

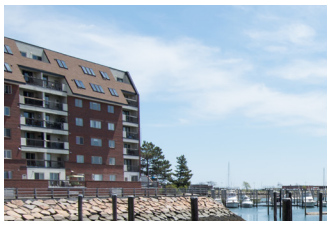



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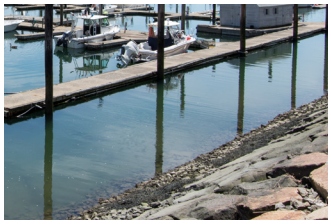
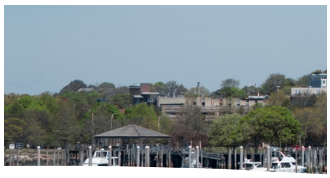
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report






City of

Lynn

MASSACHUSETTS
Economic Development and
Industrial Corporation

Lynn Coastal Resiliency Assessment

July 2016

Prepared for

EDIC

Funded by

Massachusetts Office of
Coastal Zone Management

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Technical Memorandum 1

Technical Memorandum 2

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1.0 | Introduction



The City of Lynn Economic Development and Industrial Corporation (EDIC) conducted a community-based process to assess vulnerability and consider adaptation strategies to future climatic conditions along the Lynn shoreline and Saugus River areas. The overall goal of this project is to improve coastal resilience.

Coastal Resilience

Capacity of shoreline areas to protect and preserve infrastructure and other socioeconomic resources in response to predicted sea level rise (SLR) and increased frequency and intensity of coastal storms.

Purpose of the Study

The purpose of the Lynn Coastal Resilience study is to evaluate sea level rise and coastal flooding that could occur under future climate change predictions, and to identify ways that the community can plan to adapt to these changes to improve resiliency.

Three technical memoranda were prepared in support of this study and are included as attachments to this final report. The reader is directed to these memoranda for additional details on technical approach, analysis and results. In addition, three public meetings were conducted to present results of the study, and the presentations are available on the City of Lynn website.

The report is organized as follows:

Section 1 - Overview of Potential Climate Change Effects provides a general overview of how climate change may affect conditions and impact coastlines in the northeast U.S.

Section 2 - Study Scenarios and Approach describes the scenarios used to evaluate future conditions along the Lynn coastline defined by the number of years into the future and climate change projection. Technical Memorandum 1 is included as Attachment A for additional details.

Section 3 - Lynn Vulnerability Assessment presents the extent of potential tidal and storm flooding along the Lynn coastline that could occur under scenarios defined in Section 2, identifies vulnerable public infrastructure, and discussing existing coastal protection structures. Technical Memorandum 2 is included as Attachment B for additional details.

Section 4 - Adaptation Strategies presents engineering and programmatic approaches that Lynn could implement to adapt to predicted inundation from sea level rise and storm surge. These approaches include retrofitting existing municipal infrastructure and improvements to coastal protection. Technical Memorandum 3 is included as Attachment C for additional details.

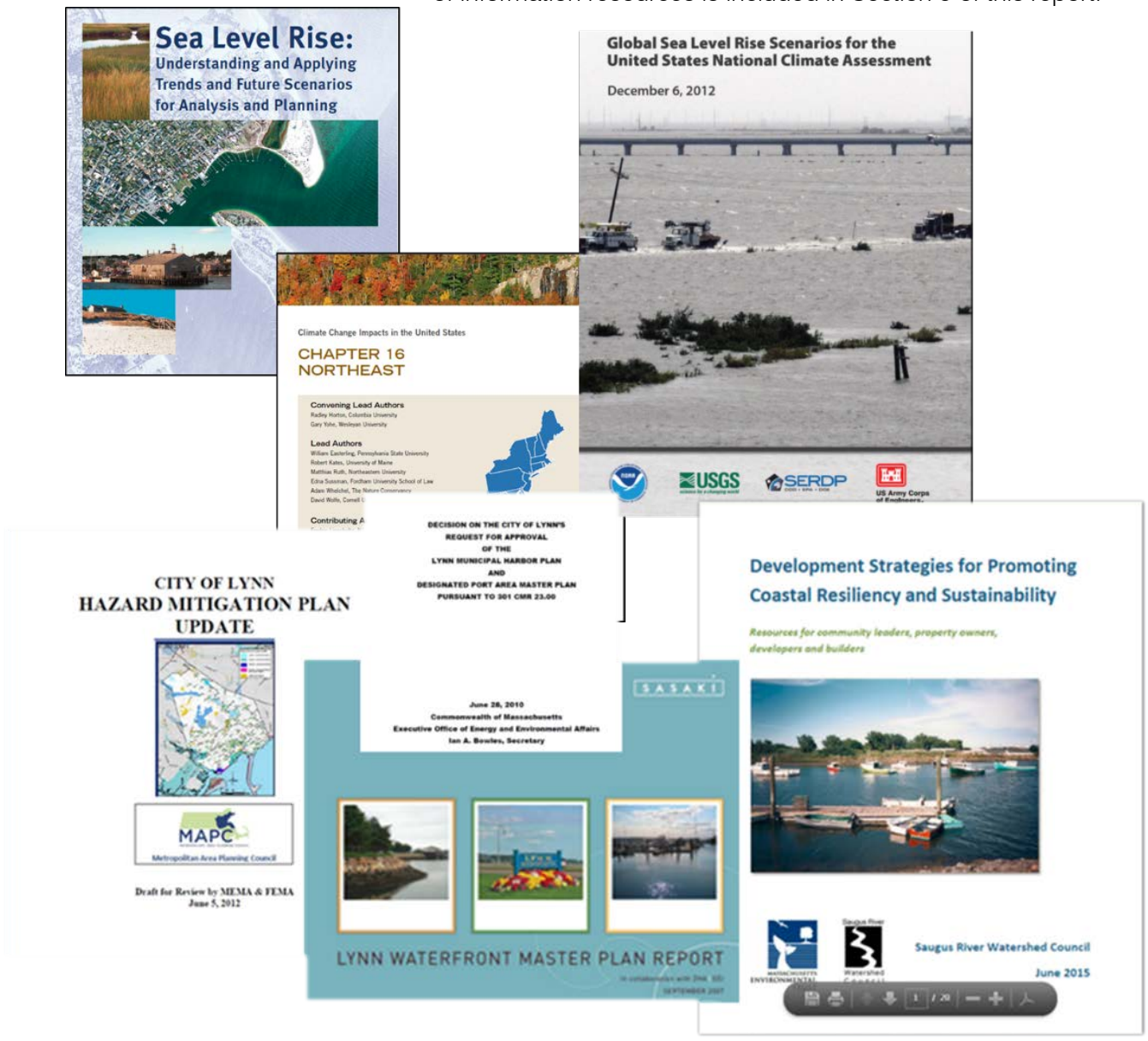




Basis of Study

Estimates of global sea level rise and other possible climate change effects have been the subject of researchers internationally. In the U.S., federal agencies including National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the Federal Emergency Management Agency (FEMA), and the US Army Corps of Engineers have reviewed published scientific data and issued guidance for communities to plan for future climate change effects. The Massachusetts Office of Coastal Zone Management (MACZM) has also issued guidance specific for the Commonwealth's coastal communities.

The basis of this study is to use those available resources and build upon previous local and regional planning initiatives to prepare a focused evaluation for the City of Lynn. A full bibliography of information resources is included in Section 5 of this report.



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Project Funding and Working Group

The project is funded through a grant provided by the Coastal Community Resilience Grant Program of the Massachusetts Office of Coastal Zone Management (MACZM).

A working group assembled specifically to support and direct the scope of this project and development of conclusions and recommendations included the following:

Economic Development & Industrial Corporation of Lynn	Jim Cowdell
	Bill Bochnak
	MaryJane Smalley
Massachusetts Office of Coastal Zone Management	Patricia Bowie
	Kathryn Glenn
City of Lynn, Inspectional Services Department	Michael Donovan
Lynn Water and Sewer Commission	RaeAnna Hughes
City of Lynn, Department of Public Works	Andrew J. Hall P.E.
Office of Emergency Management (OEM) Lynn Fire Department	Paul Ricchi
	Thomas Hines
Saugus River Watershed Council	Joan Leblanc
Friends of Lynn-Nahant Beach	Bob Tucker

Overview of Potential Effects of Climate Change

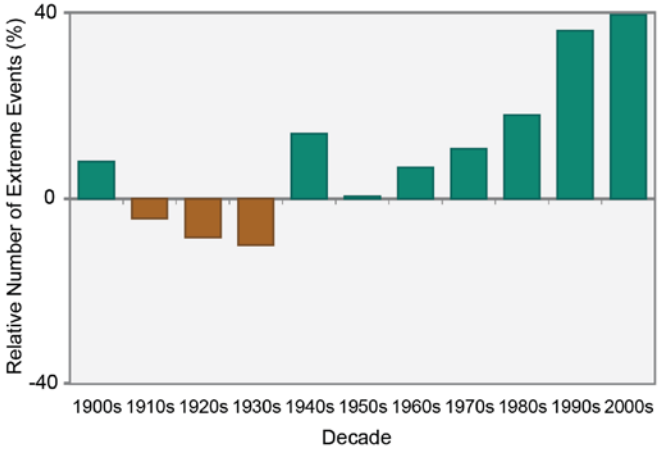
This study focuses specifically on the potential effects of future sea level rise and storm effects on the coastline of the City of Lynn. The following provides a general overview of how these changes may affect the Northeast U.S. to provide context for the remainder of this report.

Climate change has the potential to impact the environment and communities in noticeable ways including:

- Increases in sea level rise
- Increases in the number, duration and intensity of storms
- Changes in precipitation patterns
  - 10% increase (approximately 5 inches) in precipitation between 1895 and 2011 (National Climate Assessment (NCA) 2014)
  - 70% increase in the amount of precipitation falling in very heavy events between 1958 and 2012 (NCA 2014)
  - Greater recent increase in extreme precipitation than any other region in the U.S.
  - Increase in winter precipitation from snow to rain (New England Aquarium (NEAQ))
- Increases in seasonal temperatures, with longer periods of drought.
  - Climate change has the potential to increase the frequency of hot days during the summer and may increase heat-related deaths in Boston by 50% by 2050. (NCA 2014)
  - If climate change continues, the Boston area climate may become more similar to that in Charlotte, North Carolina, or Atlanta, Georgia (NEAQ).

> Sea level rise will *exac*erbate impacts to development, infrastructure, and natural systems from erosion and storm damage. Impacts could include: loss of life; extensive property damage; destruction of public infrastructure; release of sewage, oil, debris, and other contaminants; and loss of commercial and marine-related businesses
>
> *MA Climate Change Adaptation Report Chapter 8*

Observed U.S. Trend in Heavy Precipitation



Source: NCA 2014

Increased precipitation is one element of increased intensity of expected storms. Intensity of precipitation was not evaluated in this study in favor of a storm surge analysis due to the vulnerability of coastal areas to a combination of sea level rise, storm surge and wave caused erosion.

The purpose of this study focuses on the impact of sea level rise and storm surge on the Lynn Community. Increased precipitation and seasonal temperatures were not part of the scope of this study.

Coastal Impact

Coasts are sensitive to climate change effects including sea level rise, increasing frequency and intensity of coastal storms, and warmer ocean temperatures that can change circulation patterns. The effects can be devastating as:

- High tide water levels become increasingly higher and flood coastal areas.
- More intense storms coupled with sea level rise result in storm damage to increasingly larger areas.
- Increasing storm intensities and rising sea levels change wave patterns and increase the rate of shoreline erosion and loss of coastal land.





A summary of the potential effects of sea level rise and coastal flooding is provided in Table 1 below (Source: Moser et. al. 2014).

Table 1. Impacts of sea level rise and coastal floods on critical coastal infrastructure by sector.

Communications	Energy	Transportation	Water and Waste
Higher average sea level			
• Increased saltwater encroachment and damage to low-lying communications infrastructure not built to withstand saltwater exposure • Increased rates of coastal erosion and/or permanent inundation of low-lying areas, causing increased maintenance costs and shortened replacement cycles • Cellular tower destruction or loss of function	• Increased coastal erosion rates and/or permanent inundation of low-lying areas, threatening coastal power plants • Increased equipment damage from corrosive effects of saltwater encroachment, resulting in higher maintenance costs and shorter replacement cycles	• Increased saltwater encroachment and damage to infrastructure not built to withstand saltwater exposure • Increased coastal erosion rates and/or permanent inundation of low-lying areas, resulting in increased maintenance costs and shorter replacement cycles • Decreased clearance levels under bridges	• Increased saltwater encroachment and damage to water and waste infrastructure not built to withstand saltwater exposure • Increased release of pollution and contaminant runoff from sewer systems, treatment plants, brownfields, and waste storage facilities • Permanent inundation of low- lying areas, wetlands, piers, and marine transfer stations • Increased saltwater infiltration into freshwater distribution systems
More frequent and intense coastal flooding			
• Increased need for emergency management actions with high demand on communications infrastructure • Increased damage to communications equipment and infrastructure in low-lying areas	• Increased need for emergency management actions • Exacerbated flooding of low- lying power plants and equipment, as well as structural damage to infrastructure due to wave action • Increased use of energy to control floodwaters • Increased number and duration of local outages due to flooded and corroded equipment	• Increased need for emergency management actions • Exacerbated flooding of streets, subways, tunnel and bridge entrances, as well as structural damage to infra- structure due to wave action • Decreased levels of service from flooded roadways; increased hours of delay from congestion during street flooding episodes • Increased energy use for pumping	• Increased need for emergency management actions • Exacerbated street, basement, and sewer flooding, leading to structural damage to infrastructure • Episodic inundation of low- lying areas, wetlands, piers, and marine transfer stations

2.0 | Study Scenarios and Approach

Future Coastal Sea Level for the City of Lynn



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Future coastal conditions depend on the three primary factors described below and in the following sections. Details on the calculations are available in the technical memorandums in Appendices A and B.

FUTURE WATER LEVELS =

REGIONAL SLR + FUTURE GLOBAL SLR + STORM SURGE

Regional Sea Level Rise (SLR)

Sea level rise relative to the coastline has been regionally documented over the last century by using tide gauges. Land subsidence and historic SLR due to climate change have resulted in landward migration of shorelines at varying rates depending on location. Figure 1 depicts water levels recorded at Boston Harbor since 1920. A regional SLR of +0.43 inches per year was used for this study.

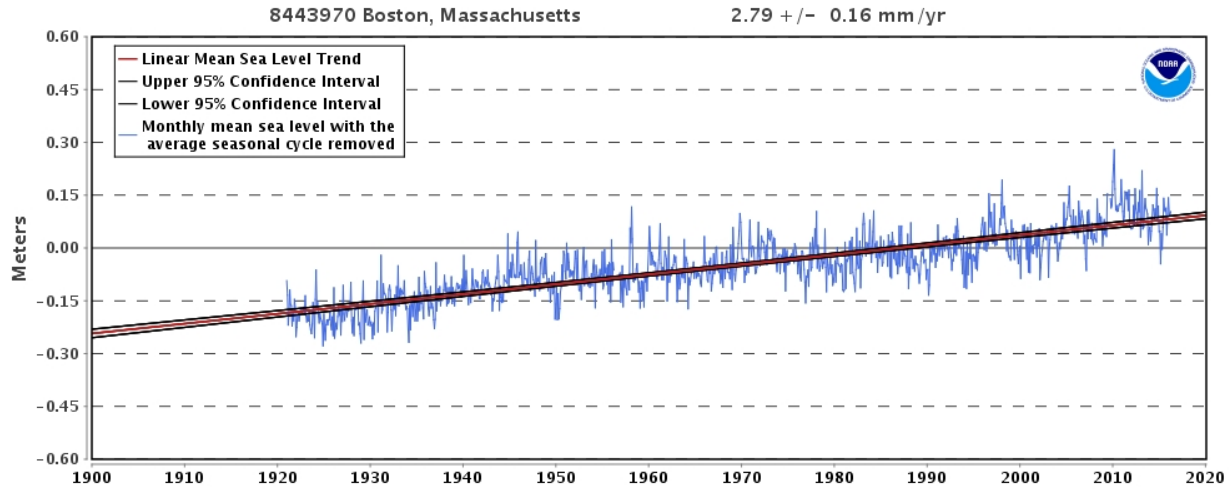


Figure 1. Data Source: Historic water level data (NOAA, Boston Harbor Tide Gage)

Future Global Sea Level Rise

The rate of sea level rise published by Parris et al (2012) was developed based on extensive modeling of climate change scenarios and associated sea level rise. It is used as a standard to predict the range of potential general increases in future sea levels in the United States.

Four projections were developed to represent different scenarios, as depicted in Figure 2. The amount of ice sheet melt and rate of climate change varies between the projections with the lowest assuming no ice melt. The Lynn study was based on the **Highest**, **Intermediate-High**, and **Lowest** projections.

Mean Higher High Water (MHHW)

The average of the higher high water height of each tidal day.

NOAA, Tides and Currents Website

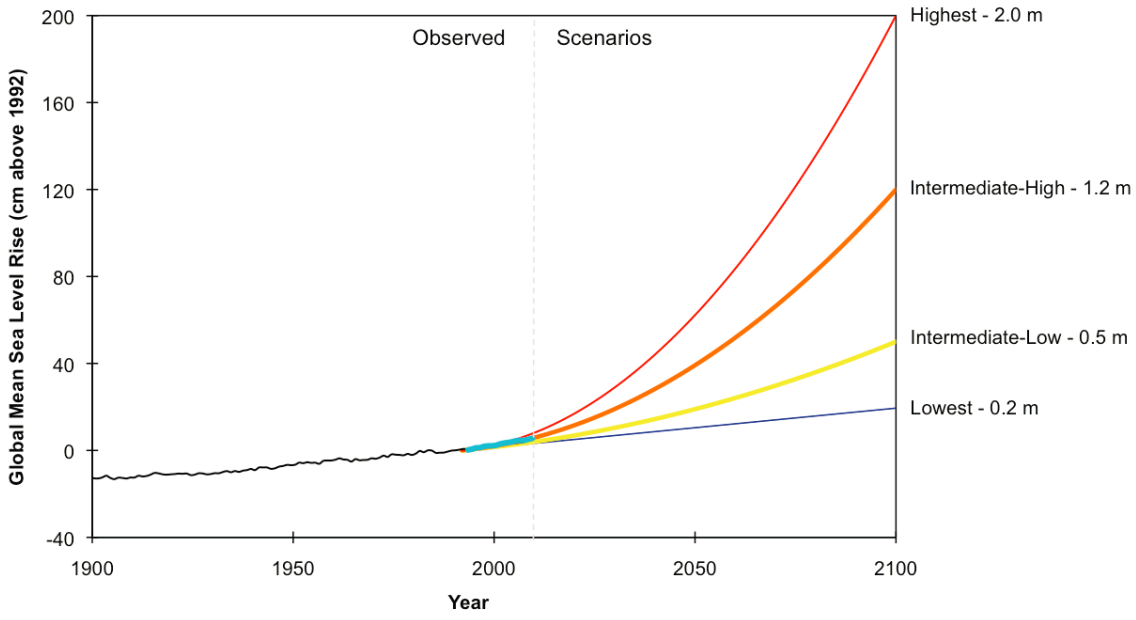


Figure 2 – National Climate Assessment Global Sea Level Rise Scenario Projections (Source: Parris et al. 2012)

Uncertainty in Predictions

The NOAA sea level rise projections are based on extensive modeling of climate change scenarios and associated sea level rise, and are standardly used to predict the range of potential general increases in future sea levels. Local and global predictions for sea level rise are developed by considering multiple factors, including land water storage, ice sheet melt, glacier retreat, oceanographic processes, and vertical land motion modelling. Contributions from ice sheet remain uncertain, and sea level rise predictions may change with time as more scientific data becomes available. (Little 2016).

Storm Surge

The increase in the water level above the normal tidal range associated with a storm (i.e., storm surge) is one of the most influential factors in storm damage and flooding and is therefore a primary focus of this evaluation. Lynn is particularly vulnerable to storm flooding, and much of the city is within the 100-year floodplain established by the Federal Emergency Management Agency (FEMA).

Several lines of evidence were considered in combination to estimate storm surge water elevations, including the results of forecasting models and historic storms experienced by the Boston area. Flood levels were estimated for storms that could produce storm surges with a 1% probability of occurring in any given year (100-year storm surge elevation) and 10% probability of occurring (10-year storm surge elevation).

Nor'easters have occurred more frequently in New England than hurricanes, particularly over the past several decades. Although not associated with a storm, the extreme high tide (sometimes referred to as a "perigean spring tide" or "King Tide") that occurred in November 2015 is also included for reference. King tides occur once or twice a year when the orbits of the Sun, Moon, and Earth align (EPA 2015). The extents of inundation associated with three representative high water events, the Blizzard of 1978, Hurricane Bob, and the November 2015 King Tide, are illustrated in the oversized Figure 3 included at the end of this report.

The November 2015 King Tide resulted in a tidal elevation of 7.2 feet in the Lynn area, which was 2.4 feet higher than the current MHHW tidal datum.

Two model-based approaches to estimating storm surges were used during the evaluation: Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model and FEMA flood elevations. Both of these flooding estimates are based on the evaluation of large databases of historic storms. SLOSH was developed as a weather forecasting tool by the National Weather Service.

How Will Sea Level Change in the Future in Lynn?

This section describes water elevation of high tides and storm conditions under future climate change scenarios. Changes in the MHHW level under future climate change scenarios were calculated based on:

- Global sea level rise projections developed by NOAA (Parris et al. 2012); and
- Local sea level change based on local historic tide records.

Additional details on approach used for the Lynn assessment, discussion of the sea level rise projections, and calculations of local sea level changes are provided in the Attachment A.

A 25-year time horizon (2041) was selected to support short-term planning, and a 50-year time horizon (2066) was selected to support longer term planning of municipal projects and multi-use development. The estimated changes in MHHW levels due to climate change for the respective time horizons are listed in Table 2 on the next page.

Table 2. Estimates of Sea Level Rise under Future Climate Change Scenarios for Lynn, MA

Estimated Sea Level Rise including local effects relative to 2016[1] (feet)			
Year	NOAA Low	NOAA Intermediate High	NOAA High
2041	+0.23	+0.75	+1.16
2066	+0.46	+1.86	+2.97

Notes: Estimates include local sea level changes from subsidence calculated from historic record.

These estimates were calculated by adding the projected global sea level rise for each time horizon described by NOAA (Parris et al 2012), plus the current local sea level change of 1.1 mm/yr (0.043 inches), calculated based on historic tide records from Boston Harbor.

The estimated level of MHHW under future sea level rise scenarios plus the estimated storm surges for 10- and 100-year storms at Lynn are summarized in Table 3 below.

Table 3. Estimated Sea Level Elevation under Climate Change Scenarios for Lynn, MA

Scenario	2016	2041			2066		
		NOAA Low	NOAA Intermediate High	NOAA High	NOAA Low	NOAA Intermediate High	NOAA High
Mean higher high water (MHHW)	4.8	5.0	5.5	6.0	5.3	6.7	7.8
10-year Storm (Category 1 Storm Results from SLOSH)	7.1	7.3	7.8	8.2	7.5	8.9	10.0
100-year Storm (Category 2 Storm Results from SLOSH)	11.1	11.3	11.8	12.2	11.5	12.9	14.0

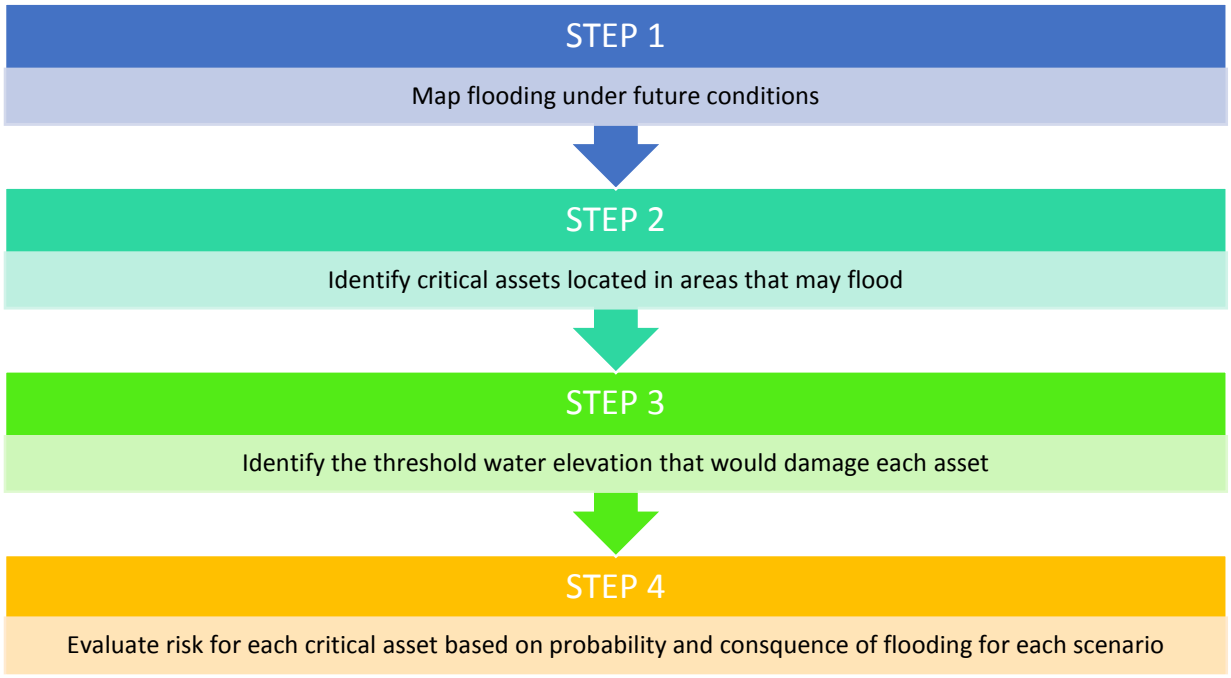
Notes: All elevations in North American Vertical Datum 1988 (NAVD88)

3.0 | Lynn Vulnerability Assessment



Facilities and Infrastructure

The objective of the vulnerability assessment is to identify the assets, infrastructure and resources in Lynn most vulnerable to changing coastal conditions expected under future climate change conditions. Vulnerability was evaluated in four steps:



Step 1: Map flooding under future conditions

Based on the estimated future high tide and storm surge water levels, the following maps were developed in a geographic information system (GIS) to depict the extent of inundation under the study scenarios. These oversized figures as included at the end of the report.

Figure 4: 2041 Estimated MHHW Inundation under Future Sea Level Rise Scenarios

Figure 5: 2066 Estimated MHHW Inundation under Future Sea Level Rise Scenarios

Figure 6: 2041 Estimated Inundation under Future Climate Change Scenarios - 100-year Storm

Figure 7: 2066 - Preliminary Estimated Inundation under Future Climate Change Scenarios – 100-year Storm

Step 2: Identify critical assets located in areas that may flood

The vulnerability/risk assessment focused on facilities and other resources essential to public safety and health, and the economic viability of the City of Lynn. Other federal, state, and privately-owned facilities that are not critical to protecting public health and safety were not included in the assessment. Critical assets were identified from the City's Hazard Mitigation Plan, analysis of available GIS information, and discussions with City and state officials. The results of the vulnerability assessment will support planning to further define and implement adaptation measures to reduce hazards and increase resiliency.

Step 3: Identify threshold water elevation that would damage each asset

The threshold elevation is the level of inundation that would cause damage/impact to functionality of each critical facility. Threshold elevations were determined based on one or more sources including onsite observation, estimates from aerial photography and contour data, owner supplied information, and published data.

Step 4: Evaluate risk for each critical assets based on probability and consequence of flooding for each study scenario.

If an asset was flooded by water exceeding the threshold elevation under any of the study scenarios, the risk was calculated for that specific asset. Probability of flooding above the threshold elevation was determined as:

- 100% for the predicted MHHW level
- 10% for the predicted 10-year storm water level
- 1% for the predicted 100-year storm water level
- 0% if estimated flooding did not exceed the threshold elevation for a particular study scenario

The consequence of flood water exceeding the threshold elevation was determined using a matrix of consequence type and severity, as shown in Table 4 below.

Table 4. Criteria Describing Consequence

Score		Public Safety, Emergency Services	Public Health, Environment	Repair cost	Reduced Economic Activity	Public Services; Duration
Severity	5	Regional Emergency	Regional Emergency	>$20 MM	Regional Emergency	>1 Month
	4	City Emergency	City Emergency	$2 MM - $20 MM	City Emergency	15-30 Days
	3	High	High	$200 K - $2 MM	High	7-14 days
	2	Moderate	Moderate	$20K - $200K	Moderate	1-6 days
	1	Low	Low	<$20K	Low	< 1 day

Coastal Protection

Shoreline erosion from increasingly intense storms and changes in wave patterns as sea levels rise pose additional risk of inundation and flooding. A review of coastal physical processes and the existing seawalls and coastal structures that currently protect the Lynn shoreline was conducted to evaluate the potential risk due to shoreline erosion.

Lynn is located north of Boston, along a southeast-facing shoreline, as shown on the National Oceanic and Atmospheric Administration (NOAA) navigation chart for the Lynn coastline provided in Figure 8. The Nahant Causeway connects Nahant to the mainland at Lynn and separates the Lynn shoreline into northern and southern sections. The causeway provides a natural barrier that shields Lynn Harbor from the open Atlantic Ocean.

Most of the Lynn shoreline is protected by hard infrastructure. North of the Nahant Causeway, a seawall runs along the edge of Lynn Shore Drive. Sandy beaches (Kings and Lynn beaches) and rocky intertidal areas (Red Rock Park) lie between the seawall and the ocean. Land use is primarily single- and multi-family residential and beach areas (City of Lynn 2005). The approximately 4-mile-long shoreline is on Nahant Bay, which opens to the Atlantic Ocean.

Hard Infrastructure

Engineered physical structures such as bulkheads, seawalls, groins, and jetties that provide coastal protection.

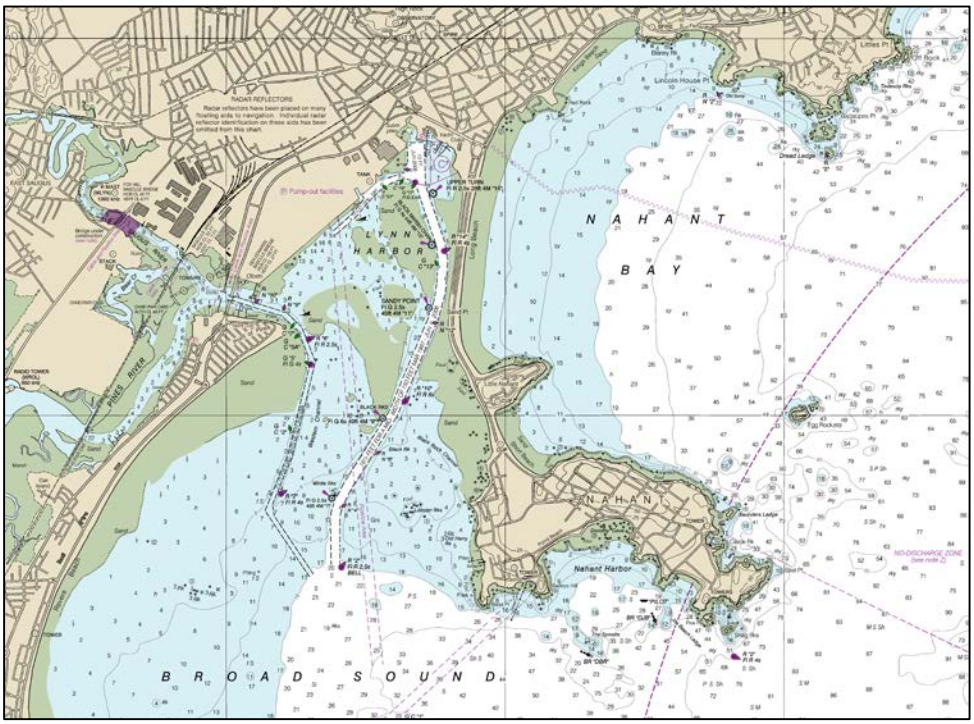


Figure 8: Lynn Harbor and Nahant Bay Navigation Chart (Source: U.S. Department of Commerce et al. 2013)

Seawalls and bulkheads of varying types and condition run along the Lynn shoreline south of the Nahant Causeway. Soft features, such as beaches and tidal flats are also present on the water side of the seawalls (MassGIS Moris 2016). Land use is industrial intermixed with residential and commercial uses, vacant land, and Heritage State Park (City of Lynn 2005). Lynn Harbor lies between the Lynn shoreline and the Nahant Causeway and opens to Broad Sound to the south. The Saugus River discharges into the southern portion of Lynn Harbor.

Much of the Lynn shoreline along the Saugus River is protected by earthen berms or in some cases, small retaining walls. Land use is industrial near the mouth of the Saugus River, and primarily residential, with some industrial/commercial, farther upstream. Riverfront property is not as susceptible to wave action as the eastern, Atlantic-facing shoreline. However, residents indicated during public meetings conducted for this study that they are experiencing increasing flooding under normal tidal conditions, and especially during extreme high tides such as King Tides. Although a King Tide is an unusually high water elevation that occurs once or twice a year now, as sea level rises due to global climate change, these high tides will become more frequent and increased flooding will occur.

Coastal Protection Structures

A general evaluation of coastal structures that protect the Lynn shoreline was primarily based on a database developed by the Commonwealth of Massachusetts and available on the Massachusetts Ocean Resource Information System (MORIS) online mapping tool, discussions with EDIC and City department managers, and input during public meetings conducted during this study. Coastal protection structures located in Lynn are depicted on oversized Figure 9 at the end of the report and are color coded to indicate if the structure will be overtopped under a current storm or future climate change scenario. The ownership of the structures–either public or private–is also indicated. Based on this mapping and anecdotal information from EDIC, the protective structures are generally effective flood protection for the Lynn shoreline.



The shoreline in front of a closed landfill located between the Riley Way Extension and the Lynn Wastewater Treatment Plant was identified as a potential erosional area that could affect the stability of the landfill. The seawall protecting this area is heavily damaged and offers no protection from wave erosion or flooding. Further, future sea level rise would result in landward advancement of the high tide level. Also, increases in local sea level would allow larger waves to propagate closer to the shore and thus increase the potential for shoreline retreat.

Shoreline Retreat

Landward movement of the shoreline as a result of erosion and wave propagation.



Damaged seawall near Riley Way

Erosion Analysis

An analysis including estimates of waves and erosion under future climate change conditions was conducted as a first level screening to evaluate the potential for erosion of the shoreline and risk to the landfill at the Riley Way Extension.

The erosion analysis was based on the NOAA-**Highest** sea level rise projection for 2041 and 2066. Results indicate that waves impacting the Lynn Harbor shoreline could have significant wave heights between four to five feet during a 100-year (1% probability) storm event.

Based on this analysis, there is a potentially high risk of erosion and shoreline retreat bordering the landfill at the Riley Way Extension. The seawall that was constructed to protect this shoreline is not functional, and the shoreline, along with the landfill and protective cap, is currently at risk.



Erosion resulting in 7 to 18 ft. of shoreline loss in front of the closed landfill is estimated under climate change scenarios.



Rendering of Lynn shoreline before (above) and during (below) a 100-year storm event

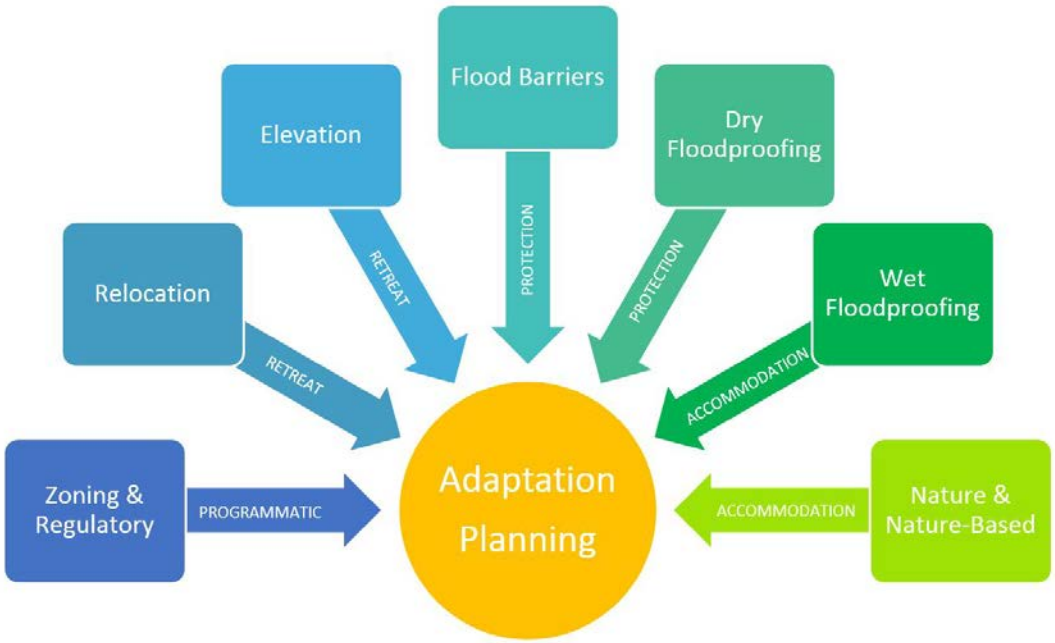
4.0 | Adaptation Strategies



Adaptation strategies developed for this study draw on a wide array of options for minimizing vulnerability and risk to sea level rise effects. In general, adaptation strategies can be categorized as programmatic measures or capital investments.

Programmatic measures typically include: administrative measures; community involvement; zoning and regulatory measures; operations and management; and acquisitions.

Capital investments are generally engineering measures that retreat from, protect, and/or accommodate flood waters.



Adaptation Approaches to Address Coastal Climate Change Vulnerability

The strategies outlined in the sections to follow are meant to list potential alternatives that can be used in conjunction with other strategies for compounded adaptation planning. No alternatives analysis or feasibility assessment has been completed for this study at this time.

Adaptation strategies are presented below to address vulnerabilities and risk for:

- General coastal protection
- General infrastructure sectors (transportation, utilities and energy, wastewater and drainage)
- Specific facilities in the City of Lynn critical to public health and safety.

Coastal Protection

As described in Section 3, the City of Lynn is protected from the Atlantic Ocean by a series of seawalls of varying height and condition. Industrial facilities on the Saugus River, such as General Electric (GE), are also protected by seawalls, as are many residential properties.

> In urban areas with large populations – especially those that are environmental justice communities – implementation of highly engineered structural protection measures will likely be a high priority for extensive public infrastructure and private development.
>
> *Massachusetts Climate Change Adaptation Report*
> *Chapter 8 - Coastal Zone and Ocean; MA EOEEA 2011*

Green or integrated flood protection typically requires space between the normal high tide line and the infrastructure or resource to be protected. In many cases in Lynn, this space is not available, and maintenance of the seawalls at elevations that will protect against current and future flood conditions may be the preferred adaptation alternative.

Coastal adaptation measures are best developed as integrated systems with both soft and hard elements to protect coastal resources and natural systems. As such, they require feasibility analyses to establish design parameters as well as careful consideration of permitting requirements at early stages of development. The adaptation concepts presented here are meant to be a starting point to develop effective and implementable projects.

The City of Lynn has a Municipal Harbor Plan approved by the Commonwealth of Massachusetts on June 28, 2010. Coastal adaptation measures should be developed in the context of this plan, including the Designated Port Area.

Resilient coastal protection design concepts were developed for three generalized cases described below and depicted in Figure 10. Permitting requirements were considered in developing these concepts, but a specific feasibility assessment is required for a full evaluation of regulatory compliance.

Case 1: New commercial or public development where space is available between the high tide line and infrastructure

- Green design including natural coastal protection elements
- Provides recreational space
- Living with Water concept
- Commercial or public development
- Space is available between infrastructure and the high tide line
- Consider for new development

Case 2: A lower cost option for residential infrastructure with limited space between the high tide line and the house

- Lower cost solutions for existing residential areas
- Deployable seawall would be deployed prior to extreme storms, and allows the permanent hard structure to be low enough to allow an ocean view
- Habitat enhancement on vegetated, natural barrier
- Raising house freeboard improves resilience

Case 3: Commercial or public development, either existing or new, with limited space between the high tide line and infrastructure

- Hard coastal protection
- Habitat provided in subtidal shelf seaward of the hard structure
- Temporary seawall would be deployed prior to extreme storms, and allows the permanent hard structure to be low enough to allow an ocean view
- Consider for existing commercial and industrial areas

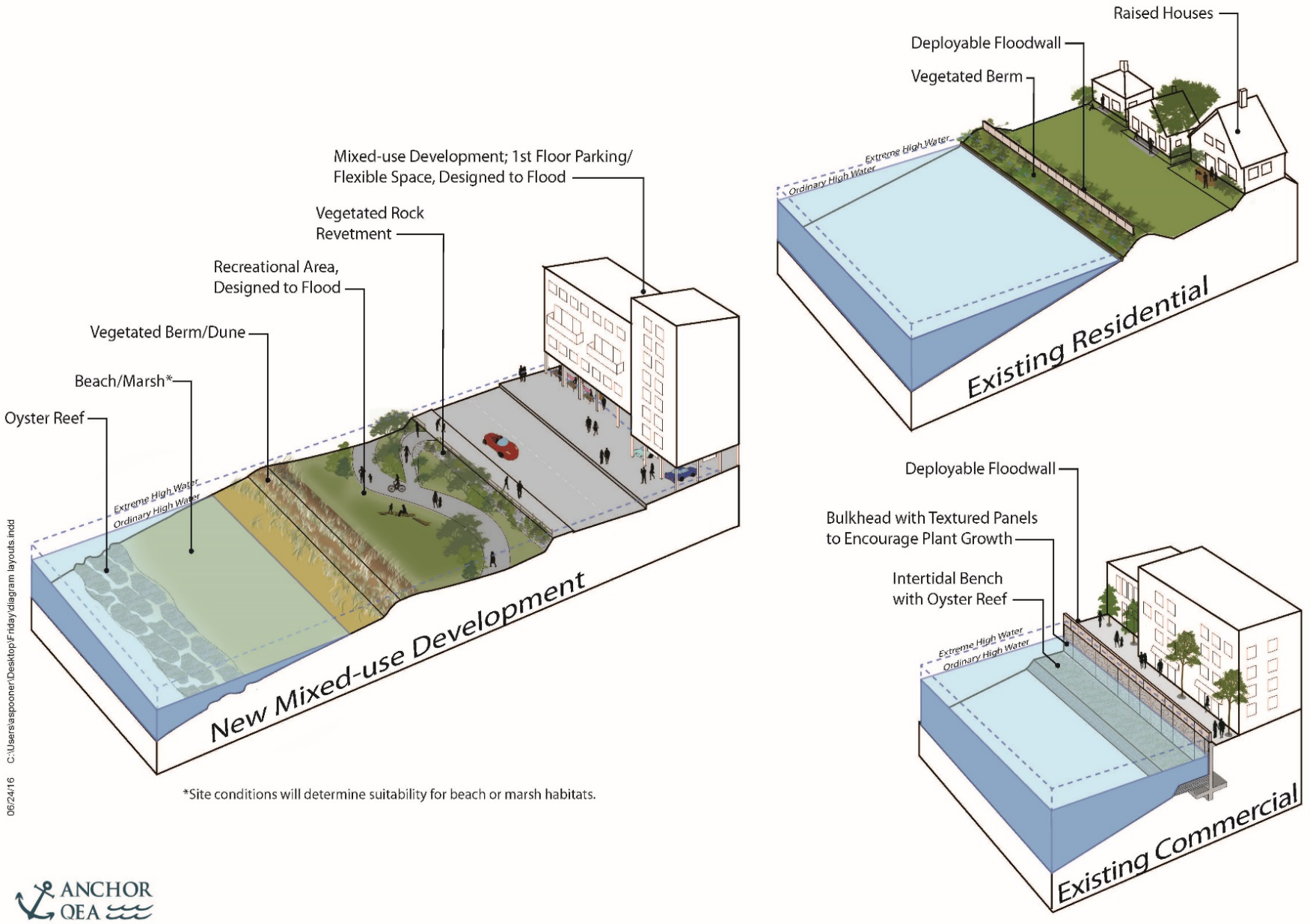


Figure 10. Coastal Protection Adaptation Concepts

Transportation

Transportation is critical for evacuation and emergency access and response before, during, and after storm events. Nuisance flooding due to high tides is also a concern for traffic and access to commercial and residential properties. Utilities buried in roadways and electrical conduit boxes may not be accessible during flooding events. An incremental approach to adaptation for climate impacts is typically recommended for transportation corridors. Plans to elevate roadways, access to buildings, and utilities should be incrementally adapted as part of capital improvements. Considerations to grading roadways and sidewalks, using pervious pavement, and developing green infrastructure solutions, such as bioswales and rain gardens, will improve infiltration and manage stormwater runoff. Short-term solutions may include road closures with advance notice to residents. Evacuation routes should be evaluated for potential inundation in coordination with emergency services and state transportation agencies and relocation of routes may be considered.



Image and rendering of Camden Street Intersection before (left) and after (right) a 100-year storm

Several of the transportation facilities were identified as potentially vulnerable to climate change effects. Adaptation alternatives are discussed below for the Lynn Ferry Pier and two critical intersections (Lynnway and Blossom and Nahant Circle). Additional information is included in Attachment C.

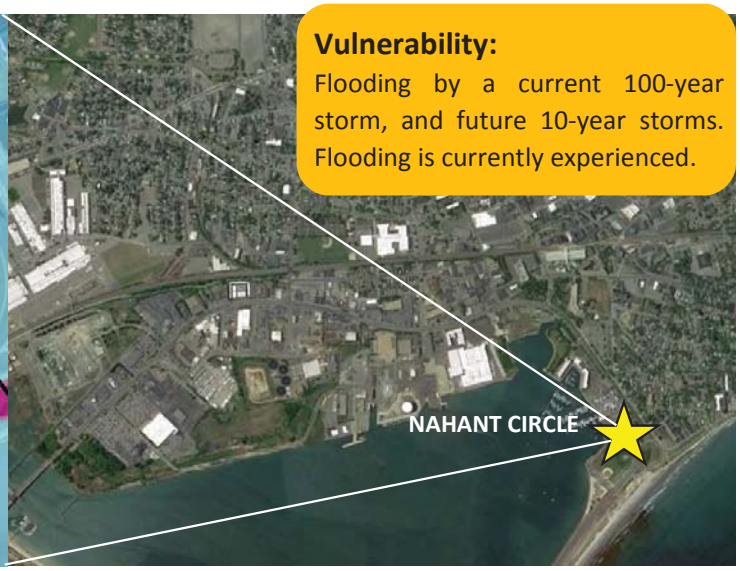
Lynn Ferry Pier

The Lynn Ferry Pier is protected by a seawall that would not be overtopped under any of the evaluated future climate change scenarios. However, results of the vulnerability and risk assessment indicate that given the elevation of the pier, if the seawall was ineffective, the area could be inundated by a 10 year (10% probability) storm in 2066. Thus, it is important to maintain the wall so that it remains in good condition to avoid flooding in the long-term. Also, the boat launch adjacent to the seawall provides a possible pathway for flooding as sea level rises and storm intensity increases. Discussions with EDIC indicate that flooding has not occurred, but if the area does start to experience flooding through the boat launch, an additional evaluation of vulnerability and adaptation alternatives should be undertaken.



Lynn Ferry Pier





Vulnerability:
Flooding by a current 100-year storm, and future 10-year storms. Flooding is currently experienced.

Consequence of Failure

Risk:
High consequence of failure as a main thoroughfare, especially for evacuation of Nahant.

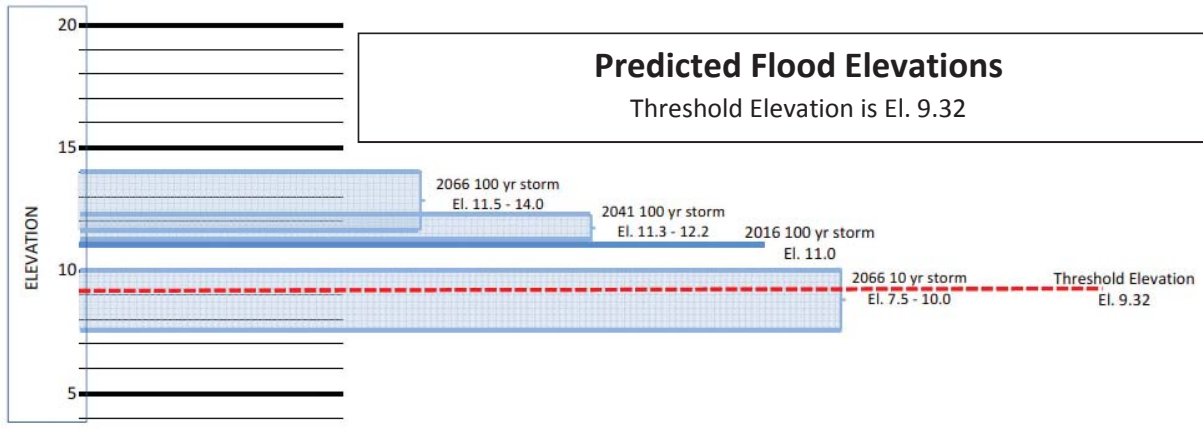
Severity	Score	Criteria Describing Consequence: Public Safety, Emergency Services	Public Health, Environment	Repair Cost	Reduced Economic Activity	Public Services; Duration
	5	Regional Emergency	Regional Emergency	>$20 MM	Regional Emergency	>1 Month
	4	City Emergency	City Emergency	$2 MM - $20 MM	City Emergency	15-30 Days
	3	High	High	$200 K - $2 MM	High	7-14 days
	2	Moderate	Moderate	$20K - $200K	Moderate	1-6 days
	1	Low	Low	<$20K	Low	< 1 day

Risk Score

Critical Intersection	Consequence Score	Probability 2016	Probability 2041	Probability 2066	Weighted Risk Score
Nahant Circle	52	0.01	0.01	0.1	1.92

Predicted Flood Elevations

Threshold Elevation is El. 9.32



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OVERVIEW OF ADAPTATION

Adaptation measures to protect Nahant Circle from current and future flooding are presented to the right in order of consideration. Any of the adaptation options would require additional feasibility assessment to fully consider the design requirements and effectiveness of the solution, which would likely involve improving coastal protection. As with any coastal project, the effects on coastal dynamics such as depositional patterns, waves and currents, should be considered.

The seawall from the Nahant/Lynn Beach could be extended and possibly increased in height to block flows from the sea. Since the public beach is an important amenity, the seawall would need to be designed to allow access to the beach. Also, it should be designed as to not interfere with natural coastal processes that result in beach deposition.

As an alternative to a hard shoreline solution, construction of stabilized, vegetated dunes as a natural barrier to flooding could be considered. Large dunes are present along the Nahant Beach to the south, and could possibly be extended into this area. A dune system would enhance the aesthetic and recreational aspects of the beach. Also, the slope of the beach could be altered to modify coastal dynamics and water circulation that could help to suppress nuisance algae blooms that are problematic in this area. Improving drainage along the road to aid in infiltration and directing/draining water away from the roads would also help to minimize flooding potential.

Nature Based Solution: Dunes

The dune system that runs along the Nahant Causeway south of Nahant Circle could be extended to protect the roadway. May be easier to permit than a hard seawall and would provide additional coastal dune habitat and add to aesthetics.

Implementability: Moderate. Analysis of coastal dynamics and sediment transport would be required to determine the feasibility and to estimate a cost range for the entire project.

Effectiveness: Low to Moderate. Should be used in conjunction with improving drainage around the roadway to accommodate any flood waters.

Cost: Moderate to High depending on the pre-design coastal dynamics study.

Flood Barrier Solution: Permanent Hard Barrier

There is a gap in the seawall at the Nahant Rotary that allows flooding of the roadway. The seawall could be extended to protect Nahant Circle.

Implementability: Moderate. Access to the public beach adjacent to Nahant Circle would need to be provided. Permitting installation of a new section of seawall may be problematic.

Effectiveness: High. A seawall would block tidal, storm and wave inundation

Cost: High. Engineering studies to determine design parameters, potential changes to coastal dynamics, design, permitting and construction may cost several million dollars.

Nature Based Solution: Green Stormwater Infiltration and Retention

Using low impact development techniques (bioswales, pervious surfaces), improve drainage supports rapid draining of the roadway following flooding. Would benefit any roadway or intersection with flood risk and space to implement.

Implementability: Easy to Moderate. Drainage study may be required.

Effectiveness: Low. Good for drainage of nuisance flooding. Will not reduce storm surge or prevent flooding. Effectiveness decreases if stormdrain infrastructure is overwhelmed by flooding.

Cost: Low to Moderate. Evaluation of sites and planning needed. Long term benefits may outweigh costs.

Elevation Solution: Road Elevation

Elevation of the roadway will reduce vulnerability to flooding. For future planning and construction, innovations such as floating sidewalks should be assessed as technology develops.

Implementability: Moderate to Difficult. Some incremental raising of roadway could be accomplished as part of future road construction projects. Significant raising of roadway does not appear feasible.

Effectiveness: Low. High if approach roadways at or below the same elevation as the circle are raised.

Cost: High.

Flood Barrier Solution: Deployable Floodwalls

Deployable floodwalls or a temporary dike structure provide a short term solution to flood defense. Floodwall would need to protect vulnerable approach roads to be effective.

Implementability: Moderate. Panels can be easily installed, removed, and stored since they are foldable and stackable. Installation staff needs to be available and trained. Space would need to be designated for installation along the roadway.

Effectiveness: Limited benefits unless key approach roads are protected. Depends on installation prior to a storm surge event. At Nahant Circle, a permanent solution is preferable since the area currently floods.

Cost: Moderate based on materials and labor. $600/ linear foot of barrier plus installation before each storm event. Frequent installation increases cost.

See Section 5 for a comprehensive list of references used to develop these Adaptation Strategies.

Lynnway & Blossom St. Intersection — Vulnerability and Risk





Vulnerability:
Flooding mapped by current 100-year storm, and future 10-year storms. Flooding is currently mitigated by existing seawalls.

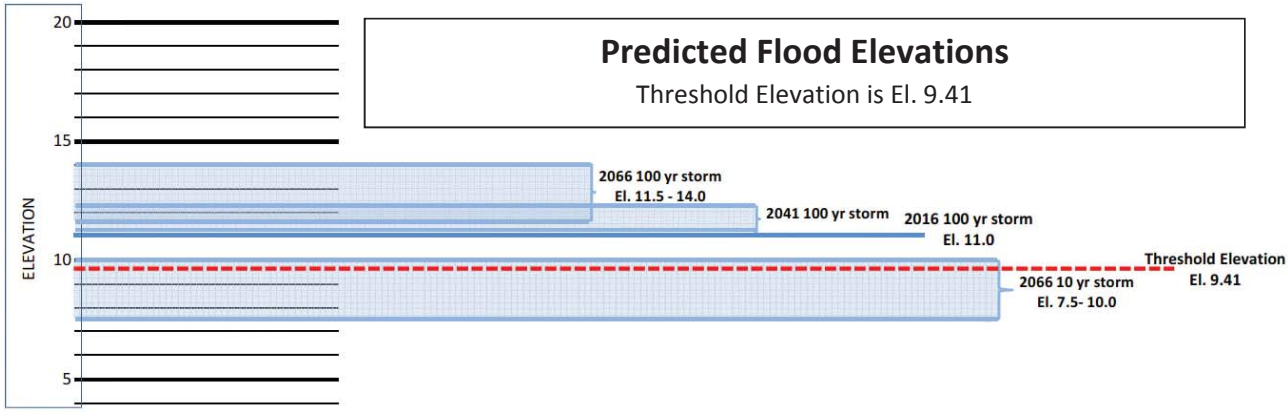
Consequence of Failure

Risk:
High consequence of failure to emergency transportation.

		Criteria Describing Consequence				
Severity	Score	Public Safety, Emergency Services	Public Health, Environment	Repair Cost	Reduced Economic Activity	Public Services; Duration
	5	Regional Emergency	Regional Emergency	>$20 MM	Regional Emergency	>1 Month
	4	City Emergency	City Emergency	$2 MM - $20 MM	City Emergency	15-30 Days
	3	High	High	$200 K - $2 MM	High	7-14 days
	2	Moderate	Moderate	$20K - $200K	Moderate	1-6 days
	1	Low	Low	<$20K	Low	< 1 day

Risk Score

Critical Intersection	Consequence Score	Probability 2016	Probability 2041	Probability 2066	Weighted Risk Score
Lynnway and Blossom	52	0.01	0.01	0.1	1.92



Predicted Flood Elevations

Threshold Elevation is El. 9.41

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Lynnway & Blossom St. Intersection — Adaptation Strategies

OVERVIEW OF ADAPTATION

Adaptation measures to protect the intersection at Lynnway & Blossom Street from future flooding are presented to the right in order of consideration. Any of the adaptation options would require additional feasibility assessment to fully consider the design requirements and effectiveness of the solution, which may be achieved by comprehensive coastal protection along the waterfront.

Several site-specific alternatives should be considered.

Improving drainage along the road to aid in infiltration and directing/draining water away from the roads may help to reduce the impact of a flood event and improve recovery time. This may be achieved by natural or nature based solutions, including bioswales and pervious surfaces.

Gradual raises in the roadway elevation as a part of future road construction projects should be considered. Redesigning the Lynnway as a raised transportation corridor that could double as a dike may be considered in future alternatives analyses.

Flood barriers placed between the Lynnway and the waterfront, either permanent or temporary, may be considered in the future. Permanent barriers may have a gate system that can be adjusted to water height and removed during dry conditions to facilitate travel and access to the area.

Nature Based Solution: Green Stormwater Infiltration and Retention



Using low impact development techniques (bioswales, pervious surfaces), improve drainage supports rapid draining of the roadway following flooding. Would benefit any roadway or intersection with flood risk and space to implement.

Implementability: Easy to Moderate. Drainage study and site redesign may be required.

Effectiveness: Low. Good for drainage of nuisance flooding. Will not reduce storm surge or prevent flooding. Effectiveness decreases if stormdrain infrastructure is overwhelmed by flooding. Provides asthetic value and mitigates heat effect of climate change.

Cost: Low to Moderate. Evaluation of sites and planning needed. Long term benefits may outweigh costs.

Elevation Solution: Road Elevation

Elevation of the intersection and Lynnway will reduce vulnerability to flooding. For future planning and construction, innovations such as floating sidewalks should be assessed as technology develops.

Implementability: Moderate to Difficult. Some incremental raising of roadway could be accomplished as part of future road construction projects. Significant raising of roadway does not appear feasible at this time, but may be reconsidered in the future.

Effectiveness: Low. High if approach roadways at or below the same elevation as the Lynnway are raised.

Cost: High.

Flood Barrier Solution: Permanent Hard Barrier



Source: Spill-barrier.info

A permanent flood barrier could be constructed between the Lynnway and the waterfront. The barrier could be adjustable for height of water and removed during dry conditions.

Implementability: Difficult. Significant permitting and design would be required prior to construction. Politics of implementation may deem project unfeasible.

Effectiveness: High for areas within the protection of the barrier. Would not provide additional protection for area between the barrier and waterfront.

Cost: High. Engineering studies to determine design parameters, design, permitting and construction may cost several million dollars.

Flood Barrier Solution: Deployable Floodwalls

Deployable floodwalls or a temporary dike structure provide a short term solution to flood defense. Floodwall would need to protect vulnerable approach roads to be effective.

Implementability: Moderate. Panels can be easily installed, removed, and stored since they are foldable and stackable. Installation staff needs to be available and trained. Space would need to be designated for installation along the roadway.

Effectiveness: Limited benefits unless key approach roads are protected. Depends on installation prior to a storm surge event.

Cost: Moderate based on materials and labor. $600/ linear foot of barrier plus installation before each storm event. Frequent installation increases cost.

See Section 5 for a comprehensive list of references used to develop these Adaptation Strategies.

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Utilities and Energy

Rising flood levels and increased frequency of flooding may result in impacts to utilities located in areas not previously flooded. Damage of this type of infrastructure can have both short and long term effects on public health and commerce. No publically owned critical utilities or energy infrastructure were identified to be at risk during this analysis, However, building managers of privately owned facilities within the projected flood zones should prepare in advance of flood events to protect utilities and energy sources. Adaptation measures for consideration include:

- Elevating utilities above flood elevation
- Making utilities or access to utilities watertight or waterproof
- Creating a barrier around utilities
- Evaluating system redundancy
- Preparing easy hook-ups for generators
- Developing an emergency plan

Wastewater and Drainage

Current climate change projections indicate increased rainfall over short periods and more frequent nuisance flooding, which have the potential to overwhelm existing drainage systems. Low-lying areas are vulnerable to flood events which may additionally impact gravity-based sewage collection during flood events. Several programmatic measures are recommended for study in coordination with the Lynn Water and Sewer Commission (LWSC):

- Conduct a Drainage System Capacity Study to evaluate current system capabilities. The results from the study can be used to prioritize the most critical/problematic components of the drainage system and incorporate these projects into the LWSC capital improvement plan.
- Evaluate installation and/or upgrade of Stormwater Lift Stations.
- Evaluate installation and/or upgrade of tide gates at outfalls. Several options might include a duckbill/tide flex, buoyant front flap, or another self-regulating structure.
- Consider options for stormwater storage including, but not limited to, above or below ground storage containers, nature based storage (bioswales or bioretention ponds), and/or permeable concrete or asphalt.



Duckbill Valves at Outfalls
(Source: TideFlex)

- Evaluate merits of a water level monitoring and alert system to identify inundation and manage water and sewer operations during storm and flood events.

According to the Lynn Water and Sewer Commission, the increased rainfall would create high flows in the stormwater drainage collection system. If the stormwater collection system is combined with the sewer (also known as a combined sewer overflow or CSO, then the system would eventually reach capacity and overflow at the weir locations and discharge at the CSO outfalls.

Flooding from rainfall occurs in low-lying areas where there is poor drainage, primarily due to impervious surfaces, not because the system is at capacity and cannot take any more flow. Green infrastructure solutions or pervious pavements should be considered to reduce stormwater runoff volume in the system. Additionally, the Lynn Water and Sewer Commission has plans to separate the combined system in the future which will significantly increase the capacity for drainage and essentially eliminate CSO discharges.



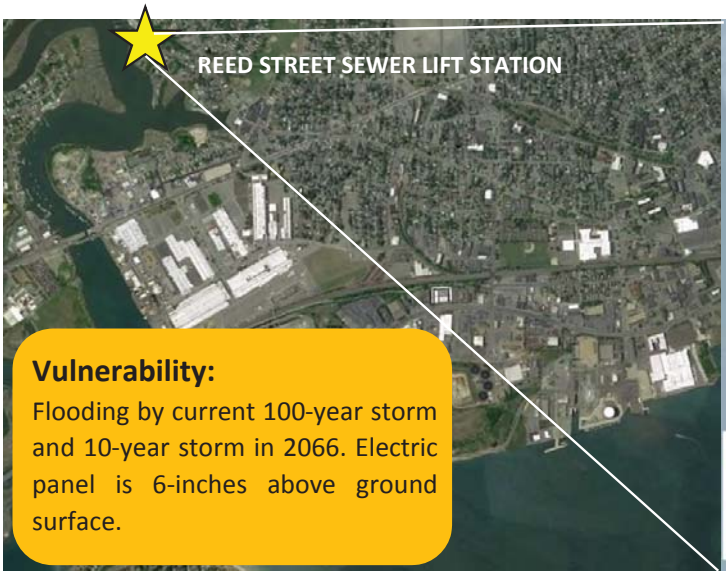
Bioretention Rain Garden
(Source: Massachusetts Stormwater Handbook)

Several sewer lift stations were identified during the risk and vulnerability study including the Camden Street Sewer Lift Station and the Reed Street Sewer Lift Station. An overview of each pump station, including the risk and vulnerability scores and several adaptation strategies are included in this section. Additional information is included in Attachment C.

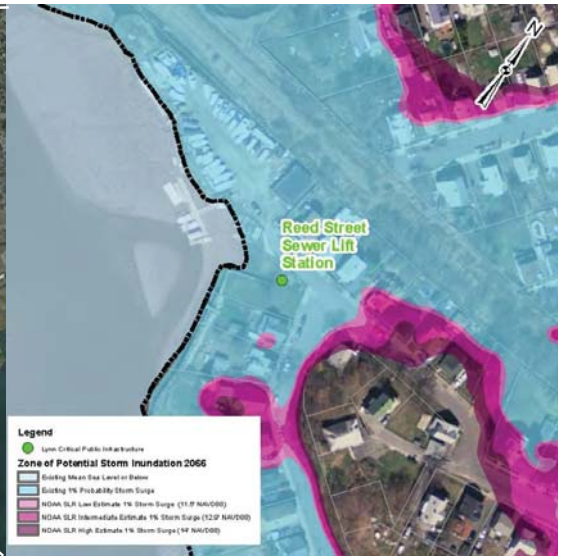




Image and rendering of Reed Street Pump Station before (left) and after (right) a 100-year storm



Vulnerability:
Flooding by current 100-year storm and 10-year storm in 2066. Electric panel is 6-inches above ground surface.



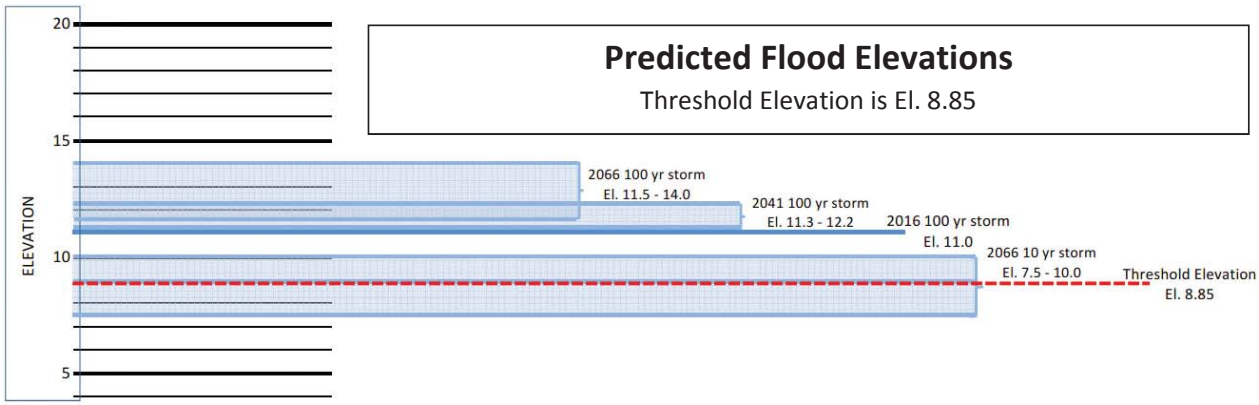
Consequence of Failure

Risk:
High consequence of failure to Lynn wastewater system

Severity	Score	Criteria Describing Consequence: Public Safety, Emergency Services	Public Health, Environment	Repair Cost	Reduced Economic Activity	Public Services; Duration
	5	Regional Emergency	Regional Emergency	>$20 MM	Regional Emergency	>1 Month
	4	City Emergency	City Emergency	$2 MM - $20 MM	City Emergency	15-30 Days
	3	High	High	$200 K - $2 MM	High	7-14 days
	2	Moderate	Moderate	$20K - $200K	Moderate	1-6 days
	1	Low	Low	<$20K	Low	< 1 day

Risk Score

Facility	Consequence Score	Probability 2016	Probability 2041	Probability 2066	Weighted Risk Score
Reed Street Sewer Lift Station	64	0.01	0.01	0.1	2.37



Predicted Flood Elevations

Threshold Elevation is El. 8.85

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OVERVIEW OF ADAPTATION

Adaptation measures to protect Reed Street Sewer Lift Station from future flooding are presented to the right in order of consideration. Any of the adaptation options would require additional feasibility assessment to fully consider the design requirements and effectiveness of the solution.

The recommended alternatives are likely to be some combination of wet and/or dry floodproofing. Wet floodproofing prevents or provides resistance to damage from flooding while allowing floodwaters to enter the sewer lift station. Generally, this would include anchoring the station, using flood resistant building materials, protecting the mechanical and utility equipment, using openings or breakaway walls, and or installing submersible pumps. Reed Street Sewer Lift Station already has submersible pumps installed, so the primary consideration would be to protect the electrical panel from flood waters by making the panel watertight.

Another alternative would be to allow water to enter the structure, but to raise the electrical panel above the flood elevation.

Dry floodproofing prevents water from entering the structure by sealing the doors and windows. The method effectively makes the station water tight, assuming there are no vents or cracks within the flood zones. This requires that the station is structurally designed to withstand hydrostatic pressures. Small barriers can be constructed around low-lying vents to maintain ventilation and prevent flood water from entering the structure.

Wet Floodproofing Solution: Making Electrical Systems Watertight

Wet floodproofing would involve making all electrical fixtures below the predicted flood elevations waterproof and installing a watertight box around the electrical panel.
Implementability: Easy to moderate. Involves equipment retrofitting; it currently is equipped with a submersible pump.
Effectiveness: Moderate to High. Would reduce likelihood of loss of power to the pump station and maintain system functions during flood events.
Cost: Moderate, includes retrofitting parts and labor.

Elevation Solution: Raising Electrical Panel

Elevating the electrical panel out of the predicted inundation zone would eliminate the vulnerability and risk of losing power to the sewer lift station.
Implementability: Easy to moderate. Would require retrofitting of existing electrical panel and be used in conjunction with waterproofing electrical wires below flood zone.
Effectiveness: High. It would be out of the inundation zone and may be designed to be accessible during flood events.
Cost: Moderate. Roughly $20,000 for electrical panel modifications.

Dry Floodproofing Solution: Sealing the Sewer Lift Station

Dry floodproofing would involve evaluating the structural integrity of the pumpstation walls under possible flood loads, sealing access areas and vault walls, and modifying vent systems so water can't enter the station.

Implementability: Moderate. Involves modification to vault and openings.
Effectiveness: High. Effectiveness is dependent on the integrity of the seal and the ability of the pump station to withstand flood loads and buoyant loads.
Cost: Low to Moderate. Roughly $15,000 for sealing the station, modifications to vents, and analysis of structural integrity. (not including structural modifications).


Source: Resilientdesign.org


Source: FEMA

Flood Barrier Solution: Permanent barrier around structure

Building a permanent dike or barrier around the structure can protect it from flood waters. The barrier would be designed for flood loads for predicted elevations as well as piping and buoyant conditions. Systems with stop logs or gates can be used to access the structure in dry conditions.
Implementability: Moderate. Possible interferences with other site uses and permitting and code requirements.
Effectiveness: High. Prevents flood waters from reaching the station.
Cost: High. Requires determination of design parameters, design, permitting, and construction.

Redundancy

The combination of several adaptation strategies should be considered in future alternatives analyses to provide additional adaptation effectiveness and protection. Installing back up power or a water level alert system would decrease the risk of failure.

See Section 5 for a comprehensive list of references used to develop these Adaptation Strategies.

Hazardous Materials

Hazardous materials can be discharged or mobilized during a flood event by several means. Hazardous materials, including fuel, solvents, and other chemicals used in industrial and commercial facilities can be discharged and mobilized if their containers are damaged by flood waters. Contaminated sites may be flooded and contaminants mobilized under certain conditions.

Flooding from storm surges and wave action can disperse stored hazardous materials often present in commercial and industrial facilities. Larger scale catastrophic releases are possible; approximately 819,000 gallons of crude oil was released when an aboveground storage tank was damaged during Hurricane Katrina.



Oily Debris Field after Hurricane Sandy. November 2, 2012 (Source: USCG in NOAA Office of Response and Restoration)

The Resource Conservation and Recovery Act (RCRA) regulations require management and storage of hazardous waste and materials that minimize the risk of release, and provide for containment of spills. Facilities located within inundation zones that store and use hazardous materials and waste should be made aware of potential future climate change flooding risks identified in this report, and advised to account for that possibility in their containment and storage facilities, and in their spill prevention plans. In addition, the City's Fire Department (Office of Emergency Management) has been integral to this study and will be given this report to consider during inspections for hazardous material storage.

Contaminated Sites

The primary effects of storms and flooding contaminated land are offsite transport of contaminated media, or erosion/damage of controls on remediated sites (i.e. damage of a cap preventing contact with contaminated soils). Operating remediation systems, such as groundwater treatment or thermal desorption systems, may also be damaged by storms and flooding. Any identified disposal sites impacted with oils or hazardous materials within the inundation zones should be reviewed for climate change resiliency based on projections of future conditions.

Healthcare and Medical Services

Access to medical care and emergency services is critical during and after a storm or flood event. Transportation is a vital part of emergency services and related adaptation strategies.

Two healthcare/medical facilities were identified during the risk and vulnerability study: the Habit Management Center (i.e. Methadone Clinic) and the DCR Connery Skating Rink, which serves as an emergency mortuary in case of a catastrophic event. Both of these facilities were identified as relatively low-risk of flooding, neither are owned by the City and they were not evaluated for adaptation alternatives. However, each of these facilities should have a flood protection plan in place. See Attachment C for possible adaptation strategies that could be applied to these facilities.

Programmatic Adaptation

Planning and regulatory documents are some of the tools the City has to address risk due to predicted SLR and increased storm surge. As part of this coastal resiliency assessment, local regulations and plans have been reviewed, and opportunities are identified for potential revisions of existing plans and regulatory modifications that could increase coastal resiliency, including along the Saugus River. In general, the types of regulatory changes would pertain to land use, zoning, and building codes.

Administrative Adaptation Measures

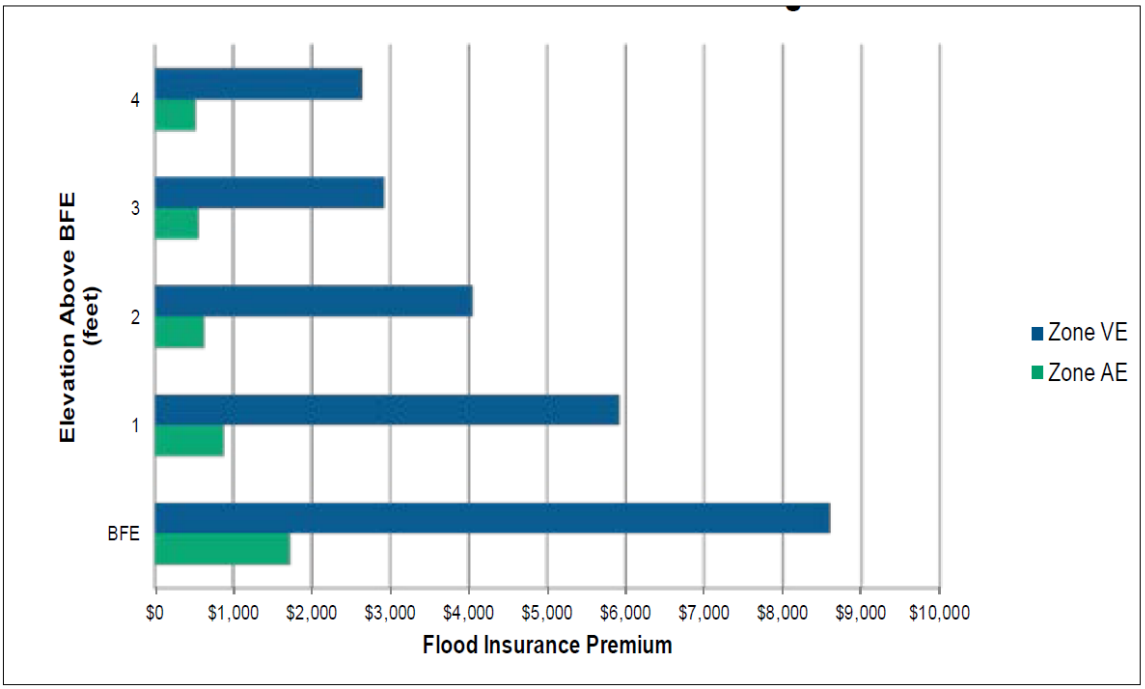
Other administrative adaptation alternatives include raising the elevation of the structures (see Hull Massachusetts Coastal Resiliency report), implementing zoning and planning approaches that discourage development close to the high tide line or encourage integration of flood protections into development plans. Increasing the amount of space between the anticipated high water level and building floors, referred to as the freeboard, can provide both protection against flooding and property loss, and savings on flood insurance. FEMA's general estimate of potential savings is summarized in Figure 11.

Increasing Freeboard

Elevating a building's lowest floor above predicted flood elevations, typically 1 to 3 feet above the National Flood Insurance program minimum height requirements

MA CZM StormSmart Communities

In Massachusetts, increasing freeboard can be initiated by communities through incentives, as changing regulations is not allowed. In Hull, the program provides a discount on building permits if freeboard is resilient to climate change effects. This program has been reportedly successful.



FEMA Zone VE: Area inundated by 1% annual chance flooding with additional hazards due to storm induced velocity wave action.
FEMA Zone AE: Area inundated by 1% annual chance of flood.

Figure 11: Maximum Coverage for a $25,000 residential building and $100,000 contents (Source: FEMA Building Higher in Flood Zones: Freeboard – Reduce Your Risk, Reduce Your Premium)

Local Regulations and Planning Documents

Potential changes to the planning documents and regulations that could support coastal resilience and protection are provided below, and are intended for discussion purposes only. Any changes would be developed through a public process by appropriate local, state, and federal entities prior to adoption of any suggestions in Table 5.

Table 5: Potential Changes to Local Regulations and Planning Documents

Planning Document	Section	Title	Considerations (For Discussion Only)
General Wetlands Protection By-Law (2001)	I.	Purpose	Consider adding a reference to "change in sea level."
	II.	Areas Subject to Jurisdiction	Consider expanding local regulations to include entire FEMA flood zone and make provisions for incremental increased flood zone area.

Planning Document	Section	Title	Considerations (For Discussion Only)
General Wetlands Protection By-Law (2001)	III.	Notice of Intent	Through a revision of the application forms and guidelines, consider requiring a discussion of whether (and how) the proposed action would be affected by sea level rise and storm surge.
	VII.	NOI and Conditions	Consider clarifying the basis for requiring conditions by adding jurisdiction to lands subject to inundation due to projected sea level rise and storm surge.
	XIX.	Application Procedures	Consider showing "Flood Zones" designated in the latest FEMA Flood Insurance Maps
	XX.	Design Criteria	Consider adding explicit mitigation objectives for storm surge due to projected sea level rise. Clarify the level of function that facilities must retain during and after storm surge. Allow a benefit cost analysis in the analysis of alternatives to address the design criteria.
	XXI.	Performance Standards	Consider providing performance standards for use of temporary flood barriers and elevation of existing structures to meet storm surge with 50 year sea level rise projection. (page 20).
	Appendix A	Definitions	Consider increasing the width of the buffer zone to allow review of projects that may affect wetlands based on predicted sea level rise.
	Appendix B and C		Consider adding FEMA flood zones to the maps
	Appendix D		Consider including recommendations to prevent release of hazardous material

Planning Document	Section	Title	Considerations (For Discussion Only)
Zoning Ordinance (2009)	1	Purpose	Consider adding references to flooding and inundation
	2	Definitions	Consider adding FEMA flood zones Consider adding Sea Level Rise
	3	Establishment of Districts	Consider a Floodplain Overlay District By-Law based on FEMA 0.2% flood level to control development in high hazard zones (such as V zones).
	4	Use Regulations	Consider adding a Flood Hazard Overlay District. Consider limiting permitted uses to avoid risk of hazardous materials spill, minimize damage to new and substantially renovated structures,
	7	Non-Conforming Uses	Consider limiting rebuilding of non-conforming structures unless they incorporate flood resistant or flood proof design features. (7.4 Damaged or Destroyed)
	12	Special Permits	Consider adding requirement that the City make findings regarding mitigation of risk from sea level rise for the life of the structure
	16	Site Plan Review	Consider adding a requirement that submittals discuss the risk and mitigation from sea level rise and storm surge for the expected live of the structure
Lynn Zoning Map (2011)		Zoning Map, City of Lynn	Consider establishing a flood risk zoning district overlay that includes entire FEMA flood zone and make provisions for incremental increased flood zone area with time.

Planning Document	Section	Title	Considerations (For Discussion Only)
Open Space and Recreation Plan (2005)	II.A	Statement of Purpose	Consider adding a discussion of the benefits of utilizing open space to help mitigate flooding.
	IV.	Environmental Inventory and Analysis	Consider adding a discussion of nature of predicted sea level rise and storm surge.
	IV.C	Water Resources	Consider adding a discussion of the risk and mitigation from sea level rise and storm surge.
	IV.G	Environmental Challenges (vision)	Consider adding a discussion of the increased risk to these areas from sea level rise and storm surge.
	VIII	Goals and Objectives	Consider adding a discussion of alternative ways to improve public access consistent with upgrading coastal protections facilities.
	IX	Five-Year Action Plan	Consider adding a discussion of these improvements in the context of sea level rise and storm surge.
Protected Open Space Map (2008)		Protected Open Space, City of Lynn	Consider adding areas that help mitigate flood risk.
Hazard Mitigation Plan (2012)	IV	Risk Assessment	Consider adding sea level rise to the hazard discussion
	VIII	Hazard Mitigation Strategy	Consider adding specific measures for adaptation measures to prevent and respond to: road flooding, chemical releases, and erosion areas.
	Appendix B	Hazard Mapping	Consider expanded scope to include the FEMA flood zone and areas subject to sea level rise and storm surge.

Planning Document	Section	Title	Considerations (For Discussion Only)
Waterfront Master Plan Report (2007)	2	Existing Conditions	Consider adding a discussion of existing coastal protection structures.
	2	Environmental Issues	Consider adding plans to prevent hazardous material releases related to flooding (i.e. spill prevention, control and countermeasure plans).
	3	Design Guidelines	Consider incorporating enhanced coastal protection in the design guidelines

5.0 | References

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Acronyms

CZM	Massachusetts Office of Coastal Zone Management
EDIC	City of Lynn Economic Development and Industrial Corporation
EPA	US Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRMS	FEMA Flood Insurance Rate Maps
GIS	Geographic Information System
LLC	Limited Liability Company
MEOWS	Maximum of the Maximum Envelopes of Water
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MOMs	Storm Surge Maximums of the Maximum
MORIS	Massachusetts Ocean Resource Information System
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
SLR	Sea Level Rise

Glossary of Terms

100-year Flood Event (1% event)

Flood event that has a 1% probability of occurring in any given year.

100-year Flood Plain

The land area covered by a 100-year flood as defined by FEMA.

10-year Flood Event (10% event)

Flood event that has a 10% probability of occurring in any given year.

Coastal Resilience

The capacity of shoreline areas to protect and preserve infrastructure and other socioeconomic resources in response to predicted sea level rise and increased frequency and intensity of coastal storms.

Dry Floodproofing

A combination of measures that results in a structure, including the attendant utilities and equipment, being watertight with all elements substantially impermeable and with structural components having the capacity to resist flood loads.

Elevation

The height of a geographic location above or below a fixed reference point.

Flood Barriers

A structure designed to prevent a storm surge or high tide from flooding the protected area behind the barrier.

Green (Soft) Infrastructure

In the case of coastal protection, nature or nature-based systems that control flood or surface water. Includes dunes, living shorelines, oyster reefs, as well as engineered systems that mimic natural systems, such as pervious concrete.

Hard Infrastructure

In the case of coastal protection, engineered systems or structures that control flood or surface water. Includes seawalls, tide gates, bulkheads, impervious surface drainage systems and rip-rap drainage areas.

Ice Sheet Melt

Melting of polar ice sheets due to increasing global temperatures, with meltwater resulting in increases in global sea level rise.

Inundation

The extent of flood waters.

King Tide

An extreme high tide also referred to as a “perigean spring tide” that occur once or twice a year when the orbits of the sun, moon and earth align. A king tide is not associated with a storm.

Mean Higher High Water (MHHW)

The average of the higher high water height of each tidal day.

Relocation

Moving critical infrastructure assets to areas outside flood areas.

Sea Level Rise (SLR)

The increase in sea water levels as a result of land water storage, ice sheet melt, glacier ice cap retreat, oceanographic processes, and vertical land motion (subsidence).

Shoreline Retreat

Landward movement of the shoreline due to sea level rise or erosion of coastal land.

Storm Surge

The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the height above the level expected from the normal tide elevation at that time and place.

Threshold Elevation

The water elevation of a flood that results in damage to a specific asset, resource or infrastructure. This term is specific to the Lynn Coastal Resilience Study.

Wet Floodproofing

The use of flood-damage-resistant materials and construction techniques to minimize flood damage to areas below the flood protection level of a structure, which is intentionally allowed to flood.

Acknowledgements

The City of Lynn Coastal Resiliency Assessment was directed by the Lynn Economic Development Industrial Corporation. The work was funded by the Massachusetts Office of Coastal Zone Management through the Coastal Resiliency Grant Program. The process included a Working Group committee involved in the data collection and evaluation process. The Working Group members represented City Departments and key organizations that are involved in environmental efforts in the Lynn area. The Technical work was performed by Weston & Sampson Engineers and Anchor QEA, a team of subject matter experts that included climate scientists, engineers, and planners. Three public meetings were held to present and discuss comments on the project as it developed. A final public meeting was held on May 31, 2016 to present the final report.

The following individuals were instrumental to the completion of this project:

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Weston & Sampson Engineers	George Naslas Frank Ricciardi Robert Almy Julie Eaton Dan Shiniick
Anchor QEA	Erin Healy Mark Mahoney

OVERSIZED FIGURES

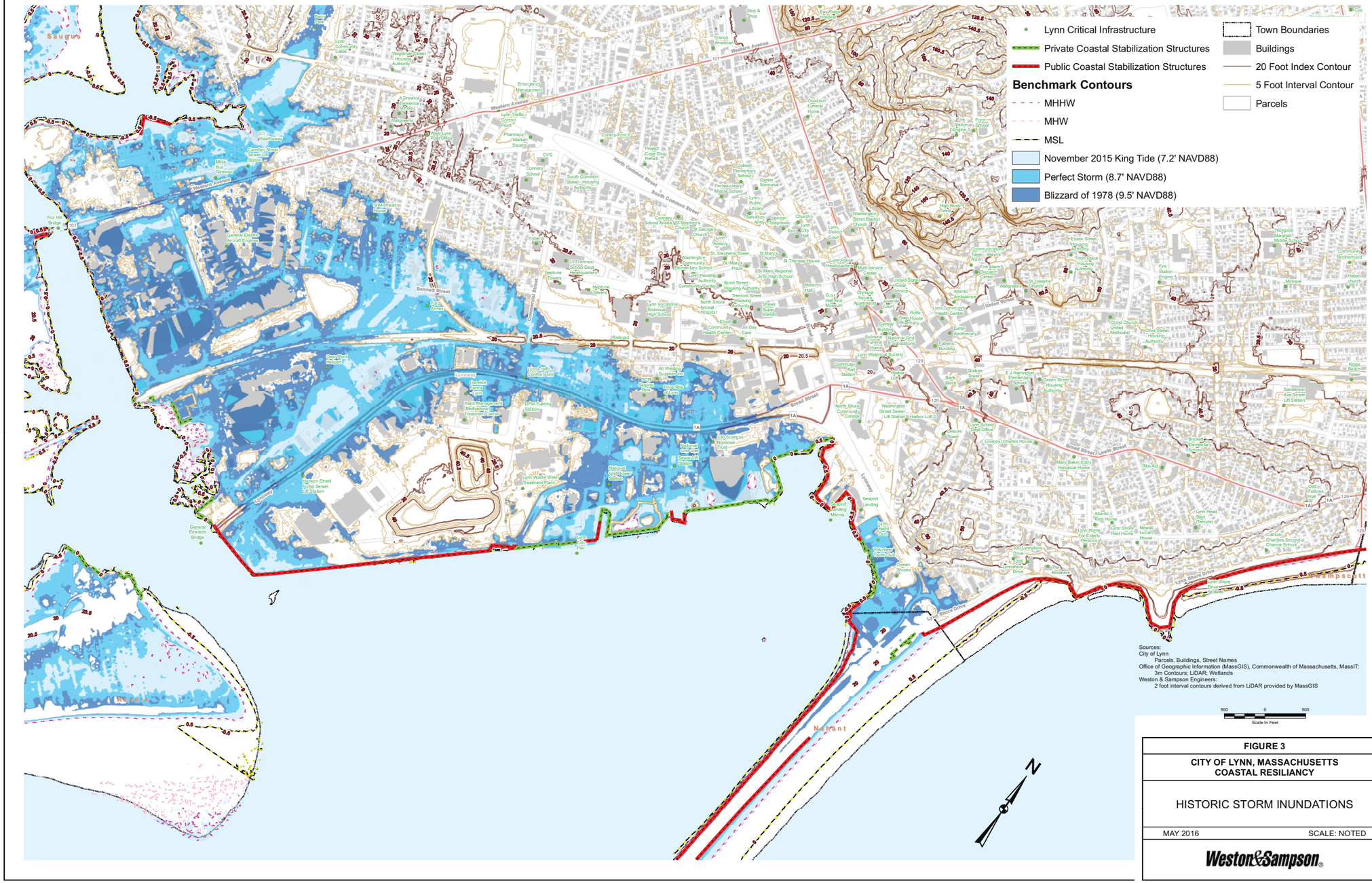


FIGURE 3

CITY OF LYNN, MASSACHUSETTS
COASTAL RESILIANCY

HISTORIC STORM INUNDATIONS

MAY 2016 SCALE: NOTED

Weston&Sampson

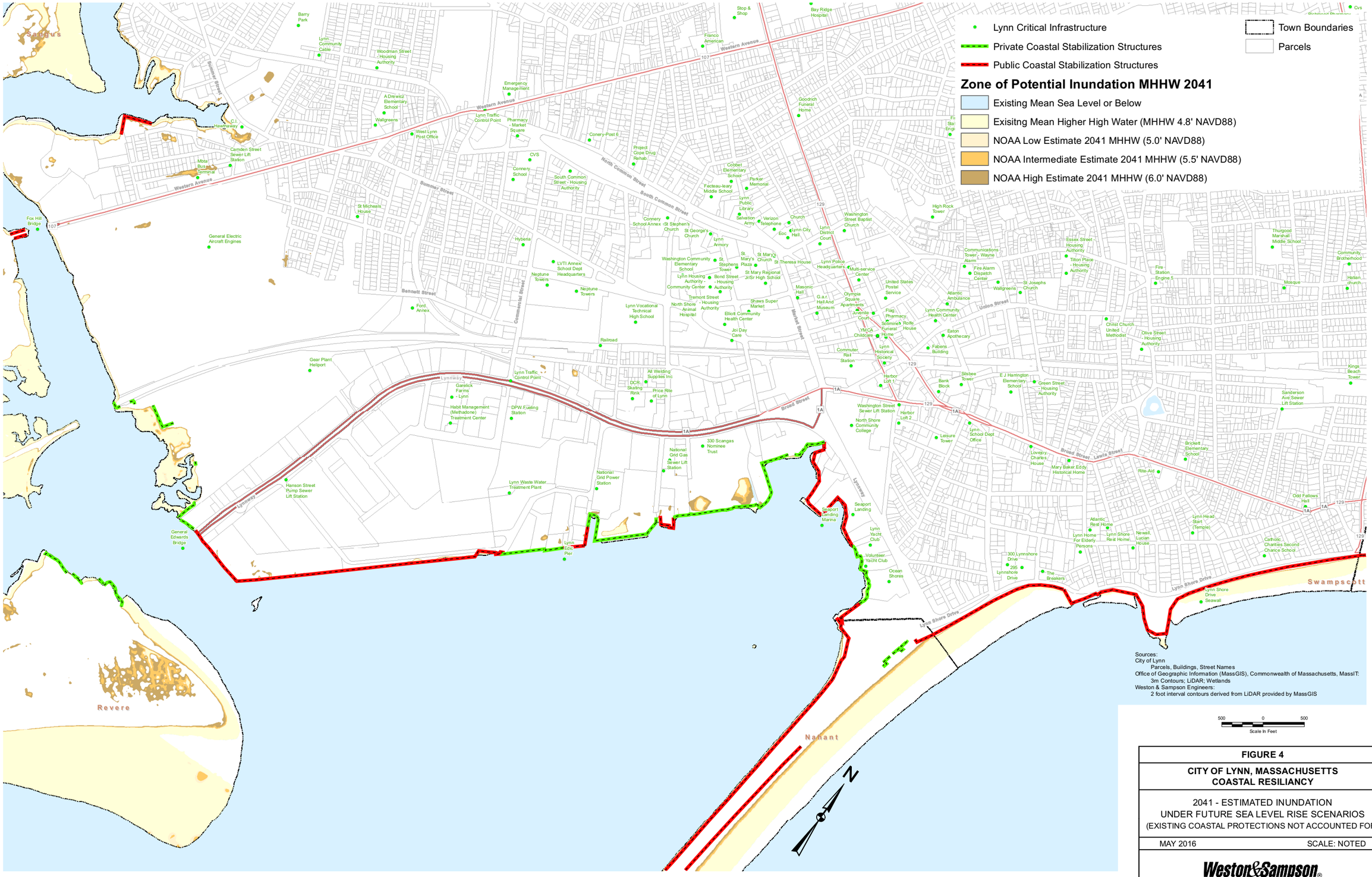


FIGURE 4

CITY OF LYNN, MASSACHUSETTS
COASTAL RESILIANCY

2041 - ESTIMATED INUNDATION
UNDER FUTURE SEA LEVEL RISE SCENARIOS
(EXISTING COASTAL PROTECTIONS NOT ACCOUNTED FOR)

MAY 2016 SCALE: NOTED

Weston&Sampson®

- Lynn Critical Infrastructure
- Town Boundaries
- Parcels

Zone of Potential Inundation MHHW 2066

- Existing Mean Sea Level or Below
- Existing Mean Higher High Water (MHHW)
- NOAA Low Estimate 2066 MHHW (5.3' NAVD88)
- NOAA Intermediate Estimate 2066 MHHW (6.7' NAVD88)
- NOAA High Estimate 2066 MHHW (7.8' NAVD88)

Sources:
City of Lynn
Parcels, Buildings, Street Names
Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT:
3m Contours; LiDAR; Wetlands
Weston & Sampson Engineers:
2 foot interval contours derived from LiDAR provided by MassGIS

500 0 500
Scale In Feet

FIGURE 5

CITY OF LYNN, MASSACHUSETTS
COASTAL RESILIANCY

2066 - ESTIMATED INUNDATION
UNDER FUTURE SEA LEVEL RISE SCENARIOS
(EXISTING COASTAL PROTECTIONS NOT ACCOUNTED FOR)

MAY 2016 SCALE: NOTED

Weston&Sampson®

Lynn Critical Infrastructure

Town Boundaries

Parcels

Zone of Potential Storm Inundation 2041

- Existing Mean Sea Level or Below
- Existing 1% Storm Surge (11.1' NAVD88)
- NOAA SLR Low Estimate 1% Storm Surge (11.3' NAVD88)
- NOAA SLR Intermediate Estimate 1% Storm Surge (11.8' NAVD88)
- NOAA SLR High Estimate 1% Storm Surge (12.2' NAVD88)

Saugus

Revere

Nahant

Swampscott

Lynnway

Western Avenue

Summer Street

Bennett Street

Commercial Street

North Common Street

South Common Street

Market Street

Broad Street

Lynn Shore Drive

Union Street

Lewis Street

Railroad

Barry Park

Lynn Community Cable

Woodman Street Housing Authority

A Drewicz Elementary School

Wallgreens

C I Hawthaway

West Lynn Post Office

Emergency Management

Lynn Traffic Control Point

Pharmacy - Market Square

Conery-Post 6

Project Cope Drug Rehab

Camden Street Sewer Lift Station

Mbta Bus Terminal

CVS

Connery School

South Common Street Housing Authority

Fox Hill Bridge

St Michaels House

General Electric Aircraft Engines

Connery School Annex

St Stephen's Church

St George's Church

Hybernia

Lynn Armory

LVTI Annex/ School Dept Headquarters

Neptune Towers

Ford Annex

Lynn Vocational Technical High School

Gear Plant Heliport

Garelick Farms - Lynn

Habit Management (Methadone) Treatment Center

DPW Fueling Station

Lynn Traffic Control Point

DCR Skating Rink

Price Rite of Lynn

All Welding Supplies Inc

330 Scangas Nominee Trust

National Grid Gas Sewer Lift Station

National Grid Power Station

Lynn Waste Water Treatment Plant

Hanson Street Pump Sewer Lift Station

General Edwards Bridge

Lynn Fish Pier

Stop & Shop

Bay Ridge Hospital

Franco American

Goodrich Funeral Home

Cobbet Elementary School

Fecteau-leary Middle School

Parker Memorial

Lynn Public Library

Salvation Army

Verizon Telephone

Church

Lynn City Hall

Eoc

Lynn District Court

Washington Street Baptist Church

Washington Community Elementary School

St Stephens Tower

St Mary's Plaza

St Mary's Church

St Theresa House

Lynn Police Headquarters

Multi-service Center

St Mary Regional Jr/Sr High School

Lynn Housing Authority - Community Center

Bond Street - Housing Authority

Tremont Street - Housing Authority

North Shore Animal Hospital

Shaws Super Market

Elliot Community Health Center

Joi Day Care

Masonic Hall

G.a.r. Hall And Museum

Olympia Square Apartments

Juvenile Court

YMCA Childcare

Commuter Rail Station

Lynn Historical Society

Harbor Loft 1

Harbor Loft 2

Washington Street Sewer Lift Station

North Shore Community College

Leisure Tower

Lynn School Dept Office

United States Postal Service

Flag Pharmacy

Sommers Rolfe Funeral Home

Lynn Community Health Center

Eaton Apothecary

Fabens Building

Bank Block

Silsbee Tower

Communications Tower - Wayne Alarm

Fire Alarm Dispatch Center

Atlantic Ambulance

Wallgreens

St Josephs Church

Essex Street Housing Authority

Tilton Place - Housing Authority

High Rock Tower

Ingalls Elementary School

Thurgood Marshall Middle School

Community Brotherhood

Fire Station Engine 5

Haitian Church

Mosque

Christ Church United Methodist

Olive Street Housing Authority

E J Harrington Elementary School

Green Street - Housing Authority

Sanderson Ave Sewer Lift Station

Kings Beach Tower

Brickett Elementary School

Rite-Aid

Lovejoy Charles House

Mary Baker Eddy Historical Home

Odd Fellows Hall

Lynn Head Start (Temple)

Atlantic Rest Home

Lynn Home For Elderly Persons

Lynn Shore Rest Home

Newell Lucian House

Catholic Charities Second Chance School

Lynn Shore Drive Seawall

Seaport Landing

Seaport Landing Marina

Lynn Yacht Club

Volunteer Yacht Club

Ocean Shores

300 Lynnshore Drive

295 Lynnshore Drive

The Breakers

Sources:
City of Lynn
Parcels, Buildings, Street Names
Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT:
3m Contours; LiDAR; Wetlands
Weston & Sampson Engineers:
2 foot interval contours derived from LiDAR provided by MassGIS

Notes: SLR - Sea Level Rise

N

500 0 500
Scale In Feet

FIGURE 6

CITY OF LYNN, MASSACHUSETTS
COASTAL RESILIANCY

2041 - ESTIMATED INUNDATION
UNDER FUTURE SEA LEVEL RISE SCENARIOS
INCLUDING 1% PROBABILITY STORM SURGE
(EXISTING COASTAL PROTECTIONS NOT ACCOUNTED FOR)

MAY 2016 SCALE: NOTED

Weston&Sampson®

Lynn Critical Infrastructure

Town Boundaries

Parcels

Zone of Potential Storm Inundation 2066

- Existing Mean Sea Level or Below
- Existing 1% Probability Storm Surge
- NOAA SLR Low Estimate 1% Storm Surge (11.5' NAVD88)
- NOAA SLR Intermediate Estimate 1% Storm Surge (12.9' NAVD88)
- NOAA SLR High Estimate 1% Storm Surge (14' NAVD88)

Scale In Feet: 500 0 500

Sources:
City of Lynn
Parcels, Buildings, Street Names
Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT:
3m Contours; LiDAR; Wetlands
Weston & Sampson Engineers:
2 foot interval contours derived from LiDAR provided by MassGIS

Notes: SLR - Sea Level Rise

FIGURE 7

CITY OF LYNN, MASSACHUSETTS
COASTAL RESILIENCY

2066 - ESTIMATED INUNDATION
UNDER FUTURE SEA LEVEL RISE SCENARIOS
(EXISTING COASTAL PROTECTIONS NOT ACCOUNTED FOR)

MAY 2016 SCALE: NOTED

Weston&Sampson®

Lynn Critical Infrastructure

Private Coastal Stabilization Structures

Topped Scenario

- No Topping
- 10% Storm 2041
- 10% Storm 2066
- 1% Storm 2066
- Mean Higher High Water 2014
- Mean Higher High Water 2066

Public Coastal Stabilization Structures

- No Topping
- 10% Storm 2016
- 1% Storm 2041
- Mean Higher High Water 2066
- Buildings
- Parcels

Sources:
City of Lynn
Parcels, Buildings, Street Names
Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT:
3m Contours; LiDAR; Wetlands
Weston & Sampson Engineers:
2 foot interval contours derived from LiDAR provided by MassGIS

500 0 500
Scale in Feet

FIGURE 9

CITY OF LYNN, MASSACHUSETTS
COASTAL RESILIANCY

COASTAL PROTECTION STRUCTURES
VULNERABILITY ASSESSMENT

MAY 2016 SCALE: NOTED

Weston&Sampson®