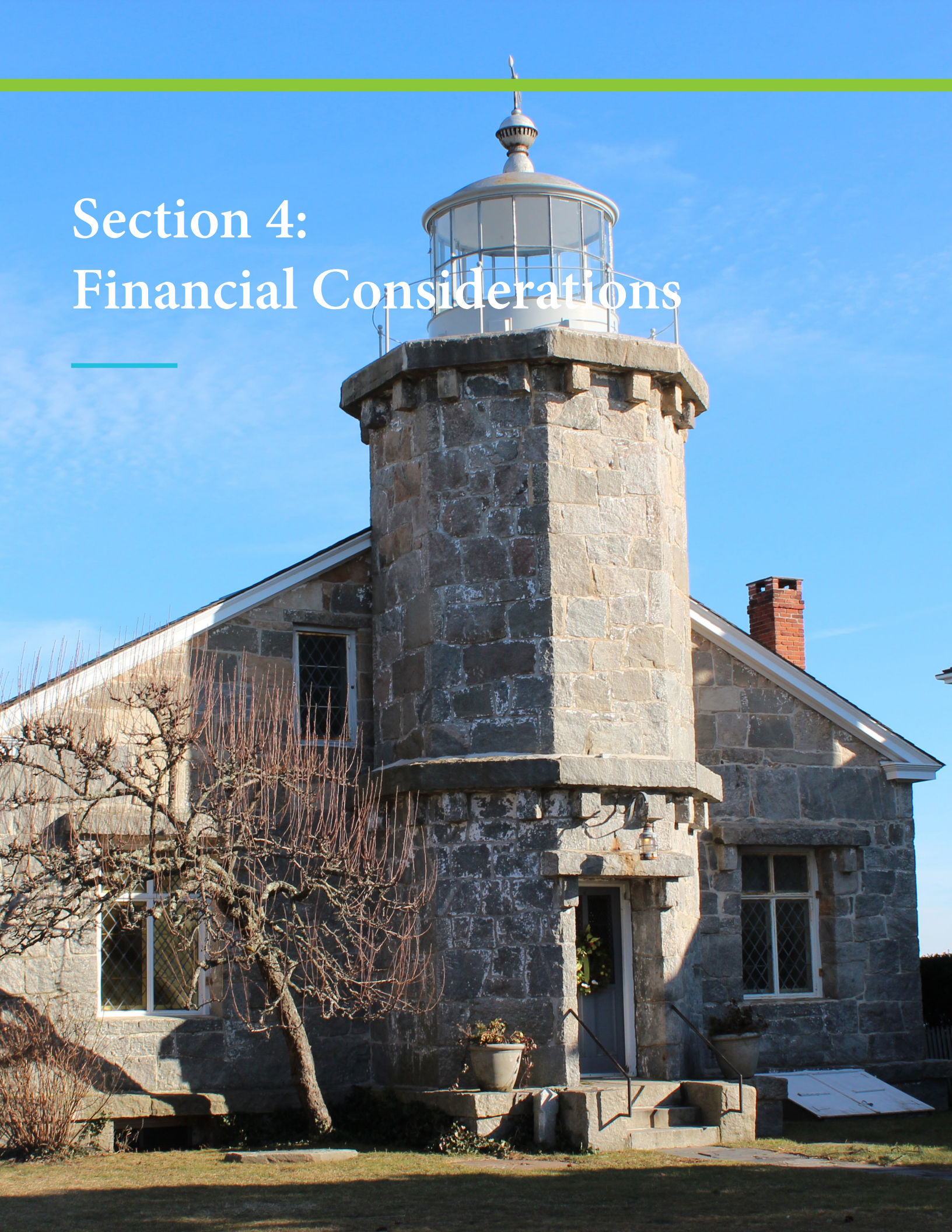


Figure 86: Elements of potential regional protection approach for the Mystic area.

Section 4: Financial Considerations



Cost-Benefit Analysis

While there is an inherent appreciation that climate resilience is a good thing, it is a more challenging task to fully capture that benefit in monetary terms. There have been several attempts to develop a general metric for assessing the savings associated with investing in climate resilience as compared with the costs associated with post-disaster response and recovery. The results vary based on the factors identified as part of each analysis, but some of the outcomes have shown the following rates of return on investment:

- $1 invested in building resilience saves $4 in disaster response and recovery[13]
- $1 invested in resilience saves: $4-7 in response, $5-10 in avoided economic losses[14]
- $1 invest in disaster preparedness saves $7-10 on response[15]
- $1 invested in preparedness is worth $15 in disaster relief efforts[16]

To supplement these estimates, this plan provides a high-level overview of the amount of land area and value of property in Stonington that could be at-risk to future sea level rise and storm surge, as well as an estimate of the acres of land that would be protected from inundation as a result of each of the proposed regional adaptation solutions. The costs associated with the adaptation solutions were expressed as an order of magnitude. Likewise, the land values were ascertained simply by using the current market values available in the town's assessors' database. It is important to note that these values are highly generalized, high level estimates and should only be used to understand the potential order of magnitude of these costs, impacts and potential savings. They should be not be used for any detailed planning work or design and engineering studies.

In order to understand the full value of the proposed solutions, a more comprehensive cost-benefit analysis would be required. A holistic cost-benefit analysis would include not only the economic considerations but also social and environmental co-benefits. Below is a representative listing of the types of information that would be included in a more comprehensive cost-benefit analysis.

Economic impacts:

- Direct, physical impacts
- Business continuity and cascading regional impacts
- Lost opportunities
- Creditworthiness and insurability

Social impacts:

- Costs associated with not being able to access critical services
- Job loss, public health impacts, decrease in quality of life
- Recurrent challenges borne by those most vulnerable
- Public safety concerns

Environmental considerations:

- Degradation of the natural environment and associated ecosystems

Funding

Many of the solutions suggested in this plan will require a significant amount of funding in order to implement. The following section details potential funding sources and initiatives; however, funding sources are constantly changing and the Town will

need to remain diligent in identifying new funding opportunities as they become available.

While there are a variety of funding sources available, it is important that the Town recognize the need to contribute its own funding to these solutions. With the current political climate, it is likely that many of the government-supported funding opportunities may become unavailable. In addition, the federal government is taking steps to encourage states and cities to take on more responsibility for resilience. FEMA is in the process of developing a disaster deductible that will require state and local government to implement resilience measures in order to be eligible for certain post-disaster funding sources provided by the federal government. Furthermore, many of the current funding opportunities require a minimum of a 25% matching contribution for the entity that receives the grant. Therefore, the Town will need to think about identifying ways to leverage Town funds for coastal resilience projects. Some potential town funding mechanisms may include:

- Town budget and capital improvement plans – The town should advocate for the inclusion of coastal flood protection and climate adaptation measures as an annual line item in the town budget and capital improvement plan. This could begin as a small allocation in the annual budget and increase over time as the Town's flood protection priorities become clearer.
- Tax Increment Financing (TIF) districts and impact fees to support flood protection infrastructure.
- Public-Private Partnerships (P3) – P3 allows for cost sharing between the Town and private entities and many communities are beginning to use P3 funding for large-scale infrastructure improvements.

Additional funding sources include:

Community Development Block Grants (CDBG) funding from Department of Housing and Urban Development (HUD) can be used for infrastructure improvements. Within Connecticut, the CDBG programs – also known as the Small Cities Program – is only available to towns and cities with populations of less than 50,000. Resilience based intentions should be described in annual Action Plan (or in their overall Consolidated Plan if due again after a 5 year period). If the work significantly departs from what has been proposed in the previous Consolidated Plan, communities must submit an amendment to HUD for incorporating new approaches. For the Town to use CDBG funding from HUD, they must meet the national objectives of the program:

- Benefit to low- and moderate-income(LMI) persons;
- Aid in the prevention or elimination of slums or blight; and
- Meet a need having a particular urgency (referred to as urgent need).

While 20% of the CDBG grant can be deducted for administrative purposes, 70% of the overall grant must benefit LMI persons. In Stonington, past CDBG Small Cities grants have been used to revitalize public housing. If the town demonstrated in the future that at least 70% of this source would still benefit LMI populations, it could ostensibly use the remaining funds on administrative and infrastructure resilience projects having particular urgency. The intended use would have to be clear and presented to the State of Connecticut in the application for funding. This source would likely cover a minor project or part of a project and cannot be viewed as a substantial source of

funding for larger infrastructure projects.

The **Community Development Block Grant-Disaster Recovery (CDBG-DR) program**, from which this Coastal Resilience Plan was funded, is associated with federally-declared disasters. Eligible uses of the funding depend on the Action Plan of the CDBG-DR grantee and how the grantee determines the funds will be used, subject to HUD's restrictions. In this case, the State of Connecticut is the CDBG-DR grantee and those funds are administered through the Connecticut Department of Housing. Typically, eligible uses for CDBG-DR funds are based on a post-disaster needs assessments of housing, economic development, and infrastructure. For the latest allowable uses, refer to the State of Connecticut's CDBG-DR Action Plan and associated Amendments.

The National Oceanic and Atmospheric Administration (NOAA) sponsored a 2017 **Coastal Resilience Grants Program** that supports two categories of activities: (1) activities that improve capacity for coastal jurisdictions to manage extreme weather events and climate-related hazards, and (2) activities that restore and strengthen existing coastal ecosystems to mitigate the impact of extreme weather and climate hazards. Although the 2017 application window has closed, the program may be reprised and is a potential source of future funding.

The **Federal Emergency Management Agency's (FEMA) Community Rating System (CRS)** is a voluntary program that incentivizes communities to engage in floodplain management activities beyond the minimum standards set forth in the National Flood Insurance Program (NFIP). Property owners in the community can receive up to a 45% discount on their flood insurance premiums, depending on the floodplain management activities implemented by the community. Stonington previously participated in the CRS program and is actively working with FEMA to have Stonington reinstated into the program.

The **FEMA Pre-Disaster Mitigation Grant Program (PDM) and Hazard Mitigation Grant Program (HMGP)** provides post-disaster federal aid to states and local communities to mitigate the risks of future disasters. HMGP recipients may include individuals, businesses and private non-profits, but all groups must apply through their local governments. Grants support flood mitigation projects, including acquisition and relocation of flood-prone properties, dry floodproofing, elevation of properties, soil stabilization projects, hazard mitigation plans, and more. FEMA HMGP funds have a match requirement. FEMA will provide up to 75 percent of the project funding through HMGP and the grantee is required to fund the remaining 25% (or more depending on the terms of the grant). Homeowners, for instance, may receive HMGP funding to floodproof residences, but must show support from other sources. One potential source could be the National Flood Insurance Program (NFIP) Increased Cost of Compliance (ICC) coverage, which helps individuals cover the cost of preparation measures to reduce future flood damage, a requirement of the NFIP in certain instances. FEMA also offers Preparedness (Non-Disaster) Grants for communities wishing to enhance their capacity for emergency preparation, response and recovery.

The **FEMA Flood Mitigation Assistance (FMA) Program** provides funding to state and local governments, and certain non-profits, to implement measures that will reduce or eliminate risk of flood damage to buildings insured under NFIP. The primary responsibility for administering mitigation activities resides with the states. The state point of contact is the State Hazard Mitigation Officer. Cost sharing is typically required for

all FMA projects, with the federal government providing up to 75% of the cost of the project.

The **FEMA Emergency Management Performance Grant (EMPG)** program supports comprehensive, all-hazard emergency preparedness systems and planning, including planning for future disasters and catastrophic events. Cost sharing is required and the federal government will provide up to 50% of the funding for a specific project.

The **Environmental Protection Agency's (EPA) Nonpoint Source Program and the Urban Waters Small Grants Program** provides up to $60,000 of funding to states to reduce pollution from stormwater runoff, improve water quality and generally create healthy urban waters. Such projects should spur further community revitalization and, ideally, will benefit underserved communities. The types of projects funded in the Small Grants Program may yield co-benefits of flood or storm mitigation.

The **National Fish and Wildlife Foundation's (NFWF) 2017 Resilient Communities Program** helps communities prepare for future impacts associated with sea level rise, water quantity and quality. The program includes focuses on water quality and sea level rise. Specifically, communities are eligible for between $100,000 and $250,000 for projects supporting "community capacity building and demonstration projects" and $200,000 to $500,000 for projects to combat sea level rise. Between three and six grants are typically awarded annually, with projects lasting up to 24 months. Matching contributions of 1:1 or higher are considered more competitive; matching funds may include cash, in-kind contributions of labor or time, materials, and services donated. Although the 2017 funding proposal date has passed, the Resilient Communities Program is a good option for future funding.

The **Connecticut Institute for Resilience and Climate Adaptation (CIRCA) administers the Municipal Resilience Grant Program**, focused on furthering the climate resilience of Connecticut's municipalities. CIRCA has administered other grant programs in the past, so it would be valuable to pay attention for future grant opportunities.

The **Connecticut Flood and Erosion Control Board (FECB)** program. Under this program, the Town creates a local flood control board that could be eligible for state funding.

The **U.S. Army Corps of Engineers** offers a variety of grant opportunities in addition to its ongoing flood control work, both to construct and maintain flood control structures, such as those in the Village of Pawcatuck.

The U.S. Department of Agriculture's Natural Resources Conservation Services (NRCS) administers the **Emergency Watershed Protection (EWP) program** and the **Watershed and Flood Prevention Operations (WFPO) program**. The EWP responds to emergencies created by natural disasters and is designed to help people and conserve natural resources that are impacted by floods, fires, windstorms, and other natural occurrences. The WFPO provides technical and financial assistance to States, local governments, and Tribes to plan and implement authorized watershed project plans to provide watershed protection, flood mitigation, and other watershed benefits.

The **Clean Water State Revolving Fund (CWS-RF)** provides communities with a permanent, independent source of low-cost financing for a wide range of water quality infrastructure proj-

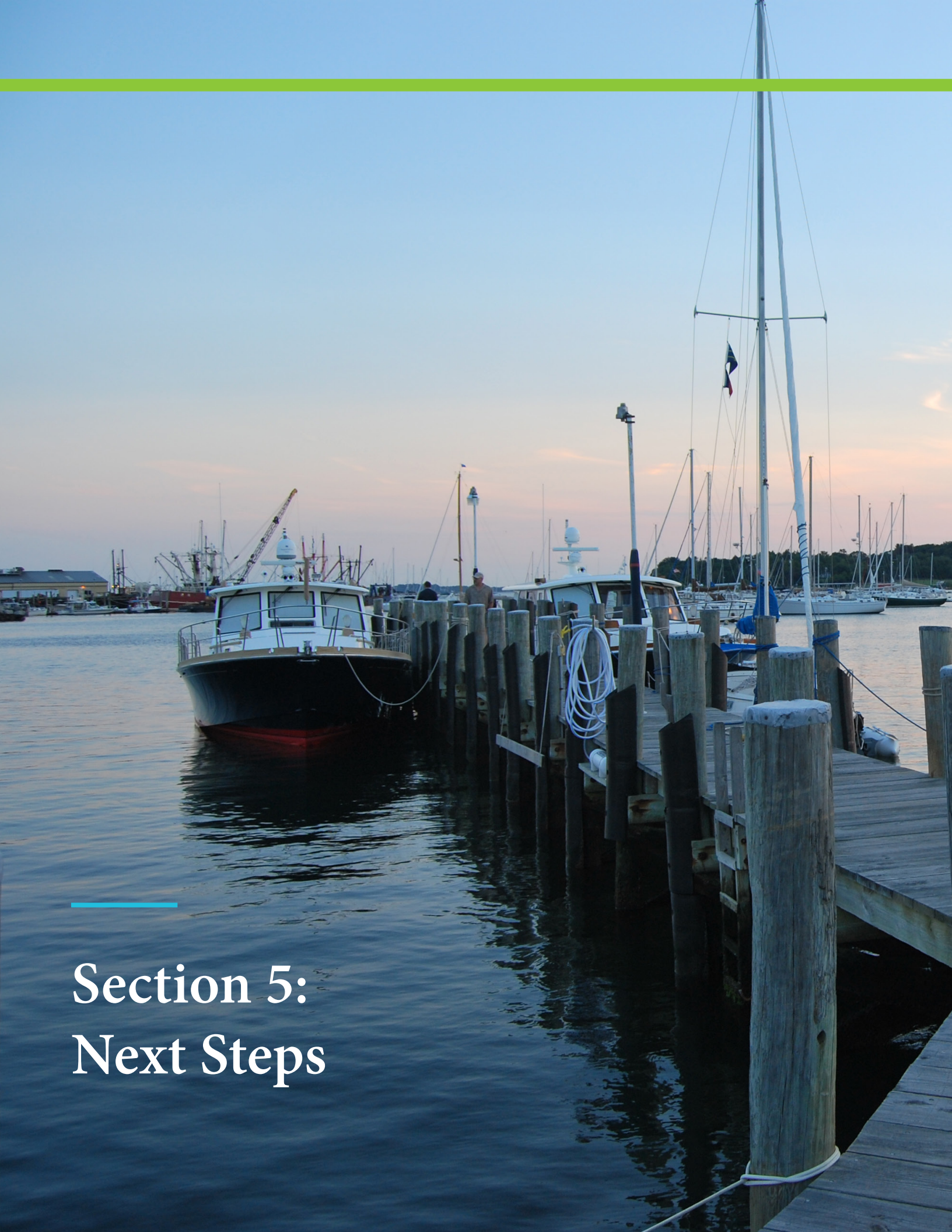
ects, including stormwater projects, watershed pilot projects, energy efficiency, and wastewater treatment facilities.

Philanthropic Sources include several large philanthropic organizations that support resilience work on a regular basis. These include the *Rockefeller Foundation*, the *Kresge Foundation*, the *Tides Foundation*, and the *Oak Foundation*, to name a few. Smaller grants are made available by organizations such as *Lions Club International Foundation*, which offers grants for disaster preparedness and recovery.

Partners for Places offers grant funding for local projects that promote healthy environments, strong economies, and well-being of all residents. The grant is made possible through a partnership with the Funders' Network for Smart Growth and Livable Communities, the Urban Sustainability Directors Network Bloomberg Philanthropies, The JPB Foundation, Kendeda Fund, the New York Community Trust, the Summit Foundation and Surdna Foundation. Grants range from $25,000 to $150,000 depending on the size and length of project and require a one-to-one match with local foundations.

Enterprise Community Partners recently closed their 2017 application for the Climate and Cultural Resilience Grant Program, which awarded five grants of $100,000 to local organization looking to build more resilient communities. It may be valuable to pay attention to future opportunities from Enterprise.

Resilience bonds are an emerging resource that modifies traditional catastrophe bonds to provide insurance savings that can be captured as rebates in order to invest in resilient infrastructure.



Section 5: Next Steps

Top Priority

Based on the town-wide vulnerability and risk assessment, the neighborhood-specific assessments, and the proposed regional solutions for the Town of Stonington, the proposed Mystic Regional Adaptation is likely to have the greatest capacity to protect the Town of Stonington from coastal flood impacts. The Mystic Regional Adaptation solution protects the greatest amount of vulnerable land area and would likely preclude the need for an additional resilience solution, such as the I-95 Regional Adaptation, in the upper Mystic River basin. In addition, the Village of Mystic is one of the town's most vulnerable neighborhoods in terms of number of vulnerable assets and land area as well as impacts to the Town's economy. Stonington's economy is largely a tourism-driven economy and many of the resources that drive that tourism are located in and around the Village of Mystic, including important and priceless historical assets. In addition, the solution would help protect the Mystic Amtrak station, which is also highly vulnerable and plays an important role in bringing tourists to Stonington as well as allowing Stonington residents to commute in and out of the Town for access to jobs.

There may be opportunities for collaboration and cost sharing with businesses and residents that would be protected by this solution, including the coordination with the neighboring Town of Groton, which would also benefit from the implementation of this type of solution.

Next Steps

This Coastal Resilience Plan is intended to be a first step in the Town of Stonington's efforts to become more prepared for and protected against coastal flood events. While the Mystic Regional Adaptation solution is a high priority solution for the Town, we recognize that implementing this type of solution will be challenging, as it will require a significant amount of funding, coordination across multiple local, state and federal actors, and several years of coordination, design and construction. Therefore, the following section details additional smaller scale solutions that can help ensure a more resilient future for Stonington and will result in less challenging implementation and funding barriers.

Short-Term (Over the next 1-2 years)

1. Stonington should renew its participating in the Community Rating System (CRS) program and work to improve its CRS score in order to improve the community's resilience and reduce flood insurance premiums for the residents and business owners in the community.

2. Stonington should consider the feasibility of implementing a targeted floodplain buyout and relocation program for the most at-risk areas of town. Potential pilot studies for this type of program could focus on vulnerable neighborhoods, like Masons Island or Lords Point, or could be based on all properties located in the current FEMA VE zone or designated as at-risk properties as part of The Nature Conservancy's Salt Marsh Advancement study.

3. The Town has already done a significant amount of community engagement through this planning process and other town-wide

resilience initiative. It is important to build off the current interest and engagement from the community, cultivated as part of this planning process, and continue to engage with the community on a regular basis in regards to on-going resilience and flood protection initiatives. Education is often one of the most important aspects of making a community more resilient. Communities that not only understand their risks, but also build deep community ties and the communities that are more prepared for flood events and are more resilient in the face of flood events, as a result of the connections within the community. Some examples of future community engagement efforts could include:

- Developing brochures and other quick guides to disseminate to residents and business owners to explain their risks and ways that they can better protect their properties and assets.

- Maintaining the dialogue on coastal resilience with the Mystic Aquarium, Mystic Seaport, and other key community stakeholders, so they can promote events, distribute materials, and engage with their members on these important issues. One key group to continue engagement with is the Mystic Aquarium's Youth Conservation Corps. This group of teens is actively engaged in environmental conservation and has been excited to be part of this planning study. They also provide an important, and often missed, connection to the younger demographic and can engage and educate their peers on these important issues; issues that will have a greater impact on their generation than their parents' and grandparents' generations. Some community events could include a coastal resilience-related scavenger hunt, geared at engaging young families, creating community art pieces, such as statues or murals, that help educate on climate change and flooding, and hosting community tree planting and other events.

4. Stonington has already taken several steps towards modifying its policies and regulations to encourage more resilient building practices; however, additional regulatory measures should be implemented to require more resilient development practices in floodprone areas. These regulatory measures may include: extending the boundaries of the CAM Overlay District and the Flood Hazard Overlay District, allow for more flexibility in the regulations for residents looking to implement resilience solutions on their properties, and modifying elevation and height restriction requirements. For more information, please refer to the Regulatory Audit Memorandum in Appendix X.

5. One important, and often overlooked, action is to leverage current projects as a means for furthering the Town's resilience goals. Obtaining funding and buy-in for infrastructure and development projects specifically geared at flooding and climate change can sometimes be difficult; however, the Town should formulate a process for ensuring that existing and future capital improvement projects also incorporate resilient design solutions. One example of this type of effort can be seen in Partners HealthCare's Spaulding Rehabilitation Hospital in Boston, MA. Partners made a commitment to incorporating many resilience initiatives into this hospital during construction and they found that incorporating these resilience measures only increased the cost of construction by

less than 1%. By thinking progressively, they were able to both keep costs down and ensure that their patients, staff, and the facility, itself, are all protected against future flood scenarios. Taking this approach to resilience is often a more cost-effective approach and an easier mechanism for making progress on resilience than proposing and funding an entirely new capital project geared at resilience.

Long-Term (Over the next 5 years)

1. Perform a stormwater modeling analysis to understand the impact of rainfall on Stonington's flood risk. Stonington is likely to experience increased rainfall events as a result of climate change and it is important to understand whether the Town's current drainage infrastructure has the capacity to handle this increase in precipitation. In addition, increased rainfall events in conjunction with a coastal flood event could have significant impacts on the flood risk of the Town. This analysis could be performed in phases, as necessary, depending on time and budget constraints.

2. In order to make meaningful progress on coastal flood protection and resilience, it will be vital for the Town to form working partnerships with local, state and federal actors as well as community stakeholders and non-profit institutions. This will build off and often overlap with the Town's continued community engagement efforts, but will also require a separate, dedicated effort to identify important partners and facilitate a dialogue on these flood-related concerns. Some potential partners that the Town should explore developing relationships with include:

   - Historic commissions and non-profits. Because Stonington has a large amount of priceless historic resources, engaging with entities that have an interest in protecting these resources would be highly valuable. Some examples include the Connecticut Trust for Historic Preservation and the Connecticut Office of Culture and Tourism. These relationships will likely be valuable in gaining support and promoting awareness of the Town's vulnerability, but also identifying funding sources to implement flood protection solutions.

   - Federal, state and local institutions that are actively engaged in coastal resilience issues. The University of Connecticut's Connecticut Institute for Resilience Climate Adaptation (CIRCA) would be a valuable partner in these efforts. Similarly, Connecticut Sea Grant is also very active on coastal resilience issues and may have opportunities for grant funding to further Stonington's resilience work.

   - Neighboring communities, such as Groton, Westerly and New London. New London could be a particularly important partner, due to the location of the United States Coast Guard Academy and the Naval Submarine Base. Both institutions are likely to garner interest on a federal level, which may result in additional funding for regional solutions that could also protect those important facilities. Stonington should leverage this plan to advance the climate change and resilience conversation by educating its neighboring communities on the risks and advocating for a regional climate coalition to coordinate on these issues. Flooding is not limited to Town boundaries and efforts to minimize coastal flooding concerns will require regional solutions. This coalition could be limited

to neighboring municipalities or it could be a broader coalition that includes local chambers of commerce and business leaders, neighborhood leaders, and other stakeholders in the region.

- Business owners within Stonington who are particularly at risk. The Town should facilitate conversations with these institutions to investigate potential mutually-beneficial projects. Some examples may include Amtrak, local energy providers, Apple Rehab Mystic, Mystic Aquarium, and Mystic Seaport.

- Non-profit entities who are already working in this space or should be acting in this space. The Nature Conservancy and the Trust for Public Land are two national actors that have particular interests in coastal resilience; however, there are likely many local non-profits who would also be interested in engaging with Stonington on this topic.

- Partnerships with similar communities. These types of partnerships could help Stonington leverage lessons learned in communities that are grappling with similar issues. Two particular communities could be Annapolis, MD and Norfolk, VA. Both of these communities have significant flood risk in addition to having priceless historic resources that they would like to protect from flood damage. Reaching out to the community planners and historic preservation officers in these communities may help Stonington identify important next steps from furthering its coastal resilience efforts.

3. The Town should consider implementing a TIF district, including funding for coastal resilience in its annual budget and pursuing opportunities for public-private partnerships geared at implementing resilience solutions. Amtrak may be a potential partner in these endeavors.

4. Pursuing a variety of grants, loans, and other outside sources of funding to fund the implementation of a variety of resilience solutions.

5. Conduct a feasibility analysis of the potential regional adaptation solutions in order to identify the costs and benefits of each solution and develop a potential implementation plan.

Stonington Commons (Author: By Pi.1415926535, Wikimedia Commons)

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Appendices

Appendix A:
GIS Data and Methodology Memo and GIS Maps

Appendix B:
Vulnerability and Risk Assessment Memo

Appendix C:
Resilience Solutions Memo

Appendix D:
Regulatory Audit Memo

Appendix E:
Literature Review Memo

Appendix F:
Sea Level Rise Memo

Appendix G:
Community Engagement Efforts

Appendix A:
GIS Data and Methodology Memo and GIS Maps

Memorandum

ARUP

To	Keith Brynes, Town Planner Town of Stonington	Date	February 16, 2017
Copies		Reference number	251043.00
From	Lisa Dickson, Arup Katie Wholey, Arup	File reference	
Subject	GIS Data and Methodology		

As part of the coastal resilience assessment, we collected all readily-available GIS data from the Town of Stonington in order to assess which assets are vulnerable to coastal flooding. Woods Hole Group (WHG) also compiled coastal flood projections for the following time horizons: present-day, 2030, 2050, and 2070. The information below details the GIS data we collected and what we are planning to use for the vulnerability and risk assessment. The data in red in the "Additional Data" category is the information that we received from the Town, but we are proposing not to use for this assessment.

1 GIS Layers

We worked with New England Geosystems to collect all of the town's available GIS layers applicable to this study. The following table includes all of the layers we received from New England Geosystems and any additional applicable information for each of the layers.

Category	Layer Name	Description	Notes from NE Geosystems
Drainage and Utilities	GPS_Outfalls GPS_outfallsAnno CulvertPoints	Stormwater Outfalls	GPS_outfallsAnno = Labels for GPS_Outfalls layer CulvertPoints and GPS_Outfalls are different versions of the town's data on outfalls
	GPSCBPoints GPSCBpoints2	Catch Basins	GPSCBPoints has 7 more points than GPSCBPoints2, so GPSCBPoints is likely the most up-to-date layer
	StormMH	Stormwater Manholes	
	CulvertPipes StormLines	Stormwater Pipes	CulvertPipes are the pipes that connect between culverts. StormLines are drain pipes

			underground which are usually connected by catch basins
	san_manholes	Wastewater Manholes	
	san_pumpstations	Wastewater Pump Stations	
	Sewer_Accts	Address points for all properties on town sewer	
	san_pipes	Wastewater Pipes	
	Sewer_Districts	Sewer Districts	
	Sewer_service_areas	Areas of Town Connected to Sewer	
	util_lines	Electrical Transmission Lines	
	ROW_Easement	Right of Ways and Easements	
Environmental Resources	Hydro_Names hydroArc hydro_poly	Water Bodies	Hydro_Names = Labels for hydroArc Hydro_poly is the same as hydroArc, but it also contains streams
	Island_Names	Labels of Islands	
	WetlandSurvey	Wetlands Boundary (by Survey)	
	Basins	Watersheds	
	ShellFish	Shellfishing properties (owned)	The layer was created from digitizing over a large scale map. The actual property boundaries would have to be researched in the archives for precise areas. Some are owned privately and possibly by the Town.
	Groundwaterprotection Groundwaterprotection_2	Designated groundwater protection zones	These seem to be the same layer.
	tree_cover	Tree Canopy	
	Soils_poly DEP_soils	Soil Types	DEP_soils has non wetland soils deleted and Soils_poly contains all soils, including non-wetlands soils
	AquiferDEP	Regulated Aquifers	

Boundaries	Coastal_Town_Boundary town	Stonington Boundary	Coastal town boundary is in relation to where the parcels ends. Town would include the water areas that fall within Stonington's jurisdiction.
	Address_points	Point locations of all Addresses in Stonington	
	Borough_Boundary	Stonington Borough Boundary	
	Border_Town_Poly	Bordering Town Boundaries	
	Zoning_2010	Zoning Districts	
	CAM	Coastal Area Management Zone	
	PARCELS_2015	Parcel boundaries	
	FEMA_BFE_2013	FEMA Base Flood Elevation	FEMA Base Flood Elevation. It is a line representing how far between one side of the coast to the other side of the flood coast in the 100yr flood zone.
	FEMA_2013	FEMA Flood Zones	
Critical Assets	POI_point	Points of interest	Hand-picked items that were believed to be points that would be of interest like schools, police, fire, aquarium etc. No certain schema and not sure who picked them.
	Schools_poly	School Parcels (not building footprint)	
	Town_Hall_poly	Town Hall Parcel (not building footprint)	
	town_owned_property_poly	All Town-owned Parcels	
	Police_Dept_Point	Point Locations of the Stonington Police Department	
	Fire_Station_Poly	Fire Station Parcels (not building footprints)	
	Schools	Point Location of Schools	
	Open_space	Preserved open space	

	plan_lines	Fences, Walls, Culvert, Hedges, Retaining Wall, Trail	Digitized layer of planimetric features located on the Aerial photo of 1999. They are interpreted to the best guess of whoever was digitizing those objects. Whether a wall is really just a wall or a retaining wall is not verified. This layer was purchased in conjunction with their 1999 aerial photo.
	buildings	Building Footprints	
	PlaniPoly	Cemetery, Docks, Golf Course, Headwall, Pier, Pools, Sports, Stock Piles, Tanks	Digitized layer of planimetric features located on the Aerial photo of 1999. They are interpreted to the best guess of whoever was digitizing those objects. This layer was purchased in conjunction with their 1999 aerial photo.
	Assessor_Database_2015	Assessor's data	GISLINK, MBL or unique ID would be best fields to join with parcels layer.
Transportation	Road	Paved and Unpaved Roads, Driveways and Parking	
	Railroad	Railroad tracks	
	Centerline	Streets (except dirt roads)	Street centerline layer, contains names and address ranges along with other information
	roadLine	Street Curbs	Showing street curbs.
Historic Resources	NewLondon_SHPO	State Historic Properties Layer	*Note: This layer was provided by Keith (not NE Geosystems)*
Additional Data	streetlights	Street light locations	
	Fire_Hydrants_2016	Location of Fire Hydrants	
	FireDistricts_Poly	Fire District Boundaries	
	Voting_Districts	Voting Districts	

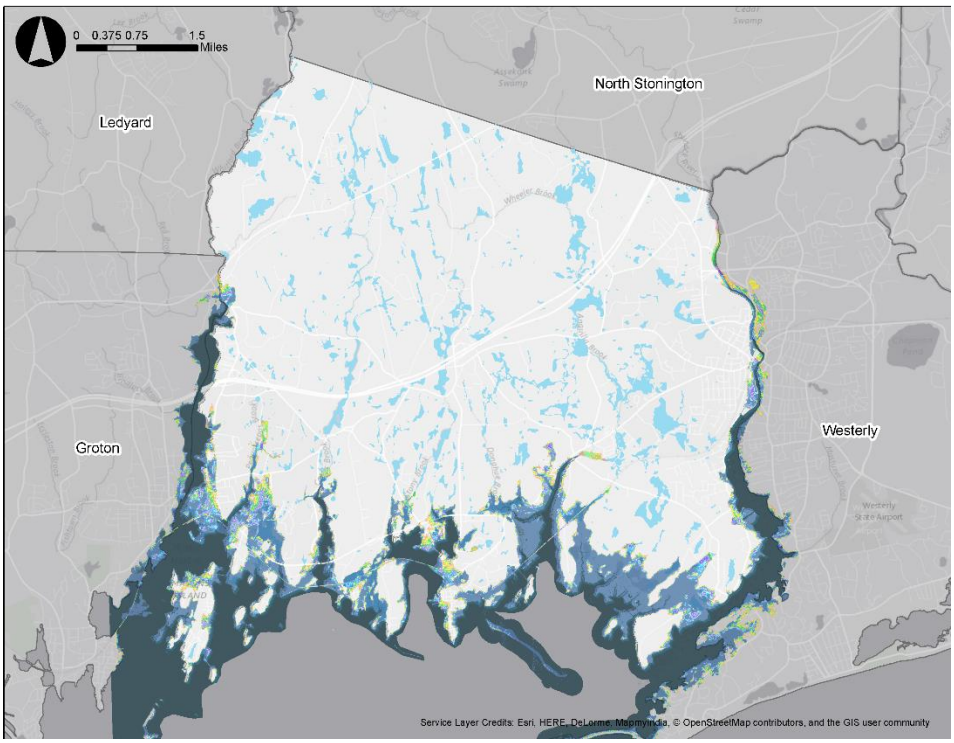
Woods Hole Group (WHG) also prepared coastal flood layers based on projected sea level rise and storm surge for the present-day, 2030, 2050, and 2070. The following table details what layers were provided.

Layer Name	Description
Present-day Probability	Probability of flooding (displayed as an annual %) in the present-day
Present-day 1% annual storm	Depth of flooding associated with a 1% annual storm (or 100-year storm) in the present-day
Present-day 0.1% annual storm	Depth of flooding associated with a 0.1% annual storm (or 1000-year storm) in the present-day
2030 Probability	Probability of flooding (displayed as an annual %) in 2030
2030 1% annual storm	Depth of flooding associated with a 1% annual storm (or 100-year storm) in 2030
2030 0.1% annual storm	Depth of flooding associated with a 0.1% annual storm (or 1000-year storm) in 2030
2050 Probability	Probability of flooding (displayed as an annual %) in 2050
2050 1% annual storm	Depth of flooding associated with a 1% annual storm (or 100-year storm) in 2050
2050 0.1% annual storm	Depth of flooding associated with a 0.1% annual storm (or 1000-year storm) in 2050
2070 Probability	Probability of flooding (displayed as an annual %) in 2070
2070 1% annual storm	Depth of flooding associated with a 1% annual storm (or 100-year storm) in 2070
2070 0.1% annual storm	Depth of flooding associated with a 0.1% annual storm (or 1000-year storm) in the present-day

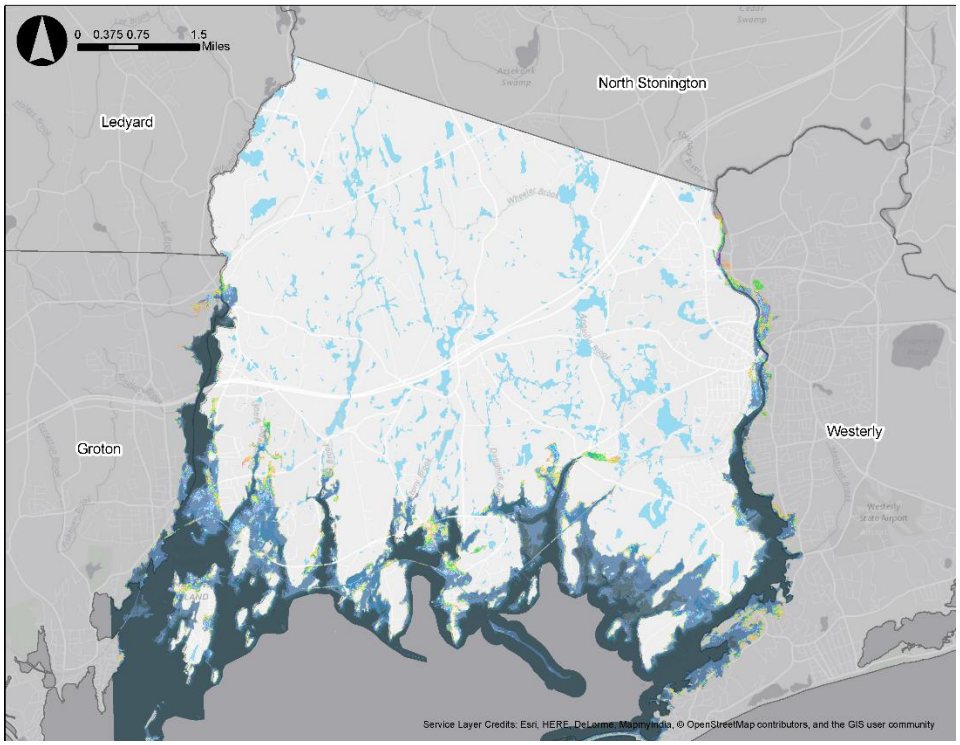
2 Mapping Methodology

Because there is very little difference between the 2030 and 2050 coastal flooding scenarios (see maps below) and this study is heavily focused on developing solutions rather than analyzing vulnerability, we propose mapping the assets against the 2050 1% storm and completing the vulnerability assessment based on that scenario. The layers are organized into those five main categories in the table above and we anticipate that the maps will follow a similar schema. The categories include: drainage and utilities, environmental resources, critical assets, transportation, and historic resources. The layers identified as “boundaries” in the table above, will be used to assist with the basemaps.

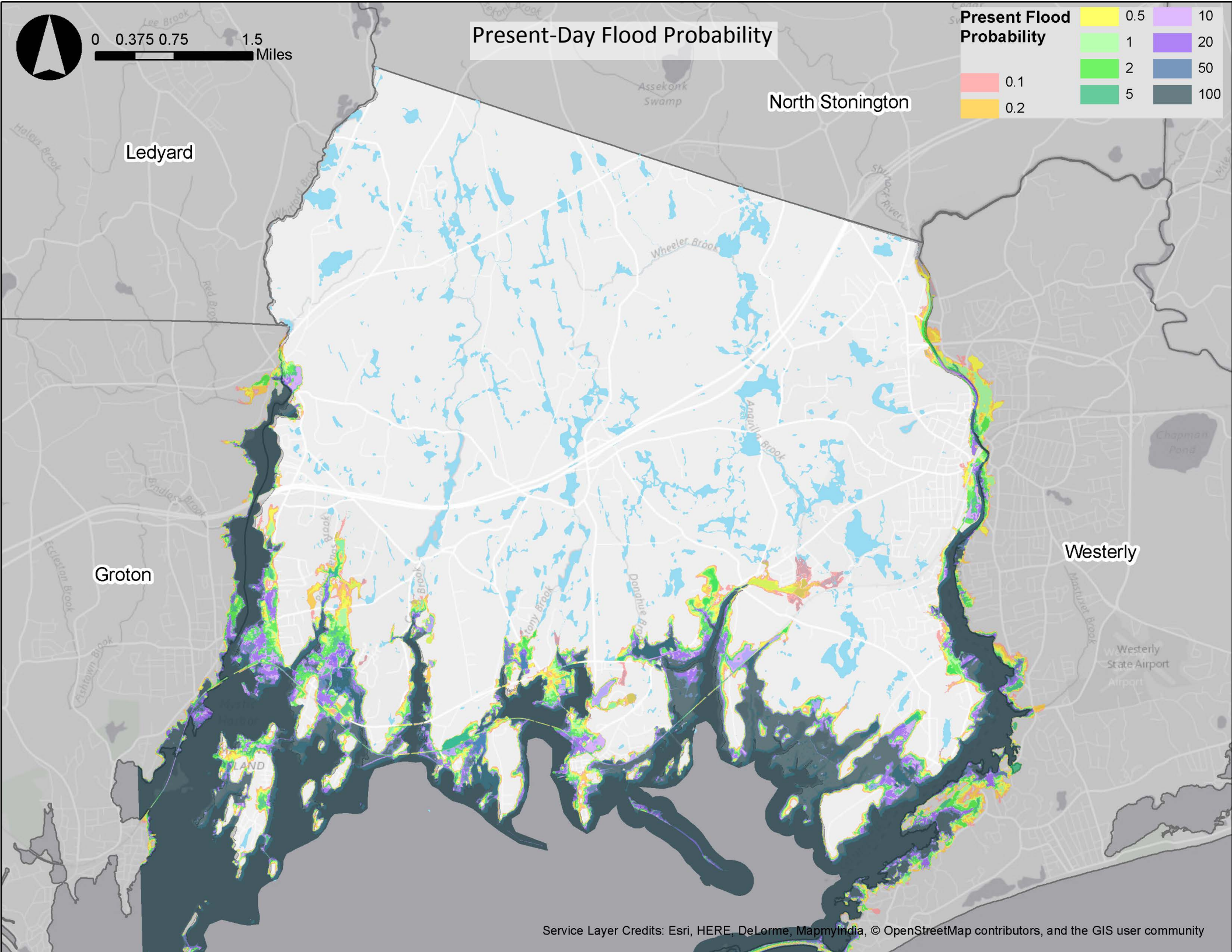
Memorandum

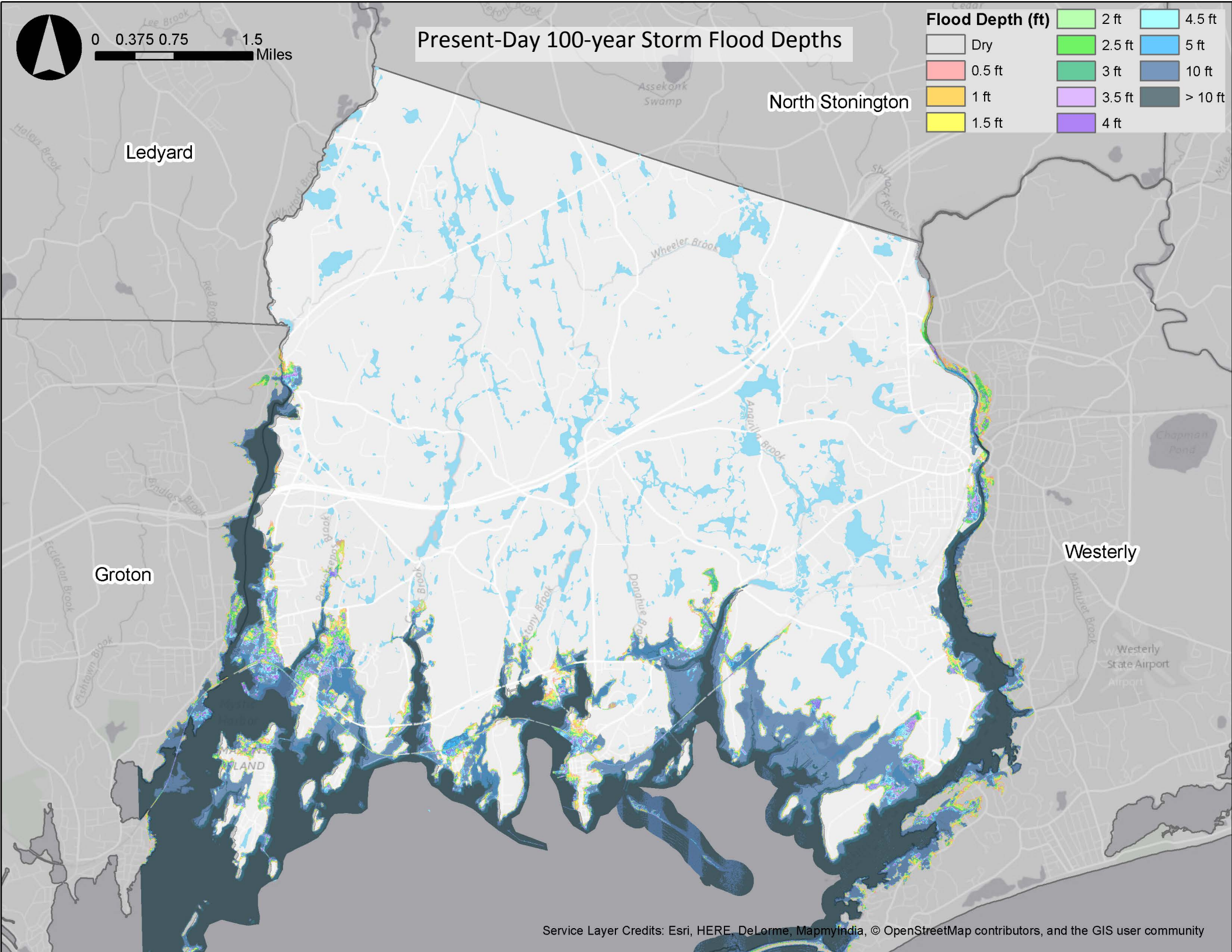


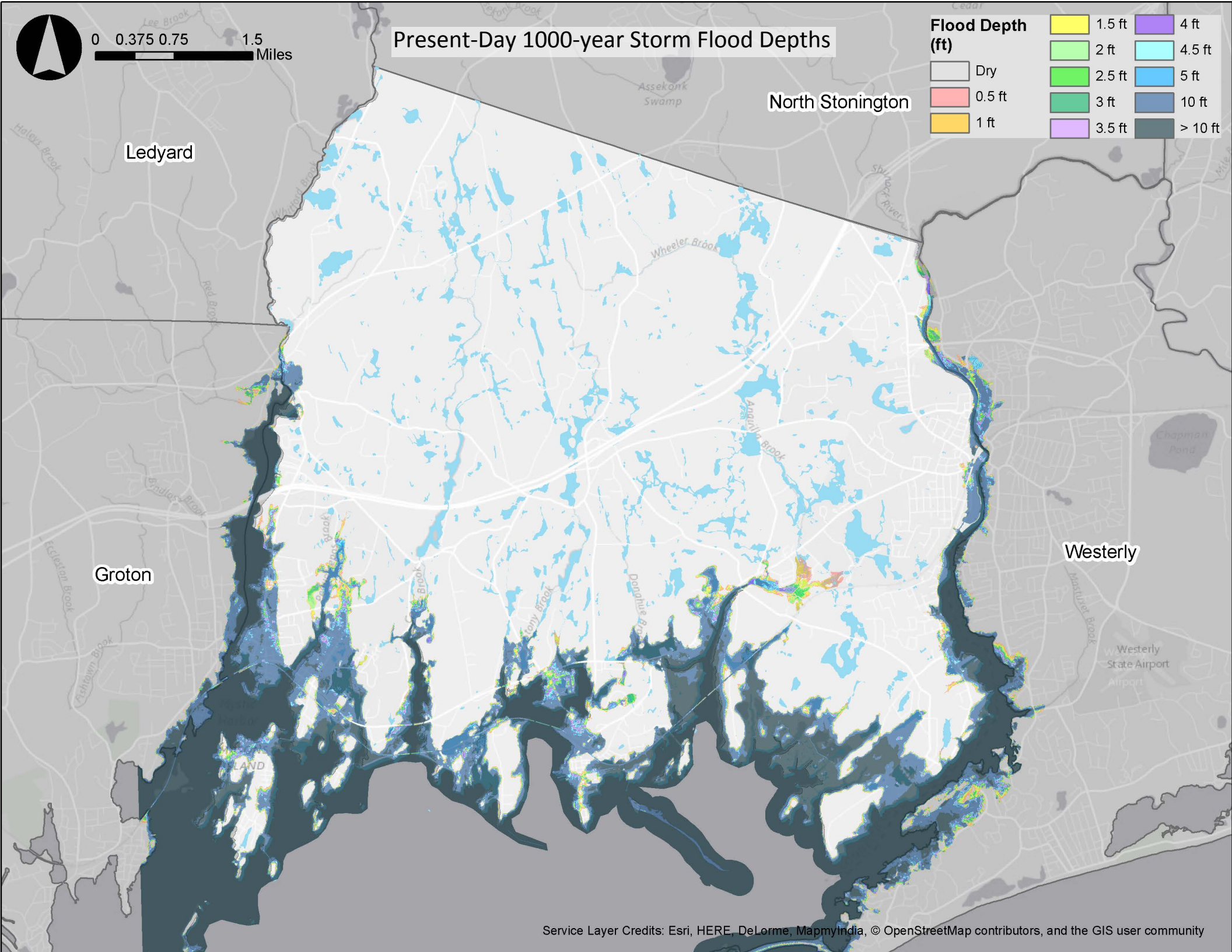
2030 1% Annual Flood

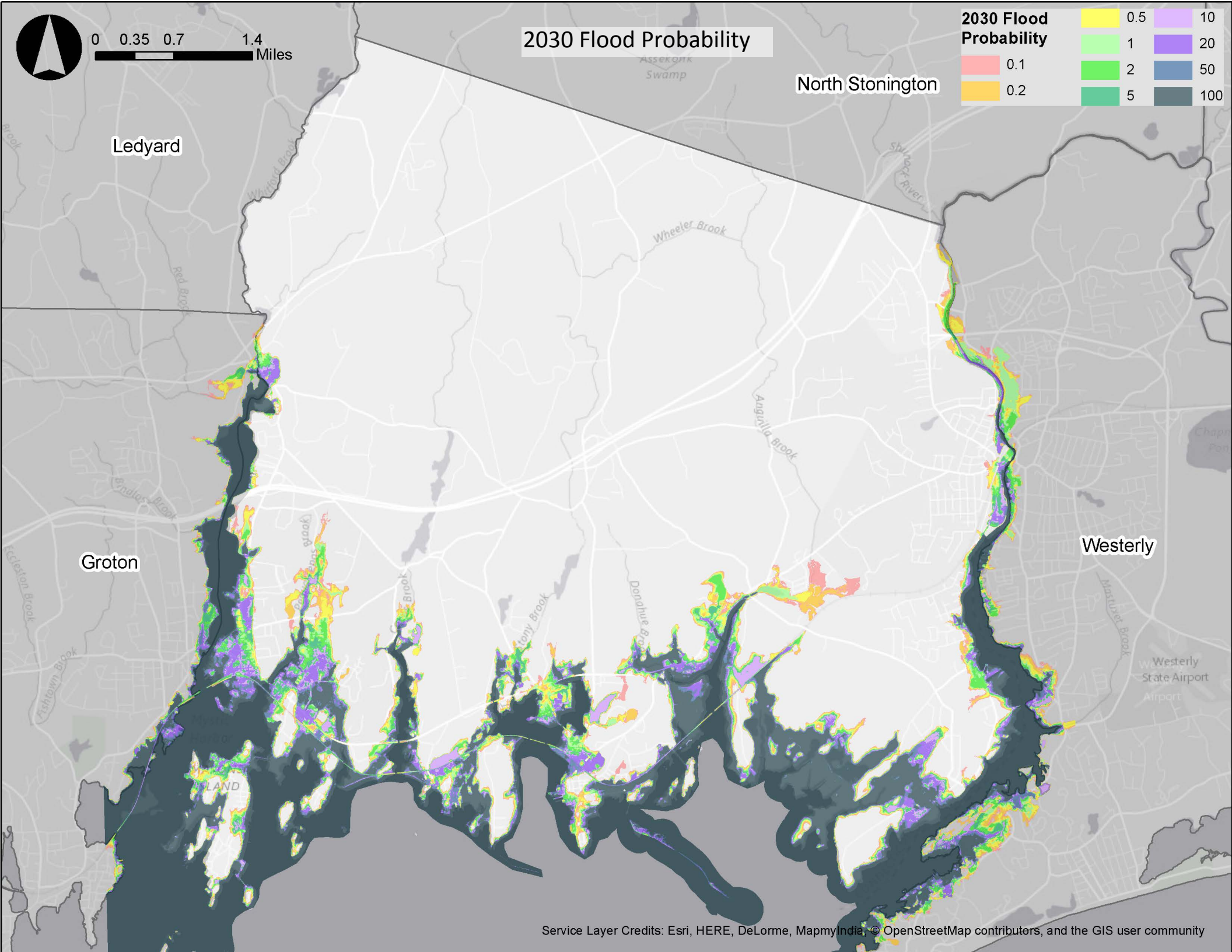


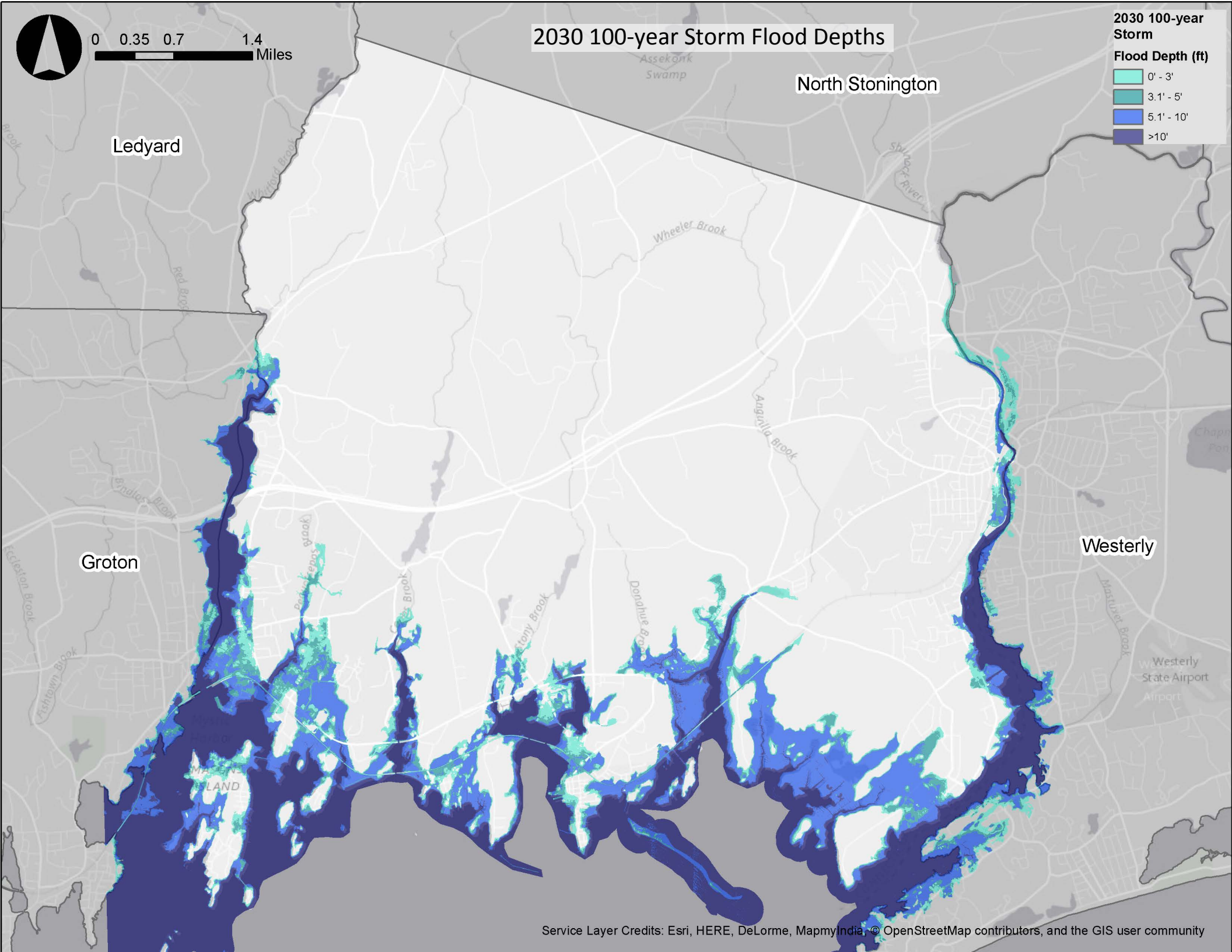
2050 1% Annual Flood

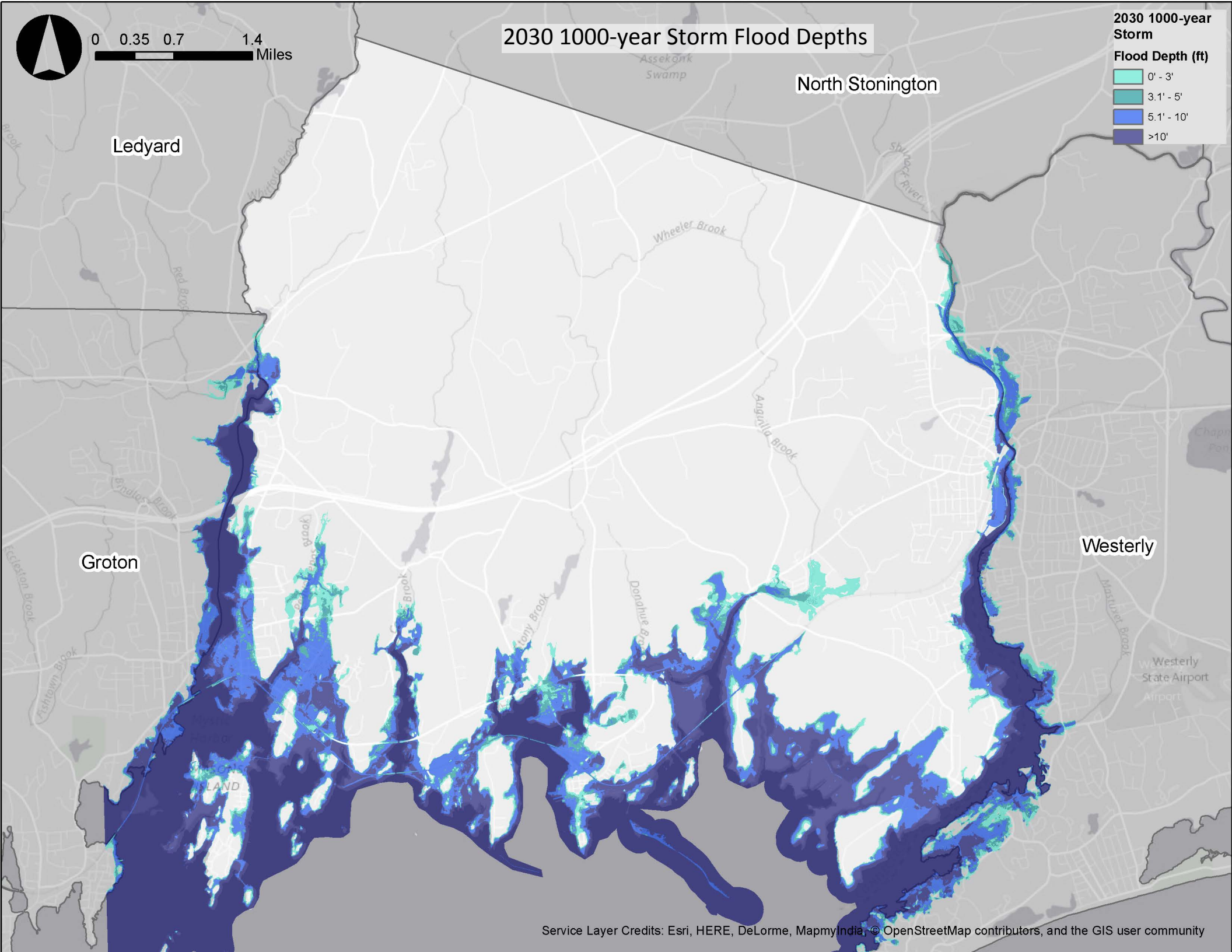

Present-Day Flood Probability
0 0.375 0.75 1.5
Miles
Present Flood Probability
0.1
0.2
0.5
1
2
5
10
20
50
100
North Stonington
Ledyard
Groton
Westerly
Assekonk Swamp
Wheeler Brook
Anguilla Brook
Donahue Brook
Tony Brook
Chapman Pond
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

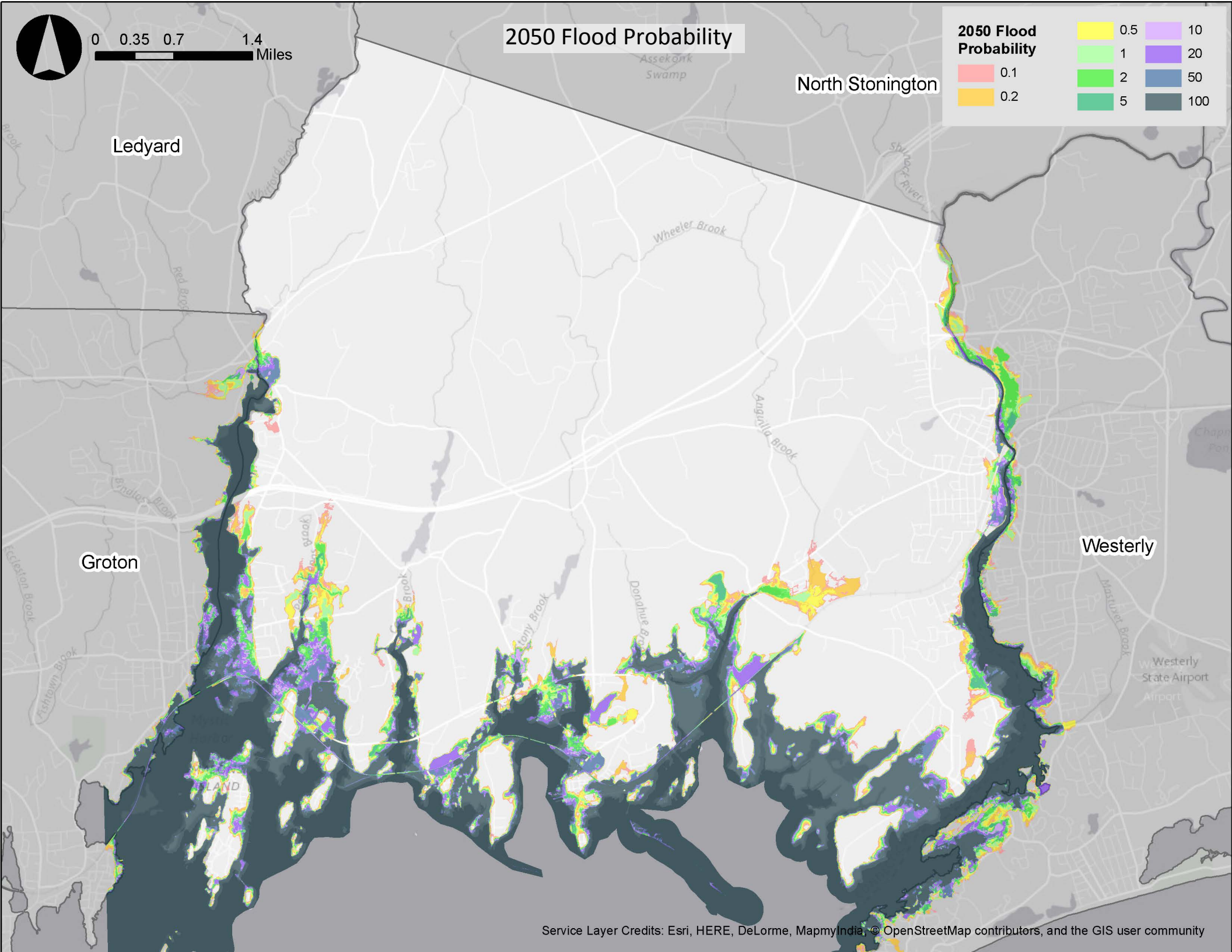

Present-Day 100-year Storm Flood Depths
0 0.375 0.75 1.5
Miles
Flood Depth (ft)
Dry
0.5 ft
1 ft
1.5 ft
2 ft
2.5 ft
3 ft
3.5 ft
4 ft
4.5 ft
5 ft
10 ft
> 10 ft
North Stonington
Ledyard
Groton
Westerly
Assekonk Swamp
Wheeler Brook
Anguilla Brook
Donahue Brook
Stony Brook
Mastuxet Brook
Westerly State Airport
Chapman Pond
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


Present-Day 1000-year Storm Flood Depths
0 0.375 0.75 1.5
Miles
Flood Depth (ft)
Dry
0.5 ft
1 ft
1.5 ft
2 ft
2.5 ft
3 ft
3.5 ft
4 ft
4.5 ft
5 ft
10 ft
> 10 ft
North Stonington
Ledyard
Groton
Westerly
Assekonk Swamp
Wheeler Brook
Anguilla Brook
Donahue Brook
Mantuxet Brook
Westerly State Airport
Chapman Pond
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


2030 Flood Probability
0 0.35 0.7 1.4
Miles
2030 Flood Probability
0.1
0.2
0.5
1
2
5
10
20
50
100
North Stonington
Ledyard
Groton
Westerly
Wheeler Brook
Anguilla Brook
Donahue Brook
Mastuxet Brook
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


2030 100-year Storm Flood Depths
0 0.35 0.7 1.4
Miles
2030 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
North Stonington
Ledyard
Groton
Westerly
Assekonk Swamp
Wheeler Brook
Anguilla Brook
Donahue Brook
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


2030 1000-year Storm Flood Depths
0 0.35 0.7 1.4
Miles
2030 1000-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
North Stonington
Ledyard
Groton
Westerly
Assekonk Swamp
Wheeler Brook
Anguilla Brook
Donahue Brook
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


2050 Flood Probability
0 0.35 0.7 1.4
Miles
2050 Flood Probability
0.1
0.2
0.5
1
2
5
10
20
50
100
North Stonington
Ledyard
Groton
Westerly
Assekonk Swamp
Wheeler Brook
Anguilla Brook
Donahue Brook
Mastuxet Brook
Westerly State Airport
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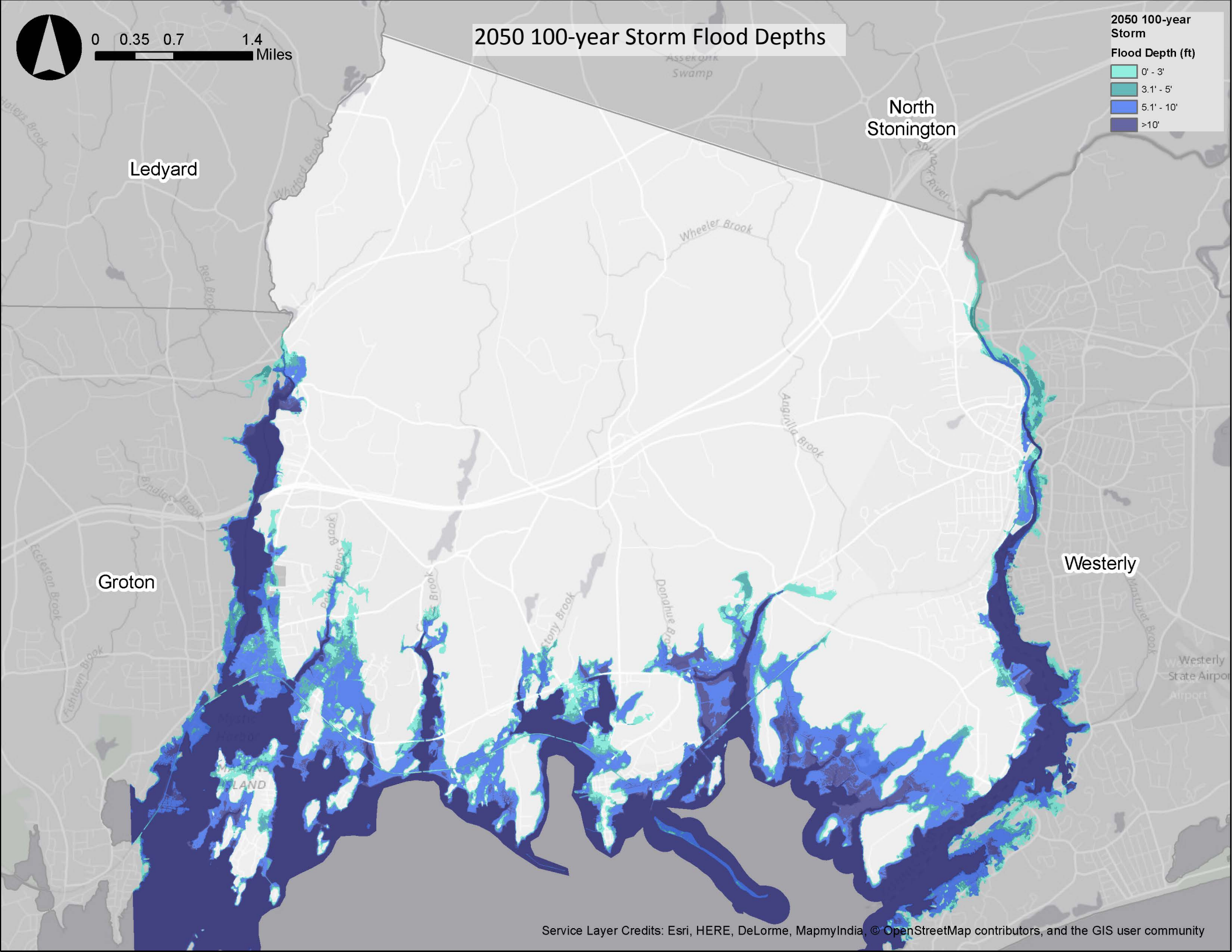
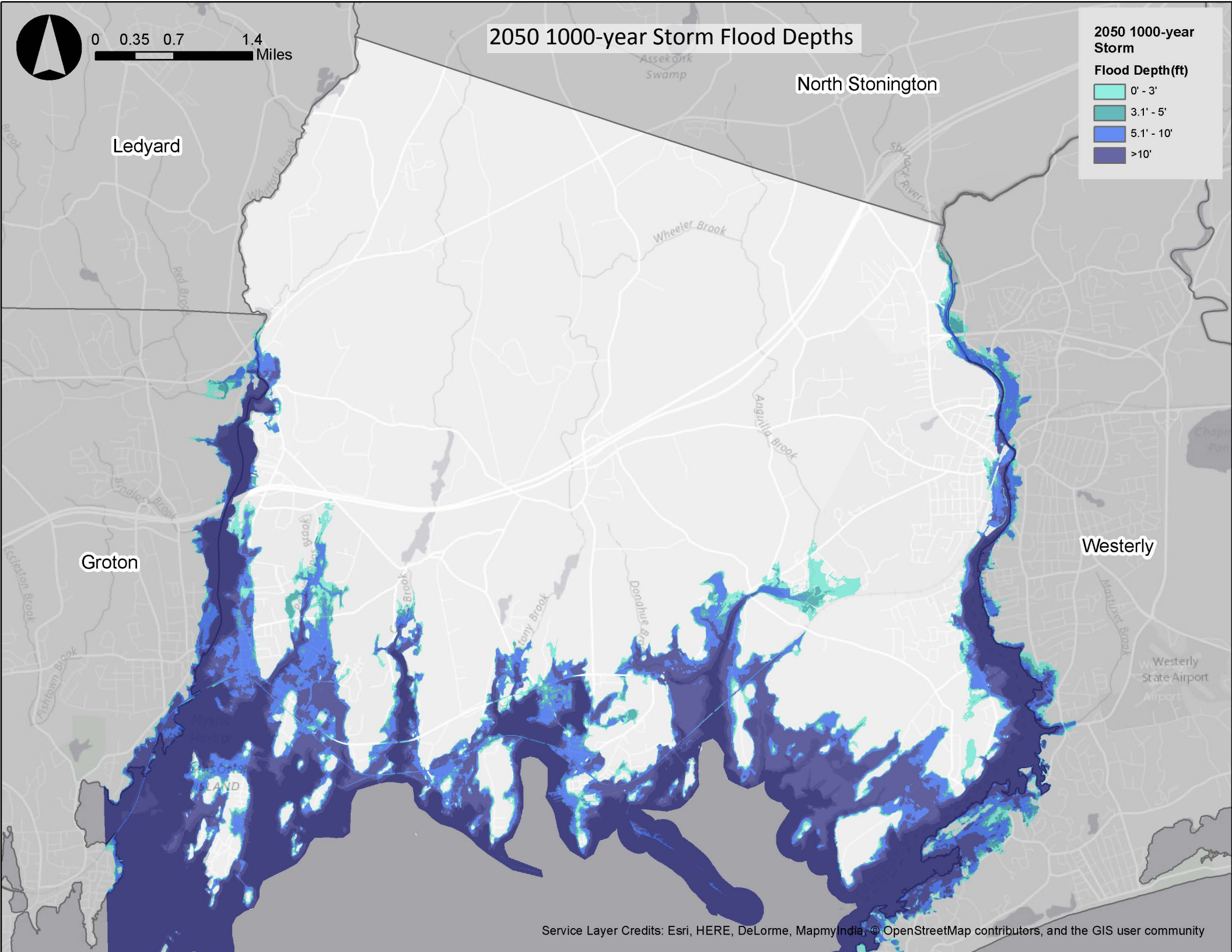
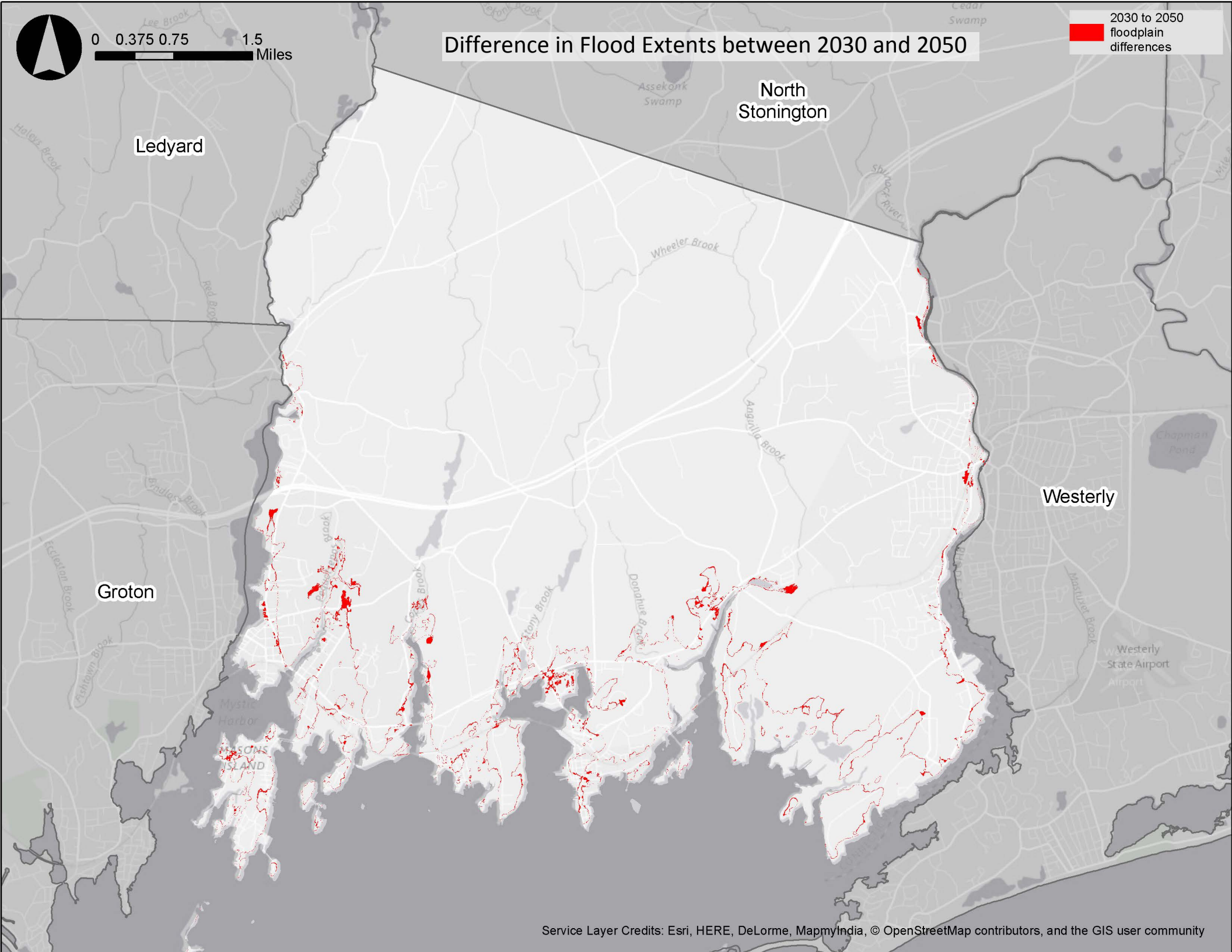
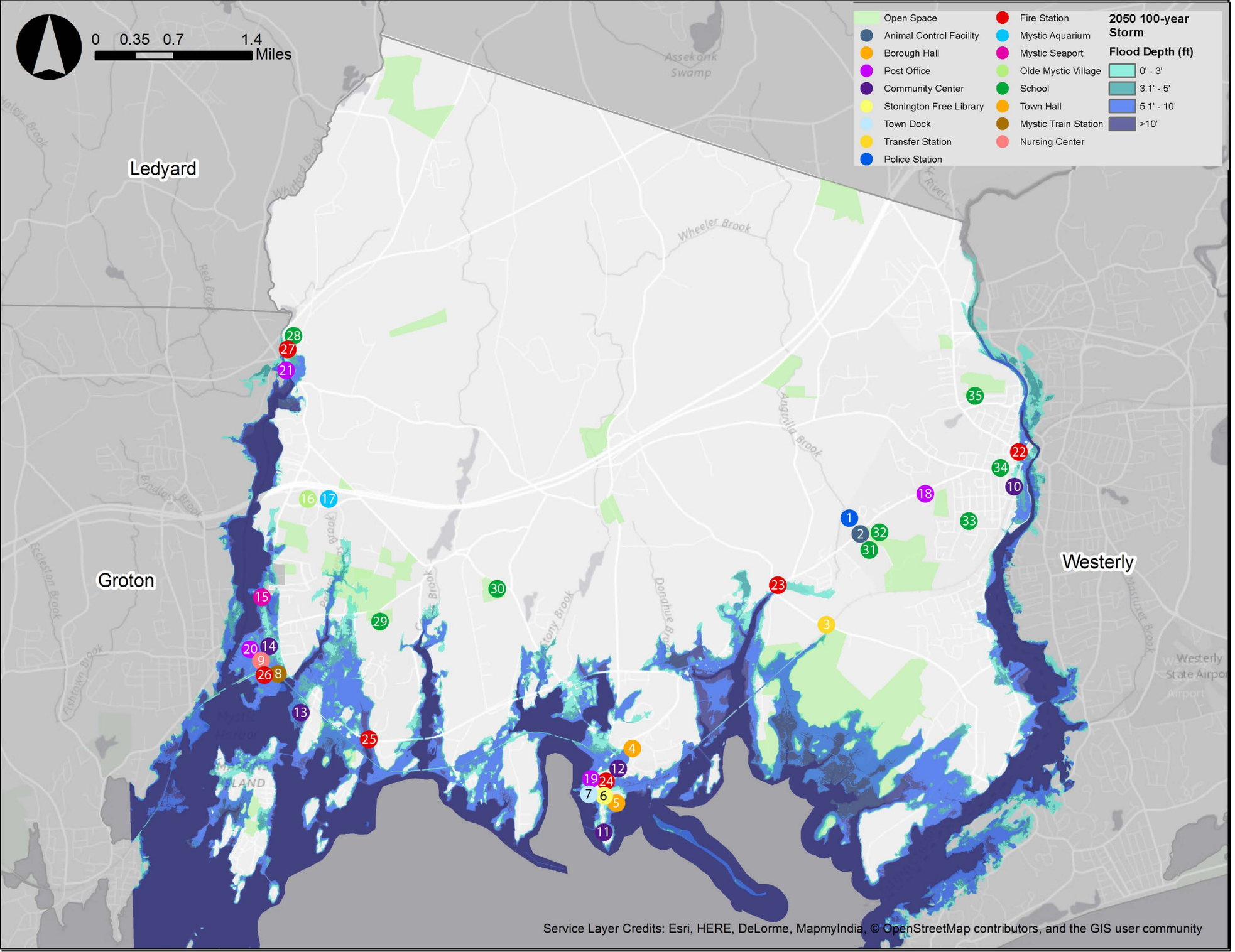

2050 100-year Storm Flood Depths
0 0.35 0.7 1.4
Miles
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
North Stonington
Ledyard
Groton
Westerly
Wheeler Brook
Anguilla Brook
Donahue Brook
Stony Brook
Red Brook
Ashtown Brook
Eccleston Brook
Mastuxet Brook
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

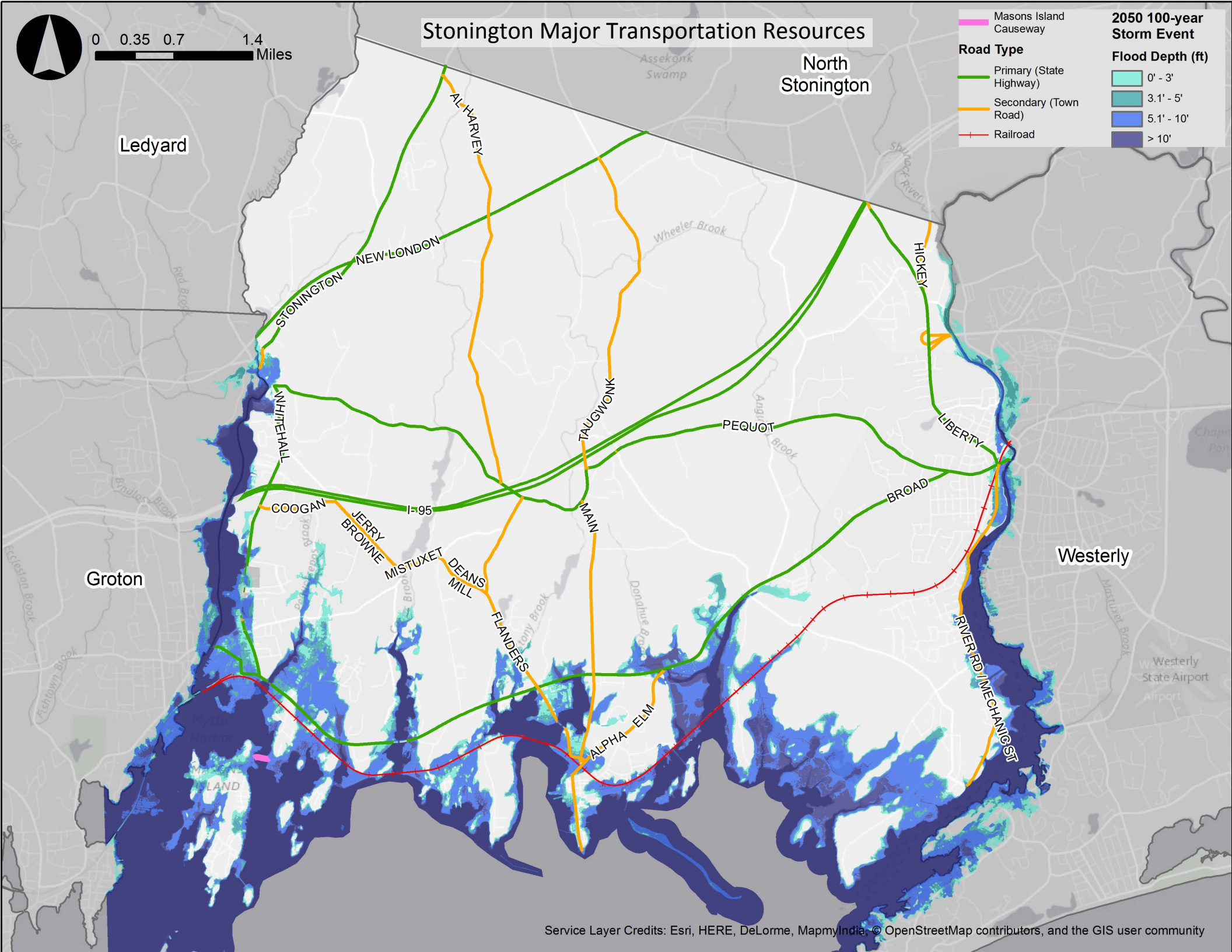

2050 1000-year Storm Flood Depths
0 0.35 0.7 1.4
Miles
2050 1000-year Storm
Flood Depth(ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
North Stonington
Ledyard
Groton
Westerly
Assekonk Swamp
Wheeler Brook
Anguilla Brook
Donahue Brook
Mastuxet Brook
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


Difference in Flood Extents between 2030 and 2050
2030 to 2050 floodplain differences
0 0.375 0.75 1.5 Miles
North Stonington
Ledyard
Groton
Westerly
Wheeler Brook
Anguilla Brook
Donahue Brook
Stony Brook
Mystic Harbor
Masons Island
Westerly State Airport
Assekonk Swamp
Cedar Swamp
Chapman Pond
Shunock River
Lee Brook
Haleys Brook
Whitford Brook
Red Brook
Bradley Brook
Eccleston Brook
Ashtown Brook
Mastuxet Brook
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



Community Facilities

1. Stonington Police Station
2. Animal Control Facility
3. Transfer Station
4. Stonington Town Hall
5. Stonington Borough Hall
6. Stonington Free Library
7. Town Dock
8. Mystic Train Station
9. Apple Rehab Mystic
10. Pawcatuck Neighborhood Center
11. La Grua Center
12. Stonington Community Center (COMO)
13. Ocean Community YMCA
14. Former Fourth District Voting Hall
15. Mystic Seaport
16. Olde Mystic Village
17. Mystic Aquarium
18. Pawcatuck Post Office
19. Stonington Borough Post Office
20. Mystic Post Office
21. Old Mystic Post Office
22. Pawcatuck Fire Department
23. Wequetequock Fire Department
24. Stonington Borough Fire Department
25. Quiambaug Fire Department
26. Mystic Fire Department
27. Old Mystic Fire Department
28. Stonington Superintendent of Schools
29. Mystic Middle School
30. Deans Mill School
31. Stonington Human Services Building
32. Stonington High School
33. Pawcatuck Middle School
34. West Broad Street School
35. West Vine Street School



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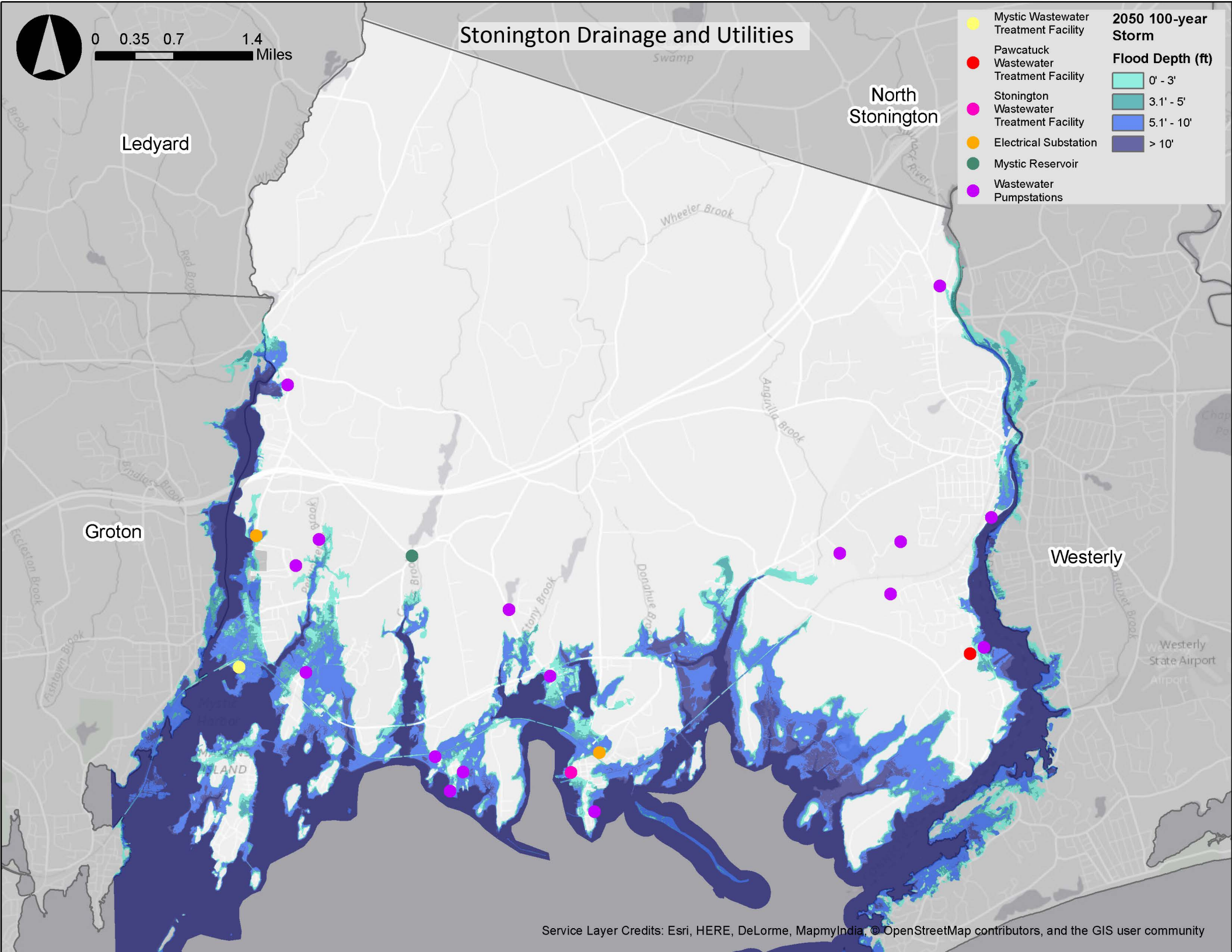
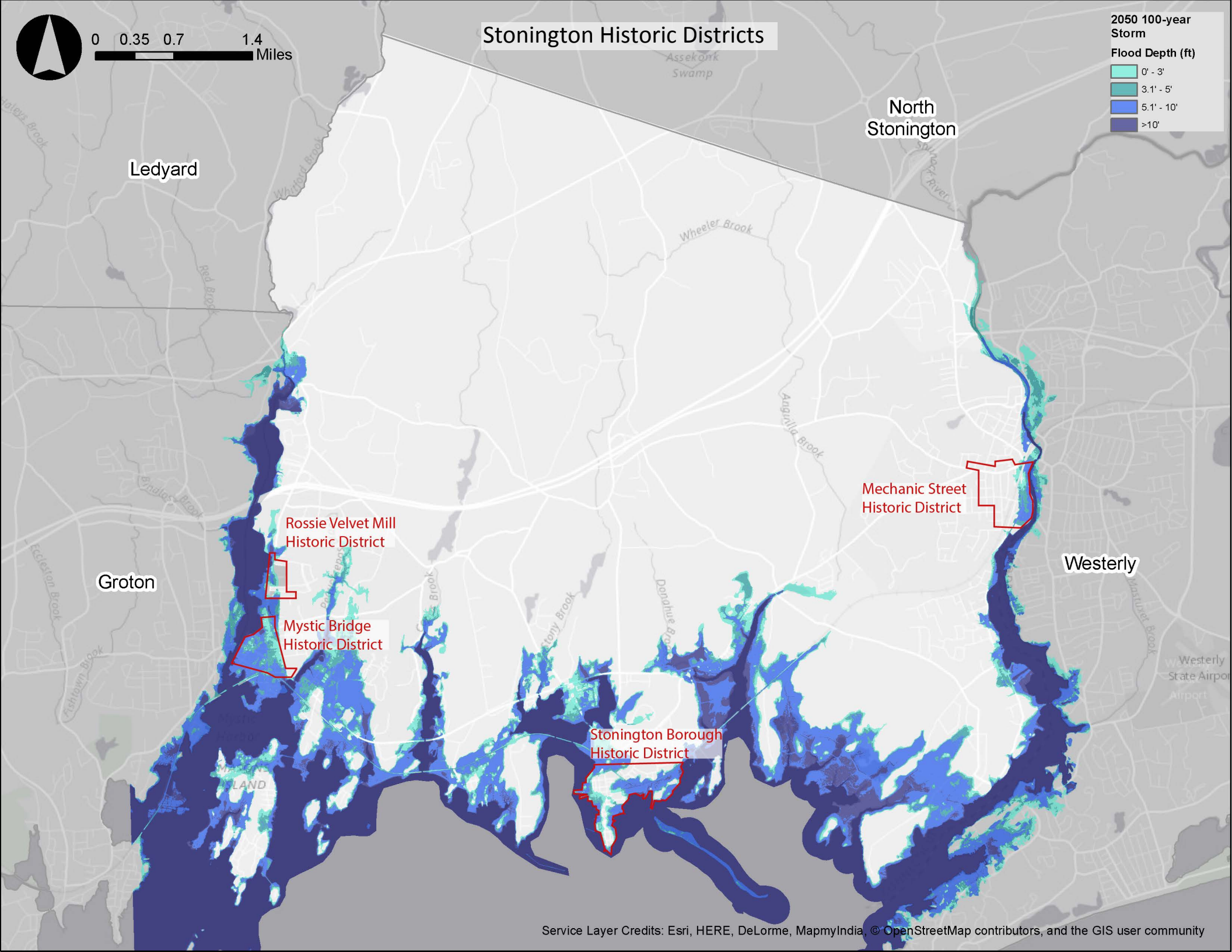
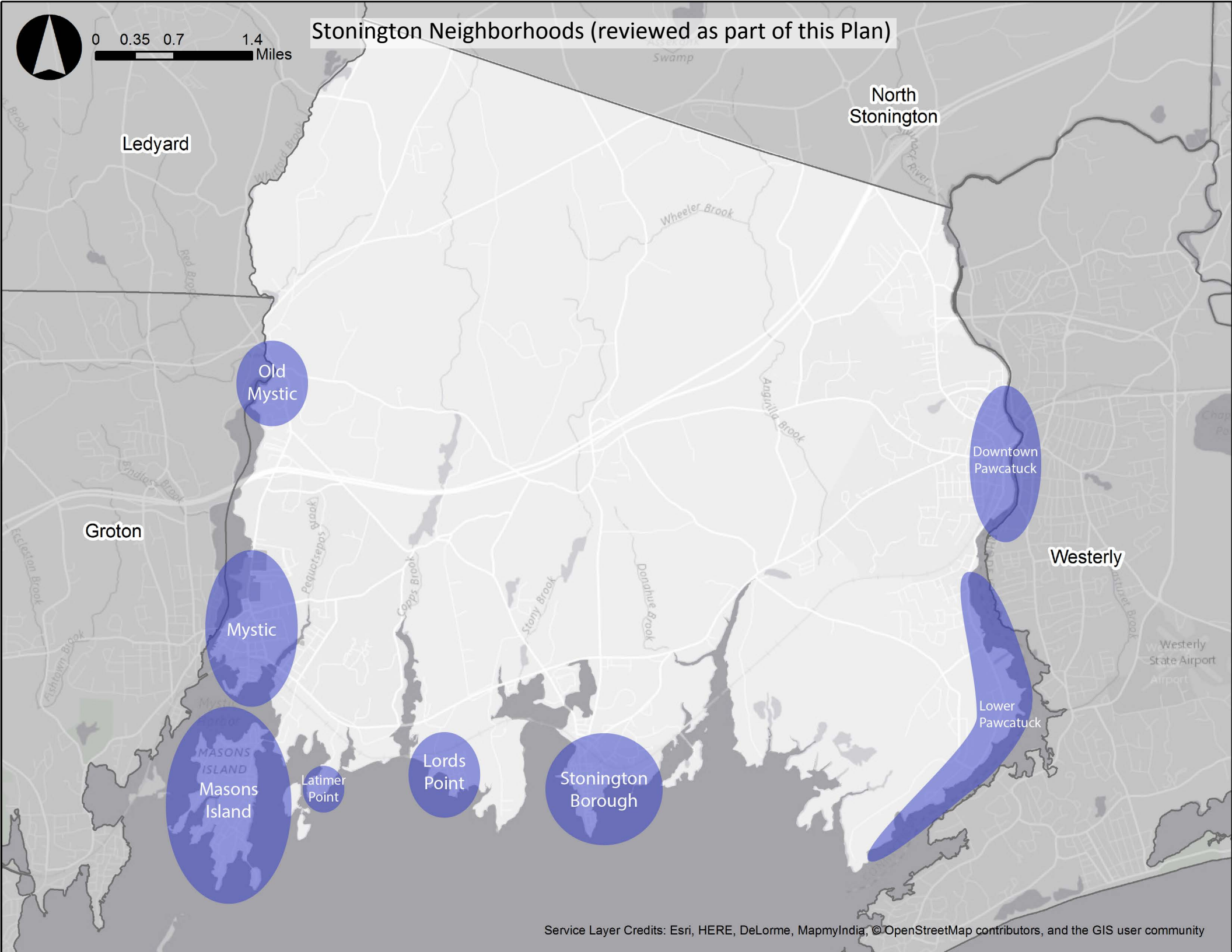
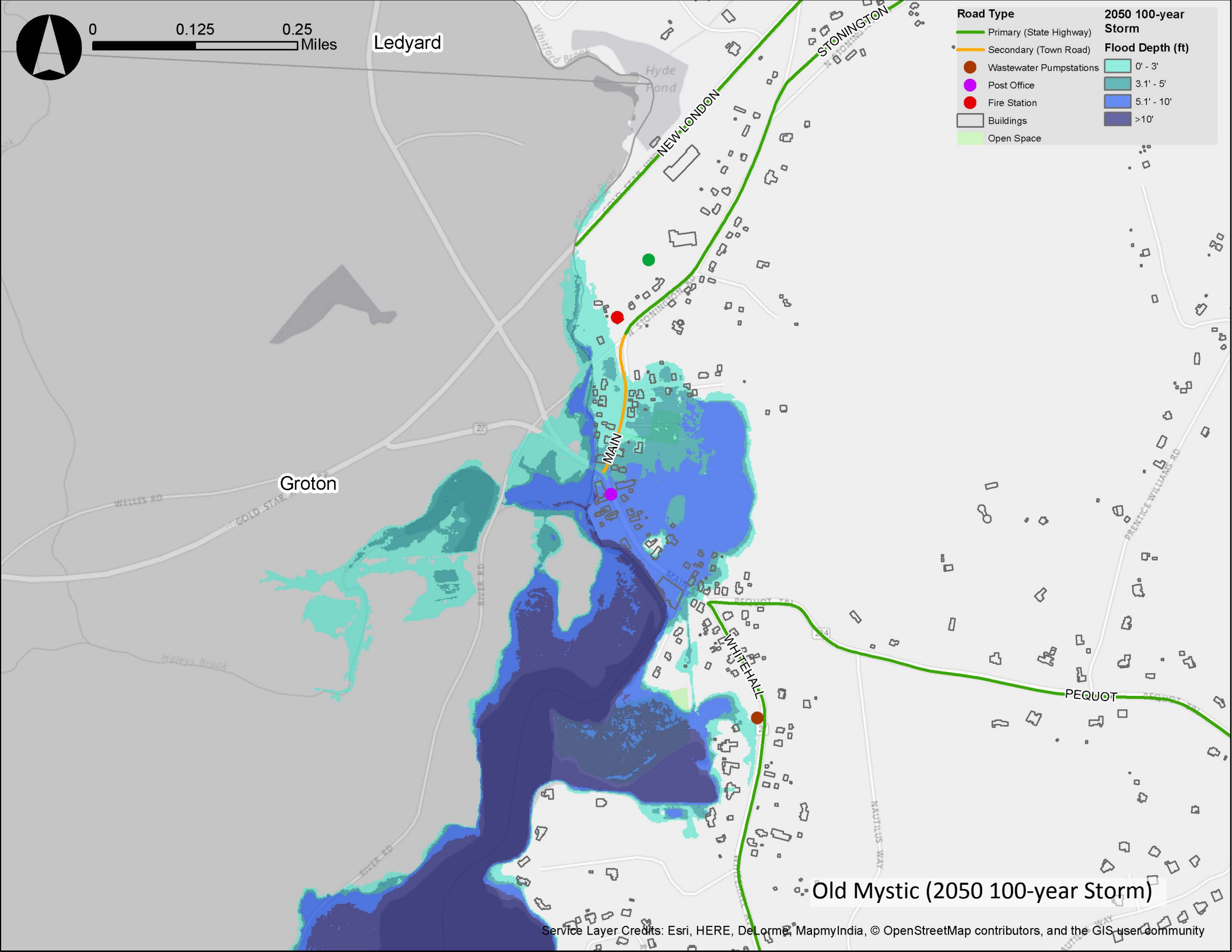
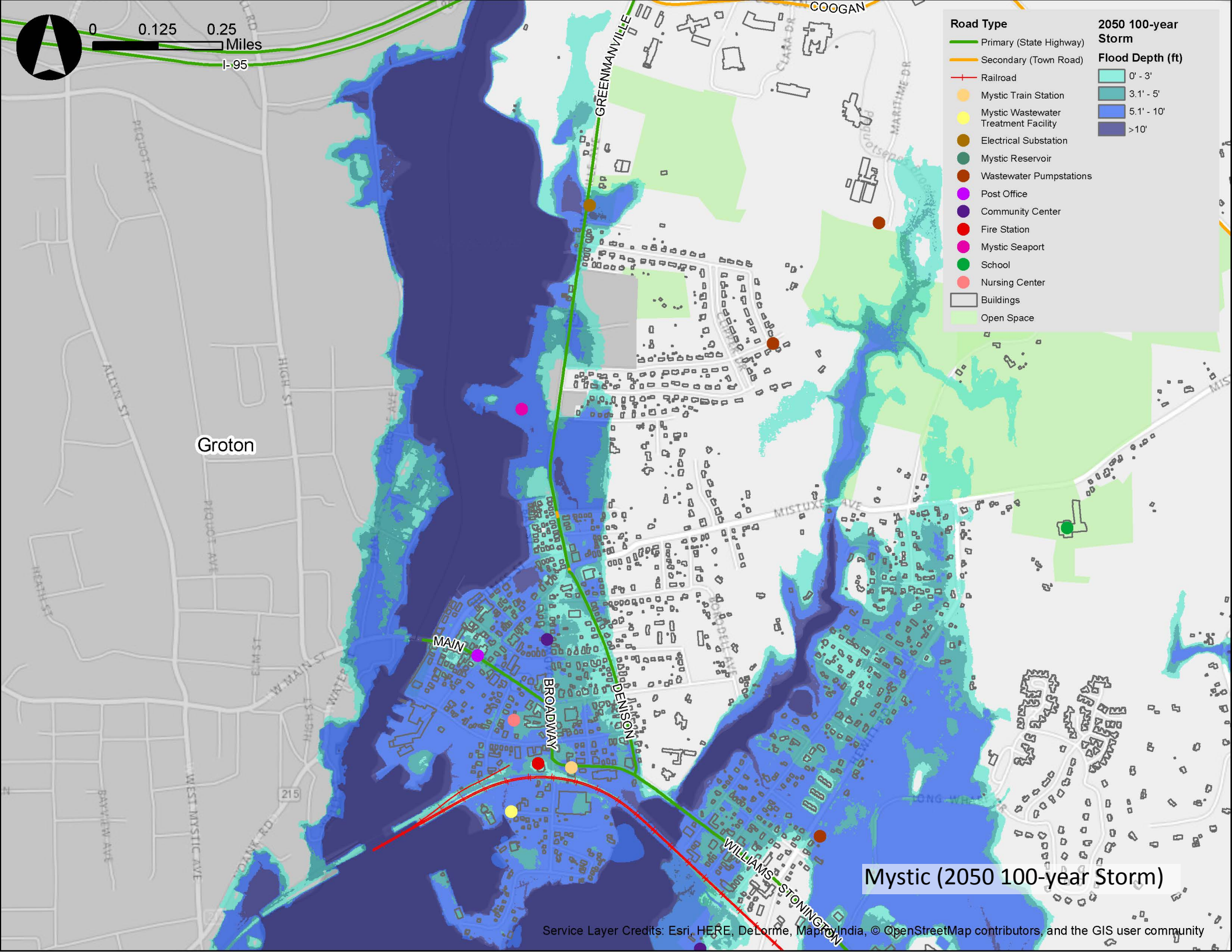
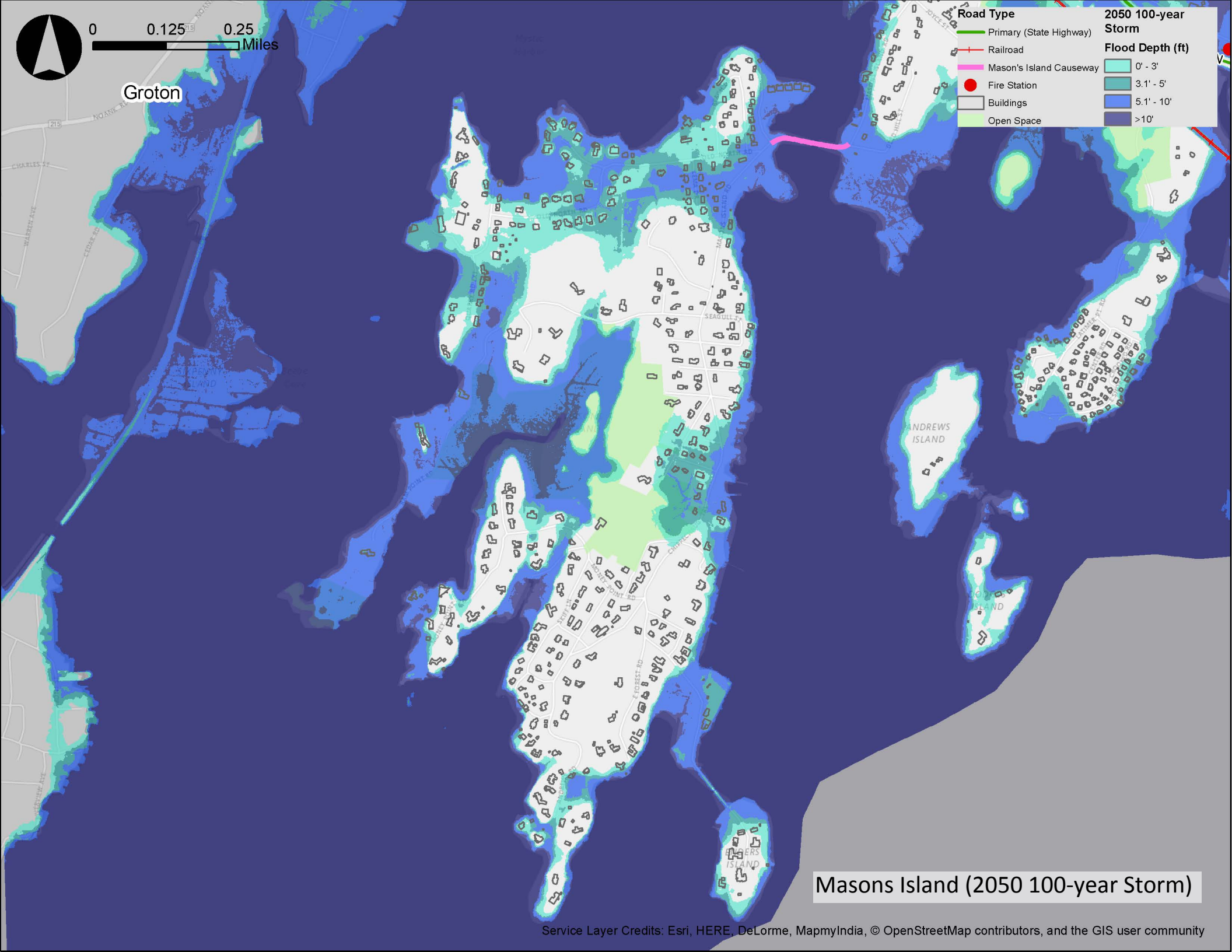

Stonington Drainage and Utilities
0 0.35 0.7 1.4
Miles
Mystic Wastewater Treatment Facility
Pawcatuck Wastewater Treatment Facility
Stonington Wastewater Treatment Facility
Electrical Substation
Mystic Reservoir
Wastewater Pumpstations
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
> 10'
Ledyard
North Stonington
Groton
Westerly
Wheeler Brook
Anguilla Brook
Donahue Brook
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

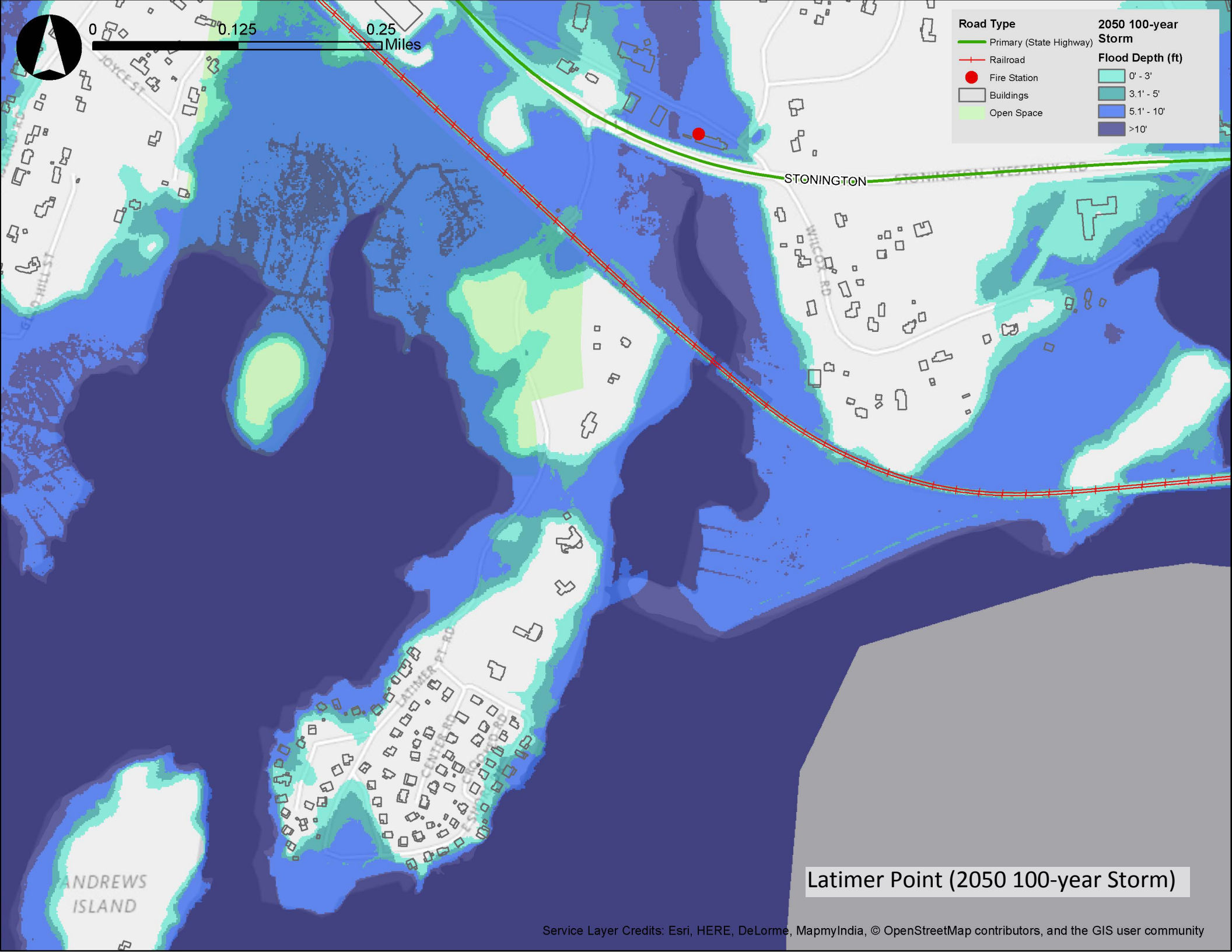

Stonington Historic Districts
0 0.35 0.7 1.4
Miles
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
North Stonington
Ledyard
Groton
Westerly
Rossie Velvet Mill Historic District
Mystic Bridge Historic District
Mechanic Street Historic District
Stonington Borough Historic District
Assekonk Swamp
Wheeler Brook
Anguilla Brook
Donahue Brook
Stony Brook
Red Brook
Whitford Brook
Bradley Brook
Eccleston Brook
Ashtown Brook
Mastuxet Brook
Mystic Harbor
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


Stonington Neighborhoods (reviewed as part of this Plan)
0 0.35 0.7 1.4 Miles
North Stonington
Ledyard
Groton
Westerly
Old Mystic
Mystic
Masons Island
Latimer Point
Lords Point
Stonington Borough
Downtown Pawcatuck
Lower Pawcatuck
Wheeler Brook
Angitilla Brook
Pequotsepos Brook
Copps Brook
Stony Brook
Donahue Brook
Westerly State Airport
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


0
0.125
0.25
Miles
Ledyard
Groton
Hyde Pond
Whitford Brook
Holeys Brook
NEW LONDON
STONINGTON
MAIN
WHITEHALL
PEQUOT
WELLES RD
GOLD STAR
RIVER RD
PRENTICE WILLIAMS RD
NAUTILUS WAY
Road Type
Primary (State Highway)
Secondary (Town Road)
Wastewater Pumpstations
Post Office
Fire Station
Buildings
Open Space
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
Old Mystic (2050 100-year Storm)
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


0
0.125
0.25
Miles
I-95
COOGAN
GREENMANVILLE
Road Type
Primary (State Highway)
Secondary (Town Road)
Railroad
Mystic Train Station
Mystic Wastewater Treatment Facility
Electrical Substation
Mystic Reservoir
Wastewater Pumpstations
Post Office
Community Center
Fire Station
Mystic Seaport
School
Nursing Center
Buildings
Open Space
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
Groton
MISTUXET AVE
MAIN
BROADWAY
DENISON
WILLIAMS-STONINGTON
Mystic (2050 100-year Storm)
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


0
0.125
0.25
Miles
Groton
Road Type
Primary (State Highway)
Railroad
Mason's Island Causeway
Fire Station
Buildings
Open Space
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
ANDREWS ISLAND
Masons Island (2050 100-year Storm)
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community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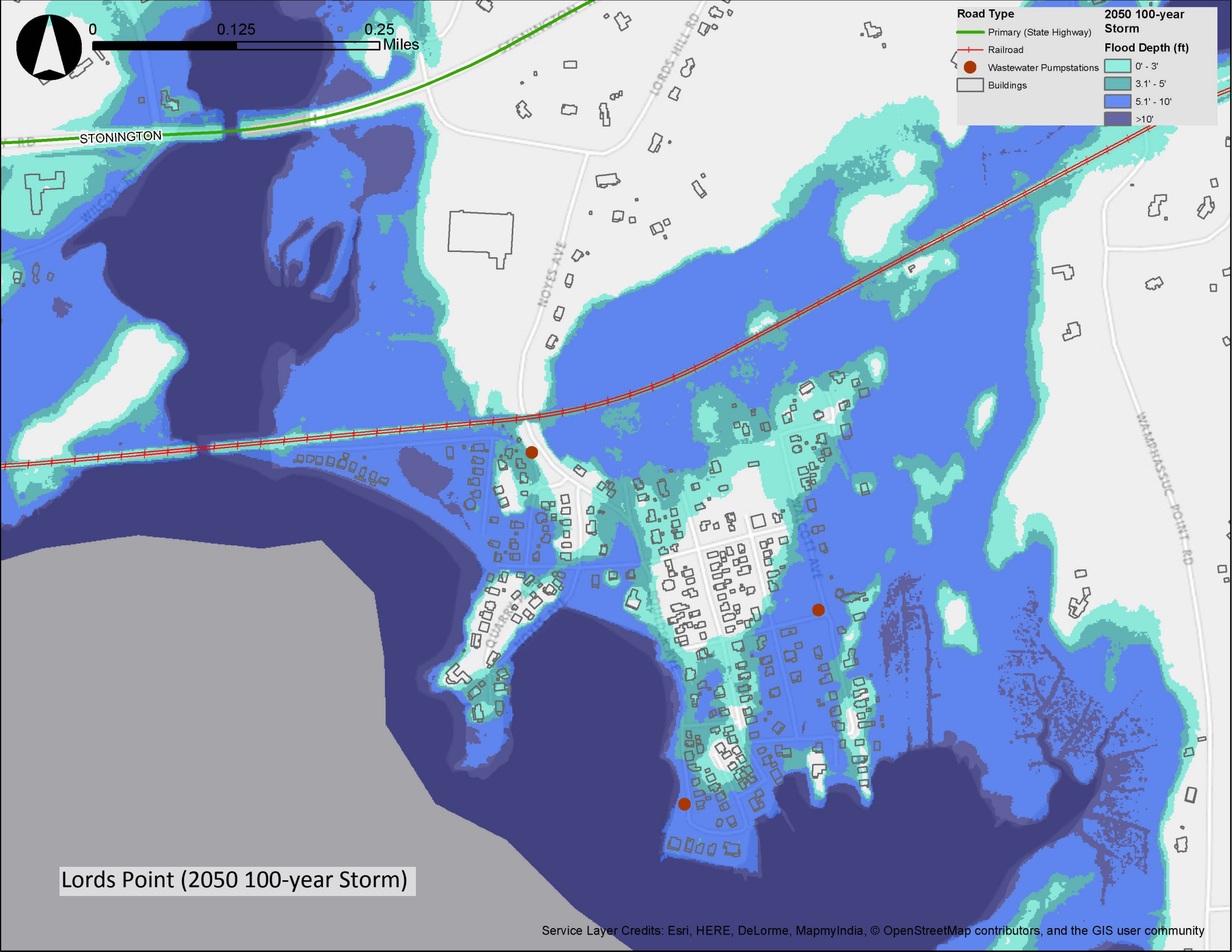
Miles
Road Type
Primary (State Highway)
Railroad
Fire Station
Buildings
Open Space
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
STONINGTON
STONINGTON WESTERLY RD
WILCOX RD
JOYCE ST
LATIMER PT RD
CENTER RD
CROCKER RD
ESTHER RD
ANDREWS ISLAND
Latimer Point (2050 100-year Storm)
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community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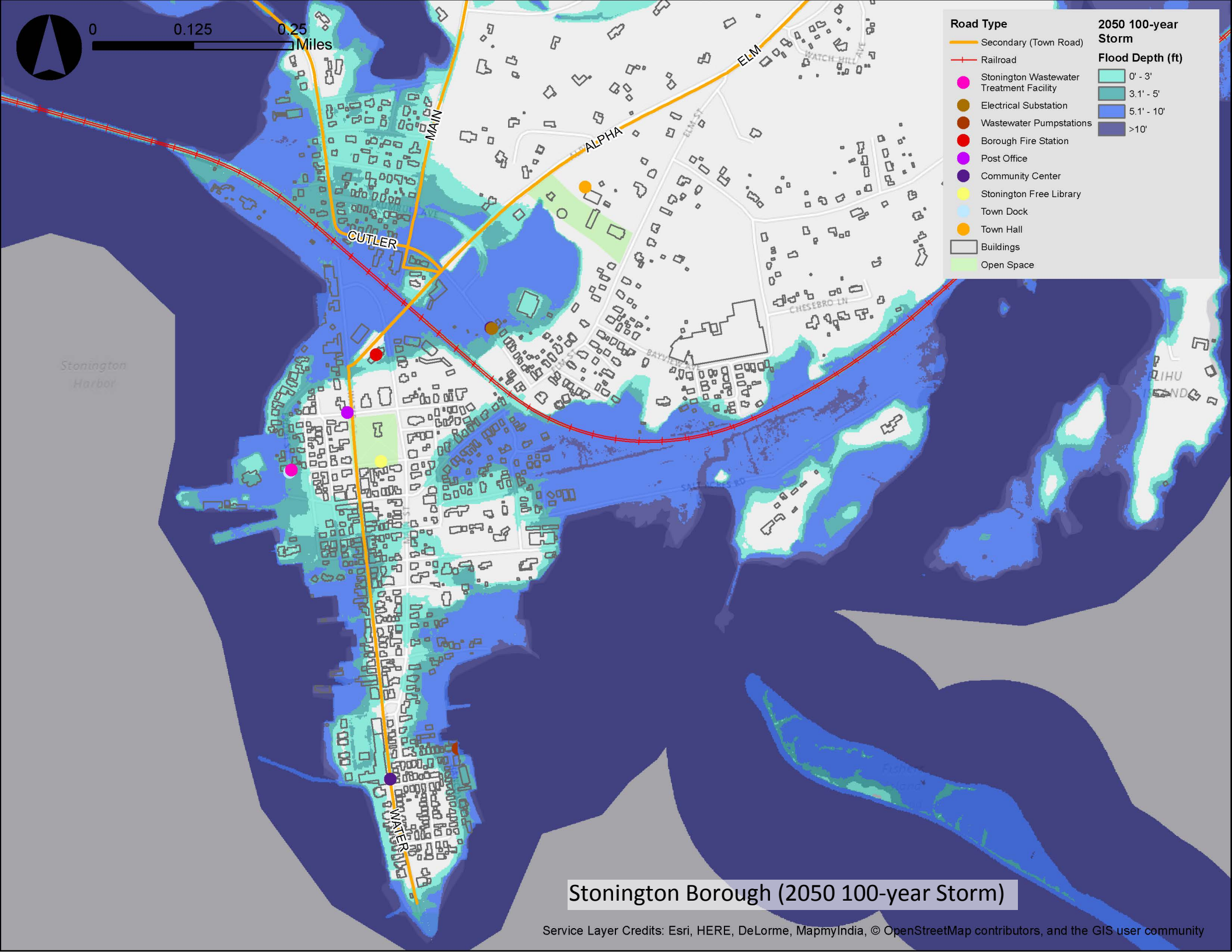
Road Type
Primary (State Highway)
Railroad
Wastewater Pumpstations
Buildings
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
STONINGTON
LORDS HILL RD
NOYES AVE
WAMPHASSUC POINT RD
Lords Point (2050 100-year Storm)
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community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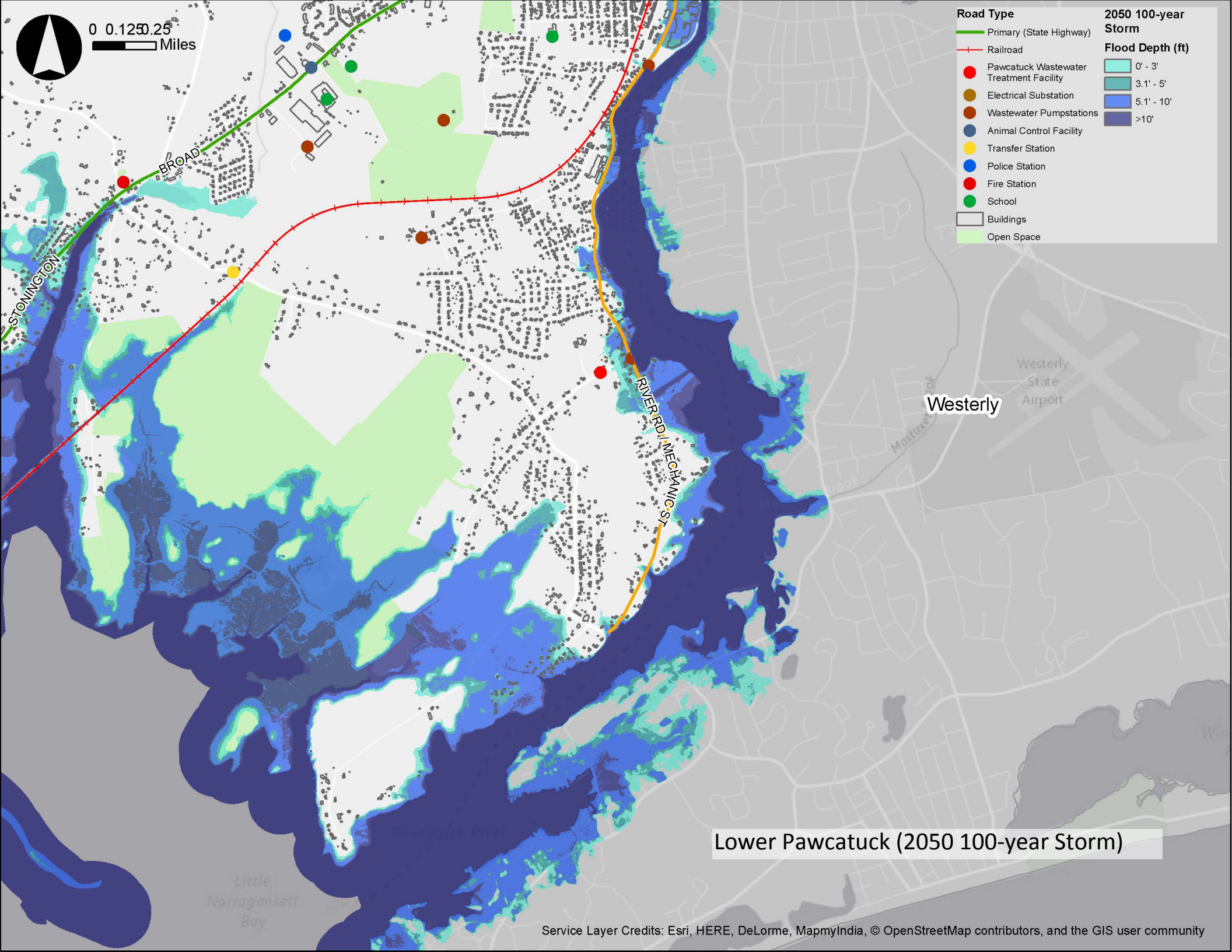
Miles
Road Type
Secondary (Town Road)
Railroad
Stonington Wastewater Treatment Facility
Electrical Substation
Wastewater Pumpstations
Borough Fire Station
Post Office
Community Center
Stonington Free Library
Town Dock
Town Hall
Buildings
Open Space
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
MAIN
CUTLER
ALPHA
ELM
WATER
Stonington Harbor
Stonington Borough (2050 100-year Storm)
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community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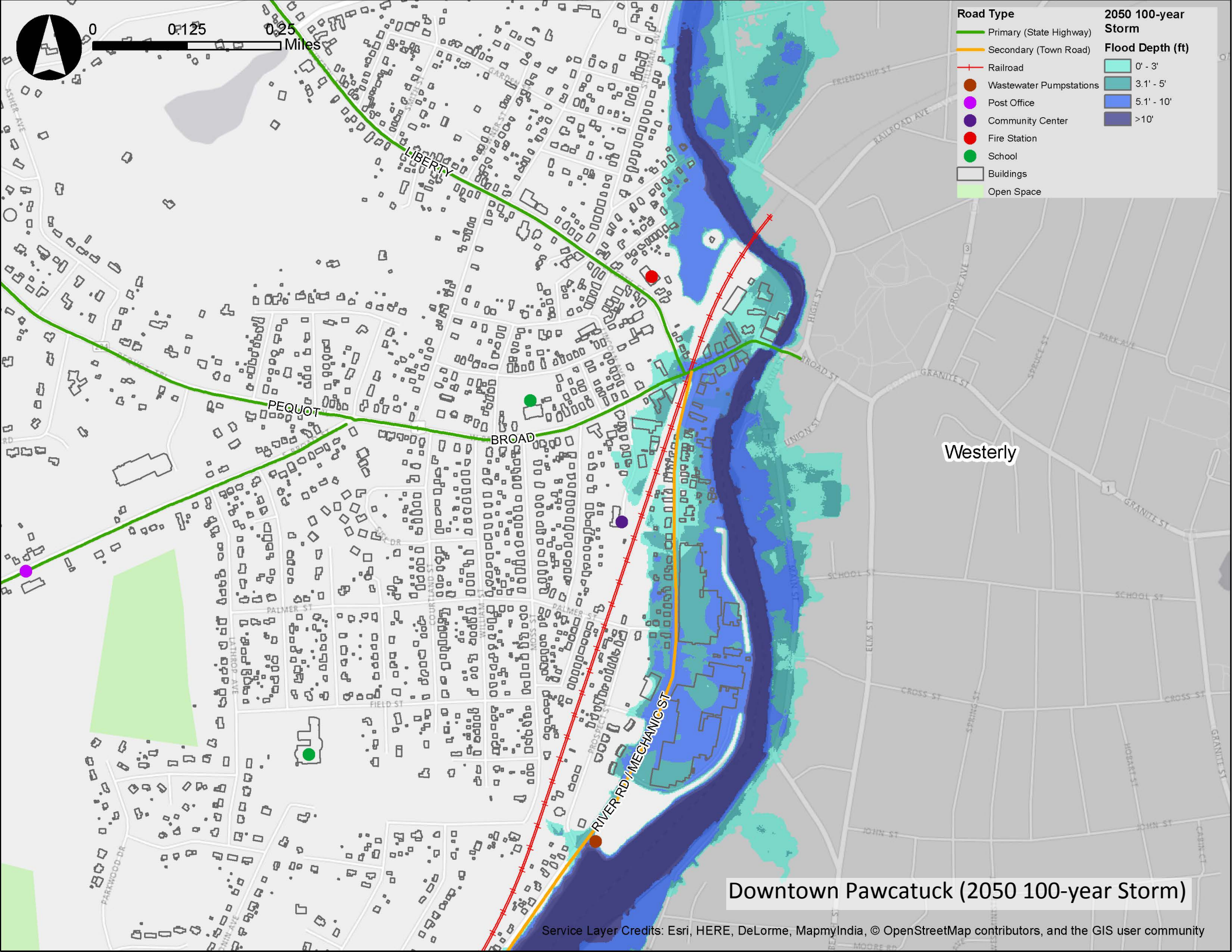
Miles
Road Type
Primary (State Highway)
Railroad
Pawcatuck Wastewater Treatment Facility
Electrical Substation
Wastewater Pumpstations
Animal Control Facility
Transfer Station
Police Station
Fire Station
School
Buildings
Open Space
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
BROAD
STONINGTON
RIVER RD / MECHANIC ST
Westerly
Westerly State Airport
Pawcatuck River
Little Narragansett Bay
Lower Pawcatuck (2050 100-year Storm)
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


0
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Miles
Road Type
Primary (State Highway)
Secondary (Town Road)
Railroad
Wastewater Pumpstations
Post Office
Community Center
Fire Station
School
Buildings
Open Space
2050 100-year Storm
Flood Depth (ft)
0' - 3'
3.1' - 5'
5.1' - 10'
>10'
LIBERTY
PEQUOT
BROAD
RIVER RD / MECHANIC ST
Westerly
Downtown Pawcatuck (2050 100-year Storm)
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Appendix B: Vulnerability and Risk Assessment Memo

Memorandum

ARUP

To	Keith Brynes, Town Planner Town of Stonington, CT	Date	April 28, 2017
Copies		Reference number	251043-00
From	Katie Wholey, Arup Lisa Dickson, Arup	File reference	
Subject	Town of Stonington Risk Assessment		

1 Overview

The Vulnerability and Risk Assessment is intended to provide a high-level analysis of the impact of coastal flooding on Stonington's most important community assets and resources. The Town suffered considerable damage from Superstorm Sandy, including impacts to the Town Dock, Masons Island Causeway and several other facilities. As a result, the Town of Stonington started a comprehensive planning process to assess its vulnerability to impacts from sea level rise and coastal flooding. This memo details the first step in that process.

2 Methodology

Each of the assets and resources included in this assessment were provided by the Town's GIS services and vetted by the Town Planning Department, the Town Engineer, and the Climate Change Task Force. In most cases, assets are individual buildings or structures (e.g. fire station or wastewater treatment facility); however, some assets may consist of larger areas or multiple components dispersed across Stonington (e.g. Barn Island Management Area or drainage facilities). In addition, a high level overview of some of Stonington's most important neighborhoods was also included in this assessment. Due to the large number of outfalls and catch basins in Stonington, the decision was made to treat both of these as individual asset classes, instead of assessing the risk to each individual outfall and catch basin. Similarly, Stonington has a large number of historic properties; because most of these properties are concentrated in four historic districts, the assessment of the historic resources was based on the risk to the district as a whole.

This risk assessment is based on an analysis of the type of hazard (or the likelihood of the coastal flooding event) to which the asset is exposed, the level of exposure (or how much flooding is expected to impact the asset), and the vulnerability of the asset (or the level of importance of that asset to the community). The risk score incorporates each of these components using the following equation and definitions.

Memorandum

Risk = Hazard x Exposure x Vulnerability

Hazard

The hazard analysis is intended to assess the likelihood that an asset will be impacted by coastal flooding. The scoring was based on the following ranking of storm types:

Hazard Type	Hazard Score
Present-day 1% storm	3
2030 1% storm	2
2050 1% storm	1

Note: For the 2030 and 2050 hazards, we also included assets that were impacted by the 0.1% storm.

Exposure

The exposure analysis focuses on the anticipated depth of flooding associated with the 0.1% annual storm in 2050. Because some of the assets spread across several anticipated flood depths, we used the maximum depth of flooding at any point along the asset. For example, whereas a building can be assessed at a specific point location, a roadway or park spans a lot more area; therefore, the maximum depth was used in order to provide one depth number for each asset.

The following chart details the breakdown of exposure scores:

Depth of Flooding	Exposure Score
> 10 ft.	4
5.01-10 ft.	3
2.01-5 ft.	2
0-2 ft.	1

Vulnerability

The vulnerability score is based on a set of assumptions for each of these assets; these assumptions are intended to provide a measure of the asset's importance to the community. In order to accomplish this, four scores are given to each asset and then combined into one overall vulnerability score. The first score is a measure of the criticality of the facility. This scoring is based on the FEMA definition of a critical facility.

"FEMA defines four kinds of critical facilities:

- Structures or facilities that produce, use or store highly volatile, flammable, explosive, toxic and/or water-reactive materials.

- Hospitals, nursing homes and housing likely to have occupants who may not be sufficiently mobile to avoid injury or death during a flood.
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for flood response activities before, during and after a flood.
- Public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during and after a flood."[1]

In addition, "other essential assets" refers to assets that are important to providing essential municipal services, but are not included in FEMA's definition of critical facilities. Municipal services are typically defined as services that residents expect the local government entity to provide in exchange for the residents' tax dollars (i.e. schools).

Based on this definition, the following scoring system was developed:

Critical Facility	Critical Facility Score
Critical Facility by FEMA's definition	3
Other essential assets	2
Non-critical and non-essential assets	1

A second analysis was performed to assess the consequence of failure of the asset. A simple estimate was completed to approximate the percentage of the population that would be impacted by failure of the asset. The analysis was a high-level representation of the redundancy of each asset. Percentage impacted is a function of the number of facilities that provide the same services to the community, as a whole. For example, Stonington only has one high school and emergency shelter, therefore the assumption was made that flooding of the high school would impact 100% of Stonington's population; similarly, there are six fire stations in Stonington, so the assumption was made that failure of any one of these facilities would impact 16.66% of the population. In the case of the three wastewater treatment facilities, it is important to note that the Stonington WPCA provided data on the service areas for each facilities; therefore no assumptions needed to be made because that data was used to assess the impact to the community for each of those facilities.

The impact to the community was scored based on the following system:

Impact by %	Community Impact Score
67-100%	3
34-66%	2
0-33%	1

The third analysis used to determine vulnerability was a high-level economic impact analysis. For this analysis, assumptions were made regarding the magnitude of the anticipated replacement cost of each

[1] https://www.fema.gov/media-library-data/20130726-1535-20490-3720/unit6.pdf

asset; a simple assessment was then conducted to assess the direct economic impact based on damage to the asset in question. A more detailed and in-depth cost-benefit analysis for the most at-risk assets is anticipated in the next phase of this scope of work. This economic impact was assessed according to the following system:

Economic Impact/Replacement Cost	Economic Impact Score
High = important infrastructure equipment	3
Medium = other buildings	2
Low = open space and recreation areas	1

The fourth analysis was intended to capture the importance of historic districts and tourism in Stonington. Tourism is largely driven by the historic nature of the Town and its proximity to the ocean and as a result, tourism has become an important economic driver for the Town. Because we do not have detailed statistics on the value of tourism on Stonington's economy, we conducted a high-level assessment to identify important tourism assets and districts. Tourism and historic resources in the Town seem to be closely correlated, as the most historic districts also seem to be the most popular tourist destinations. Therefore, we combined the two into one category to assess the value of tourism and historic resources. Any asset or district identified by the Town as an important historic district or tourist destination was given a score of three. All other assets were not scored in this category. Specifically, the assets that received a score of three in this category include:

- Mystic Seaport
- Mechanic Street Historic District
- Mystic Bridge Historic District
- Rossie Velvet Historic District
- Stonington Borough Historic District

An average was taken of the critical facility score, the community impact score, the economic impact score, and the tourism/historic resources score in order to determine one vulnerability score. It is important to note that the vulnerability assessment of the historic districts was based on the criticality of the impacted historic properties to the Town of Stonington and its residents; the assessment did not take into account other types of facilities that may be located within the historic district, since those facilities were assessed separately and given their own individual risk scores. Therefore, the historic districts may have a lower risk score than some of the facilities located in those districts, because they have different vulnerability scores based on different levels of criticality to the Town.

Risk

The risk score was determined by multiplying the hazard score, the exposure score, and the vulnerability score to establish one overall risk score for each asset. The risk score will be used to prioritize the most at-risk assets in Stonington (Note: The highest possible risk score for any asset is 36). The following example details the full risk scoring for one of Stonington's assets.

Mystic Wastewater Treatment Facility:

Hazard:

- This asset is at risk as early as the present-day 100-year flood event
    - Hazard Score = 3

Exposure:

- Maximum depth of flooding during the 2050 0.1% annual storm = 10.9 ft.
    - Exposure Score = 4

Vulnerability

- Wastewater Treatment is considered a critical facility under FEMA's definition
    - Critical Facility Score = 3
- The Mystic Wastewater Treatment Facility services approximately 14% of the population in Stonington (based on data provided by the WPCA); therefore, failure of the asset would impact approximately 14% of the population
    - Community Impact Score = 1
- Wastewater treatment facilities require expensive infrastructure in order to function properly; therefore, damage to the facility would have a high economic impact
    - Economic Impact Score = 3
- Wastewater treatment facilities are not a tourist attraction
    - Tourism/Historic Resources Score = N/A
- Overall vulnerability score = (3 + 1+ 3 + 0) / 4 = 1.75

Risk

Hazard Score (3) x Exposure Score (4) x Vulnerability Score (1.75) = 21

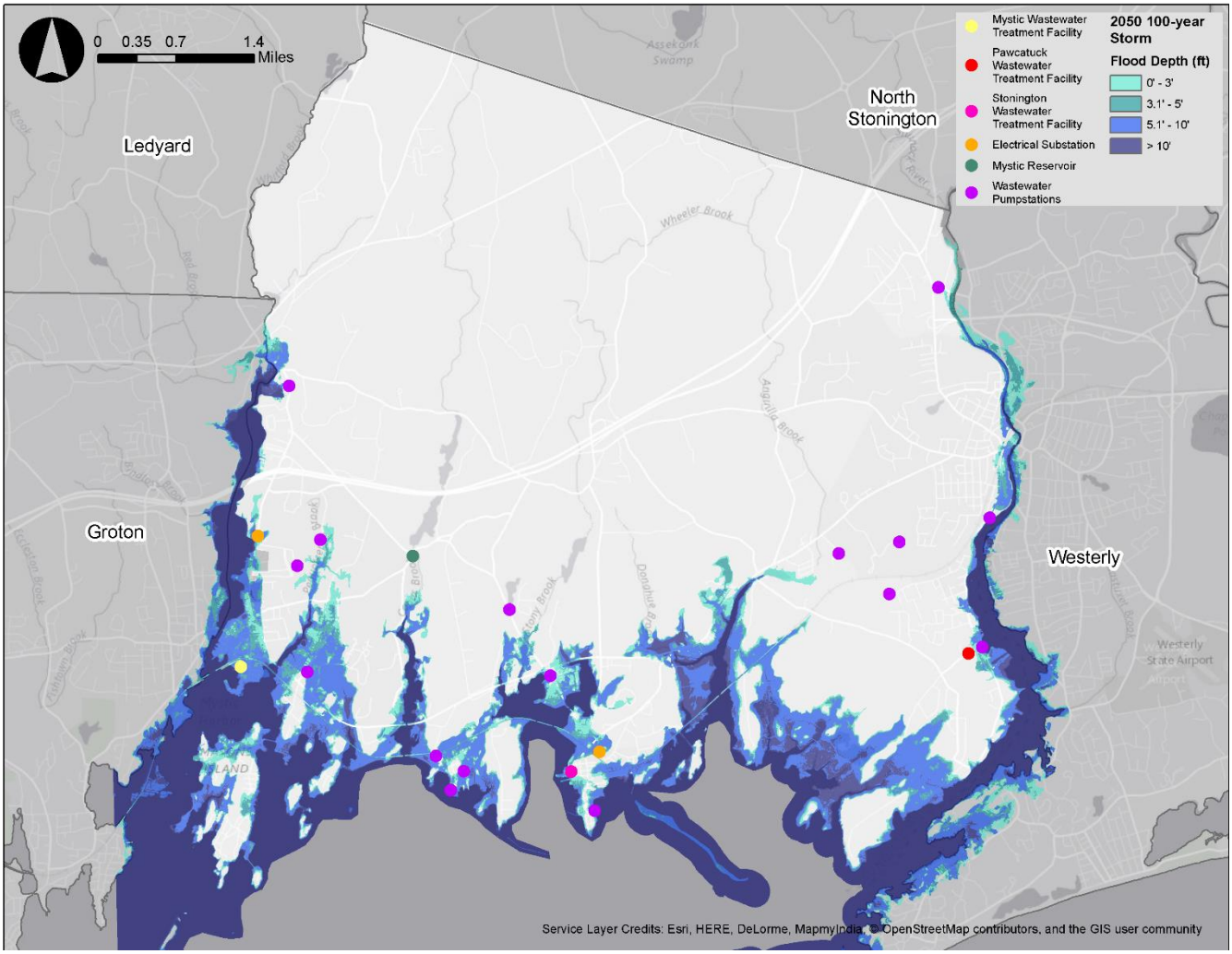
3 Risk Assessment

Based on this methodology, we assessed the risk across a variety of community assets and resources in Stonington. The full risk assessment and back-up information can be found in the attached Risk Assessment spreadsheet. The results of the analysis are displayed in the following tables – the first table displays the risk associated with town-owned assets while the second table displays the risk associated with important assets in Stonington that fall outside of the Town's jurisdiction. The results were divided in this way in order to prioritize those assets that the Town has direct control over as compared to those assets where the Town will need to serve in more of an awareness and advocacy role in order to encourage the owners of those assets to make improvements to the asset's resilience.

Assets were divided into four main categories as detailed below:

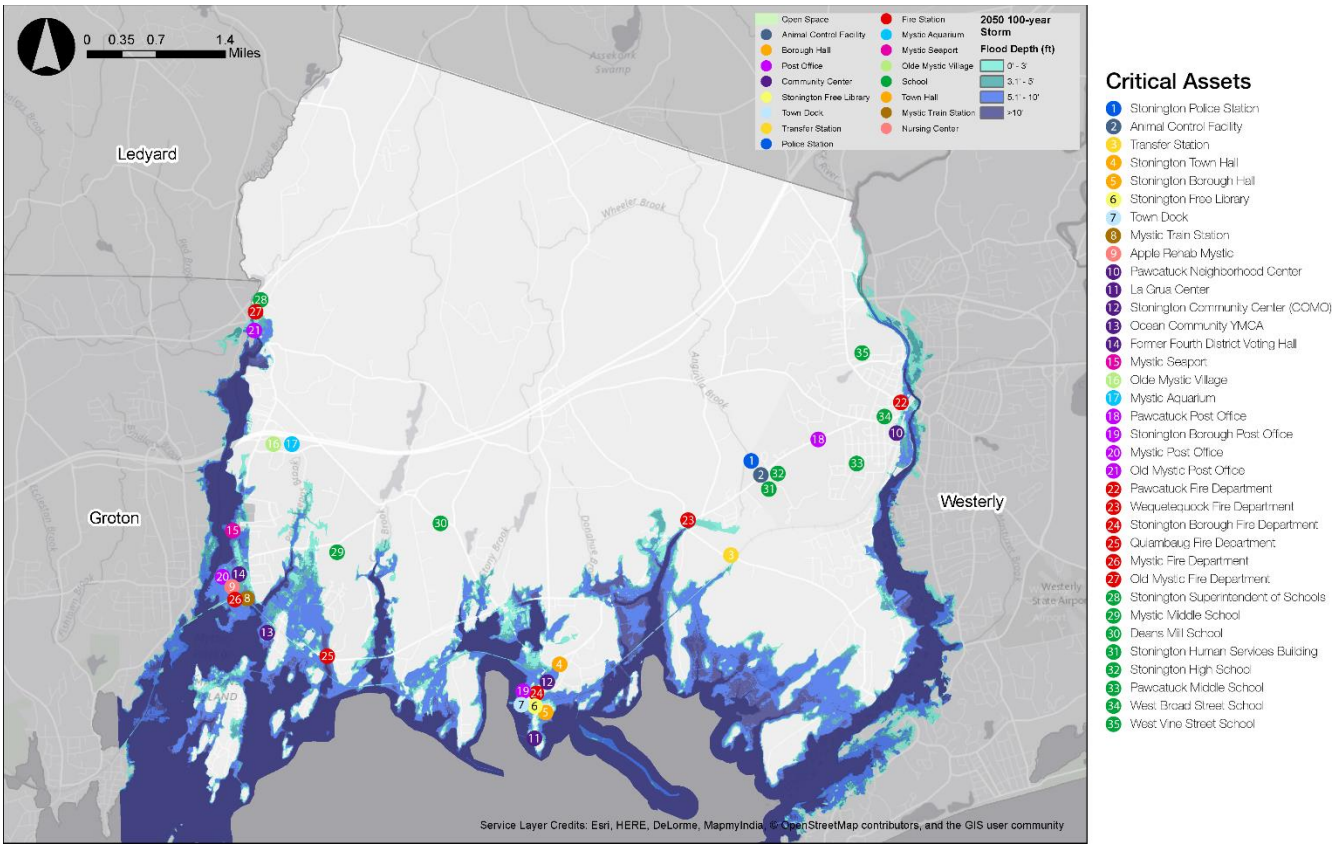
- Drainage and Utilities (D&U): Drainage and utility infrastructure, including wastewater treatment plants, pumping stations, catch basins, and outfalls.
- Critical Assets (CA): Important assets in Stonington, including critical facilities (fire stations, schools, police stations) and open space.
- Transportation (T): Transportation assets, including major roadways and rail infrastructure.
- Historic Resources (HR): Important historic districts in Stonington

Drainage & Utilities



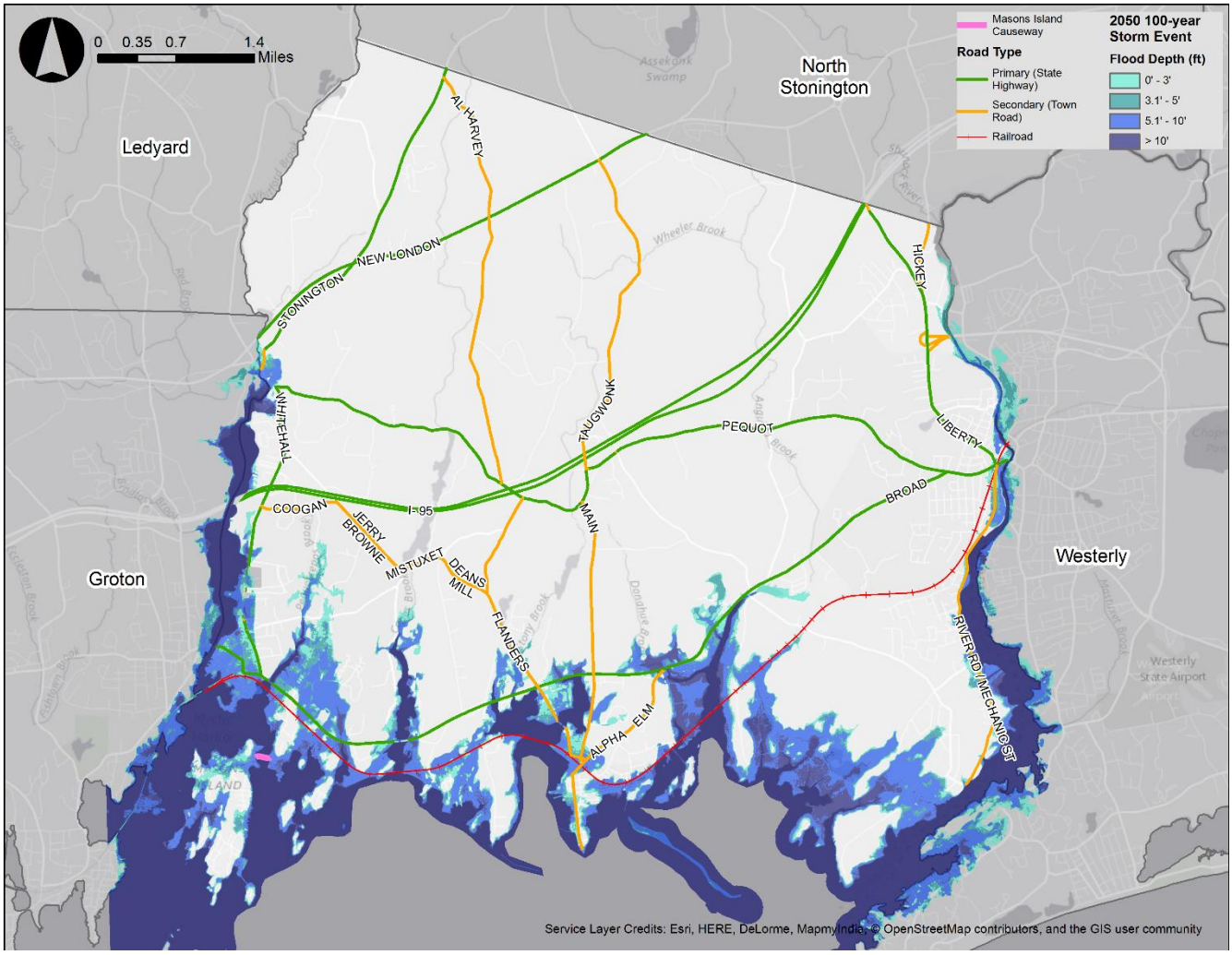
Memorandum

Critical Assets



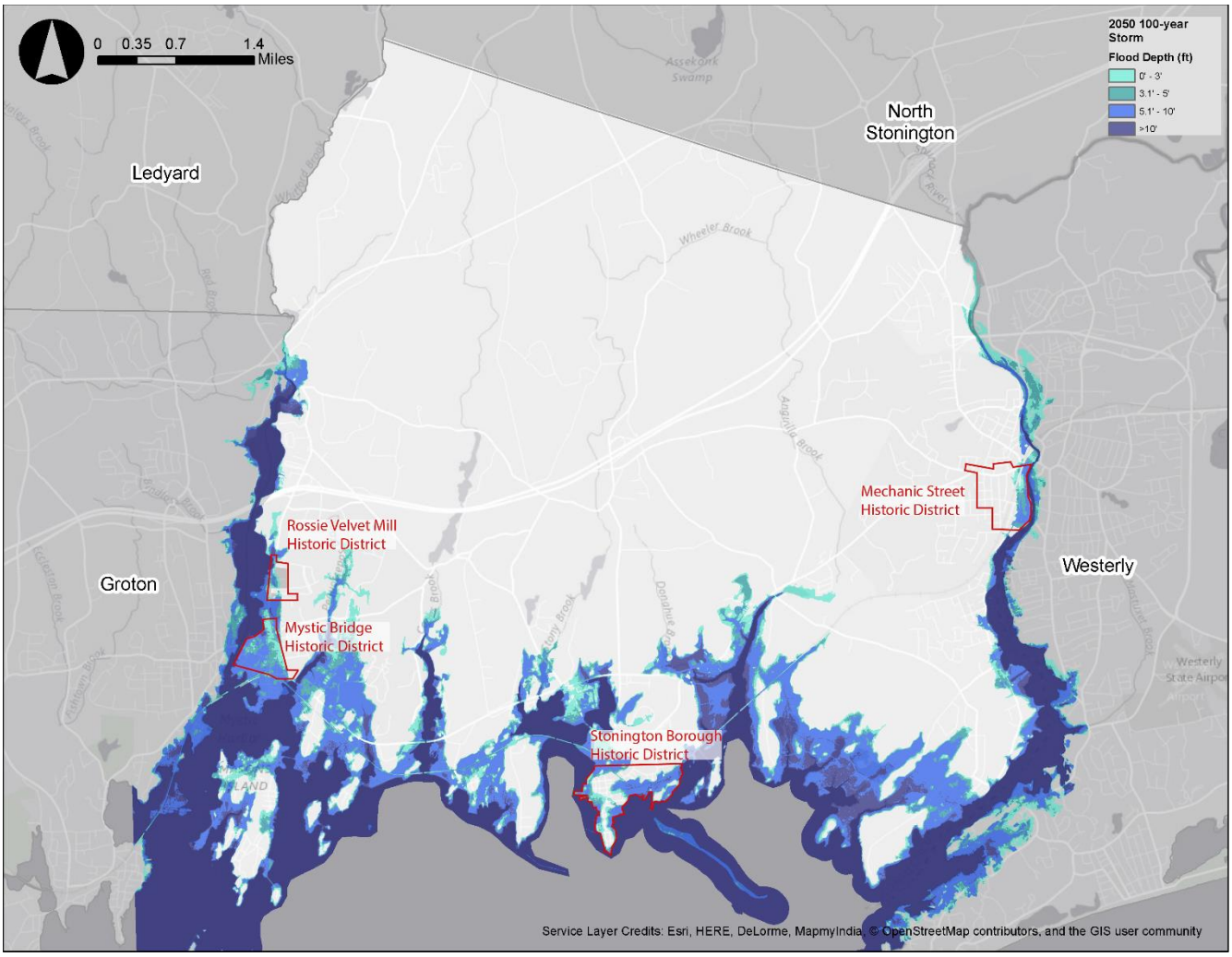
Memorandum

Transportation



Memorandum

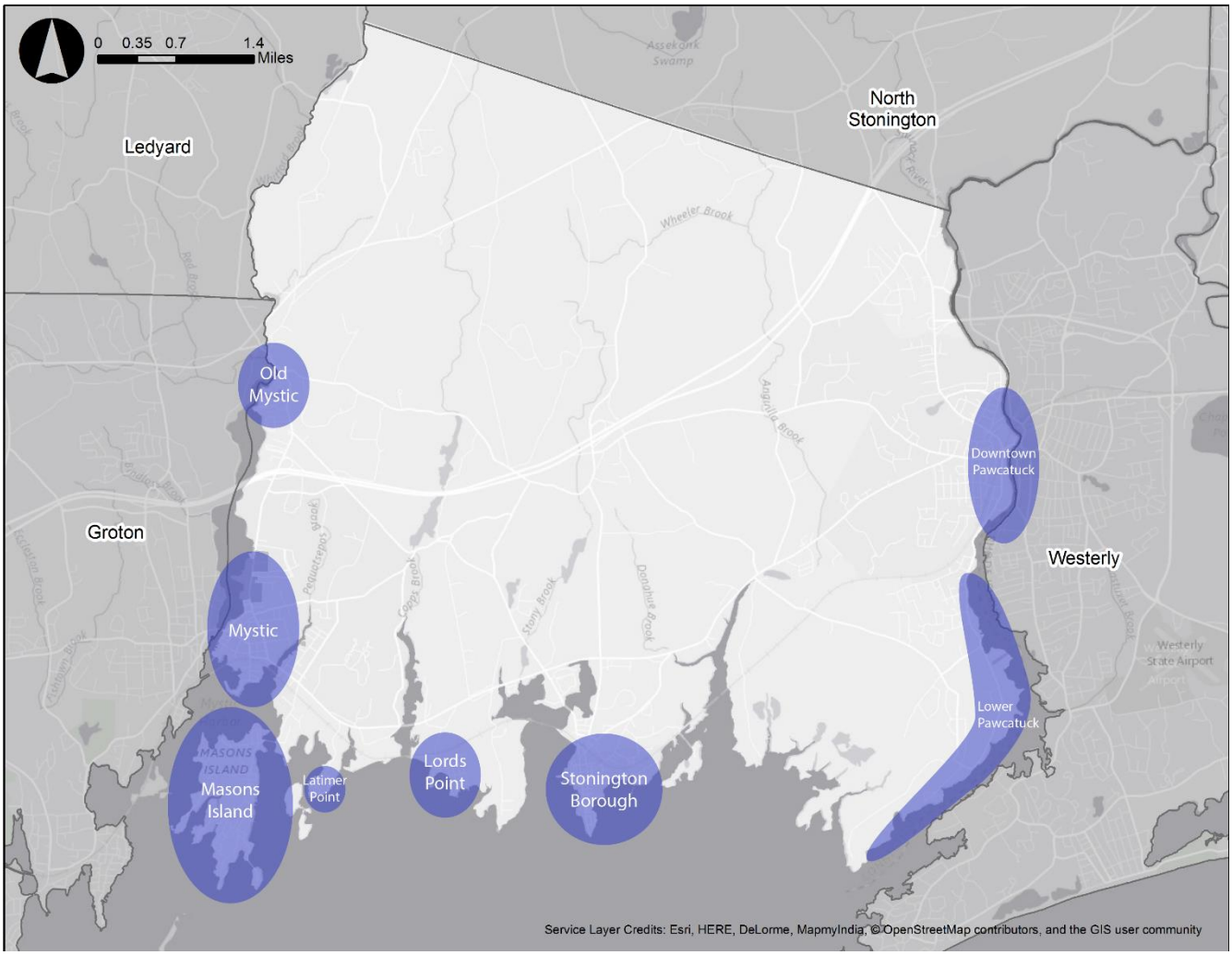
Historic Resources



Memorandum

The purpose of this Memo is to identify that most at-risk assets in order to determine which assets will be the focus of developing resilience solutions. However, it is important to note that, as part of the Coastal Resilience Plan, we will also complete a high-level review of the five focus areas/neighborhoods that have particular importance to the Town:

- Downtown Mystic (including Mystic Seaport)
- Old Mystic
- Waterfront Communities (including Masons Island, Latimer Point, and Lords Point)
- Stonington Borough
- Pawcatuck (including Downtown Pawcatuck and Lower Pawcatuck)



Memorandum

Risk Ranking

The following tables show the results of the risk ranking, with the assets separated by ownership type.

Town and Borough-Owned Assets

Asset	Asset Class	Ownership	Hazard	Exposure	Vulnerability	Risk
Masons Island Causeway	CA	Town	3	4	2.00	24
Mystic Wastewater Treatment Facility	CA	Town	3	4	1.75	21
Mechanic Street Historic District	HR	Private and Town	3	4	1.75	21
Mystic Bridge Historic District	HR	Private and Town	3	4	1.75	21
Rossie Velvet Historic District	HR	Private and Town	3	4	1.75	21
Stonington Borough Historic District	HR	Private and Town	3	4	1.75	21
Boulder Avenue Pump Station	D&U	Town	3	4	1.50	18
Diving Street Pump Station	D&U	Town	3	4	1.50	18
River Road/Mary Hall Road Pump Station (Pump Station No. 3)	D&U	Town	3	4	1.50	18
Wolcott Avenue Pump Station	D&U	Town	3	4	1.50	18
River Road/Mechanic Street	T	Town	3	4	1.50	18
North Main Street	T	Town	3	4	1.50	18
Elm Street	T	Town and Borough	3	4	1.50	18
Flanders Road	T	Town	4	3	1.50	18
Cutler Street	T	Town	4	3	1.50	18
Town Dock	CA	Town	3	3	1.75	16
Catchbasins	D&U	Town	3	4	1.25	15
Outfalls	D&U	Town	3	4	1.25	15
Hewitt Road Pump Station	D&U	Town	3	3	1.50	14
Mechanic Street (Pump Station 1)	D&U	Town	3	3	1.50	14
Willow Street	T	Town	3	3	1.50	14
Water Street	T	Borough	3	3	1.50	14
Donahue Park	CA	Town	3	4	0.75	9
Ensign Lane Pump Station	D&U	Town	3	2	1.50	9

Former 4th District Voting Hall	CA	Town	3	3	1.00	9
Mystic River Park	CA	Town	3	4	0.75	9
Borough Hall	CA	Borough	3	2	1.25	8
Old Mystic Playground	CA	Town	3	3	0.75	7
Stonington Police Department	CA	Town	3	1	2.25	7
Stonington High School & Emergency Shelter	CA	Town	3	1	2.00	6
Borough Fire Station	CA	Borough	3	1	1.75	5
Old Mystic Pump Station	D&U	Town	3	1	1.50	5
Lindbergh Road Pump Station	D&U	Town	1	1	1.50	2
Stonington Town Park	CA	Town	1	1	0.75	1

Assets Not Owned by the Town or Borough

Asset	Asset Class	Ownership	Hazard	Exposure	Vulnerability	Risk
Apple Rehab Mystic	CA	Private	3	4	2.00	24
Mystic Seaport	CA	Private	3	4	1.75	21
Greenmanville Ave Electrical Substation	D&U	Private	3	3	2.25	20
Cutler St Electrical Substation	D&U	Private	3	3	2.25	20
Amtrak Rail Line	T	Private	3	4	1.50	18
East Main Street	T	State	3	4	1.50	18
Greenmanville Avenue	T	State	3	4	1.50	18
North Water Street	T	State	3	4	1.50	18
Roosevelt Avenue	T	State	3	4	1.50	18
State Highway 27/Denison Avenue	T	State	3	4	1.50	18
Stonington Road	T	State	3	4	1.50	18
West Broad Street	T	State	3	4	1.50	18
Williams Avenue	T	State	3	4	1.50	18
Mystic Train Station	CA	Private	3	3	1.75	16
Mystic Fire Department	CA	Fire District	3	3	1.75	16
Quiambaug Fire Department	CA	Fire District	3	3	1.75	16
Alpha Avenue	T	State	3	3	1.50	14
Broadway Avenue	T	State and Town	3	3	1.50	14
Liberty Street	T	State	3	3	1.50	14
Westerly Bypass	T	State	3	3	1.50	14
Ocean Community YMCA	CA	Private	3	3	1.25	11

Stonington Community Center	CA	Private	3	3	1.25	11
Old Mystic Post Office	CA	Private	3	3	1.00	9
Town Open Space (Dubois Beach)	CA	Private	3	4	0.75	9
Barn Island Management Area	CA	State	3	4	0.75	9
Mystic Post Office	CA	Federal	3	3	1.00	9
Avalonia Land Conservancy (Ram Point)	CA	Private	3	4	0.75	9
Paffard Marsh Preserve	CA	Private	3	4	0.75	9
Denison Pequot Nature Center (Greenmanville Ave)	CA	Private	3	4	0.75	9
Denison Pequot Nature Center (Pequotsepos Rd)	CA	Private	3	4	0.75	9
Cottrell Marsh (owned)	CA	Private	3	4	0.75	9
TNC Gallup Salt Marsh (easement)	CA	Private	3	4	0.75	9
TNC Mason Island Company (easement)	CA	Private	3	4	0.75	9
South Broad Street	T	State	3	2	1.50	9
Whitehall Avenue	T	State	3	2	1.50	9
Pawcatuck Neighborhood Center	CA	Private	3	2	1.25	8
La Grua Center	CA	Private	3	2	1.25	8
Denison Pequotsepos Nature Center, Inc.	CA	Private	3	3	0.75	7
Mystic Reservoir	D&U	Private	3	1	2.00	6
Pawcatuck Fire Station	CA	Fire District	3	1	1.75	5
Borough Post Office	CA	Federal	3	1	1.00	3
Anguilla Preserve	CA	Private	3	1	0.75	2
Avalonia Land Conservancy (N. Stonington Rd)	CA	Private	3	1	0.75	2
Avalonia Land Conservancy (North Main Street)	CA	Private	3	1	0.75	2
Pawcatuck Little League	CA	Private	3	1	0.75	2
Stonington Soccer Club	CA	Private	3	1	0.75	2

4 Top 25 Assets

Based on this analysis and conversations with the Town, the following assets highlighted were identified as the top 25 most are-risk assets in Stonington. These assets will be reviewed at a higher-level for potential resilience solutions.

Town / Borough Owned

- Masons Island Causeway
- Mystic Wastewater Treatment Facility
- Boulder Ave. Pump Station
- River Road/Mary Hall Rd. Pump Station
- Stonington Wastewater Treatment Facility
- Town Dock

Assets Not Owned by Town or Borough

- Mystic Fire Dept.
- Quiambaug Fire Dept.
- Mechanic Street Historic District
- Mystic Bridge Historic District
- Rossie Velvet Mill Historic District
- Stonington Borough Historic District
- Apple Rehab Mystic
- Mystic Seaport
- Greenmanville Ave. Electrical Substation
- State Hwy 27
- Donahue Park
- State Hwy 1
- Cutler St. Electrical Substation
- Mystic Train Station & Rail Line

- Barn Island Management Area
- Stonington Community Center (COMO)
- Mystic River Park, Cottrell Street
- Lords Point neighborhood
- Murphy's Point neighborhood

5 Top 5 Assets

After the higher-level review of the Top 25 most at-risk assets, the next step in the Stonington Coastal Resilience Plan is to develop resilience solutions for five of the Town's most at-risk assets. Based on the results of this risk assessment and discussions with the Town, Arup recommends completing detailed resilience solutions for the following five assets:

- Apple Rehab Mystic: One of the most at-risk medical facilities in Stonington.
- Masons Island Causeway: Masons Island Causeway is an important asset as it is the only means of access and egress for nearly 800 residents living on Masons Island. It was also impacted by Superstorm Sandy and is often flooded even during smaller flooding events.
- Mystic Wastewater Treatment Plant: Mystic Wastewater Treatment Plant services approximately 14% of the population in Stonington and is a valuable part of the town's infrastructure.
- Mystic (neighborhood, seaport, historic district): Mystic is one of the most important tourist destinations in Stonington and is also home to several important historic properties. In addition, Mystic Seaport ranked as one of the Town's most at-risk assets. This asset would be treated as a neighborhood and the resilience solution would be a neighborhood-scale recommendation with a secondary emphasis on protecting historic properties and the Mystic Seaport.
- A typical single-family structure in Stonington and a typical mixed-use building (based off examples from Pawcatuck): Although individual properties were not assessed as part of this risk assessment, feedback from the Town, the CCTF, and the public have shown that there is a strong interest in protecting personal property and understanding what individual homeowners or small business owners can do to make their properties more resilient. Therefore, we are recommending an assessment of resilience solutions for a typical single-family home structure and a typical commercial mixed-use structure as a means to incorporate the community's interest and concerns.

Appendix A: List of All Assets Reviewed

Critical Assets
Animal Control Facility
Borough Fire Station
Borough Hall
Pawcatuck Post Office
Old Mystic Post Office
Mystic Post Office
Borough Post Office
La Grua Center
Stonington Community Center
Pawcatuck Neighborhood Center
Former Fourth District Voting Hall
Ocean Community YMCA
Stonington Free Library
Town Dock
Transfer Station
Stonington High School
School Adminstration Central Office
Mystic Middle School
Pawcatuck Middle School
Apple Rehab Mystic
Stonington Police Department
Borough Fire Station
Mystic Fire Department
Old Mystic Fire Department
Pawcatuck Fire Department
Quiambaug Fire Department
Wequetequock Fire Department
Mystic Aquarium
Mystic Seaport
Olde Mystic Village
Town Hall
Barn Island Management Area
Denison Pequot Nature Center
Mystic River Park
Stonington Soccer Club
Anguilla Preserve
Town Open Space (Jerry Browne Road)
Avalonia Land Conservancy (N. Stonington Road)
Town Open Space (route 2)
Mystic Little League Field
The Nature Conservancy Mason Island Company (easement)
Town Open Space (Elm Street)
Avalonia Land Conservancy (North Main Street)
Town Open Space (Water & High Streets)
Avalonia Land Conservancy (Ram Point)
The Nature Conservancy Cottrell Marsh (owned)
The Nature Conservancy Gallup Salt Marsh (easement)
Town Open Space (Dubois Beach)
Williams Beach (Mystic Community Center)
Paffard Marsh Preserve
Avalonia Land Conservancy
Stonington Town Park
Moss Park (Enterprise Avenue, Rear)
Town Open Space (Farmholme Road)
Avalonia Land Conservancy (Williams Rd, Rear)
Town Open Space (Water & High Streets)
Old Mystic Playground
Pawcatuck Little League
Pawcatuck Park
Denison Pequotsepos Nature Center, Inc
Mystic Train Station
Historic Districts
Mechanic Street Historic District
Mystic Bridge Historic District
Rossie Velvet Historic District
Stonington Borough Historic District

Transportation
Amtrak Rail Line
Masons Island Causeway
Al Harvey Road
Alpha Avenue
Broadway Avenue
Coogan Boulevard
Cutler Street
Deans Mill Road
Denison Avenue
East Main Street
Elm Street
Flanders Road
Greenmanville Avenue
Hickey Drive
Jerry Browne Road
Liberty Street
Main Street
Mistuxet Avenue
New London Turnpike
North Main Street
North Stonington Road
North Water Street
Norwich-Westerly Road
Pequot Trail
River Road/Mechanic Street
Roosevelt Avenue
Route 27
South Broad Street
State Highway 27
Stonington Road
Taugwonk Road
Voluntown Road
Water Street
West Broad Street
Westerly Bypass
Whitehall Avenue
Williams Avenue
Willow Street
Drainage & Utilities
Cutler St. Electrical Substation
Greenmanville Ave. Electrical Substation
Outfalls
Catch Basins
Cutter Drive Pump Station
Hewitt Road Pump Station
Diving Street Pump Station
Flanders Road Pump Station
Ensign Lane Pump Station
Boulder Avenue Pump Station
White Rock Road Pump Station
Clarks Village Pump Station
Spellman Street Pump Station (Pump Station No. 2)
Extrusion Drive Pump Station
Wolcott Avenue Pump Station
River Road/Mary Hall Road Pump Station (Pump Station No. 3)
Mechanic Street (Pump Station 1)
Lindbergh Road Pump Station
Maritme Drive Pump Station
Old Mystic Pump Station
Pawcatuck Wastewater Treatment Facility
Mystic Wastewater Treatment Facility
Stonington Wastewater Treatment Facility
Mystic Reservoir

Appendix B: Risk Scoring Tables

Risk = Hazard x Exposure x Vulnerability

Hazard = the hazard area where the asset is located (based on storm type and FEMA flood zones)

Hazard Type	Hazard Score
Present-day 1% storm or FEMA AE/VE Zone	3
2030 1% or 0.1% Storm	2
2050 1% or 0.1% storm	1

Exposure = Depth of flooding (in ft) to which the asset is exposed

Depth of Flooding	Exposure Score
> 10	4
5.01-10 ft	3
2.01-5 ft	2
0-2 ft	1

Vulnerability = Criticality of facility and impact on community

Critical facility is based on FEMA's definition of critical facility (found on pg. 6-18 to 6-20 here: https://www.fema.gov/media-library-data/20130726-1535-20490-3720/unit6.pdf):

Structures or facilities that produce, use or store highly volatile, flammable, explosive, toxic and/or water-reactive materials.
Hospitals, nursing homes and housing likely to have occupants who may not be sufficiently mobile to avoid injury or death during a flood.
Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for flood response activities before, during and after a flood.
Public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during and after a flood.

Critical Facility	Critical Facility Score	
Critical Facility by FEMA's definition	3	Fire, Police, Wastewater Treatment, Electric substation, Mystic Reservoir, sewer treatment plant
Other essential assets	2	Other municipal buildings (i.e town hall), community/neighborhood centers, schools, Amtrak, major roadways, pump stations, outfalls, catch basins
Non-critical and non-essential assets	1	

Impact on community is a function of assumptions made relative to % of community served by the asset; assumed % population affected based on redundancy of other facilities performing similar services (for wastewater treatment facilities, we used actual numbers provided by the WPCA)

Impact by %	Community Impact Score
67-100%	3
34-66%	2
0-33%	1

Economic Impact is a function of the value of the asset impacted; facilities with important infrastructure or equipment are considered high, buildings and structures without vital infrastructure are medium, open space is low

Impact	Economic Impact Score
High = important infrastructure equipment	3
Medium = other buildings	2
Low = open space and recreation areas	1

Impact on Tourism/Economy is a function of areas designated as important historic and tourism areas of the Town; because Stonington's economy is supported by tourism, this is an important factor to consider

Impact	Tourism Score
High = important historic district/tourist attraction	3

Vulnerability is an average of the critical facility, community impact, and economic impact score
For example, if critical facility score = 3, economic impact score = 1, and community impact score = 2, then vulnerability score = (3+1+2)/3 = 2

Asset	Hazard	Hazard Score	Exposure	Exposure Score	Vulnerability				Vulnerability Score	Total Risk Score
			Max Depth in 2050 0.1% (in ft)		Critical Facility	Impact on Community	Economic Impact	Tourism Impact		
Community Facilities										
TNC Mason Island Company (easement)	Present 100 & FEMA	3	17.2	4	1	1	1		0.75	9
Avalonia Land Conservancy (Ram Point)	Present 100 & FEMA	3	17.4	4	1	1	1		0.75	9
TNC Cottrell Marsh (owned)	Present 100 & FEMA	3	17.5	4	1	1	1		0.75	9
TNC Gallup Salt Marsh (easement)	Present 100 & FEMA	3	17.1	4	1	1	1		0.75	9
Town Open Space (Dubois Beach)	Present 100 & FEMA	3	16.7	4	1	1	1		0.75	9
Ocean Community YMCA	2050 100 / 500 & FEMA	3	6.9	3	2	1	2		1.25	11.25
Paffard Marsh Preserve	Present 100 & FEMA	3	18.2	4	1	1	1		0.75	9
Old Mystic Playground	Present 100 & FEMA	3	9.0	3	1	1	1		0.75	6.75
Donahue Park	Present 100 & FEMA	3	17.8	4	1	1	1		0.75	9
Barn Island Management Area	Present 100 & FEMA	3	17.4	4	1	1	1		0.75	9
Borough Fire Station	FEMA	3	0.0	1	3	1	3		1.75	5.25
Borough Hall	2030 100 / 500 & FEMA	3	3.0	2	2	1	2		1.25	7.5
Borough Post Office	FEMA	3	0.0	1	1	1	2		1	3
Denison Pequot Nature Center (Cottrell St)	Present 100 & FEMA	3	14.8	4	1	1	1		0.75	9
Denison Pequot Nature Center (Pequotsepos Rd)	Present 100 & FEMA	3	12.2	4	1	1	1		0.75	9
Denison Pequotsepos Nature Center, Inc.	2050 100 / 500 & FEMA	3	6.8	3	1	1	1		0.75	6.75
Former 4th District Voting Hall	Present 100 & FEMA	3	9.0	3	1	1	2		1	9
La Grua Center	2030 100 / 500 & FEMA	3	3.2	2	2	1	2		1.25	7.5
Old Mystic Post Office	Present 100 & FEMA	3	9.6	3	1	1	2		1	9
Pawcatuck Fire Station	FEMA	3	0.0	1	3	1	3		1.75	5.25
Pawcatuck Neighborhood Center	2030 100 / 500 & FEMA	3	2.8	2	2	1	2		1.25	7.5
Stonington Community Center	Present 100 & FEMA	3	9.5	3	2	1	2		1.25	11.25
Stonington High School & Emergency Shelter	FEMA	3	0.0	1	3	3	2		2	6
Stonington Town Park	2050 100 / 500	1	1.6	1	1	1	1		0.75	0.75
Town Dock	Present 100 & FEMA	3	8.3	3	1	3	3		1.75	15.75
Mystic Seaport	Present 100 & FEMA	3	10.5	4	1	1	2	3	1.75	21
Mystic Fire Department	Present 100 & FEMA	3	5.3	3	3	1	3		1.75	15.75
Quiambaug Fire Department	Present 100 & FEMA	3	8.8	3	3	1	3		1.75	15.75
Stonington Police Department	FEMA	3	0.0	1	3	3	3		2.25	6.75
Pawcatuck Little League	FEMA	3	0.0	1	1	1	1		0.75	2.25
Stonington Soccer Club	FEMA	3	0.0	1	1	1	1		0.75	2.25
Anguilla Preserve	FEMA	3	0.0	1	1	1	1		0.75	2.25
Avalonia Land Conservancy (N. Stonington Rd)	FEMA	3	0.0	1	1	1	1		0.75	2.25
Avalonia Land Conservancy (North Main Street)	FEMA	3	0.0	1	1	1	1		0.75	2.25
Apple Rehab Mystic	Present 100 & FEMA	3	10.2	4	3	3	2		2	24
Mystic Post Office	Present 100 & FEMA	3	7.9	3	1	1	2		1	9
Mystic River Park	Present 100 & FEMA	3	16.9	4	1	1	1		0.75	9
Mystic Train Station	Present 100 & FEMA	3	5.3	3	2	3	2		1.75	15.75
Drainage & Utilities										
Mystic Wastewater Treatment Facility	Present 100 & FEMA	3	10.9	4	3	1	3		1.75	21
Stonington Wastewater Treatment Facility	Present 100 & FEMA	3	8.2	3	3	1	3		1.75	15.75
Greenmanville Ave Electrical Substation	Present 100 & FEMA	3	9.9	3	3	3	3		2.25	20.25
Cutler St Electrical Substation	Present 100 & FEMA	3	5.5	3	3	3	3		2.25	20.25
Mystic Reservoir	FEMA	3	0.0	1	3	3	2		2	6
Hewitt Road Pump Station	Present 100 & FEMA	3	8.7	3	2	1	3		1.5	13.5
Diving Street Pump Station	Present 100 & FEMA	3	11.8	4	2	1	3		1.5	18
Ensign Lane Pump Station	2030 100 / 500 & FEMA	3	5	2	2	1	3		1.5	9
Boulder Avenue Pump Station	Present 100 & FEMA	3	11.1	4	2	1	3		1.5	18
Wolcott Avenue Pump Station	Present 100 & FEMA	3	10.5	4	2	1	3		1.5	18
River Road/Mary Hall Road Pump Station (Pump Station No. 3)	Present 100 & FEMA	3	13.1	4	2	1	3		1.5	18
Mechanic Street (Pump Station 1)	Present 100	3	7	3	2	1	3		1.5	13.5
Lindbergh Road Pump Station	2050 100 / 500	1	1.6	1	2	1	3		1.5	1.5
Old Mystic Pump Station	FEMA	3	1.3	1	2	1	3		1.5	4.5
Outfalls	Present 100 (109) & FEMA (119) & 2030 100 / 500 (126) & 2050 100 / 500 (130)	3	17.2	4	2	1	2		1.25	15

Asset	Hazard	Hazard Score	Exposure	Exposure Score	Vulnerability				Vulnerability Score	Total Risk Score
			Max Depth in 2050 0.1% (in ft)		Critical Facility	Impact on Community	Economic Impact	Tourism Impact		
Catchbasins	Present 100 (568) & FEMA (617) & 2030 500 (700) & 2050 500 (724)	3	13.4	4	2	1	2		1.25	15
Historic Resources										
Mechanic Street Historic District	FEMA (43), Present 100 (45), 2030 100 / 500 (84), 2050 100 / 500 (88)	3	11.9	4	1	1	2	3	1.75	21
Mystic Bridge Historic District	FEMA (359), Present 100 (328), 2030 100 / 500 (401), 2050 100 / 500 (402)	3	15.8	4	1	1	2	3	1.75	21
Rossie Velvet Historic District	FEMA (207), Present 100 (22), 2030 500 (50), 2050 500 (54)	3	11.6	4	1	1	2	3	1.75	21
Stonington Borough Historic District	FEMA (206), Present 100 (133), 2030 100 / 500 (270), 2050 100 / 500 (294)	3	16.6	4	1	1	2	3	1.75	21
Transportation										
Masons Island Causeway	Present 100 & FEMA	3	11.8	4	2	3	3		2	24
Amtrak Rail Line	Present 100 & FEMA	3	17.8	4	2	1	3		1.5	18
Alpha Avenue	Present 100 & FEMA	3	9.96	3	2	1	3		1.5	13.5
Broadway Avenue	Present 100 & FEMA	3	9.25	3	2	1	3		1.5	13.5
Cutler Street	Present 100 & FEMA	4	9.84	3	2	1	3		1.5	18
Denison Avenue	Present 100 & FEMA	3	9.74	3	2	1	3		1.5	13.5
East Main Street	Present 100 & FEMA	3	17.47	4	2	1	3		1.5	18
Elm Street	Present 100 & FEMA	3	11.56	4	2	1	3		1.5	18
Flanders Road	Present 100 & FEMA	4	7.37	3	2	1	3		1.5	18
Greenmanville Avenue	Present 100 & FEMA	3	11.2	4	2	1	3		1.5	18
Liberty Street	Present 100 & FEMA	3	9.48	3	2	1	3		1.5	13.5
Main Street	Present 100 & FEMA	3	8.65	3	2	1	3		1.5	13.5
North Main Street	Present 100 & FEMA	3	10.04	4	2	1	3		1.5	18
River Road/Mechanic Street	Present 100 & FEMA	3	13.89	4	2	1	3		1.5	18
North Water Street	Present 100 & FEMA	3	16.32	4	2	1	3		1.5	18
Roosevelt Avenue	Present 100 & FEMA	3	10.25	4	2	1	3		1.5	18
South Broad Street	Present 100 & FEMA	3	2.11	2	2	1	3		1.5	9
State Highway 27	Present 100 & FEMA	3	10.46	4	2	1	3		1.5	18
Stonington Road	Present 100 & FEMA	3	16.35	4	2	1	3		1.5	18
Water Street	Present 100 & FEMA	3	8.65	3	2	1	3		1.5	13.5
West Broad Street	Present 100 & FEMA	3	11.96	4	2	1	3		1.5	18
Westerly Bypass	Present 100 & FEMA	3	8.61	3	2	1	3		1.5	13.5
Whitehall Avenue	Present 100 & FEMA	3	2.06	2	2	1	3		1.5	9
Williams Avenue	Present 100 & FEMA	3	16.57	4	2	1	3		1.5	18
Willow Street	Present 100 & FEMA	3	7.9	3	2	1	3		1.5	13.5

Appendix C:
Resilience Solutions Memo

Memorandum

ARUP

To	Mr. Keith Brynes, Town Planner Town of Stonington, CT	Date	June 1, 2017
Copies	Mr. Scot Deledda, Town Engineer Town of Stonington, CT	Reference number	251043.00
From	Lisa Dickson, Arup Katie Wholey, Arup	File reference	
Subject	Proposed Resilience Solutions		

Overview

Based on the Vulnerability and Risk assessment for the Town of Stonington, previously completed as part of this scope of work, the Top 25 and the Top 5 most at-risk assets for the Town were identified. Those at-risk assets were carried into this next phase of work to identify proposed resilience solutions for each of the assets. For the Top 25 assets, we have identified high-level solutions that are intended to help the Town understand the types of resilience solutions that may be well-suited for Stonington and should be explored in further detail as the Town moves towards a more resilient future. More detailed solutions were developed for each of the Top 5 assets. These resilience solutions provide greater detail on the various benefits associated with each solution as well as estimated costs for implementing those solutions at each site.

Potential Resilience Strategies

Protection

"Hard" Solutions for Shoreline Protection

There are a variety of engineered solutions to protect coastal shorelines from flooding and erosion. These solutions include (but are not limited to) bulkheads, seawalls, levees and revetments. Bulkheads, seawalls, and levees are traditionally made of stone or concrete whereas revetments are typically constructed from stone. These "hard" engineering solutions are intended to protect exposed shorelines from erosion and mitigate the effects of sea level rise and storm surge.

Living Shoreline

Living shorelines include a wide range of ecological solutions that protect coastal areas from erosion, sea level rise, and coastal flooding. These solutions prioritize natural solutions and green infrastructure over “hard” coastal engineering solutions. Living shorelines are typically a system of green infrastructure (or “soft” engineering solutions) that creates a buffer along the water’s edge with the goal of minimizing erosion and absorbing wave action.

Tides Gates (or Floodgates)

Tide gates, also known as floodgates, are gate that can be deployed to control water flow and prevent flooding. These gates are typically implemented as part of a larger flood control system to protect the coast from large storm surges.

Floodplain Buyout and Acquisition Programs

A large portion of homes and businesses in Stonington were built in the floodplain and, therefore, are at increased risk from coastal flooding. Buyout and acquisition programs are some of the most cost-effective to reduce flood risk to these vulnerable properties. Floodplain buyout programs are typically voluntary programs where owners in the floodplain can be “bought out” by the government. The government entity removes those properties from the floodplain and often returns the land to nature by creating community parks and open space that can be flooded during a storm event, but also provide recreational opportunities to the community.

Relocation

Relocation can mean moving homes and businesses to an area on the same lot that is outside the floodplain or it can be relocating structures to an entirely different lot that is outside the floodplain. Relocation can be a complement to buyout and acquisition programs.

Raised Streets and Infrastructure

Rebuilding and raising streets that are prone to flooding during storm events is a common form of mitigation. Additionally, other types of infrastructure may be suitable for this type of strategies, including rail lines. Cities and towns typically invest in additional mitigation measures along with raising the streets and infrastructure, including installing pump stations and raising the height of adjacent seawalls.

Wet Floodproofing

Wet floodproofing is typically used for structures that cannot easily be elevated, such as large multi-family residential buildings. Instead of elevating the building above the design flood elevation (DFE), wet floodproofing allows for floodwaters to enter and exit the building during flooding events. In order wet floodproof the building, mechanical and electrical systems (along with other utilities and

equipment) must be elevated above DFE, flood-resistant materials should be used in the area below DFE, and modifications must be made to the building to allow the floodwaters to both enter and exit the building (typically through the use of flood vents).

Dry Floodproofing

Dry floodproofing is the process of making a structure watertight below DFE. Dry floodproofing measures typically include sealing walls with waterproof coatings, installing backflow preventers, and installing watertight shields over windows and doors (also known as floor shields). Floor shields are temporary, watertight barriers that are placed over windows and doors to prevent floodwaters from entering through those building openings.

Floodplain Policies and Regulations

Amendments to Stonington's regulations can assist in limiting the amount and type of construction occurring in flood prone areas. Changes to the regulations should include both more stringent requirements as well as less stringent requirements, as needed. For example, building codes could require elevation of mechanical systems above DFE for all new construction or major renovations in the floodplain whereas zoning regulations may consider loosening height restrictions for individuals who would like to elevate their properties or allowing for more flexibility in locating mechanical systems above DFE, so that the regulations are not a barrier to increasing resilience. Additionally, innovative financing, such as tax increment financing (TIF) can be employed to help fund community resilience projects.

Offshore Breakwaters

Offshore breakwaters are stone or concrete structures constructed off the coast to absorb wave energy before they reach the shore. Breakwaters can significantly protect the coast from damaging storm surges and often provide new habitats for marine species living in the area.

Hurricane Barrier

Hurricane barriers are permanent barriers typically constructed across a harbor or other water opening, extending across the water to the land on either side. The barriers are costly, large-scale infrastructure projects that are typically implemented as a more regional solutions, rather than a site-specific protection measure. These barriers vary widely in length and height and construction type, depending on the specific site where they are constructed and typically include some sort of gate to allow for the passing of boats through the barrier.

Temporary Flood Barriers

Temporary flood barriers can range significantly in cost and construction timeframes for implementation, from using sand bags to protect properties during an anticipated flood event to

installing deployable flood barriers. Most home owners and business owners in coastal communities already use sandbags to protect their properties from coastal flooding, but temporary flood barriers should be considered as alternatives to sand bags. Temporary flood barriers can be constructed/deconstructed during an event and are typically reusable. However, they range in cost and level of effort needed to deploy these barriers. Some examples include inflatable flood barriers that use incoming flood waters to inflate the barrier as the storm surge increases and modular barriers that are constructed from a range of materials.

Adaptation

Buoyant Architecture (or Floating Buildings)

Buoyant architecture allows buildings to rise and fall in response to rising water levels. There are two methods of constructing floating buildings. The first is by constructing the buildings on floating barges that are anchored in place with piles and the second version are built on the ground, but can float if water inundates the surrounding area. The goal is to implement systems that add buoyant displacement to existing structures without raising the living or public space. Different structures allow for varying levels of buoyancy either directly underneath, around the perimeter, or a combination of both. This enables the building to go up and down with the rising waters.

Elevation

Buildings in the floodplain can be protected by elevating the buildings above DFE. There are several different methods of elevating buildings, including using fill to modify the topography of the site and elevate the building, abandonment of the first floor and wet floodproofing that area, and elevating the structure on piles.

Protecting and Elevating Critical Mechanical and Electrical Systems

Traditionally, critical mechanical and electrical systems are located in the basement or first floor of a building, the floors most vulnerable to impacts from flooding. Elevating critical equipment above DFE or relocating equipment to a higher floor or the roof will protect these critical systems from flooding. This includes ensuring the electrical wiring is located above DFE or taking sufficient measures to ensure that the equipment is protected by installing watertight enclosed walls and other floodproofing measures.

Backflow Preventers (or Backflow Valves)

Backflow valves are installed on sewage pipes to prevent the backflow of contaminated water into a building. During a flooding or rainfall event, pipes can get inundated with flood waters, resulting in the unwanted flow of water in the reverse direction. These contaminated waters can cause flood damage as well as serious public health concerns.

Sump Pumps

Sump pumps are used to discharge unwanted flood waters that may enter a building during a flood event. Sump pumps are often used in conjunction with other floodproofing techniques and require electricity in order to operate. Therefore, a backup generator or battery power should also be installed.

Fill Basement or Cellar

If the first floor is above DFE, then filling the basement may be an effective flood protection option. The critical mechanical, electrical, heating, plumbing, and air conditioning equipment must be relocated above DFE prior to filling the area. In order to maintain the square footage of the property, property owners often construct a new floor on top of the existing structure to replace the area lost by filling the basement.

Operable Windows

Operable windows provide many co-benefits. During a flood event, operable windows may be important for emergency routes out of a building; however, operable windows are also essential for temperature control and minimizing urban heat island impacts through passive ventilation.

Underground Power Lines

Underground power lines are less prevalent in the United States than they are in European nations, largely due to the increased costs associated with placing lines underground. However, underground power lines can have several benefits and provide more reliable services, especially during a storm event. Above-ground utility lines are prone to outages, physical deterioration, safety issues and storm impacts, including wind and downed trees; many of those issues can be mitigated by placing lines underground.

Green Infrastructure

There are a wide variety of green infrastructure strategies that can be implemented to help control flooding. Many of these strategies also have significant co-benefits in reducing the urban heat island effect and beautifying the community with more green space. Some examples of green infrastructure measures that should be considered include:

- Permeable paving: Permeable paving allows for stormwater to drain through porous pavement into a stone base layer that helps capture and filter stormwater to reduce runoff into the stormwater management system.
- Green roofs: Green roofs are vegetated areas grown on roofs with the intention of enhancing stormwater management as well as reducing heat absorption.
- Bioswales and rain gardens: Bioswales and rain gardens seek to achieve the same goals: slowing and filtering stormwater; however, bioswales are designed to manage greater quantities of water

than rain gardens and usually require the use of engineered soils as well as deeper trenches. Rain gardens are shallow depressions planted with native plants and grasses and positioned near a runoff source to capture water before it enters the sewer and storm drainage systems.

- Rainwater harvesting: Harvesting rainwater in barrels or cisterns can reduce the amount of runoff from buildings during a storm event and lessen the amount of water entering the town's drainage system. This rainwater can be used for watering gardens and other uses that do not require potable water.

Securable and Removable Equipment

Efforts can be made to ensure that equipment is protected from flood impacts. In some case, it is acceptable for the equipment to get wet, so elevating the equipment above DFE may be unnecessary; however, it is important to ensure the equipment is fully secured to prevent flotation in flood waters. Additionally, it may be valuable to invest in equipment that can be temporarily removed in advance of a flood event.

Backup

Microgrid

A microgrid is a small-scale version of the centralized electricity system that includes all the necessary components to operate in isolation of the centralized grid. Microgrids operate independently allow for the import or export of electricity when connected to the wider electricity grid. This enables power continuity in critical areas when power outages and service disruptions affect the wider grid.

Backup Power

Backup power can be implemented through the use of batteries or generators. Batteries can be used to store energy for emergencies, allowing for buildings to maintain power for essential functions for hours or days without electricity. Increasingly, battery systems are being used in conjunction with solar photovoltaics (PV), decreasing the reliance on fuel delivery and reducing energy bills. Generators are another common form of backup power. Generators range in size and cost, depending on the need of the home or business owner and can provide essential backup power for heat, hot water, charging medical devices and cellphones, and providing power to appliances.

Emergency Charging Stations

In the event of a storm or power outage, many residents are often without backup power. Designating emergency charging stations in advance of an outage can significantly increase the resilience of the community by allowing them to charge cell phones, laptops, and other electronics that allow for effective communication and continued business operations during the event.

Renewable Energy Supply

Renewable energy sources, such as solar and wind power, provide a variety of benefits to the community. In addition, to reducing greenhouse gas (GHG) emissions, renewable energy also allows for continuity of power supply, since the power source is not dependent on the grid. In the event of a power outage, buildings and systems that operate on renewable energy will be able to maintain their power sources.

Community Resilience

Community Assistance Centers

A central location that can provide emergency preparedness information to residents and can also be a central location for disaster recovery information and resources in the event of a disaster.

Business Continuity Program

Business continuity planning ensures that businesses have the capability to maintain essential functions during a range of potential emergencies. The assistance provided by a Business Continuity Program would include planning assistance, access to alternative spaces or facilities, communications provisions, and provisions for vital records backup and management. At the base of this program is the creation of a part-time Business Continuity Program facilitator responsible for educating the local business community on crisis preparedness and management, organizational structure, and policies and procedures.

Public Education Program

Educating the public on flood safety, adaptation and mitigation measures, and emergency management plans is one of the most cost-effective strategies for resilience. An active public engagement program will ensure that community understands the risks, takes steps to mitigate those risks and protect themselves and their properties against those risks, and understands proper emergency management procedures during a major event.

Community Rating System

FEMA's Community Rating System (CRS) is a program designed to encourage community-wide floodplain management activities. CRS floodplain management activities are designed to enhance public safety, reduce property damages and human suffering, protect public infrastructure, minimize economic losses, and protect the environment. In addition, participation in CRS can reduce flood insurance premium rates by up to 45%, depending on the community's level of participating.

Building Community Ties and Organizing for Resilience

In the event of disaster, neighbors and community institutions and leaders often become the "first responders," assisting with providing resources, support, and information. Communities with strong social ties and important community institutions have been proven to better weather storm events. In addition to having strong social ties, it is important for communities, neighborhoods, and institutions to form networks to share lessons learned, best practices, and resources.

Location/Relocation of Emergency Shelters

Locating emergency shelters in areas that are accessible during a storm event and equally distributed throughout the community is important to providing refuge during a flood event. Specifically, designating shelters that are outside the floodplain and ensuring that access to those shelters is not blocked by flooded streets is essential.

Stormwater Modeling and Analysis

As a complement to this study, an assessment of Stonington's stormwater management system will also be a critical piece to ensuring the community's resilience. Coastal flooding and rainfall events do not typically happen in silos, but rather are combined during large storm events. As a result, understanding the predicted amount of rainfall and the capacity of the stormwater drainage system to handle coastal floodwaters as well as stormwater from a rain event will be important to effectively mitigating and adapting buildings and systems to future flood events.

Top 25 Resilience Solutions

The following table details the potential solutions for each of the Top 25 assets in the Town. These strategies will be further investigated as part of the final Coastal Resilience Plan, but will also require additional research and analysis on the part of the Town prior to implementation. The strategies are intended to help focus Stonington's future resilience efforts and provide a path forward in investigating potential solutions.

Asset	Resilience solutions for protecting the asset	Community resilience strategies that can be "hosted" by the asset
Masons Island Causeway	Included in Top 5 solutions	
Mystic Wastewater Treatment Facility	Included in Top 5 solutions	
Apple Rehab Mystic	Included in Top 5 solutions	
Pump Stations (Boulder Ave & River Rd)	• Backup power • Dry floodproofing • Wet floodproofing • Green infrastructure	

Stonington Wastewater Treatment Facility	• Backup power • Dry floodproofing • Wet floodproofing • Securable and removable equipment • Green infrastructure	
Town Dock Fire Departments (Mystic & Quiambaug)	• Raised infrastructure • Tide gates • Temporary flood barrier • Hurricane barrier • Offshore breakwater • Relocation • Backup power • Dry floodproofing • Wet floodproofing	
Historic District (Mechanic Street, Mystic Bridge, Rossie Velvet Mill & Stonington Borough)	• Floodplain policies and regulations • Protecting and elevating critical mechanical and electrical systems • Fill basement or cellar • Dry Floodproofing • Wet Floodproofing • Elevation	Public education program
Mystic Seaport	• Relocation • Backup power • Dry floodproofing • Wet floodproofing • Elevation	Public education program
Electrical Substation (Greenmanville Ave & Cutler St)	• Backup power • Underground power lines • Sump pump • Backflow preventers • Elevation	
State Roads (Highway 27 & Highway 1)	• Raised street • Green infrastructure	
Parks (Donahue Park, Barn Island Management Area & Mystic River Park)	• Green infrastructure	• Public education program • Building community ties and organizing for resilience

Mystic Train Station & Rail Line	• Relocation • Raised infrastructure • Renewable energy supply • Backup power	Public education program
Stonington Community Center (COMO)	• Emergency charging stations • Renewable energy supply • Backup power • Elevation • Wet floodproofing • Dry floodproofing • Green infrastructure	• Community assistance center • Public education program • Building community ties and organizing for resilience
Neighborhoods (Lords Point & Murphy's Point)	• Floodplain buyout and acquisition • Relocation • Floodplain policies and regulations • Shoreline hardening • Living shoreline • Offshore breakwaters • Temporary flood barrier • Elevation of homes • Protecting and elevating critical mechanical and electrical systems • Renewable energy supply • Microgrid • Green infrastructure	• Community assistance center • Building community ties and organizing for resilience

Memorandum

Top 5 Resilience Solutions

Solution #1: Masons Island Causeway

Masons Island is an approximately 600-acre island containing three marinas, a yacht club, a 47-acre nature preserve, and numerous residential homes. Masons Island also provides the only land-based access to Enders Island. Since the Masons Island Causeway is the only land-based access to the island, its long-term usability is an important component for emergency planning and climate change adaptation in Stonington.

Masons Island Causeway and the adjacent access roads have high probabilities of coastal flood impacts. The Causeway itself has a relatively low elevation and is already susceptible to flood events, in the present-day. The annual probability of flooding for the Causeway is only expected to increase throughout the century, with annual flood probabilities ranging from:

- 10% to 20% in the present day,
- 10% to 50% by 2030,
- 20% to 100% by 2050, to

- 100% by 2070.

A 1% probability event can flood the Masons Island Causeway and access roads under present-day conditions. Under future scenarios, the extent and depth of this flooding will increase.

Project Elements

The Masons Island proposed regional adaptation, displayed above, is comprised of the following elements:

- Masons Island Bridge
- Elevating portions of Masons Island Road north of Shaffer's Boat Livery
- Hybrid shoreline treatment with rising gate for Shaffer's Boat Livery vicinity
- Green infrastructure solution (berm and living shoreline) for portion of Gled Hill Street east of bridge
- Green infrastructure solution (marsh creation, living shoreline, natural berm) for portion of Masons Island Road south of bridge
- Elevating portion of Masons Island Road south of bridge
- Elevating Dubois Drive north of bridge

These elements may be strategically phased over time to distribute capital investment and implement adaptive management, while providing the necessary level of protection against the combined effects of future sea level rise and storm surge.

The priority element for the Masons Island regional adaptation project should be the replacement of the causeway with a suitably elevated bridge. The figure below provides a rendering of the proposed Masons Island Bridge. While a bridge is recommended, other alternatives, including raising the causeway could also be considered. The proposed bridge alternative also promotes improved tidal exchange and flushing throughout Mystic Harbor and may have ancillary ecological benefits for the region.

Near term accessibility of the bridge during storm conditions will be insured if additional elements (in addition to the bridge or elevation of the causeway) are constructed contemporaneously. On the mainland, implementing green infrastructure along Gled Hill Street and a proposed hybrid shoreline treating at Shaffer's Boat Livery will prevent inundation of the mainland approach to the bridge and address access issues at Shaffer's created by the bridge approach. On the island, elevating Dubois Drive and installing green infrastructure (e.g., living shorelines, expanded salt marsh, berms) along Masons Island Drive will prevent inundation of the island approach to the bridge and reduce the probability of flooding in northern portions of Masons Island. These road raising, green infrastructure, and nature-based solutions would need to be developed and designed more fully in a subsequent phase of work.

Community Benefits

The proposed solutions for Masons Island Causeway could have significant community benefit to Stonington and its residents. The proposed solutions will not only help protect the 600+ residents of Masons Island, both during storm events and nuisance flooding, but they will also help to minimize flooding in neighboring areas of Stonington.

In addition, given the vulnerability of the Causeway to flood events, there is likely to be increased maintenance costs associated with future flooding to the Causeway. By constructing a bridge, the Town can minimize those future impacts and maintenance costs.

While these adaptation elements will maintain access to Masons Island and provide some regional reductions in flood vulnerability over the approximate design life of the project, the projected flooding for 2070 (and beyond) presents severe challenges to maintaining safe and reliable access to Masons Island during storms. While the proposed Masons Island regional adaptation project should provide for long-term daily access to the island in non-storm conditions, decisions will have to be made in the future regarding the emergency management planning for Masons Island (e.g. preemptive evacuation).

Potential Costs

The components of this project range greatly in cost. There is likely to be significant costs from feasibility, planning, design, and construction phases associated with the proposed Masons Island Bridge project, as well as the potential raising of Masons Island Road. Some of the green infrastructure solutions are likely to be less costly and have quicker implementation timeframes than the proposed "hard" solutions.

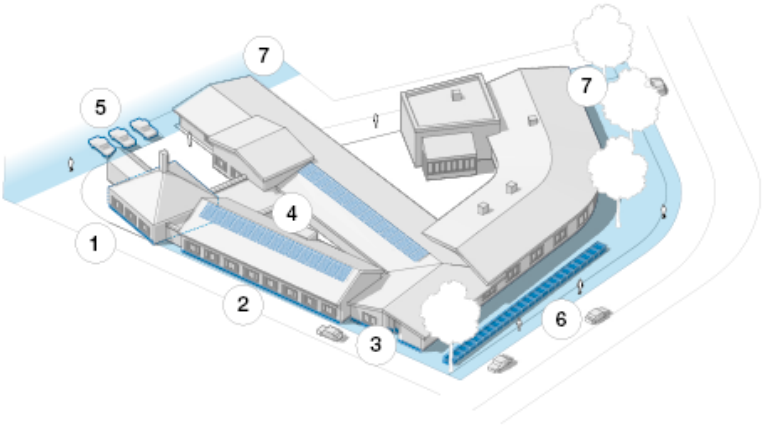
Implementation

The strategy for Masons Island Causeway is a phased solution, with the top priority being the construction of the proposed Masons Island Bridge and complementary green infrastructure solutions along Gled Hill Street and at the Shaffer's Boat Livery, in the near-term. By 2030, a second phase of elements may become necessary to protect access to the bridge. These elements include elevating both mainland and island portions of Masons Island Road, and tying them into the existing green infrastructure and hybrid shoreline treatments on either side of the bridge.

These construction of a proposed Masons Island Bridge along with potential future elevation of portions of Masons Island Road will require significant time to implement. These are larger infrastructure projects and therefore, will need stakeholder buy-in and agreement within Town management that these projects are necessary. In addition, due to the high cost of these types of projects, the Town will need time to identify funding sources or build the project into the Town's budget and capital improvement planning process. And lastly, the planning, design, approval, and construction process for the bridge will take a significant amount of time to complete. In order to navigate the potential roadblocks to implementation, the Town will need to conduct a more extensive study of the feasibility of such a solution and the benefits to the Town.

Memorandum

Solution #2: Apple Rehab Mystic



1 **COMMUNICATION CENTER**
If it is infeasable to protect a large building complex, one or several areas dedicated to communicating and managing disaster responses should be prioritized, using waterproofing applications or waterproofed walls (e.g. using CMU block).

2 **IMPERMEABLE WALLS**
Sealants or wraps can protect the lower stories of a property. Applications include waterproof membranes, flood wraps, spray applied sealants on the positive side and fiber-reinforced polymer wraps on the negative side.

3 **FLOOD SHIELDS**
Flood shields and other dry floodproof measures can help protect windows and doors from rising waters. These are temporary, watertight barriers built of metal (aluminum, stainless steel) or plastic, often using rubber or similar materials to seal the barrier.

4 **ENERGY SUPPLY**
Alternative energy sources, such as roof solar panels can provide electricity if traditional energy sources are temporarily made unavailable. Solar energy is a one attractive option because it is naturally elevated and at low risk of flooding.

5 **PROVISIONS & STORAGE**
Especially for vulnerable populations, the facility should ensure adequate stockpiles of critical goods, including food and water, and medical supplies such as first aid kits, antibiotics, medications, sanitation supplies, mobility aids, age-appropriate clothing, etc. These should be packaged and stored in dry, protected areas.

6 **EMERGENCY BARRIERS**
As a last resort, emergency measures such as gravel-filled containers, sandbags and water-filled containers can reduce or eliminate the impacts of floodwater.

7 **GREEN INFRASTRUCTURE**
Landscaped berms, rain gardens, street trees and plantings can reduce, divert or retain floodwater and storm surges and provide a range of urbanistic and ecological benefits.

As both a significant economic driver for the community, and home to an elderly population that may be at particular risk during storm events, Apple Rehab Mystic was identified as a priority asset for protection during emergency events. Resilience strategies for the facility involve both physical protections and operational procedures put in place to mitigate the impact of a flood event. While the strategies suggested here are considered specifically for the Apple Facility, many of these strategies are applicable to other large facilities within the Town of Stonington.

Project Elements

Potential project elements include temporary or permanent flood barriers, landscaping, floor shields and other dry flood proofing measures to be implemented in the case of an emergency. Because the facility is not immediately adjacent to the water, large-scale permanent flood barriers such as flood walls may not be appropriate. However, impermeable walls, flood wraps, waterproof membranes, sprays and other sealants that protect the ground floor can be quickly deployed in the case of anticipated flooding. Given the size of the facility, it may be necessary to prioritize a limited number of buildings or rooms, retrofitted with waterproofing applications such as sealants and waterproofed walls. Additionally, emergency measures such as gravel filled containers, sandbags and water-filled barriers can reduce the impact of any storm surges. In the medium-term, alternative energy sources, including

additional solar panels mounted on the facility's roof, can provide electricity when and if outside sources are temporarily disabled. Because the facility serves a vulnerable population that relies on electric-operated medical equipment and may be particularly vulnerable to prolonged exposure to heat or cold, ensuring an adequate supply of electricity is especially critical.

Another strategy entails the introduction of green infrastructure on to the site. Apple rehab sits adjacent to four small parking lots and Broadway Avenue, and may be vulnerable to flooding due to the high proportions of impermeable paving. Efforts to mitigate the impact of flooding, in both normal rainfall events and longer-term flood impacts, could include the introduction of green infrastructure, native plantings, trees and permeable paving materials for the parking facilities and along Broadway Avenue.

A range of operational strategies should complement the protections described above. These include well-rehearsed emergency evacuation procedures with clearly-delineated responsibilities, information dissemination and adequate disbursement of key supplies in the case of an emergency. Storing food, medical equipment, clothing, blankets, and other emergency supplies in dry, elevated or otherwise protected areas within the facility is also critical.

Community Benefits

These risk reduction strategies should focus on protection of human life, reducing damage from floodwaters, ensuring that the building functions adequately during the event, and establishing quick recovery after an emergency. Unlike assets described elsewhere in this report, it may not be feasible to evacuate large numbers of residents, who may have limited mobility. The facility should therefore prioritize protective measures that allow at least some areas within the building to continue functioning even in the midst of a disaster event.

Ensuring that residents are safe and well-cared for in the event of an emergency delivers a clear social good to the community, including residents and their family members and friends. Helping the facility recover quickly and resume operations soon after an event may also carry ancillary economic benefits to the town. Additionally, green infrastructure measures that bolster the attractiveness of the streetscape and reduce the amount of impervious surface in the neighborhood will result in reduced flood risk during typical rain events and extraordinary flooding.

Potential Costs

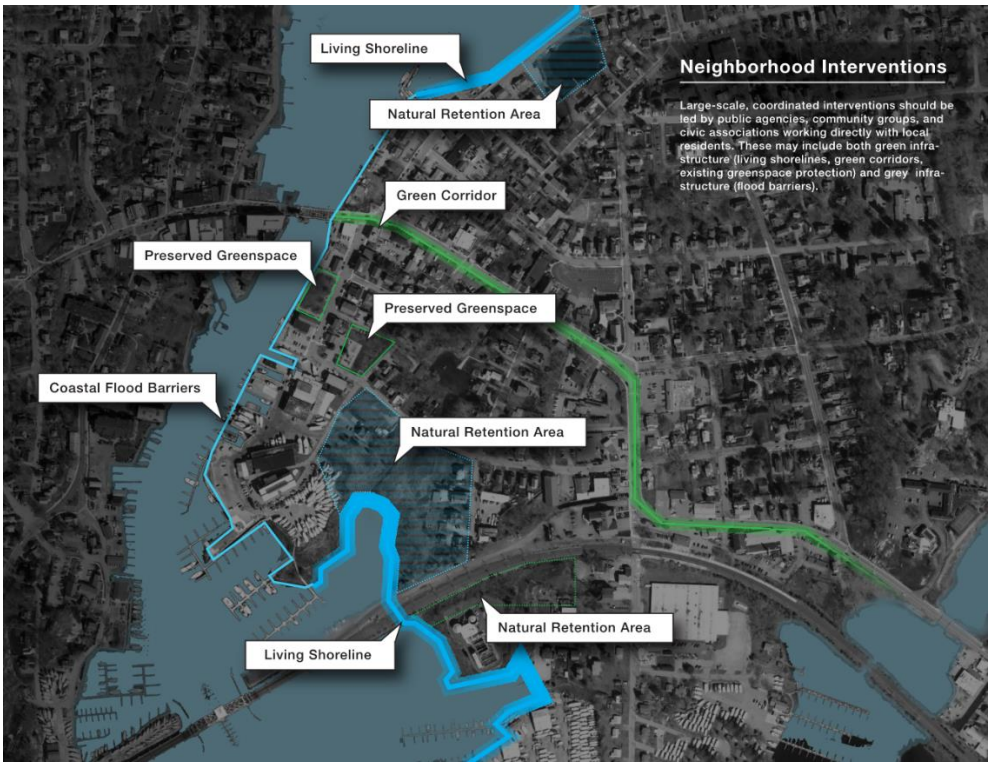
Developing a comprehensive and rehearsed operational plan for preparing for storm events – including communication and evacuation procedures, and storing and protecting food, water and medical supplies – will incur minimal financial costs. Procuring and storing temporary floodproofing measures such as floor shields, waterproof membranes and other sealants are more expensive, and emergency barriers carry a higher cost that includes procurement, training and storage expenses. Additional landscaping that introduces elevation changes to the site, and new alternative energy supplies will incur additional costs. The cost of additional solar panels will be defrayed by cost savings during normal times, however.

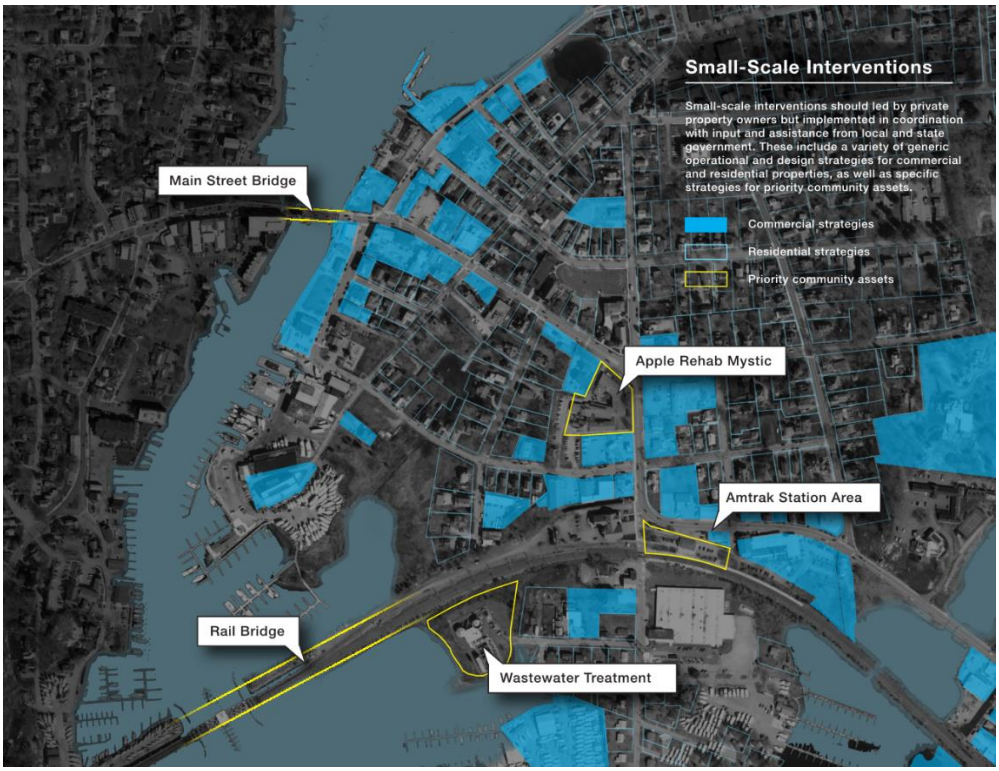
Implementation

Unlike other resilience measures that require buy-in from multiple stakeholders, strategies for Apple Rehab Mystic can be implemented unilaterally by the facility in consultation with residents. The engineered solutions proposed here are not overly complex – solar panels and landscaping may require some engineering consultation, but other proposed measures can be implemented largely in consultation with product manufacturers. As a result, the single largest barrier to implementation may be cost, as well as the training required to instruct staff on new operational procedures. Strategies may be implemented over the short and medium term.

Memorandum

Solution #3: Village of Mystic





Memorandum

The Village of Mystic is an important historic and economic development area, located in both Groton and Stonington, CT. The village is situated along the Mystic River and the portion of the village located in Stonington is home to many historic resources and tourist destinations. As such, the village is an important part of both the character and the economy of Stonington. Historically, the village was home to one of the area's most important seaports; that seaport is now home to one of the nation's leading maritime museums and is an important tourism destination in the Town of Stonington. The portion of the village that is located in Stonington is also home to the Mystic Aquarium, the Mystic Train Station (and Amtrak rail line), a multitude of historical resources located in the Mystic Bridge Historic District, the Mystic Wastewater Treatment Plant, and a variety of residential properties, businesses, parks, and roadways.

Project Elements

In order to develop a comprehensive strategy to protect the neighborhood, as a whole, and its key assets, a variety of resilience solutions must be considered. Due to the historic character of the neighborhood and its important relationship with the coast, strategic retreat is not a popular option; therefore, flood prevention and protection will be critical. A comprehensive approach to neighborhood-scale resilience will require a combination of green and grey infrastructure as well as individual asset-level solutions and larger neighborhood-wide protection. At an individual asset level, Solution #2 and Solution #4 detail how to protect Apple Rehab Mystic and the Mystic Wastewater Treatment Plant. Similarly, Solution #5 provides detail on strategies that individual homeowners and business owners in Mystic can implement on their own properties. Many of these strategies are also applicable to other building assets. On a more neighborhood-wide scale, a variety of temporary and permanent strategies can be used in commercial, residential, and mixed-use zones and, specifically, along pedestrian-friendly strips located in downtown areas. Potential measures include both grey infrastructure – hardscapes and engineered solutions – and green infrastructure such as trees, plantings and landscaping. Both green and grey solutions can provide additional community benefits, including more beautification of the neighborhood, additional green space that can be accessed and used by the residents, and new access points to the waterfront. Additional strategies should include regulatory considerations, such as a waterfront overlay zone that may restrict the types of uses in those zones and also enforce alternative building methods. These strategies are intended to work together as one cohesive whole, rather than implementing a variety of strategies separately without consideration of how they will interplay with each other.

Community Benefits

Beyond their value as flood mitigation measures, these measures may carry a range of other positive benefits. In particular, green infrastructure that introduces new green space to the local streetscape brings both ecological benefits and additional social benefits. Reducing the amount of permeable paving in downtown areas, for instance, can reduce flooding during typical rainfall events. New plantings reduce the impact of the 'urban heat island effect' and new street trees provide shade on hot summer days. Flood barriers have the potential to reduce or limit access to the water if designed poorly, but may actually highlight or channel pedestrian activity to the waterfront if designed carefully and with an eye to minimizing disruption to natural pedestrian movement.

When implemented in a manner that is sensitive to the needs of the community, local property owners, and users, these strategies can provide flood protection while also improving the look and feel of the neighborhood. Unlike many of the other strategies proposed for the town, these strategies will inherently involve multiple stakeholders, including not only the people who live and work in affected areas, but also those who frequent these areas as shoppers, tourists, or otherwise as part of their regular routine. As such, the process of negotiating what strategies are appropriate where, and who assumes responsibility for financing, building, and maintaining key infrastructure, will involve substantial effort to ensure that all stakeholders are heard and that costs and benefits are distributed fairly.

Potential Costs

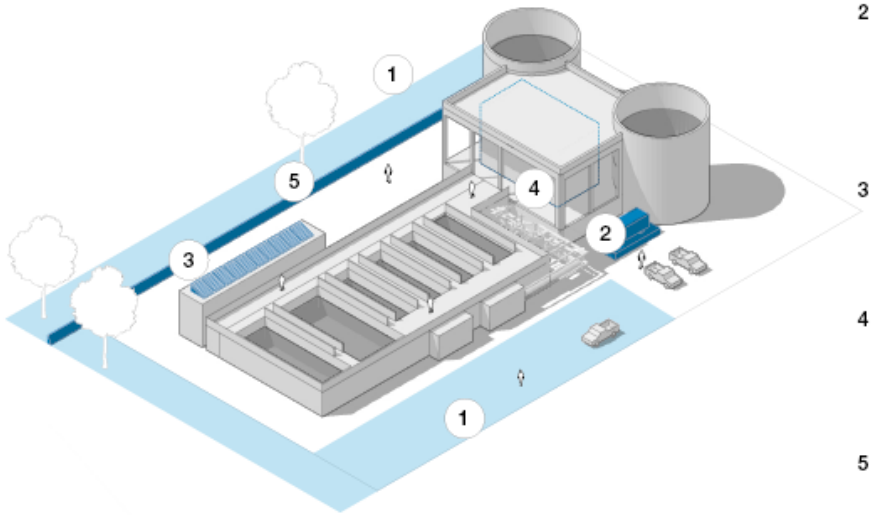
In addition to immediate financial costs associated with each of these measures (which vary widely depending on the solutions that the Town chooses to implement), implementation should be careful to consider potential negative effects of such strategies on the local streetscape. The downtown Mystic area is currently a vibrant, walkable area. Implementing these measures should consider how each measure interacts with the local streetscape. For instance, while protecting ground floor commercial land uses is of high priority, any new flood protection measure should take care to maintain a strong connection with the street, through easy access and attractive facades. New green infrastructure should be planned to minimize costs associated with streetscape changes, such as widening sidewalks or digging up pavement to accommodate new plantings.

Implementation

Because decisions about mixed-use properties involve multiple landowners, tenants and users, implementation will require aligning the interests of a range of stakeholders. Choosing what strategies are best-suited for particular areas will necessitate a broad conversation about community priorities – what areas are most in need of public dollars, and what areas carry the largest benefit to the larger community. Additionally, all strategies must balance flood mitigation demands with the needs of local users; store owners may be reluctant to disrupt normal retail activity to prepare for the uncertainty of a future storm event. While there are no easy answers to these questions, open conversations about available resources and shared priorities, viewed in light of risk assessments provided elsewhere in this report, will help begin a process of implementing these strategies.

Strategies may be implemented over the short and long term, with immediate investigations into the availability of temporary measures, and longer term considerations of more complex and permanent solutions such as flood barriers and green infrastructure.

Solution #4: Mystic Wastewater Treatment Plant



1 **GREEN INFRASTRUCTURE**
Native plant species can divert or reduce the impact of flooding, stabilize soils and provide protection against wind erosion. Landscaped swales may provide a natural buffer to rising waters. Additionally, where hard surface are necessary, permeable paving can reduce pooling and speed recovery.

2 **ELECTRICAL EQUIPMENT**
All electrical equipment, inlcuding electrical controls, computers and records, should be elevated or relocated. An emergency generator should be elevated above the DFE. Additionally, the treatment facility can work with the local power utility to ensure a reliable connection to its power source; for example, it might install a substation or dedicated feeder expressly for the facility.

3 **ENERGY SUPPLY**
Alternative energy sources, such as roof solar panels can provide electricity if traditional energy sources are temporarily made unavailable. Solar energy is a particularly attractive option because it is naturally elevated and at low risk of flooding.

4 **SECURABLE & REMOVABLE EQUIPMENT**
If necessary, critical equipment such as tanks should be secured to prevent floatation if flooded. During upgrades or design of new equipment, the plant may invest in capacity to temporarily remove and safely store vulnerable components when there is advanced warning of a flood.

5 **FLOOD BARRIERS**
Permanent barriers built to DFE should be installed along the facility's perimeter. Anchored flood barriers may include flood walls, berms and levees, prevent floodwaters from reaching critical facilities. These can be built using a variety of natural and synthetic materials. Such measures are specially appropriate to protect critical infrastructure in isolated, non-public areas, where the negative impact of permanent barriers is minimal.

The Town of Stonington is responsible for three sanitary sewer systems and related wastewater treatment facilities, the oldest of which is the Mystic Wastewater Treatment Plant. The Mystic plant, which receives higher flows and loads than either the Pawcatuck and Stonington Borough plants, has been in service for over 40 years and lies directly adjacent to Mystic Harbor, immediately south of downtown Mystic. Due to its proximity to the village, its vulnerability to flooding and its criticality to the overall sanitary system, the treatment facility was deemed a high priority asset.

Project Elements

The facility, which is located on the harbor, is particularly vulnerable to coastal flood events. Potential project elements include a range of measures to prevent water from entering the facility, as well as strategies to protect key equipment from being damaged by floodwaters. Although the tanks and equipment are elevated, an additional layer of protection would include flood barriers such as walls or berms surrounding the facility. Landscaping that provides additional elevation, and plantings that reduce the flow or intensity of water along the water's edge will also reduce the force and elevation of flooding.

Another layer of protection exists in the combination of operational and physical measures that protect key equipment, including electrical controls, computers and records. These materials may reside in

elevated or flood-proofed areas. The plant may also invest in capacity to temporarily remove and store vulnerable components in anticipation of a flood event.

Alternative energy sources – including wind and solar power, backup generators and substations to power the plant – will also be critical to operate equipment in the event of a power outage or other impact to the energy supply. In some cases, pumping systems and channel or culvert systems may be used to collect and divert flood water from the facility.

Community Benefits

Given its vulnerable location, there exists significant risk to the Mystic Wastewater Treatment Plant, and severe consequence if it fails. The strategies described above are intended to achieve two key aims of, first, reducing or eliminating the risk of sewage overflow into the harbor and, second, resuming normal operations immediately after a flooding event.

Protecting the treatment facility has clear and significant impact on the village of Mystic, which relies on the treatment plant to process all waste for the village. Additionally, allowing untreated waste to enter the harbor would bring significant ecological harm to the area, and negatively impact the town's economy which relies heavily on tourism and recreational activities.

Potential Costs

Because of the plant's proximity to Mystic Harbor and due to the complexity of the equipment involved, strategies to mitigate flood impacts on the plant may be more expensive than for other assets identified. Specifically, high costs may be involved in developing the required mix of permanent flood barriers, equipment relocation, and alternative power sources. Electrical infrastructure, including substations, backup generators, solar panels or wind turbines that reduce dependency on the electrical grid will carry significant costs. However, the facility is critical to the functioning of the town, both on a daily basis and following a storm event.

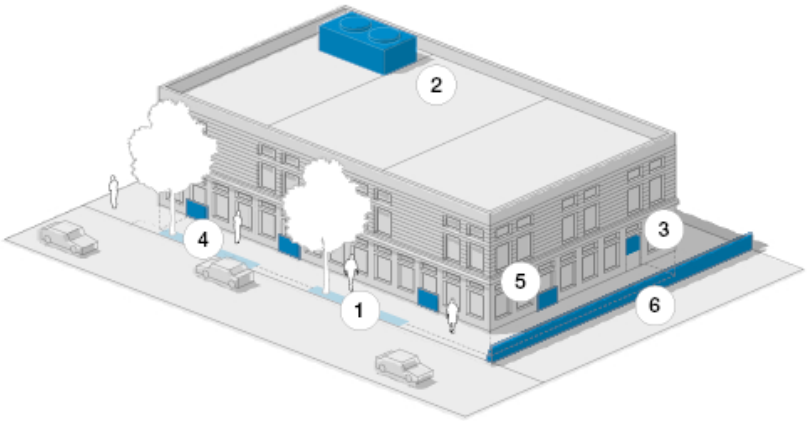
Implementation

Upgrades to the wastewater treatment facility are the responsibility of the town and do not directly impact private landowners. The greatest obstacle to implementation is, therefore, the significant funding required to install the various mitigation strategies described above.

Memorandum

Solution #5: "Typical" Stonington Structures

Mixed-Use Building



1 **GREEN INFRASTRUCTURE**
Landscaping elements such as street trees, plantings and rain gardens will reduce the impact and absorb floodwaters. These measures also improve the quality of local streetscape during normal conditions, and provide a range of other ecological benefits.

2 **CRITICAL EQUIPMENT**
Critical equipment, including utilities and electrical facilities should be located above Design Flood Elevation (DFE). Where this is not possible, electrical wiring in flood-prone areas should be installed so that it can be easily replaced and even reused.

3 **INTERIOR PROTECTION**
In addition to waterproofing interior walls and installing impermeable core areas (for instance, using CMU walls or cast-in-place concrete), groundfloor users can introduce interior steps to elevate wares above ground level.

4 **BASEMENTS**
Where possible, existing basements can be abandoned and filled with sand, gravel or concrete to reduce the impact of flooding. Critical infrastructure should be moved from basements to higher ground areas wherever possible.

5 **FLOOD SHIELDS**
Flood shields and other dry floodproof measures can help protect windows and doors from rising waters. These are temporary, watertight barriers built of metal (aluminum, stainless steel) or plastic, often using rubber or similar materials to seal the barrier.

6 **FLOOD BARRIERS**
Anchored flood barriers, which may include flood walls, berms and levees, prevent floodwaters from reaching critical facilities. These may be built using a variety of natural and synthetic materials. Permanent barriers require maintenance and may impact the local streetscape, but provide greater protection in case of emergency.

Stonington has a variety of mixed-use and commercial buildings in the downtown areas of the boroughs and villages. Similar to the single-family property solutions listed above, there was a great deal of interest in understanding what resilience solutions are available to property owners for mixed-use and commercial structures throughout Stonington. A combination of building-specific strategies as well as green infrastructure and landscaping along the streetscapes can provide significant protection from coastal flooding. When implementing strategies in these commercial districts, it is important to understand how different strategies will change the character and feel of the streetscape. For example, elevation of all of the buildings would inhibit the fluid interaction between the pedestrians on the street and the businesses and thus, negatively impact the user experience. Therefore, a variety of strategies should be employed to reduce any negative impacts to the tourism experience and the general look and feel of the downtown corridors.

Project Elements

Strategies for protecting and adapting the building include elevation, where appropriate, as well as a mix of protection and adaptation strategies. In the example above, elevation may be difficult because of the size of the structure; however, there are some free-standing structures in some of these downtown locations, where elevation is a potential option. In lieu of elevating the entire building, property owners

may consider elevation of mechanical and electrical systems, filling basements to prevent infiltration of flood waters, installing temporary floodproofing measures like floor shields and sandbags, and using materials that are flood-resistant. More expensive protection measures include retrofits of interior spaces to waterproof interior walls and install impermeable coatings for core areas (either structurally critical spaces, or areas used for protecting key equipment). Interior raised floors may also be introduced into ground floor retail spaces without negatively impacting internal uses, or changing the opening to the street. In addition, property owners should consider installing generators and other forms of backup power and investigate the potential of renewable energy, such as solar panels.

Additional strategies should be employed along the streetscape. Some of those strategies may include flood barriers, such as flood walls, berms and levees along the coast that prevent floodwaters from reaching critical facilities. These permanent measures have proven to be highly effective elsewhere, but require greater financial investment than temporary alternatives, and may negatively impact the local streetscape. In order to maintain Stonington's unique and historic character, green infrastructure may be a more appropriate solution along these downtown streetscapes, as they often enhance the aesthetic of the area and also provide stormwater management solutions. Some potential strategies include street trees, rain gardens, impermeable paving, bioswales and plantings.

Community Benefits

In addition to the intended flood mitigation benefits, these strategies can provide long-term economic benefits and cost savings. On an individual level, business owners that consider switching to renewable energy sources may see long-term cost savings. On a community level, small businesses and the character of these downtown, mixed-use corridors are essential to Stonington's economy, both from the revenue generated by the businesses themselves and the tourism generated by the historic nature and character of the Stonington. Protecting these assets from flood vulnerability is important to protecting Stonington's future economy.

Potential Costs

The financial costs ranged drastically depending on the solutions that the Town and the business owners choose to implement. Planting street trees and using sandbags as flood protection measures are fairly low cost. Some of the more permanent solutions, such as elevation of critical equipment and installing flood barriers would come at a greater cost. In addition to immediate financial costs associated with each of these measures, implementation should be careful to consider potential negative effects of such strategies on the local streetscape, as discussed above.

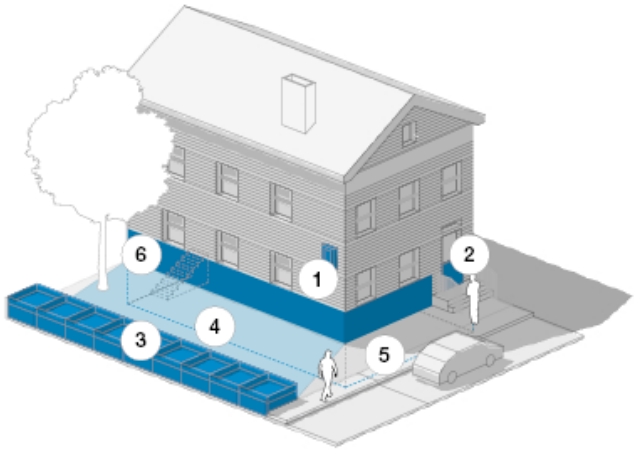
Implementation

Because decisions about mixed-use properties involve multiple landowners, tenants and users, implementation will require aligning the interests of a range of stakeholders and ensuring that the character of Stonington is not negatively impacted by these flood mitigation strategies. Choosing what strategies are best-suited for particular areas will necessitate a broad conversation about community priorities – what areas are most in need of public dollars, and what areas carry the largest benefit to the larger community. However, strategies in these locations may be phased – those solutions that can be implemented at the discretion of the business owner may be implemented in an earlier phase than those

that require community buy-in. Stonington should review the suggested strategies and create a phased plan that accounts for budget, ease of implementation, and which strategies are most effective for the location.

Memorandum

Single-Family Home



1 **ELECTRICAL WIRING**
Electrical wiring in flood-prone areas should be installed so that it can be easily replaced or cleaned and then reused. Cable systems are easy to replace if damaged.

2 **FLOOD SHIELDS**
Flood shields and other dry floodproof measures can help protect windows and doors from rising waters. These are temporary, watertight barriers built of metal (aluminum, stainless steel) or plastic, often using rubber or similar materials to seal the barrier.

3 **EMERGENCY BARRIERS**
As a last resort, emergency measures such as gravel-filled containers, sandbags and water-filled containers can reduce or eliminate the impacts of floodwater.

4 **LANDSCAPING**
Terraced front yards with plantings provide additional elevation, protecting the house from rising floods. Organic material can diminish the impact of flood waters and absorb water during and after a flood event.

5 **IMPERMEABLE WALLS**
Sealants or wraps can protect the lower stories of a property. Applications include waterproof membranes, flood wraps, spray applied sealants on the positive side, and fiber-reinforced polymer wraps on the negative side.

6 **BASEMENT**
When structures are built on solid foundation walls or have other enclosures below the Design Flood Elevation (DFE), foundation walls should have openings that permit the automatic entry and exit of floodwater. Battery powered sump pumps can be relied on to remove water in the case of flooding.

Stonington is a highly residential community and, as such, there is a lot of interest in understanding what individual homeowners can do to protect their own properties. This set of solutions is intended to provide a range of solutions that homeowners can consider implementing on their properties. Understanding the geography of the site, the character of the neighborhood, the expected intensity and frequency of flooding on the site, and the homeowner's budget and appetite for risk will all be key considerations for determining which solutions are best suited for each property.

Project Elements

There are a variety of protection and adaptation strategies that homeowners can implement on their own properties. These strategies include landscaping and green infrastructure to capture stormwater runoff and protect the house from flood waters. Many homeowners likely already use sandbags to protect their property during a known flood event. Sand bags are a low cost protection solution. There are several alternative types of emergency barriers, such as floor shields, that can also be used as a flood protection mechanism. Additionally, elevation of the property or filling the basements to prevent entry of floodwaters are some of the more complex flood protection solutions. Some additional adaptation measures include installing a sump pump, ensuring that electric wiring is in either protected from floodwaters or installed in such a way that it can be easily replaced if damaged, and installing a generator to maintain power in the event of an emergency.

Community Benefits

Stonington is a largely residential community. As a result, if each individual property owner takes action to protect their property, those actions could have a large impact on the resilience of the community, as a whole. Additionally, if homeowners start taking action to protect and adapt their properties, other property owners are likely to take notice. These efforts might influence neighbors or nearby business owners to take steps to protect their own properties and also help educate the public on coastal flooding and resilience.

Potential Costs

For homeowners, costs can vary widely. Resilience measures such as landscaping and using sand bags, can often be implemented at relatively low cost to the homeowner. However, the most intensive resilience measures, such as elevation, often come at a high upfront cost to the homeowner and many homeowners may have difficulty implementing these measures without additional funds. Overall, there are strategies that can be implemented across all income levels and each homeowner will take a different approach to resilience. By combining a variety of different strategies, homeowners can tailor their resilience solutions to their own income levels and risk appetites.

Implementation

Overall, implementation of these strategies is typically dependent on the income of the homeowner and whether they have the funds to take action. However, if funds are readily available, many of these strategies are relatively easy to implement when compared to large-scale engineering solutions. Implementation of these strategies may require cooperation from the Town. Often homeowners will need to acquire building permits for implementing these strategies. In addition, some strategies may be in conflict with current zoning requirements or other town regulations. Therefore, the homeowners will need to work with the Town for the appropriate variances or waivers to those requirements. One common issue is that homeowners that want to elevate their homes often have difficulty because the elevation would cause their home to be raised above the height restrictions for the community.

Conclusion

These strategies are intended to help the Town of Stonington think about resilience in a way that is more concrete, with actionable strategies that can be implemented. The Coastal Resilience Plan will include more detail on next steps for Stonington, including helping to identify priorities. However, some of the ways that the Town can start thinking about these resilience strategies include:

- Changes to regulations, including zoning and building codes, to require more resilient development in areas prone to flooding;
- Requiring certain resiliency standards as part of the building permit, and other permitting, requirements;
- Advocating for the inclusion of resilience and coastal flood protection as an annual line item in the Town's budget and capital improvement process;
- Pursuing additional funding and financing options, through mechanisms such as grant funding or investigating the possibility of taking loans for implementing resilient solutions;
- Leveraging current projects as a means for furthering the Town's resilience goals by building resilience into existing projects that are already planned and/or underway. This is often an easier mechanism for making progress than proposing and funding an entirely new capital project geared at resilience;
- Seeking out partnerships with private and non-profit entities that are also interested in advancing resilience in Stonington. Some potential partners include: Apple Rehab Mystic and other businesses in Stonington, Amtrak, and local energy providers; and
- Leveraging this plan to continue to advance the climate change and resilience conversation by advocating for a regional climate coalition. Flooding is not limited to Town boundaries and efforts to minimize coastal flooding concerns will require regional solutions. This coalition could be limited to neighboring municipalities or it could be a broader coalition that includes local chambers of commerce and business leaders, neighborhood leaders, and other stakeholders in the region.

Appendix D:
Regulatory Audit Memo

Memorandum

ARUP

To	Mr. Keith Brynes, Town Planner Town of Stonington, CT	Date	July 7, 2017
Copies	Mr. Scot Deledda, Town Engineer Town of Stonington, CT	Reference number	251043.00
From	Katie Wholey, Arup Lisa Dickson, Arup Susan Silberberg, CivicMoxie	File reference	
Subject	Regulatory Audit of Zoning Code		

Overview

As part of the coastal resilience planning process, the Town of Stonington requested a regulatory audit of its zoning code, with a focus on coastal flooding. The purpose of this memorandum is to provide an overview of potential coastal resilience strategies that can be incorporated into the Town of Stonington's zoning code. This is not a full audit of the Town's regulations; if the town is considering implementing any of these suggestions, a complete audit of any legal or regulatory challenges should be completed. A complete audit is necessary to ensure that the Town has the legal authority to implement these zoning amendments and that the proposed amendments do not conflict with any pre-existing codes or regulations, at the local, state, or national level.

Current Status of Flood Resilience in Stonington's Zoning Code

Stonington's current zoning regulations include various regulations related to flood hazards; however, most of these regulations are based on the current FEMA flood zones, which do not account for increased risk from sea level rise and storm surge. The regulations include a Coastal Area Management (CAM) Overlay District and a Flood Hazard Overlay District, both of which are under the jurisdiction of the Town of Stonington Planning and Zoning Commission. The CAM boundary includes: areas covered by the National Flood Insurance Program (NFIP), areas within 1,000 feet of the mean high water mark of coastal waters, and areas within 1,000 feet of the State-designated tidal wetlands. Projects within the CAM are evaluated for any adverse impacts to land and water resources; proposed mitigating measures are required in the CAM application and the Commission may approve, deny, modify, or modify with conditions any project within the CAM boundary. The Flood Hazard Overlay District (FHOD) applies special regulations to all land in the floodplain of rivers, streams, and bodies of water. This district regulates all aspects of construction in the floodplain in order to (1) minimize loss of life, injury, and property damage; (2) protect the health, safety, and general welfare of the people; and (3) help control and minimize the extent and depth of floods. In general, all new

construction in the flood zone must be elevated at least one foot above the base flood elevation and no new construction or alterations of buildings in the floodplain shall reduce the water holding capacity of the floodplain. Additional requirements include: (1) prohibition on new construction and substantial improvements within 100 feet of mean high tide in V-zones; and, (2) designation of a 100-foot non-infringement area within the RC-120 zone (Residential Coastal), which prohibits development or improvements within 100 feet of coastal features (with a few exceptions, such as boat access and greenways).

Suggested Amendments

The Town of Stonington has a strong foundation coastal regulatory authority. Through a few, small modifications to its zoning regulations, the town's zoning code can be leveraged to improve resilience to coastal flooding. Specifically, the Town can make modifications to the CAM Overlay District and the Flood Hazard Overlay District that will encourage more resilient practices. However, certain challenges related to disaster recovery and rebuilding must be addressed.

One of the biggest challenges that most communities face in the wake of a disaster is that rebuilding efforts often conflict with the municipality's regulations and building code. By using some of the lessons learned from the communities that experienced these challenges in the wake of Superstorm Sandy, the Town of Stonington can encourage more resilient development and ensure that recovery efforts will not be unnecessarily impeded by Town regulations in subsequent disaster scenarios. The following provides an overview of the various strategies that Stonington should consider. These strategies seek to achieve two overarching goals: (1) removing barriers to building resiliently (and recovering in the wake of a flood event) and (2) encouraging smarter building and development practices.

Extending the Boundaries of the CAM & Flood Hazard Overlay District

The Town should consider ways to extend the boundaries of the CAM Overlay District and the Flood Hazard Overlay District, so that both districts account for areas that may not be in the current 100-year floodplain, but may be impacted by future storm events due to sea level rise and storm surge. In addition, if not already conducted, regular reviews based on modeling projections should inform these boundaries. Factors that influence projections and district boundaries may include land use changes (density changes, new development, unbuilding, erosion, etc.), coastal formulation changes (hard-to-soft and vice versa), new modeling projections based on updated sea level rise and storm surge assumptions, hydrologic and hydraulic changes resulting from updated precipitation assumptions or stormwater infrastructure changes.

Evaluation Criteria and Exceptions to Review Process for the CAMOD

The CAMOD regulations require that projects be evaluated for adverse impacts on a number of land and water resources. These areas of evaluation do not currently include an assessment of how new development, or changes to existing properties, affect the overall burden on the Town's evacuation plan

and emergency plans nor to their contribution to the overall impact of using public resources for protection of lives in the CAMOD in the case of storm surges and sea level rise. The CAMOD regulations also exempt from the regulations the "construction of an individual conforming single family residential structure except in or within 100 **feet** of the following coastal areas: coastal wetlands, tidal bluffs, and escarpments, beaches and dunes." It is recommended that there be consideration to review this exception.

Section 2.6.3 Reconstruction

This section of the zoning code exempts stuctures that were damaged during a natural disaster and reconstructed within one year of the date the damage occurred from the Planning and Zoning Commission approval process, provided that the structure is identical to the original structure in external appearance and location. This section also allows for the Commission to extend that deadline for reconstruction to a maximum of two additional years (3 years total). It is recommended that the Town review this provision to allow for flexibility in reconstruction as it applies to implementing flood resilience solutions without penalizing the resident by forcing them to obtain Commission approval for those resilience solutions. The added benefit of this flexibility is that it will allow the Town to recover more quickly post-disaster by reducing the quantity of reconstruction applications that require approval. Some examples of how the section could incorporate flexibility include allowing for elevation of the structure and construction that meets ADA accessibility requirements. The other regulatory suggestions outlined in this memorandum should also be taken into consideration in relation to this section of the code.

Elevation Requirements

Stonington already requires new construction in the flood zone to be elevated at least one foot about the base flood elevation (BFE), which is a great practice for encouraging smarter floodplain development. However, the Town should review that requirement to investigate whether the freeboard requirement should be increased. As a point of reference, in the wake of Superstorm Sandy, many communities required a minimum of BFE+2. In addition to the required height of elevation, there are many related considerations for elevated properties. Some of those considerations include:

- Allowing for additional elevation of homes that must be raised between 6-8 feet to accommodate for parking and storage below the building.
- Allowing for encroachments into the backyard to provide for outdoor stairs to access elevated structures.
- Exempting enclosed entryways from floor area calculations to provide for indoor stairs to access elevated living space
- Allowing for a waiver of requirements to provide parking spaces, or conversion of front or side yards to parking, where compliance with flood-resistant standards results in the loss of parking spaces.

- Allowing for floodproofing of ground floor space and conversion to parking, commercial or community space where compliance with the flood-resistant standards results in loss of usable ground floor space.

ADA Compliance

In order to ensure compliance with the Americans with Disabilities Act (ADA), the Town should also consider access and egress on elevated properties, so that the property remains accessible to all potential inhabitants. In many cases, municipalities provide these accommodations by allowing for the installation of lifts on elevated residential properties. In order to do so, Stonington may need to allow for lifts as a permitted obstruction.

Height Restrictions

In the wake of Superstorm Sandy, many communities experienced challenges with elevating properties due to the limitations of the municipality's height restrictions. Many properties were required to elevate in order to be eligible for federal Community Development Block Grant – Disaster Recovery (CDBG-DR) funds, but the elevation of their property was prohibited because the elevated property would exceed height restrictions. Acknowledging that height restrictions are often put in place to preserve neighborhood character, Stonington should engage community members and discuss potential future community-wide height restrictions and subsequently adjust height restrictions as needed.

Design Considerations

Property elevation can often have distinct impacts on the character of the neighborhood as elevation reduces the interaction between the property and the street, effecting the experience of pedestrians and passers-by. This is an especially important consideration for Stonington due to the historic character of the Town. It is important not to lose that character when implementing these flood resilience measures. Some design strategies that the town should consider include the allowance of streetscape enhancements, such as porches, plantings, raised yards, and sloped yards, to soften the visual transition of elevated homes; whether the Town will allow open or closed elevations – both provide the necessary elevation benefits, but create a distinctly different visual experience; and, the impact of elevation on setback regulations.

Historic Preservation

The economic health of the Town of Stonington is very closely tied to the Town's historic resources and the resulting visitor economy. Many of these resources are located in the flood zone or in areas impacted by sea level rise and storm surges. The zoning regulations in special overlay districts should strike a balance between protecting historic significance and character and ensuring properties are protected in the long-term from rising seas and flooding due to storm surges. Currently, properties on the National Register are exempt from many of the regulations regarding minimum elevations and

other requirements. While in the short term that may protect historic significance, in the long-term, properties may be at greater risk from such practices.

Clearly there are many challenges to elevating historic properties, as the elevation may significantly alter the historic nature of the building or historic district. Some important considerations for historic properties include materials and types of elevation allowed, height of allowable elevation, and the context of the surrounding neighborhood. There are several guidance documents for elevation design guidelines specifically geared at historic homes (two of which are included in the References section at the end of this Memo) that may be of value as the Town considers amending its zoning code to allow for more resilient building efforts. It would be wise for the Town to engage with the Connecticut Trust for Historic Preservation and/or other local historic preservation resources to figure out an approach that will satisfy both objectives: to protect properties from flood impacts and preserve the historic character of the building and the community.

Alternatives to Elevation

In some cases, it may not be feasible to elevate a property, either due to the size of the building, restrictions placed on historic properties, or other engineering, economic or environmental limitations. There are alternatives to elevation that the Town should make allowances for in its zoning code. These considerations include:

- Allowing for alternative locations of mechanical and electrical systems, so they can be removed from below-grade spaces. This may also require permitting obstructions in the rear or side yards or on rooftops, as needed, based on the siting of the systems.
- Permitting the use of temporary, deployable flood control measures in yards and open spaces.
- Allowing yards to be raised and graded to assist with flood protection.

Setbacks

Increasing setbacks for waterfront properties can also be a useful tool in communities that are still experiencing waterfront development. Increasing the required setbacks from the water will help avoid the need for shoreline hardening while also helping to preserve coastal features and allow for the continuation of private property use. In some communities, instead of providing a distance requirement for these setbacks, the requirement is the maximum practicable setback for the property in question.

Rolling Easements

An alternate or complementary measure to setbacks are rolling easements. Rolling easements are regulations on land in which a property owner’s interest in preventing real estate from eroding or being inundated yields to the public or environmental interest in allowing natural features (wetlands, beaches, tidal marshes) to migrate freely. This regulation prohibits the property owner from building coastal defenses and shifts inward as the sea level rises.

Rolling easements do not deprive land owners of the full economic use of the property, as they only apply to the interface between land and sea. In the near-term, landowners are not directly impacted. However, in the long-term, when sea level rise creates a scenario where nuisance flooding occurs regularly, the property owner would be encouraged to voluntarily vacate the property. Rolling easements can avoid constitutional takings because land owners maintain use of their property for a long time and have sufficient notification that the use of their property is timebound. In some cases, compensation for the easement is offered to further insure against takings litigation.

Downzoning

The Town may also consider downzoning in certain districts that are particularly vulnerable to flooding and sea level rise. This will help limit that amount of development in those areas and therefore, limit the overall vulnerability of the Town.

Open Space Conservation

Protection and preservation of open space in vulnerable areas can also be an effective tool, as it minimizes the development potential and also provides the Town with land area to install natural flood protection solutions, in addition to the multitude of other benefits that access to open space provides a community.

Solar Access

Access to solar power for cell phones and and computer use is an important consideration in the case of storm surges and loss of general power distribution. The Solar Access regulations should be reviewed to ensure that property owners have the options to place solar panels (ground, wall, roof) that best serve their ability to provide a secondary power source.

Additional Considerations

In addition to the zoning strategies listed above, there are a few other important considerations that the Town should take into account as it evaluates a potential amendment to its zoning regulations. These considerations include:

- The interplay between the zoning code and the building code and ensuring that the two codes work together in an effective manner to promote coastal resilience. In addition, some strategies may be more applicable to one code than they are to the other code; the Town should be aware of this symbiotic relationship between the two regulatory devices.
- Opportunities for coastal retreat. Often communities will modify regulations to phase out development in the most vulnerable areas and also encourage coastal retreat, either after a property is damage by a storm or in other applicable circumstances. In addition, similar consideration should be placed on how the Town can phase out nonconforming uses in its flood hazard areas over time. While this may appear to be a longer term strategy, uncertainty of future

climate change impacts require planning for possible scenarios now. A near-term solution could include exploring changes to taxation or budgetary processes than enable the Town to set aside funds for future buyout or acquisition programs.

- Using the site plan review process to require applicants to demonstrate potential sea level rise impacts, and how the property owner or developer plans to mitigate and/or adapt to those impacts in the siting and design. Importantly, the methodology and assumptions used to demonstrate impacts should be defined by the Town to ensure analyses are as accurate and honest as possible.

Community Rating System (CRS)

One of the added benefits to making changes to the zoning regulations to incorporate flood protection and resilience strategies is that these strategies may assist the Town in its reapplication to the Community Rating System and help the Town reach a higher level than the level for which it had previously been eligible.

Potential Challenges & Legal Considerations

As the Town reviews these suggested amendments and decides which strategies to implement, it is important to take into consideration any potential challenges or barriers to implementation. Some of the most important considerations include:

- Ensuring that the Town has the resources to enforce these standards. Updating codes and regulations to be more resilient is a great proactice, but if these regulations are not enforced appropriately, then the Town's efforts towards increasing resilience will be undermined.
- Making sure that Stonington has the legal authority to enact regulations to protect against sea level rise. This is unlikely to be an issue for Stonington, because Connecticut is a home rule state and therefore, the Town likely has the authority to amend its zoning code to protect against sea level rise.
- If the Town is interested in using the sea level rise maps from this study to inform the boundaries of a potential overlay district, Town officials should do some additional research before enacting such measures. There may be legal issues with using these sea level rise maps for zoning purposes, since they are not officially adopted maps. However, some municipalities have found ways to increase the boundaries of their flood overlay districts beyond the boundaries of the FEMA maps and Stonington could employ similar measures. One example is the Town of Seabrook, NH, which developed an "extended coastal flood hazard overlay" to account for increased storm surge and sea levels. To do this, the town used the existing Flood Insurance Rate Maps (FIRMs) published by FEMA, which established a base flood elevation of nine feet above mean sea level. The town then expanded this zone to include all land within fifteen feet of mean sea level to account for increased storm surge and rising sea levels.

- When adopting new provisions, the Town will likely need to consider a grace period for certain permits and applications that were already underway at the time of the newly adopted provisions. In addition, many properties will inevitably be grandfathered in under the old zoning code; however, the Town should consider a way to bring all properties into compliance with these new regulations over time.
- Changes to coastal regulation may diminish coastal land values overtime. This can result in financial impacts on both homeowners and the town. Easements and setbacks can decrease demand for and resale value of coastal homes, and potentially expose the town to takings litigation. Decreasing land values can also impact tax revenue for the town. Additionally, neighboring towns may offer less stringent regulations and further perpetuate these financial hardships.

References & Resources

Several communities have successfully implemented the flood resilience considerations into their zoning codes. Some communities that the Town of Stonington could use for reference include:

New York City, NY

New York City made several changes to its zoning code to better protect against future flood events and to remove barriers to post-disaster recovery, based on the lessons learned from Superstorm Sandy.

Reference: NYC Flood Resilience Text Amendment can be found here: http://www1.nyc.gov/assets/planning/download/pdf/plans/flood-resiliency/final_text.pdf

Norfolk, VA

Norfolk is currently undergoing a rewrite of its zoning ordinance; expanding flood resilience considerations is one of the main goals of this rewrite.

Reference: The draft plan is currently available online and that draft as well as details of the zoning revision process and public meetings can be found here: http://www.zonenorfolk.com/

Boston, MA

The City of Boston implemented a Climate Change Preparedness and Resiliency Checklist that must be submitted as part of the review process for all new development projects. The City is in the process of updating that checklist.

Reference: More information on the checklist and proposed updates can be found here: http://www.bostonplans.org/planning/planning-initiatives/climate-change-checklist-update

Additional helpful resources include:

- The Nature Conservancy: Municipal Zoning Options for Adaptation to Sea Level Rise in Connecticut: http://www.scrcog.org/wp-content/uploads/hazard-mitigation/background_material/TNC_CT_Municipal_Zoning_Options-for-SLR.pdf

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- Georgetown Climate Center: A Model Sea-Level Rise Overlay Zone for Maryland Local Governments: http://dnr.maryland.gov/ccs/Publication/GCC_MD-SLROrdRpt_FINALv3_11-2011.pdf
- Louisiana Office of Cultural Development, Elevation Design Guidelines for Historic Buildings in the Louisiana GO Zone: http://www.crt.state.la.us/Assets/OCD/hp/uniquely-louisiana-education/Disaster-Recovery/Final%20Elevation%20Design%20Booklet%2012-07-15%20v2.pdf
- Mississippi Development Authority, Elevation Design Guidelines for Historic Homes in the Mississippi Gulf Coast Region: http://www.nj.gov/dep/hpo/hrrcn_sandy_pdf%20files/mississippi.pdf
- Adapting to the Rise: A Guide for Connecticut's Coastal Communities: http://www.ct.gov/ctrecovers/lib/ctrecovers/TNC_Adapting_to_the_Rise.pdf

Appendix E:
Literature Review Memo

Memorandum

ARUP

To	Keith Brynes, Town Planner Town of Stonington	Date	February 16, 2017
Copies		Reference number	251043.00
From	Lisa Dickson, Arup Katie Wholey, Arup	File reference	
Subject	Literature Review		

1 Overview

The following plans and reports were reviewed as part of the coastal resilience planning process. Key points and areas of overlap between these plans and the coastal resilience plan are noted in this memo.

- **Stonington Borough Hazard Mitigation Plan:** http://www.seccog.org/Hazmit2012/stonington_boro%20annex%20update.pdf
- **Town of Stonington Hazard Mitigation Plan:** http://www.seccog.org/Hazmit2012/stonington%20annex%20update.pdf
- **2015 Plan of Conservation and Development:** http://www.stonington-ct.gov/sites/stoningtonct/files/file/file/2015_pocd_final_version.pdf
- **The Nature Conservancy Salt Marsh Advancement Assessment:** https://www.conservationgateway.org/ConservationPractices/Marine/crr/library/Documents/Stonington%20Salt%20Marsh%20Advancement%20Zone%20Assessment_Small.pdf
- **Stonington Harbor Management Plan & Mystic Harbor Management Plan:** http://www.stonington-ct.gov/sites/stoningtonct/files/stonington_harbor_management_plan.pdf & http://www.stonington-ct.gov/sites/stoningtonct/files/file/file/mystic_harbor_management_plan_may_1995.pdf
- **Zoning Regulations (Revised 2015):** http://www.stonington-ct.gov/sites/stoningtonct/files/file/file/zr_e25_7_1_15_0.pdf
- **Open Space Plan (Revised 2007):** http://www.stonington-ct.gov/sites/stoningtonct/files/file/file/open_space_plan_7_17_07.pdf
- **Rt. 1 Corridor Study (Adopted March 2008):** http://www.stonington-ct.gov/sites/stoningtonct/files/file/file/r1cs_adopted_3_4_08.pdf
- **Mystic Mobility Study (Feb 2011)**
- **NE Corridor Rail Plan:** http://www.necfuture.com/alternatives/default.aspx

2 Stonington Borough Hazard Mitigation Plan

The primary purpose of the Hazard Mitigation Plan is to reduce the loss of or damage to life, property, infrastructure, and natural, cultural, and economic resources. The borough is largely residential in nature and has seen very little new development since the 1980s. Thus, the coastal resilience concerns in the Borough of Stonington are likely more focused on protecting homeowners and private property, rather than commercial development. There is also an increasing trend towards seasonal housing in the Borough with approximately 25% of the current housing units being seasonal, recreational, vacation or rental homes. Most of the housing units predate 1970, so they likely do not meet current building codes and are more susceptible to damage from natural hazards, unless the units have undergone recent renovations.

Inland flooding issues are largely a result of drainage issues in the Borough and nuisance basement flooding, resulting from heavy rainfall. Coastal flooding is a more significant concern throughout the Borough. There are several existing programs, policies and regulations in place to mitigate inland flood damage and coastal flooding, including:

- Zoning regulations that restrict development in the 100-year floodplain and require elevation of new construction above base flood elevation (BFE).
- Regular annual cleaning of catch basins and culverts
- Participation in the Community Rating System
- Outreach to residents on potential acquisition elevation programs (but they are more interested in hardening the coastline to protect against flooding)
- Private seawalls and bulkheads, and larger breakwater structures and groins are located throughout the Borough

Identified vulnerabilities include:

- Nuisance flooding on private properties, from rainfall events
- Coastal flood impacts to the Fire Station (100 Main Street), Borough Hall (26 Church Street), and the Water Pollution Control Facility (High Street)
- 62% of the Borough is located in the 100-year floodplain
- East Grand Street/Salt Acres Road, all of the main roadways in the borough (and several other roads) could be exposed to wave action and/or inundated during a 1% annual chance flood
- Amtrak railroad is vulnerable to overtopping
- One repetitive loss property in the Borough. A repetitive loss property is any insurable building that has been paid for two or more $1,000+ claims by the National Flood Insurance Program

(NFIP) in a 10-year period. In addition, there are many private properties (approximately 291) located in the 100-year floodplain

There are many valuable recommendations listed in the Hazard Mitigation Plan that should be considered in concert with any resilience planning options in order to identify co-benefits and places where the two plans can leverage each other to make Stonington more resilient. Notably, this plan was updated in July 2012, a few months prior to Superstorm Sandy in October 2012. Therefore, the plan does not include an analysis of impacts resulting from Superstorm Sandy.

3 Town of Stonington Hazard Mitigation Plan

The land use in the Town is comprised of approximately 25% residential (of which, approximately 32% of the housing units are multi-family, apartments, or mobile homes), 5% commercial and industrial, 7% agricultural, 9% institutional or transportation, 15% open space, and 40% vacant or underutilized. There is tremendous potential for development and 96% of the vacant land is zoned residential.

The Hazard Mitigation Plan (HMP) identifies several critical facilities located in vulnerable locations, including several Fire Department stations and water treatment and pollution plants. The HMP also recognizes that the communication system is heavily reliant on the five cellular towers in town, one of which is located in the 100-year floodplain. The Masons Island Causeway is the only mode of egress from Masons Island and the bridge was submerged during Tropical Storm Irene; therefore, the bridge is a critical asset for the 400 people living on Masons Island year-round. As noted in the Borough HMP above, the Mystic Amtrak station is also highly vulnerable.

The heaviest storms resulting in inland flooding occurred in July 2009 and March 2010. Approximately 50-60 cars were inundated during the 2009 storm and two dams were overtopped. The March 2010 nor'easter destroyed the Rt. 184 Bridge and submerged a large area of Old Mystic. Serious basement flooding occurred in many homes and also in Stonington Town Hall. Several roads were damaged by the storm and closed due to flooding. In addition, coastal flooding is a significant concern, particularly in the southern section of the Town, where structures and infrastructure are closer to sea level, and therefore, more vulnerable. There are several existing programs, policies and regulations in place to mitigate inland flood damage and coastal flooding, including:

- Flood control structural projects, such as the USACE construction of the levee in Pawcatuck, and on-going maintenance and improvements
- Potential grant funding for drainage upgrades to prevent basement flooding under FEMA's Hazard Mitigation Grant Program (HMGP)
- Zoning regulations that place additional requirements on development in the 100-year floodplain and require elevation of new construction above base flood elevation (BFE).
- Regular annual cleaning of catch basins and culverts
- Participation in the Community Rating System

- Outreach to residents on potential acquisition elevation programs (but they are more interested in hardening the coastline to protect against flooding)
- Private seawalls and bulkheads, and larger breakwater structures and groins are located throughout the Town
- The Town is also working with The Nature Conservancy on coastal resilience planning to address sea level rise and develop cost analyses for potential mitigation projects

Identified vulnerabilities include:

- Areas along Mystic River, Copps Brook, Stony Brook, Anguilla Brook, Pequotsepos Brook, Whitford Brook and the Pawcatuck River are vulnerable to flood impacts, largely as a result of insufficient culvert sizes
- Stonington has been impacted by significant flooding due to poor drainage, largely resulting from undersized drainage systems
- 1,381 private properties are located in the 100-year floodplain
- The 200+ homes in Lords Point have experience the most damage from coastal flooding, historically
- There are four repetitive loss properties in the Town that have been impacted by inland flooding and five repetitive loss properties impacted by coastal flooding
- Three fire stations, 2 wastewater treatment plants, a water treatment plant, and many roads are vulnerable to coastal flooding
- Masons Island Causeway may be overtopped by even a moderate coastal event
- In additional to the vulnerable residential areas, commercial and industrial areas in Mystic and along the Pawcatuck River
- Deans Reservoir Dam, Long Pond Dam, Mystic Reservoir Dam, and Silvias Pond Lower Dam are particularly vulnerable to overtopping and failure during storm events

There are many valuable recommendations listed in the Hazard Mitigation Plan that should be considered in concert with any resilience planning options in order to identify co-benefits and places where the two plans can leverage each other to make Stonington more resilient. Notably, this plan was updated in July 2012, a few months prior to Superstorm Sandy in October 2012. Therefore, the plan does not include an analysis of impacts resulting from Superstorm Sandy.

4 2015 Plan of Conservation and Development

The 2015 Plan of Conservation and Development is intended to guide the future of Stonington with visionary goals and action-oriented recommendations. Therefore, the coastal resilience plan should be

considered in concert with the Plan of Conservation and Development to make sure that the recommendations align and to ensure that solutions that could provide multiple co-benefits are identified and prioritized. The overarching principles of the plan include: providing for sustainable development, strengthening existing villages, and promoting low impact commercial and residential approaches. Some major trends in Stonington include: (1) Modest projected population growth; (2) Ageing population; (3) Continued growth in the number of housing units; (4) Less diverse housing stock (most new growth is single-family housing); (5) Decreasing housing affordability; (6) Significant growth potential in the Town; (7) Zoned for residential growth; (8) Overall average income is high and masking the need for services for lower income residents; (9) Major structural shifts in the regional economy (mostly away from manufacturing); and, (10) Changing fiscal conditions with the potential for increased reliance on property taxes.

The plan specifically identifies the need to prepare and plan for climate change. Maintaining a balance between environmental preservation and increasing development is expected to become increasingly more difficult as the climate continues to change. One specific project to address sea level rise and storm surge is the restoration of the Old Stonington Wharf/Breakwater; however, there are many additional policy and task recommendations to help protect the Town against impacts from climate change. These recommendations include: protecting and restoring sensitive coastal resources; promoting the use of green infrastructure and "living shorelines"; ensuring better coordination amongst the various commissions that manage coastal activities and the various federal, state, and local regulatory agencies; adopting a Pawcatuck Harbor Management Plan and a plan for adaptation to sea level rise; discouraging new public infrastructure and development in flood prone areas; and modifying regulations to better account for flood vulnerabilities. In addition, the plan highlights the importance of agricultural resources, which are an important consideration in climate change planning, and the need to protect inland and coastal wetlands.

Some of the tasks that are of specific relevance to the coastal resilience study, as identified in communication with the Town (during a meeting on January 3, 2017), include the following. The comments in red indicate how the coastal resilience plan is intended to advance these tasks.

- **Task 3.3.4** – Plan for tidal wetland "advancement zones," in which such wetlands are expected to expand, by restricting densities and lot coverage in "V" flood zones. The scope of this study is not anticipated to include developing recommendations or regulations related to tidal wetlands. However, the Town is currently in the process of auditing its zoning regulations and that audit may result in recommendations for additional requirements in V-zones, similar to those suggested in this task.

- **Task 3.3.5** – Identify possible modifications to public infrastructure to account for increases in sea level rise. As part of this study, we anticipate developing 5 resilience/adaptation design recommendations for public facilities. Therefore, this task will be partially advanced by the coastal resilience plan.

- **Task 3.3.6** – Review regulations to assure that appropriate setbacks for residential uses from the Coastal Jurisdiction Line are provided. Discourage seawalls as a solution to protecting development when other options are feasible. A complete review of zoning regulations, beyond

this memorandum, is not currently part of the scope of this study. However, some additional review of the zoning regulations could be provided as an add-on service to help advance this task.

- **Task 3.3.7** – Restrict assisted living facilities, hotels, elderly housing, and schools, which have the potential to increase exposure of vulnerable populations in coastal flood hazard areas. An assessment related to vulnerable populations may be included in this study, depending on the level of analysis needed to ensure compliance with HUD CDBG-DR funding requirements. In addition, the Town is currently in the process of auditing its zoning regulations and that audit may result in recommendations to limit development in coastal flood hazard areas that would increase the exposure of vulnerable populations.
- **Task 3.3.10** – Work with the Borough to identify climate-related vulnerability in Town and issue a Climate Change Impact Report with recommendations for mitigation measures. This task will be advanced by this study with the completion of a vulnerability and risk assessment of the Town's critical assets.

The community has identified maintaining the character of the Town and enhancing the villages as important priorities. While the plan does not specifically address how coastal flooding may impact historic resources and the village centers, it does identify the need for flexibility and creativity in addressing flood hazard requirements in historic zones. It is important to note that many of the Town's historic resources are located in the three villages, which are all prone to impacts from coastal flooding. Therefore, any recommendations for the preservation of historic resources or the development of the villages should also include considerations of the impact of coastal flooding on those resources.

This plan identifies important transportation consideration throughout the Town; however, there is little mention of the impacts of coastal flooding on these resources. Any proposals to increase bicycle and pedestrian mobility, improve public transit, and provide maintenance for roadways should also take into consideration the potential for flood impacts to those resources.

All of the recommendations listed in the "Sustainability and Resiliency" section of the plan are important climate change considerations, both from an adaptation and mitigation standpoint. These recommendations include: promoting energy conservation, promoting water conservation, promoting waste reduction/recycling, promoting "green buildings", educating residents about sustainability, and promoting resiliency.

Overall, the 2015 Plan of Conservation and Development includes many recommendations for promoting a more resilient Stonington and this plan should be used to guide and focus the future resilience planning efforts.

5 Salt Marsh Advancement Assessment

Sea level rise and flooding is altering the presence and abundance of natural resources throughout Connecticut and one of the most notable changes is the advancement of coastal salt marsh upslope into areas that are currently considered uplands. The Nature Conservancy completed an analysis of salt

marsh advancement in Stonington in 2014. This advancement is of concern because it has the potential to extend into developed areas of the Town (i.e. areas with roads, buildings, parking lots, etc.). While the rate of change is relatively slow and will occur gradually over the next several decades, it is something that the Town should take into consideration during its resilience planning process. Two important concerns are: (1) a large amount of current development is in direct conflict with sea level rise and advancing marshes; and (2) the Town currently has a large amount of unprotected open space that will be vital to maintaining the Town's wetland resources in the future. Approximately 2,000 acres of land are expected to experience salt marsh advancement through 2080. Of that, 268.2 acres are not suitable for such advancement because that land is already developed. This plan provides a basis for helping the Town develop regulations on future development and protect vital open space in order to prevent future property damage and promote resilience in Stonington.

6 Stonington Harbor Management Plan & Mystic Harbor Management Plan

The Stonington and Mystic Harbor Management Plans mostly focus on the administrative management of the harbor, including provisions related to collecting fees for mooring permits, assigning mooring locations, and enforcing regulations related to wake, noise, speed, etc. The problems and recommendations specifically focus on moorings and anchor anchorages, commercial fishing, other water uses and safety, water quality and shoreside development. While the plans do not specifically address climate resilience or the impacts of flooding on the harbor infrastructure, the Stonington Harbor Plan mentions concerns related to the Town Dock in past flooding events. In addition, some of the identified goals and recommendations would provide co-benefits to the Town by assisting with the management of the harbors and making Stonington more resilient through minimizing damage to property and loss of life around the harbor during a coastal flood event.

7 Zoning Regulations

The Zoning Regulations include a number of regulations related to flood hazards; however, most of these regulations are based on the current FEMA flood zones, which do not account for increased risk from sea level rise and storm surge. The regulations include a Coastal Area Management (CAM) Overlay District and a Flood Hazard Overlay District. The CAM boundary includes: areas covered by the National Flood Insurance Program (NFIP), areas within 1,000 feet of the mean high water mark of coastal waters, and areas within 1,000 feet of the State-designated tidal wetlands. Projects within the CAM are evaluated for any adverse impacts to land and water resources; proposed mitigating measures are required in the CAM application and the Commission may approve, deny, modify, or modify with conditions any project within the CAM boundary. The Flood Hazard Overlay District (FHOD) applies special regulations to all land in the floodplain of rivers, streams, and bodies of water. This district regulates all aspects of construction in the floodplain in order to (1) minimize loss of life, injury, and property damage; (2) protect the health, safety, and general welfare of the people; and (3) help control and minimize the extent and depth of floods. In general, all new construction in the flood zone must be elevated at least one foot above the base flood elevation and no new construction or alterations of

buildings in the floodplain shall reduce the water holding capacity of the floodplain. Additional requirements include: (1) prohibition on new construction and substantial improvements within 100 feet of mean high tide in V-zones; and, (2) designation of a 100 foot non-infringement area within the RC-120 zone (Residential Coastal), which prohibits development or improvements within 100 feet of coastal features (with a few exceptions, such as boat access and greenways).

8 Open Space Plan

Approximately 30% of the land in the Town of Stonington is perceived as open space; however, that land in not permanently protected open space and could be developed in the future. In fact, only about 9-10% of the land in Stonington is permanently protected open space. Through the Open Space Plan, the Town set an ambitious goal of preserving a minimum of 30% of its land as open space by 2020 and increasing connectivity between open space in order to create green belts and wildlife corridors. The Town currently has some regulations that require the preservation of open space: mandatory set-asides of 15% are required by subdivision regulations and the Open Space Development (OSD) alternative requires 50% of a parcel to be preserved as open space. The overall goals of this plan include:

1. Preserve town character and enhance economic sustainability
2. Protect natural resources to ensure public health and safety
3. Protect wildlife habitats and natural resources
4. Maintain and enhance recreational areas

While the plan does not specifically address coastal resilience concerns, the recommendations in the Action Plan work in concert with effective coastal resilience strategies and provide co-benefits to the town. These recommendations include: increasing the amount of protected open space in Stonington, modifying regulations to protect environmentally sensitive areas from development, limiting the amount of impervious surface, proactively acquiring beach property for public use, increasing public awareness of the need for protecting open space and other environmental resources, and developing greenways and connected open spaces.

9 Rt. 1 Corridor Study

U.S. Route 1 is a major transportation corridor extending the length of the east coast of the United States, from Maine to Key West, Florida. Route 1 serves as the principal connection between the villages of Mystic and Pawcatuck, the borough of Stonington, and the Wequetequock area. This plan sought to develop a vision for the corridor. The main focus of the study was to allow for increased economic development opportunities along the corridor while also maintaining community character, protecting of open space and environmental resources, minimizing traffic, and protecting village resources.

While the plan does not directly address coastal flooding or climate resilience, many of the recommended strategies are in line with resilience recommendations for addressing coastal flooding and other climate impacts. Those recommendations include:

- Promoting bicycle and pedestrian connections;
- Protecting natural resources and preserving open space;
- Heavily scrutinizing environmental encroachments and impacts to natural resources from development;
- Preventing excessive grading and limiting pavement widths, as appropriate;
- Enhancing public access to the coast; and
- Promoting and expanding bus and rail transit, where possible.

10 Mystic Mobility Study

The Mystic Mobility Study does not address the impacts of climate change or flood events on the transportation system in Stonington; however, there are opportunities to incorporate coastal resilience into the planning and improvement efforts denoted in the mobility study.

The three main focus areas presented in the study include the Mystic Trolley Shuttle Service, water taxis, and mobility hubs. All of these transit options would be subject to impacts from coastal flooding and further analysis of the route and operations should consider those impacts. The study also details improvement plans and costs for many transit services in the Mystic Area. There are opportunities to leverage these pre-existing improvement plans to incorporate coastal resilience design solutions into planned improvements as a way to leverage the existing funding and also provide co-benefits to improve the transit system and increase the resilience of the Mystic Area.

11 Northeast Corridor Rail Plan

NEC FUTURE is the Federal Railroad Administration's (FRA) comprehensive effort to plan for future investment along the rail transportation spine that extends from Washington, D.C. to Boston, MA. This railway corridor is known as the Northeast Corridor (NEC) and runs through Stonington, CT, along the coastline. Several alternatives were developed to address the following needs of the NEC:

- State of Good Repair: The current infrastructure is aging and has received insufficient investment in maintenance needs. This results in service delays.
- Connectivity: There are currently gaps in connectivity between the railway and various transportation modes.

- Capacity: There are severe capacity constraints and critical chokepoints along the current railway that effect current ridership and limit growth in ridership.
- Performance: Improvements in travel time, frequency and service hours are needed to make rail competitive with other modes of travel.
- **System-Wide Resiliency: The destruction caused by Hurricane Irene and Superstorm Sandy raised awareness of the vulnerability of the NEC. There is a need for increased redundancy throughout the rail network and enhancements to improve the resiliency of the infrastructure.**
- **Environmental Sustainability: Increasing ridership on passenger rail can help reduce energy use and emissions throughout the region.**
- Economic Growth: Convenient, reliable, and frequent rail service will allow for continued economic growth in the Northeast region, where the knowledge-based economy is especially reliant on rail service.

The system-wide resiliency and environmental sustainability needs are particularly relevant to the Coastal Resilience Assessment. The Tier 1 Final Environmental Impact Statement was completed in December 2016 and the Preferred Alternative includes a proposed new segment running through Stonington that would locate the new rail segment further from the coast, along the Rt. 95 corridor, reducing its vulnerability to coastal flooding.

Appendix F:
Sea Level Rise Memo

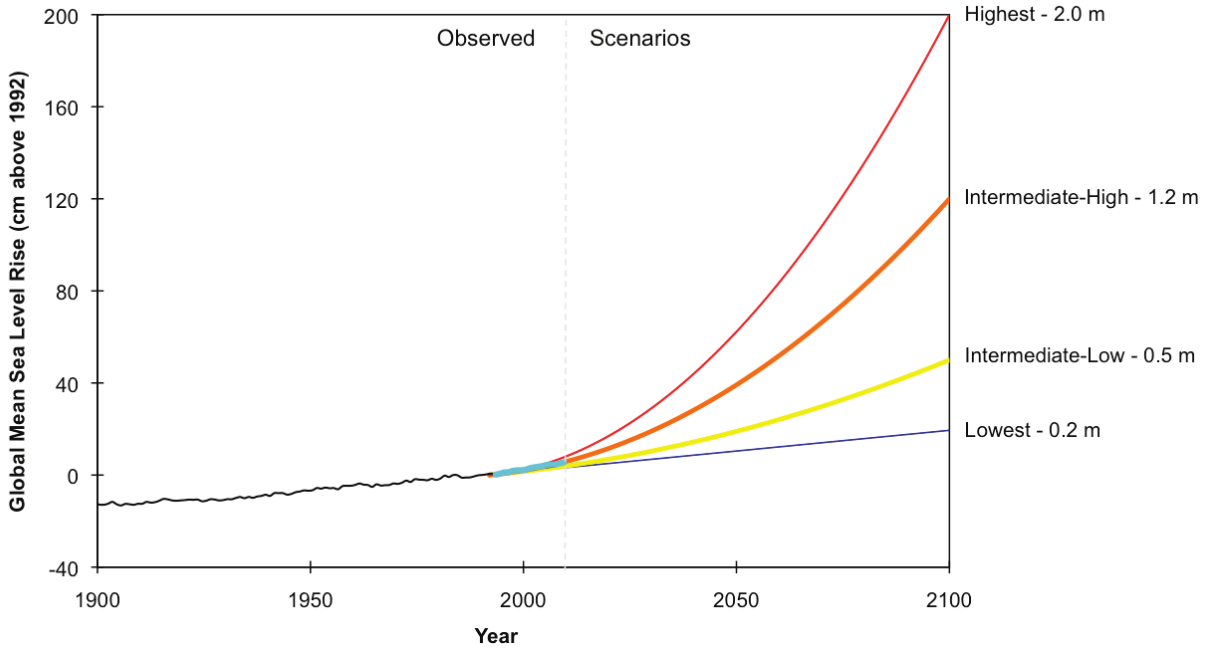
Memorandum

ARUP

To	Mr. Keith Brynes, Town Planner Town of Stonington, CT	Date	September 13, 2016
Copies		Reference number	251043.00
From	Lisa Dickson, Arup Kirk Bosma, Woods Hole Group	File reference	
Subject	Recommended Sea Level Rise Assumptions		

Recommendation: *Based on the information below, we would recommend that the Town of Stonington use the projected Highest SLR curve at 2070 as its long-term climate scenario* (see table on page 2 for those values).

Below is the sea level rise curve from the latest National Climate Assessment that is standardly used to determine appropriate SLR levels for different planning horizons and with respect to overall risk tolerance. It should be noted that these curves represent the average global sea level rise (SLR) and is not corrected for other geographic variability. Since sea level rise is happening three times faster on the East Coast than the global average, we generally recommend that clients with assets along the eastern seaboard adopt the highest sea level curve to more closely approximate those local conditions.



Memorandum

Below is a description of the data that was used to construct each of the curves shown in the figure above (from https://scenarios.globalchange.gov/sites/default/files/NOAA_SLR_r3_0.pdf).

- Highest Scenario: derived from a combination of estimated ocean warming from IPCC AR4 global SLR projections and a calculation of the maximum possible glacier and ice sheet loss by the end of the century…should be considered in situations where there is little tolerance for risk.
- Intermediate-High Scenario: average of the high end of semi-empirical, global SLR projections; assess risk from limited ice sheet loss
- Intermediate-Low Scenario: based on the upper end of the IPCC 4th Assessment, B1 emission scenario; assess risk primarily from ocean warming
- Lowest Scenario: based on a liner extrapolation of the historic SLR rate derived from tide gauge records beginning in 1900; risen over 0.2 meters (8 inches) over this period of record; should be considered where there is greatest tolerance for risk

When the National Climate Assessment report was published in 2012, the following statement was made: "We [the authors] have very high confidence (>9 in 10 chance) that global mean sea level will rise at least 0.2 meters (8 inches) and no more than 2.0 (6.6. feet) by 2100."

However, more recent observations suggest that the current rates of global sea level rise are following an even steeper trajectory than what is shown here. This has led some to question whether the curves are too conservative and could perhaps be under-predicting those results.

In determining which time horizon to use, the Town must decide both on the relevance of the projections to nearer-time considerations (e.g., 10-year planning projections; capital improvement programs), as well as adequately capturing the longer-term considerations associated with the life expectancy of assets such as buildings, bridges, roadways and other infrastructure. These types of assets often have life expectancies that span 30-75 plus years. The ability to bracket possible end-members allows the town to interpolate potential intermediate risks - both temporally and geographically.

The project team has already determined that the Highest SLR scenario for 2030 will be used as a planning horizon for the near-term; the Woods Hole Group is currently modelling those runs. The time horizon of 2030 shows a SLR of approximately ½ foot. The decision remains to be made as to the appropriate planning horizon for later scenarios. The different SLR values for the various scenarios are presented below. These vary somewhat in absolute numbers from those shown on the SLR graphic. The reason for this being that the SLR graphic from the NOAA report uses 1992 as a baseline whereas the SLR projections shown in the table below use 2016 (current conditions) as the baseline.

Scenario	SLR Rate (feet)			
	Low	Int-Low	Int-High	High
2030	0.10	0.19	0.36	0.55
2050	0.25	0.51	1.06	1.69
2070	0.40	0.91	1.99	3.24

Memorandum

Appendix G: Community Engagement Efforts

Memorandum

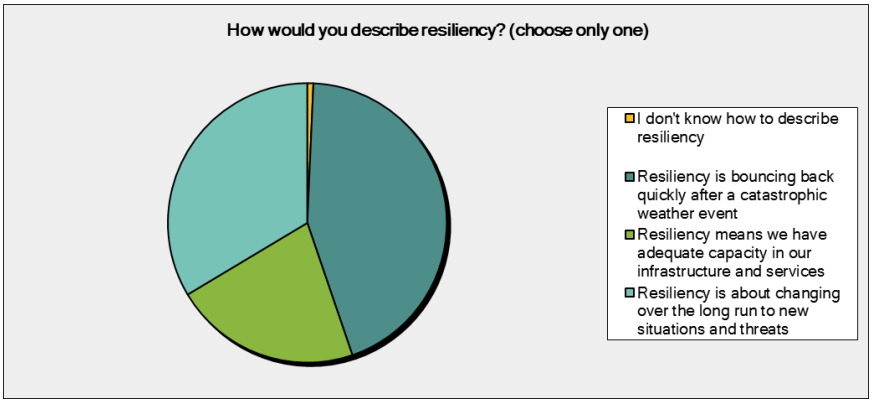
ARUP

To	Mr. Keith Brynes, Town Planner Town of Stonington, CT	Date	August 21, 2017
Copies	Mr. Scot Deledda, Town Engineer Town of Stonington, CT	Reference number	
From	Susan Silberberg, CivicMoxie Lisa Dickson, Arup Katie Wholey, Arup	File reference	
Subject	Stonington Coastal Resilience Plan - Public Engagement Efforts		

The following memo details the public engagement process for the Stonington Coastal Resilience Plan, which included an online survey for residents of Stonington as well as three public meetings throughout the course of the project.

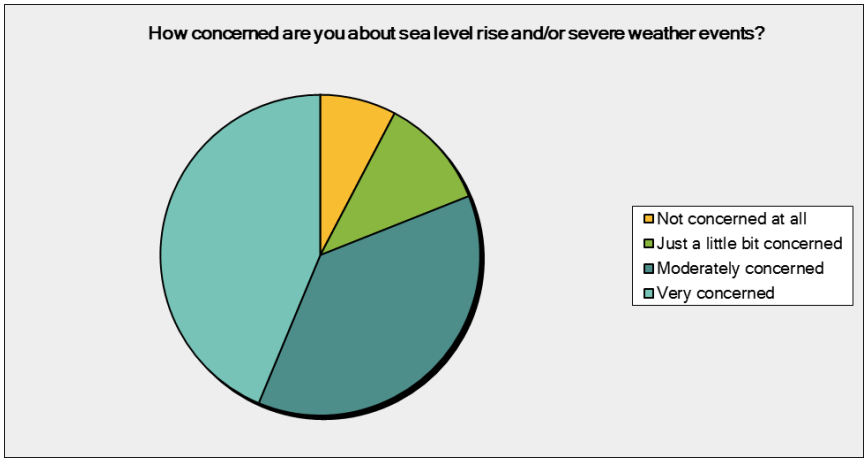
1 Online Survey Results

The survey was completed by 149 respondents. The following graphs and answer choices detail the questions asked as part of the survey and the responses received.

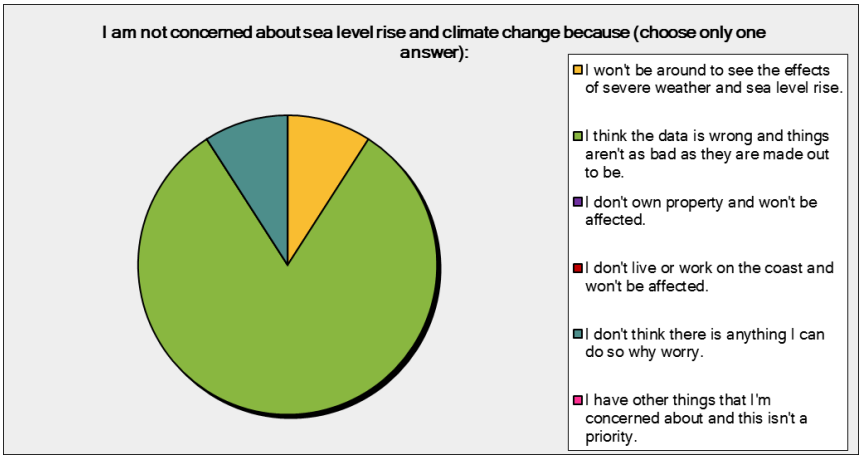


Answer Choices	Responses	
I don't know how to describe resiliency	0.70%	1
Resiliency is bouncing back quickly after a catastrophic weather event	44.06%	63
Resiliency means we have adequate capacity in our infrastructure and services	21.68%	31
Resiliency is about changing over the long run to new situations and threats	33.57%	48
Total		**143**

Memorandum

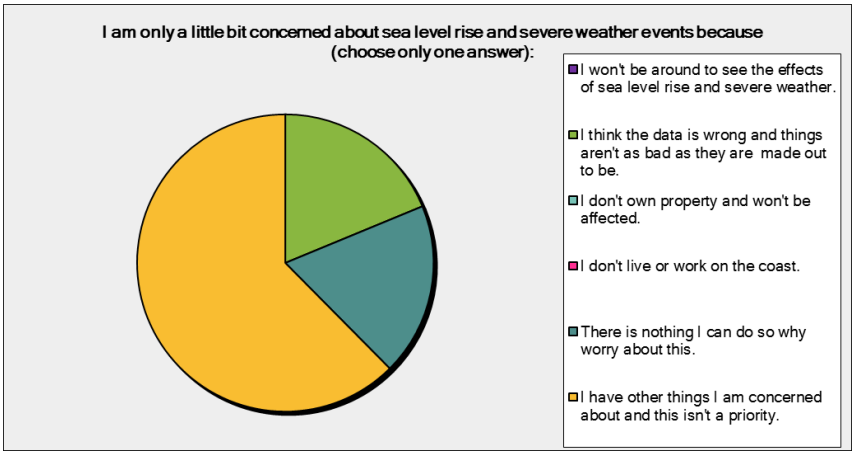


Answer Choices	Responses	
Not concerned at all	7.75%	11
Just a little bit concerned	11.27%	16
Moderately concerned	37.32%	53
Very concerned	43.66%	62
Total		**142**

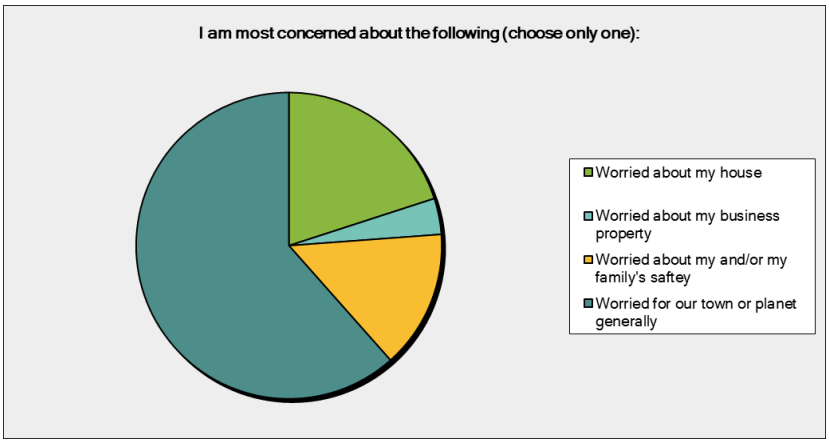


Answer Choices	Responses	
I won't be around to see the effects of severe weather and sea level rise.	9.09%	1
I think the data is wrong and things aren't as bad as they are made out to be.	81.82%	9
I don't own property and won't be affected.	0.00%	0
I don't live or work on the coast and won't be affected.	0.00%	0
I don't think there is anything I can do so why worry.	9.09%	1
I have other things that I'm concerned about and this isn't a priority.	0.00%	0
Total		**11**

Memorandum

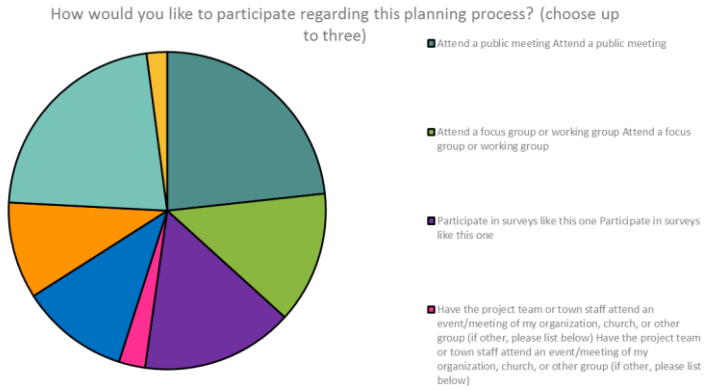


Answer Choices	Responses	
I won't be around to see the effects of sea level rise and severe weather.	0.00%	0
I think the data is wrong and things aren't as bad as they are made out to be.	18.75%	3
I don't own property and won't be affected.	0.00%	0
I don't live or work on the coast.	0.00%	0
There is nothing I can do so why worry about this.	18.75%	3
I have other things I am concerned about and this isn't a priority.	62.50%	10
Total		**16**

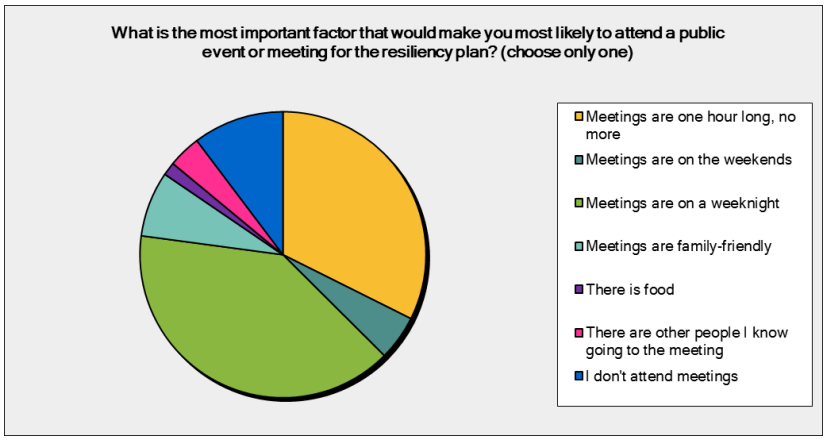


Answer Choices	Responses	
Worried about my house	20.00%	26
Worried about my business property	3.85%	5
Worried about my and/or my family's saftey	14.62%	19
Worried for our town or planet generally	61.54%	80
Total		**130**

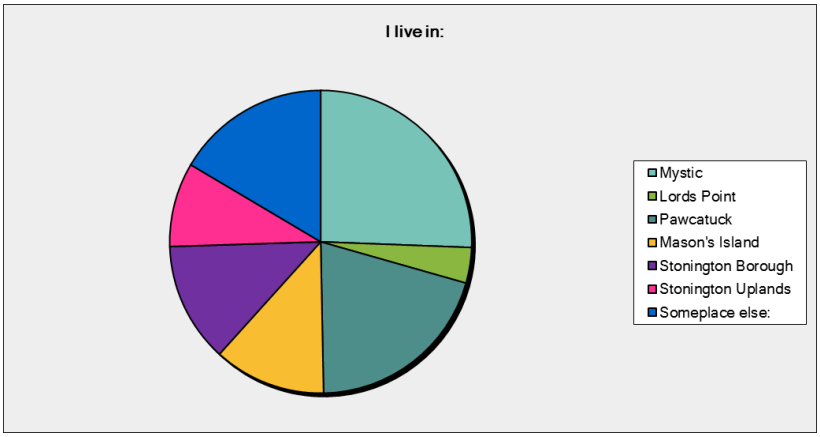
Memorandum



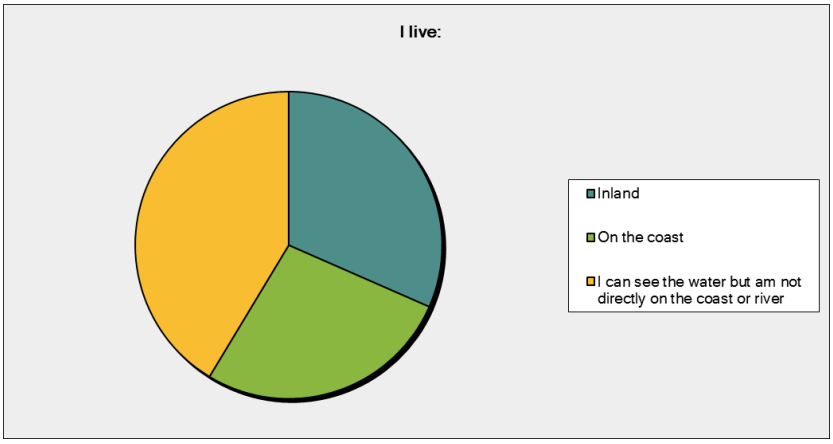
Answer Choices	Responses	
Attend a public meeting	58.21%	78
Attend a focus group or working group	33.58%	45
Participate in surveys like this one	38.81%	52
Have the project team or town staff attend an event/meeting of my organization, church, or other group(if other, please list below)	6.72%	9
Read updates on the Town website	27.61%	37
Get project news on the Town Facebook page	24.63%	33
Receive email updates	55.22%	74
Total Respondents: 134		



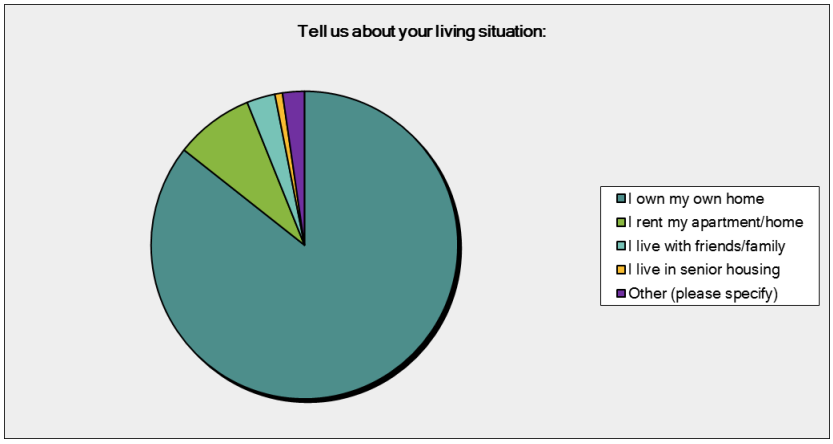
Answer Choices	Responses	
Meetings are one hour long, no more	32.35%	44
Meetings are on the weekends	5.15%	7
Meetings are on a weeknight	39.71%	54
Meetings are family-friendly	7.35%	10
There is food	1.47%	2
There are other people I know going to the meeting	3.68%	5
I don't attend meetings	10.29%	14
Total		**136**



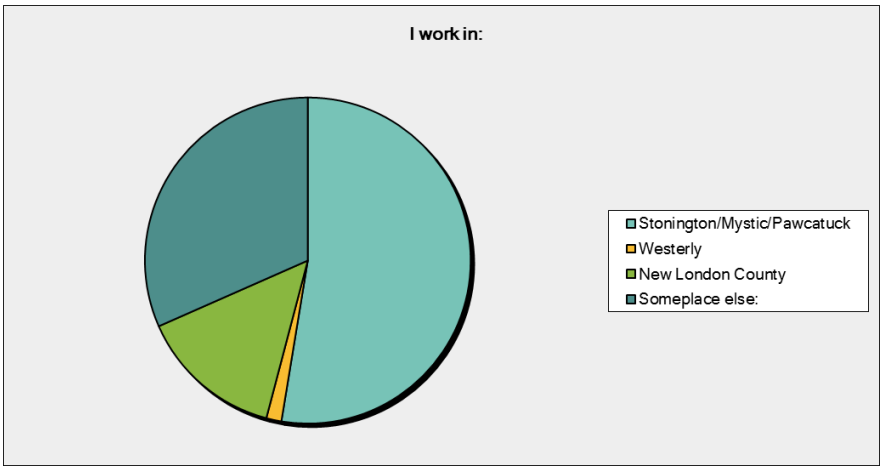
Answer Choices	Responses	
Mystic	25.56%	34
Lords Point	3.76%	5
Pawcatuck	20.30%	27
Mason's Island	12.03%	16
Stonington Borough	12.78%	17
Stonington Uplands	9.02%	12
Someplace else:	16.54%	22
Total		**133**



Answer Choices	Responses	
Inland	31.58%	42
On the coast	27.07%	36
I can see the water but am not directly on the coast or river	41.35%	55
Total		**133**

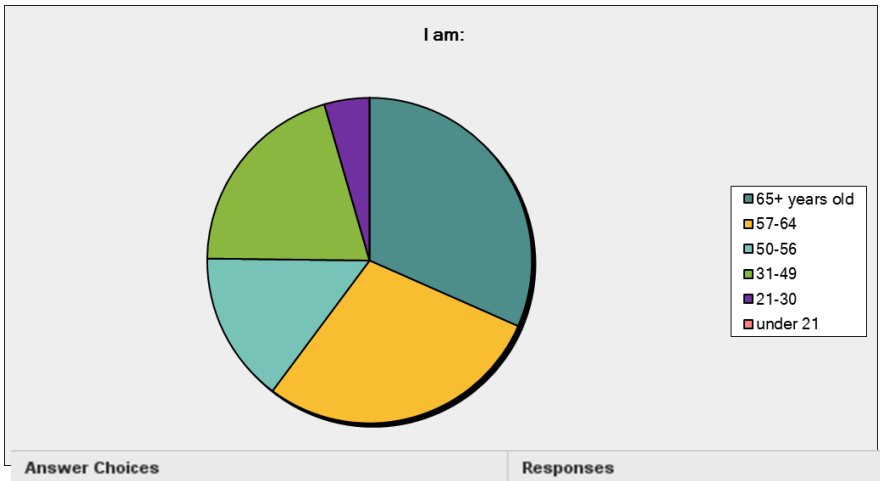


Answer Choices	Responses	
I own my own home	85.71%	114
I rent my apartment/home	8.27%	11
I live with friends/family	3.01%	4
I live in senior housing	0.75%	1
Other (please specify)	2.26%	3
Total		**133**

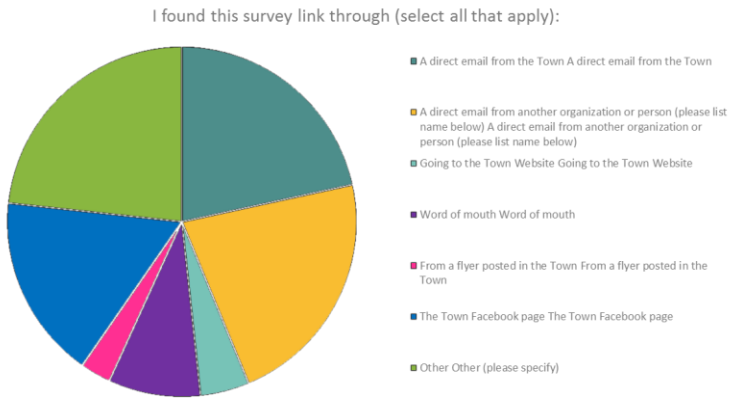


Answer Choices	Responses	
Stonington/Mystic/Pawcatuck	52.63%	70
Westerly	1.50%	2
New London County	14.29%	19
Someplace else:	31.58%	42
Total		**133**

Memorandum



Answer Choices	Responses	
65+ years old	31.58%	42
57-64	28.57%	38
50-56	15.04%	20
31-49	20.30%	27
21-30	4.51%	6
under 21	0.00%	0
Total		**133**



Answer Choices	Responses	
A direct email from the Town	28.57%	38
A direct email from another organization or person (please list name below)	29.32%	39
Going to the Town Website	6.02%	8
Word of mouth	11.28%	15
From a flyer posted in the Town	3.76%	5
The Town Facebook page	22.56%	30
Total Respondents: 133		

2 Public Meeting #1 (October 20, 2016)

The following comments were collected as part of a questionnaire that was passed out at the first public meeting, which was held at the Mystic Aquarium on October 20, 2016.

Briefly tell us your thought about the 2030 and 2050 probability maps showing flooding in Stonington. Were they surprising? Do you believe the data? Is it what you expected? Any other comments you would like to make?

- Surprised about potential flooding in upper Pawcatuck
- Not surprising, but all hands must be on deck to adequately address this impending issue
- I am new to area so don't know geographic enough to take in impact. Thought it was going to be more severe given the experimental rise
- Shocking
- Seems reasonable- good to see that.
- Is the effect of backing of water in hurry?
- Is land grant being taken into account?
- Not surprising and I do believe the data. The maps were hard to see but I will look on line
- Not surprising- believe that depends upon one it and many other factors- mostly expected
- Scary! I do not totally believe the data but believe the threat is near. There are too many immeasurable influences to make an accurate projection.
- Not surprising I have been looking at firm maps online.
- Facts surprised that there was a vulnerability in tow. Of seems very localized.
- The maps did not show very much difference in the amount of water increase to me.
- Flooding on the eastern side of Stonington Borough
- Need to look at maps in more detail. Makes sense that there will be more flooding
- Not surprising unfortunately
- Not surprising. Believable but would like to better understand models
- Concerned for the future regarding impact on real estate even for non-waterproof properties
- I do believe the data= sorry about the data and am very glad to see people paying attention just need more
- Interesting because different than FEMA
- I question the accuracy of the data. We can't accurately predict if it will rain tonight. What makes this something we can believe in?
- Makes sense to me. Looks reasonable and realistic
- Not surprising
- No there's no info from previous storms
- It's difficult to predict images of storms in 2030+2050 so that made it surprising Not enough info to judge
- No surprise, I believe it
- Can we protect our salt marshes?
- No real surprises

- Not surprising, believe the data
- Lots of assumptions used in forecasting- not any history used in hind casting. The truth lies somewhere in between maybe
- I suspect the outlook will worsen- that warming is in a feedback loop. Estimates have so far consistently been exceeded
- I think the data may be underestimating the risk.
- Not surprising. Yes, I believe. Yes expected.

What other information do you want to know?

- Ready for options! Will those be to fight the fight or to move with them? More meetings in aquarium! Thanks for that and food!
- The CT deep permitting criteria have to change to call the property grades to be raised and shorelines protected
- Can we identify undeveloped areas that are high risk and tag them in advance to not develop?
- Attenuation of surges above the I-95 bridge on the mystic river
- What can homeowners in high-risk zones do? When do we need to do? Will FEMA, EPA, Town be supportive?
- How are you going to prepare the community for these events?
- Most interested in how to preserve downtown areas and buildings given most of Stonington town centers like Mystic Stonington Boro, and Pawcatuck
- Effect on PC&D roles
- Economic impact to town or flooded properties
- Planners need to know where the money will come from to help individuals at risk know how to plan and pay for preparations
- Access to maps, fiscal motivation
- Suggestions for addressing how to protect your home? What do you do about septic systems that are vulnerable to flooding?
- Will there be suggestions for individual property owners- how to build beams. What is role of deep? Very difficult to get approval from deep for anything.
- How ongoing will act up to climate change
- Understand the issues, but would like to know how town plans to deal with it. Current regulations prevent home owners from taking preventative measures
- How do you restore any shoreline that is receding? How much do we know about what will happen at Barn island?
- How about a blog where people can ask questions and make comments?
- I look for ways to specify renovations on what we can do to restore our homes?
- What things can a waterfront home-owner do to mitigate the issues?
- How sea level rise has affected our communities already
- Look forward to staying in the 100s.
- How information will be disseminated to pubic. How recommendations will be delivered to the town and how this information can affect public policy.

- If all the property in the flood zones that does not live near town level has to be severed. Does the town have adequate capacity to do this? Same questions relates to water.
- Got confusing with percentages and risk challenging terms between risk and resiliency and percent

Tell us something about this resiliency planning initiative that excited you or worries you

- Excited town is finally taking initiative publicly. Maybe it has happened, but haven't seen it
- I am afraid that the study will be undermined by pressure from state of CT rather than accurately documenting the needs end designs of property owners to protect their property not just infrastructure.
- Concerned that people want to raise roads to provide access other than reduced development in at risk areas
- I am president of Whitehall Landing condo assoc. on the Mystic River. WE are beginning to do some planning and look forward to your information.
- Ruins coastal real estate/family legacy valuations
- Climate change readiness
- Worried about how lack of planning will affect ocean health
- Sea level rise
- It needs to coordinate with town zoning regulations. Zoning needs to be responsive to the resiliency plan and post-event responses
- We need good date, we need a plan, plan should cover residential properties as well as public infrastructure
- Convincing public then willingness to act
- Flooding at Stonington housing authority or limited access for rescheduling evacuation due to storms.
- Transportation- bicycles need to be included during sandy many trees and wires down. Travel over them was possible by bike. Police have bikes but then are not in working order
- If it helps resolve development hurdles in flood prone areas with a planful approach, that would be good!
- Concerned about additional costs for construction in and near the lower area. Limiting the opportunity for some to live in close proximity to the water due to lack of money.
- Pleased to see planning taking place
- Inaction by town after study completed
- Glad people are thinking, hopefully planning. Fear there will be no funding and true guidance with doing the actual work.
- Conflict between waterfront owners and public access when sea level rise is thrown in. Setting aside future salt wash
- Finally taking pro-active steps to acknowledge rising water
- Is the sea level rise prediction accurate?
- I serve as an emergency operations team in Simsbury. This kind of planning is critical to safety and developing cost-effective measures
- Stonington is acting- being proactive

- Vulnerability of mystic seaport
- Worry about even more government regulations
- I am on P&Z in town and still wanted to get up to speed. Do not live in a flood area
- Those of us close to the shore want to see how sea level rise will play out. In particular were concerned about protecting the marsh that protects us.
- Impact on the Mason's Island Yacht Club
- Planning and preparedness
- While I'm high and dry at 20 feet-- getting cut off is an issue
- I live on the water's edge and I am concerned about sea level change
- Representing the board-Stonington landing condo association
- Would like to understand the impact of weather and the sea rise data. How is it included, hindered, predictions?
- Worried for my kids
- We need to better prepare our community- education is key
- How sea level rise may affect my house and property. Also, how this will affect and direct public policy and spending
- Seal Level rise. Storm surge. Property damage
- What will happen on my street/value? Historic structures how will we protect them?

The following is a copy of the presentation made at this meeting.

Community Coastal Resiliency Plan

Town of Stonington, Connecticut

Public Meeting October 20, 2016

Social Media:
#StoningtonReady
@StoningtonCTGov
@ArupAmericas

MYSTIC AQUARIUM RESEARCH

TOWN OF STONINGTON, CONNECTICUT 1649

ARUP

WOODS HOLE GROUP

CivicMoxie™ experts in place

TDA TRAINING & DEVELOPMENT ASSOCIATES, INC.

Agenda

Introduction

Project Approach

Sea Level Rise/Storm Surge Modeling

Vulnerability Assessment: Preliminary Results

Brief Break

Questions and Answers

Why we are here tonight…

- We want to be wise, plan ahead, and protect people, places, and investments:
  - protect public infrastructure from coastal flooding and sea level rise
  - minimize potential for loss of life and destruction to property
  - identify ways to enhance coastal resources
  - continue to *thrive* despite these shocks and stressors

By the time we all leave…

- You will understand why we are doing resiliency planning in Stonington
- Our project approach will be clear

- You will know the results of:
  - Sea level rise (SLR)/storm surge modeling
  - The vulnerability assessment

- You will have a break to do a quick planning exercise with the person next to you
- Everyone will have a chance to ask questions
- Next steps will be clear

We promise to get you out on time at 7:30 PM!

Project Approach

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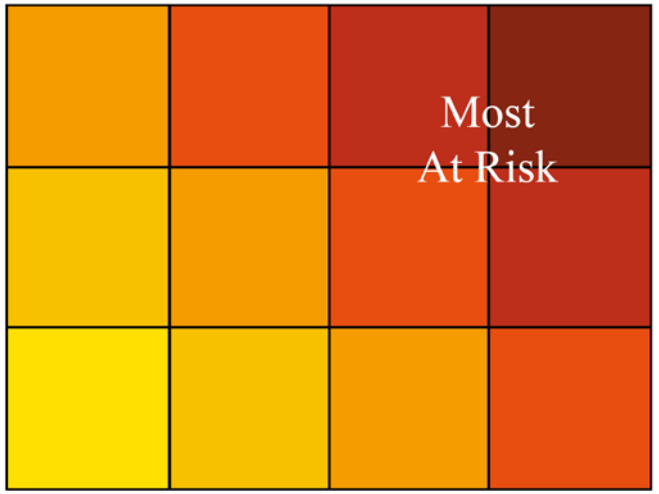
Overview of Approach

Step 1

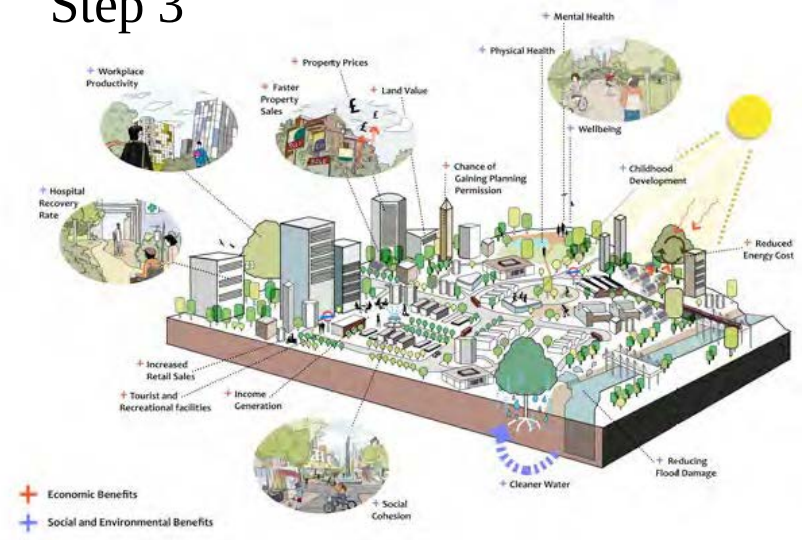
Establishing a climate baseline

Step 2



Ranking risk

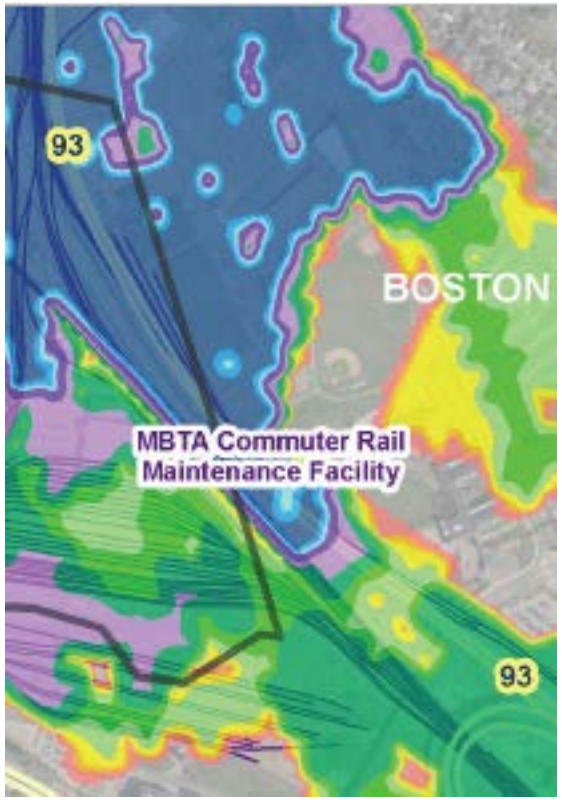
Step 3



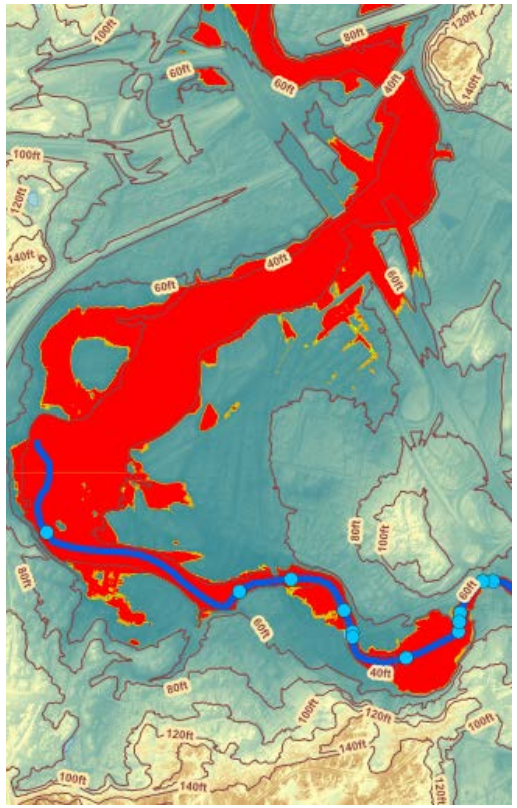
Developing solutions

Climate Baseline

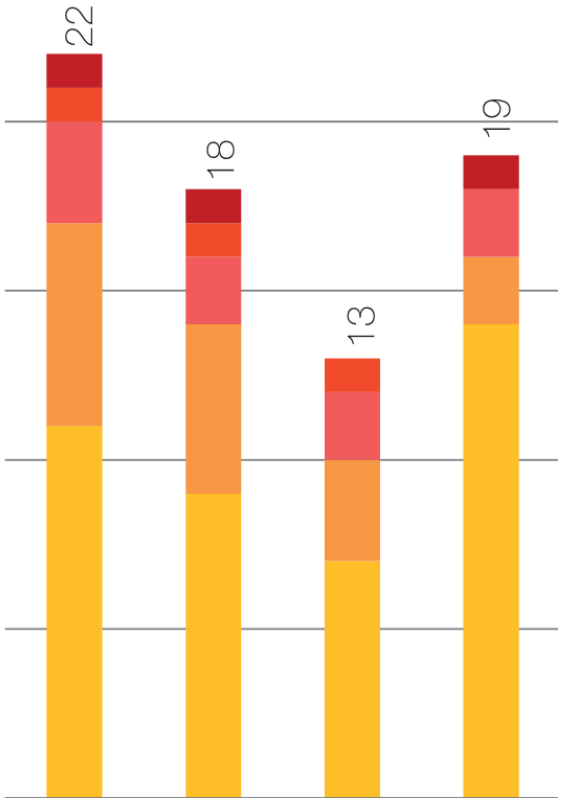
SLR & storm surge



Precipitation



Temperature



2015

2030

2050

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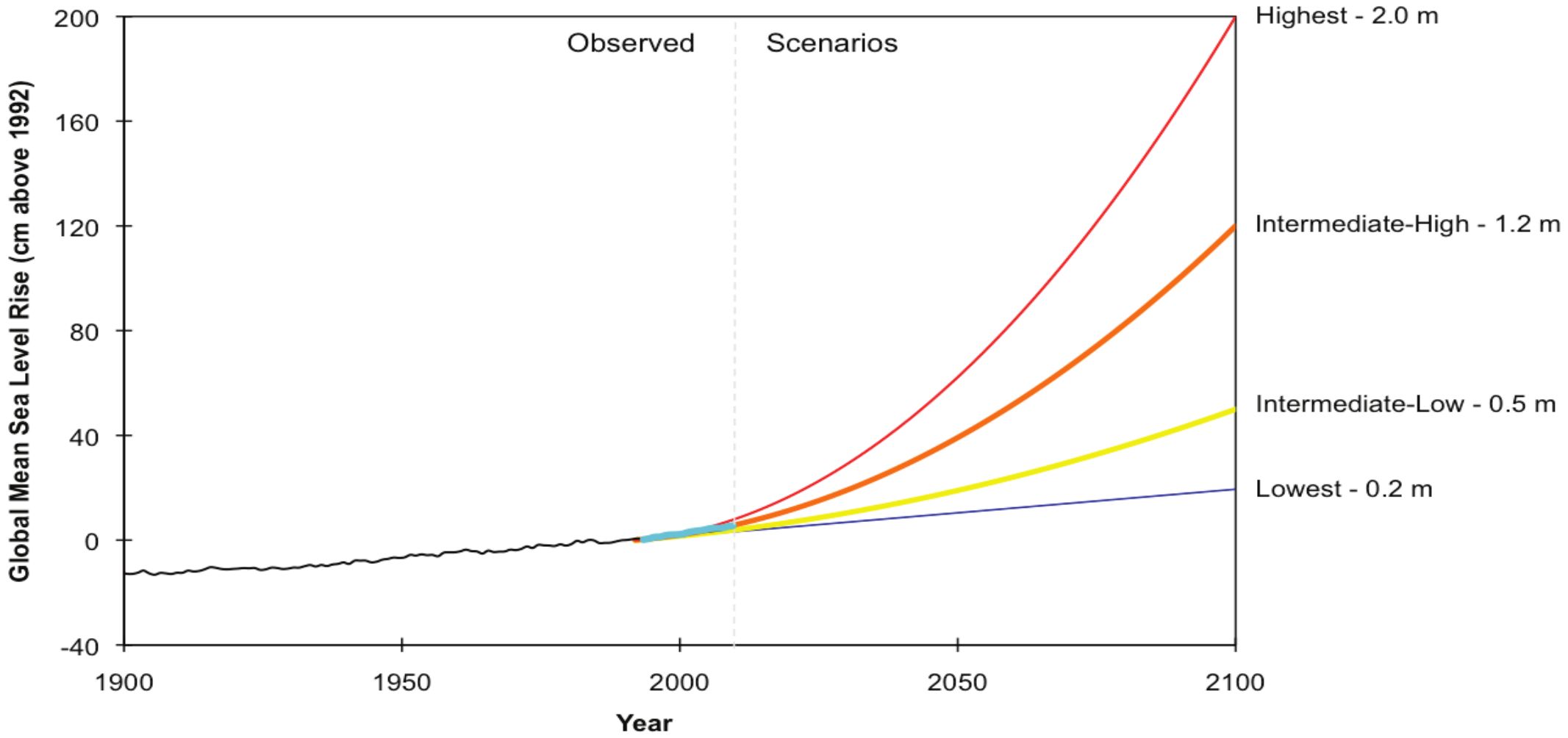
Determining the Sea Level Rise elevations



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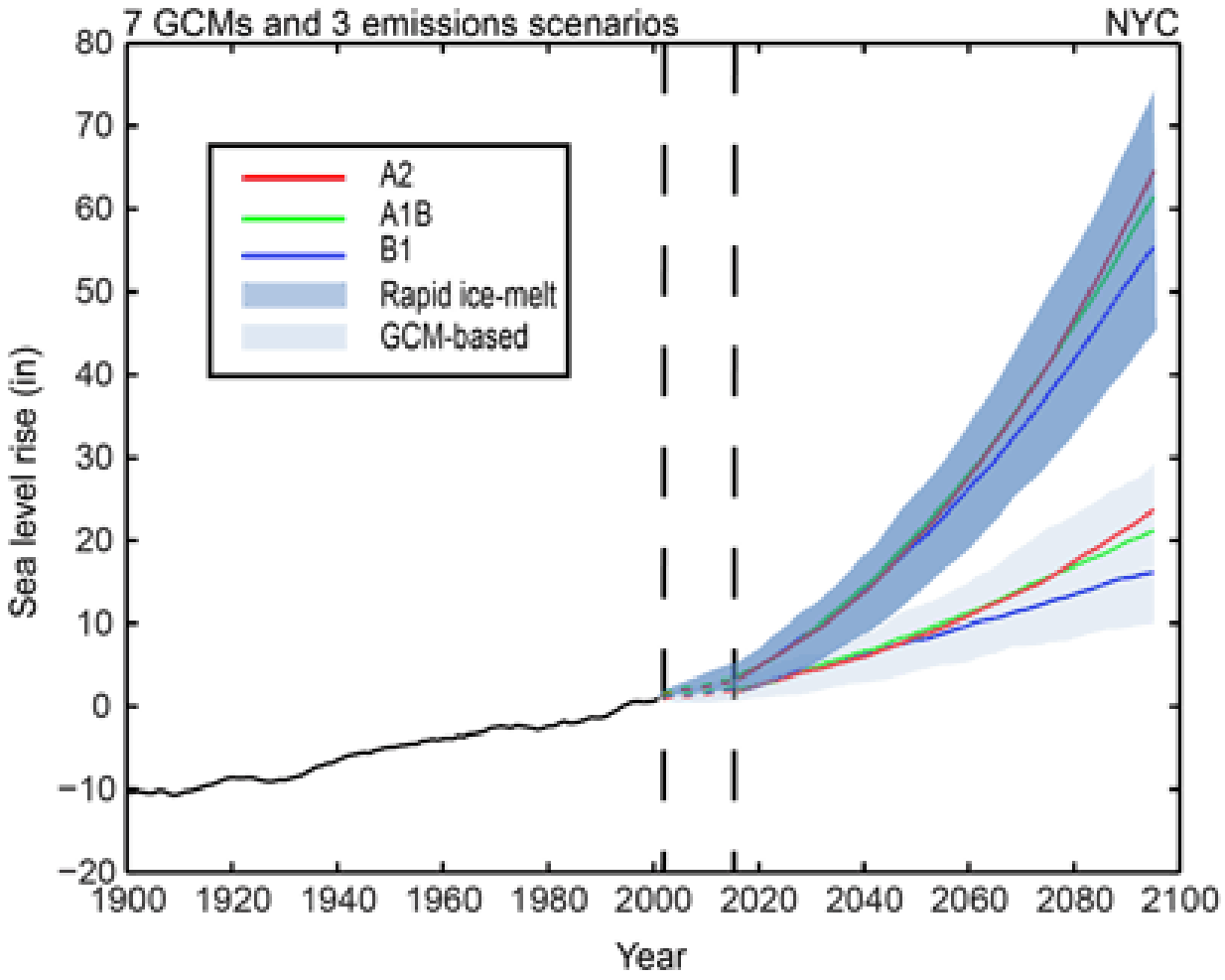
GCM projections may underestimate accelerated ice sheet melting



From: NASA: http://www.giss.nasa.gov/research/briefs/rosenzweig_03/

Sea level rise is happening 3 x faster on the East Coast than the global average

Nature Climate, 2012

Sandy-like events may become more like the 1 in 20 yr event vs. the 1 in 1000 yr event

Proceedings, National Academy of Sciences, 2016

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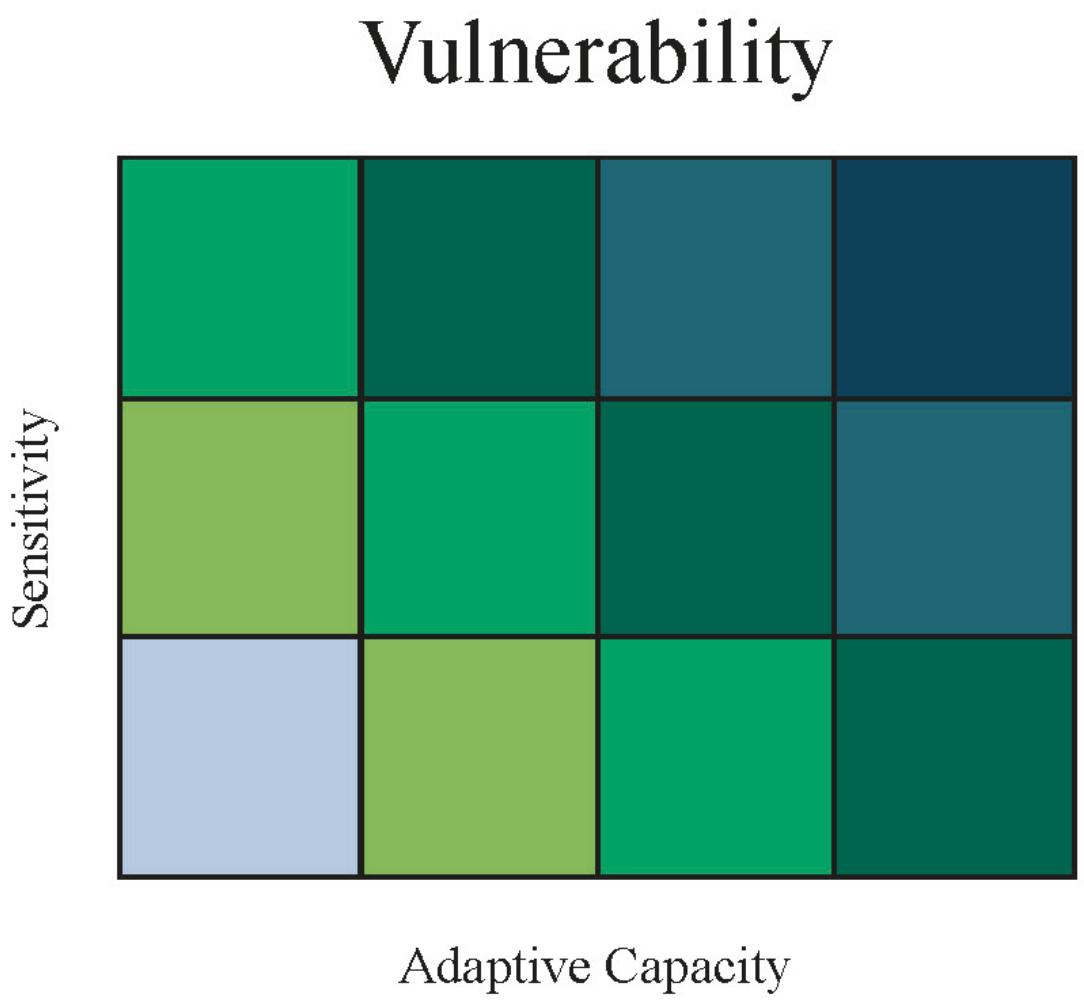
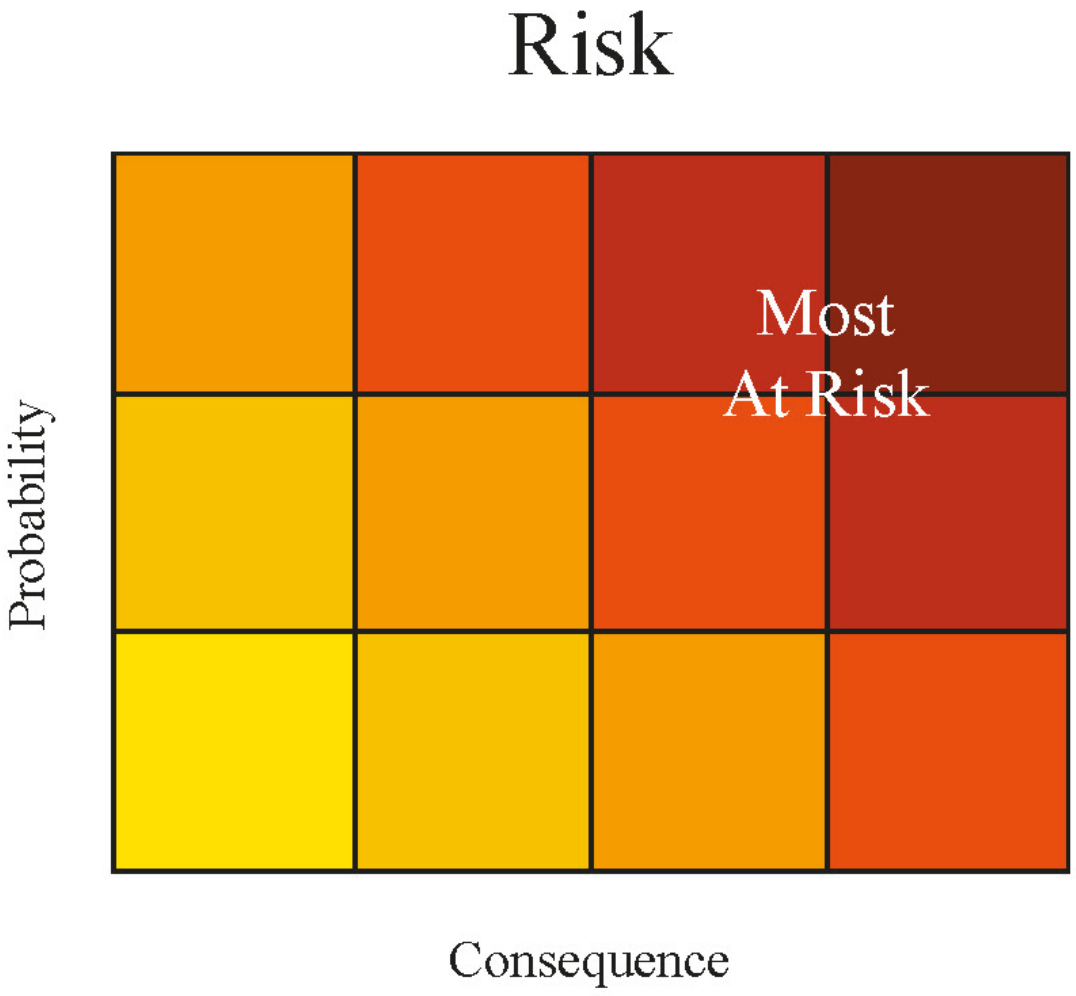
Prioritizing the Risk





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Translating Risk into Resilient Solutions

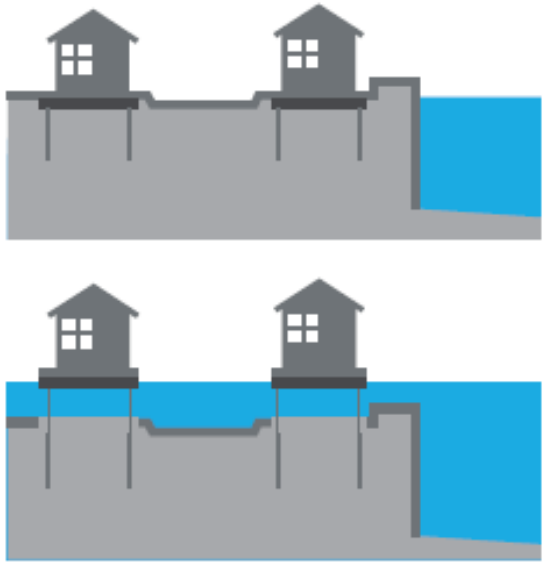
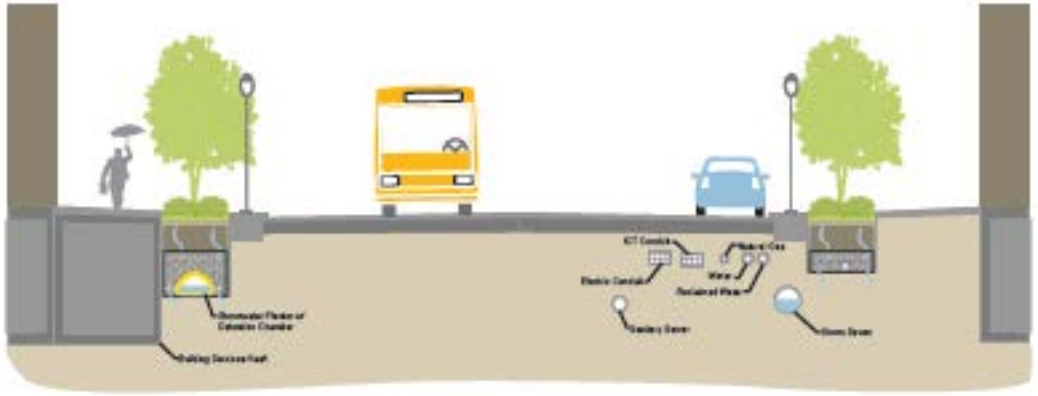


Illustration of buoyant architecture (source: Arup)



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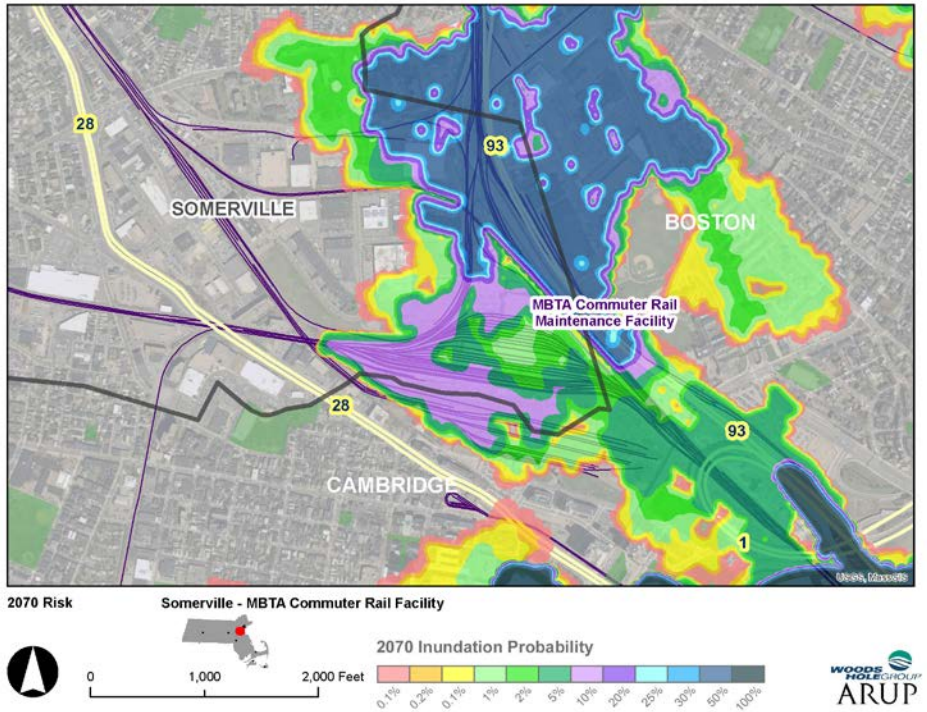
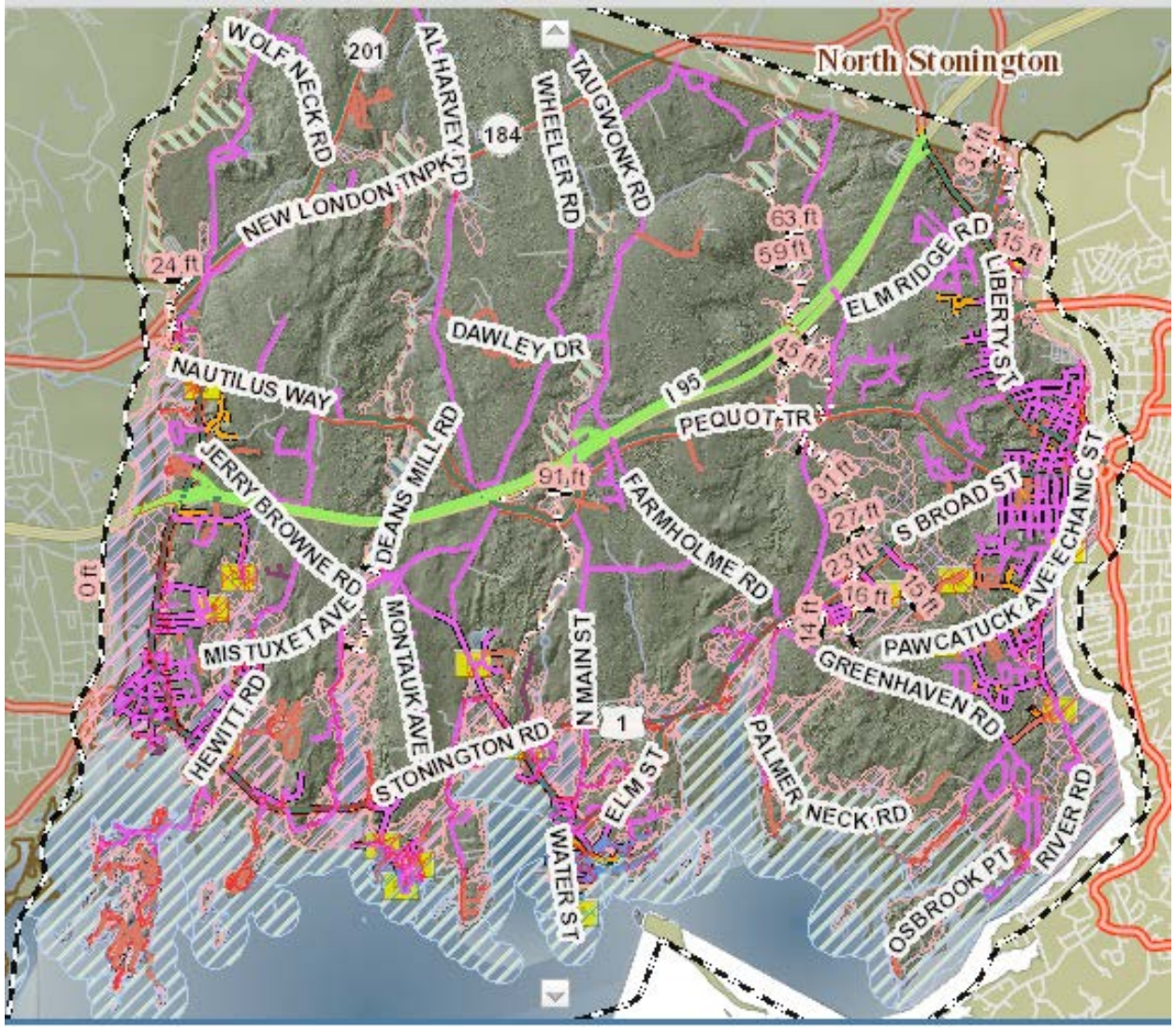
Task 1 – Data Gathering

Deliverables:

Draft and Final Technical Memo on resilience information.

GIS shape files of readily-available layers to form the basemap for subsequent analyses



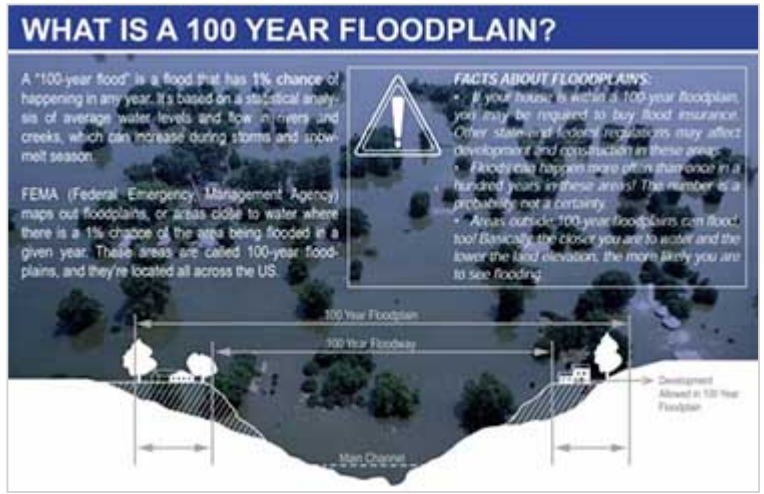


Task 2 – Public Input

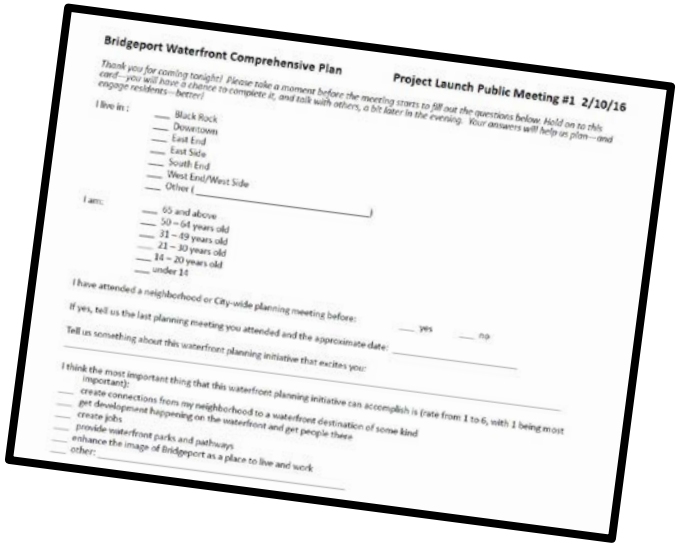
Six onsite meetings	Arup	Civic Moxie	WHG	TDA
1 kick off meeting	1	1	1	1
3 public meetings	3	3	1	
2 meetings with other boards	2	1	1	
Total meetings attended	6	5	3	1

- Promotional Flyers
- Information sheets
- Presentations
- Summary of meetings and public feedback
- Participant data (demographics, interests, etc.)

Clear summaries of outcomes and next steps – to keep the project moving



Information sheets to educate public -- to generate constructive discussions



Bridgeport Waterfront Comprehensive Plan

Project Launch Public Meeting #1 2/10/16

Thank you for coming tonight! Please take a moment before the meeting starts to fill out the questions below. Hold on to this card—you will have a chance to complete it, and talk with others, a bit later in the evening. Your answers will help us plan—and engage residents—better!

I live in :
___ Black Rock
___ Downtown
___ East End
___ East Side
___ South End
___ West End/West Side
___ Other (_____)

I am:
___ 65 and above
___ 50 – 64 years old
___ 31 – 49 years old
___ 21 – 30 years old
___ 14 – 20 years old
___ under 14

I have attended a neighborhood or City-wide planning meeting before: ___ yes ___ no

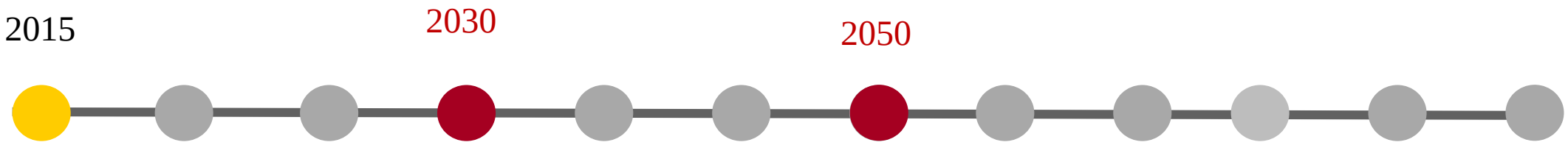
If yes, tell us the last planning meeting you attended and the approximate date: _____

Tell us something about this waterfront planning initiative that excites you: _____

I think the most important thing that this waterfront planning initiative can accomplish is (rate from 1 to 6, with 1 being most important):
___ create connections from my neighborhood to a waterfront destination of some kind
___ get developement happening on the waterfront and get people there
___ create jobs
___ provide waterfront parks and pathways
___ enhance the image of Bridgeport as a place to live and work
___ other: _____

Participant info and feedback surveys at every meeting – to provide data

Task 3 – Risk Assessment

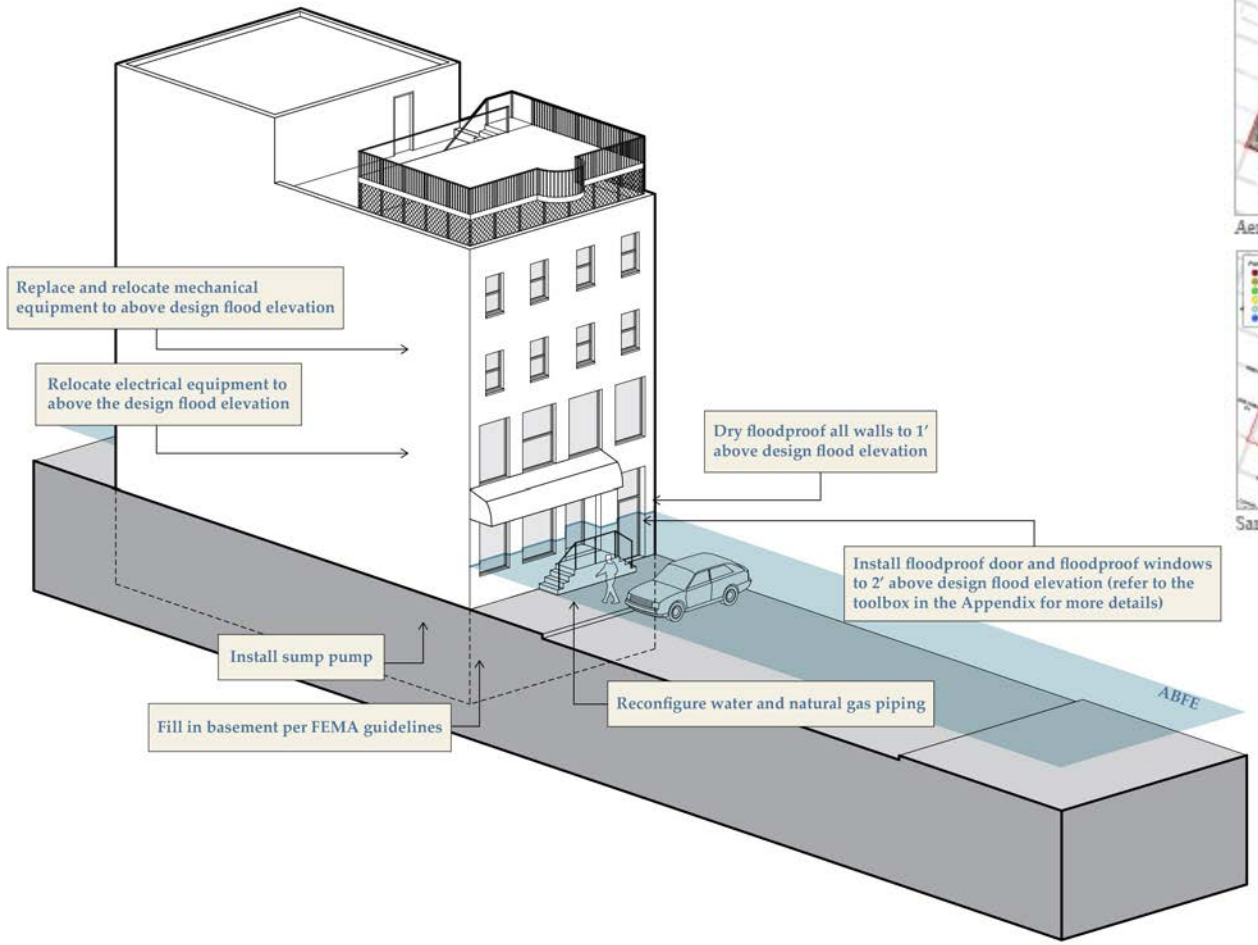


Deliverables

-Draft and Final Technical Memoranda
-Planning Horizon criteria
-Methodology and sources used to develop inundation
-GIS maps and shape files showing extent of flooding
-Levels of inundation at up to 25 assets for each scenario

		2013	2030		2070	
Exceedence Probability %	Design Year (yr)	Water Depth (ft)	Water depth per ground elevation (ft)	Water depth per lobby elevation (ft)	Water depth per ground elevation (ft)	Water dept per lobby elevation (ft)
0.1	1000	dry	dry	dry	dry	dry
0.2	500	dry	dry	dry	dry	dry
0.5	250	dry	dry	dry	dry	dry
1	100	dry	dry	dry	dry	dry
2	50	dry	dry	dry	dry	dry
5	20	dry	dry	dry	dry	dry
10	10	dry	dry	dry	dry	dry
20	5	dry	dry	dry	dry	dry
25	4	dry	dry	dry	dry	dry
30	3	dry	dry	dry	dry	dry
50	2	dry	dry	dry	dry	dry
100	1	dry	dry	dry	dry	dry

Task 4 - Recommended Resilience Solutions




Aerial


Ground Water


FEMA FIRM


Sandy Impacts


Heat Island


Prioritization

UMASS BOSTON - Coastal Climate Change Adaptation Planning	Vulnerable Flood Risk Areas		
	Morrissey Blvd. Entrance	Bayside Expo Center	Mt. Vernon Street
General Description	The Morrissey Blvd. Entrance is currently the primary entrance to the UMASS-Boston campus. A significant portion of this street, especially south of the campus entrance, is low-lying and is prone to flooding even under present day conditions (storm surge or heavy rainfall events). Once the water surface elevation overtops higher elevations along the coastline, most of Morrissey Blvd. will become flooded. At the campus entrance specifically, as shown in the aerial view, storm surge flooding initially may occur from the Patten's Cove side and subsequently the Savin Hill Cove side when water surface elevations reach between approximately 9.5-10.0 feet NAVD88.	The Bayside Expo center region, recently purchased by UMASS-Boston, is slated to undergo redevelopment. Currently, the area is prone to potential flooding, especially the low-lying parking lot regions (one of the lowest elevations in the region). It is likely that there is potential for poor drainage and flooding of this area (approximately 30 acres) even during contemporary rainfall storm events. As sea level increases, there are also lower areas along the Dorchester Bay shoreline that will become susceptible to the higher water surface elevations during storm events, resulting in significant overtopping and widespread flooding of the area. Specifically, areas along the Harbor walk area shown in the aerial view.	The southeastern end of Mt. Vernon Street is under consideration as a potential location for a secondary entrance to the UMASS-BOSTON campus. This areas currently experiences storm water drainage delays and issues. The current storm water drain lines from this area discharge into Dorchester Bay with an invert elevation at approximately Mean Higher High Water. As sea level rises, this will further impede storm water drainage ability from this region. There is also some susceptible low lying areas to the east of the Mt. Vernon Street terminus, as shown in the aerial below. Potential upland flooding may occur along some lower elevation access points in this region.
			

Mean Higher High Water (MHHW) Timeline: 2010, 2050, 2100

Annual (1-year) Storm Surge Timeline: 2010, 2050, 2100

100-year Storm Surge Timeline: 2010, 2050, 2100

Approximate Maximum Water Surface Elevation (ft, NAVD88): 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0

Morrissey Blvd. Entrance			Bayside Expo Center			Mt. Vernon Street		
Upland Flooding Potential	Recommended Engineering Adaptations	Estimated Adaptation Cost*	Upland Flooding Potential	Recommended Engineering Adaptations	Estimated Adaptation Cost*	Upland Flooding Potential	Recommended Engineering Adaptations	Estimated Adaptation Cost*
No Flooding Expected	No Action Required	N/A	Poor Drainage of Bayside Expo Parking areas during heavy rainfall events. No Flooding of areas from Dorchester Bay waters.	Minor flood proofing of structures Installation of a pump house and pumped based-drainage system for parking area+	Capital Cost: $ 2.0 Million Annual Maintenance Costs: $ 10,000	No Flooding Expected	No Action Required	N/A
Flooding of Morrissey Blvd. approximately 1/4 mile south of campus entrance. No flooding of campus entrance or campus facilities						Area has experienced poor storm water drainage. Storm water outfall at 2010 MHHW elevation may not adequately drain in future	Improve storm water removal and drainage lines. Modify storm water outfall or add pump house.	Capital Cost: $ 250,000 Annual Maintenance Costs: $ 2,000
Flooding of campus entrance. Initially from Patten's Cove (tidal pond to the west of entrance), and subsequently from Savin Hill Cove.	Tidal control structure installation at entrance to Patten's Cove. Soft solution (beach nourishment and vegetation enhancement) along Savin Hill Cove.	Capital Cost: $500-750,000 Annual Maintenance Costs: $10,000	Flooding of Bayside Expo areas from Dorchester Bay. Water overtops harbor walk in places.	Modular seawall installation at critical locations along Harbor walk Seawall extension along Harbor walk as needed	Capital Cost#: $1.0-1.5 million (1,000 foot length) Annual Maintenance Costs: $15,000	Flooding from Dorchester Bay via low-lying pathways to the east of Mt. Vernon Street	Provide clean fill in low lying areas or increase storm damage protection through targeted soft coastal engineering solutions	Capital: $300-500,000 Annual Maintenance: $5,000
Widespread flooding of UMASS Boston Campus, Morrisey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing	Widespread flooding of UMASS Boston Campus, Morrisey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing	Widespread flooding of UMASS Boston Campus, Morrisey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing

* - Initial Capital Costs and Operational and Maintenance costs provided are estimates based on costs from similar types of projects. More detailed and accurate costs would be required for actual engineering and construction. Estimated costs are based on 2010 dollar value.

- Depends on length of seawall installed.

+ - Based on a 30 acre area with a peak intensity rainfall of 5 in/hr (average of 0.3 inches/hr over a 24 hour period)

High-level, Engineering solutions

ARUP

Task 5 - Draft and Final Coastal Resilience Plan

- Draft plan presented to public
- Input captured in the subsequent rewrite
- High-level summary of comments
- Public session will be held to present the final Coastal Resilience Plan

Project Team

Lisa Dickson
Arup

Project Manager

Kirk Bosma
Woods Hole Group

Coastal Engineer

Susan Silberberg
Civic Moxie

Stakeholder Engagement

Madeline Fraser Cook
TDA

CDBG Compliance

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Sea Level Rise and Storm Surge Modeling

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Climate Change Flooding

FEMA Maps

- **FEMA is only backward looking**
- **Only considers “100-year” storm**
- **Transect based analysis**

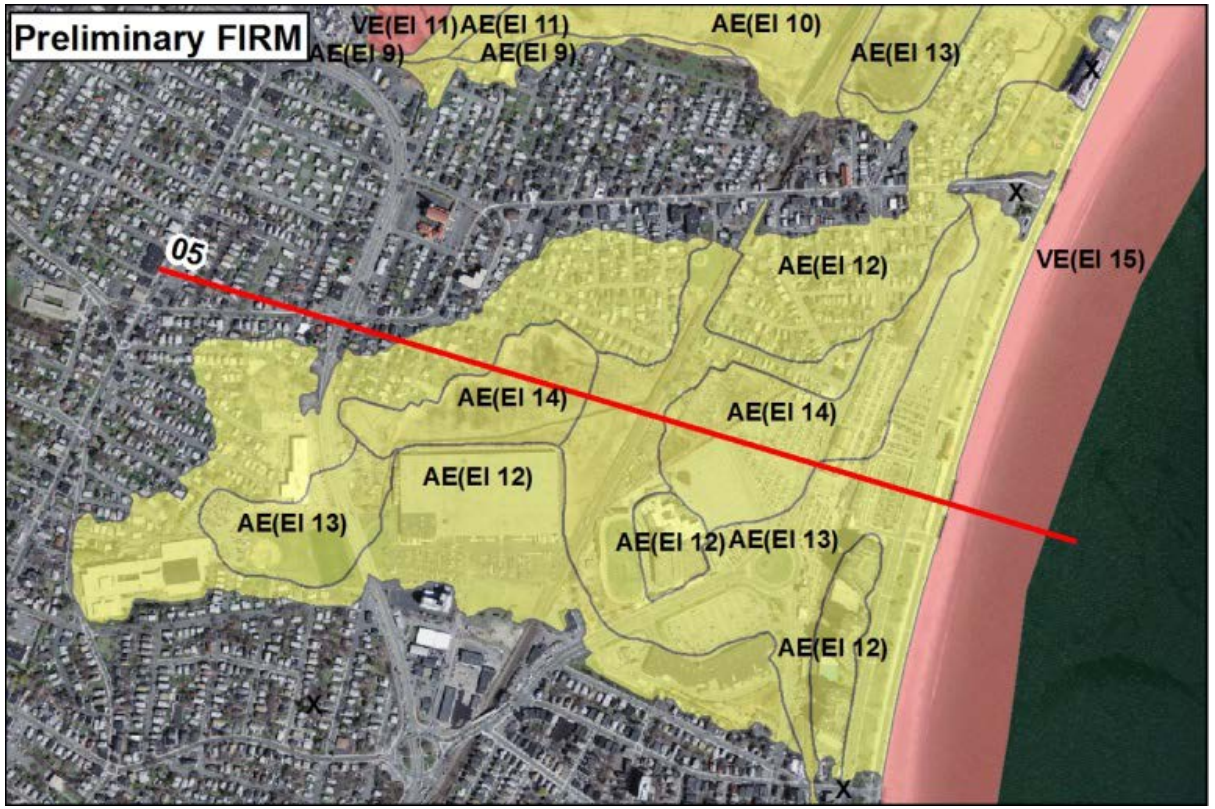
Bathtub Approach

- **Inundation maps do not reflect dynamic nature of coastal flooding**
- **Does not account for joint flooding conditions**
- **Does not account for tides**

Hurricane Evacuation Maps

- **Worst possible scenario for emergency planning (worst storm at MHW)…no associated risk planning**
- **Coarse modeling domain results in local inaccuracies**
- **Does not include impacts of waves**
- **Just hurricanes**

1. What is the probability of flooding?
2. What is vulnerable and what is the priority?
3. What interventions are available and what is the plan?



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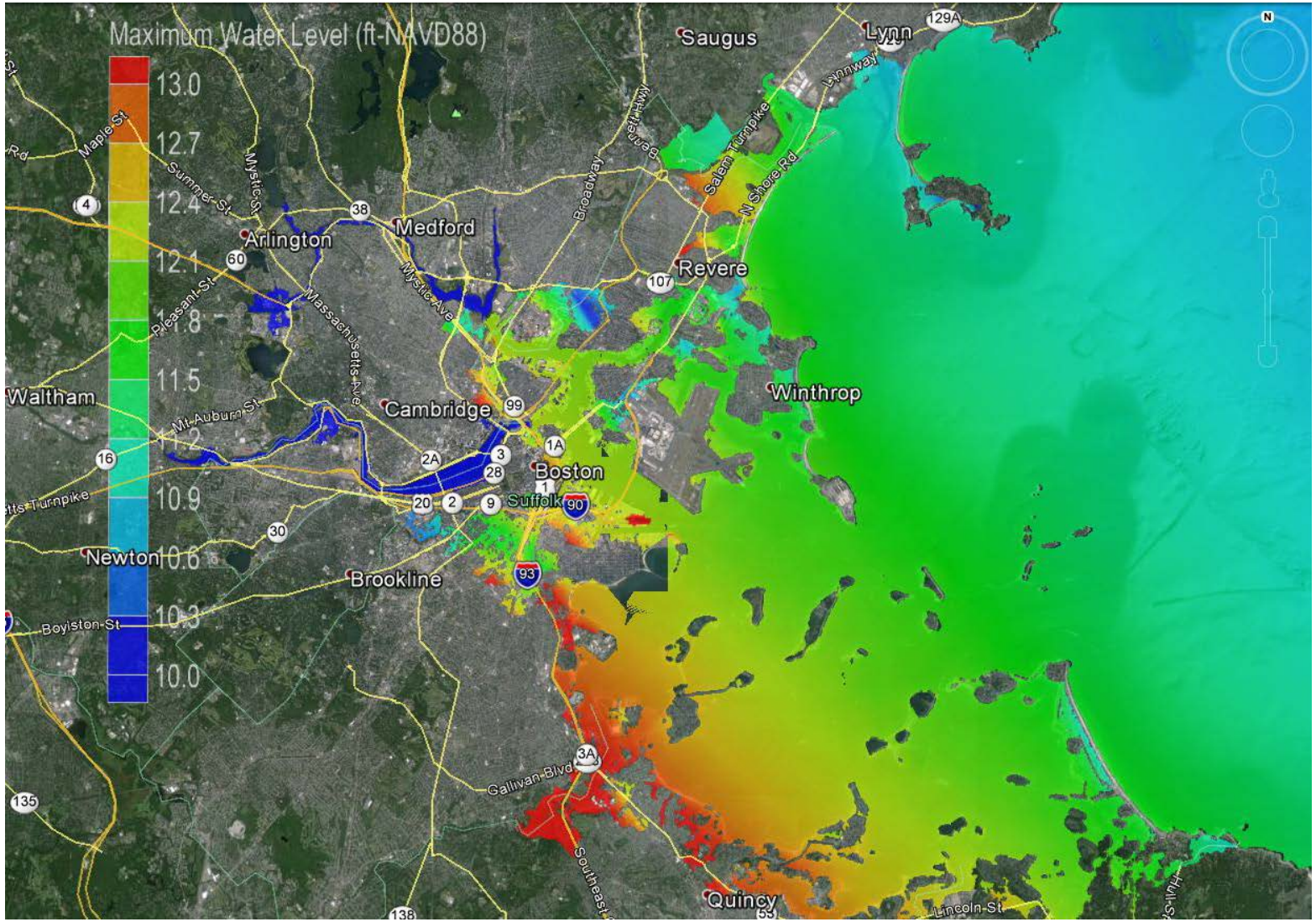
Sea Level Rise and Storm Surge



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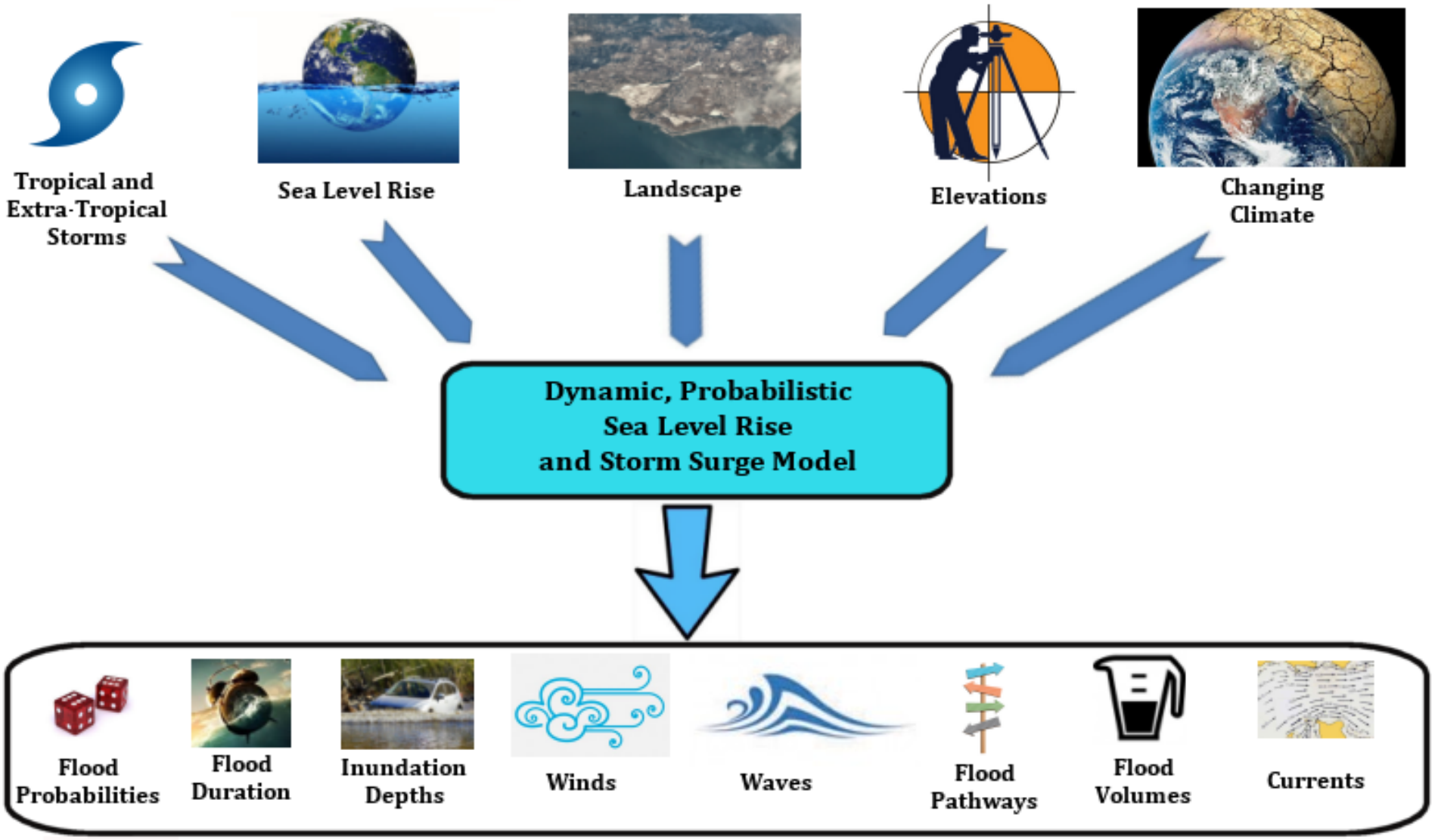
Dynamic Modeling



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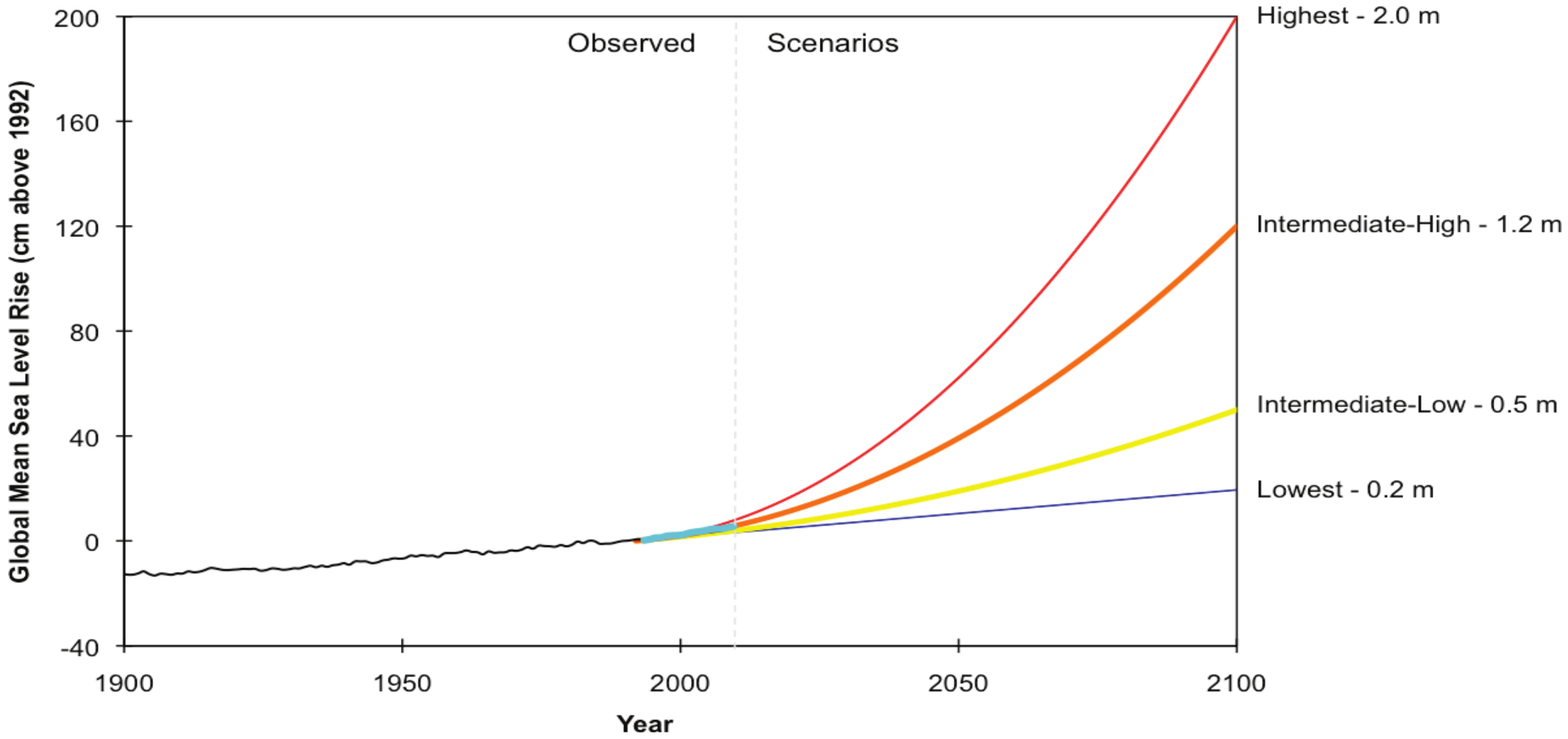
Determining the Sea Level Rise elevations



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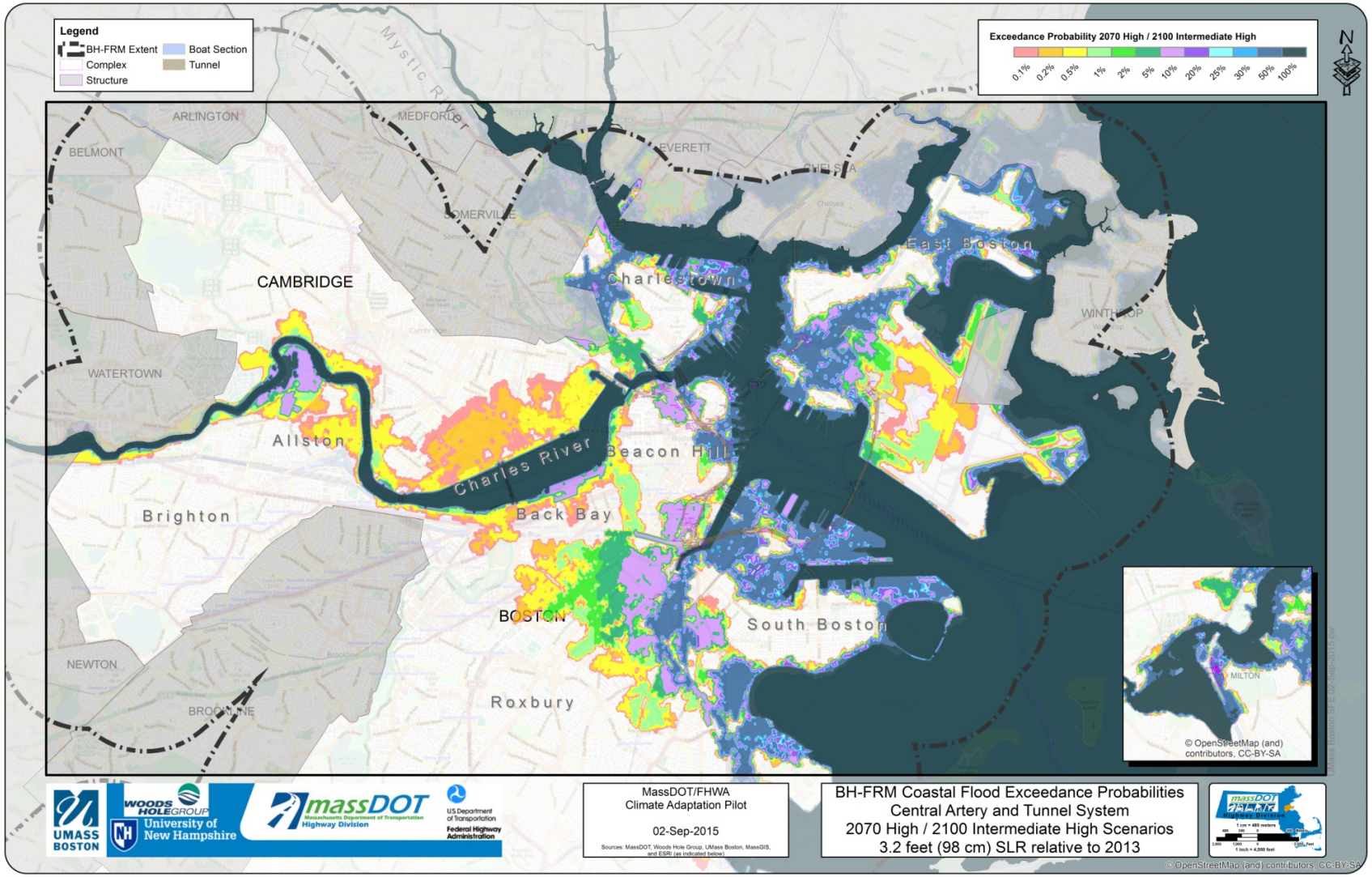
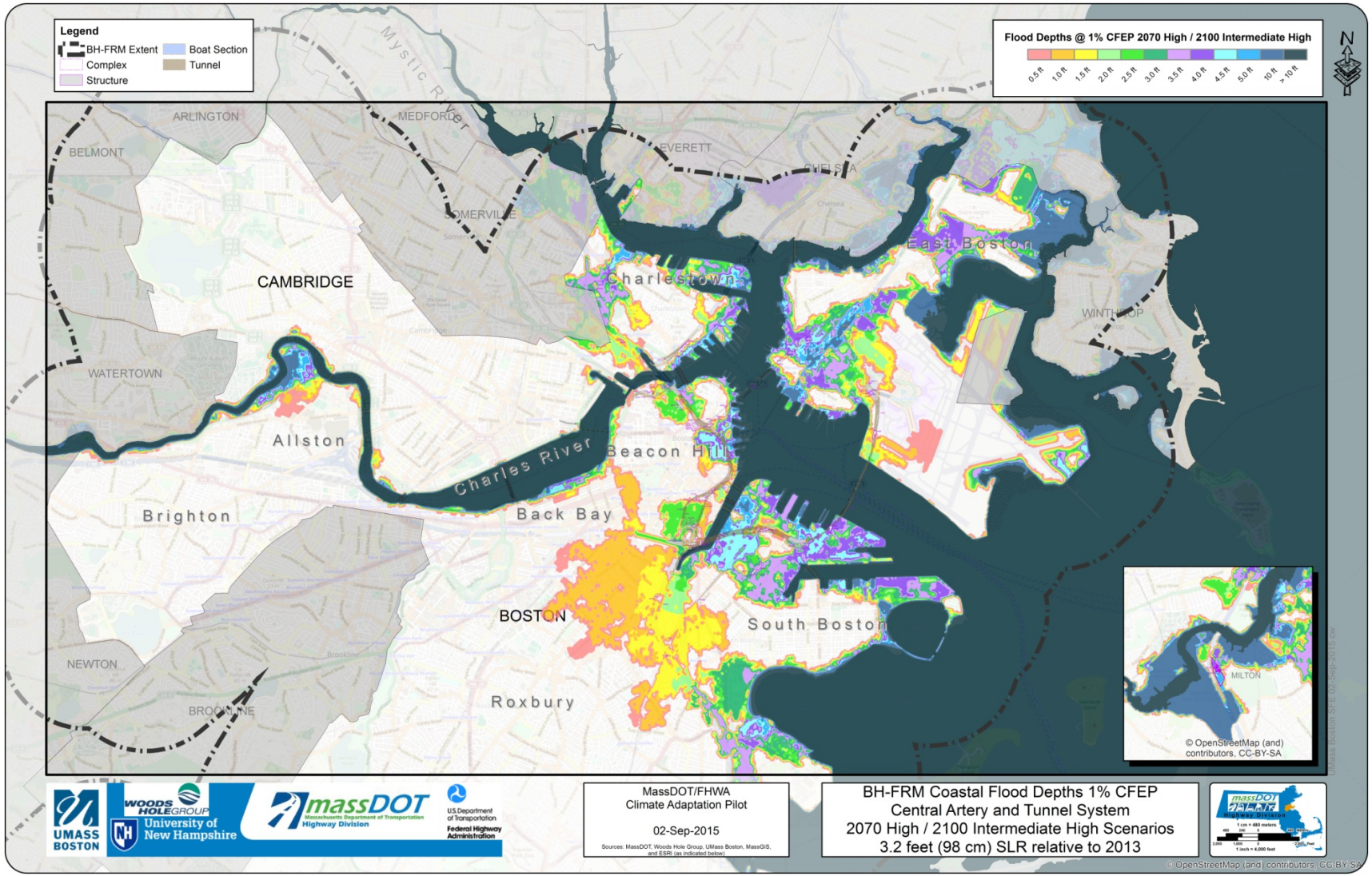
Probabilistic Mapping



ARUP

Probabilistic Mapping



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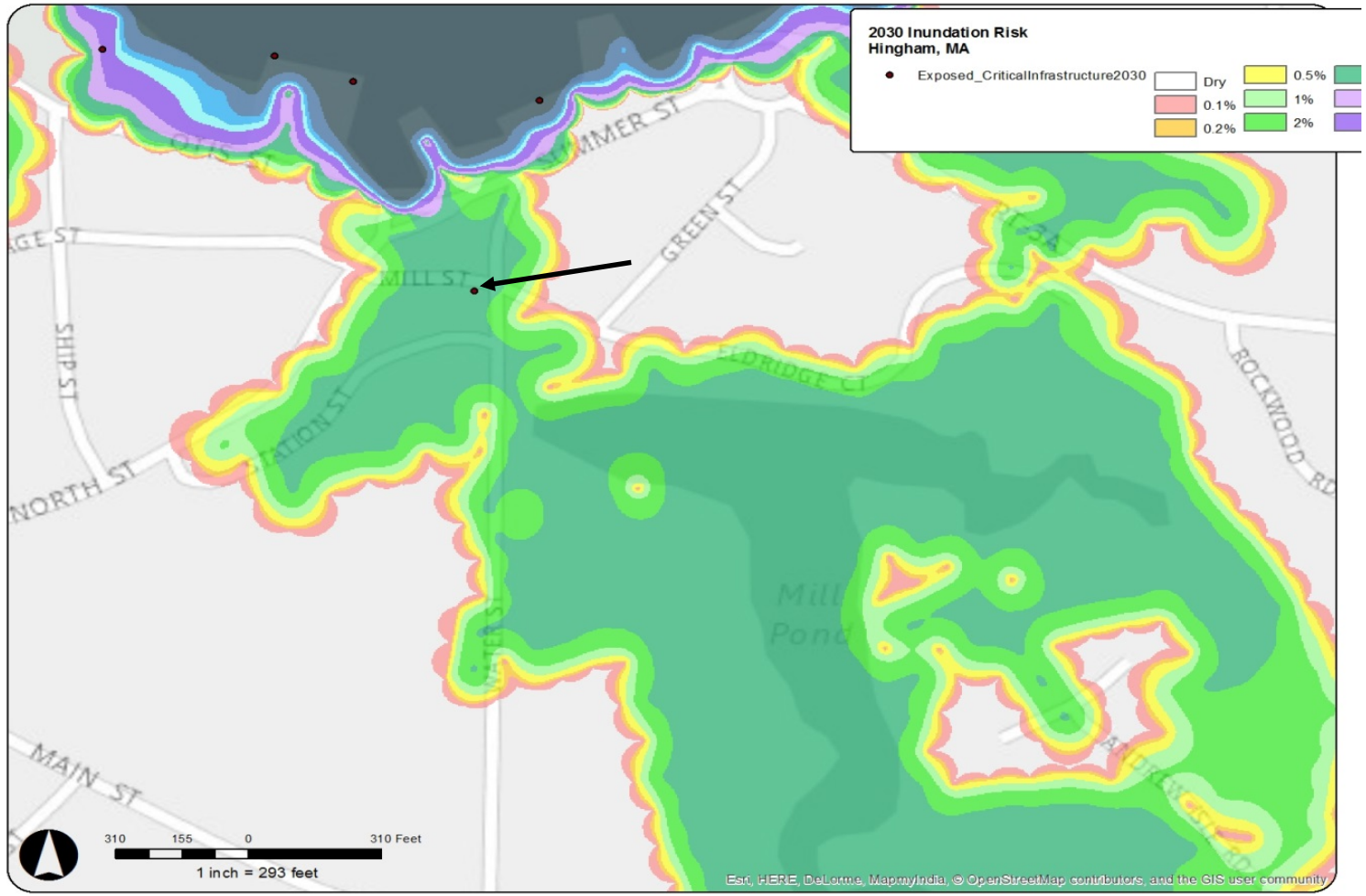
Local Engineering Assessment



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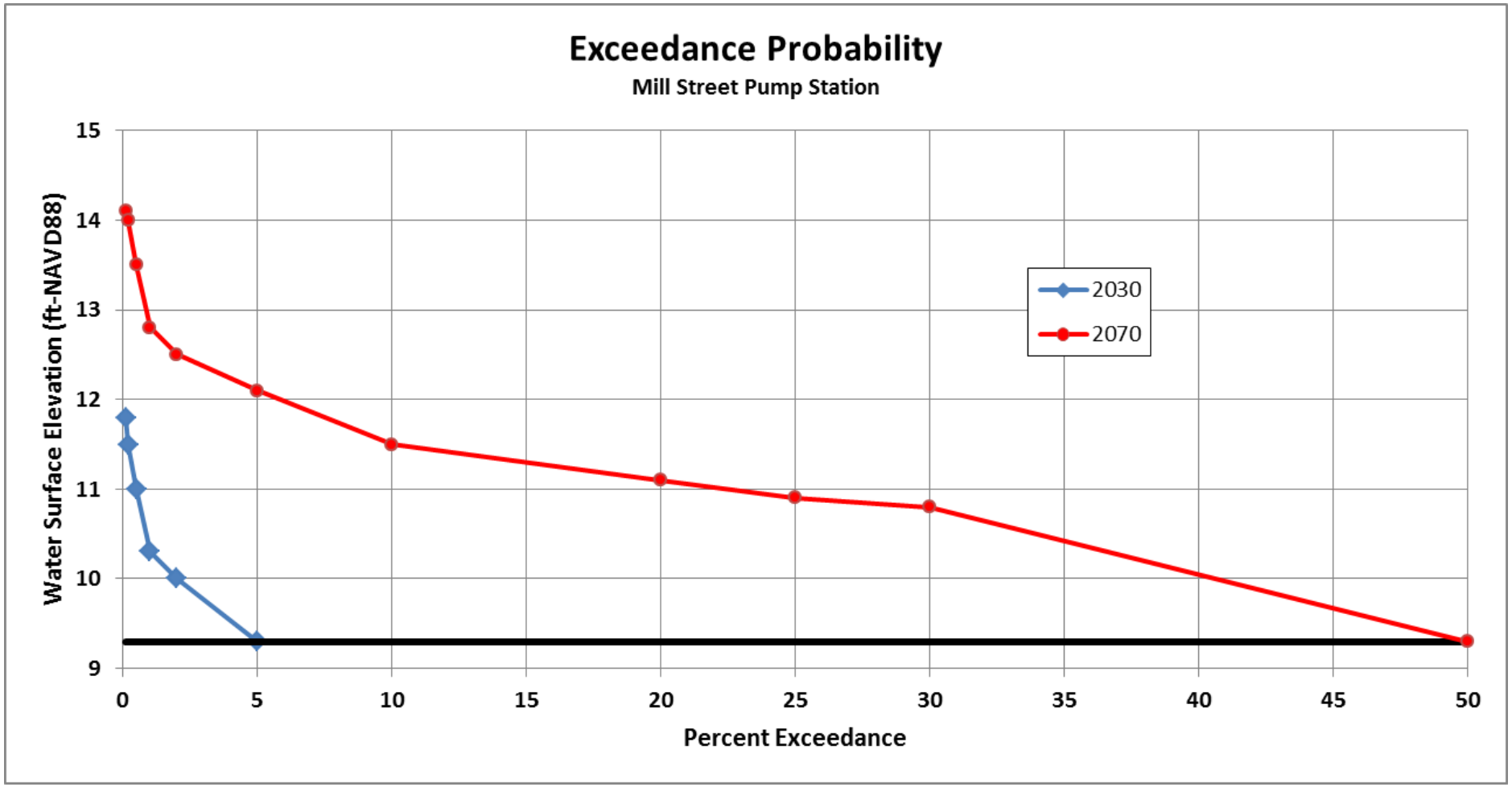

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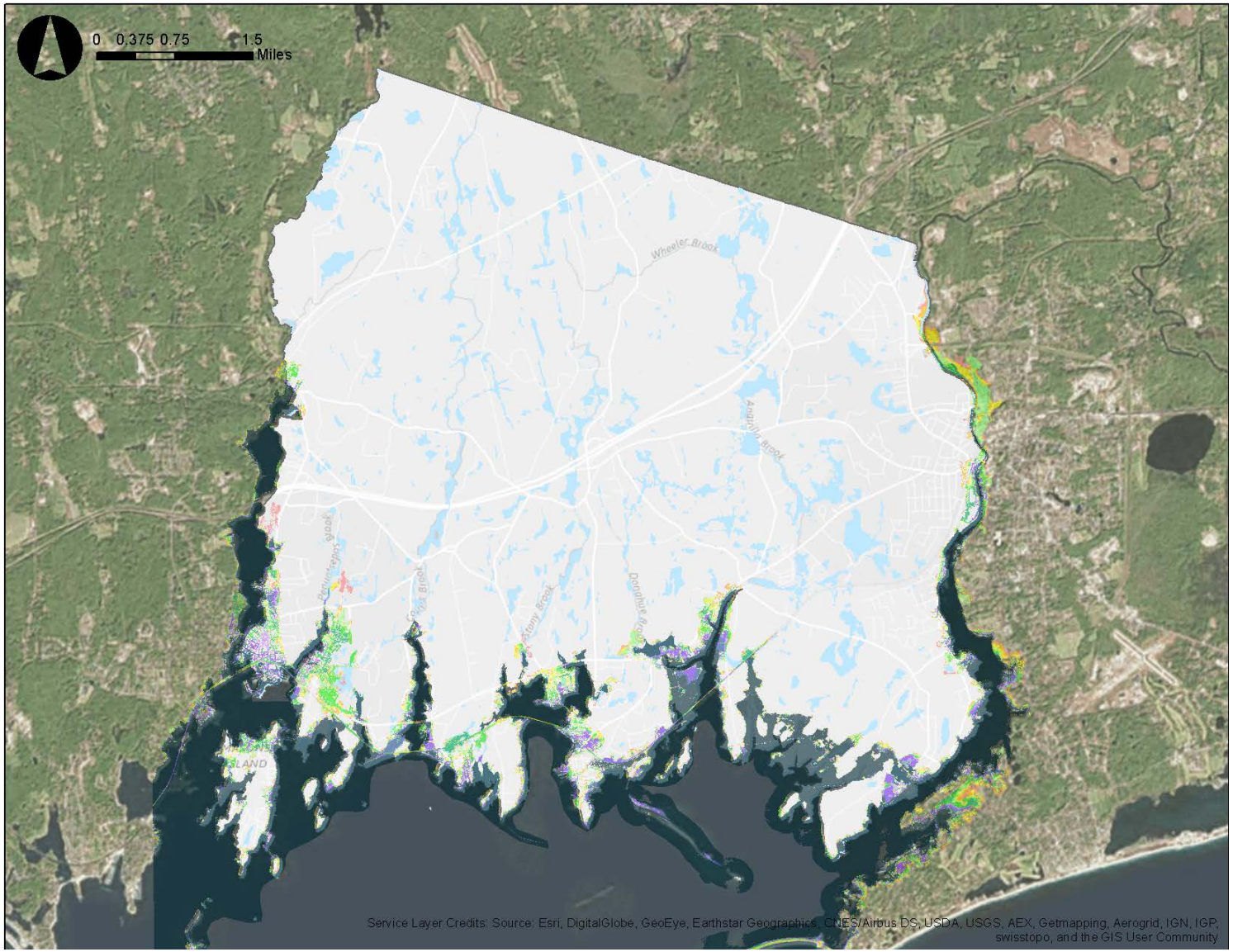
Stonington – 2030 Probability



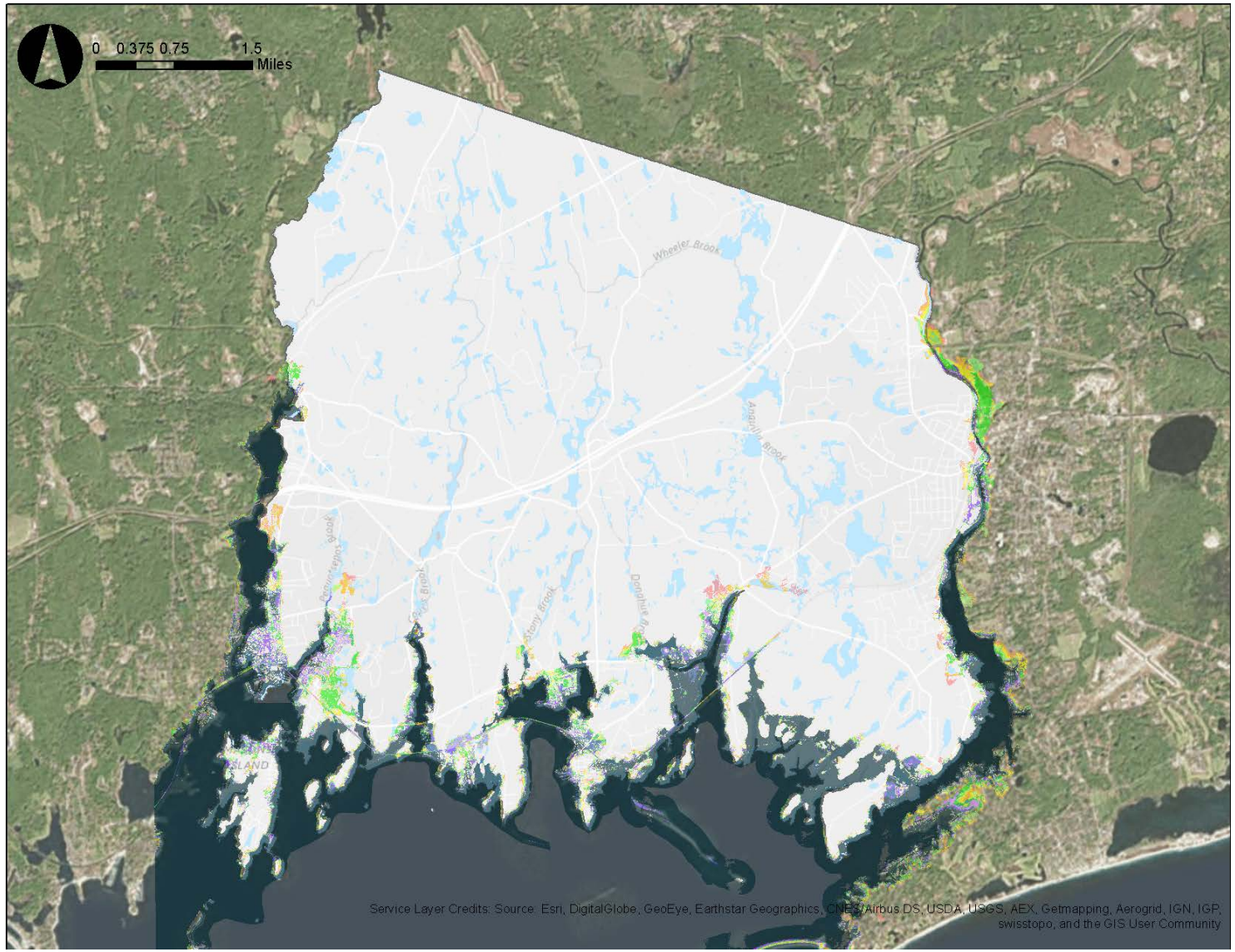
Legend

% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

ARUP

Stonington – 2050 Probability



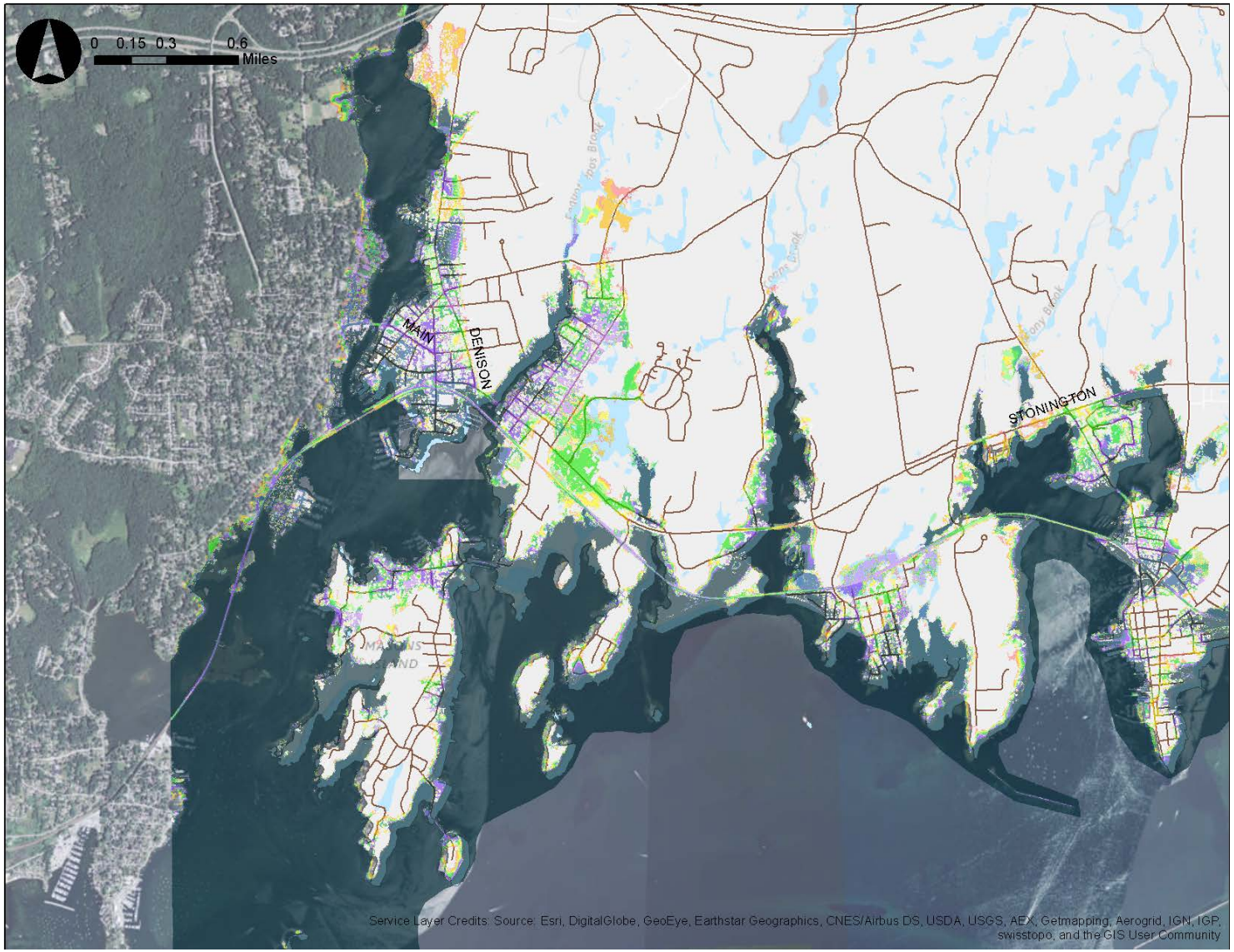
Legend

% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

ARUP

2050 Flooding Probability - Mystic Area



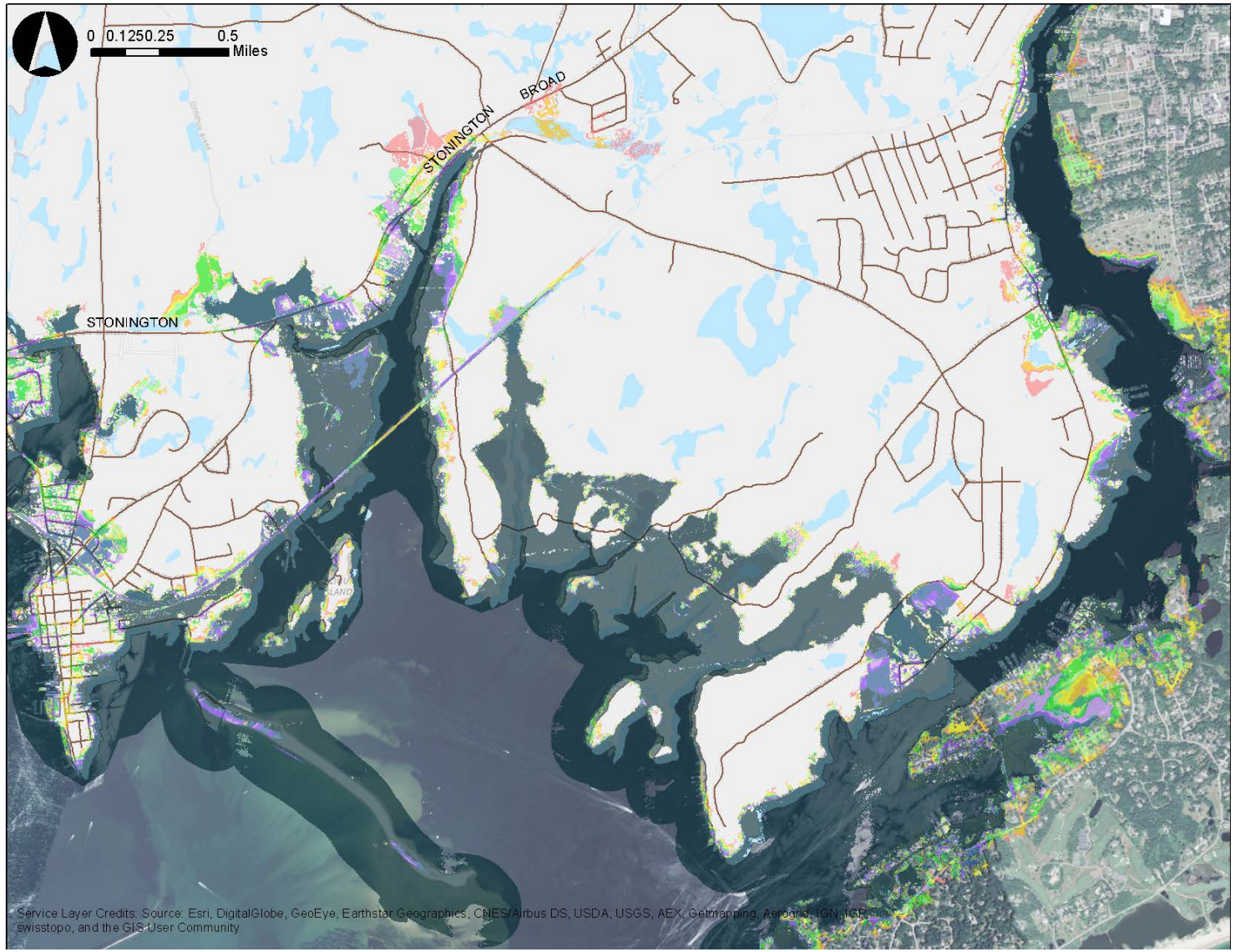
Legend

% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

ARUP

2050 Flooding Probability – Lower Pawcatuck Area



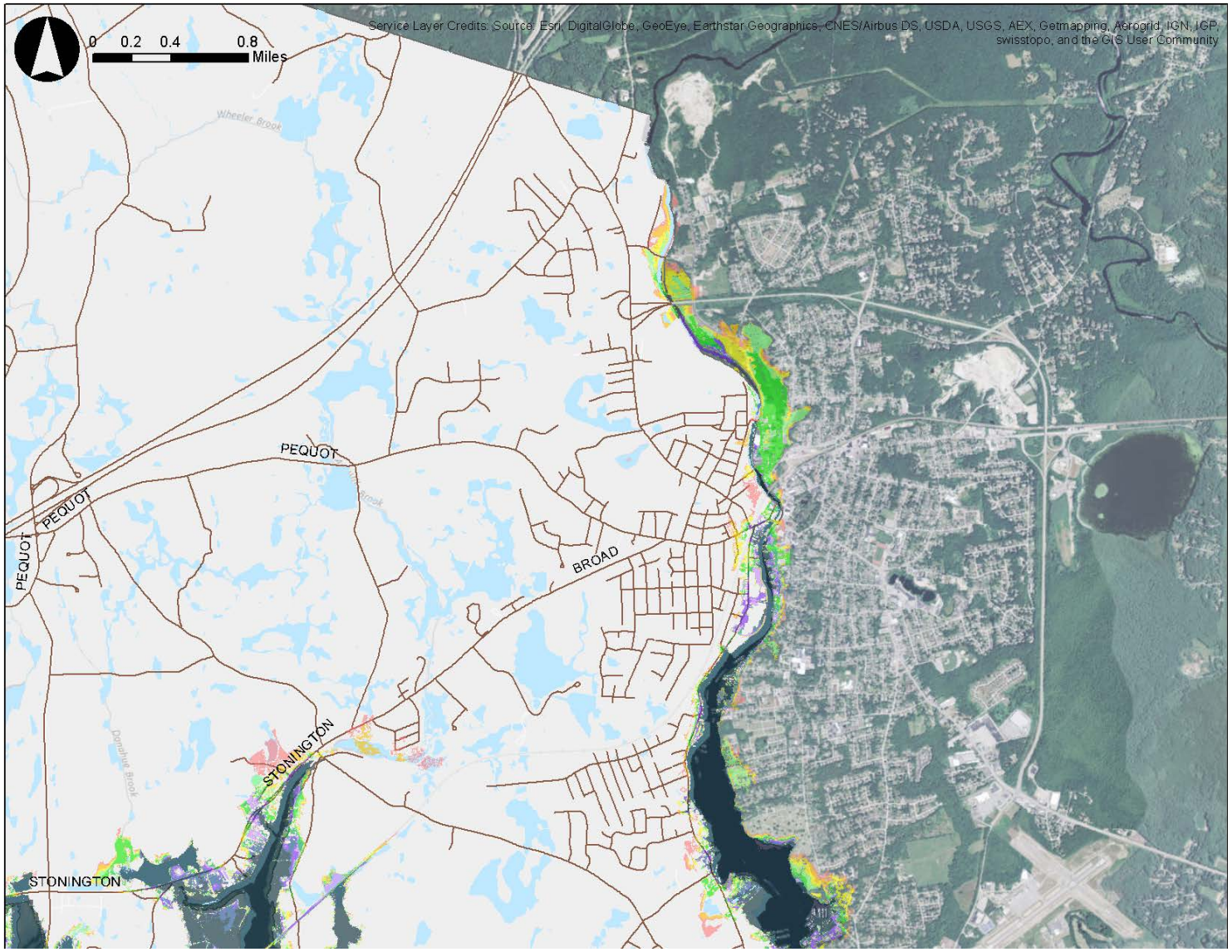
Legend

% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

ARUP

2050 Flooding Probability – Upper Pawcatuck Area



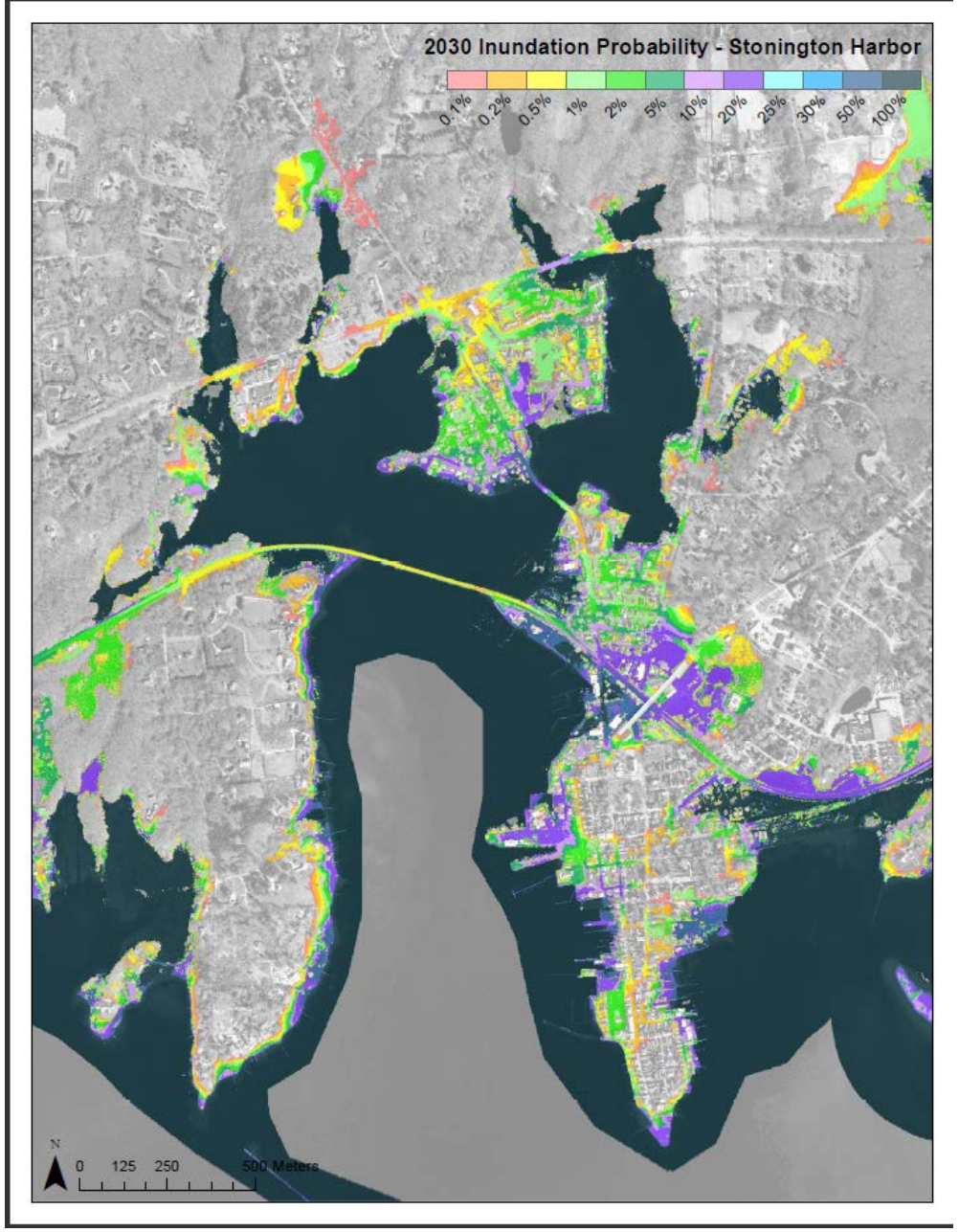
Legend

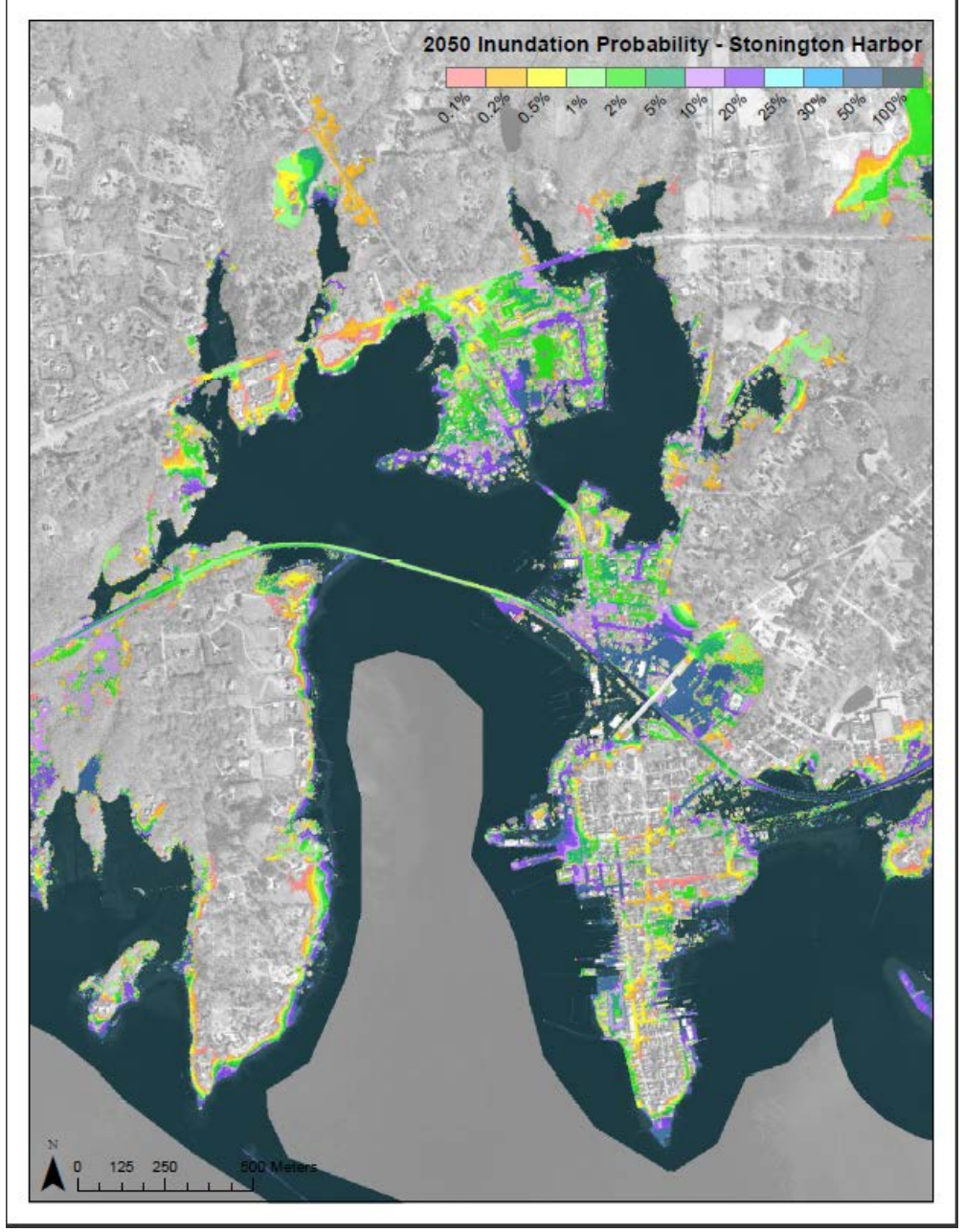
% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

ARUP

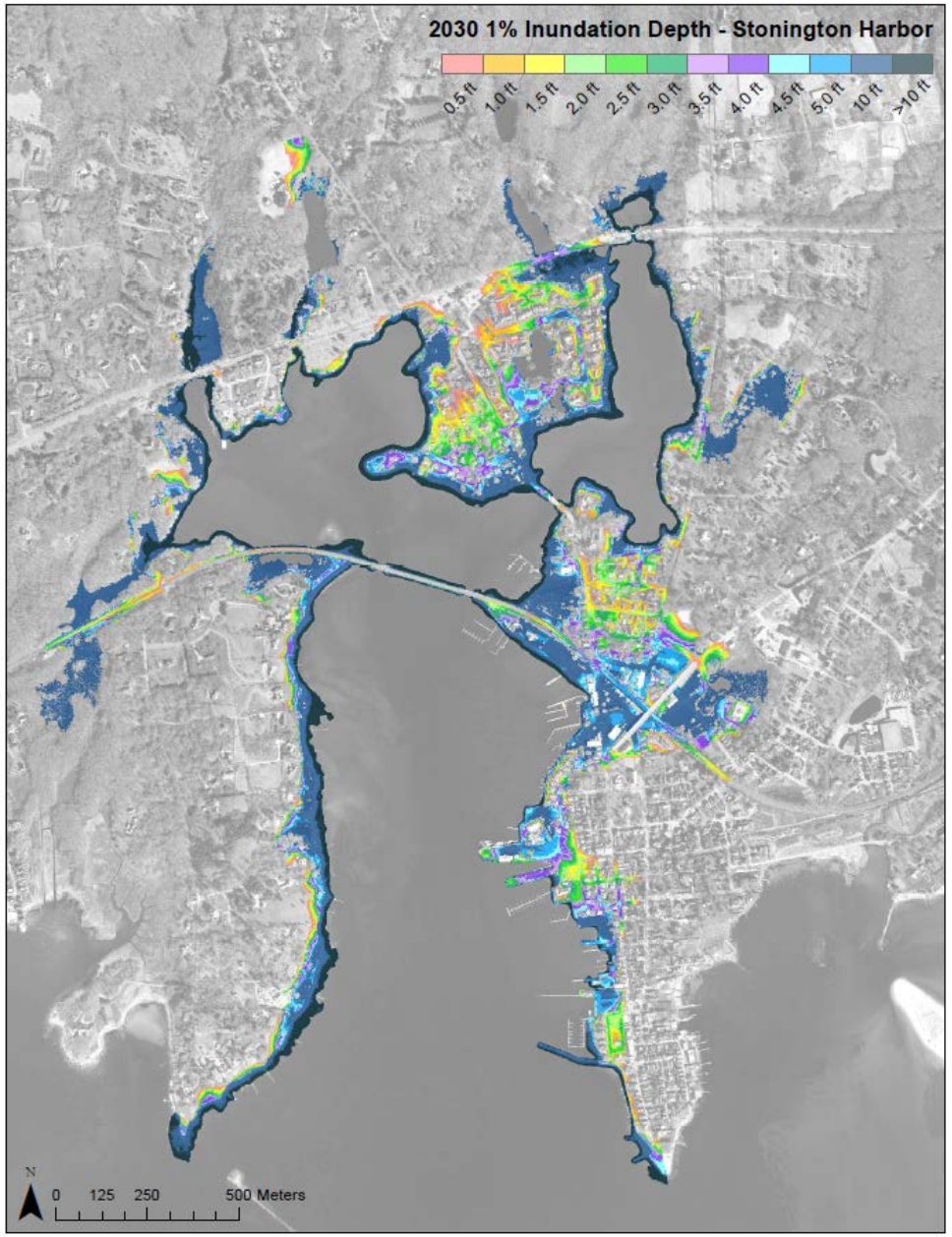
Stonington Harbor - Probability

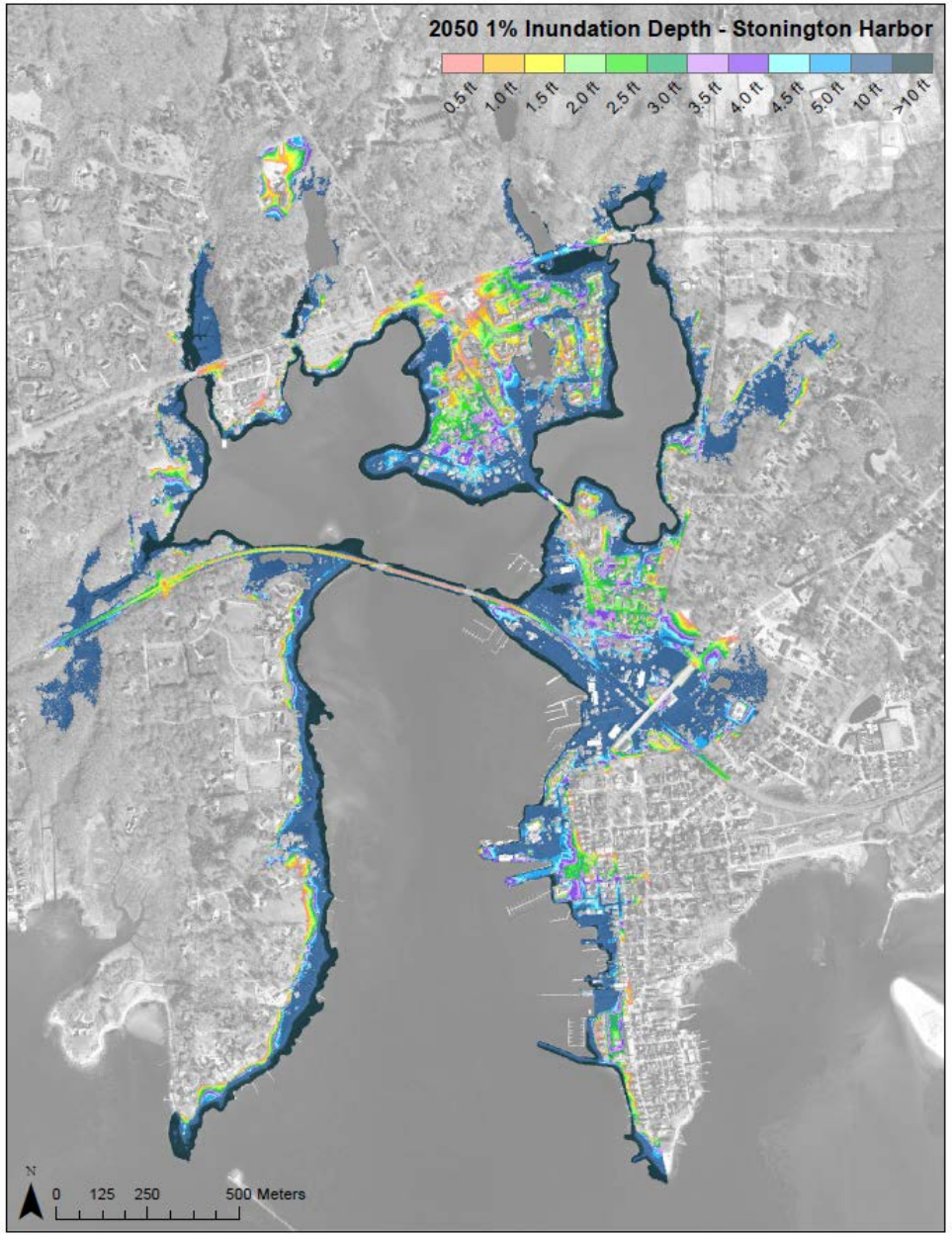




ARUP

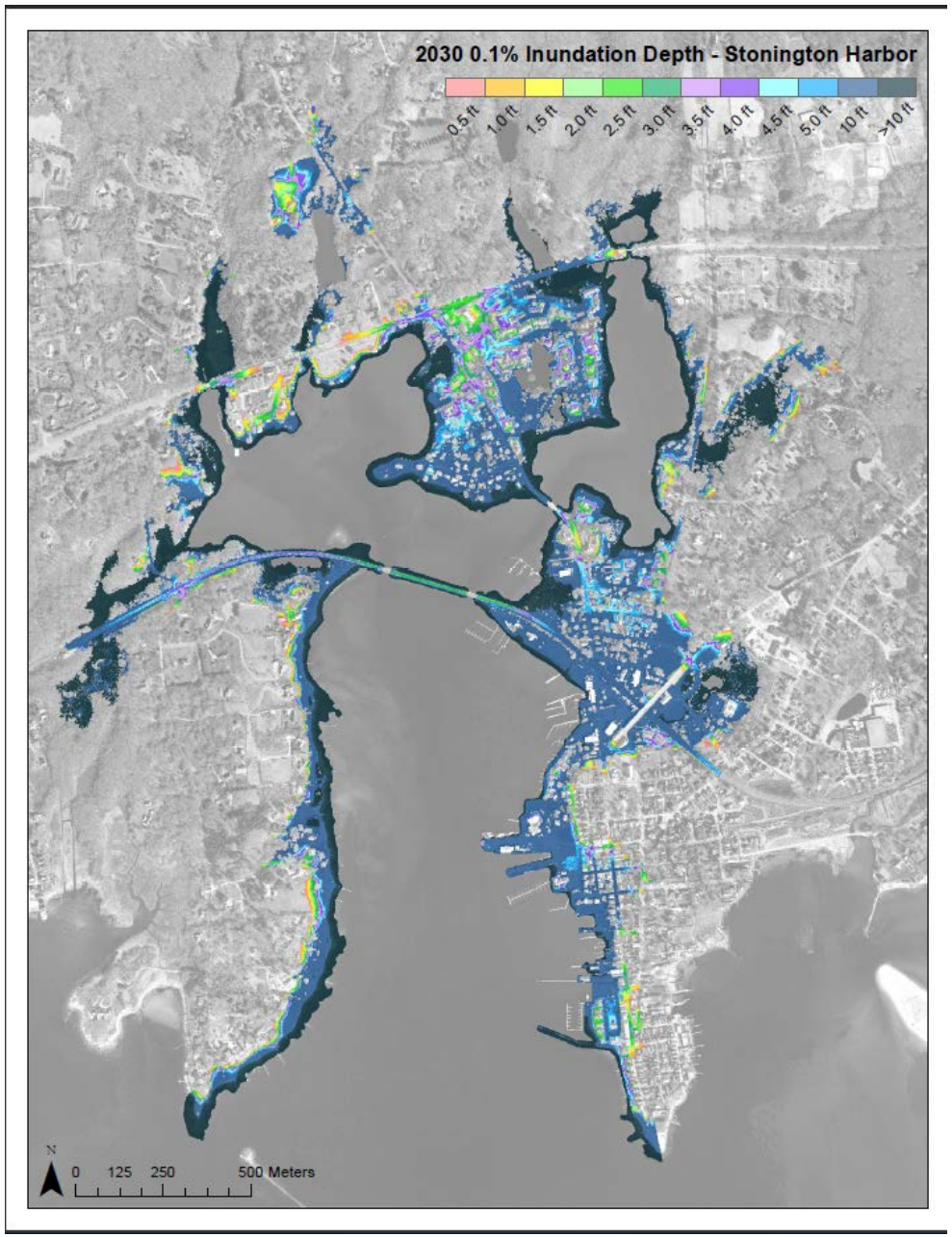
Stonington Harbor - 1% Depth

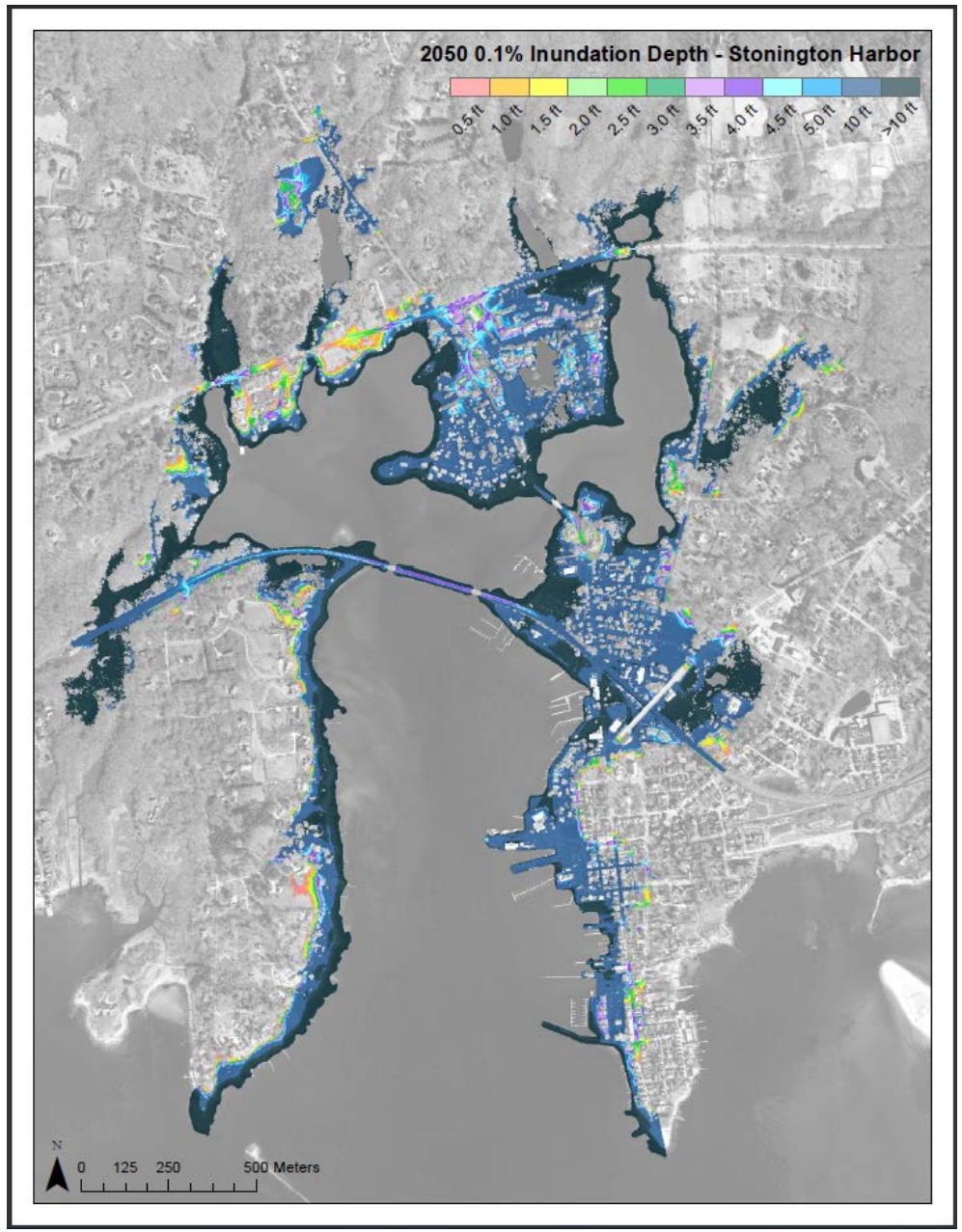




ARUP

Stonington Harbor - 0.1% Depths





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Vulnerability Assessment: Preliminary Results

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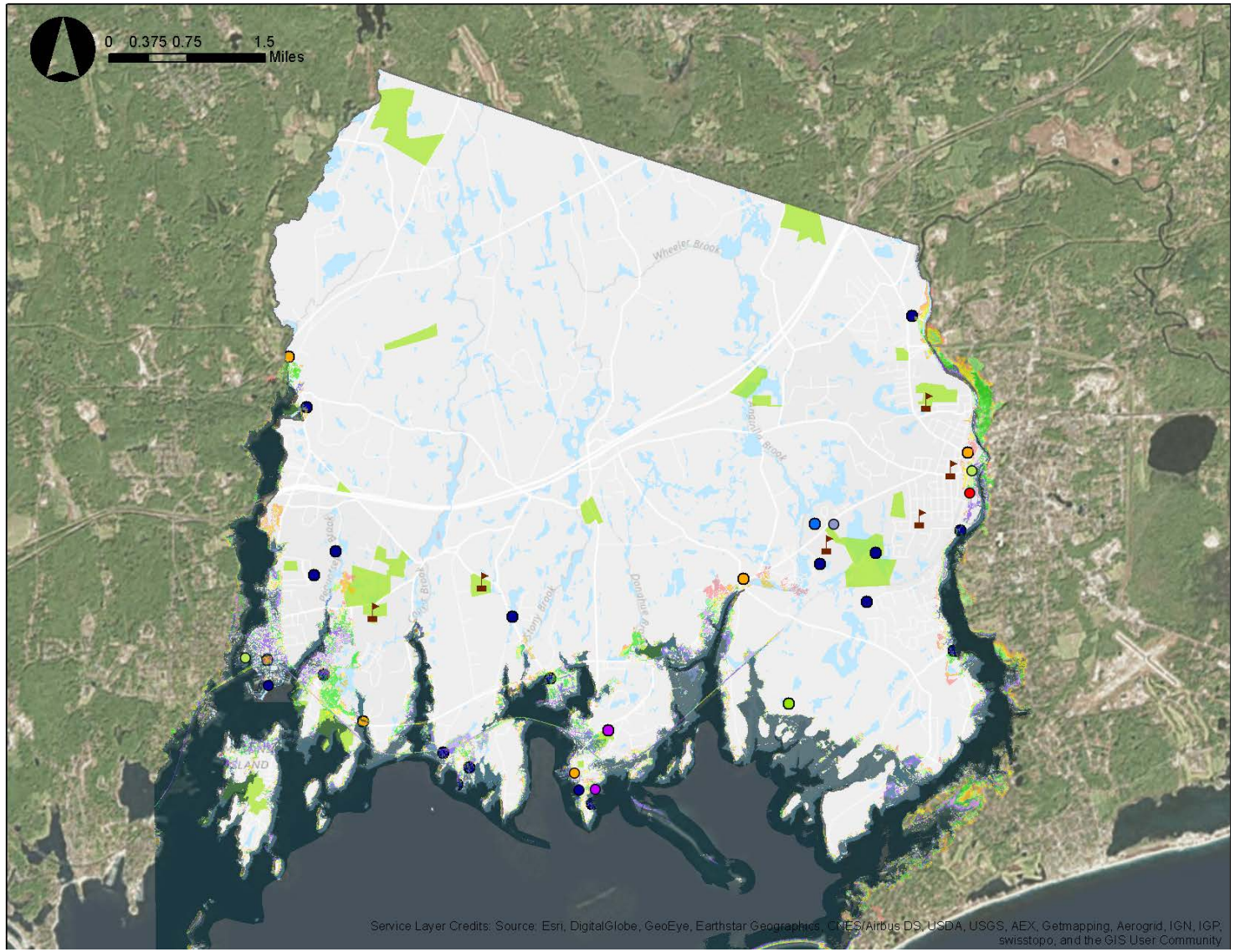
Public Infrastructure



Legend

% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

- Pump Station & Treatment Plant
- Fire Station
- Police Station
- Park
- Town and Borough Hall
- School
- Human Services Building
- Senior Center

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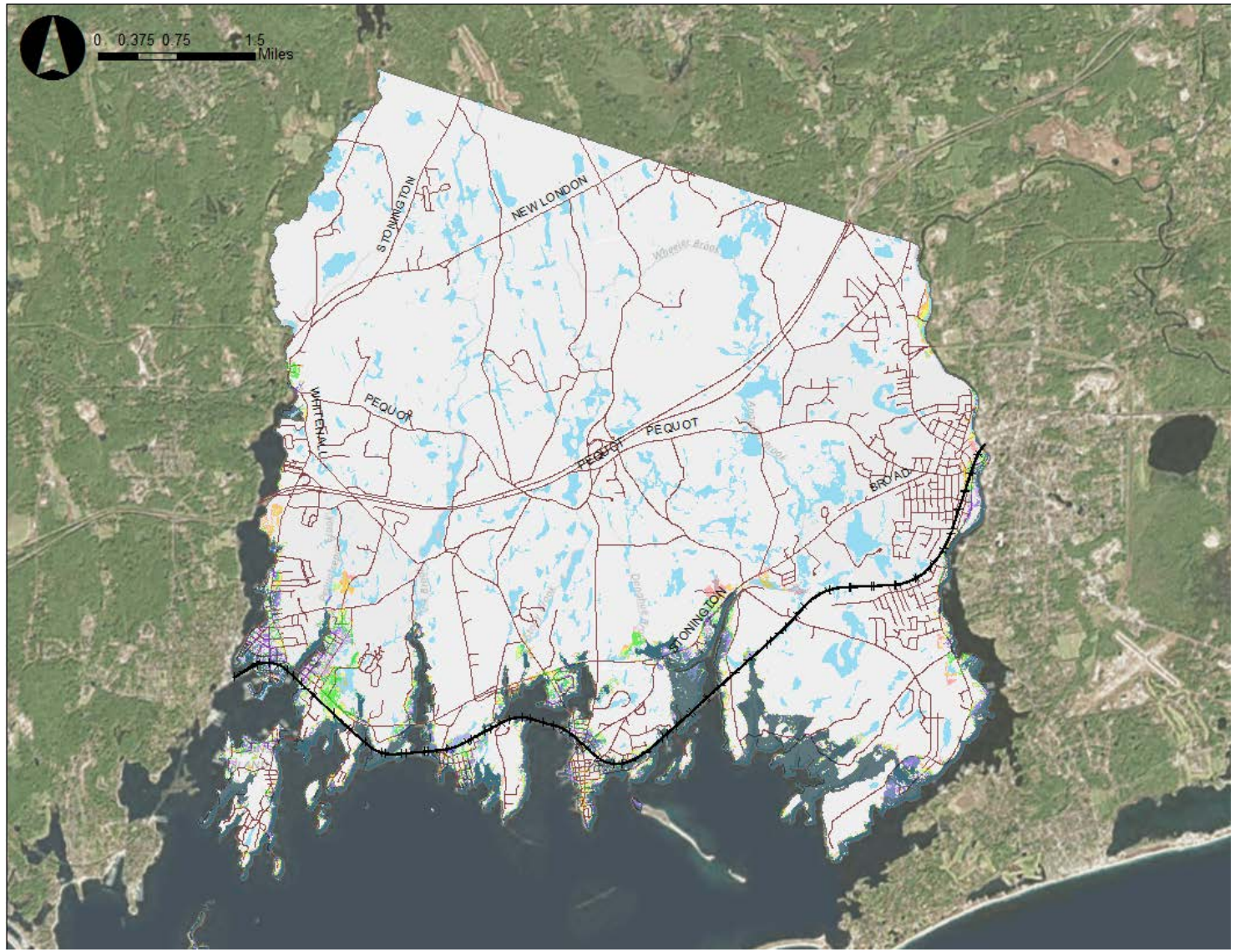
Transportation



Legend

% Annual Chance of Flooding

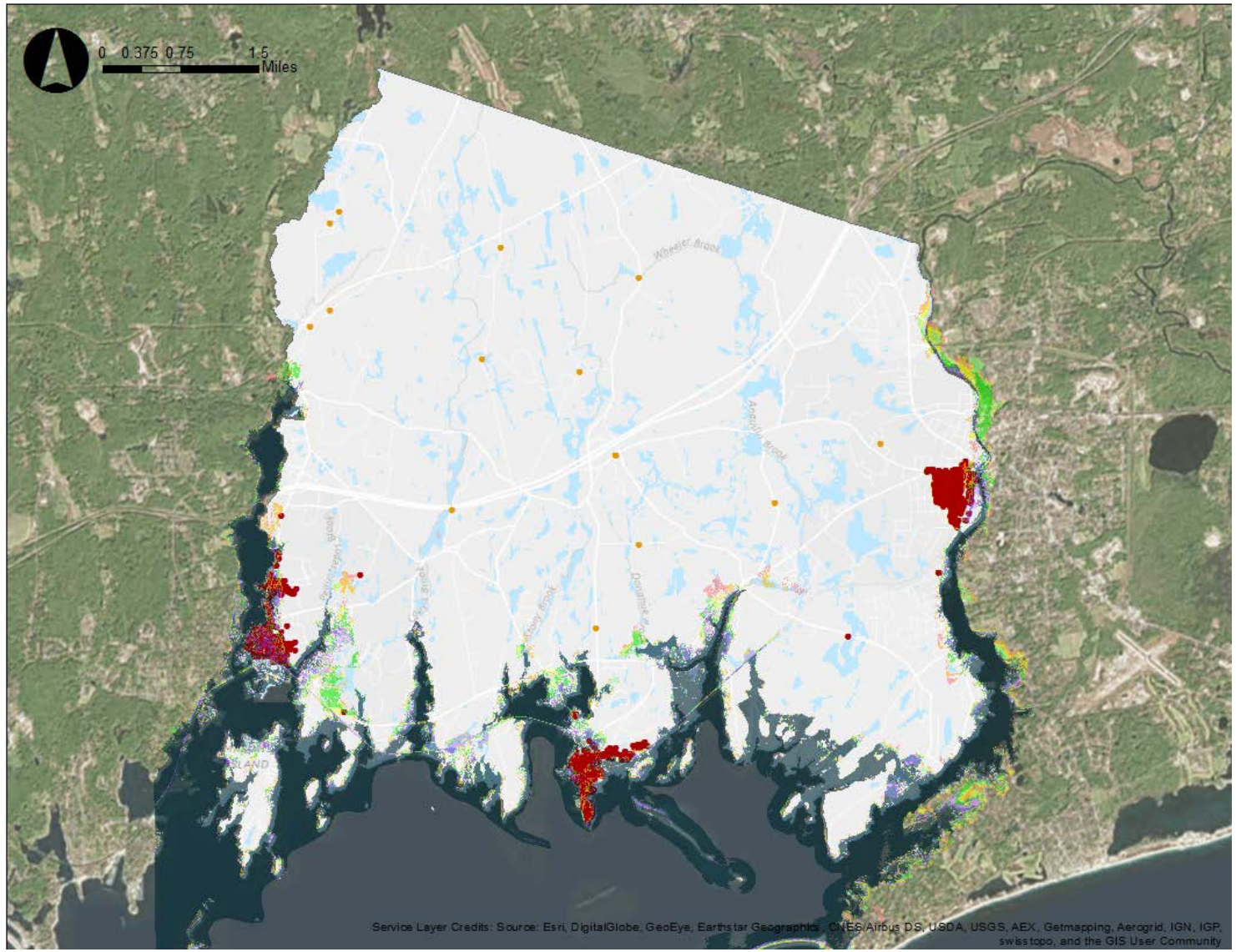
0.1	1	10
0.2	2	20
0.5	5	50
		100

Road

Railroad

ARUP

Cultural Resources



Legend

% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

- National Register Structures
- State Register Structures
- Local Register Structures

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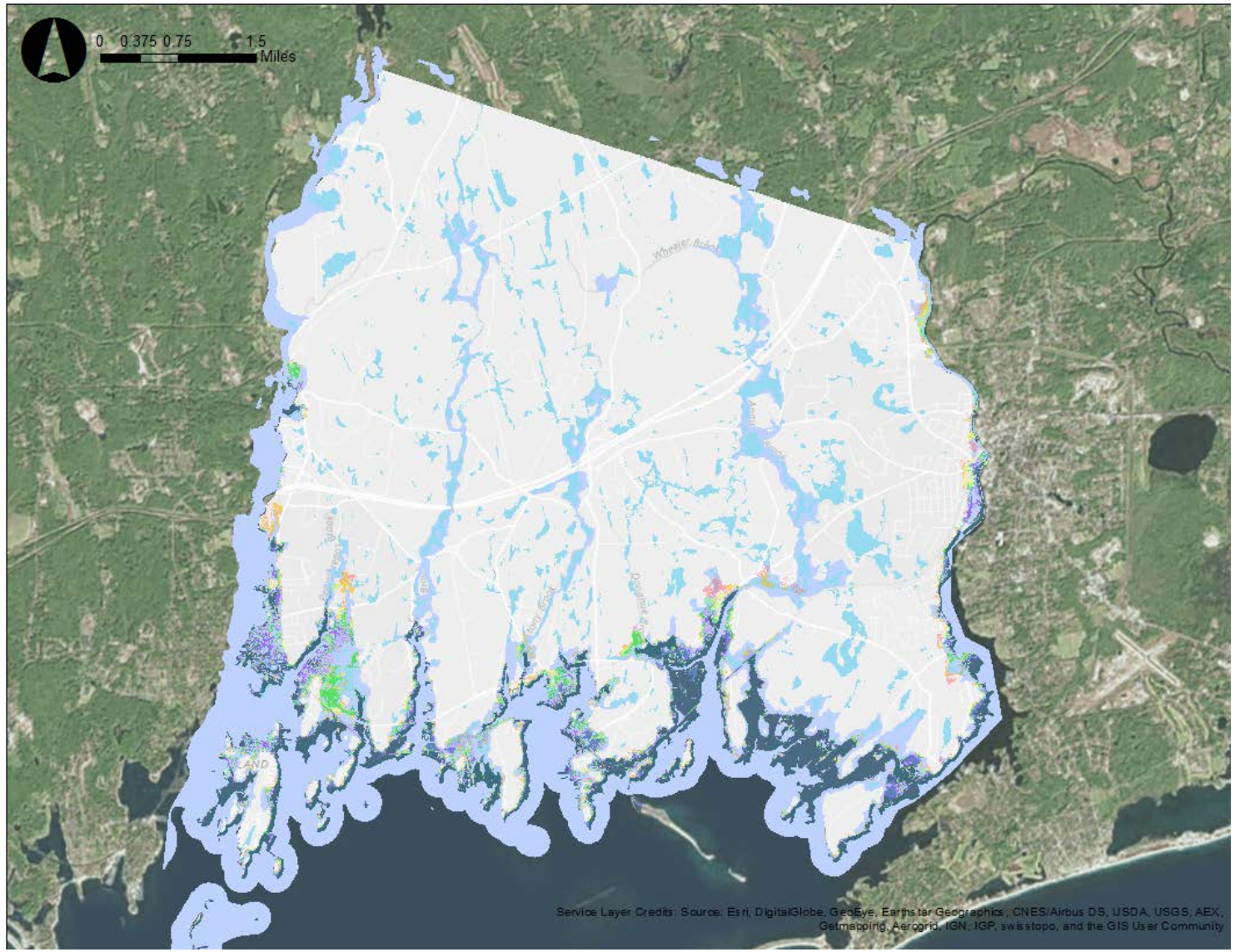
FEMA – Current Flood Zones



Legend

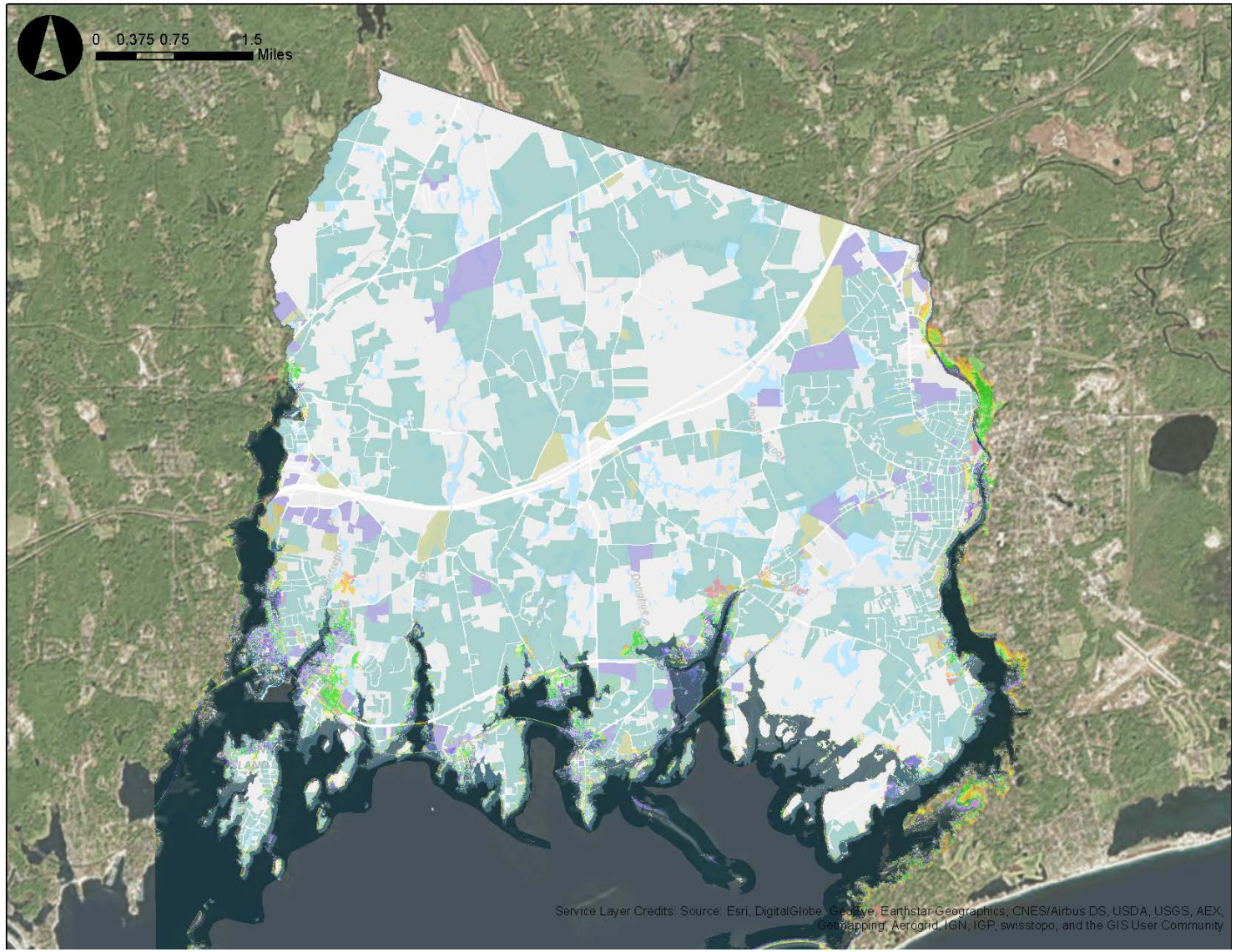
% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

100 Year Floodplain

ARUP

Major Land Uses



Legend

% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

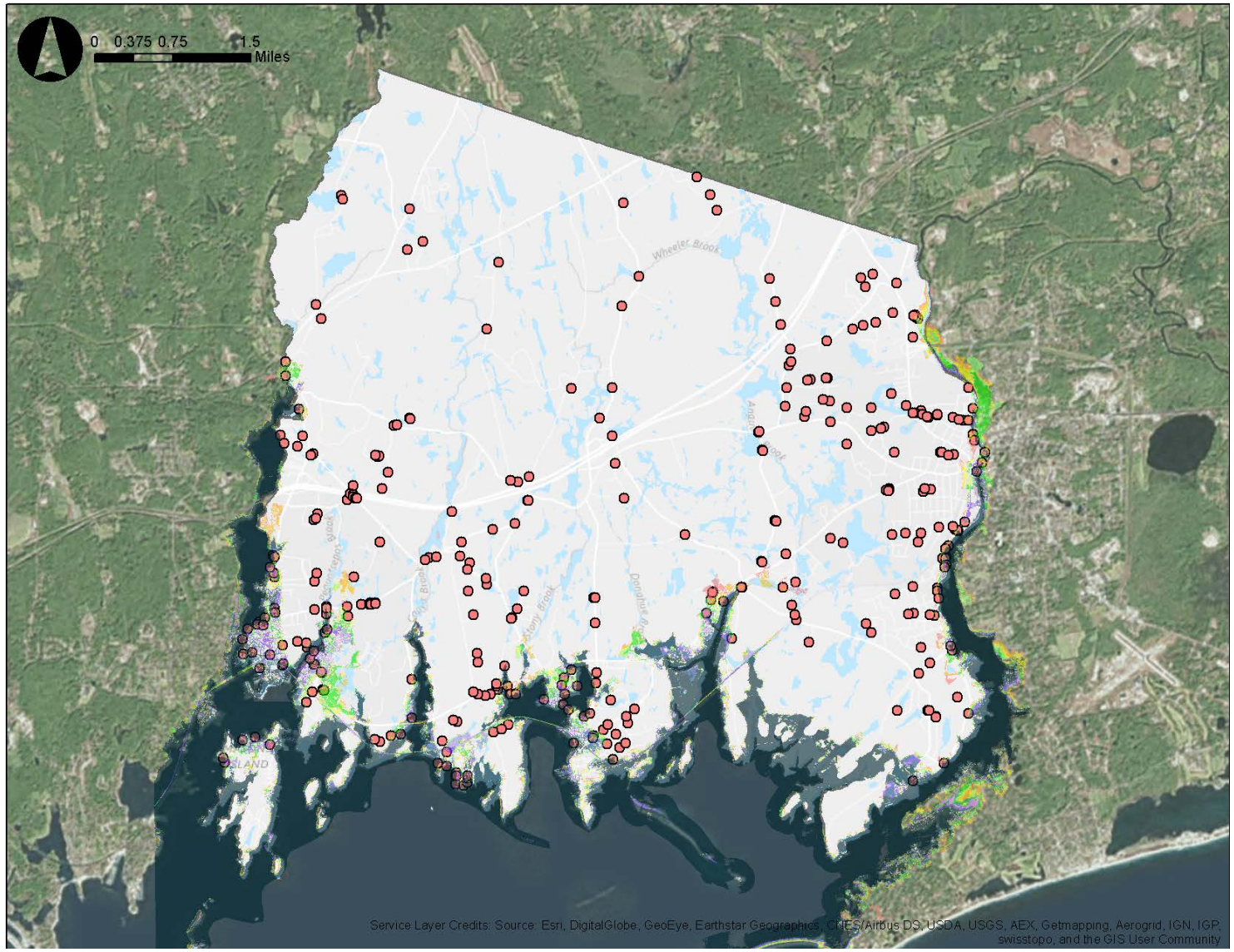
Residential

Commercial

Ind/Comm

ARUP

Outfalls



Legend

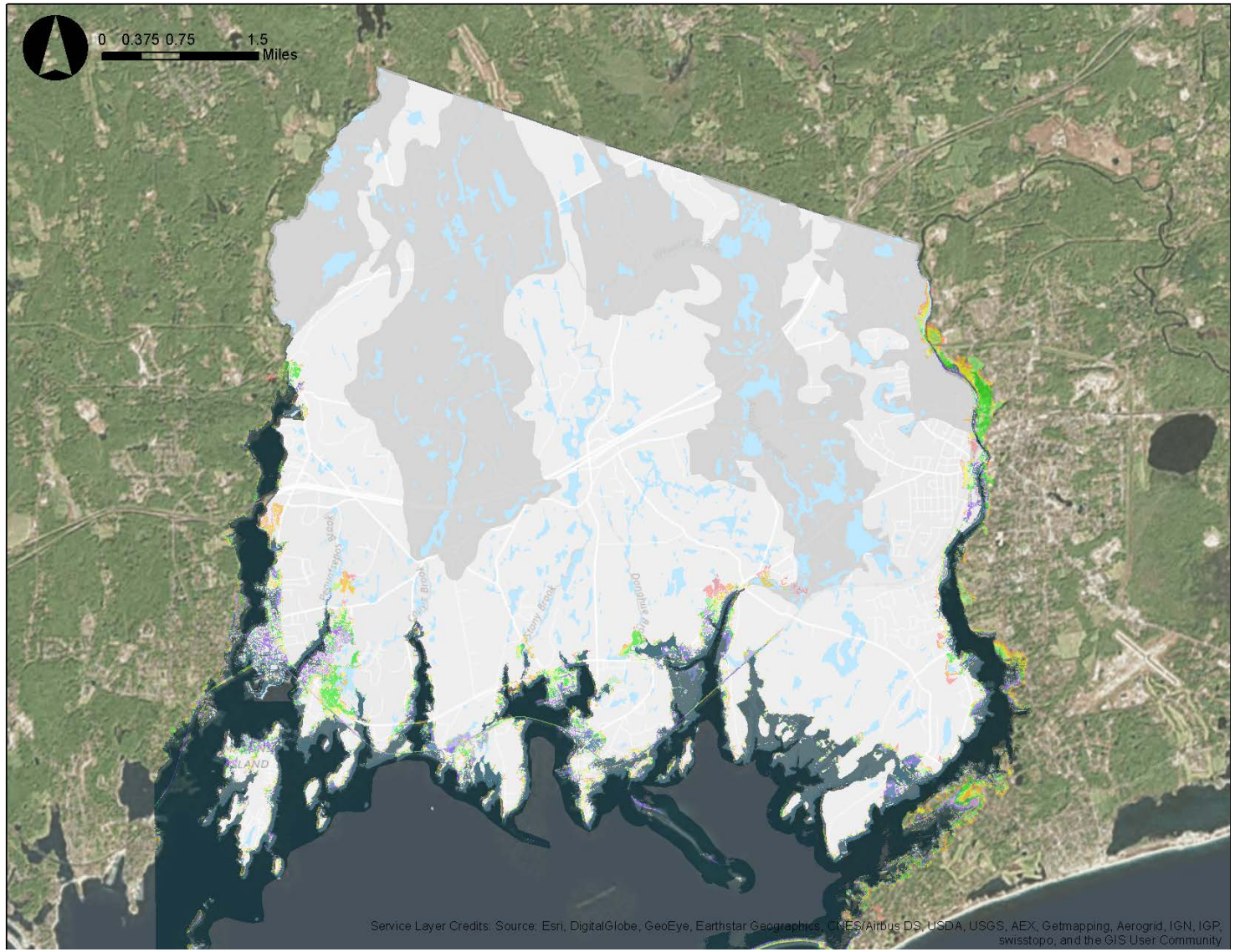
% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

Outfalls

ARUP

Groundwater Protection



Legend

% Annual Chance of Flooding

0.1	1	10
0.2	2	20
0.5	5	50
		100

Groundwater Protection

ARUP

A Brief Time Out: Survey results + a talk with the person next to you

ARUP

What people are thinking…

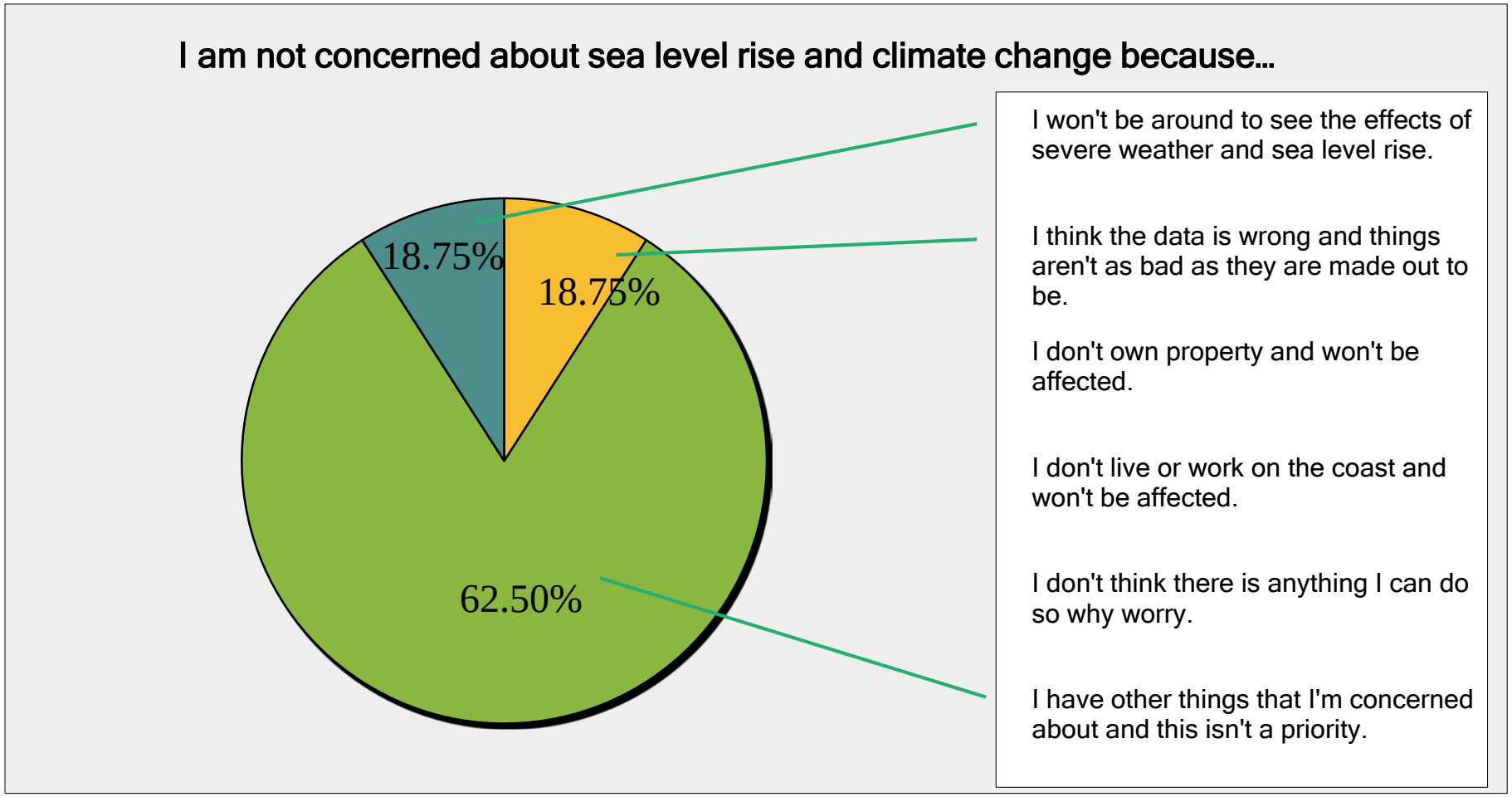
- 143 people responded to the online survey
- Respondents describe resiliency in equal measure as:
    - Bouncing back quickly after a catastrophic weather event
    - Having adequate capacity in infrastructure and services
    - Changing over the long run to respond to new situations and threats

How concerned are you about sea level rise and/or severe weather events?

Answer Choices	Responses	
Not concerned at all	**7.75%**	11
Just a little bit concerned	**11.27%**	16
Moderately concerned	**37.32%**	53
Very concerned	**43.66%**	62
Total		**142**

For those not concerned about sea level rise and climate change:

Answered: 11



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For those only a little bit concerned about sea level rise and severe weather events:

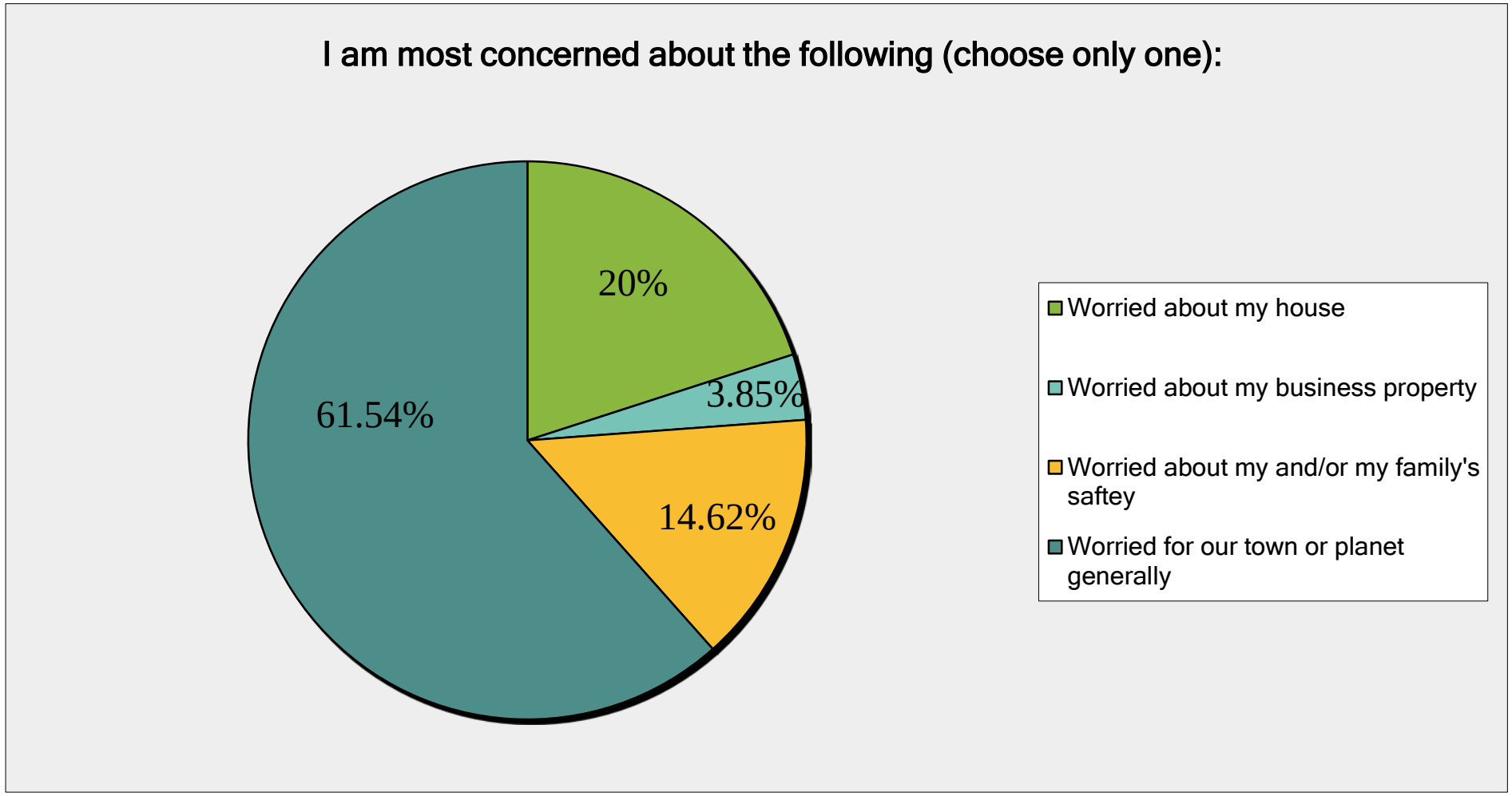
Answered: 16 Skipped: 127

Answer Choices	Responses	
I won't be around to see the effects of sea level rise and severe weather.	0.00%	0
I think the data is wrong and things aren't as bad as they are made out to be.	18.75%	3
I don't own property and won't be affected.	0.00%	0
I don't live or work on the coast.	0.00%	0
There is nothing I can do so why worry about this.	18.75%	3
I have other things I am concerned about and this isn't a priority.	62.50%	10
Total		**16**

ARUP

For those moderately or very concerned:

Answered: 130



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How would you like to participate in this planning process?

Answered: 134

Answer Choices	Responses	
Attend a public meeting	**58.21%**	78
Attend a focus group or working group	**33.58%**	45
Participate in surveys like this one	**38.81%**	52
Have the project team or town staff attend an event/meeting of my organization, church, or other group(if other, please list below)	**6.72%**	9
Read updates on the Town website	**27.61%**	37
Get project news on the Town Facebook page	**24.63%**	33
Receive email updates	**55.22%**	74
Total Respondents: 134		

You live in…

Answered: 133

Answer Choices	Responses	
Mystic	25.56%	34
Lords Point	3.76%	5
Pawcatuck	20.30%	27
Mason's Island	12.03%	16
Stonington Borough	12.78%	17
Stonington Uplands	9.02%	12
Someplace else:	16.54%	22
Total		**133**

Your relationship to the water…

Answered: 133

Answer Choices	Responses	
Inland	**31.58%**	42
On the coast	**27.07%**	36
I can see the water but am not directly on the coast or river	**41.35%**	55
Total		**133**

Your living situation:

Answered: 133

Answer Choices	Responses	
I own my own home	**85.71%**	114
I rent my apartment/home	**8.27%**	11
I live with friends/family	**3.01%**	4
I live in senior housing	**0.75%**	1
Other (please specify)	**2.26%**	3
Total		**133**

Your age…

Answered: 133

Answer Choices	Responses	
65+ years old	**31.58%**	42
57-64	**28.57%**	38
50-56	**15.04%**	20
31-49	**20.30%**	27
21-30	**4.51%**	6
under 21	**0.00%**	0
Total		**133**

Take 5 minutes to talk to the person next to you and complete your survey sheet

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Discussion, Questions & Next Steps

ARUP

Next Steps

- Please make sure you signed in at the entry table
- You will be added to email list for project updates and meeting notices
- For additional information on the project, please contact:

  Keith Brynes
  kbrynes@stonington-ct.gov
  860-535-5095

- OR follow us on social media!

  #StoningtonReady
  @StoningtonCTGov
  @ArupAmericas

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3 Public Meeting #2 (May 4, 2017)

The following comments were collected as part of a facilitated exercise during the second public meeting, held at the Mystic Seaport on May 4, 2017. The Arup Team presented a major storm scenario to the public at the meeting and asked attendees to respond to questions based on that scenario.

The Scenario: A future 100-year storm hits Stonington, resulting in major flooding along the coast and a week without electricity.

The following questions were asked of meeting attendees:

What are you most worried about during this storm event?

- Emergency Transportation
- Restoration of power and utilities
- Getting gasoline for emergency house generators, for cars
- Making sure friends and family are safe if communications are down, ability to charge cell phones
- Being about to use medical devices
- The drainage system from across the seaport do to School Street is extremely vulnerable to flooding.
- Communication within town – cell phone towers and electricity. No one will have power so how will they be reached? So few people have land lines these days.
- Sewer system and water supply – how to maintain this even in flooding?
- Six fire departments with six independent districts. They don't report to the town and chain of command isn't clear. This is a major concern during emergency events.
- Need to get young people involved. This planning will affect their lives the most.
- Where does all of this intersect with flood insurance? FEMA community rating system can help bring down rates?
- Worried if people own property on the water…if they are responsible for loss of value, will others feel like everyone can share in that loss as a community loss?
- How long will it take to get back to normal and how much will it cost?
- Politics. We need to make sure that department heads and people in charge are making the right decisions. Right now approvals happen that shouldn't. contractors are filling with fill and paying the fine because it is cheaper. There isn't trust that people will do the right thing. Could we give people fair payment to NOT build?
- At this point in our country's evolution we have reached a point where many don't trust the government. Yet we will need to depend on them in an emergency. Worried about how that all plays out.
- We have assets that are irreplaceable…historical buildings, the fabric of the town, the character. If a storm wipes this out, we can't replace it and it is also the reason for tourism. If tourism dollars are lost this would be a major blow.
- Arcane electrical distribution systems – how to provide vital utilities during flooding?

Do you have any ideas for how Stonington can protect itself in this scenario?

- Ideal is prevention by change is land uses.
- Emergency resilience plan that offers real solutions
- Town is building middle schools and these are on high ground. Make sure we plan to use these as emergency shelters. In fact, think about:
    - Using more central locations (firehouses, schools, community centers) for emergency shelters
    - Places where pets are welcome
    - Places to charge cell phones and other devices
- Make at least one shelter pet friendly. Many people endanger their lives and don't go to shelters because they won't abandon their pets.
- Get people to take evacuation seriously. Many people stay in their homes, making it difficult for everyone and endangering their lives and others.
- Didn't see entrance to Borough covered in the presentation. Bottom of Viaduct floods and essentially creates an island.
- How to communicate to let people know what roads are open/closed, where charging stations are? Showers? Respite areas?
- Develop list of residents at risk in own homes and see if local senior housing communities can take in extra residents for the short term.
- During Sandy and Irene, Groton had large sand pile and fill bags. Stonington needs to plan to offer this. We need a coordinated effort like this to help everyone mount a defense. We also need greater public service support overall prior to a potential flood event.
- A big thank you to the police and fire departments for the free checks they did after the storm of electrical and gas service to homes to ensure it was safe to go back.

Do you have any additional comments or questions?

- We need political will for implementation of solutions
- Regional solutions!!!!
- Show cell towers on the flood maps as an asset
- The study needs to provide information on FEMA loans to raise homes and rebuild after storms. Needs to list resources for residents.
- Focusing on an acute event is interesting and informative but also need to be aware of starting NOW on projects to address long-term sea level rise and resulting ground water.
- Building in flood zone should be restricted going forward. Not even flood-adapted buildings should be allowed but land should be purchased or set aside for migration of wetlands as buffers.
- Worried the "pinch in" solution at Pawcatuck River will restrict flow and normal tide flow that is needed and outflow that is needed due to heavy rain that often accompanies a hurricane.
- Town/Borough/Arup should get out and address more young groups. Set up tables at farmer's markets with brochures with details.

- Need active coordination with conservation groups – make presentations at meetings, organized lectures.

Is there anything else you want to tell us?

- Will there be proportioned food, water, and emergency supplies? Slide scale way too small!!!
- Also already list of professionals- other than service master- object conservators, restorers, etc. for disaster event.
- Great meeting! Nice to see a full house to learn more about a very important topic

The following is a copy of the presentation made at this meeting.

Stonington Coastal Resilience Plan

Town of Stonington, Connecticut

Public Meeting May 4, 2017

Social Media:
#StoningtonReady
@StoningtonCTGov
@ArupAmericas

MYSTIC SEAPORT THE MUSEUM OF AMERICA AND THE SEA

TOWN OF STONINGTON, CONNECTICUT 1649

ARUP

WOODS HOLE GROUP

CivicMoxie™ experts in place

TDA TRAINING & DEVELOPMENT ASSOCIATES, INC.

Why this study…

Source: The Westerly Sun

The impact of Superstorm Sandy could have been much worse. We want to learn from that experience and plan ahead to:

- protect public infrastructure from coastal flooding and sea level rise
- minimize potential for loss of life and destruction to property
- identify ways to enhance coastal resources

ARUP

Goals for this Meeting

1. Present Stonington's most at-risk properties.

2. Discuss proposed resilience solutions.

3. Gather feedback from residents on their biggest concerns during a coastal flood event.

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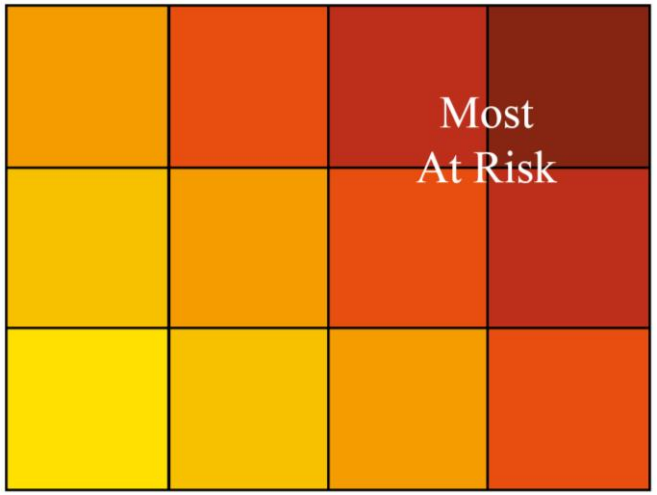
Overview of Approach

Step 1

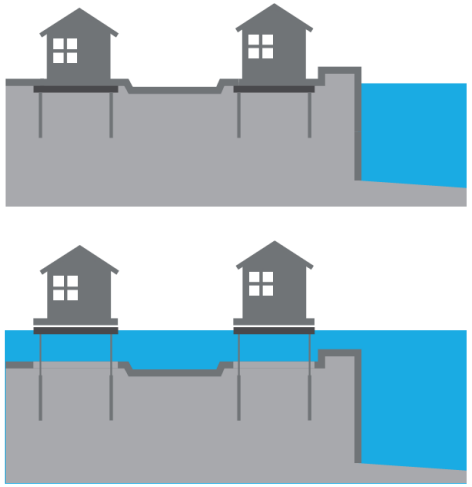
Establishing a climate baseline

Step 2



Ranking risk

Step 3



Developing solutions

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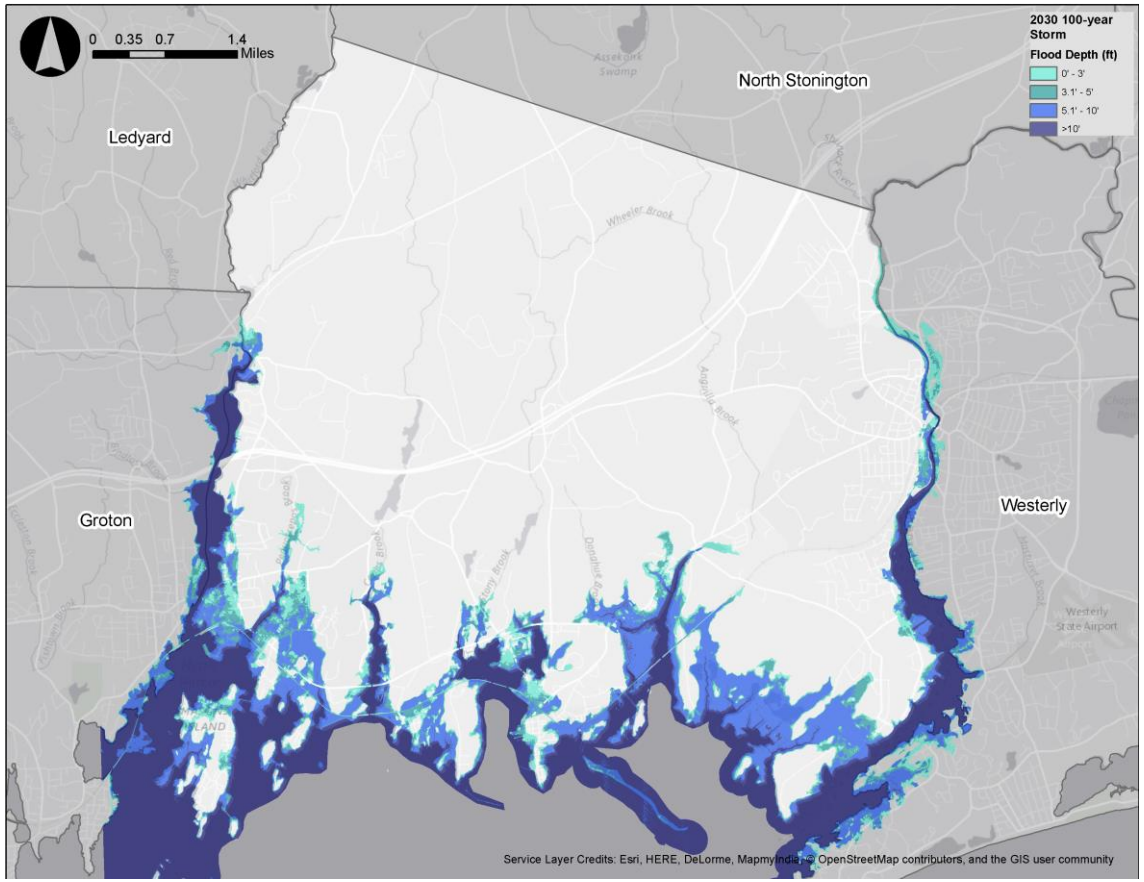
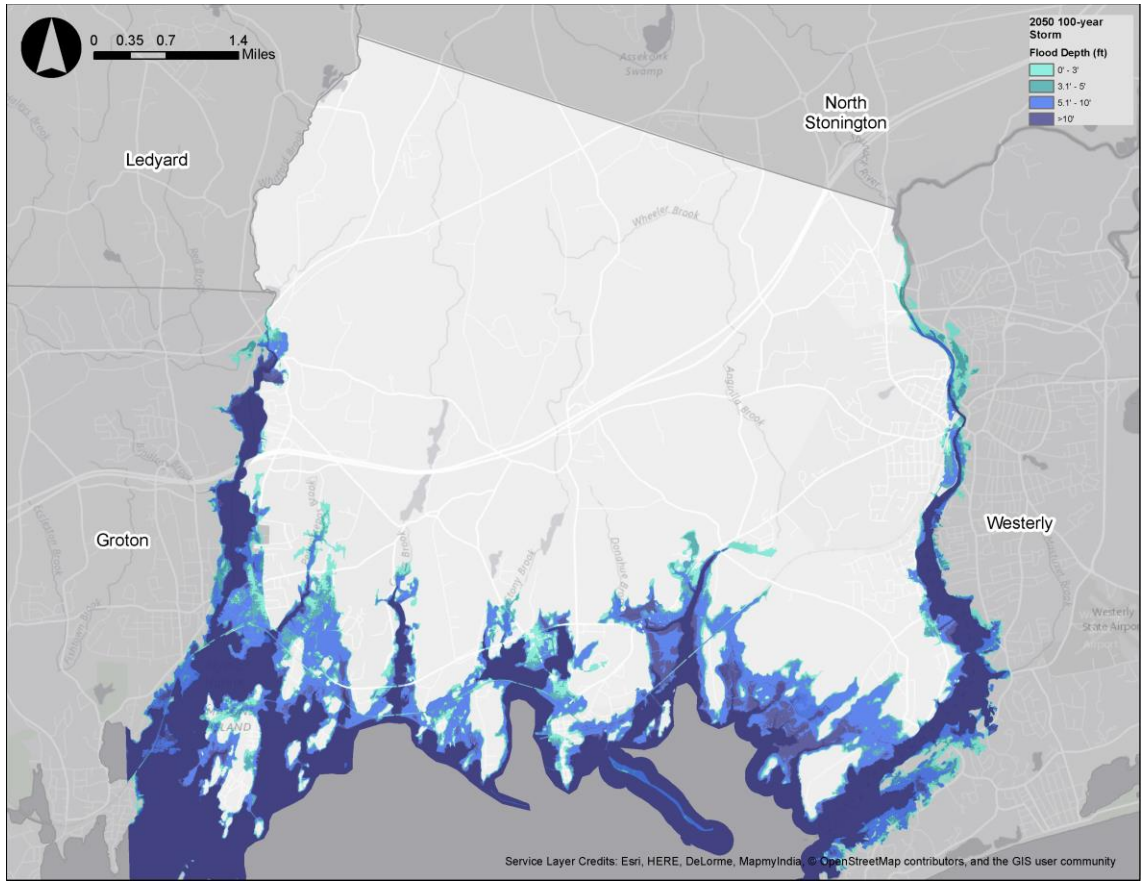
Step 1: Climate Baseline



2030 100-year Storm



2050 100-year Storm

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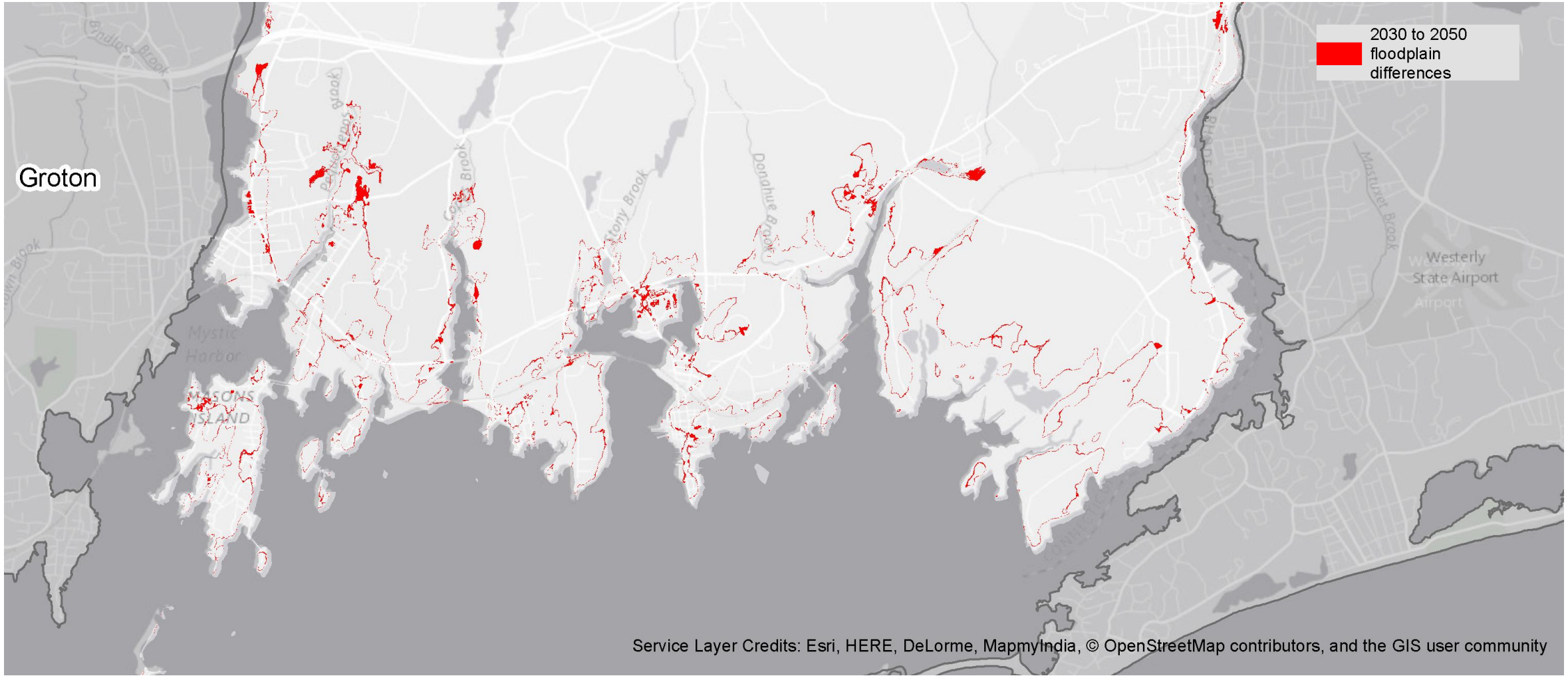
Change in Flood Extents



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Step 2: Risk Assessment

Risk = Hazard x Exposure x Vulnerability

- **Hazard** = Storm Event (i.e. Present-day 100-year storm, 100-year storm in 2030, 1000-year storm in 2050)
- **Exposure** = Depth of Flooding
- **Vulnerability** = An Assessment of:
    - Impact on community
    - Critical Facilities
    - Replacement Cost
    - Economic impact to tourism (including historic resources)

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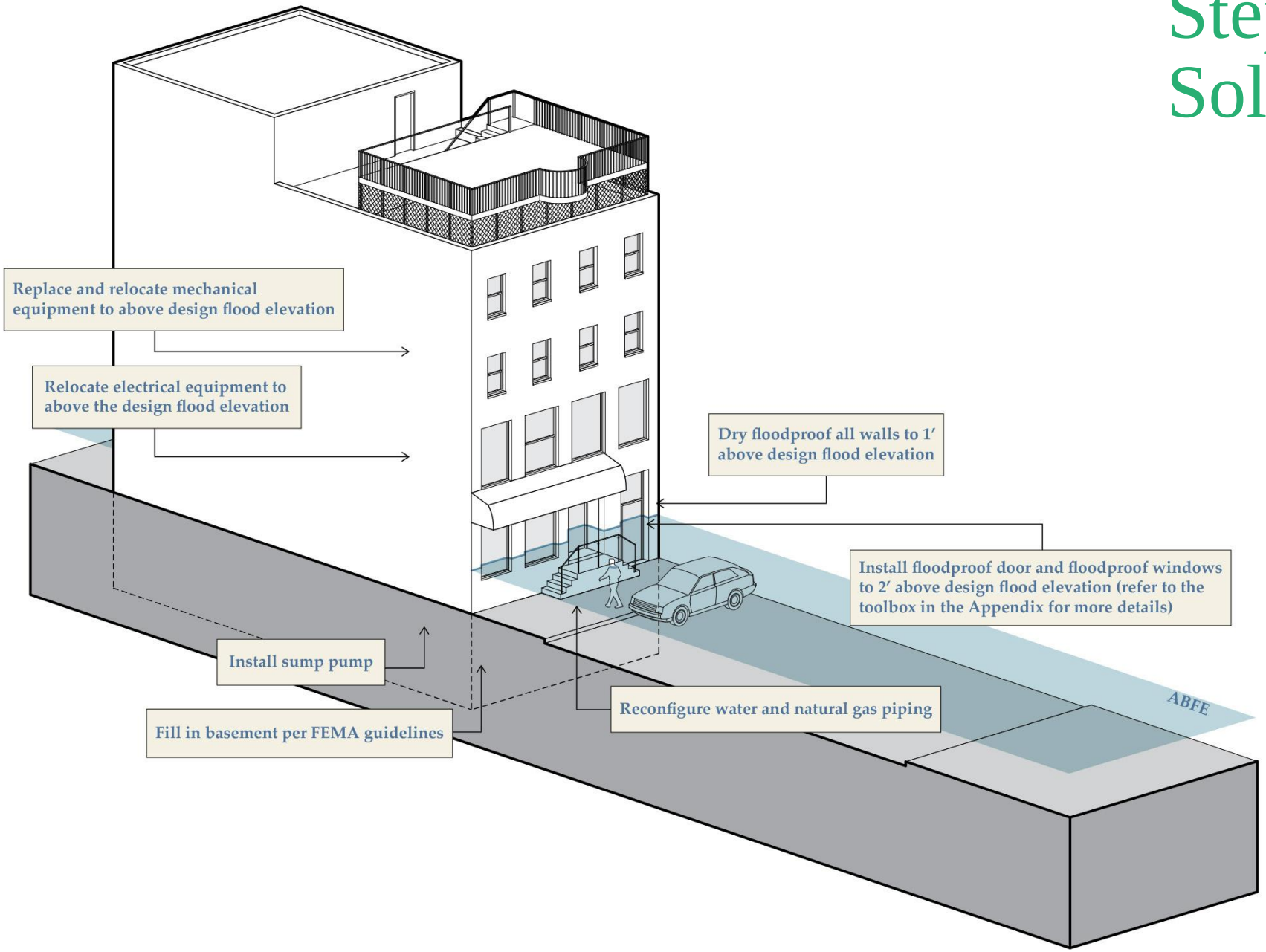
Step 3: Resilience Solutions



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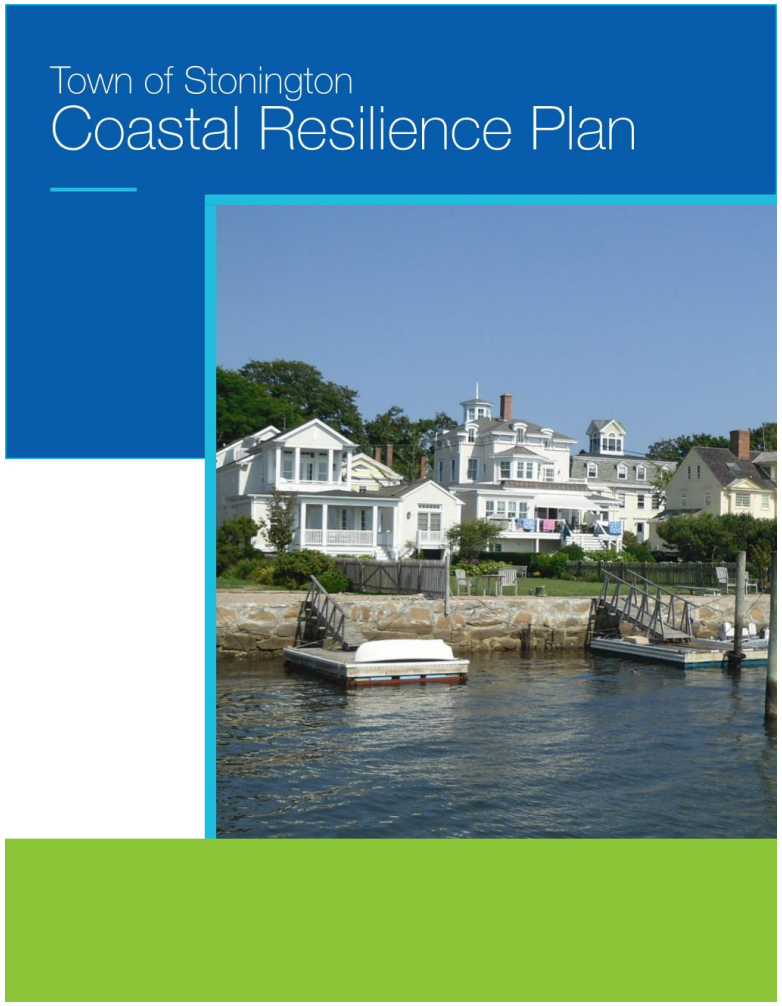
Overview of Coastal Resilience Plan

The plan will ultimately include:

- High-level analysis of **at-risk neighborhoods** and **proposed regional adaptations**
  - Regional Adaptations will be discussed later in the presentation
- Overview of **Top 25** most at-risk assets with high-level resilience solutions
- Detailed analysis of **Top 5** most at-risk assets with proposed resilience solutions
  - Draft solutions will be presented tonight



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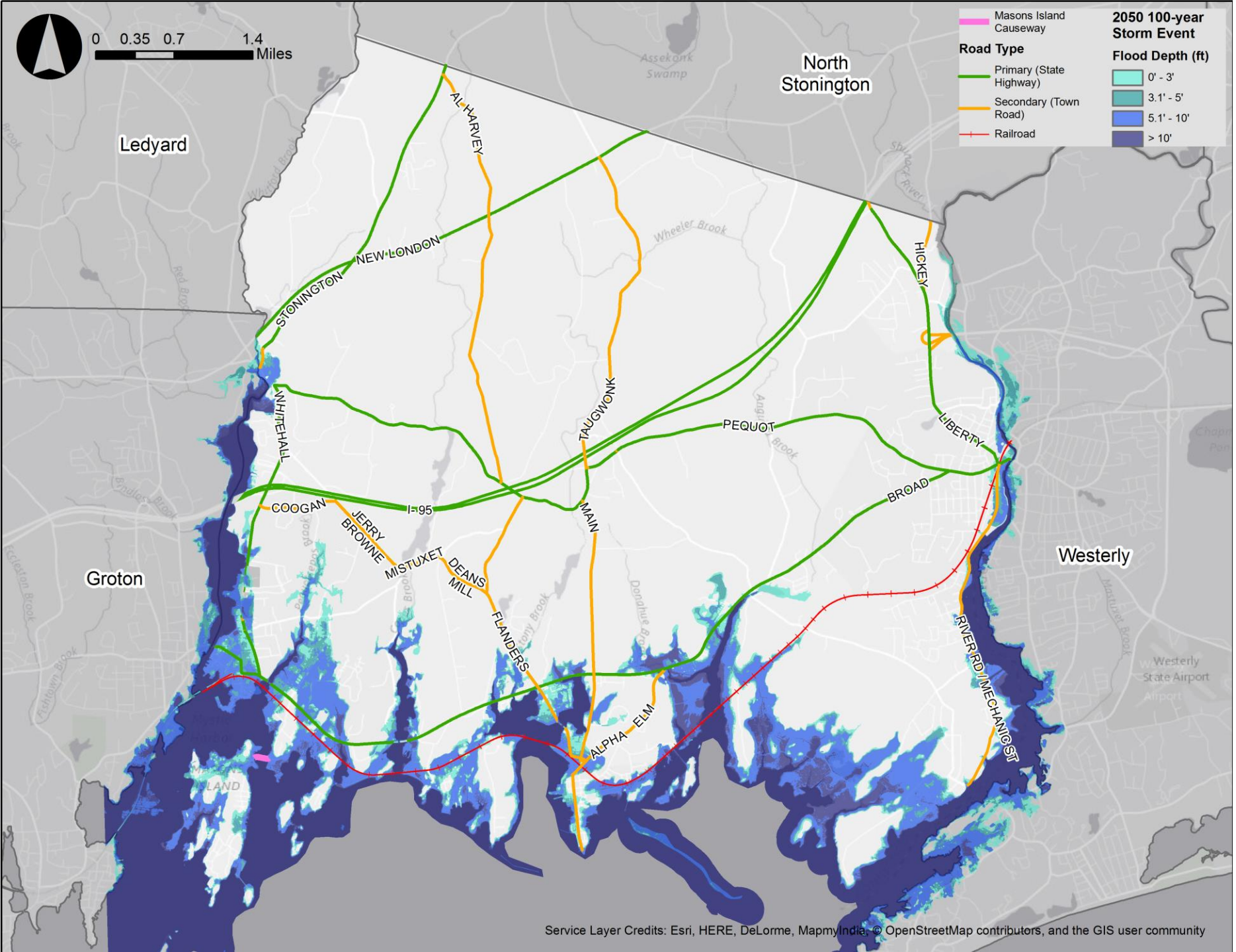
Risk Assessment

(maps using 2050 100-year storm event)

ARUP



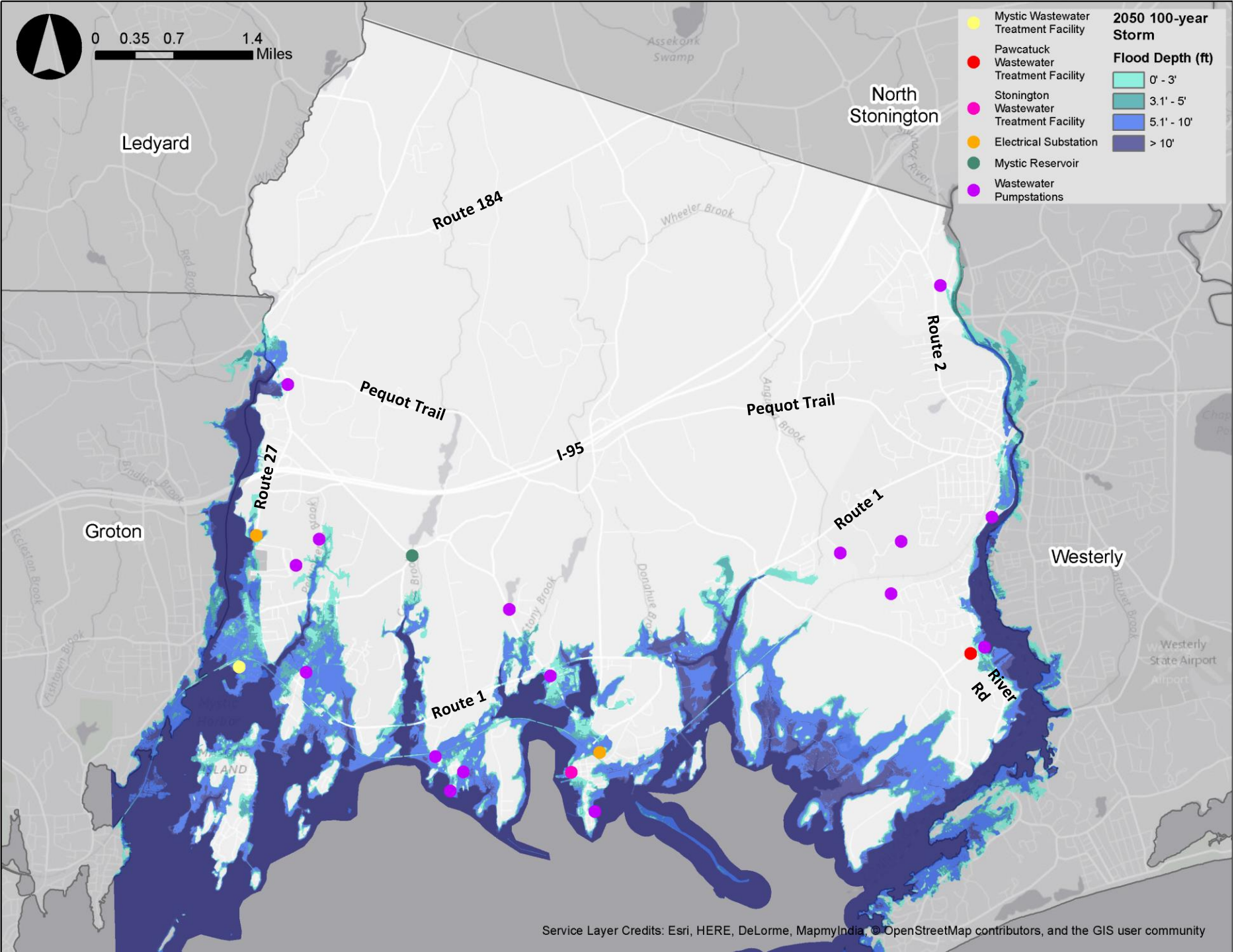
Transportation

(with 2050 100-year storm event)

Most Vulnerable:

- Masons Island Causeway
- State Highway 27
- State Highway 1

ARUP



Utilities

(with 2050 100-year storm event)

Most Vulnerable:

- Mystic Wastewater Treatment Facility
- Boulder Avenue Pump Station
- River Road/Mary Hall Road Pump Station
- Stonington Wastewater Treatment Facility
- Greenmanville Ave Electrical Substation
- Cutler Street Electrical Substation

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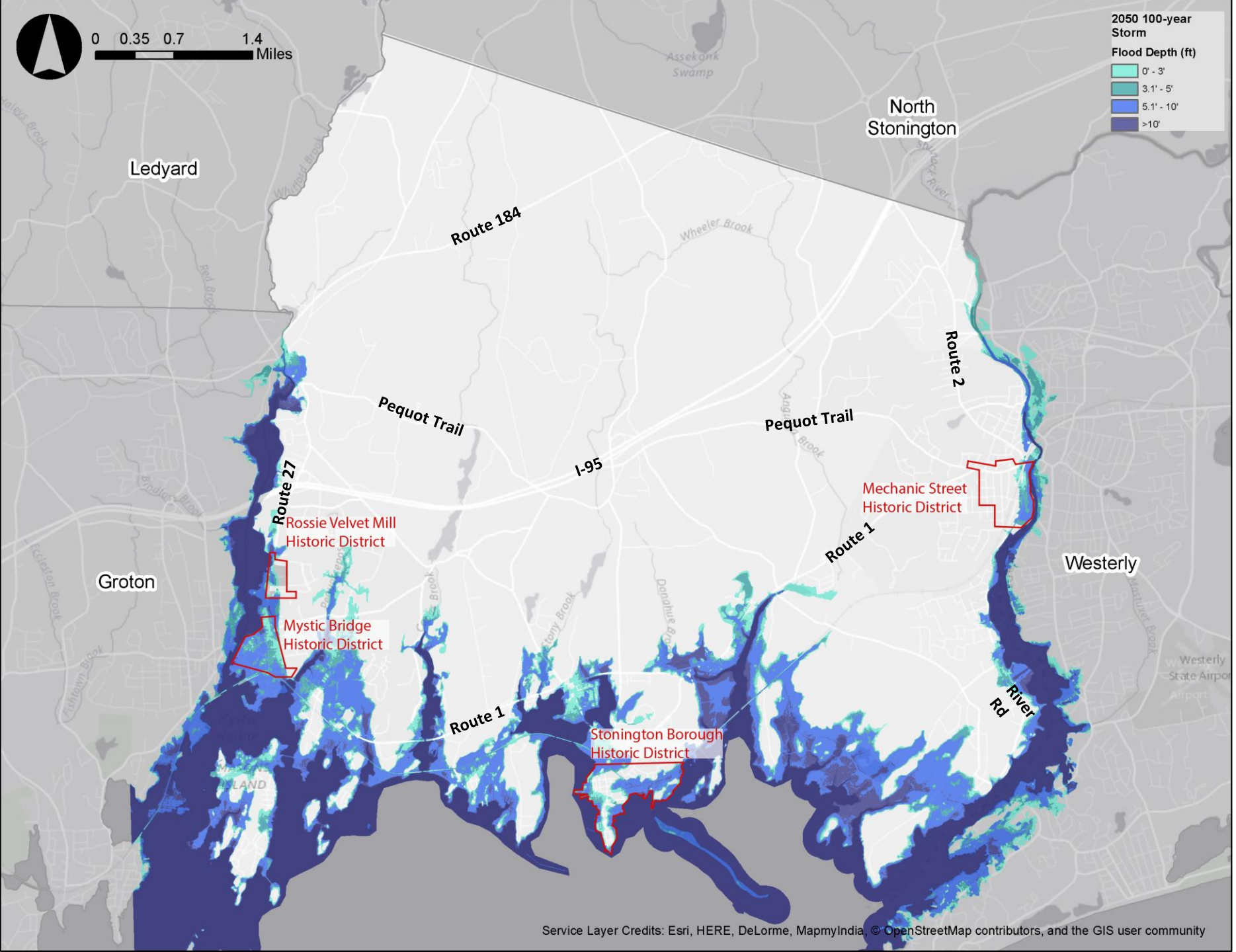

Historic Districts

(with 2050 100-year storm event)

Most Vulnerable:

- Rossie Velvet Mill Historic District
- Mystic Bridge Historic District
- Stonington Borough Historic District
- Mechanic Street Historic District

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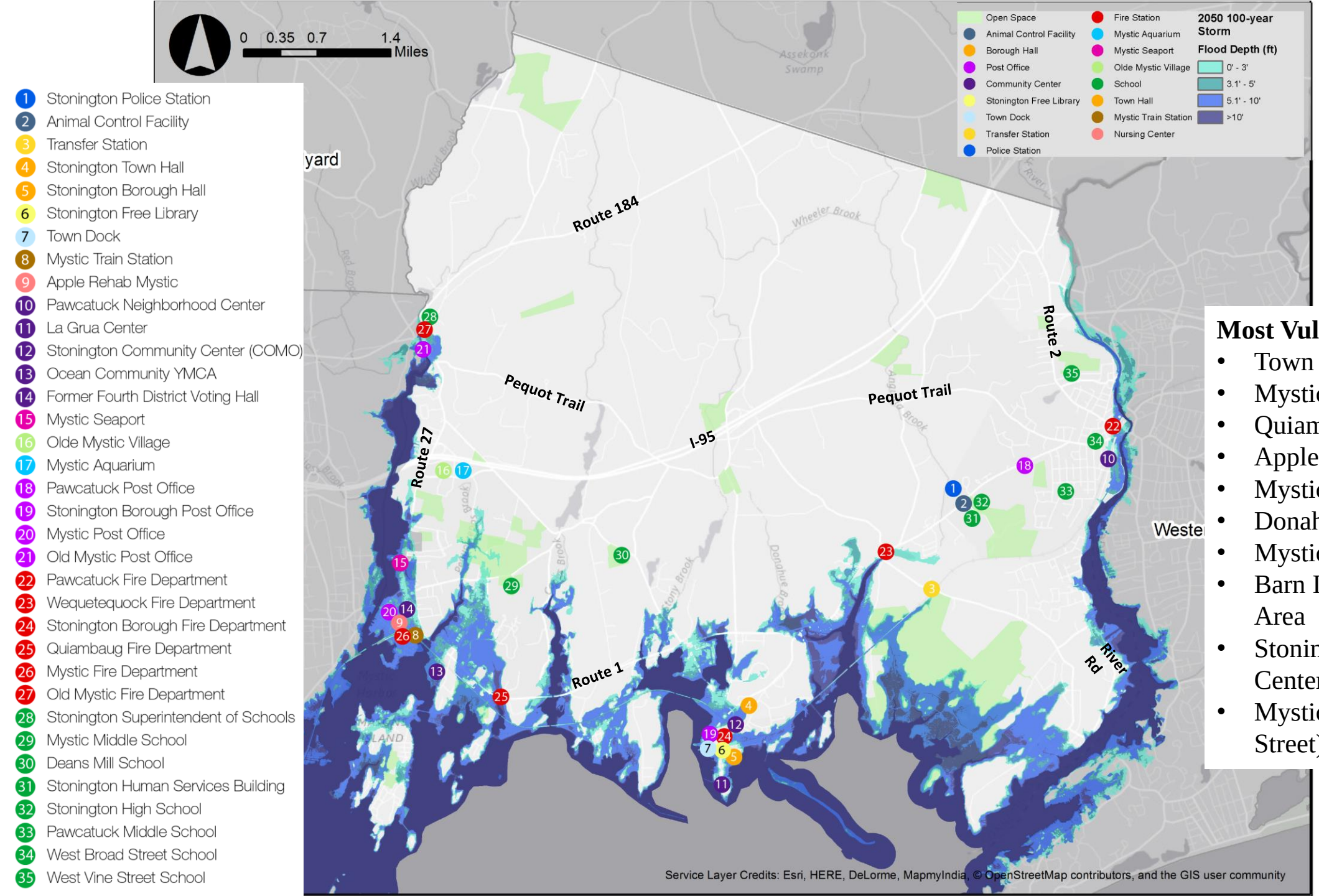
Community Facilities

(with 2050 100-year storm event)



1. Stonington Police Station
2. Animal Control Facility
3. Transfer Station
4. Stonington Town Hall
5. Stonington Borough Hall
6. Stonington Free Library
7. Town Dock
8. Mystic Train Station
9. Apple Rehab Mystic
10. Pawcatuck Neighborhood Center
11. La Grua Center
12. Stonington Community Center (COMO)
13. Ocean Community YMCA
14. Former Fourth District Voting Hall
15. Mystic Seaport
16. Olde Mystic Village
17. Mystic Aquarium
18. Pawcatuck Post Office
19. Stonington Borough Post Office
20. Mystic Post Office
21. Old Mystic Post Office
22. Pawcatuck Fire Department
23. Wequetequock Fire Department
24. Stonington Borough Fire Department
25. Quiambaug Fire Department
26. Mystic Fire Department
27. Old Mystic Fire Department
28. Stonington Superintendent of Schools
29. Mystic Middle School
30. Deans Mill School
31. Stonington Human Services Building
32. Stonington High School
33. Pawcatuck Middle School
34. West Broad Street School
35. West Vine Street School

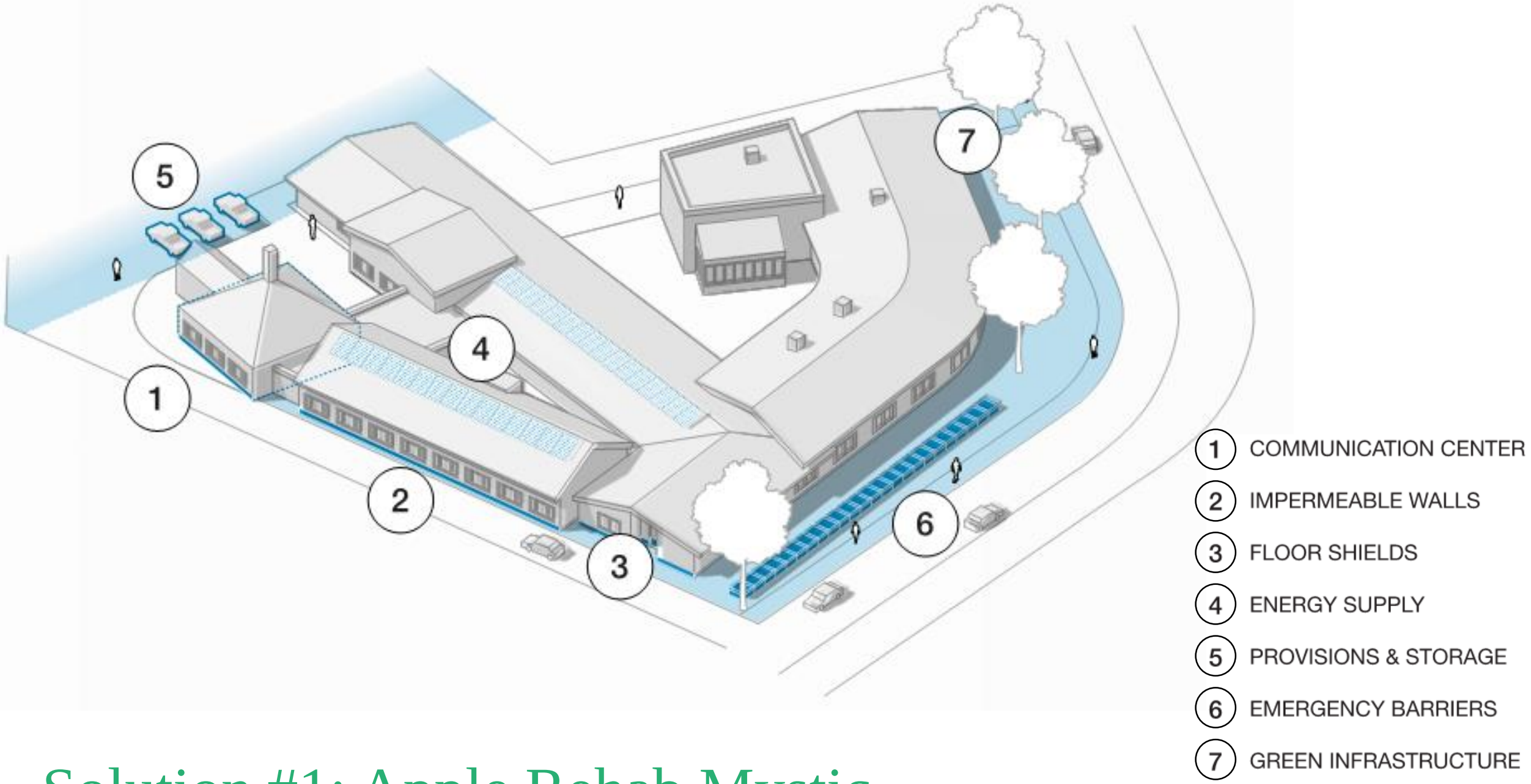
Most Vulnerable:

- Town Dock
- Mystic Fire Department
- Quiambaug Fire Department
- Apple Rehab Mystic
- Mystic Seaport
- Donahue Park
- Mystic Train Station
- Barn Island Management Area
- Stonington Community Center (COMO)
- Mystic River Park (Cottrell Street)

ARUP

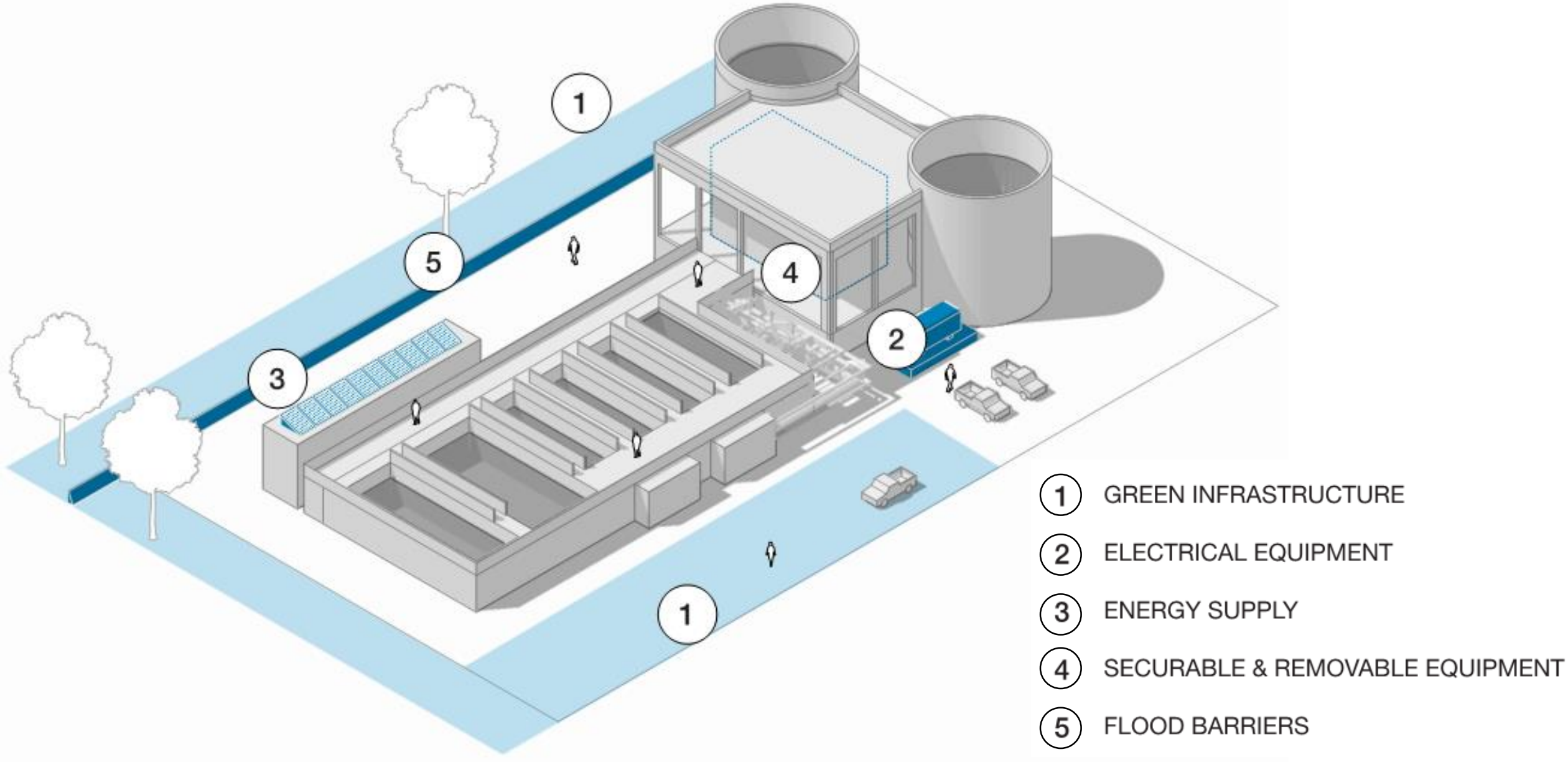
Proposed Resilience Solutions

ARUP



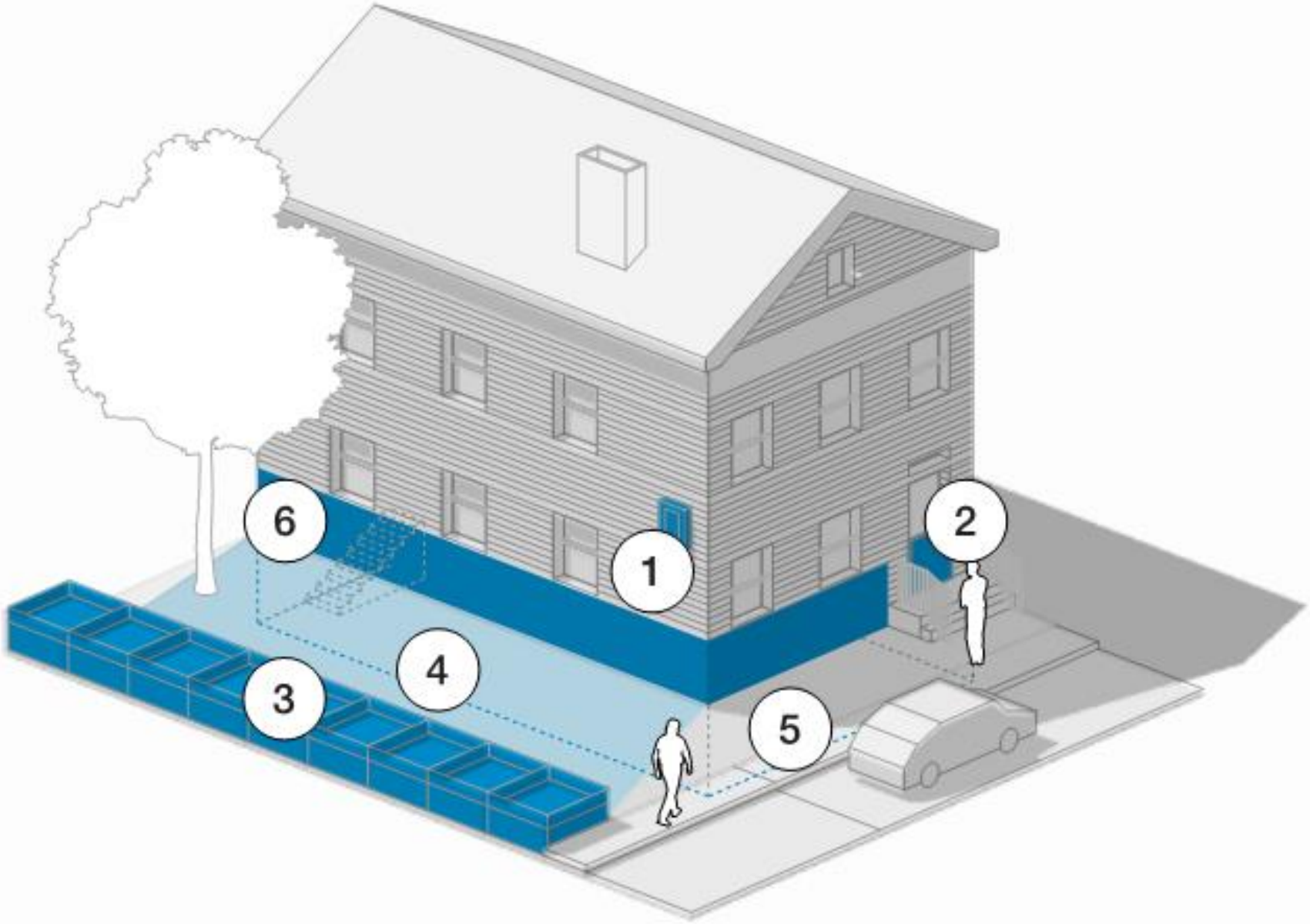
Solution #1: Apple Rehab Mystic

ARUP



Solution #2: Mystic Wastewater Treatment Facility

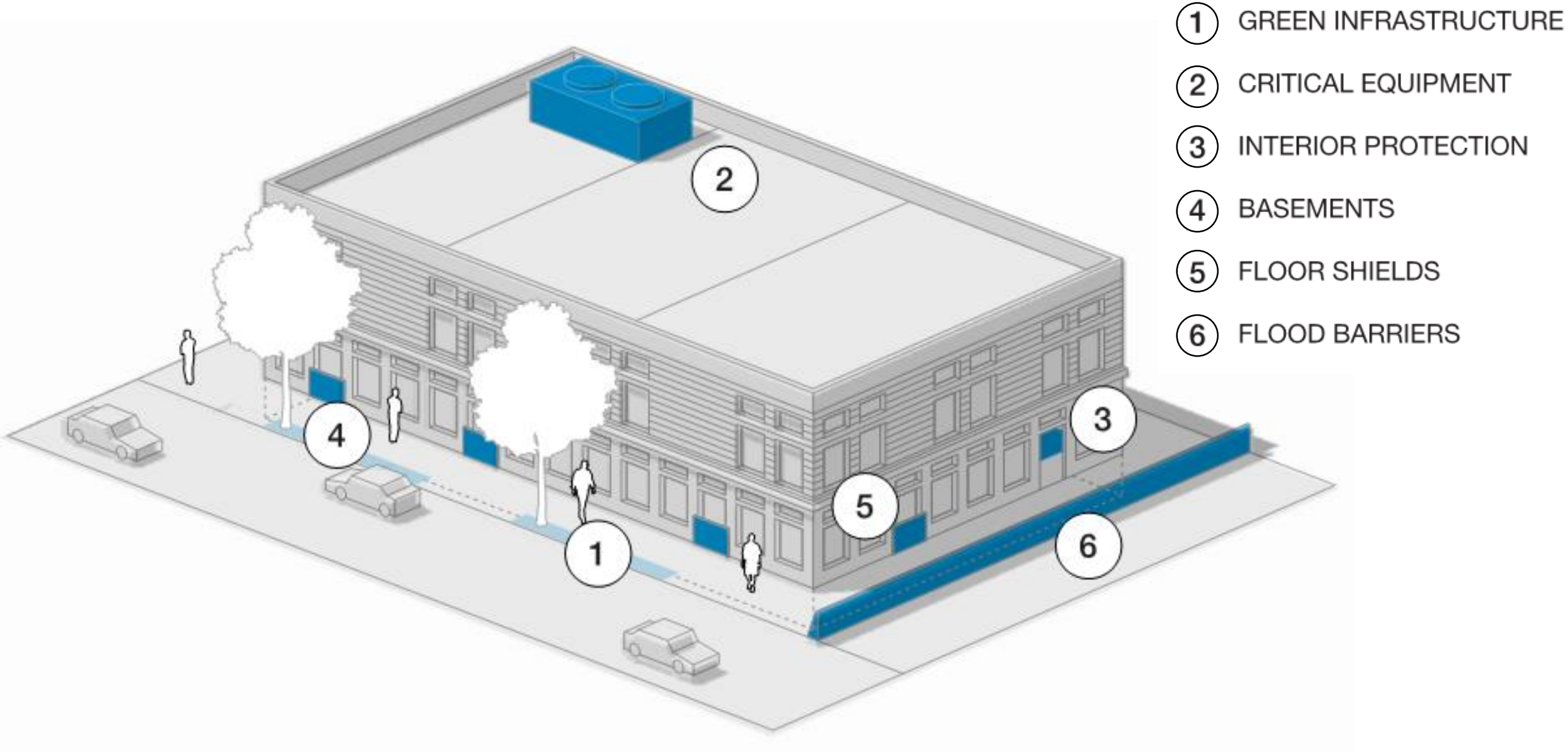
ARUP



1. ELECTRICAL WIRING
2. FLOOR SHIELDS
3. EMERGENCY BARRIERS
4. LANDSCAPING
5. IMPERMEABLE WALLS
6. BASEMENT

Solution 3(a): Typical Single-Family Home

ARUP



Solution #3(b): Typical Mixed-Use Building

ARUP

1. MYSTIC POST OFFICE
2. APPLE REHAB MYSTIC
3. FOURTH DISTRICT VOTING HALL
4. MYSTIC AMTRAK STATION
5. MYSTIC FIRE STATION
6. MYSTIC RIVER PARK
7. MYSTIC RIVER PARK PLAYGROUND
8. WASTEWATER TREATMENT PLANT
9. MAIN STREET BRIDGE

Solution #4: Mystic Neighborhood

ARUP

- Commercial and mixed-use strategies
- Natural retention and pooling areas
- Green infrastructure corridor
- Protection for critical community asset
- Alternative travel route
- Community greenspace for flood retention area
- Residential mitigation strategies
- Riverine flood barriers
- Appropriate land uses encouraged for water-adjacent areas

Solution #4: Mystic Neighborhood

ARUP

GREEN INFRASTRUCTURE

ROAD ELEVATION

SHORELINE TREATMENT

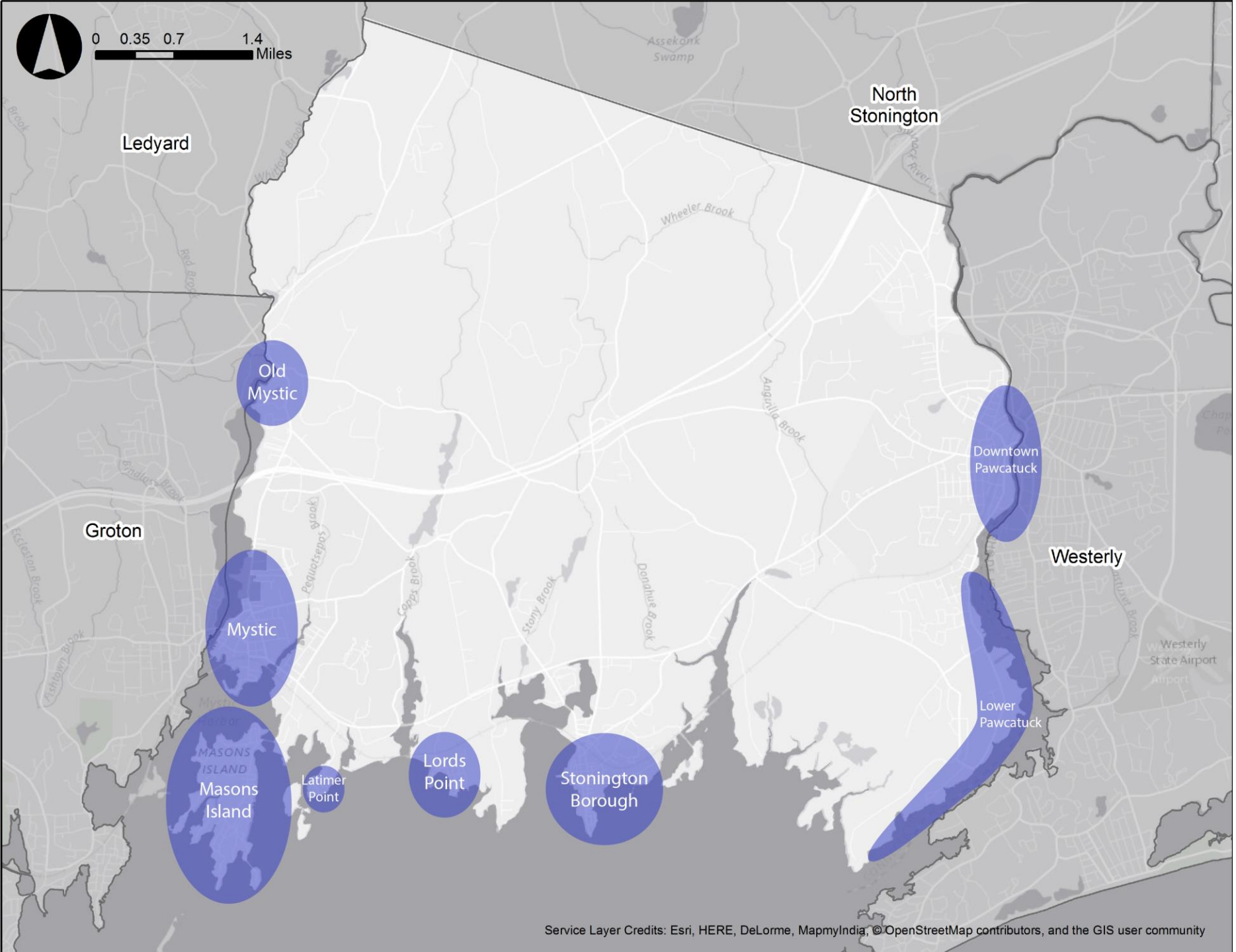
RISING GATE

Solution #5: Masons Island Causeway

ARUP

Regional Adaptations

ARUP

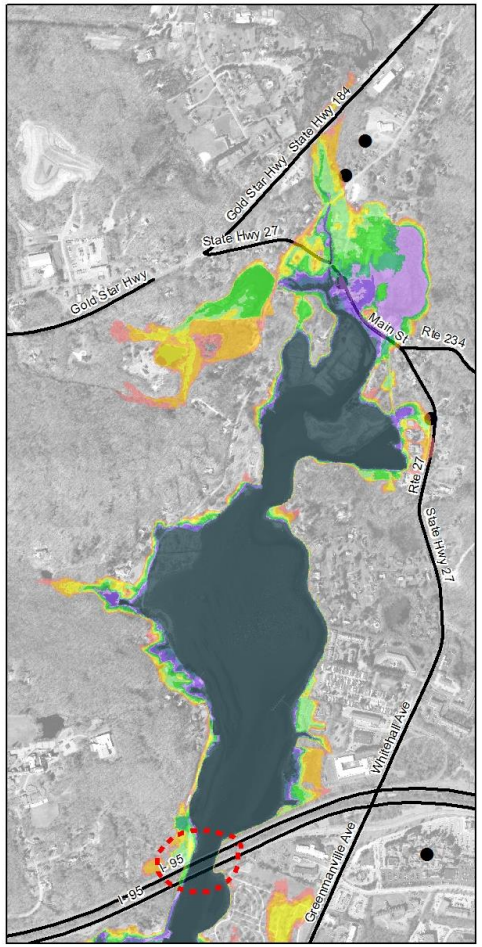


Neighborhoods

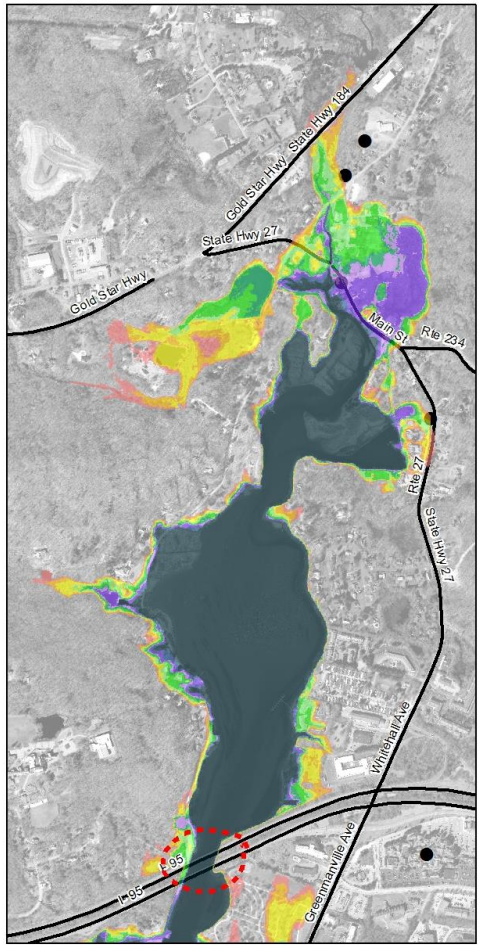
Most Vulnerable:

- Mystic / Murphy's Point
- Lords Point

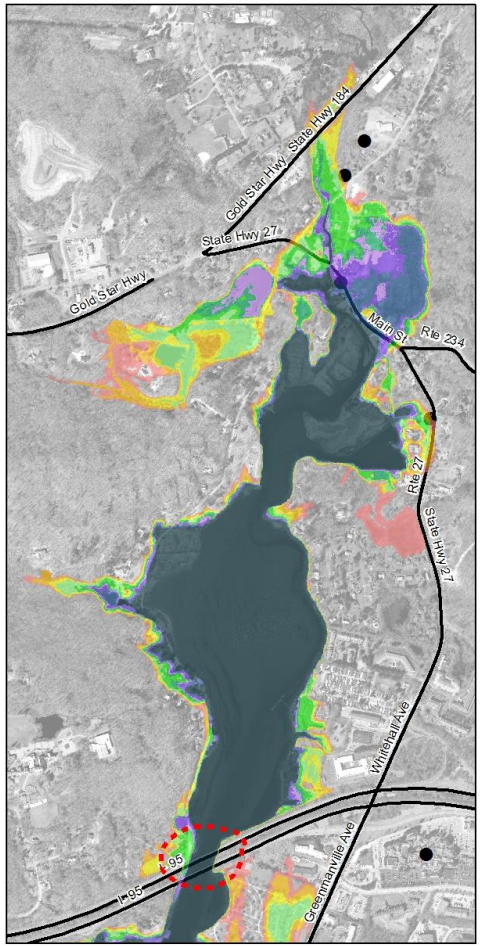
ARUP



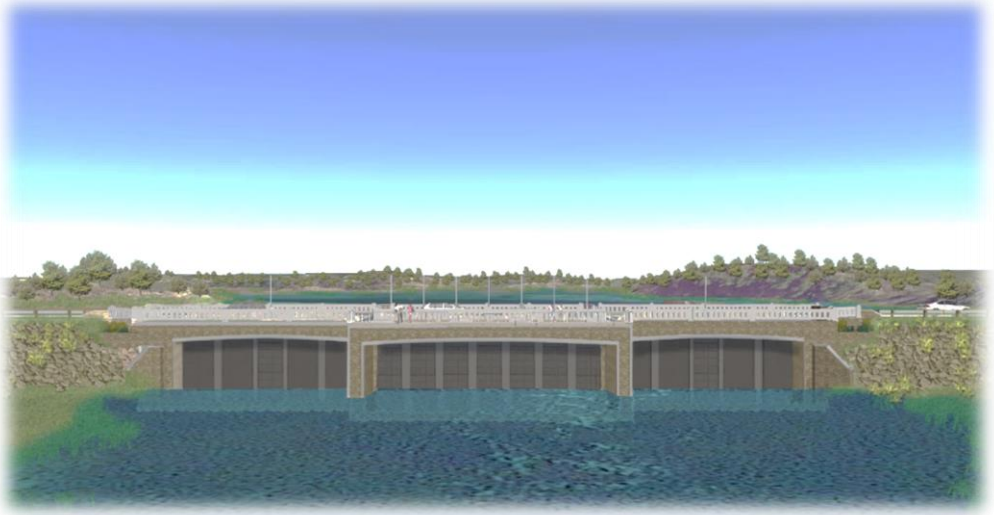
Present



2030



2050



Herring River Restoration Project, Wellfleet, MA

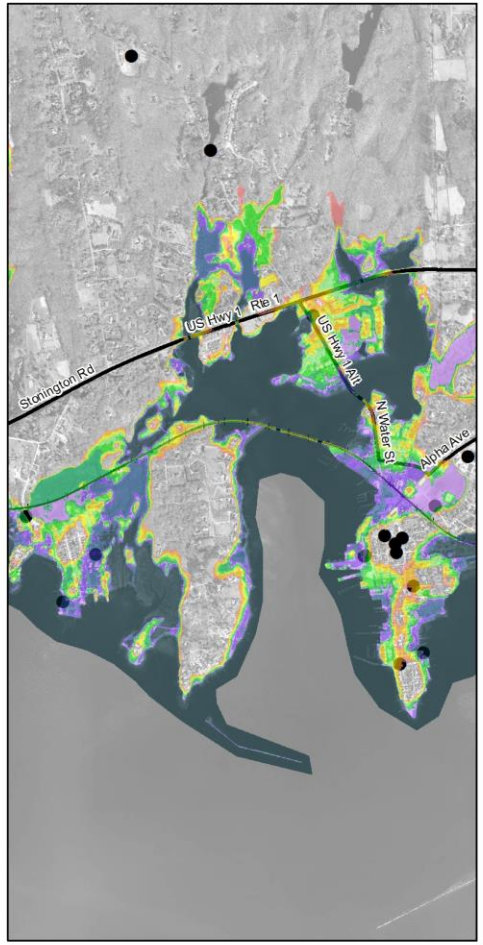
0 500 1000 2000 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

I-95 Regional Adaptation Option

ARUP



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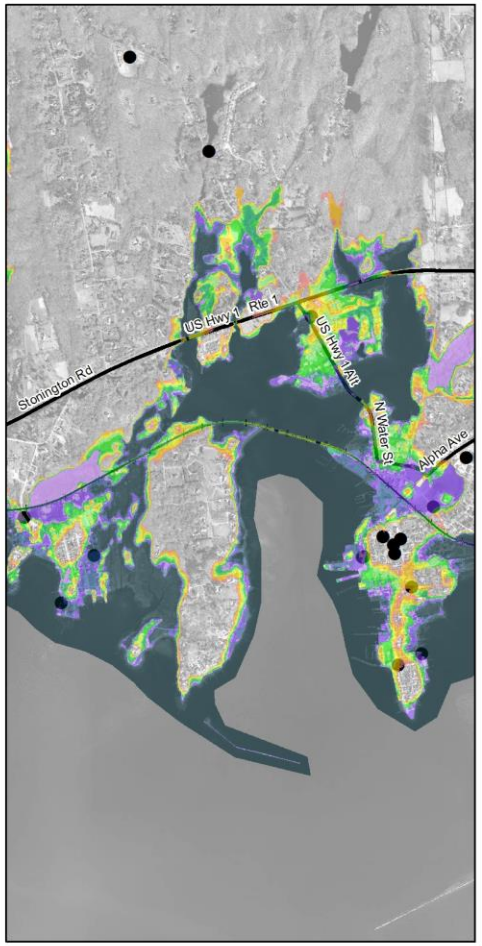

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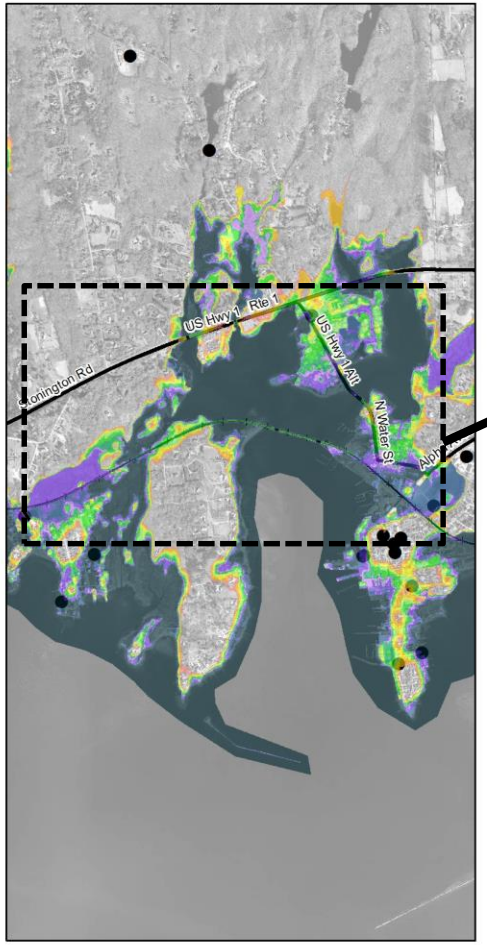
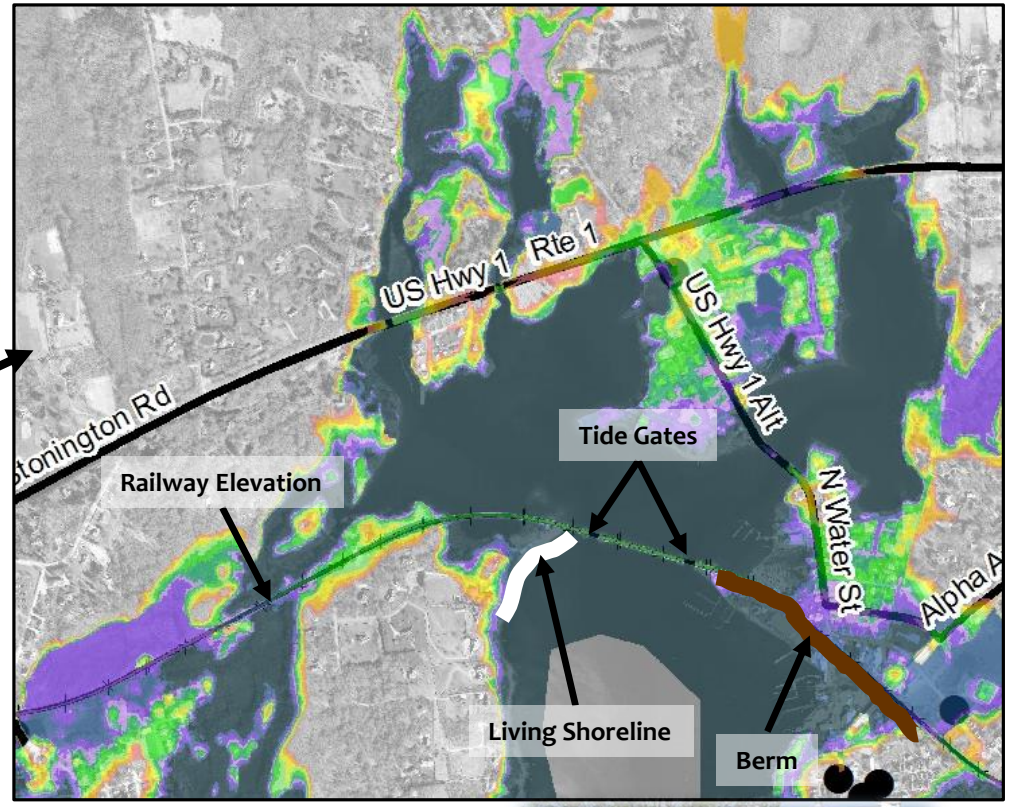


2050



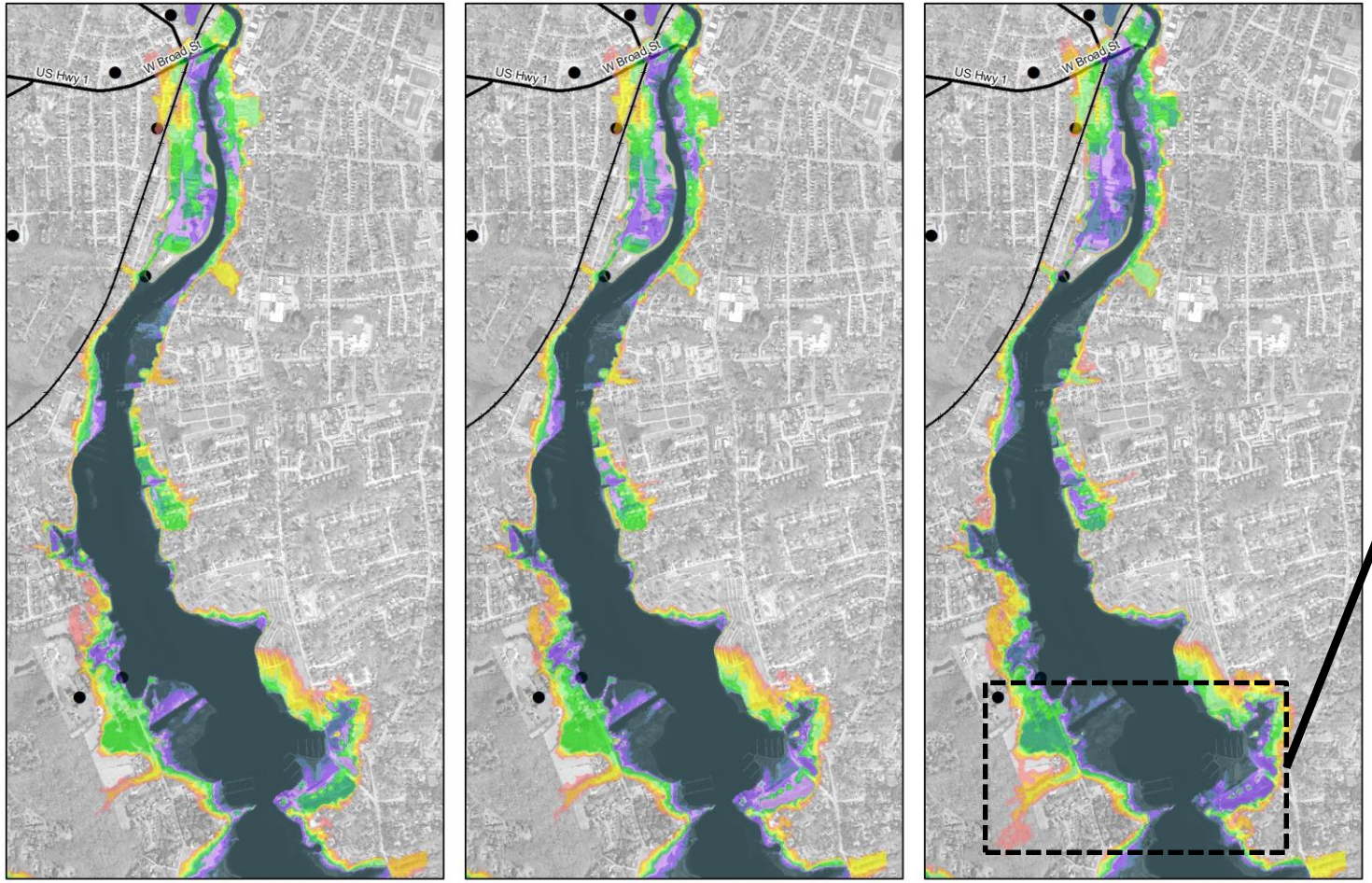
0 500 1000 2000 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

Stonington Borough Regional Adaptation Option

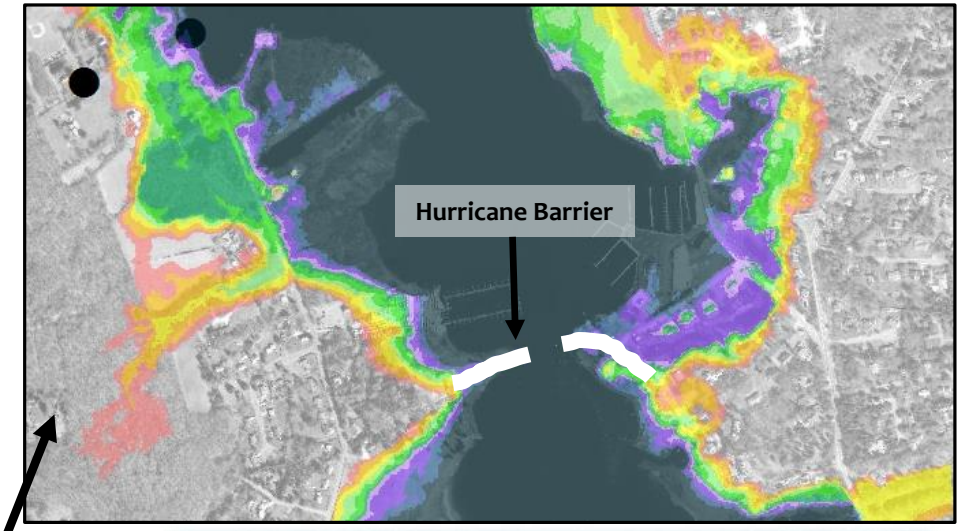
ARUP



Present

2030

2050



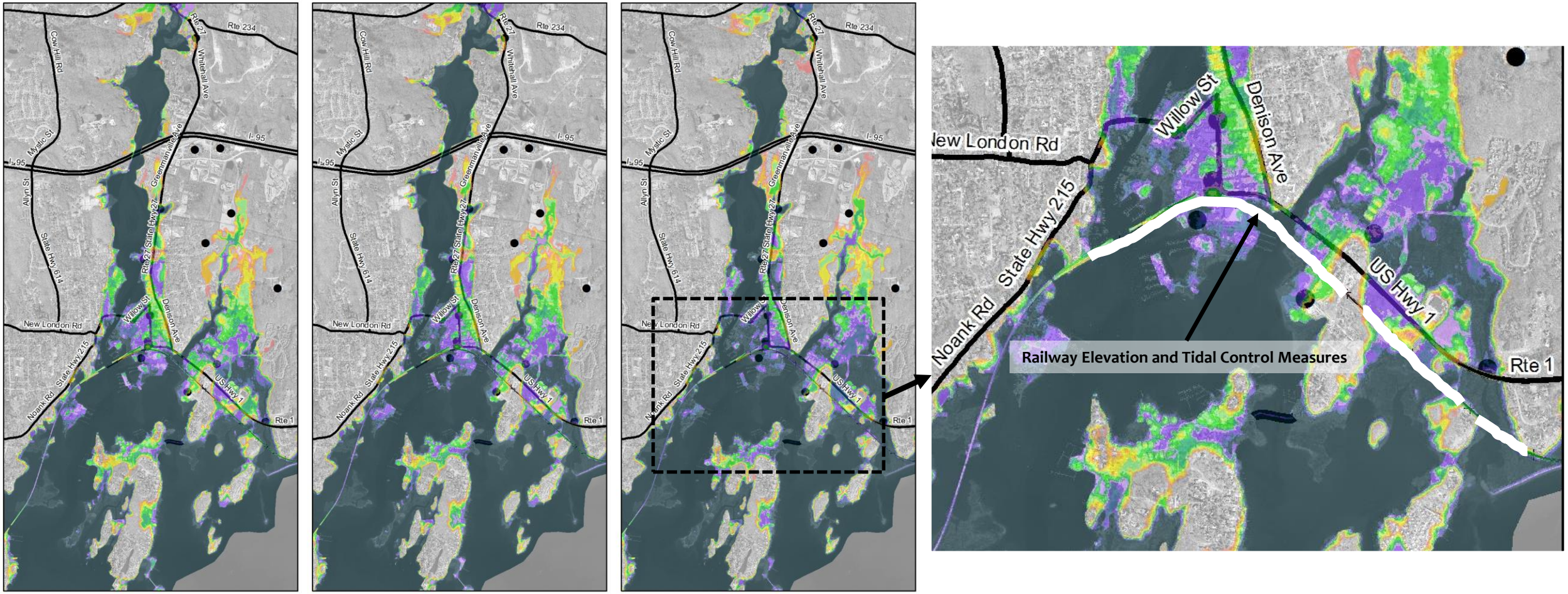
0 500 1000 2000 Meters

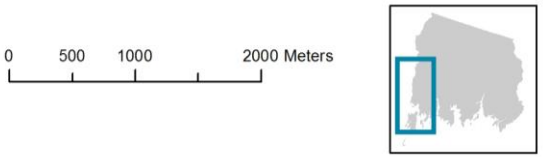
Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

Pawcatuck River Regional Adaptation Option

ARUP





Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

Mystic Regional Adaptation Option

ARUP

Next Steps

Final Plan June 2017 with public meeting launch

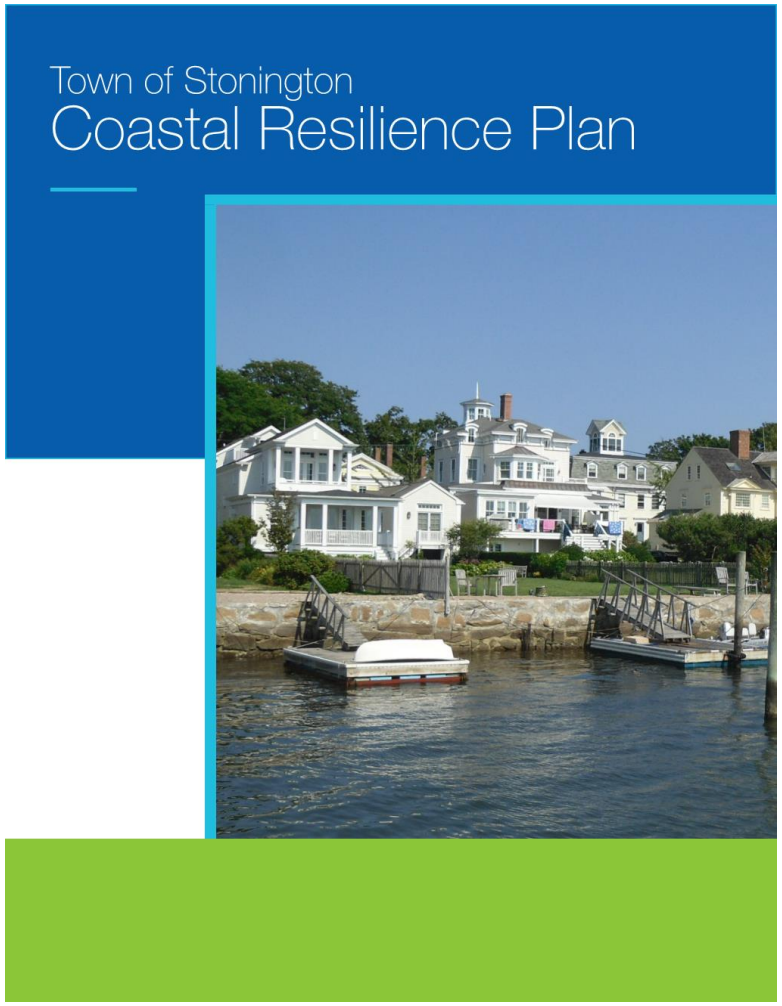
Please make sure you signed in at the entry table.
You will be added to email list for project updates.

For additional information on the project, please contact:

Keith Brynes
kbrynes@stonington-ct.gov
860-535-5095

OR follow us on social media!

#StoningtonReady
@StoningtonCTGov
@ArupAmericas



ARUP

Questions and Group Discussion

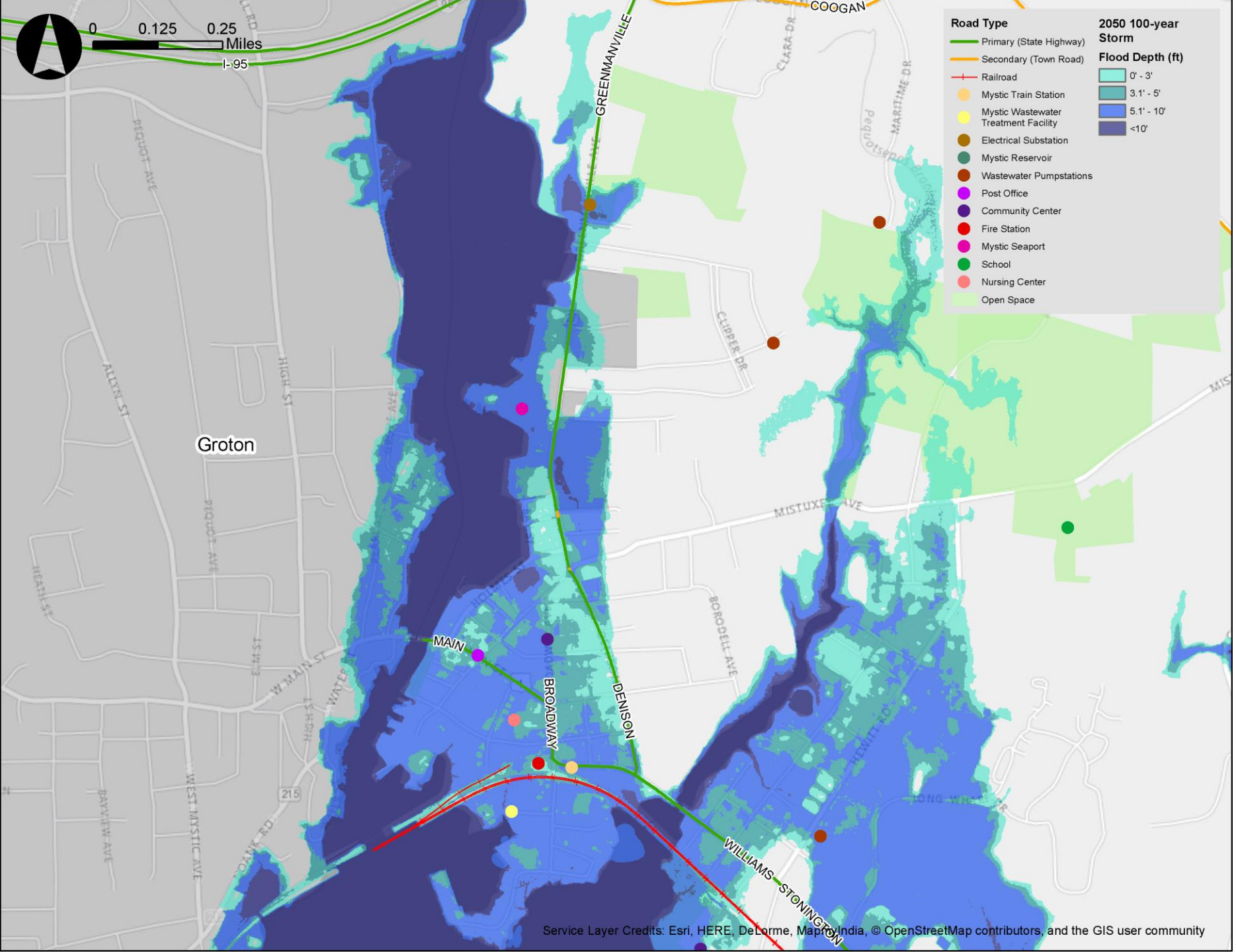
Storm Scenario: A 100-year storm event hits Stonington, causing major coastal flooding and knocking out electricity in the town for one week.

Group Discussion:

1. What are you most worried about during this event? (This can include concerns about particular assets or infrastructure in the community, concerns about the health and safety of you and your family, concerns about access to transportation in order to get to work, etc.)
2. Do you have any ideas on how the town can be better prepared and/or better protected against this type of event?

Extra Slides (not to be presented)

ARUP

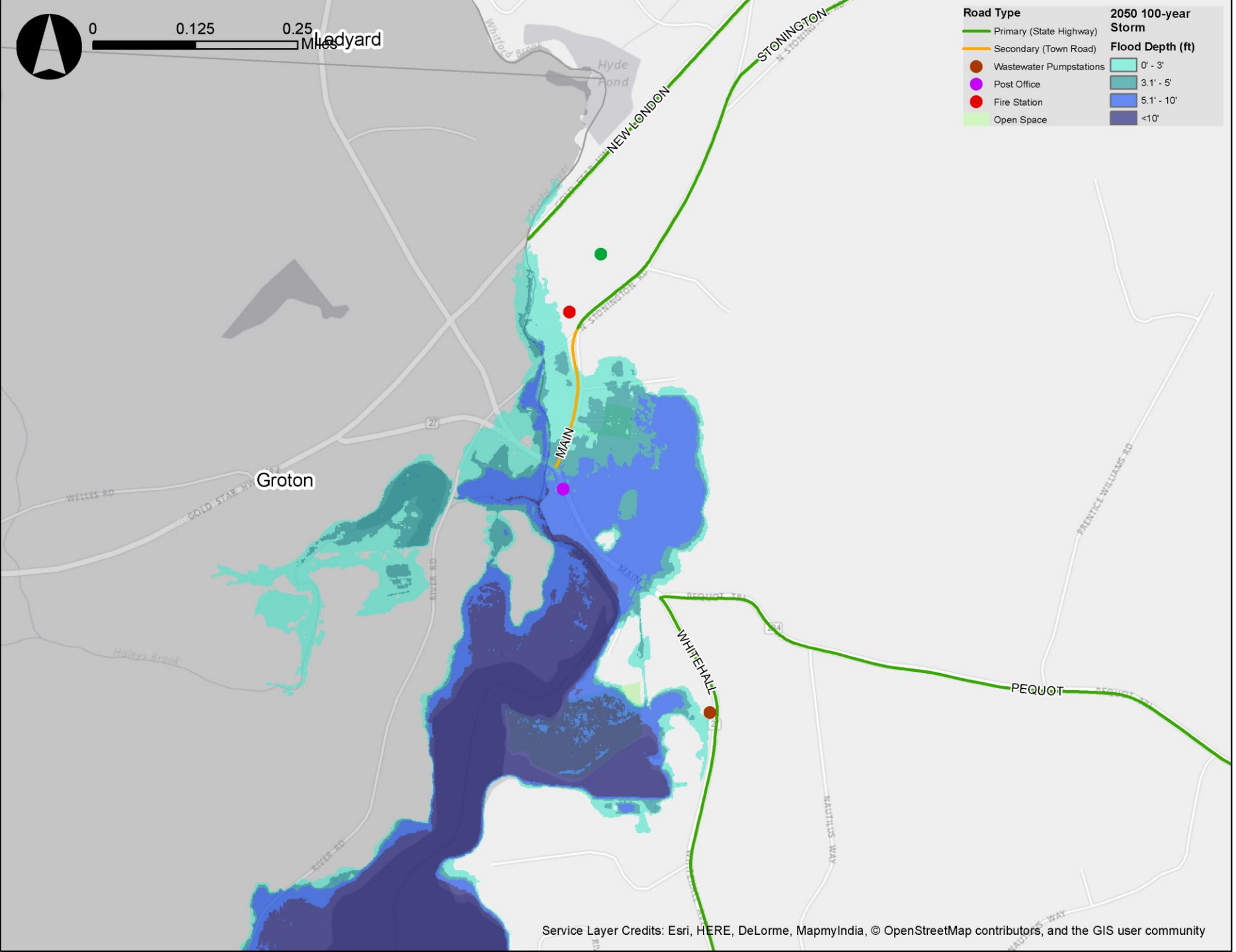


Mystic

Vulnerable Assets:

- Amtrak Rail Line
- Greenmanville Ave/Denison
- Stonington Rd
- Main St
- Greenmanville Ave Substation
- Mystic Seaport
- Mystic Post Office
- Former Fourth District Voting Hall
- Apple Rehab Mystic
- Mystic Fire Department
- Mystic Wastewater Treatment Facility
- Open Space

ARUP

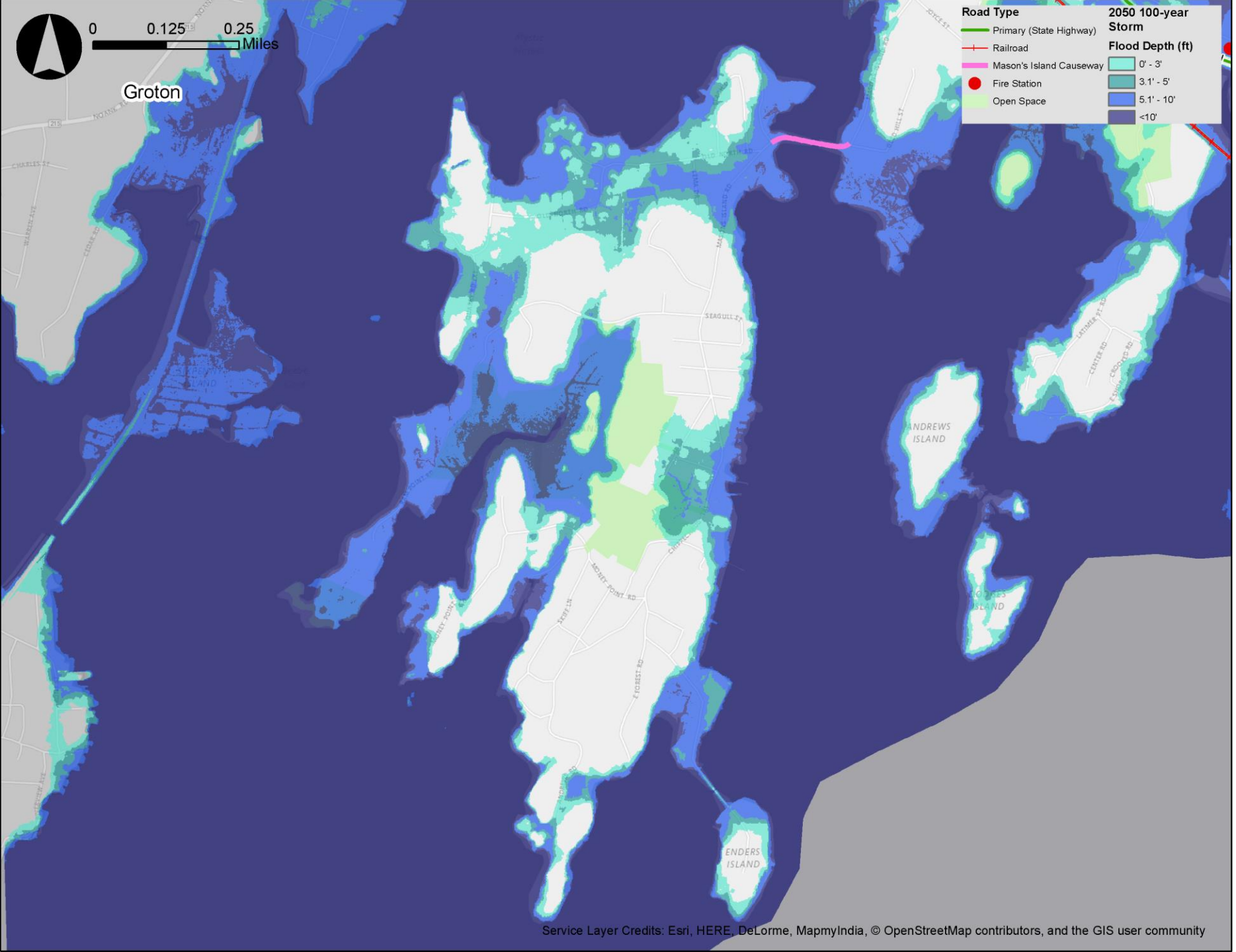


Old Mystic

Vulnerable Assets:

- Main Street
- Pequot Trail
- Old Mystic Post Office
- Open Space

ARUP

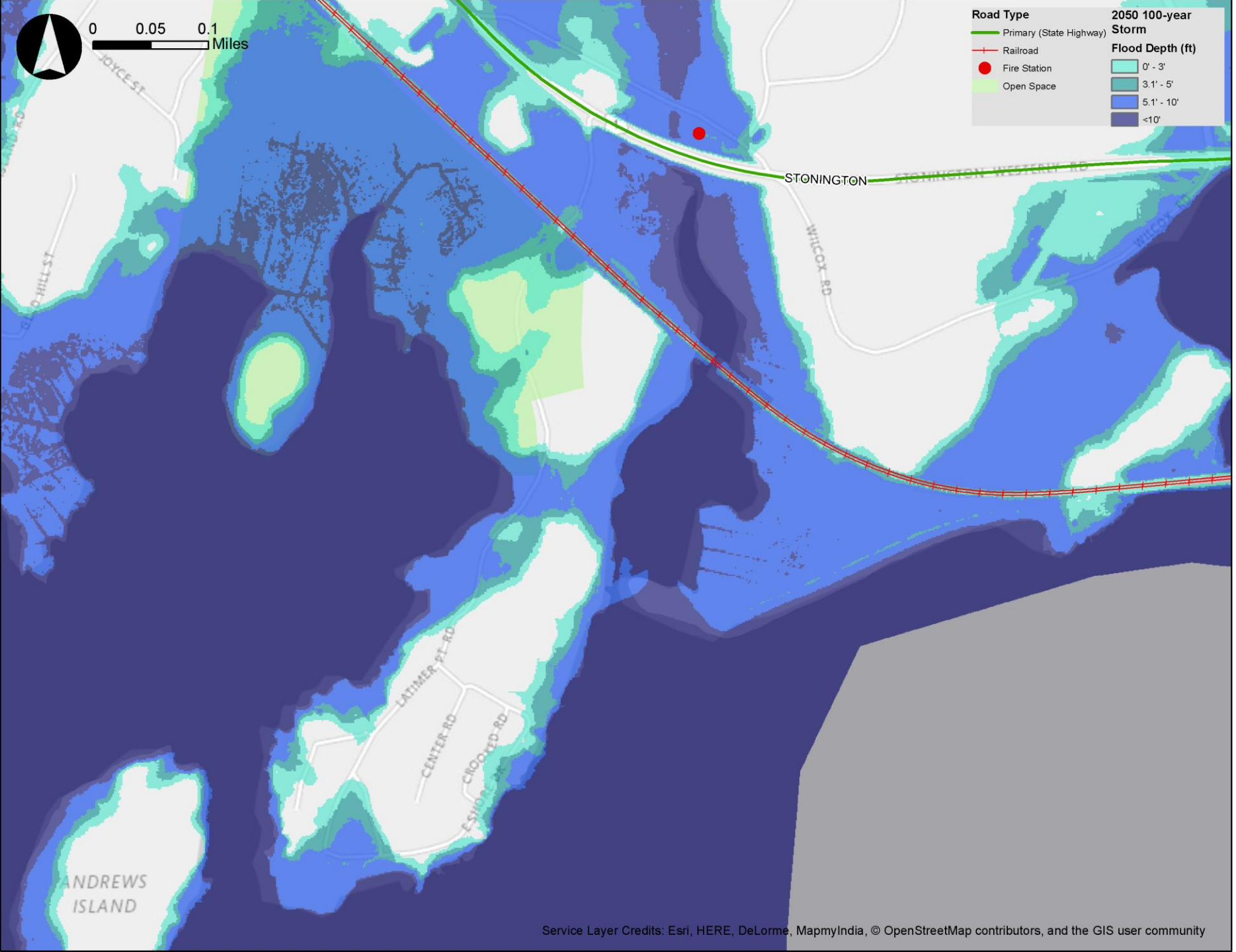


Masons Island

Vulnerable Assets:

- Masons Island Causeway
- Open Space

ARUP

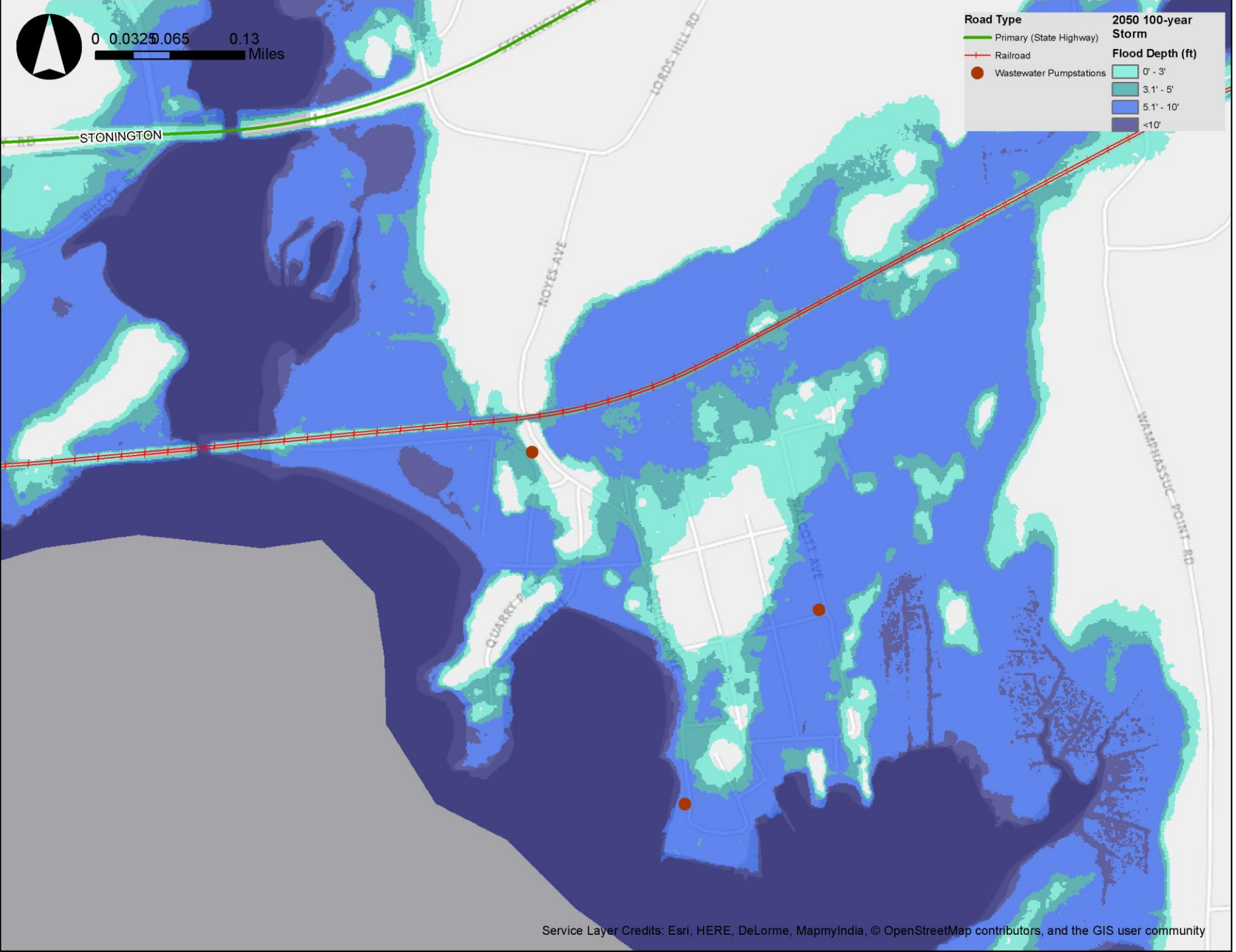


Latimer Point

Vulnerable Assets:

- Amtrak Rail Line
- Stonington Road
- Open Space
- Quiambaug Fire Department

ARUP

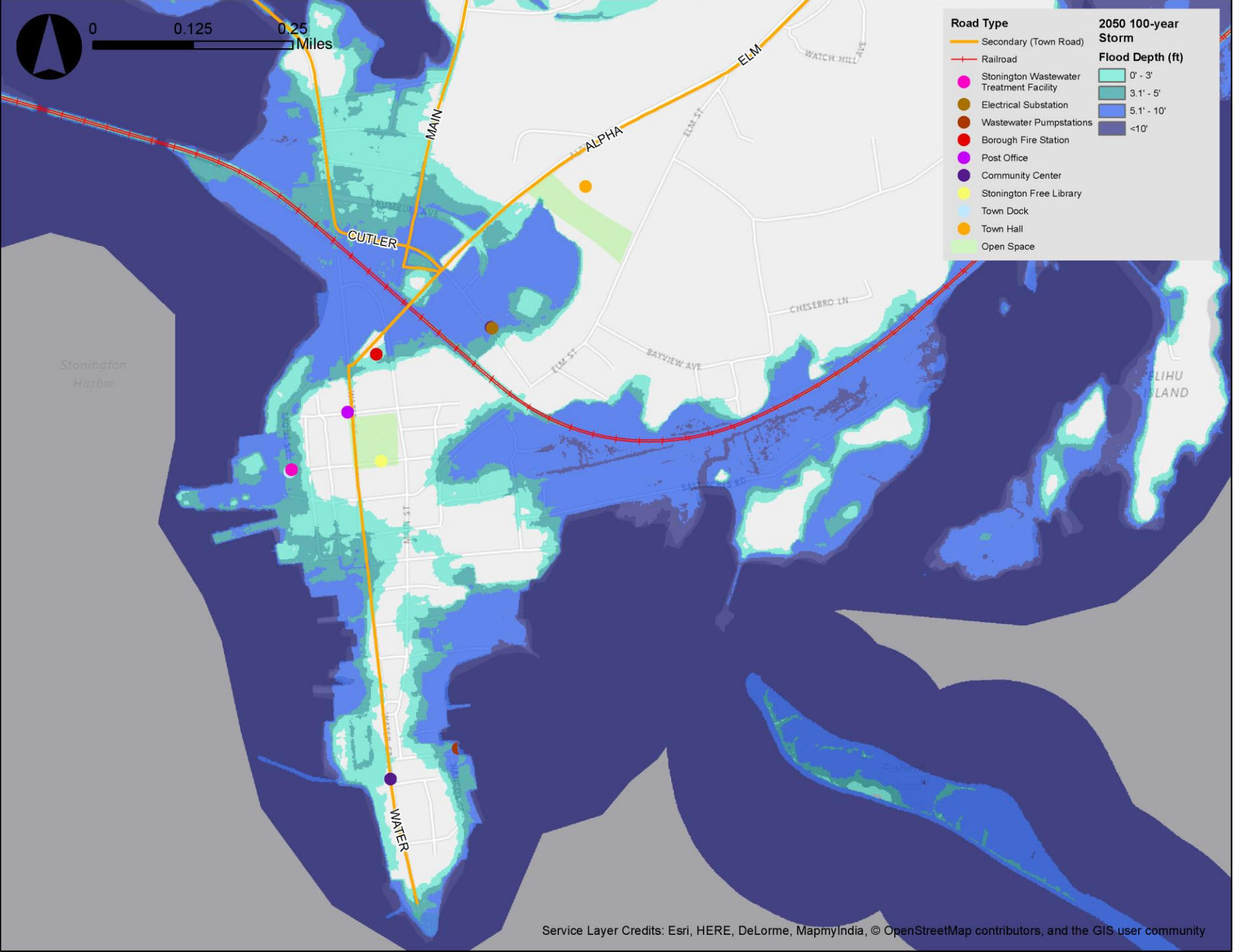


Lords Point

Vulnerable Assets:

- Amtrak Rail Line
- Stonington Road
- Wastewater Pump Stations

ARUP

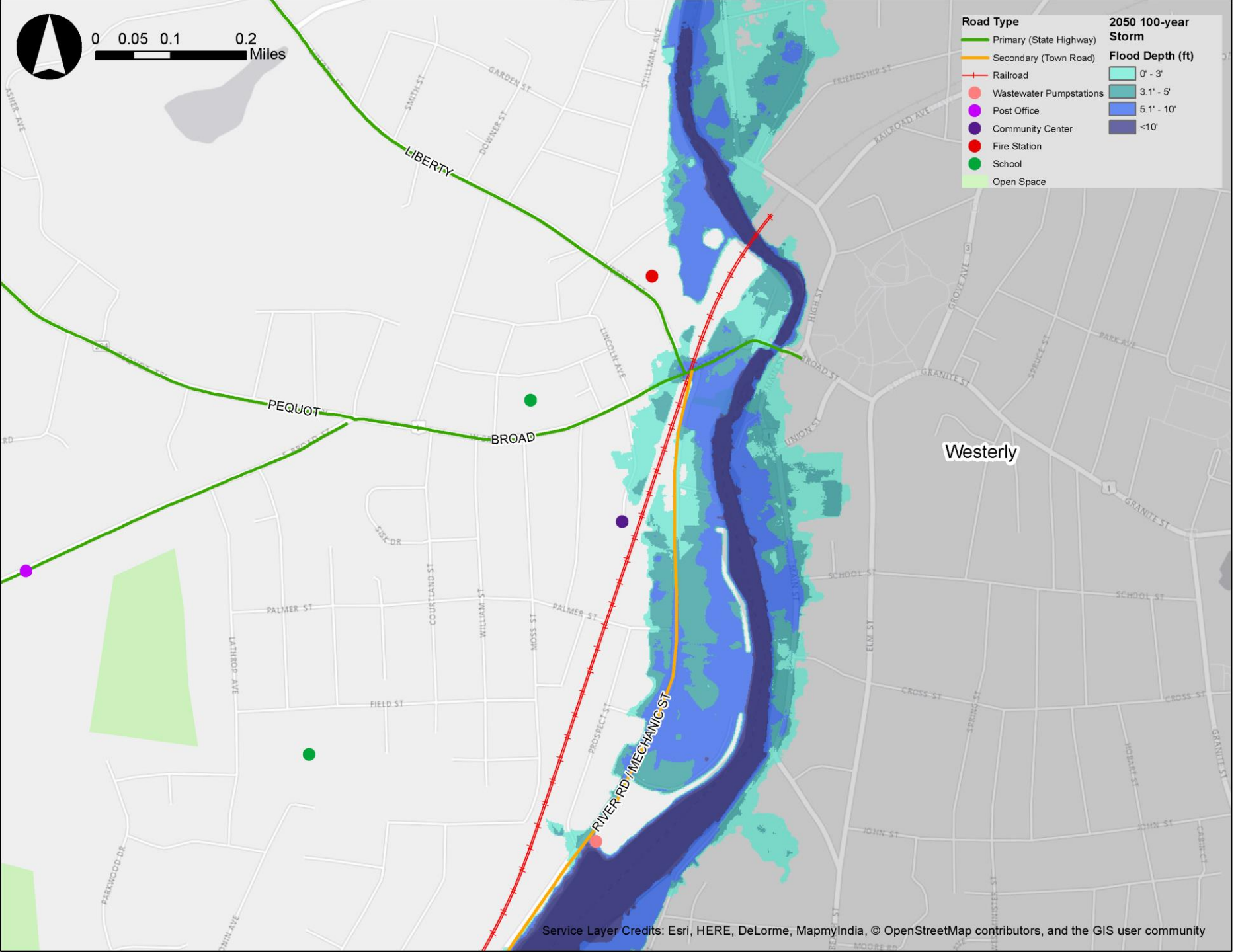


Stonington Borough

Vulnerable Assets:

- Amtrak Rail Line
- Water St
- Main St
- Cutler St
- Alpha Ave/Elm St
- Cutler St Electrical Substation
- Stonington Community Center
- Stonington Wastewater Treatment Facility
- Borough Fire Station
- La Grua Center
- Open Space

ARUP

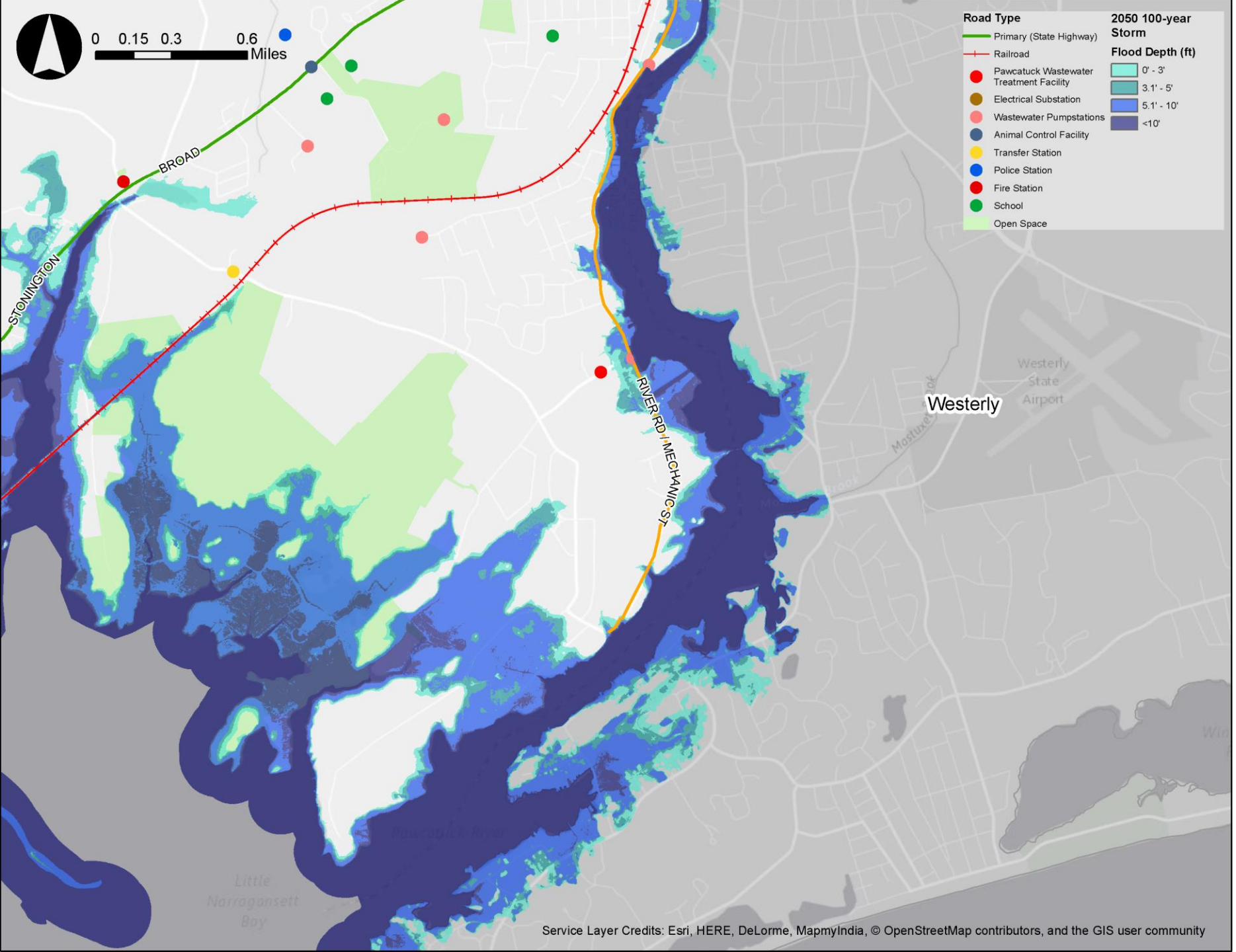


Downtown Pawcatuck

Vulnerable Assets:

- Amtrak Rail Line
- River Rd/Mechanic St
- Broad St
- Liberty Rd
- Pump Station

ARUP

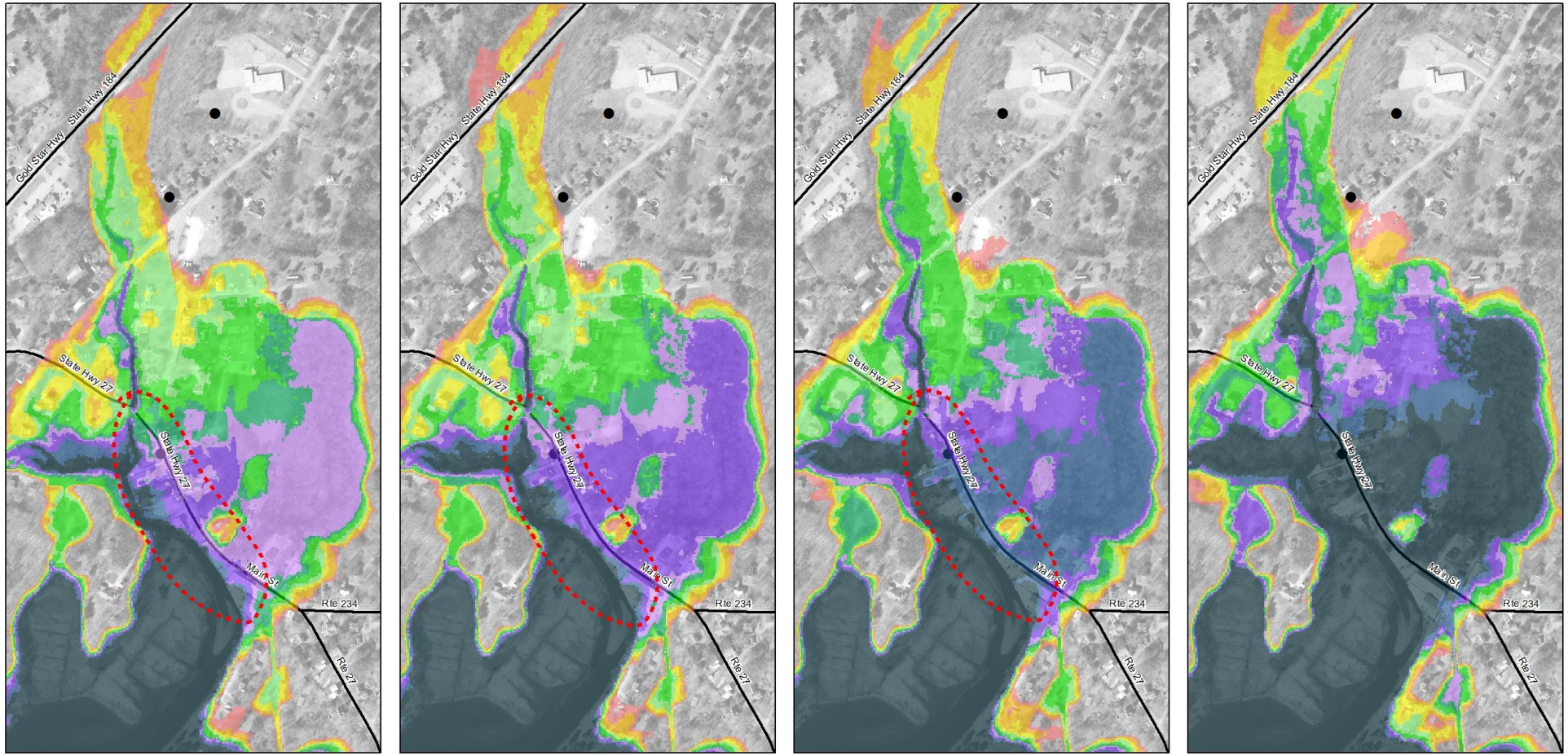


Lower Pawcatuck

Vulnerable Assets:

- Amtrak Rail Line
- River Rd/Mechanic St
- Wastewater Pump Station

ARUP



Present **2030** **2050** **2070**

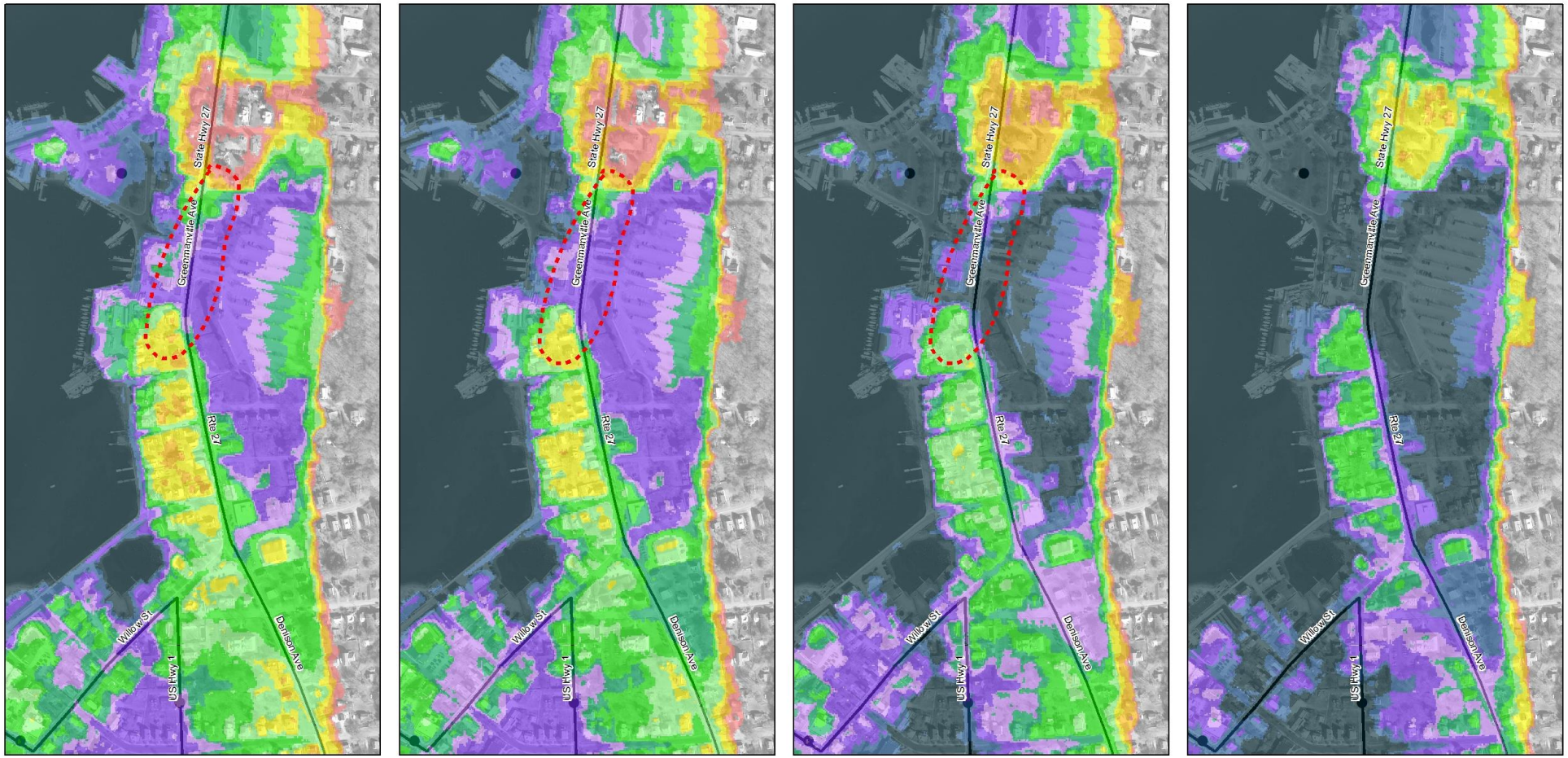
0 100 200 400 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

Old Mystic Regional Adaptations

ARUP



Present 2030 2050 2070

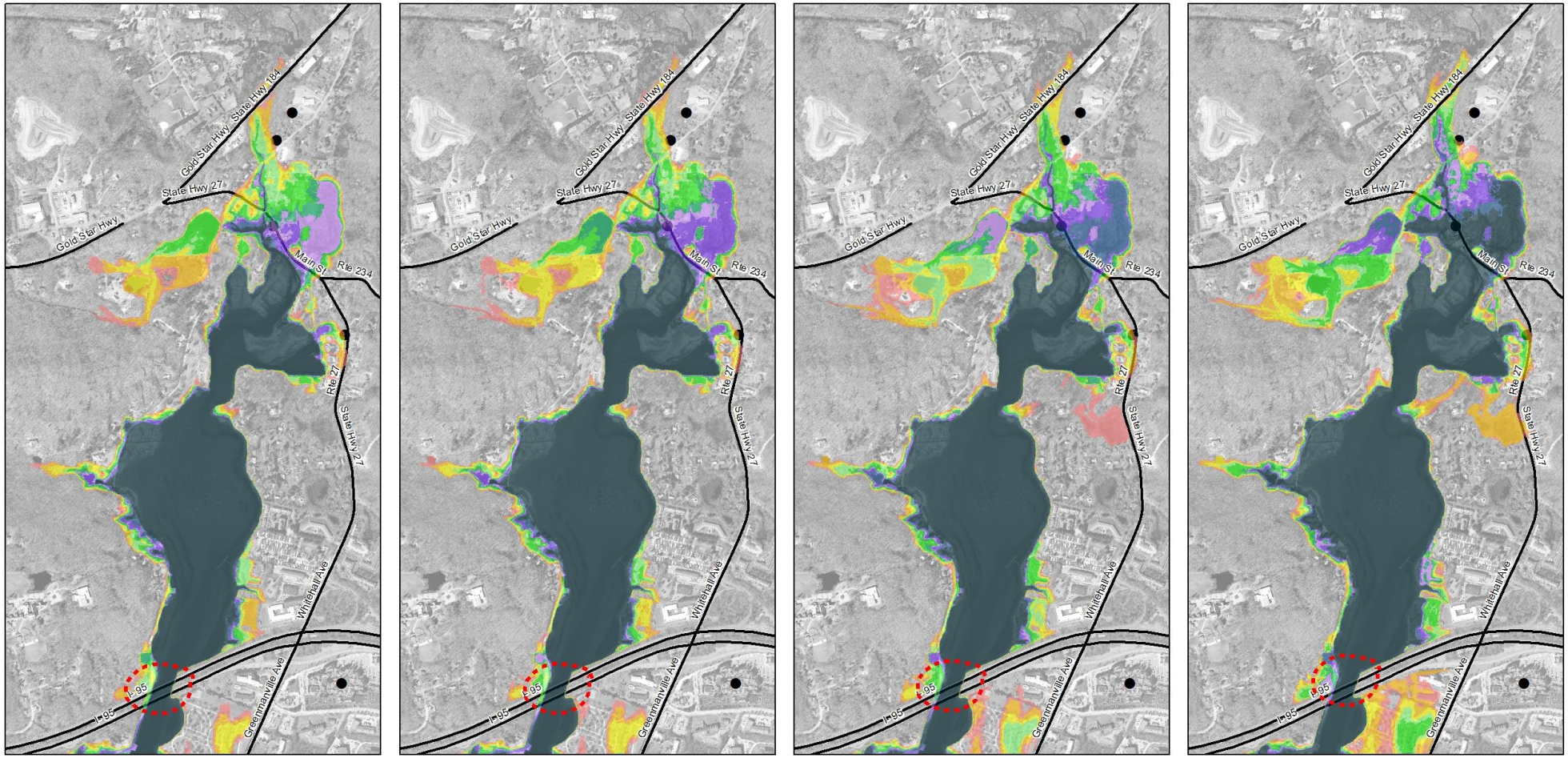
0 100 200 400 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

Mystic Flood Pathways

ARUP



Present 2030 2050 2070

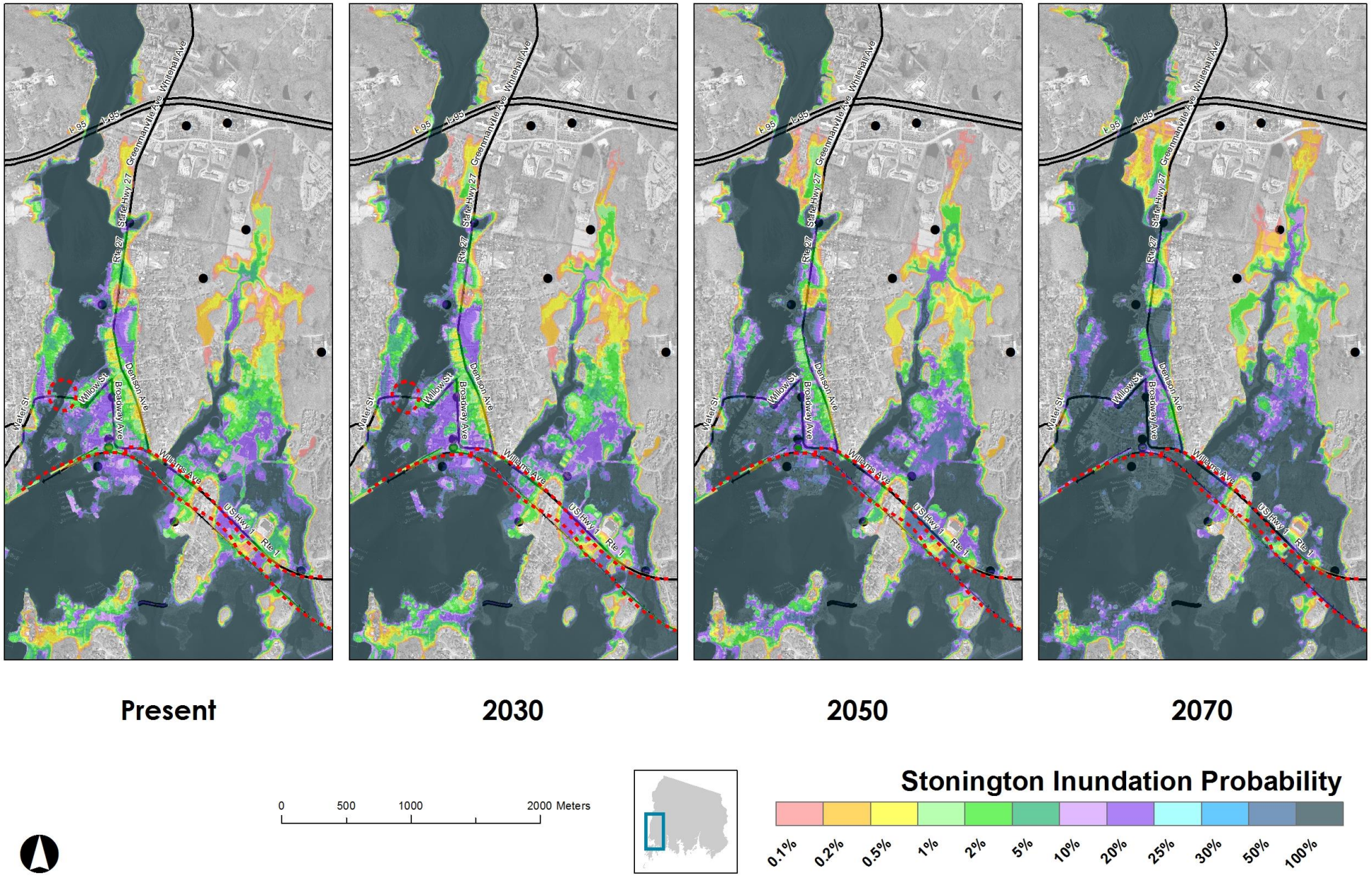
0 250 500 1000 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

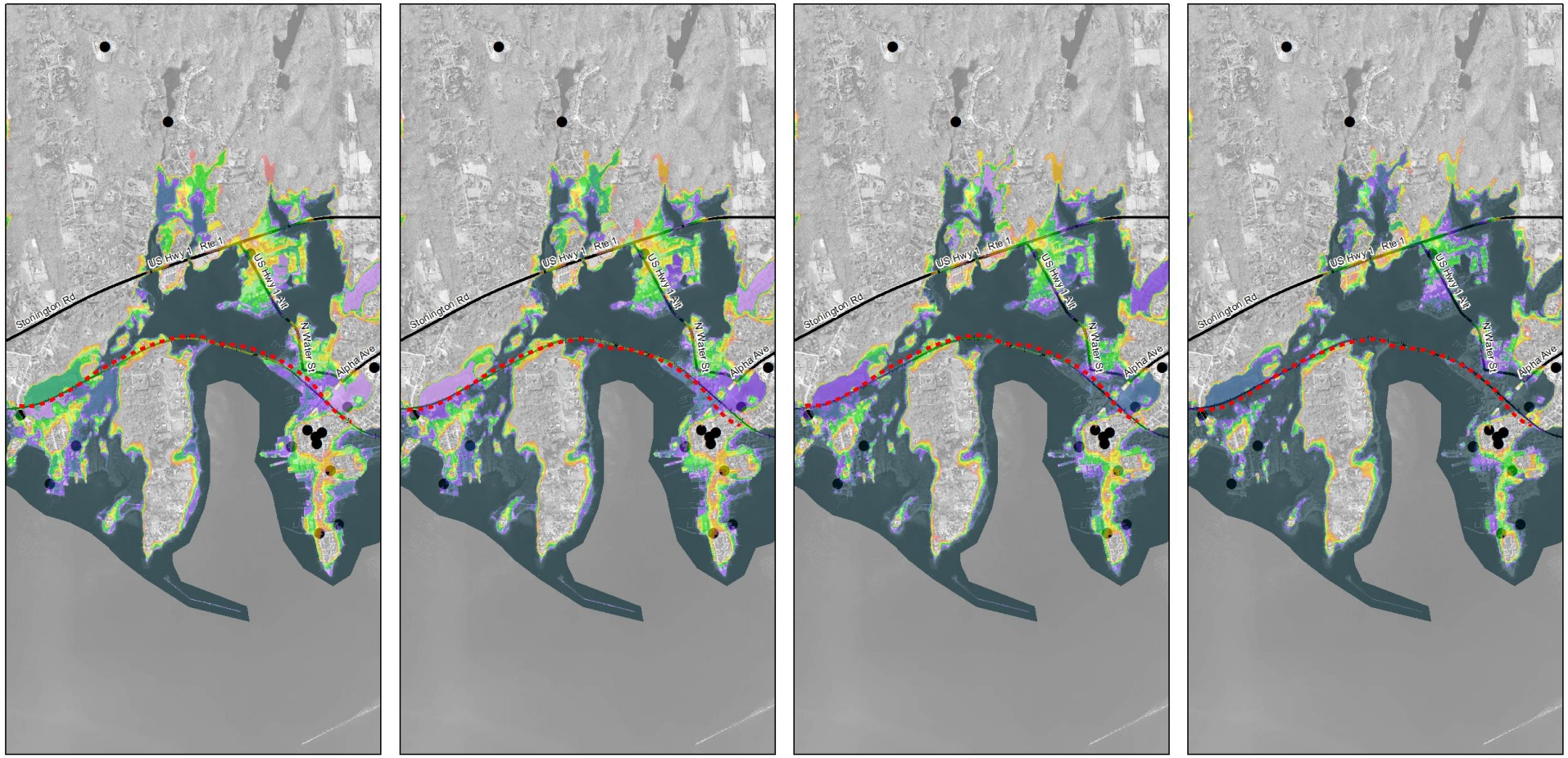
I-95 Regional Adaptations

ARUP



Mystic & Latimer Point Regional Adaptations

ARUP



Present **2030** **2050** **2070**

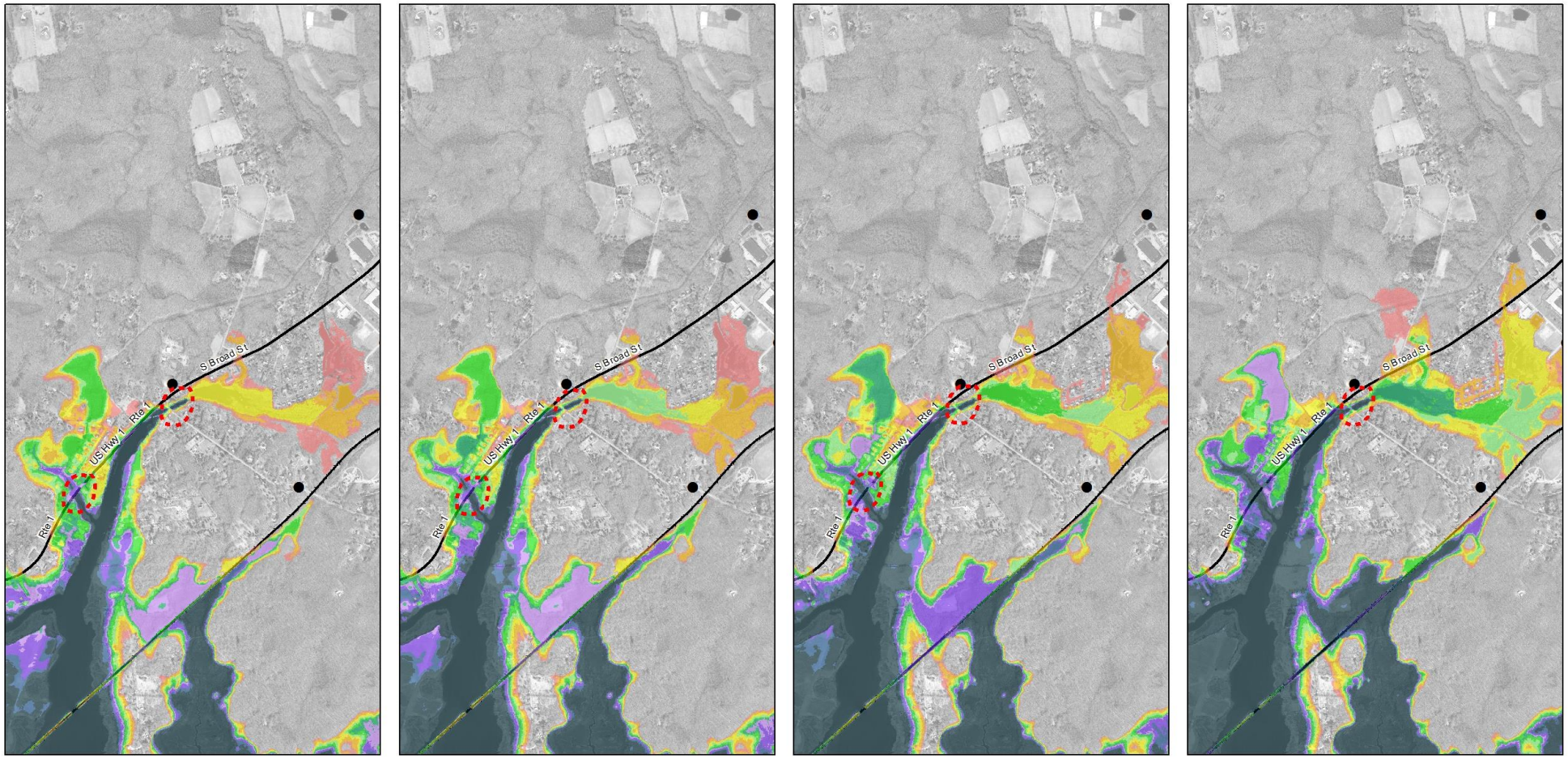
0 500 1000 2000 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

Amtrak Rail Line Regional Adaptations

ARUP



Present 2030 2050 2070

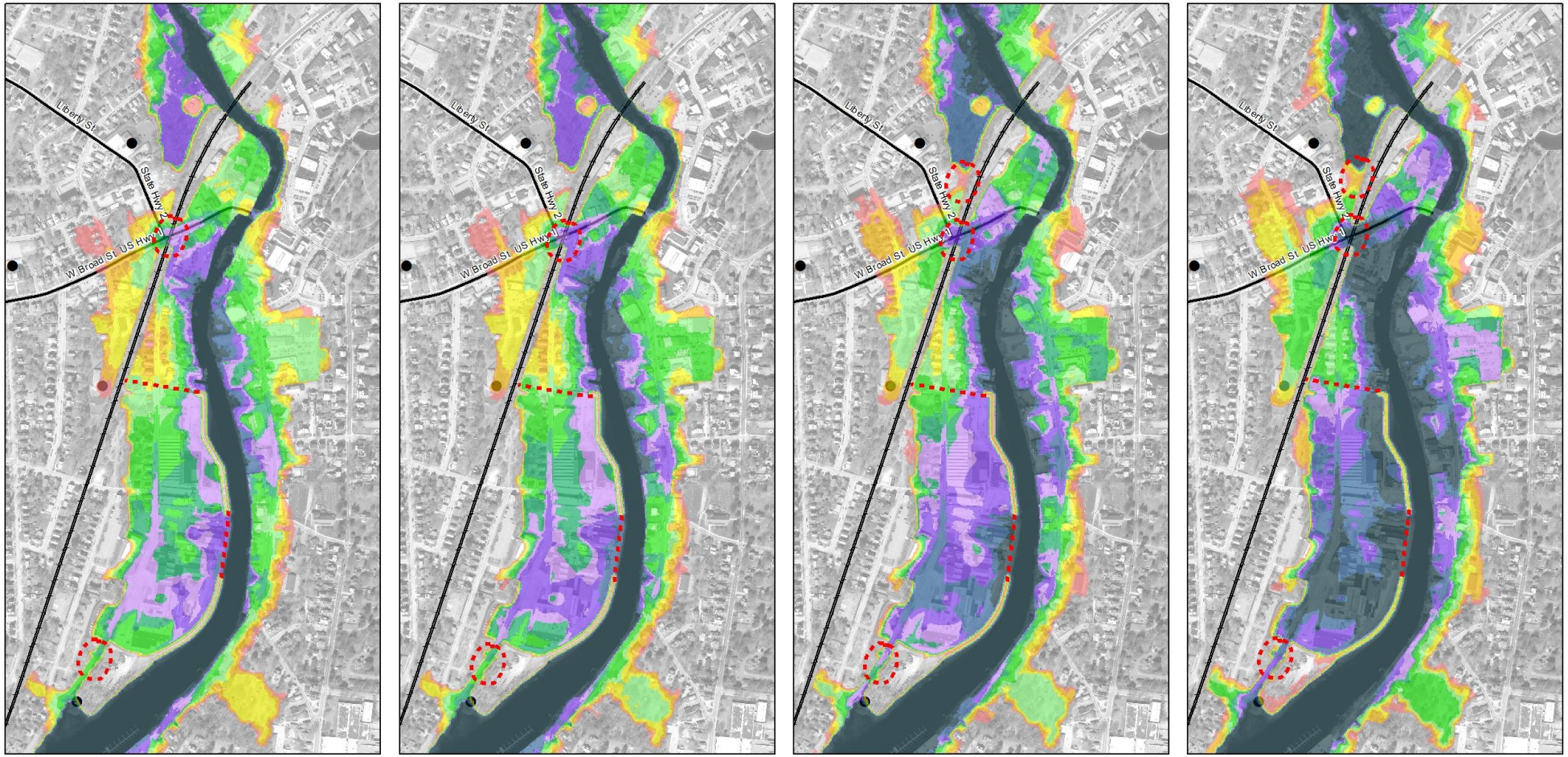
0 500 1000 2000 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

Route 1 Regional Adaptations

ARUP



Present 2030 2050 2070

0 200 400 800 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

Downtown Pawcatuck Flood Pathways

ARUP

4 Public Meeting #3 (July 19, 2017)

The final public meeting, held at the La Grua Center on July 19, 2017, presented the final results of the plan. Because this was the final meeting, there were no targeted questions for the public to answer; instead, the Arup Team held an open question and answer session to address any questions the public had in regards to the final plan.

The following is a copy of the presentation made at the meeting.

Town of Stonington

Coastal Resilience Plan

July 2017

TDA
TRAINING & DEVELOPMENT ASSOCIATES, INC.

CivicMoxie™
experts in place

WOODS HOLE GROUP

ARUP

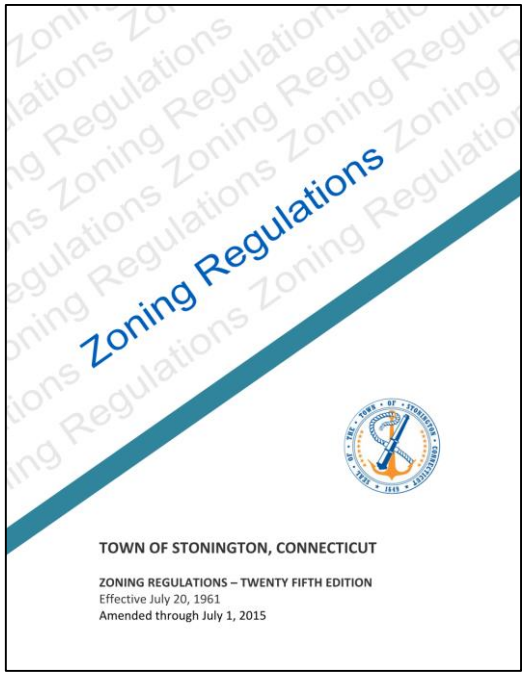
Coastal Flooding in Stonington

- Since 1978, Stonington residents have received over $4.5 million in flood insurance payouts
- Global mean sea levels have risen by 8-9 inches since 1880 (rate of 0.06-0.07 inches annually)
- In the Northeast, sea levels have risen approximately 1 foot over the last century (50% faster than the global average)
- Major flood events occurred July 2009 & March 2010
- Superstorm Sandy caused significant damage to the Town Dock and Mason's Island Causeway
- 4057 properties currently at-risk (worth $1.8 billion*)
- 4246 properties at-risk by 2050 (worth $2 billion*)

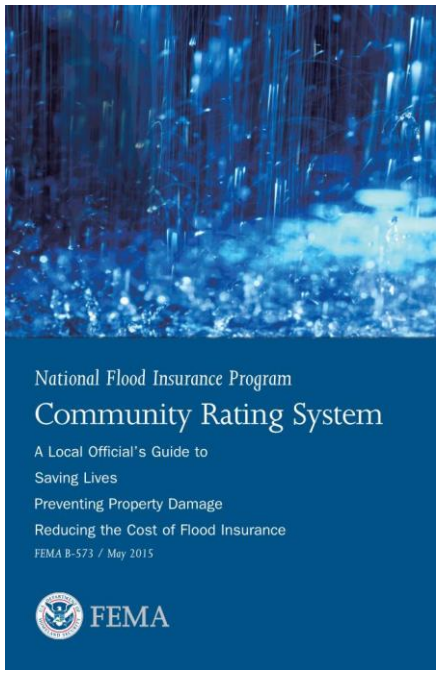
Source: The Westerly Sun

*Values taken from the 2016 Stonington Assessor's Database

Stonington's Current Flood Protection Actions



Restrict development in the 100-year floodplain and require elevation of new construction above base flood elevation



Past participation in the Community Rating System

Construction, maintenance, and improvements to flood control structures.

TDA CivicMoxie experts in place WOODS HOLE GROUP ARUP

Goals for the Coastal Resilience Plan

Identify Stonington's vulnerability

Educate the community on the coastal flood risks

Develop resilience solutions and next steps

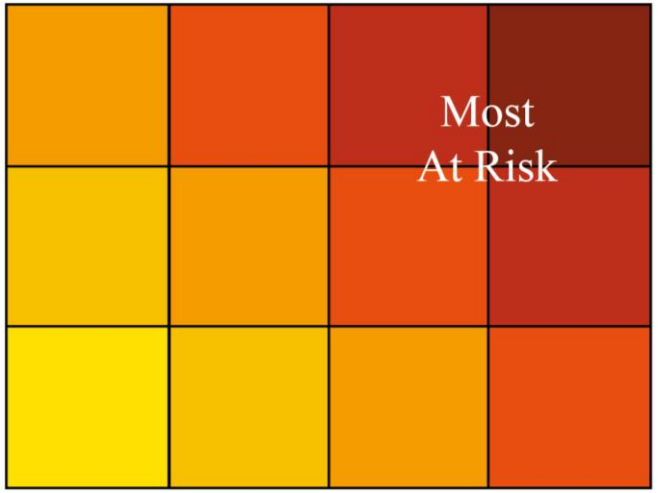
TDA CivicMoxie experts in place WOODS HOLE GROUP ARUP

Overview of Approach

Step 1

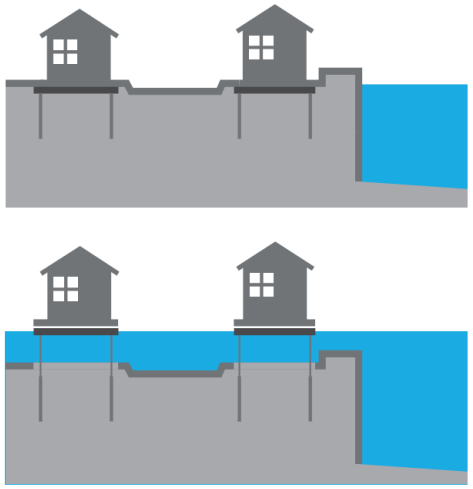
Establishing a climate baseline

Step 2



Ranking risk

Step 3



Developing solutions

2015

2030

2050

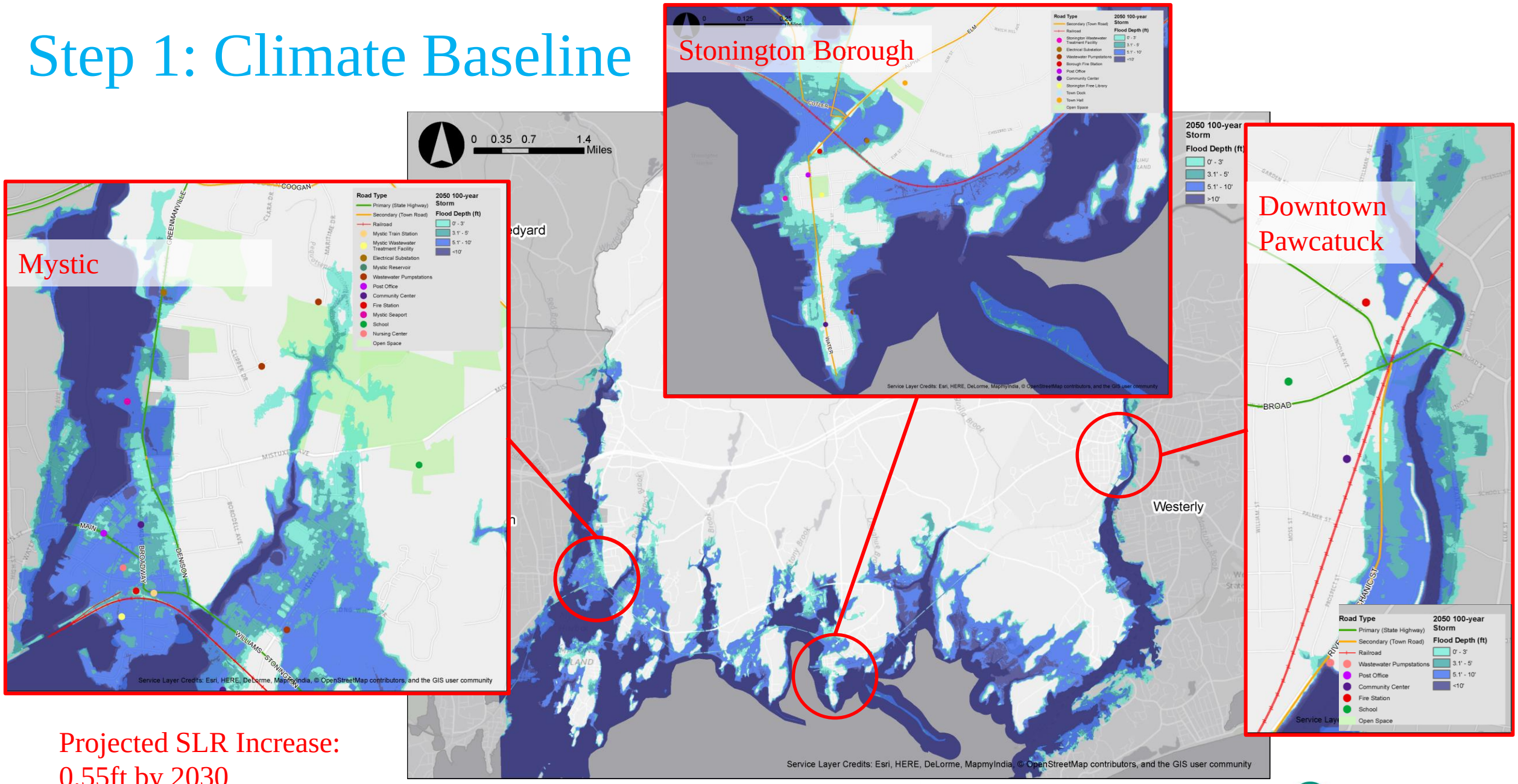
TDA

CivicMoxie experts in place

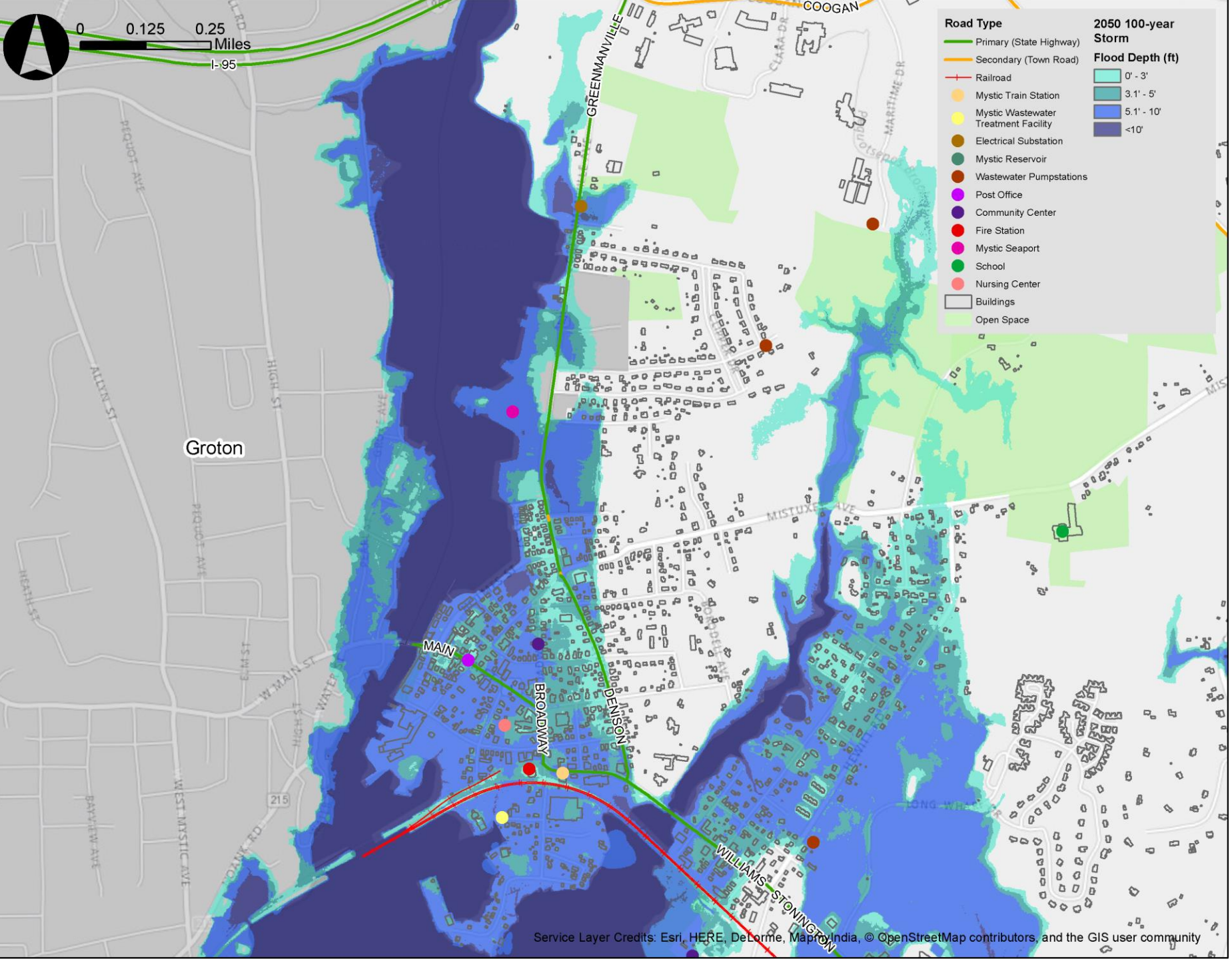
WOODS HOLE GROUP

ARUP

Step 1: Climate Baseline



Projected SLR Increase:
0.55ft by 2030
1.69ft by 2050



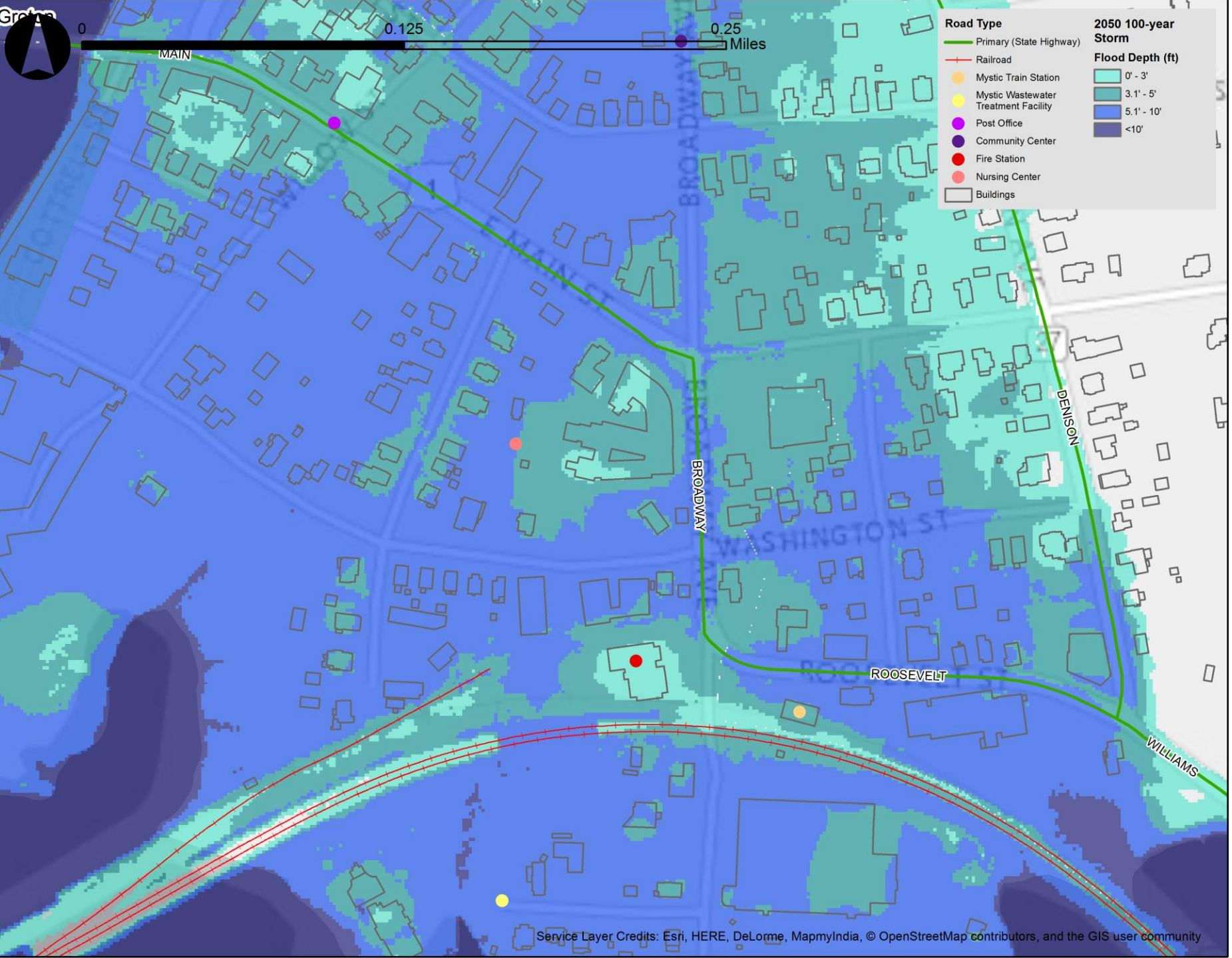
Village of Mystic

TDA

CivicMoxie
experts in place

WOODS HOLE GROUP

ARUP



Downtown Mystic

TDA

CivicMoxie
experts in place

WOODS HOLE GROUP

ARUP

Step 2: Risk Assessment

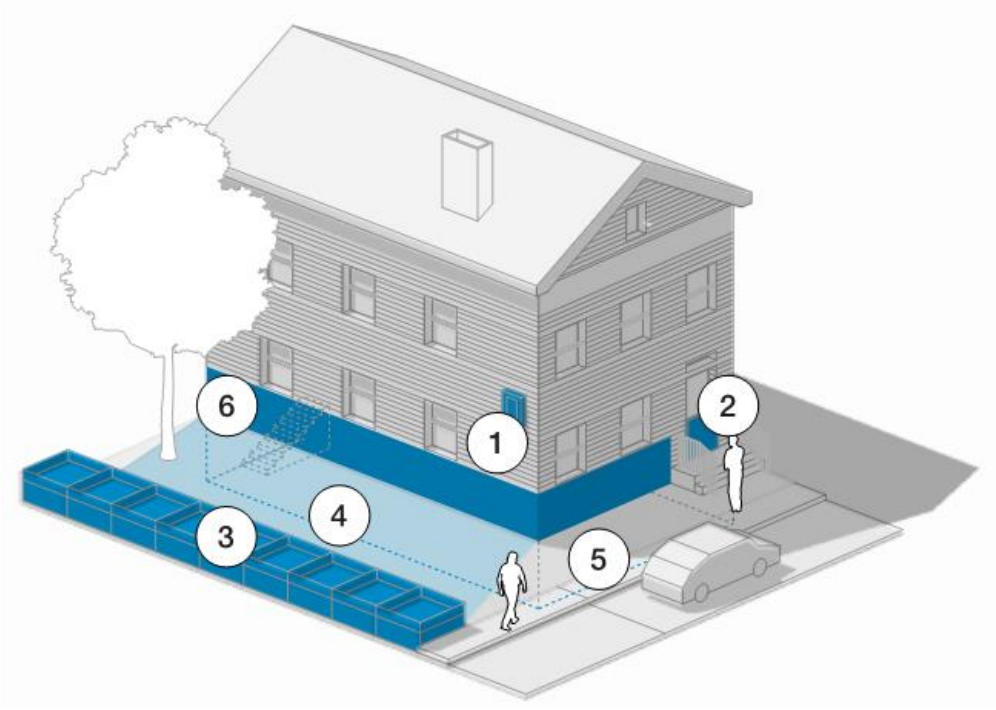
Risk = Hazard x Exposure x Vulnerability

- **Hazard** = Storm Event (i.e. Present-day 100-year storm, 100-year storm in 2030, 1000-year storm in 2050)
- **Exposure** = Depth of Flooding
- **Vulnerability** = An Assessment of:
    - Impact on community
    - Critical Facilities
    - Replacement Cost
    - Economic impact to tourism (including historic resources)

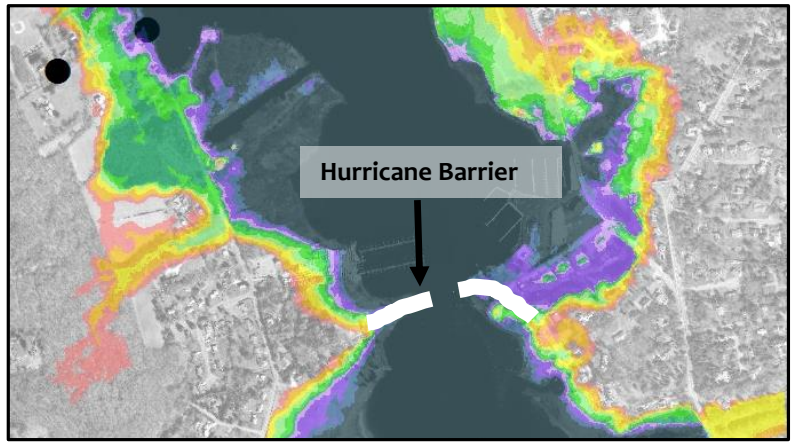
25 Highest Risk Assets

Masons Island Causeway	Mystic Bridge Historic District	State Highway 1
Mystic Wastewater Treatment Facility	Rossie Velvet Mill Historic District	Cutler St. Electrical Substation
Boulder Avenue Pump Station	Stonington Borough Historic District	Mystic Train Station & Rail Line
River Road/Mary Hall Road Pump Station	Apple Rehab Mystic	Barn Island Management Area
Stonington Wastewater Treatment Facility	Mystic Seaport	Stonington Community Center (COMO)
Town Dock	Greenmanville Ave Electrical Substation	Mystic River Park, Cottrell Street
Mystic Fire Dept.	State Highway 27	Lords Point neighborhood
Quiambaug Fire Dept.	Donahue Park	Murphy's Point neighborhood
Mechanic Street Historic District		

Step 3: Resilience Solutions



Asset Solutions



Regional Solutions

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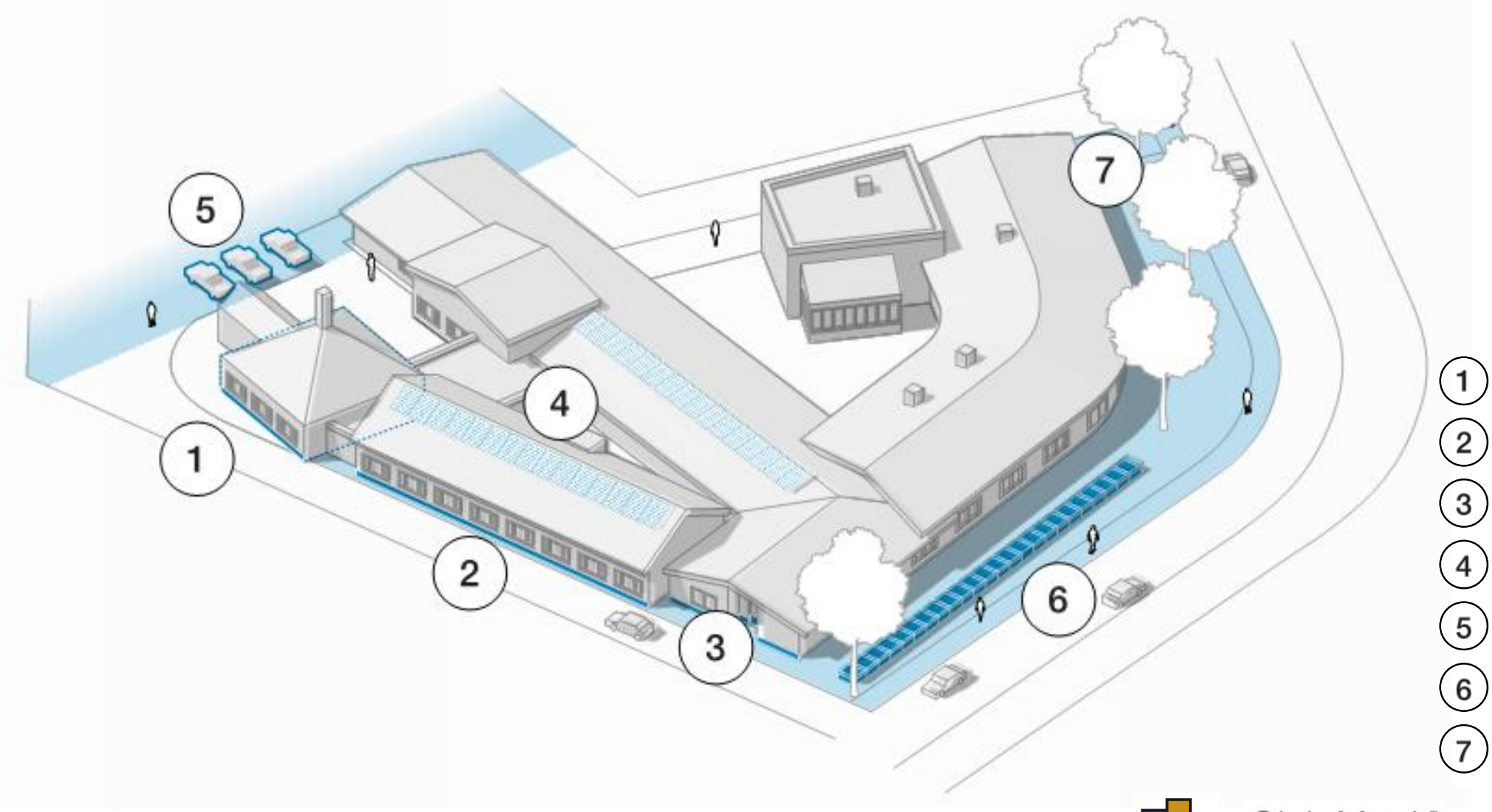
Solution #1: Apple Rehab Mystic



1. COMMUNICATION CENTER
2. IMPERMEABLE WALLS
3. FLOOR SHIELDS
4. ENERGY SUPPLY
5. PROVISIONS & STORAGE
6. EMERGENCY BARRIERS
7. GREEN INFRASTRUCTURE

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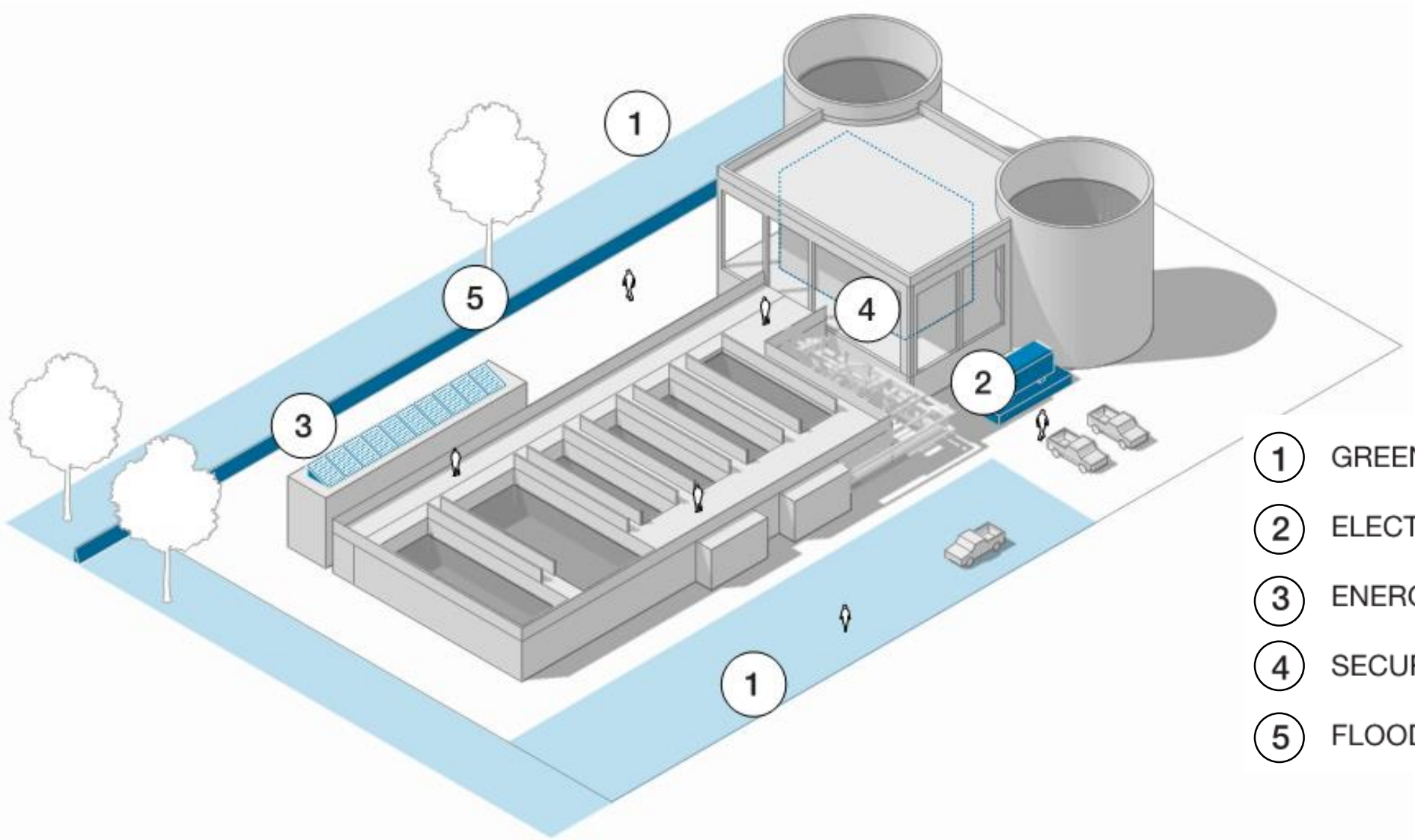
Solution #2: Mystic Wastewater Treatment Facility



1. GREEN INFRASTRUCTURE
2. ELECTRICAL EQUIPMENT
3. ENERGY SUPPLY
4. SECURABLE & REMOVABLE EQUIPMENT
5. FLOOD BARRIERS

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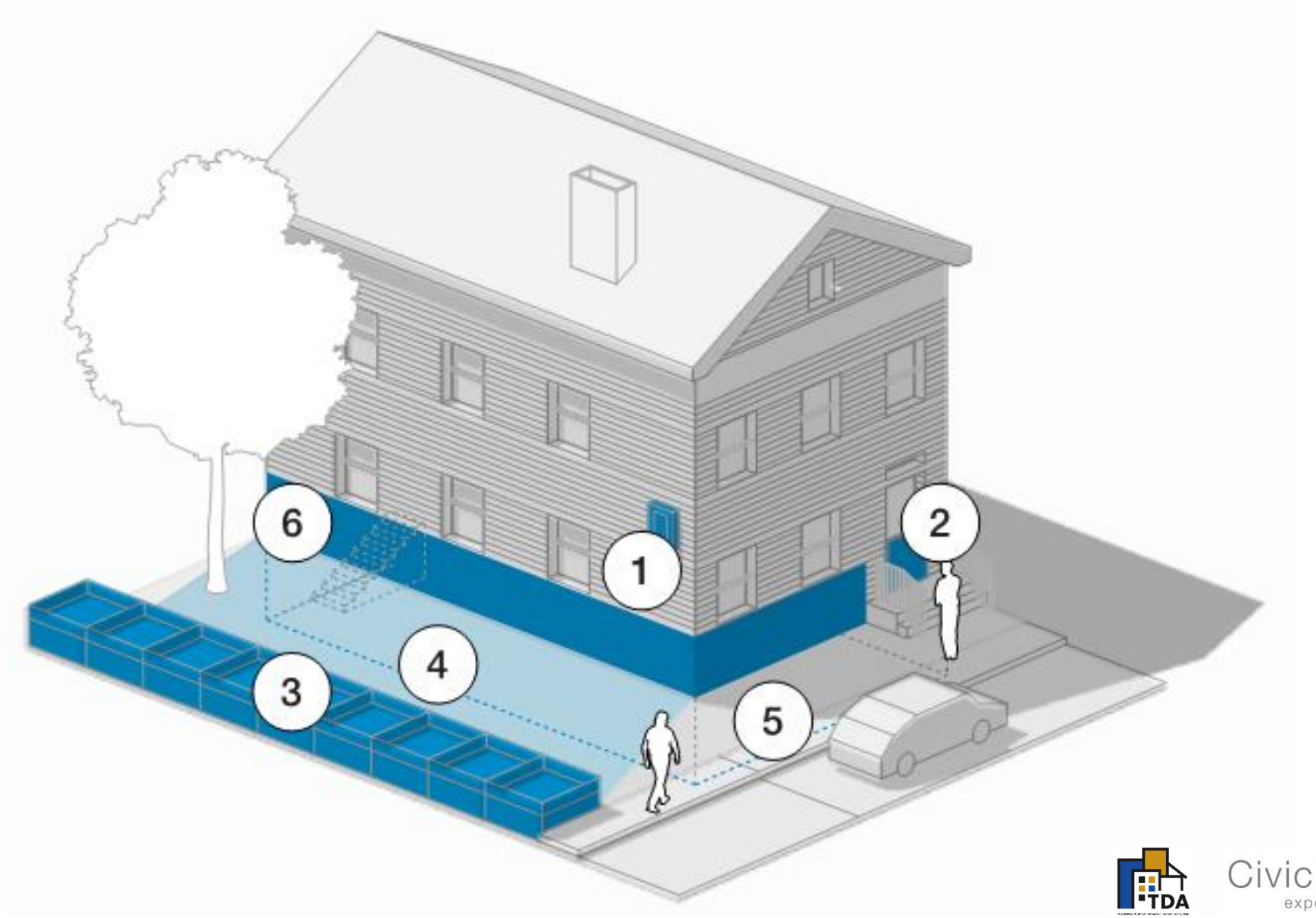
Solution 3(a): Typical Single-Family Home



1. ELECTRICAL WIRING
2. FLOOR SHIELDS
3. EMERGENCY BARRIERS
4. LANDSCAPING
5. IMPERMEABLE WALLS
6. BASEMENT

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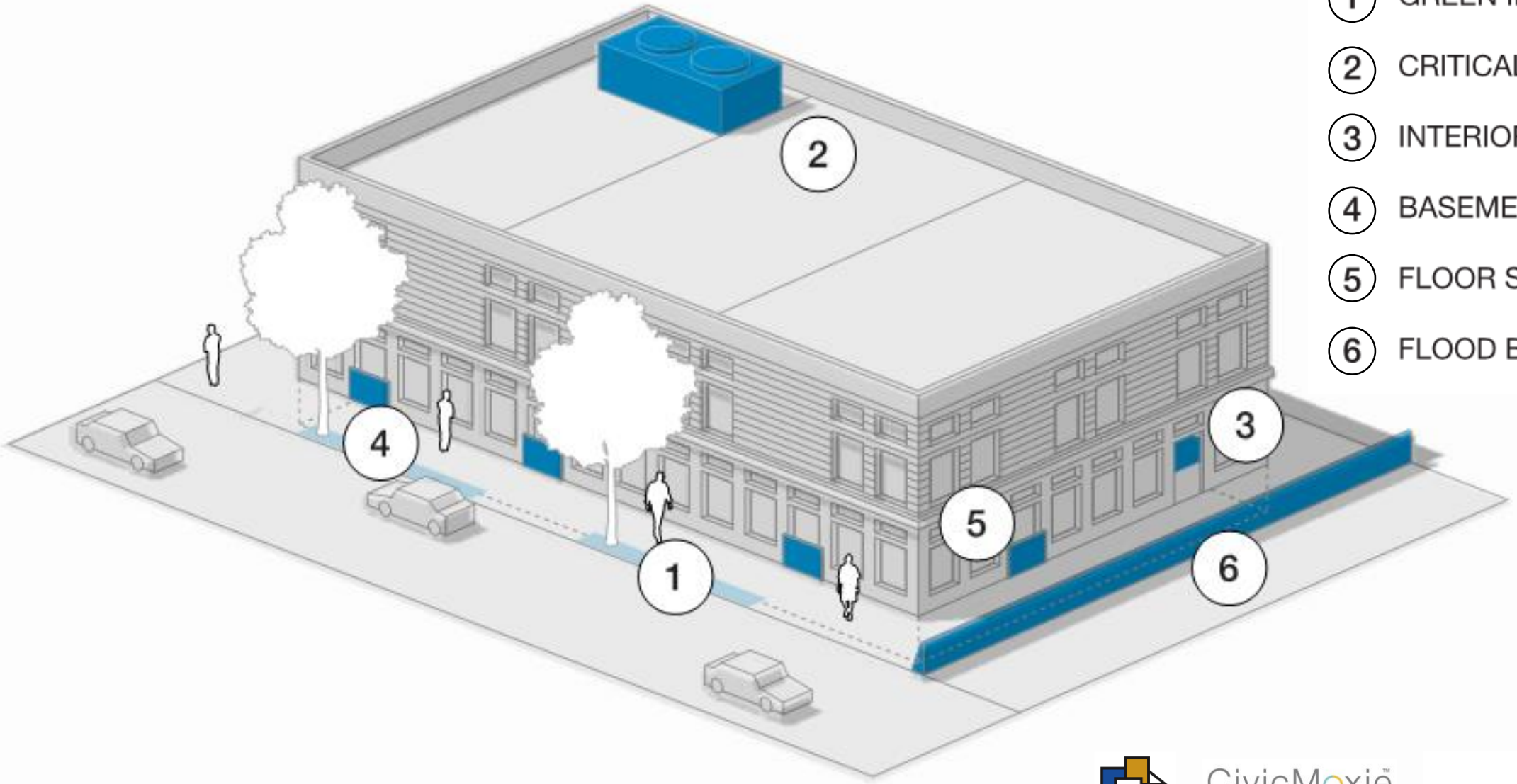
Solution #3(b): Typical Mixed-Use Building



1. GREEN INFRASTRUCTURE
2. CRITICAL EQUIPMENT
3. INTERIOR PROTECTION
4. BASEMENTS
5. FLOOR SHIELDS
6. FLOOD BARRIERS

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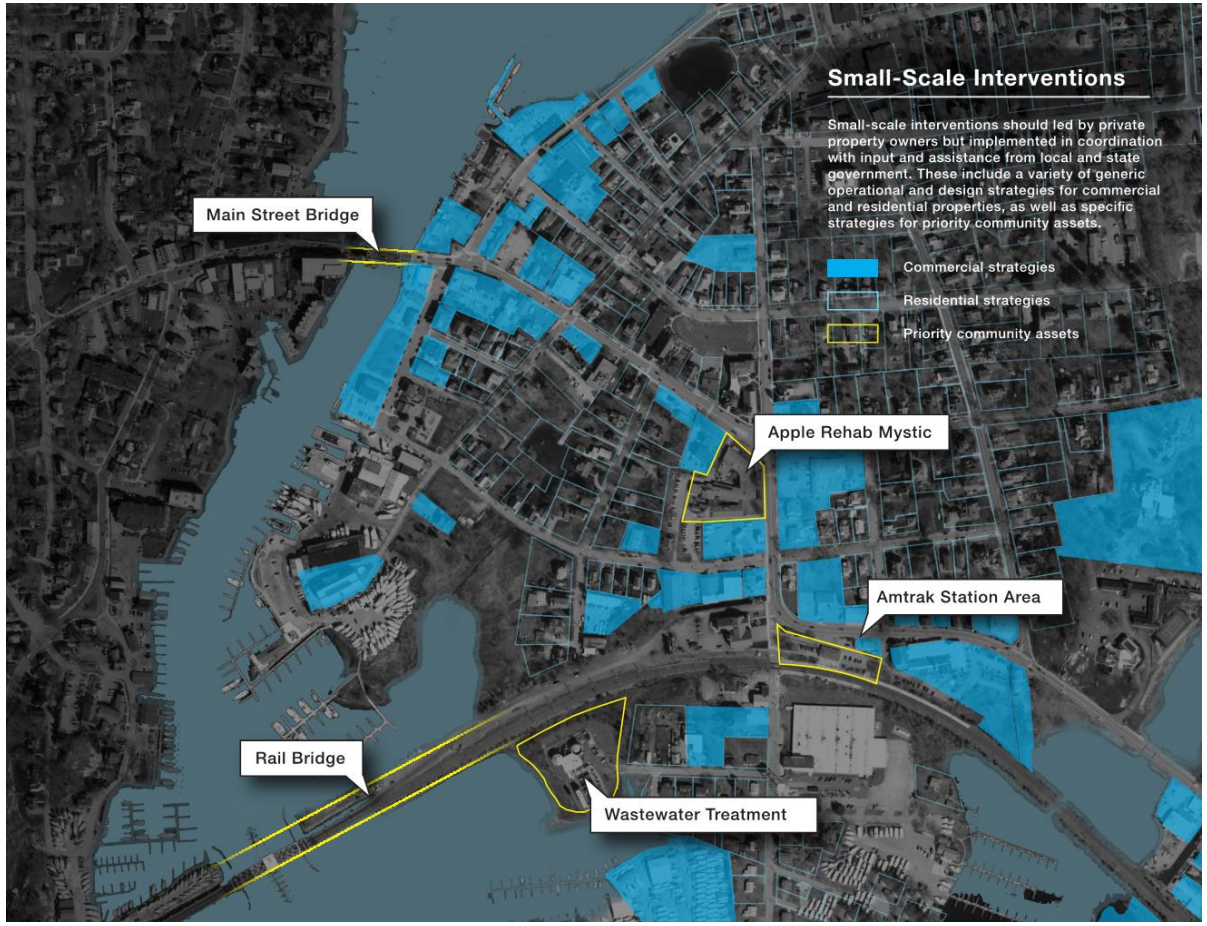
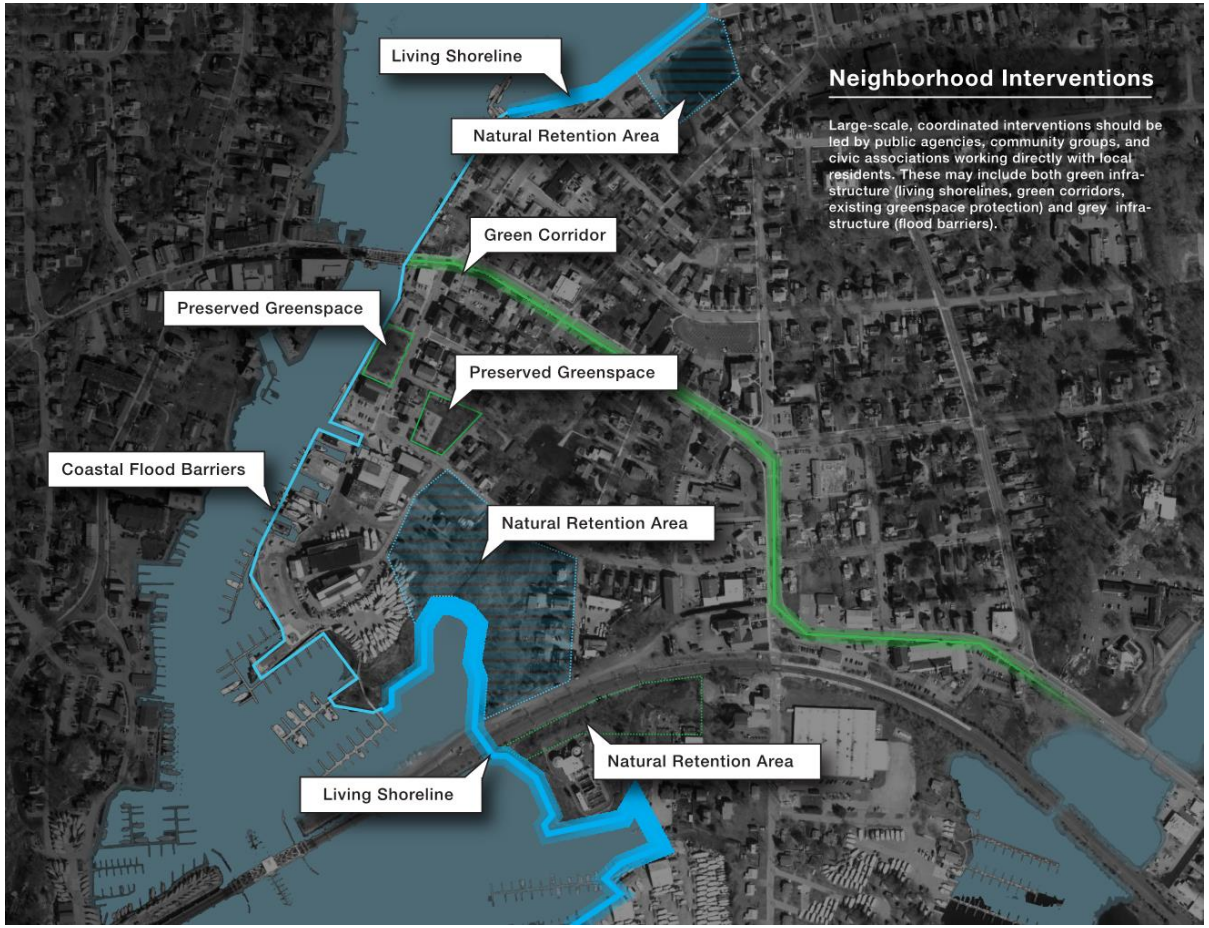
Solution #4: Mystic Neighborhood





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Solution #5: Masons Island Causeway

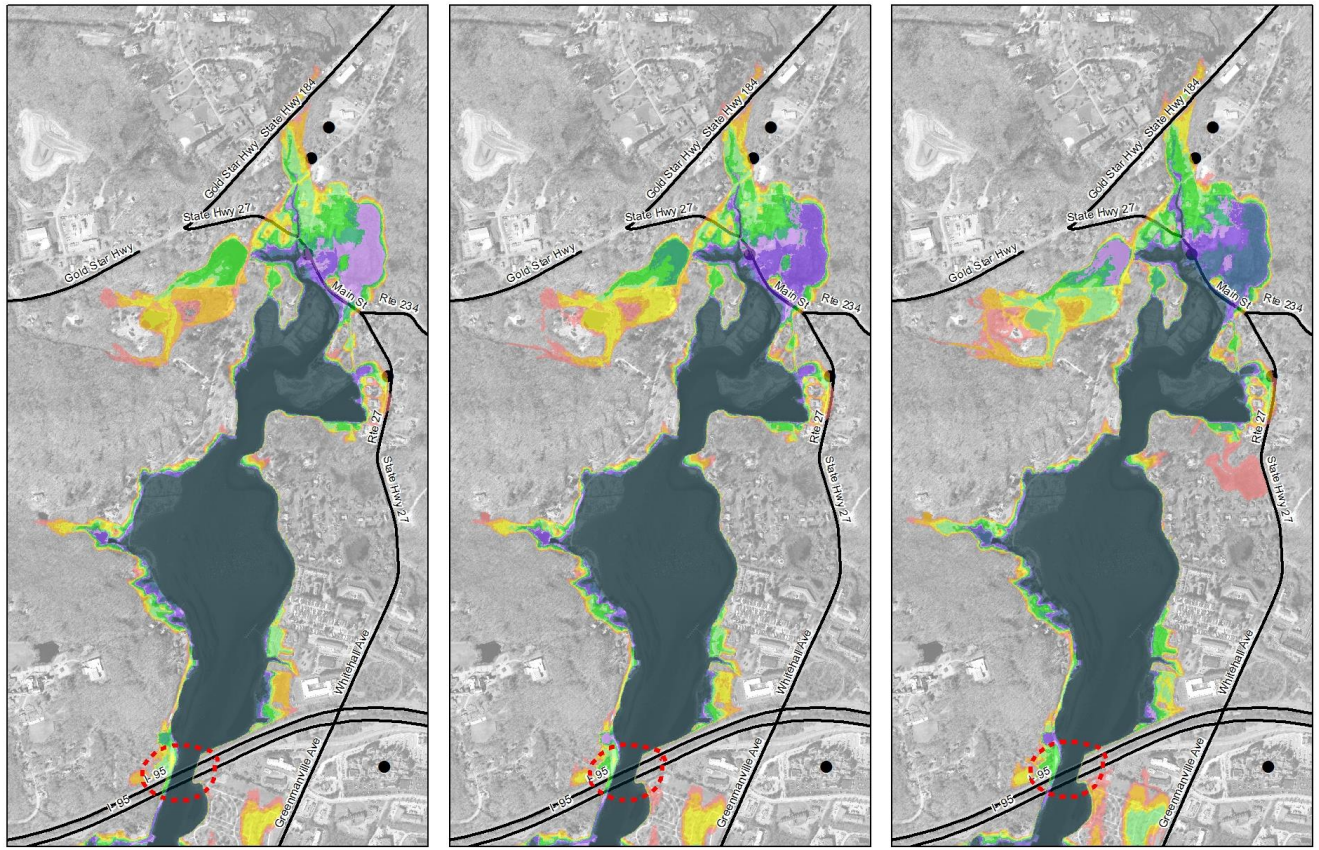
GREEN INFRASTRUCTURE

ROAD ELEVATION

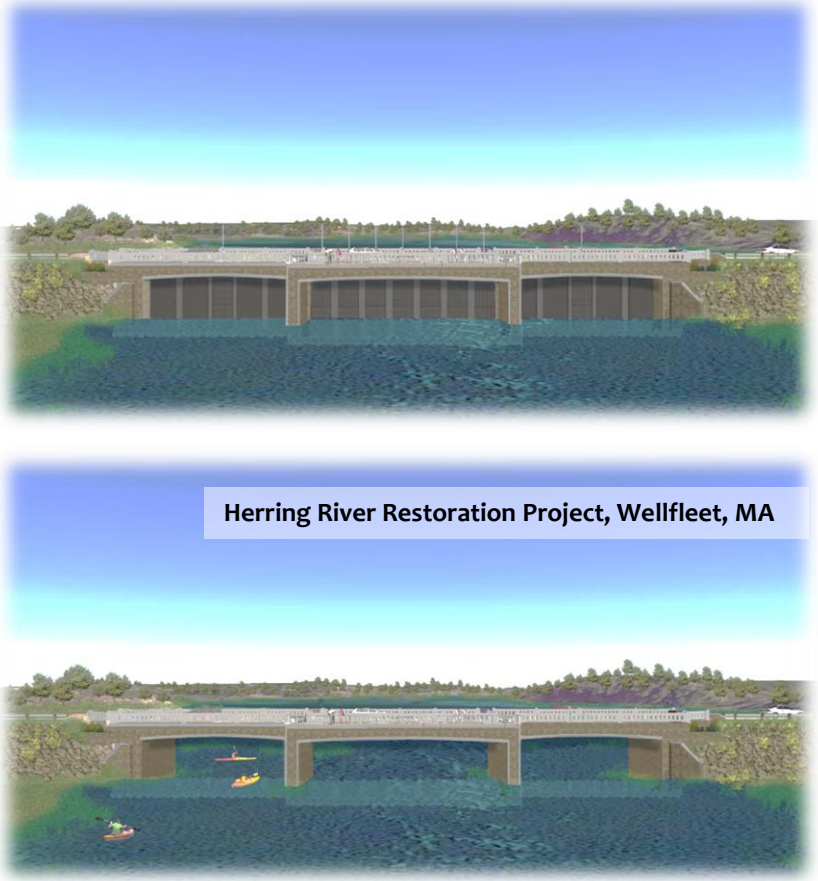
SHORELINE TREATMENT

RISING GATE

I-95 Regional Adaptation Option



Present 2030 2050



0 500 1000 2000 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

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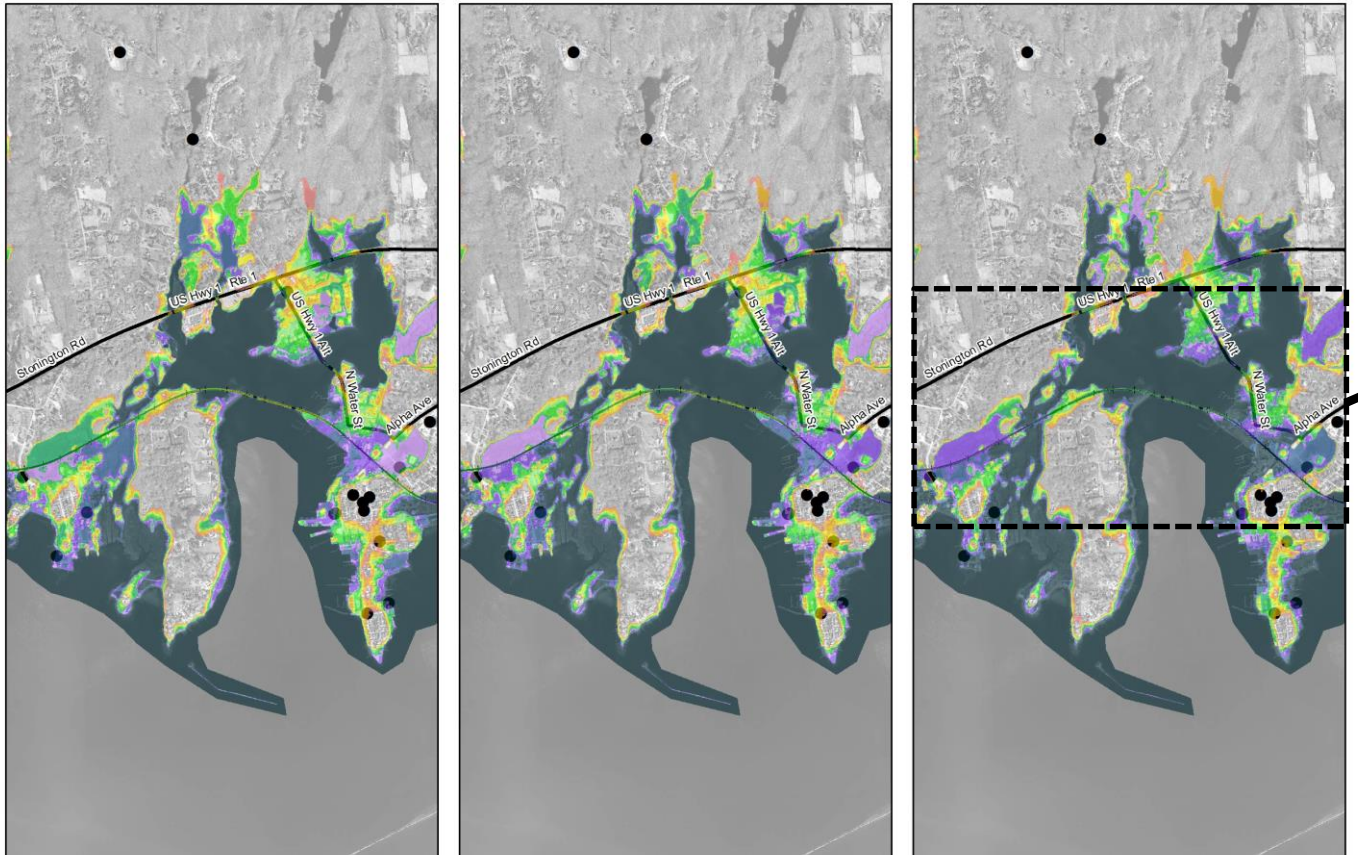
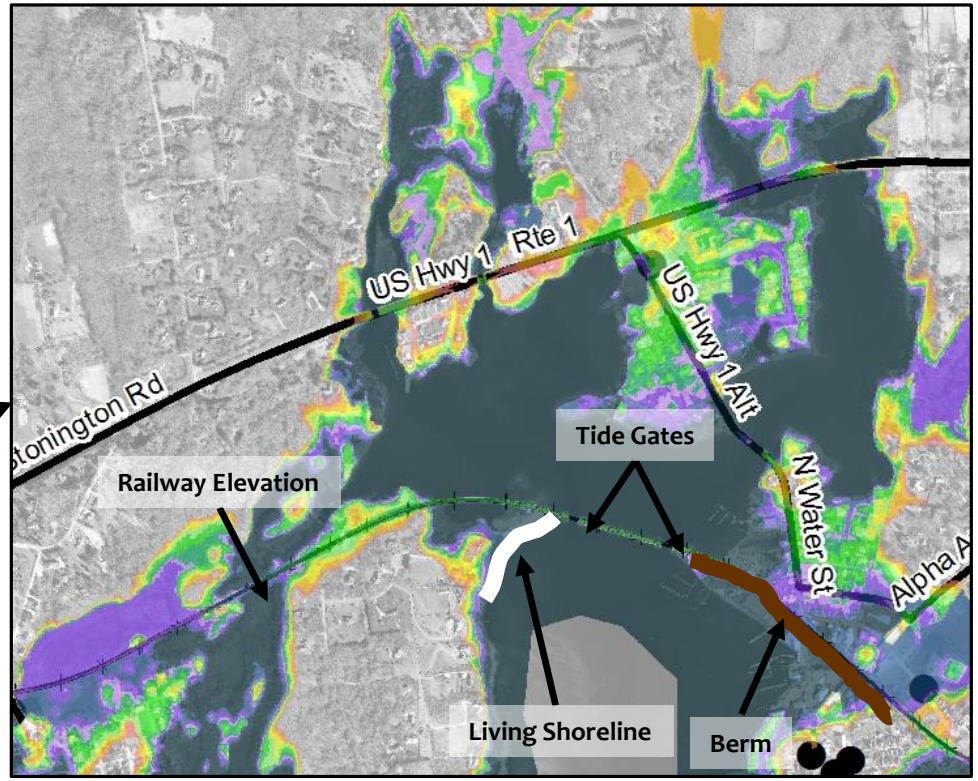
Stonington Borough Regional Adaptation Option





0 500 1000 2000 Meters

Stonington Inundation Probability

0.1% 0.2% 0.5% 1% 2% 5% 10% 20% 25% 30% 50% 100%

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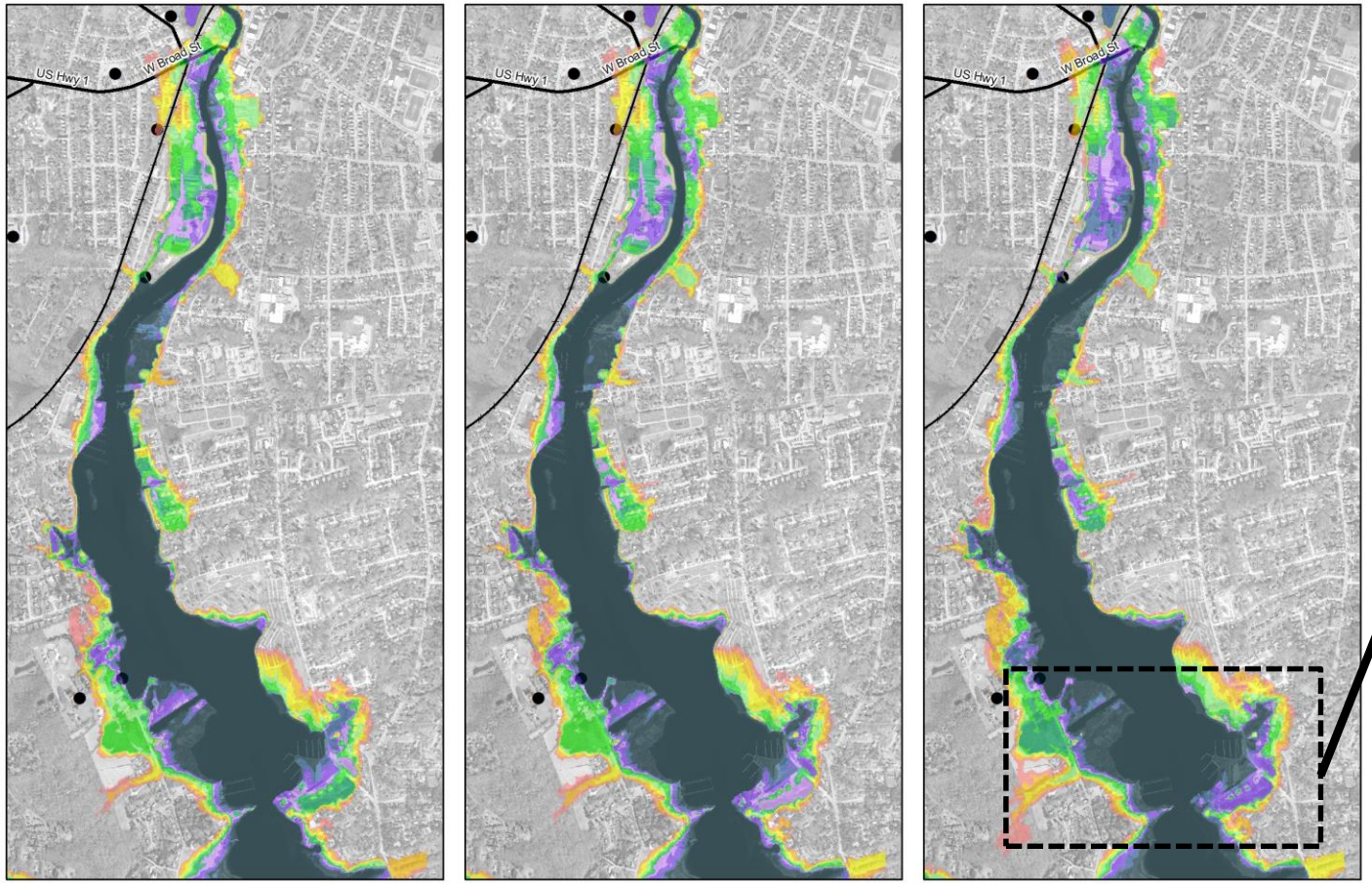
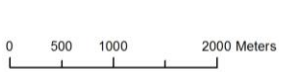
Pawcatuck River Regional Adaptation Option



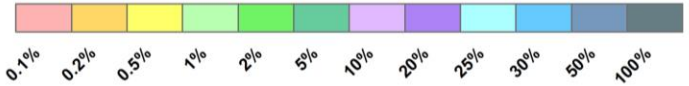
Present

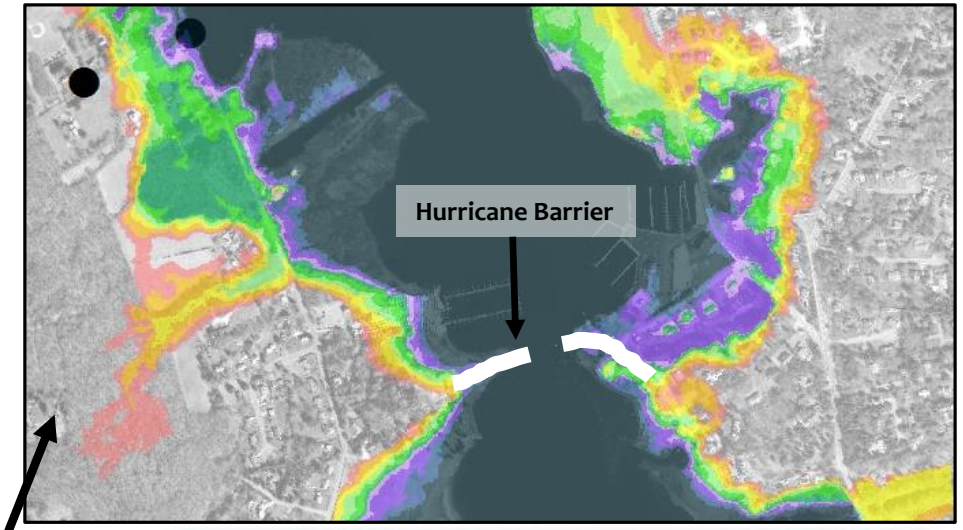
2030

2050



Stonington Inundation Probability





Hurricane Barrier - New Bedford, MA

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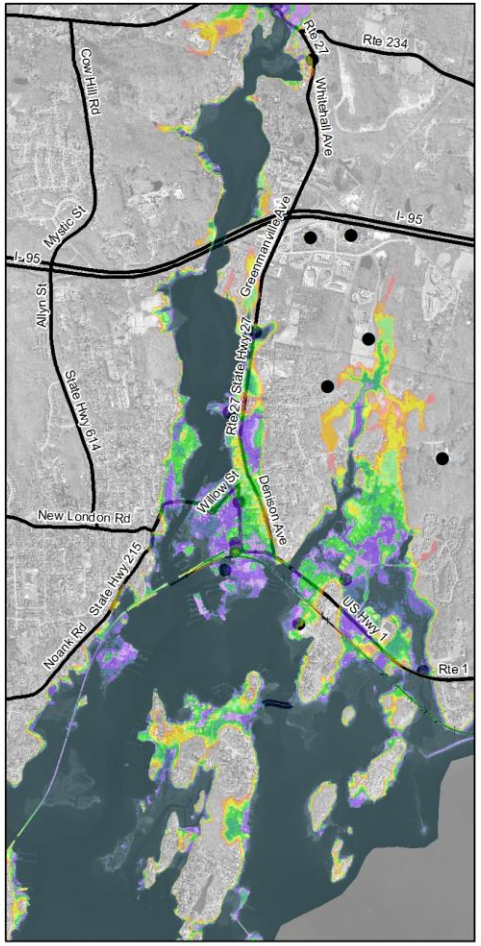
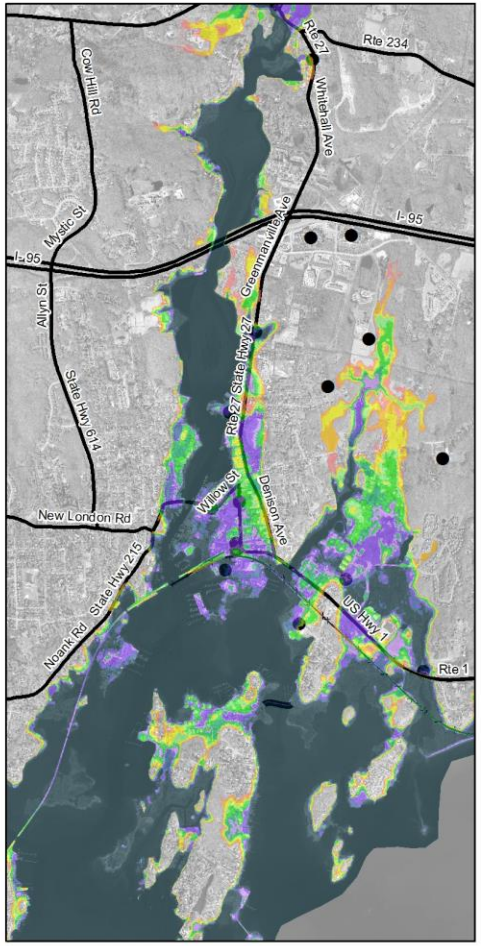
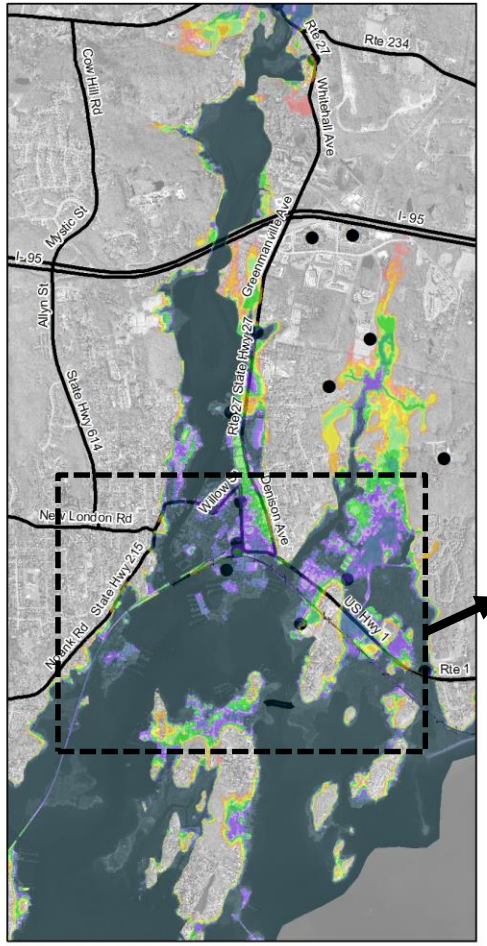
Mystic Regional Adaptation Option



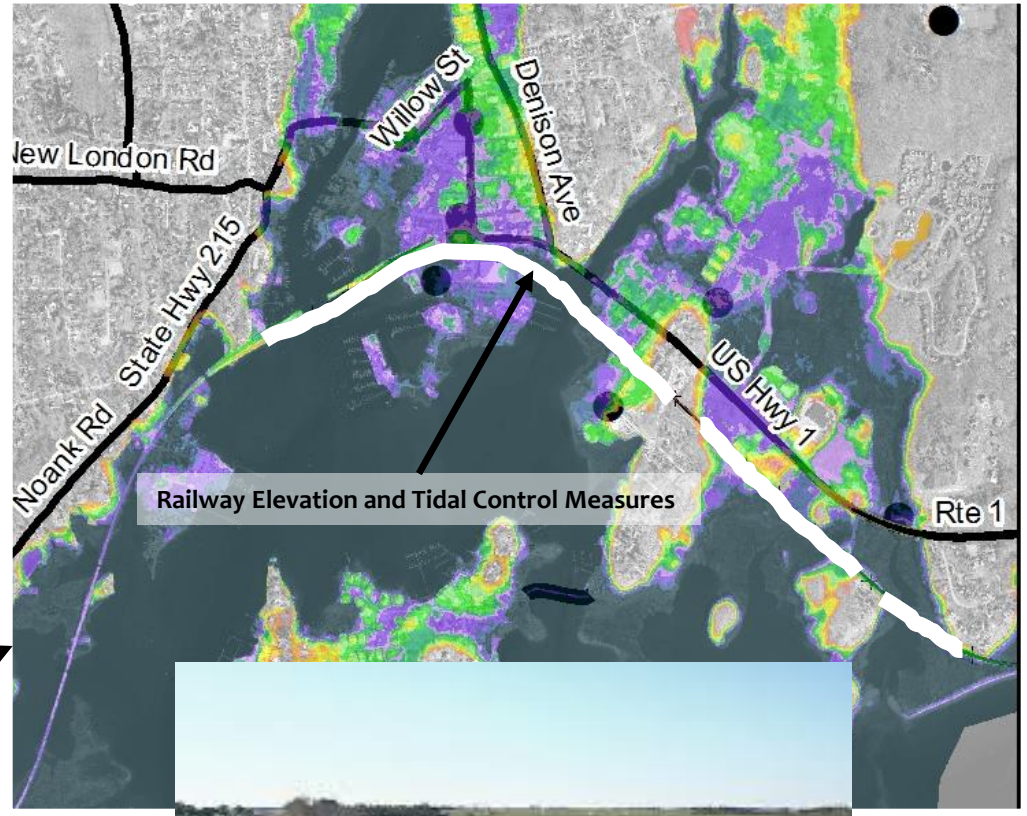
Present



2030

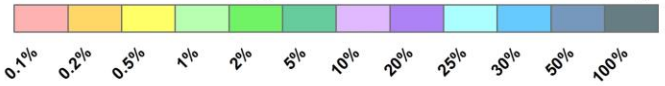


2050



0 500 1000 2000 Meters

Stonington Inundation Probability



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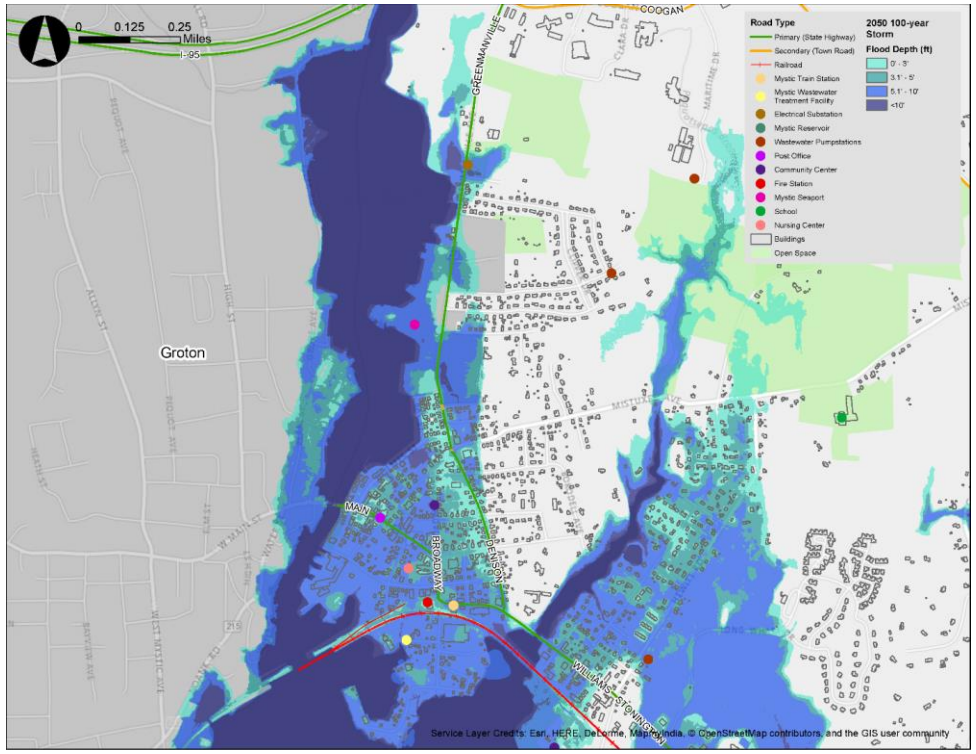
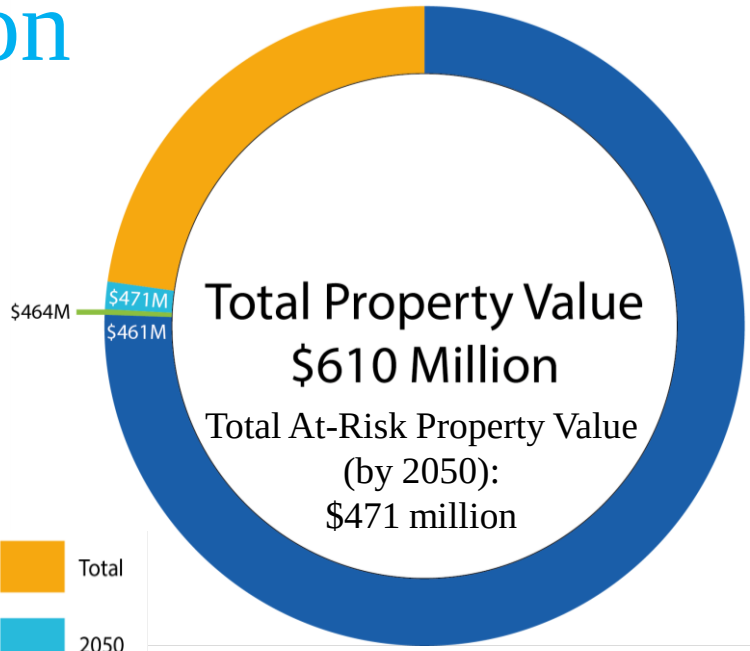
Key Priorities & Next Steps

Cost/Benefit Analysis for Mystic Adaptation





Exposed Property Value
Present-day to 2050

Disclaimer: These are very high level estimates and should only be used to understand the potential order of magnitude of these costs. They should be not be used for any detailed planning work or design and engineering studies.

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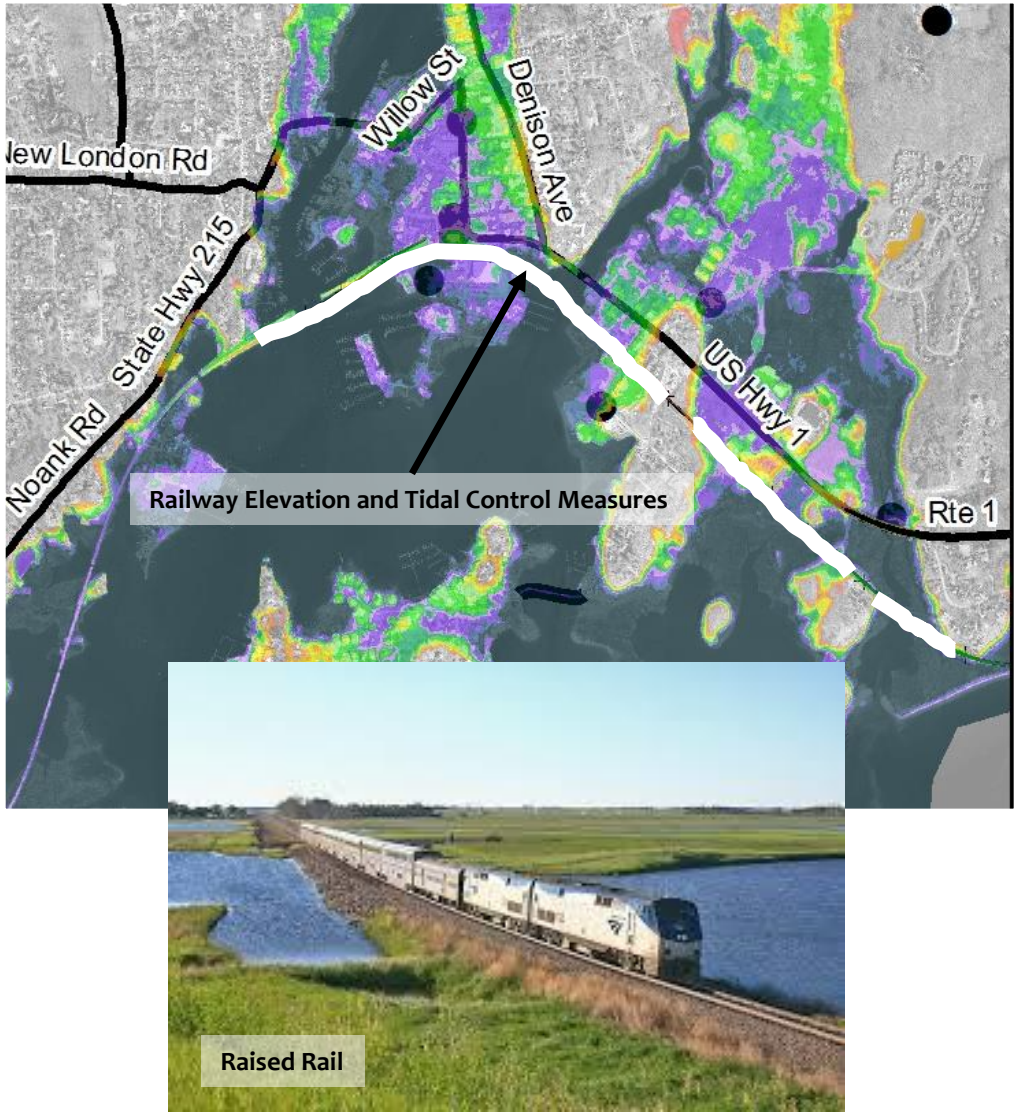
Cost/Benefit Analysis for Mystic Adaptation



Adaptation Costs: > $100 million

Acres of Land Protected from Inundation:

- Present: 706 acres of inundation
- 2030: 734 acres of inundation
- 2050: 795 acres of inundation

Approximate Value of Property Protected:

- Present: $461 million
- 2030: $464 million
- 2050: $471 million

Disclaimer: These are very high level estimates and should only be used to understand the potential order of magnitude of these costs. They should be not be used for any detailed planning work or design and engineering studies.

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Cost of Inaction	Original Source
$1 invested in building resilience saves $4 in disaster response and recovery	National Institute of Building Sciences FEMA
$1 invested in resilience saves: • $4-7 in response • $5-10 in avoided economic losses	The World Bank
$1 invest in disaster preparedness saves $7-10 on response	Catholic Relief Services
$1 invested in preparedness is worth $15 in disaster relief efforts	Stanford Business School

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Details of a Cost/Benefit Analysis

Economic impacts:

- Direct, physical impacts
- Business continuity and cascading regional impacts
- Lost opportunities
- Could impact creditworthiness and insurability

Social impacts:

- Costs associated with not being able to access critical services
- Job loss, public health impacts, decrease in quality of life
- Recurrent challenges borne by those most vulnerable
- Public safety concerns

Environmental considerations:

- Degradation of the natural environment and associated ecosystems

Funding Opportunities

1. Town Budget
   - Incorporate a line item for resilience into the annual budget
   - Tax Increment Financing Districts (TIFs) can help fund infrastructure and resilience improvements.
2. Loans & Bonds
   - Pursue low interest loans to finance large-scale resilient infrastructure strategies
     - Shore Up CT offers up to $300,000 for property owners in flood zones to retrofit their properties
   - Resilience Bonds are an emerging resource that modify traditional catastrophe bonds to provide insurance savings that can be captured as rebates to invest in resilient infrastructure
3. Grants
   - Many public, private and non-profit entities offer grants to encourage coastal flood adaptation efforts.
     - CT Institute of Resiliency & Climate Adaptation (CIRCA) provides funding to municipalities for resilience
4. Private Funding
   - Public-Private Partnerships (P3) allow for cost-sharing between the Town and private entities that also need to protect their assets from flood impacts
     - DC Water Century Green Bond is an example of one type of partnership between a public and private entity

Current Trends in Resilient Financing

Past:

- Major source of resilience funding came from federal agencies, such as FEMA, Department of Housing and Urban Development (HUD), Coastal Zone Management (CZM), Environmental Protection Agency (EPA)

Future Trends:

- Push for cities and states to take on more responsibility for resilience
  - FEMA's Disaster Deductible
  - Insurance
- Growing interest from private equity to invest in resilience
  - This will require investment-grade performance metrics for resilience in order to capture the benefits of investing in resilience projects

Short-Term Priorities (1-2 years)

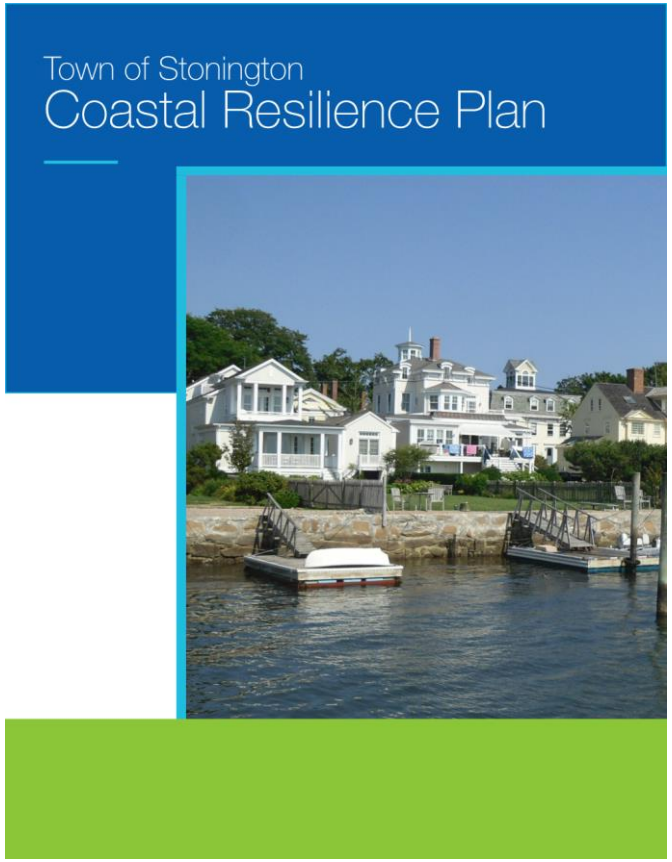
1. Continue to hold community events and educate the public on coastal flood risks
   - Ensuring that the community understands the risks and the ways to mitigate flood risk on their properties is essential for a community to be resilient
   - Neighborhoods with strong community ties are more resilient in the event of a disaster because they have a support system in place
2. Propose resilience amendments to Stonington's zoning and building codes
   - Amendments to the zoning and building codes will ensure that any future development or major property renovations are required to build resiliently
3. Incorporate resilience as a line item in the town budget
4. Leverage current projects to implement resilience solutions
5. Renew participation in the Community Rating System (CRS) and upgrade status
   - FEMA's CRS program allows for communities to reduce flood insurance rates by implementing resilience solutions
6. Pursue grants and match funding for implementing resilient solutions

Long-Term Priorities (5 years)

1. Continue to educate the public and pursue funding opportunities (these should be on-going efforts)
2. Form partnerships with:
   - Neighboring communities and like-minded communities
   - Key stakeholders in Stonington, including business owners
   - Historic commissions
   - Important local, state, and federal government entities
3. Conduct a feasibility analysis for regional adaptation solutions, starting with the Mystic Regional Adaptation
4. Perform a stormwater modeling analysis to get a complete understanding of the Town's flood risk

What You Can Do

1. Stay engaged!
2. Understand your flood risk and the adaptation strategies that you can implement on your own property
3. Educate your neighbors
4. Invite the Town to speak about coastal resilience
5. Recognize opportunities to collaborate with stakeholders on resilience solutions



The Town of Stonington Coastal Resilience Plan will be available in August 2017.

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