Belle Isle Marsh

Climate Vulnerability Assessment

June 2023

PREPARED FOR:
Town of Winthrop
1 Metcalf Square, Winthrop, MA 02152

Mystic River Watershed Association
20 Academy Street, Suite 306, Arlington, MA 02476

PREPARED BY:
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A CLS Company
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Acknowledgments

Woods Hole Group would like to thank the funders, stakeholders, and community members for the collaborative effort which led to the development of this report. Funding was provided to the Town of Winthrop by MA Executive Office of Energy and Environmental Affairs' (EEA) Municipal Vulnerability Preparedness (MVP) Program FY22-23. The Town of Winthrop consulted with the Mystic River Watershed Association (MyRWA), Friends of Belle Isle Marsh (FBIM), and Woods Hole Group (WHG) to complete technical work. Regional coordination was critical to the project's success, with thanks extended to the MA Department of Conservation and Recreation (DCR), Cities of Boston and Revere, Massachusetts Bay Transportation Authority (MBTA), MA Department of Transportation (DOT), HYM Investment Group, The Nature Conservancy (TNC), and Northeastern University for their contribution through monthly and in some cases weekly meetings. Further thanks are extended to the communities of Winthrop, Revere, and Boston, especially to individual representatives who helped makeup the Community Advisory Group.

Executive Summary

Belle Isle Marsh is the largest remaining salt marsh in Boston Harbor, designated as a 359 acres Area of Critical Ecological Concern (ACEC) and supports approximately 266 acres of salt marsh wetland and transitional marsh habitat (Figure 1). The marsh is surrounded by the low-lying, densely developed communities of East Boston, Revere, and Winthrop. Past flooding has damaged both public and private infrastructure, and has impaired critical services, such as public transportation and evacuation routes. All the while, the marsh is suffering increasing environmental stressors, negatively impacting marsh health and longevity. Climate change threatens to exacerbate such risks to both community and marsh. This project emerged from a recognition by stakeholders of the necessity for addressing near-term climate vulnerabilities through regional collaboration.

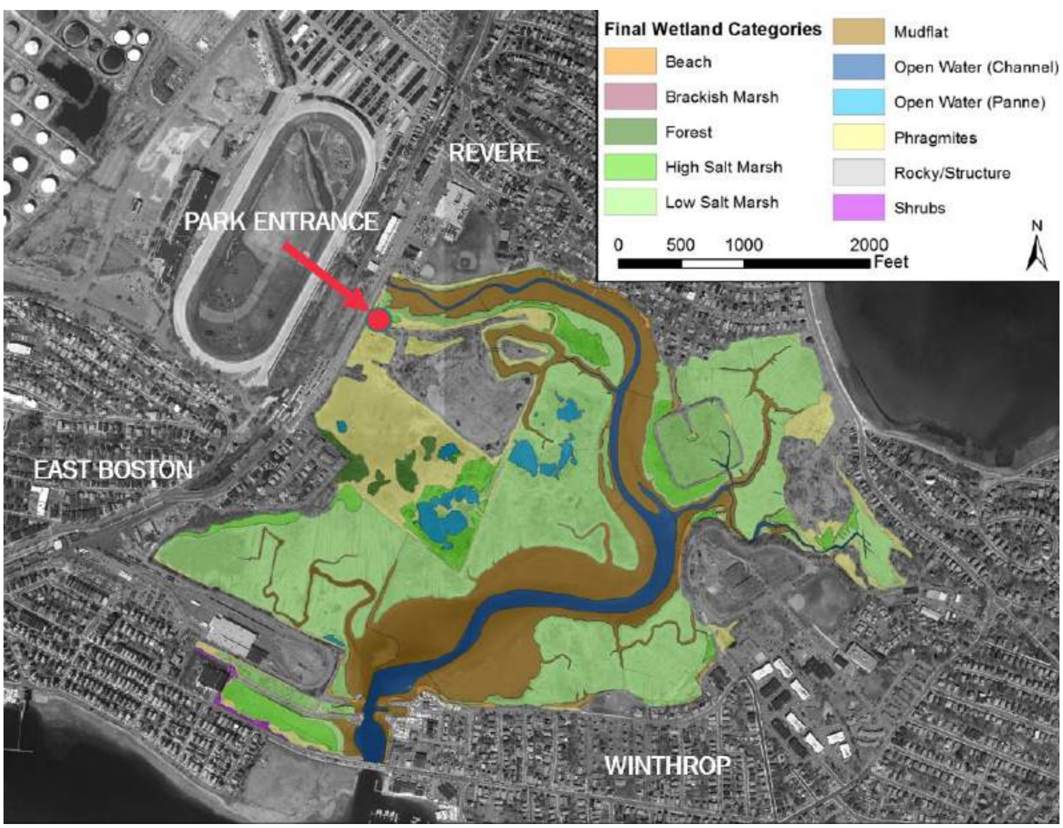

Figure 1. Belle Isle Marsh Climate Vulnerability Assessment – Project Area and Habitat Map.

This Climate Vulnerability Assessment investigates marsh and community risk to sea level rise and storm flooding and opportunity for nature-based strategies to minimize coastal flood damage to Winthrop, East Boston, and Revere and, where possible, maximize the habitat value of Belle Isle Marsh Reservation. Woods Hole Group analyzed habitat and community risk to sea level rise and storms:

> **Community Risk:** Today, there is already a threat to the mobility and safety of the communities surrounding the marsh as demonstrated on December 23, 2022, when a nor'easter caused flooding throughout the project area including Bennington Street in East Boston, Fredericks Park, the Beachmont School, Belle Isle Avenue, and Montfern Avenue in Revere, and Morton St in Winthrop. Future sea level rise and storm projections represent a significant flood risk to communities surrounding Belle Isle Marsh. Larger, lower probability storm events are anticipated to occur more frequently with sea level rise. Flood pathways which serve as tipping points for greater flood hazards were identified, in order of exposure, at Banks St and Morton St (Winthrop), Bennington St and Fredericks Park (Boston and Revere), MBTA Orient Heights Railyard and Austin Ave (Boston), Winthrop Parkway at Short Beach (Winthrop), Argyle St and Bayou St (Winthrop), and Saratoga St (Boston). These flood pathways present risks to critical infrastructure such as evacuation routes (Winthrop Parkway, Bennington St, Saratoga St/Main St), public transportation infrastructure (MBTA Blue Line and maintenance railyard), and electrical utilities (Winthrop substation), as well as numerous Environmental Justice communities.
>
> **Habitat Risk:** Belle Isle Marsh supports over 250 bird species (seven listed as threatened or endangered), serves urban development through mitigating the effects of climate change (buffer to storm surge, flood storage capacity, heat island reduction, carbon sequestration), and provides important open and recreational space for the public. Today, human impacts marsh have significantly altered the marsh through urban development, artificial fill, mosquito ditches, stormwater outfalls, and more. Resulting impacts have impaired habitat extent, biodiversity, natural hydrology, sediment delivery, and nutrient loading patterns, leading to the degradation of the marsh and loss of habitat value. In the future, Belle Isle Marsh is at risk of gradually becoming open water and mudflat due to sea level rise, eliminating its habitat, recreational, and coastal protection value. Critical habitat for the saltmarsh sparrow and other wildlife, already experiencing habitat loss, will be squeezed out from between development and the rising ocean if action is not taken.

To guide adaptation development, priorities and values were developed through a combination of literature research, discussions with stakeholders and the public, and outcomes of the Belle Isle Marsh Assessment (WHG, 2022). The intersection of priorities and values with flood risk and marsh vulnerability led to the identification of adaptation goals. Adaptation goals subsequently led to the development of adaptation strategies which could feasibility achieve such goals:

Priorities and Values	
Flood Protection	Storm surge and sea level rise protection
	Wave attenuation
	Intercept flood pathways
	Erosion control
	Stormwater management
	Risk avoidance
Habitat Quality and Biodiversity	Habitat diversity and connectivity
	Food web support
	Biodiversity
	High marsh habitat
	Transitional and upland habitat
	Water quality

Adaptation Goals
Intercept flood pathways which affect communities and critical infrastructure
Reduce flood depth within communities
Expand and enhance transitional/upland areas for flood protection and accommodation
Address marsh erosion
Enhance vegetation to maximize wave attenuation
Build elevation capital for resilience to sea level rise

Adaptation Strategies
No Action
Salt Marsh Restoration for Marsh Resilience
Engineered Sill for Marsh Toe Protection
Living Breakwater for Marsh Toe Protection
Thin Layer Deposition (TLD) (*not currently permittable*)
Living Levee
Beach Nourishment and Dune Restoration
Stormwater Management
Hard Infrastructure (seawall, revetment, raised roadway)

	Carbon storage
Community Support and Engagement	Regional approach
	Community outreach
	Educational and monitoring programs
	Recreational and open space

Expand high marsh area for saltmarsh sparrow and spring tide flood protection
Maximize social benefit of Belle Isle Marsh, while minimizing human impact to resources

Public Access Trails and Signage
Flood Control Structure
Managed Retreat (e.g., Lane Reduction)
Monitoring Program
Hybrid Approach

A prioritization matrix (below left) was developed to break down the marsh perimeter into thirteen unique reaches and identify the greatest opportunity and need for nature-based adaptation. Key criteria evaluated relative flood protection value, habitat restoration value, community and public access value, permitting feasibility, construction feasibility, design life, and cost magnitude. A second prioritization matrix (below right) supported the development of conceptual strategies for each reach.

Shoreline Site	Prioritization Score
Fredericks Park	14
Bennington St	14
Winthrop Boat Yard / Main St	14
Short Beach	14
Morton St / Marine Ecology Park	13
Rosie's Pond	13
Excel Academy	13
Bayou St / Argyle St	13
MBTA Railyard	12
Lawn Ave	10
Residential North Winthrop	9
Residential Revere	8
Cemetery	6

Adaptation Strategy	Prioritization Score
Hybrid Approach	16
Earthen Berm	15
Lane Reduction	15
Living Levee	14
Salt Marsh Restoration	14
Beach Nourishment & Dune Restoration	14
Stormwater Management	14
Public Access	13
Elevate Roadway	12
Monitoring Programs	11
Hard Infrastructure	11
Living Breakwater (Oyster Sill)	10
Engineered Sill	10
Thin Layer Deposition	9
No Action	9

Two priority sites were selected for alternatives development and performance modeling: Bennington St to Fredericks Park (Boston and Revere), and Morton St to Banks St (Winthrop). Adaptation alternatives were developed primarily to achieve flood protection, while maximizing co-benefits to marsh habitat where possible. The adaptation strategies developed for each reach prioritize flood protection, green infrastructure, living shorelines, and natural and nature-based features to the maximum extent practicable. Where necessary due to site constraints, hard infrastructure is proposed. Alternatives developed at both Bennington St/Fredericks Park and the Morton St reaches considered a living levee (wide footprint) or earthen berm (narrow footprint), roadway elevation and/or lane reduction, salt marsh restoration, stormwater management, and public access.

Each alternative would carry various pros and cons. For instance, adaptation strategies such as an earthen berm, which are sited entirely outside of the marsh, will require steep slopes to achieve flood protection levels, essentially drawing a hard line between habitat and development. However, such projects would avoid impacting existing marsh habitat and would preserve critical functions such as serving as wildlife refuge and carbon storage today. Conversely, adaptation strategies such as living levees, which are sited partially within the marsh, provide the opportunity to flatten slopes while still achieving flood protection levels. Such projects provide the opportunity for marsh migration with sea level rise and blend the boundary between habitat and development; however this can come at the expense of adding fill to existing marsh habitat and potentially altering critical functions. Furthermore, projects which impact existing salt marsh will meet regulatory hurdles, as they do not meet the Massachusetts Wetland Protection Act performance standards for salt marsh. All projects which create and/or contain open space should be planted with appropriate native vegetation for habitat enhancement as well as wave attenuation.

Utilizing the Massachusetts Coast Flood Risk Model (MC-FRM), Woods Hole Group evaluated the potential successes and drawbacks of alternative alignments for flood protection. The results of the modeling effort indicate the following:

- The Bennington Street/Frederick's Park alignment features independent benefits in eliminating flooding during storm events smaller than the 1% storm in present day, or the 25% storm in 2030 (equivalent water levels) but fails to eliminate flooding in larger events due to other flood pathways stemming from Chelsea Creek and Roughan's Point.
- The Bennington Street/Frederick's Park alignment features independent benefits of depth reduction in storms that are larger than the 1% storm in present day, or the 25% storm in 2030.
- The Morton Street project could provide protection to the community under a 1% storm in 2070. The alignment that features a living levee along the marsh edge protects an additional 1 commercial and 8 residential properties when compared to an alignment that raises Banks Street.
- There is no increase in water surface elevation, and therefore no increased flooding, to properties surrounding the alignments when the design is in place for both priority sites with all alignments considered.

At the end of this project, the team learned that effective near-term adaptation requires mitigating flood pathways across jurisdictional boundaries, as well as integrating flood protection into existing natural resources and infrastructure. Ultimately, enhancing the balance between society and nature is the intention of adaptation at these sensitive sites.

Filling and conversion of wetland resource areas is considered in certain instances to facilitate sea level rise resiliency, though it is recognized that permitting of such work does not meet Massachusetts Wetland Protection Act performance standards for salt marsh. Pre-application permitting discussions with local, state, and federal agencies will be important for identifying feasible permitting pathways, and further refining design.

Furthermore, determining a target storm and sea level rise scenario for protection will allow alternative design to progress. Owners and stakeholders should aim to strike a balance between flood protection, habitat enhancement, and natural resource impacts, while addressing public access. Extensive community outreach and regulatory coordination will be required to determine a preferred approach. On-going conversations are anticipated regarding project design elevations and alignments, as this will result in varying degrees of flood mitigation to communities.

Looking ahead, the regional group agrees that more work is necessary. Winthrop, Boston, and Revere have submitted MVP FY24 applications to facilitate further regional stakeholder and community engagement, and conduct alternatives analysis, preliminary engineering, and permit applications in support of resilience projects to mitigate flooding.

Appendix

The following appendices are included representing the technical work of this Climate Vulnerability Assessment:

Appendix A: Belle Isle Marsh Climate Vulnerability Assessment – Task 2.2 Flood Risk

Appendix B: Belle Isle Marsh Climate Vulnerability Assessment – Task 2.3 Future Conditions

Appendix C: Belle Isle Marsh Climate Vulnerability Assessment – Task 2.4 Strategy Identification

Appendix D: Belle Isle Marsh Climate Vulnerability Assessment – Task 2.5 High-resolution modeling of storm wave height and energy attenuation at Belle Isle Marsh under different restoration and climate scenarios

Appendix E: Belle Isle Marsh Climate Vulnerability Assessment – Task 6.1 Alternatives Analysis and Selection

Appendix F: Belle Isle Marsh Climate Vulnerability Assessment – Task 6.2 Cumulative Impact Modeling and Analysis

Appendix A: Appendix A: Belle Isle Marsh Climate Vulnerability Assessment – Task 2.2 Flood Risk

MEMORANDUM

DATE June 28, 2022 **JOB NO.** 2020-0076-01
Revised July 5, 2023

TO Catherine Pedemonti
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FROM Conor Ofsthun, Nasser Brahim
Woods Hole Group, Inc.

Belle Isle Marsh – Climate Vulnerability Assessment – MVP Task 2.2 Flood Risk

1.0 Introduction

This Technical Memorandum is prepared for the Town of Winthrop and Mystic River Watershed Association (MyRWA) in support of the FY22 Municipal Vulnerability Preparedness grant titled "Belle Isle Marsh – Climate Vulnerability Assessment." Belle Isle Marsh is a critical natural resource, owned by MA Department of Conservation and Recreation (DCR), and shared between the communities of East Boston, Revere, and Winthrop. Historically, the marsh was wide, undeveloped, and hydraulically connected to the wider creek and Boston Harbor system (Figure 1). Today, anthropogenic impacts, environmental stressors, and climate change have threatened the health, function, and co-benefits of the marsh. The Climate Vulnerability Assessment aims to evaluate the current and future vulnerabilities of Belle Isle Marsh and the surrounding communities to flood risk, leading towards the development of mutually beneficial natural and nature-based solutions (NBS) to protect the marsh and surrounding communities in the face of sea level rise and storms. This memo is a literature review contextualizing Belle Isle Marsh within the region's literature with respect to climate vulnerability and planning for future sea level rise and coastal storm flooding.

Figure 1. 1984 Historic Map of Winthrop, MA depicting a less developed Bell Isle Marsh in the center of the image and its connection to Sales Creek and Chelsea Creek (Town of Winthrop and The Cecil Group, 2005).

Woods Hole Group (WHG) gathered publicly available studies regarding climate change assessment and planning from the communities and major landowners surrounding Belle Isle Marsh, including the Cities of Boston and Revere, the Town of Winthrop, Massachusetts Department of Transportation, and HYM Investment Group. Additionally, Woods Hole Group reviewed key reports by Massachusetts Department of Conservation and Recreation (DCR), the primary landowner of Belle Isle Marsh. It should be noted that this project is being prepared at the same time as the Belle Isle Marsh – Marsh Management Plan. The Marsh Management Plan included a literature review focused on the existing marsh conditions and marsh health, which is provided in Appendix A.

Table 1 lists the studies most pertinent to the Belle Isle Marsh Climate Vulnerability Assessment. These references were reviewed from the perspective of their relationship to, and implications, for Belle Isle Marsh.

Table 1. Belle Isle Marsh Regional Literature Review References

Year	Author	Reference
2005	Town of Winthrop & The Cecil Group	Winthrop Harbor Assessment and Plan
2015	MassDOT & FHWA	Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery
2016	City of Boston	Climate Ready Boston – Final Report
2017	City of Boston	Coastal Resilience Solutions for East Boston and Charlestown – Final Report
2017	Town of Winthrop	Winthrop Climate Change Vulnerability Assessment
2017	MassDOT/MBTA	MBTA: Climate Change Vulnerability Assessment for the Blue Line
2018	Town of Winthrop	Winthrop Community Resilience Workshop
2018	AECOM	MBTA: Orient Heights Maintenance and Storage Facilities
2018	Douglas et. al.	Improving the environment while protecting coasts: A holistic accounting of ecosystem services of "Green Infrastructure and Natural and Nature-Based Features (NNBF)"in an urbanized coastal environment
2018	VHB	Resiliency Adaptation Study – Suffolk Downs Redevelopment
2019	City of Revere	Revere MVP Summary of Findings
2020	Boston Redevelopment Agency	Suffolk Downs Master Plan
2021	City of Revere	Revere Hazard Mitigation Plan
2021	City of Boston	Coastal Resilience Solutions for East Boston and Charlestown (Phase II) - Task 1 Memo: Review & Synthesis of Existing Information
2022	City of Boston	Coastal Resilience Solutions for East Boston and Charlestown

2.0 Literature Review – Coastal Planning

Table 2 summarizes the results of the literature review. Specifically, sea level rise, flood projections, adaptation and resilience, and community values were drawn from the reports to support the development of the Belle Isle Marsh assessment. The reason for isolating these topics is summarized below.

- Sea Level Rise – The future sea level rise projections selected for each study are highlighted to understand the similarities and differences in planning scenarios across the region. This helps to determine what each group is preparing for, and how priorities may vary across the region corresponding to newly emerging science.
- Flood Projections – While coastal storms and the resulting flooding occur on a regional scale, each jurisdiction and stakeholder has a local focus regarding its own flood mitigation. Gathering each study's findings in one place allows for a more holistic view of how flooding by way of Belle Isle Marsh is impacting surrounding communities, and when.
- Adaptation and Resilience – As stated, storm flooding is driven by regional-scale events, and as a result, regional-scale coordination and adaptation are warranted. Adaptation and resilience planning are collected across jurisdictions and stakeholders to begin to view how groups may approach their respective vulnerabilities. It is important to identify whether one group is proposing a solution which could provide wider benefits if coordinated regionally, or at worst, inadvertently may create greater problems for adjacent groups or otherwise limit their future adaptation options.
- Community Values – Ultimately, climate change adaptation is driven by the community and their needs, priorities, and values. This topic is reviewed to carry forward the lessons-learned through the outreach of past projects into future efforts.

Table 2. Coastal planning literature review of relevant reports in the vicinity of Belle Isle Marsh.

Reference	Sea Level Rise	Flood Projections	Adaptation and Resilience	Community Values
Town of Winthrop and The Cecil Group, Winthrop Harbor Assessment and Plan, 2005	Not Applicable	Not Applicable	Improve access from the waterside by dredging Belle Isle Inlet. Due to the history of dredging in the Belle Isle Inlet, and opposition expressed by the US Environmental Protection Agency, the regulatory process for the dredging of Belle Isle Inlet would be expected to be extremely difficult, time consuming, and costly. It is anticipated that the project would require the preparation of an Environmental Impact Report (EIR) and could require significant mitigation to offset impacts due to dredging. Repair/replace bridge over Belle Isle Inlet with increased height to allow for larger vessel and increased safety. Transportation access is critical to the function of a working community. The bridge over Belle Isle Inlet is one of only two access points to the Town of Winthrop. The channel under the bridge provides the only water access to Belle Isle Marsh. This bridge should be replaced and, possibly, built several feet higher to accommodate larger boats, especially emergency or rescue vessels. This project would complement the other recommendation to dredge near and under the bridge to increase the water depth for deeper draft vessel.	• Public Access/Public Ownership • Maritime Uses • Homeland Security and Logan Airport • Pollution • Recreational Activities and Tourism Potential
MassDOT, Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery, 2015	The future flood projections used in analysis derive from the Boston Harbor Flood Risk Model (BHFRM) (Bosma et al., 2015). Blue Line exposure was evaluated for a 0.1% storm surge event under the following SLR scenarios: • 2000 – 0 ft SLR • 2030 – 0.7 ft SLR • 2070 – 3.3 ft SLR These sea level rise projections reflect the fourth assessment report (AR4) high scenario given in the NOAA Technical Report OAR CPO-1 (Parris et al. 2012). This AR4 high scenario predates but roughly corresponds to the more current relative concentration pathway (RCP) 8.5 scenario, which reflects a "business-as-usual" scenario in which economic growth is projected to increase and there are no substantive attempts to curtail CO2 emissions.	BH-FRM results showing probability of flooding in 2013, 2030, and 2070 project storm floods overtopping Belle Isle Marsh habitat on an annual basis (100% exceedance probability) at minimum. Projected flood risks throughout East Boston, Revere, and Winthrop in areas surrounding the marsh are extensive, projected as frequently as a 1 in 10 annual chance today, with annual flooding anticipated under 2070 sea level rise conditions	Local adaptation options were developed for protecting individual structures, none of which were in close proximity to Belle Isle Marsh. Adaptation recommendations generally included infrastructure improvements (seawall installation or modification, revetment improvements, raising Charles River dam, installation of flood barriers) and nature-based solutions (natural/bioengineered berms, marsh restoration).	A Technical Advisory Committee (TAC), made up of experts in coastal processes, modeling, and vulnerability assessments, reviewed the methodology and technical approach of the project. A key priority for this project was to develop products that, to the degree possible, are useful to other Boston agencies and stakeholders who are also doing adaptation work. Two official stakeholder meetings and several additional meetings were held. Coordinating with interested stakeholders turned out to be a much larger effort than originally anticipated, but resulted in better communication of project goals and deliverables and even greater interest in and relevancy of project outcomes.
City of Boston, Climate Ready Boston – Final Report, 2016	Informed by the UMass-led Boston Research Advisory Group report on climate projections, the City began its planning for the following sea level rise scenarios: • 0.75 ft ~ 2030	The City of Boston's *Climate Ready Boston* vulnerability assessment and report uses the 2015 Boston Harbor Flood Risk Model (BH-FRM) to project future SLR and correlated flood risk in Boston.	Climate Resilience Principles: • Generate multiple benefits • Incorporate local involvement in design and decision making	Natural resources, like Belle Isle Marsh, serve as protective barriers in a storm surge event. These assets are susceptible to a changing climate and flooding, and the City must take care to maintain them as habitats and flood protection resources.

Reference	Sea Level Rise	Flood Projections	Adaptation and Resilience	Community Values
	• 1.75 ft ~ 2050 • 3.0 ft ~ 2070	BH-FRM flood projections in Belle Isle Marsh predict increasing water depths and wetting frequency of marsh habitat, and overtopping of marsh boundary at the Casket Company, Bennington St/MBTA Blue Line/Suffolk Downs, Revere Public Schools, and Winthrop Parkway. Complete inundation of the marsh is projected in 2070, implying that the marsh converts to open water habitat. Coastal and riverine flooding is expected to lead to the most significant increases in climate hazard consequences to people, buildings, infrastructure, and the economy. East Boston has the most land area of all Boston neighborhoods exposed to coastal storms in the coming decades	• Create layers of protection by working at multiple scales • Design in flexibility and adaptability • Leverage building cycles Coastal and riverine flooding calls for a very different approach. The resilience initiatives are intended to be targeted to the areas directly exposed and involve the creation of significant new infrastructure systems in addition to the adaptation of existing systems and buildings. Reduce Boston's risk of coastal and riverine flooding through both nature-based and hard engineered flood defenses. The western portion of the Belle Isle Marsh shoreline (around the MBTA Orient Heights Yard and Casket Company) was identified as a flood pathway and potential location for district-scale flood protection systems (see "Orient Heights" location) that would extend through Constitution Beach. This system was anticipated to be independently effective under present day (with annualized avoided losses of $260,905) through 2050 (with annualized avoided losses of $23,385,539) and in a 10% storm in 2070. In other 2070 storm scenarios, it would need to be complemented by a system along Chelsea Creek.	
City of Boston, Coastal Resilience Solutions for East Boston and Charlestown – Final Report, 2017	Consistent with the Climate Ready Boston vulnerability assessment, the neighborhood solutions plan was based on the following sea level rise scenarios: • 0.75 ft ~ 2030 • 1.75 ft ~ 2050 • 3.0 ft ~ 2070	This report did not focus on the vulnerability of areas around or affected by coastal flooding from Belle Isle Marsh.	This report did not focus on adaptation strategies for the areas around or affected by flooding from Belle Isle Marsh. Generalized open space approaches include elevated waterfront parks and plazas, elevated waterfront pathways, docks and other in-water features, nature-based features, mobility and connectivity. Generalized infrastructure and development strategies include elevated roadways and deployable flood walls, mixed-use development, local business support, and maritime industry support.	The public worries about how floods will threaten their safety, property, and livelihoods. many shared a strong desire for solutions to address other concerns that affect them every day. Those concerns include mobility, affordability, open space, and waterfront access *"I live in the Orient Heights neighborhood, but enjoy the* parks and retail *down on the point"* *"I am most concerned about* severe coastal flooding *affecting Sumner/Callahan tunnels and the Blue Line tunnel, potentially cutting East Boston off from mainland."*
Town of Winthrop, Winthrop Climate Change Vulnerability Assessment, 2017	Based on the Boston Harbor Flood Risk Model (BH-FRM), which is consistent with the US National Climate Assessment projections for Massachusetts: • 2030: 0.62 feet • 2070: 3.2 feet	Probable future flooding of Belle Isle Marsh Today: 95 acres (9% of Winthrop) 2030: 106 acres (10% of Winthrop) 2070: 135 acres (13% of Winthrop) Belle Isle infrastructure susceptible to flooding includes the Belle Isle Bridge, Pleasant Court Sewer Pump Station, Main Street (town evacuation route), Pleasant Street, Morton Street & other local roadways, Revere Street Sewer Pump	Belle Isle Marsh was identified as a flood prone area in need of a shoreline adaption strategy. Potential resilience measures to protect infrastructure in the Belle Isle area includes living shorelines and thin layer placement of fill to help marsh keep pace with sea level rise. Recommended adaptation for Belle Isle Marsh includes a planted berm/elevated sidewalk with knee wall along Morton Street. Flood modeling of the installed berm did prove to be effective for some of the adjacent Morton Street neighborhood, but ineffective for reducing flooding	During public meetings, community members voiced concern over flooding that affects residential buildings that are at high risk for increased flooding in the future as climate change progresses.

Reference	Sea Level Rise	Flood Projections	Adaptation and Resilience	Community Values
		Station, pressure reducing valve station at Revere Street, 240 houses and the Argyle Street Power Substation. Morton Street (fronted by the Belle Isle Marsh) and adjacent properties were identified in the Winthrop MVP Study/Plan as the Belle Isle Marsh flood area. The Belle Isle Bridge at Saratoga St is vulnerable to sea level rise. The critical elevation of the bridge is 12.26 ft NAVD88. The low member of the structure is about 1-2 feet above the BH-FRM mapped 1% chance water level at present. In 2030, the bridge is projected to be only six inches above the 1% chance water level. Additionally, the approaches to the bridge are low elevation; during a 1% chance water surface elevation in 2030, Main Street could experience as much as 6" of flooding, making it impassable.	on Main Street. This shows that both flood pathways, addressing the bridge and private properties, is needed for the adaptation to be effective. It is noted that residential and commercial development adjacent to the Belle Isle Bridge will limit future wetland migration. Adapting the Belle Isle Bridge to SLR faces firm height restrictions from the Federal Aviation Administration, and this is unlikely to change in the near term.	
MassDOT/MBTA, Climate Change Vulnerability Assessment for the Blue Line, 2017	The future flood projections used in analysis derive from the Boston Harbor Flood Risk Model (BHFRM) (Bosma et al., 2015). Blue Line exposure was evaluated for a 0.1% storm surge event under the following SLR scenarios: • 2000 – 0 ft SLR • 2030 – 0.7 ft SLR • 2070 – 3.3 ft SLR	Orient Heights Maintenance and Storage Facility and Suffolk Downs Station, among others, are highlighted as exposed to storm surge and sea level rise. Assets which are vulnerable are categorized and catalogued. Categories are assessed in a general sense for their sensitivity to exposure. For example, the track and rails are sensitive to damage from flowing water, and salt corrosion. The Orient Heights, Suffolk Downs, Bennington St Bridge, and Belle Isle Inlet Bridge assets are designated as having either "medium" or "high" vulnerability to sea level rise and storm surge.	Using a qualitative scale for adaptive capacity, the Orient Heights was identified as "low", Suffolk Downs Station was identified as "low", Bennington Street Overhead Bridge was identified as "high", and Belle Isle Inlet Undergrade Bridge was identified as "medium." Assets with a low adaptive capacity are considered more vulnerable to sea level rise as protecting, accommodating, or retreating from such exposure is logistically difficult, cost-prohibitive, or otherwise less feasible. The Orient Heights Maintenance and Storage Facility was identified as 1 of 3 critically vulnerable assets in the short-term.	Massachusetts Bay Transportation Authority (MBTA) is concerned with identifying vulnerabilities within its system to minimize service disruptions, ensure reliable transportation to support the regional economy, and protect taxpayer investments. The Blue Line is a critical transportation route for many passengers, especially Environmental Justice community members.
Town of Winthrop, Winthrop Community Resilience Workshop, 2018	N/A	Coastal flooding, storm events, and heavy precipitation will increase with climate change leading to more severe flooding.	Belle Isle Marsh is listed as one of Winthrop's top six recommended focus areas for climate resiliency. Adaptation strategies which may impact or incorporate the marsh include: • Maintain existing seawalls • Install floating dams for protection • Preserve natural environments that serve as natural flood barriers • Town-wide natural barrier system (dune enhancement, berms, etc.)	One of the key issues raised during the workshop was the need to preserve, maintain and enhance natural infrastructure in Winthrop so that it can continue to function as a natural barrier for the community. Ideas include dune enhancement, building additional trees to lessen heat island impact, add more natural vegetation where it is needed, develop an overall Town wide natural barrier enhancement plan and conducting feasibility studies to determine what types of enhancement will make sense and their anticipated impact.

Reference	Sea Level Rise	Flood Projections	Adaptation and Resilience	Community Values
			• Relocating key community infrastructure/buildings out of floodplains • Increasing education/support for homeowners to mitigate flood risk and impact.	Overall, the Winthrop community values robust flood protection through both hard engineering structures and green infrastructure/the natural environment. Additionally, public education and awareness on hazards such as flooding is also important.
AECOM, MBTA: Orient Heights Maintenance and Storage Facilities, 2018	Flood surge elevations were obtained from the MassDOT Vulnerability Assessment, which utilized the Boston Harbor-Flood Risk Model (BH-FRM) for flood projections. • 2030 SLR with 100-yr and 500-yr Storm Surge • 2070 SLR with 100-yr and 500-yr Storm Surge	The Orient Heights Car Yard facility is located adjacent to a coastal bank already today exposed to some impacts as a result of a storm surge. Under year 2030 projections, the perimeter of the facility, including security controllers, is vulnerable to flooding, however projections do not encroach on most major infrastructure. Under year 2070 projected sea level rise and storm surge scenarios, the entire Orient Heights Car yard facility is inundated by several feet of water, including water intrusion into the buildings themselves of several feet in depth. At the year 2070 predicted 100-year recurrence the depth of water inside the Maintenance Facility building ranged between 2 to 3 feet above the floor. Outside near to the building depths ranged from 3 to 4 feet and in some areas of the Car Yard. It is apparent that during the year 2070 predicted storm event, the facility could not continue to function.	Identified steps to be taken to minimize downtime at the facility and expedite the return to operations. Proposed solutions are operational or structural, and include some form of: • Elevating Equipment, • Dry Flood Proofing, • Asset Relocation (e.g., office trailers), and/or Vehicle Protection.	The MBTA's Orient Heights Car Yard serves a critical function in supporting the operations of the Blue Line. If these assets were exposed to coastal flooding from a Superstorm Sandy-like storm, the consequences could be the inability of the Blue Line to function, requiring a large, medium- to long-term mobilization of alternative transit options (e.g., buses) in order to ensure that tens of thousands of East Boston and Revere residents are able to reach medical facilities, schools, and places of employment.
Douglas et al, Improving the environment while protecting coasts, 2018	The future flood projections used in analysis derive from the Boston Harbor Flood Risk Model (BHFRM) (Bosma et al., 2015). Coastal storm flooding was investigated in terms of annual probability of occurrence for the following SLR scenarios: • 2000 – 0 ft SLR • 2030 – 0.7 ft SLR • 2070 – 3.3 ft SLR	The annual probability of coastal flooding in much of this area is currently 1 to 2% and increases 2% to 10% by 2030 and 10% or more across the entire area by 2070.	Investigated benefits of conceptual green, gray and hybrid adaptation alternatives at the Suffolk Downs/Belle Island Marsh flood pathway over Bennington Street. The Suffolk Downs adaptation was envisioned to potentially include a natural berm, tidal control measures to control tidal exchange and precipitation discharge, creation of an open span bridge for an MBTA railway and local roadway that would allow the marsh to naturally migrate and expand. Potential secondary measures identified consisted of target thin layer deposition in existing salt marsh areas, as well as habitat expansion amongst developable areas. By 2030, the potential for managed marsh migration into the former Suffolk Downs racetrack was identified (this study was prior to final redevelopment plans). Flooding into the northeast portion of the site was identified as possible with an extreme (0.1% annual probability) event but may be due to a different flood pathway.	The environmental, economic, and social benefits of including green infrastructure and natural and nature-based features in coastal planning and preparedness strategies. The need to integrate these benefits into coastal adaptation planning and the impacts and trade-offs in doing so. Efforts to improve community resilience in the face of chronic and episodic risks related to climate change call for community engagement and workable approaches.

Reference	Sea Level Rise	Flood Projections	Adaptation and Resilience	Community Values
			While gray infrastructure reduces the flood extent somewhat (12 to 17%), the green strategy is designed at this site to nearly double the flood extent under present day conditions, to promote marsh migration. By 2030, the flood extent reduction under the green strategy is about half of the reduction by the gray strategy (24% vs 45%) for moderate storms but similar for both strategies (70% reduction for green, 76% reduction for gray) from more extreme storms. A high-level Benefit-Cost Analysis incorporating ecosystem benefits (flood protection based on value of various green land uses per acre) was conducted, with results indicating that the hybrid green-gray strategy would be cost-effective.	

VHB, Resiliency Adaptation Study – Suffolk Downs Redevelopment, 2018	Analyzed 22 scenarios, most significantly current and sea level rise conditions under normal and 100-year tide level, as well as no precipitation and 100-year precipitation.
	
	• Present Day – 0.0 ft of SLR
	• 2035 – 1.5 ft of SLR
	• 2070 – 4.2 ft of SLR
		Hydraulic and hydrologic modeling of the "no build" and "build" condition.
		
		Under 1.5 ft of SLR, projections demonstrate flooding of Revere Public Schools, Bennington St, and Sales Creek (within the existing Suffolk Downs track). The build condition is shown to improve flood conditions in select areas within Suffolk Downs, but not for adjacent properties such as Revere Public Schools or the MBTA. The 4.2 ft SLR scenario was not presented.
		
		A flood pathways analysis identified critical elevations where flooding hazards occur. When storm surge or high tide reaches 14.3 BCB (7.8 ft NAVD88) water would begin to flow from Belle Isle Marsh over Bennington St, rendering the Bennington Street Tide Gate ineffective. As Sales Creek fills, water would spill into the floodplain, flowing up the eastern intermittent stream and through the northern stables area. Storm surge or watershed runoff would flow under MBTA right-of-way via twin 96" culverts. As water levels rise, storm surge or watershed runoff would spill into the on-site floodplain.
			Targeting BPDA 2070 Design Flood Elevations for all finished floor elevations. These are based on BH-FRM 1% storm water surface elevations in 2070 plus freeboard.
			
			After flooding overtops Bennington St, the project proposes the Washburn Avenue Berm, perpendicular to Bennington St in Revere to prevent further flooding to the north. Additionally interim storage is proposed to manage precipitation.
			
			Alter the existing Bennington Street Alfred H. Long Pump Station from 300 cubic feet per second (cfs) to 600 cfs and update and adjust the pump automation to engage at lower water surface elevations as compared to current day practice.
			
			Add additional tide gate at east end of Sales Creek, just west of Bennington St.
			
			A conceptional regional berm alternative is presented as the "Belle Isle Inlet Berm Protection." The berm runs along the boundary of Belle Isle Marsh and Bennington St/Revere Public School fields. The berm would be approximately 2,800 ft long, with an elevation of 18 ft. The presentation states, "HYM has committed to completing a feasibility study of the regional berm."
				Project Goals:
				• Construct a resilient project
				  ○ 16.5 million square feet mixed-use development
				  ○ Targeting BPDA finished floor elevations
				• Analyze potential impacts to abutters
				  ○ Over 1,000 low-lying hydraulically connected properties in Revere and Boston
				• Mitigate (if necessary) impacts to abutters
				• Provide flood protection measures for the project site and abutters

City of Revere, Revere MVP Summary of Findings, 2019	Not Applicable	The convergence of freshwater and tidal systems in the vicinity of Belle Isle Marsh and Rumney Marsh has led to significant flooding during combined high tide and rain events including streets to the north of Belle Isle Marsh.	Identified Belle Isle Marsh as a focus area and critical asset within their planning process. Proposed improvements include the dredging of Belle Isle Creek, the building of levees to prevent flooding of	MVP workshop participants noted that flooding has led to pollution in marshes, wetlands, and other surface water bodies due to associated sediment and nutrient loading. It has also increased the amount of trash and debris, impacting the performance of tide gates.

Reference	Sea Level Rise	Flood Projections	Adaptation and Resilience	Community Values
		Storm surge has damaged seawalls and other coastal infrastructure, as well as contributed to erosion. More intense precipitation events and larger, more frequent storms coupled with increased development have exacerbated flood hazards in Revere and expanded flood zones. In the future, sea level rise is projected to result in coastal flooding that will extend further inland than in the past or present.	properties adjacent to Belle Isle Marsh, and the completion of a land swap between DCR and Revere.	Goals developed in the MVP Workshop related to community values include building greater community awareness of climate change and resilience planning.
Boston Redevelopment Agency, Suffolk Downs Master Plan, 2020	Suffolk Downs development will follow Boston Planning & Development Agency guidance to provide 1 to 2 feet of freeboard above the projected 2070 Sea Level Rise Base Flood Elevation, which are based on BH-FRM 1% water surface elevation projections. The Proponent will also incorporate forward-thinking resiliency strategies intended to address future sea level rise and other impacts of climate change. Stormwater mitigation strategies are based on present precipitation data, not future projections.	Building and site improvements designed at a minimum to meet the City's most current requirements respecting climate resiliency policies and standards to manage storm events and be resilient to both coastal and inland flooding, including the potential impacts of extreme precipitation events due to climate change and coastal flooding due to sea level rise.	Resiliency measures include storm water drainage system improvements such as improved storm water channels, infiltration chamber systems, rain gardens, and deep sump pump catch basins with oil and gas separators, as well as increased elevations of streets, increased elevations of first floors and utilities in buildings, adaptable first floor space, and garage lower levels that can be used as potential flood storage areas. HYM is financially committed to funding the study of the proposed regional berm adaptation strategy, or similarly focused coastal flood solutions at Bennington St, the pump station, and Revere Public School. The commitment to funding for the regional berm strategy is tied to a specific, future phase of development.	The project agreement requires public progress reporting and engagement with the community. With the submission of each progress report, the BPDA shall conduct a community meeting at which the Proponent shall present information from the progress report and answer questions from members of the community, and community members shall have an opportunity to provide comments to the BPDA regarding the progress report and the Master Project.
City of Revere, Revere Hazard Mitigation Plan, 2021	The document references sea level rise projects from the 2018 Statewide Hazard Mitigation and Climate Adaptation Plan: • 1 to 3 feet in the near term (2000 to 2050) • 4 to 10 feet by the end of 2100	The Beachmont neighborhood was identified as being flood prone when storm surge from Belle Isle Inlet overtops Belle Isle Avenue and Bennington St. Beachmont, which is adjacent to Belle Isle Marsh, is a densely developed area containing schools, subway stations, police departments, etc. Streets bordering the marsh that frequently experience flooding include Pearl Avenue, Belle Isle Avenue, Winthrop Avenue, and Bennington Street. Flooding is predicted to increase in frequency and severity with climate change.	As part of the hazard planning process, mitigation actions were developed to address high impact hazards and decrease vulnerability to hazards. One mitigation action developed in the 2015 plan and carried over to the 2021 plan is to install levees along Belle Isle Inlet/Avenue to mitigate flooding. Additional mitigation actions focus on installing pump stations, upgrading seawalls, acquiring flood prone lands, improving the wetlands ordinance, etc. to address flooding impacts on the city.	During open public meetings, members of the Revere community were able to comment on their concerns and priorities for hazard planning within the city. Concerns were voiced over flood impact on transportation and that high marsh vegetation can be a wildfire hazard. It was noted that construction within the flood plain of Suffolk Downs will be built/updated according to resiliency standards. Overall, residents of Revere value early hazard preparedness and resiliency planning.
City of Boston, Coastal Resilience Solutions for East Boston and Charlestown (Phase II), 2021	Consistent with other Climate Ready Boston planning studies, Boston used the following sea level rise projections to inform the plan (note that the 2070 sea level rise projections were updated from 3.0 ft to 3.33 ft in order to align with the BH-FRM scenarios, which are the basis for evaluating, planning, and designing resiliency strategies in Boston): • 0.75 ft ~ 2030	East Boston was once a collection of small islands that have been joined together into one landmass through episodes of filling tidal areas over time. Much of the land that was created through fill is now vulnerable to flooding, as it exists at a lower elevation than the surrounding areas that were once islands.	Climate Ready East Boston project boundary encompasses only western Belle Isle Marsh, beginning at Main St bridge, tracing the main channel centerline, and ending at the Sales Creek tide gate at Suffolk Downs. This excludes the eastern portions of the marsh within the municipal boundaries of Revere and Winthrop.	Community participation will be encouraged because proposed coastal resilience solutions must strive to protect places that serve essential community functions, and these essential functions are best understood based on local knowledge and values.

Reference	Sea Level Rise	Flood Projections	Adaptation and Resilience	Community Values
	• 3.33 ft ~ 2070			
City of Boston, Coastal Resilience Solutions for East Boston and Charleston, 2022	Consistent with City of Boston, 2021, the City used the following sea level rise projections: • 0.75 ft ~ 2030 • 3.33 ft ~ 2070	Vulnerabilities of roadway and railway are present and exacerbated by sea level rise. Present day storm flood entry points are projected at Revere public schools, the Sales Creek tide gate/Suffolk Downs, and Bennington St. Year 2030 storm flood entry points are additionally projected at the Casket Company and MBTA railyard. Year 2070 storm flood entry points are additionally projected at over Main St bridge, and much more extensively along Bennington St.	Belle Isle Marsh is identified as a focus area of the project. Concepts are intended to reduce flood risk to development and create recreation opportunities. Adaptation would incorporate a lane diet, elevated roadway, floodwall, and multi-use trail at the landward edge of the marsh.	Ongoing collaboration and coordination with Revere is noted where flood protection is proposed to impact hydrodynamics at the jurisdictional boundaries.

3.0 Literature Review – Flood Risk Figures

This section collects and presents relevant flood risk figures identified in the sources presented above. Figure captions are provided to describe each figure and the significance with respect to Belle Isle Marsh.

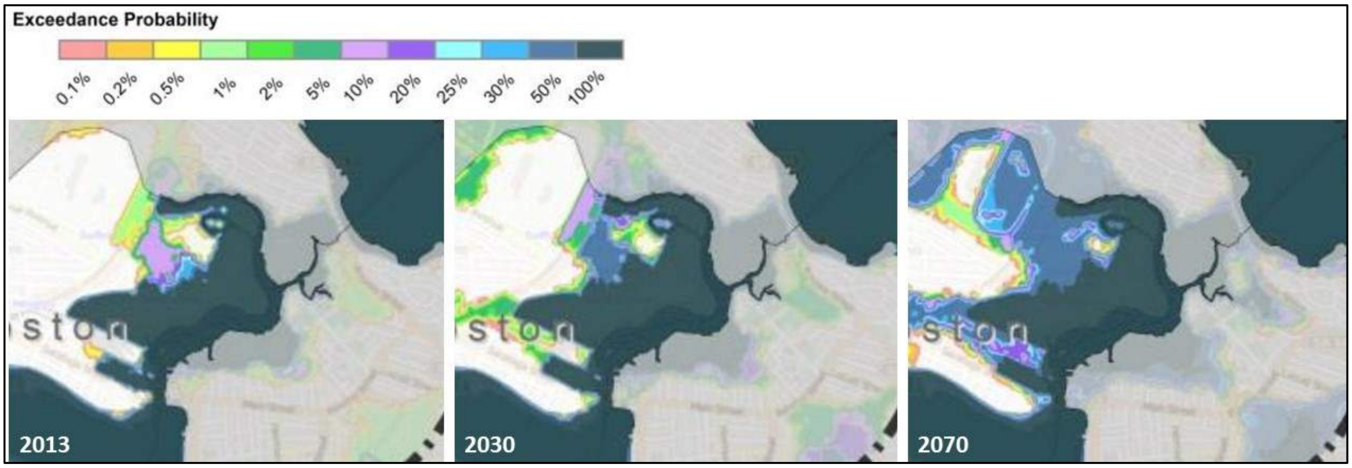

Figure 2. BH-FRM results showing probability of flooding in 2013, 2030, and 2070. Flood projections in Belle Isle Marsh depict overtopping of the marsh habitat on an annual basis (100% exceedance probability) at minimum. Flood projections throughout East Boston, Revere, and Winthrop are extensive, projected as frequently as a 1 in 10 annual chance today, with annual flooding anticipated under 2070 sea level rise conditions (MassDOT, 2015).

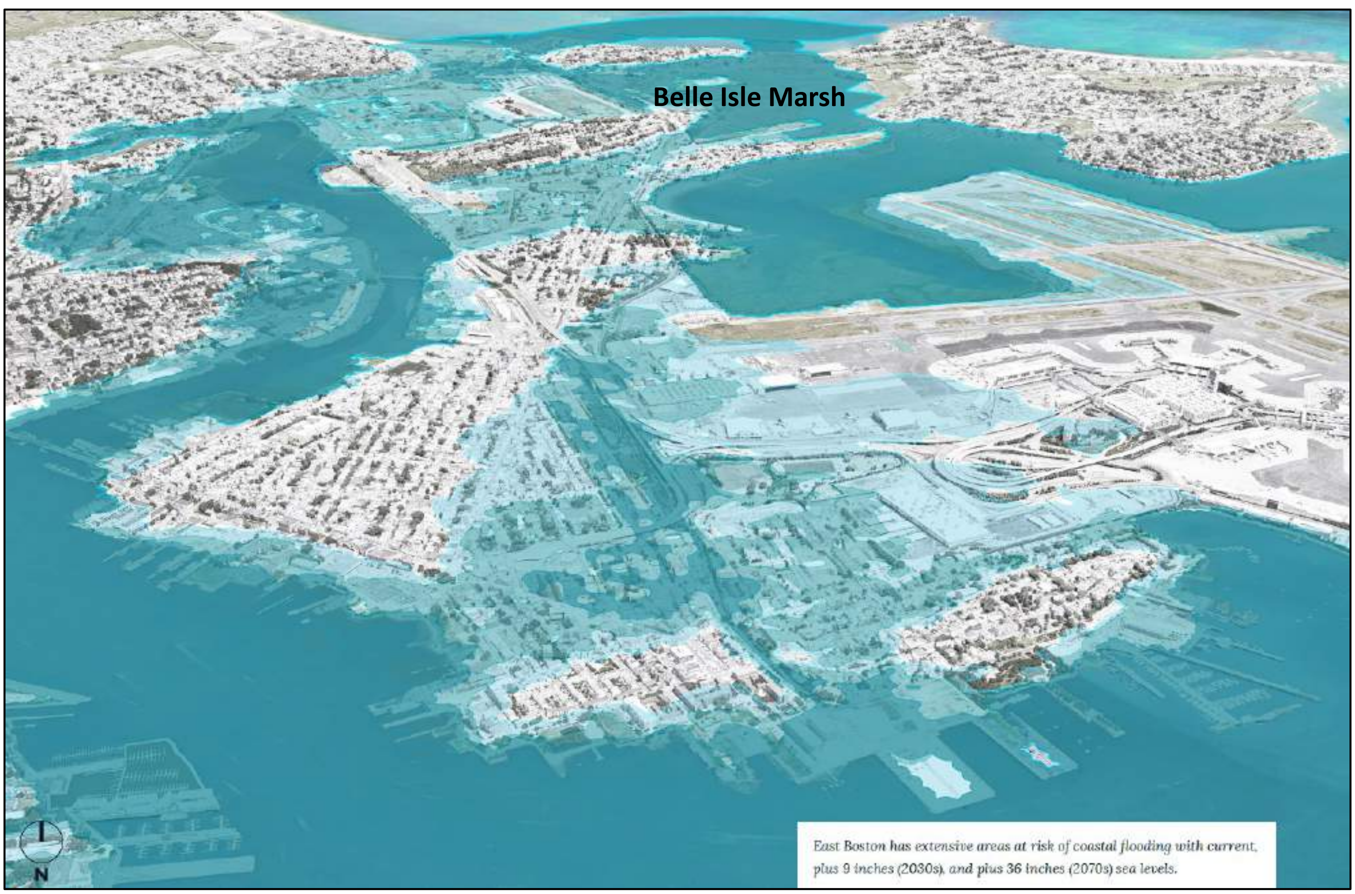

Figure 3. Climate Ready East Boston Phase 1 visualization of 2030 and 2070 sea level rise and storm flooding, based on BH-FRM, depicting flood water overtopping Belle Isle Marsh at the MBTA Orient Heights railyard, Bennington St, and Short Beach (City of Boston, 2017).

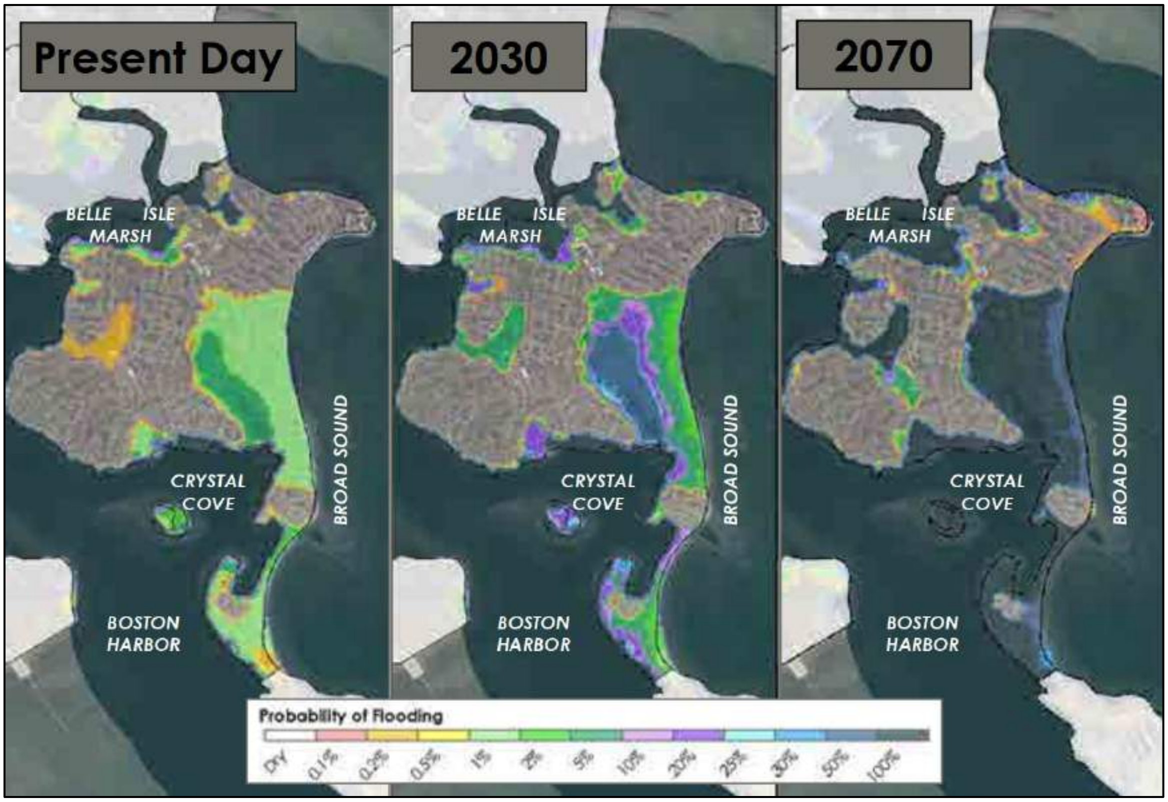

Figure 4. Town of Winthrop: Areas of probable flooding, based on BH-FRM, depicting overtopping along Morton St/Banks St, Argyle St/Bayou St, and the Winthrop Parkway (Town of Winthrop, 2017).

LAND USES	Mostly residential, with some industrial business on Argyle Street and commercial properties near the Belle Isle Bridge, natural resources & open space
ASSOCIATED WATERBODIES	Boston Harbor & Belle Isle Inlet
PUBLIC SHORELINE STRUCTURES	Stone revetment (<5 feet high) along Morton Street from Fairview Street to the Town Cemetery 5- to 10-foot stone revetment, below the Town Cemetery 5- to 10-foot bulkhead/seawall at Short Beach 10- to 15-foot stone revetment along Seawall Avenue
PUBLIC BUILDINGS	Pleasant Court Sewer Pump Station Revere Street Sewer Pump Station Pressure Reducing Valve Station at Revere Street
TOTAL BUILDINGS	240
TRANSPORTATION INFRASTRUCTURE	Belle Isle Bridge to East Boston Winthrop Parkway Land Bridge to Revere Main Street, Pleasant Street, Morton Street & other local roadways Winthrop Harbor Walk & Eco Park
WATER AND WASTEWATER INFRASTRUCTURE	Pleasant Court Sewer Pump Station Winthrop Parkway Sewer Pump Station Underground local and MWRA sewer mains Pressure Reducing Valve Station at Revere Street
STORMWATER INFRASTRUCTURE	Underground system, catch basins, and outfalls
ENERGY INFRASTRUCTURE	Argyle Street Substation Electric & natural gas distribution system
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	Belle Isle Marsh Short Beach Fort Banks Playground Kilmartin trail and footbridge

Figure 5. Left – Critical Infrastructure susceptible to coastal flooding, including 6 assets surrounding Belle Isle Marsh: B – Belle Isle Bridge, D – Main Street (evacuation route), F – Pleasant Court Sewer Pump Station, H – Power Substation (Argyle Street), J – Pressure Reducing Valve Station (Revere St), and M – Revere St. Sewer Pump Station. Right – Land uses and public infrastructure within projected flood areas of Belle Isle Marsh (Town of Winthrop, 2017).

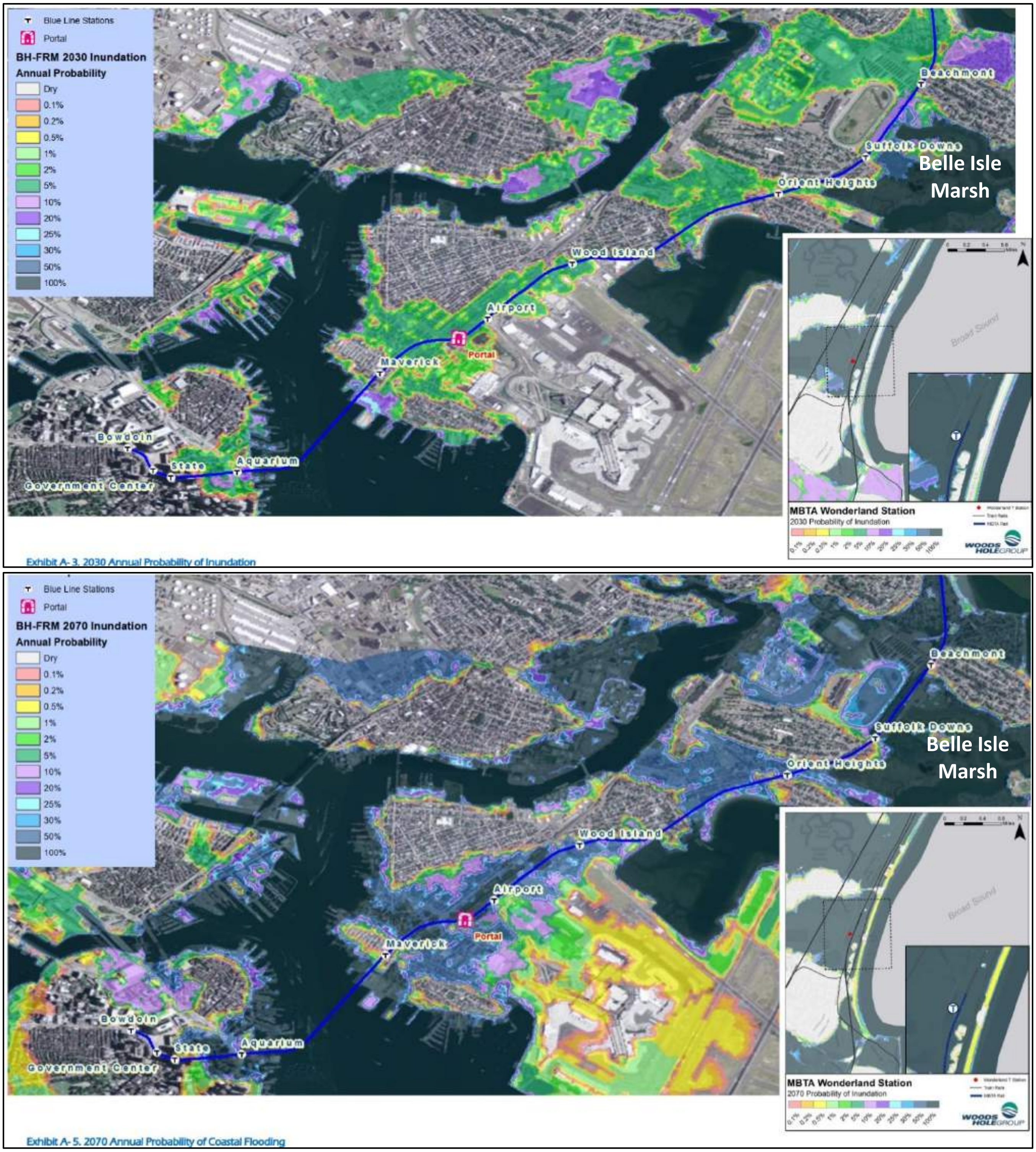

Figure 6. MBTA Blue Line Climate Change Vulnerability Assessment flood probability maps depicting a zoom-in view of the same BH-FRM 2030 and 2070 data presented in Figure 2. The vulnerability of Beachmont, Suffolk Downs, and Orient Heights stops along Bennington St are apparent in the 2030 time horizon. By the 2070 time horizon, the frequency of flooding of these assets is significantly increased, becoming a potentially annual occurrence. While Belle Isle Marsh represents a key flood pathway of such vulnerability, flooding is also anticipated to pose a threat from other areas such as Constitution Beach, Chelsea Creek, and Revere Beach (MassDOT/MBTA, 2017).

Figure 7. Sea level rise and storm flood projections in 2070 for the MBTA Orient Heights maintenance yard. The 100-year flood depth (blue contour) and 500-year flood depth (purple contour) depict flooding across the majority of the railyard. Under the 2070 predicted storm event, the facility could not continue to function (AECOM, 2018).

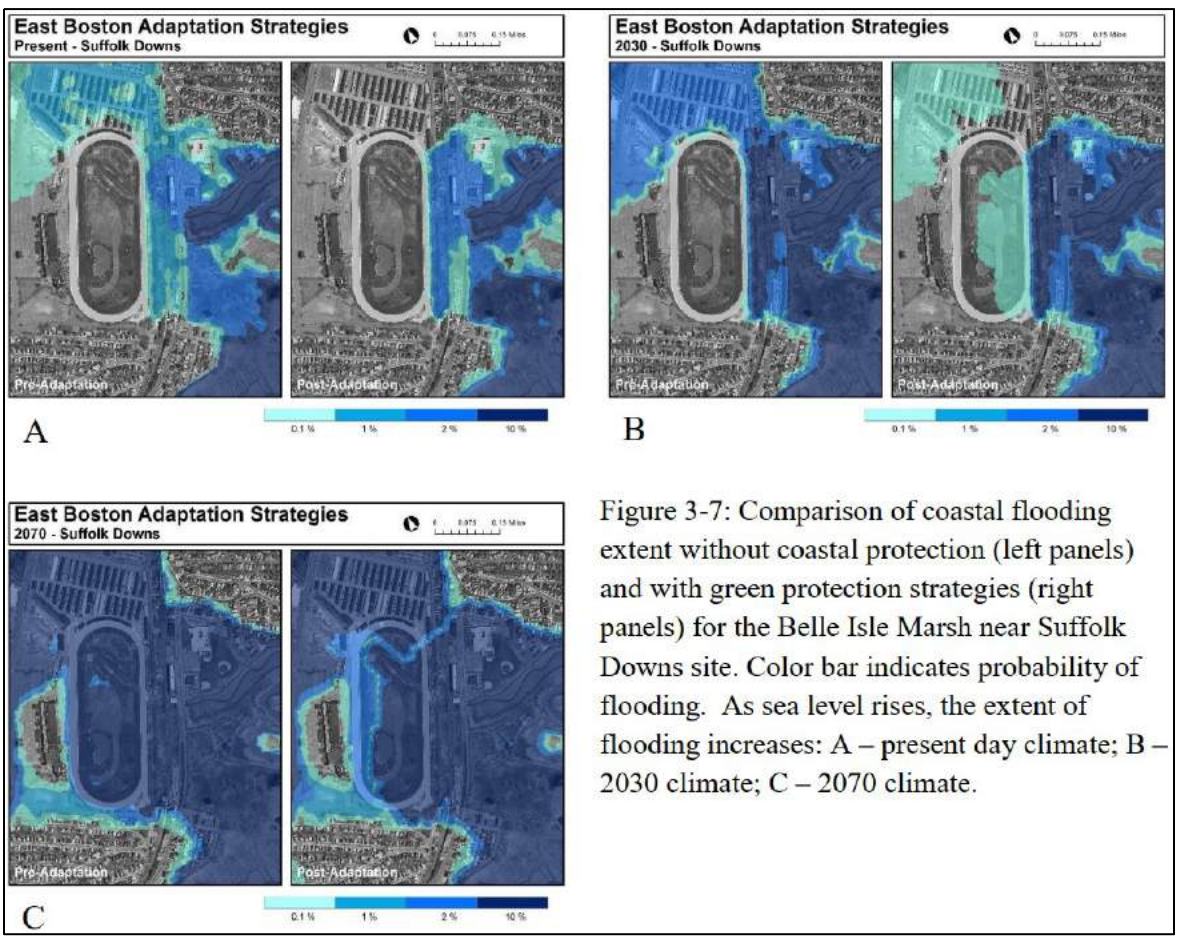

Figure 8. Storm flood projections of Belle Isle Marsh and Suffolk Downs under present day, 2030, and 2070 sea level rise scenarios using BH-FRM. Projections are presented under a No Action condition (left panel) and Green Protection condition (right panel). Green protection strategies are shown in Figure 12, and include raising the railway, raising and converting Bennington St to a bridge feature, allowing salt marsh to migrate into Suffolk Downs, construction of a berm in Suffolk Downs, thin layer deposition in the marsh, and relocation of Revere Public Schools.

Figure 9. Flowpath and current velocities under a "No Build" (left) and "Full Build" (right) condition which includes the HYM development, pump station upgrades, installation of a berm at Washburn Ave, construction of flood storage within the proposed development. Scenario depicted represents 1.5 ft of sea level rise, a 100-yr rainfall event, and a 100-yr tide event (VHB, 2018). Impacts to Bennington St and adjacent public assets such as the MBTA Blue Line and Revere Public Schools are not significantly mitigated by the "Full Build" condition.

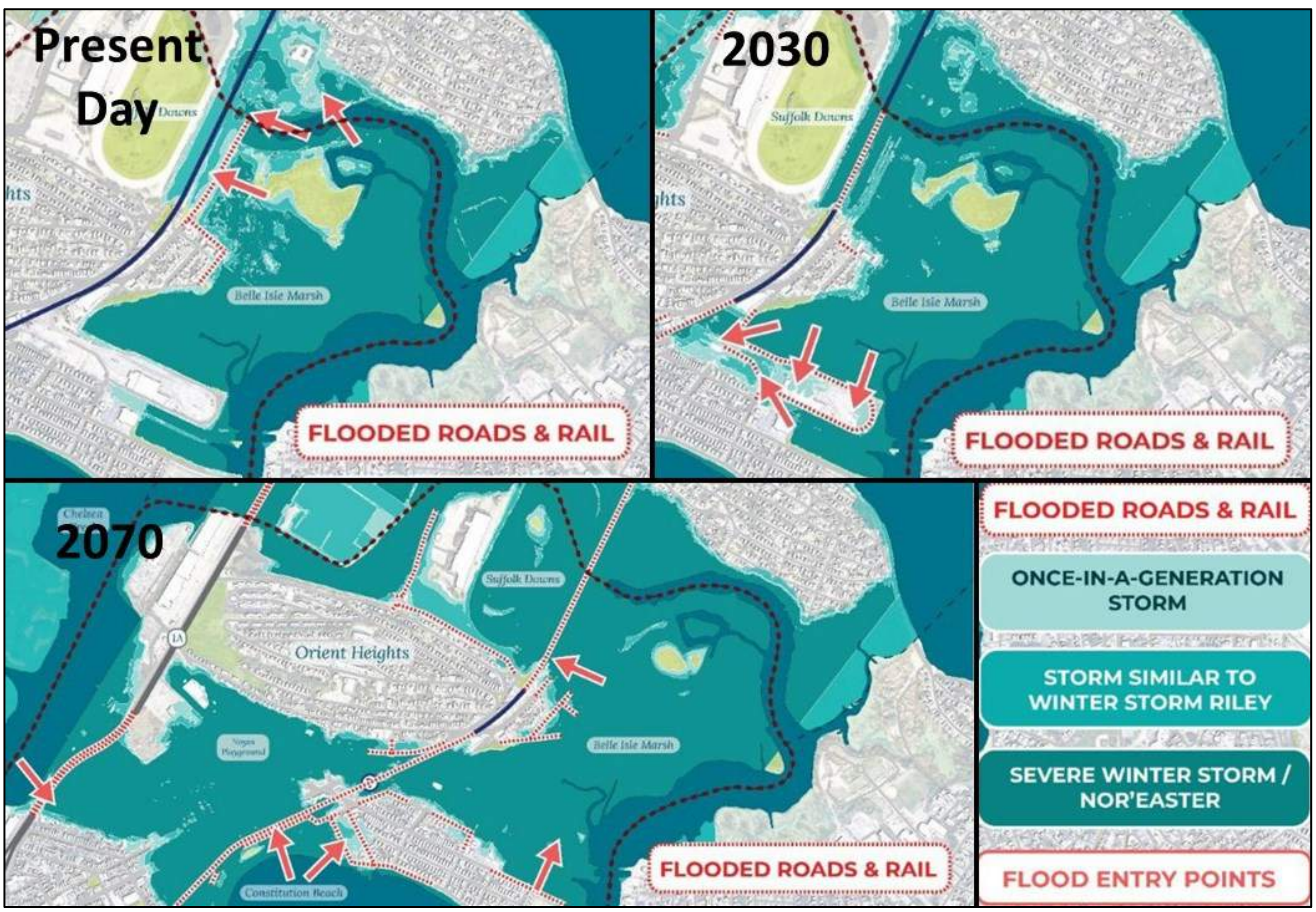

Figure 10. Climate Ready East Boston Phase II storm flood pathways for present day, 2030, and 2070 sea level rise scenarios. Flood projections mirror that of previous MassDOT studies, which also utilize results of the BH-FRM. Flood pathways identify the low elevation entry points along Bennington St and the MBTA maintenance railyard in the near term, and the added complexity of flooding at Constitution Beach, Chelsea Creek, and Revere Beach (not shown) by 2070 (City of Boston, 2021).

4.0 Literature Review – Adaptation Strategy Figures

This section collects and presents relevant adaptation strategies identified in the sources presented above. Figure captions are provided to describe each figure and the significance with respect to Belle Isle Marsh.

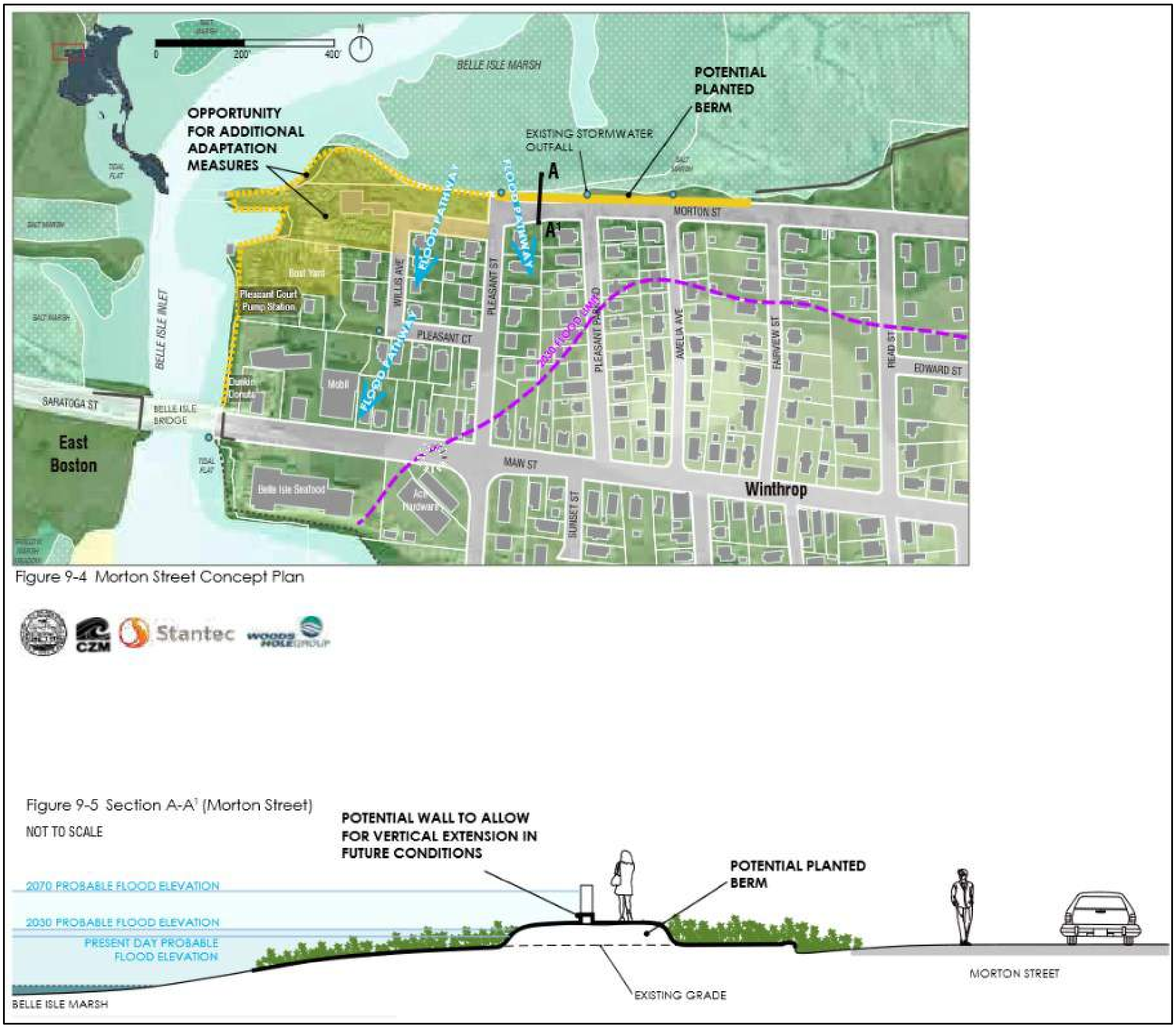

Figure 11. Conceptual design for elevated and planted berm along Morton St, Winthrop, MA. Model efforts found the adaptation strategy is insufficient on its own to provide adequate protection, as flood pathways to the west through the existing boat yard and stormwater issues remain unaddressed (Town of Winthrop, 2017).

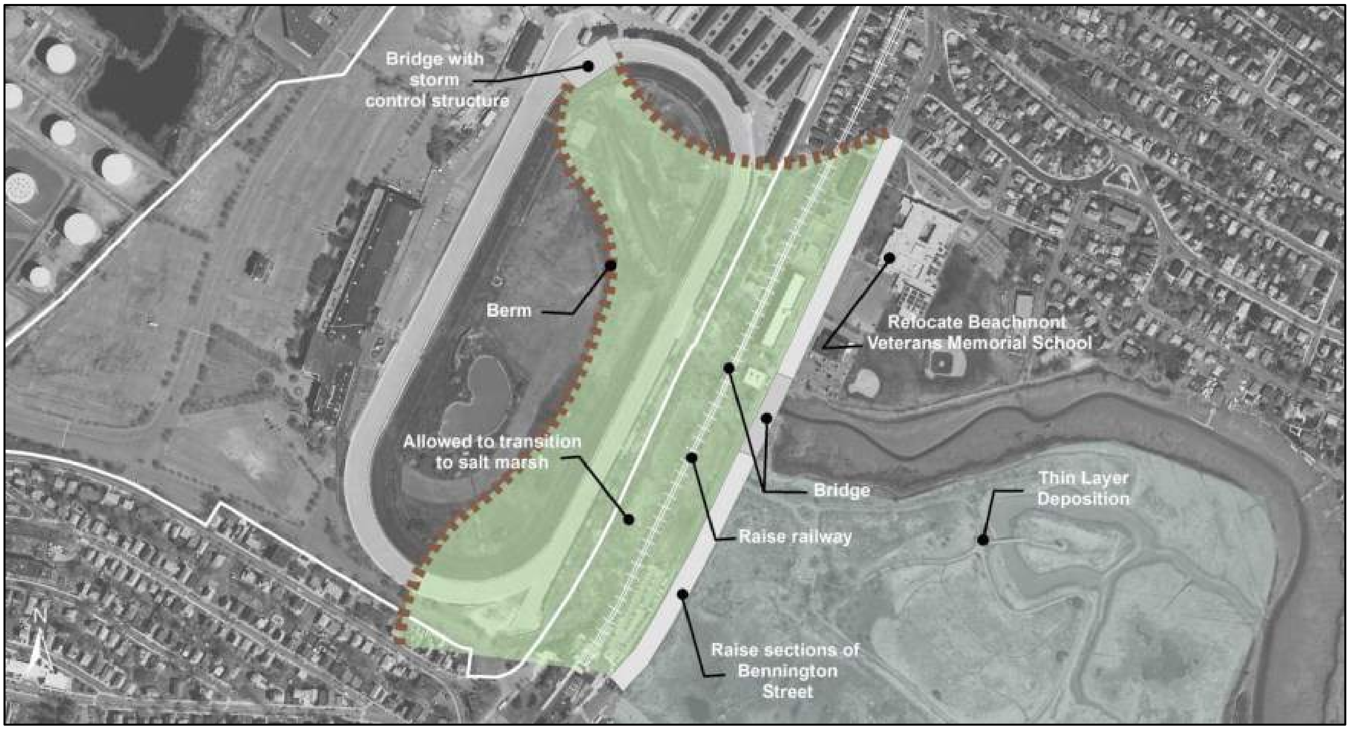

Figure 12. Conceptual green-gray protective strategy for Suffolk Downs site, designed by Woods Hole Group. Elevating Bennington St on a bridge and promoting marsh migration into the Suffolk Downs area would allow for the expansion and preservation of marsh habitat with sea level rise (Douglas et. al., 2018).

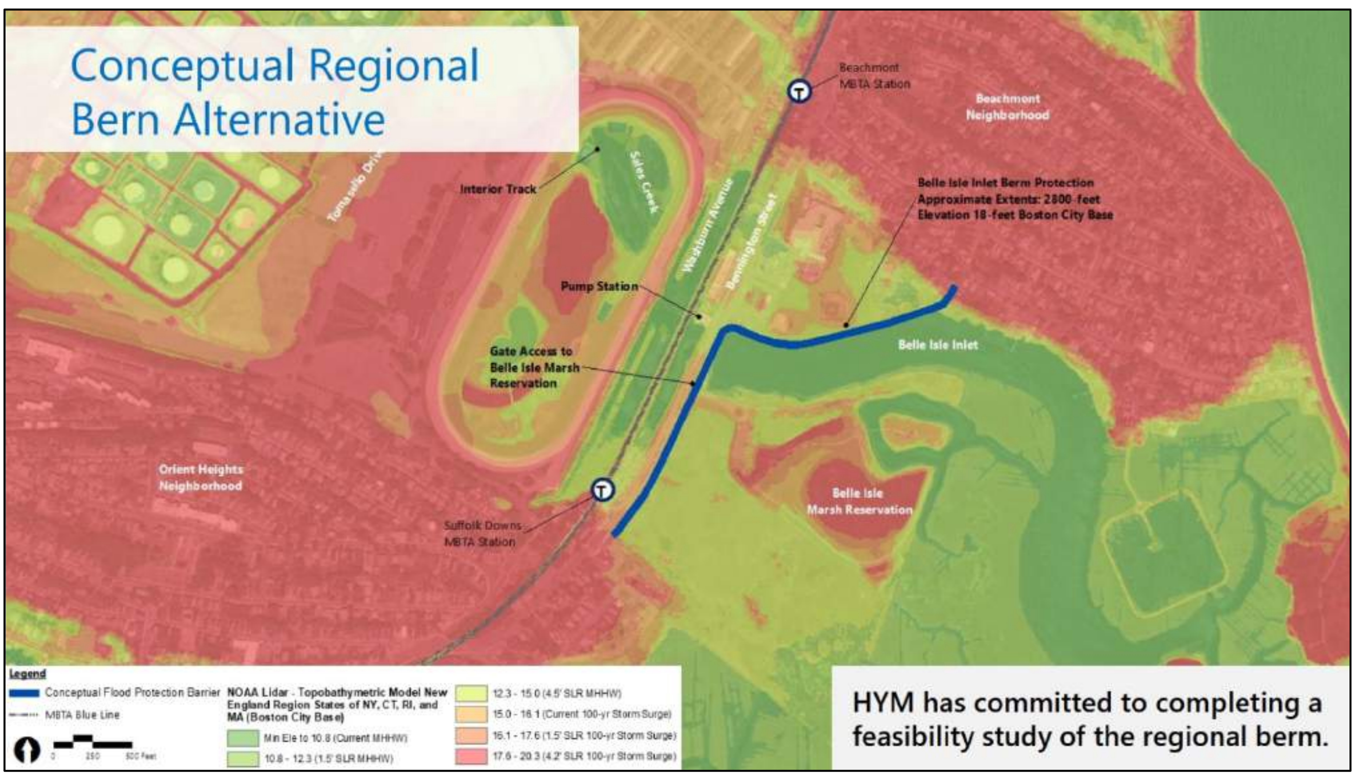

Figure 13. Conceptual regional berm for flood protection of Bennington St and consequently, East Boston, the Suffolk Downs Development, and Revere. The berm alternative would necessarily impact Belle Isle Reserve as its footprint would occupy the edges of the Reserve, and would imply a commitment to protection of infrastructure and the abandonment of future marsh migration in this area with sea level rise (VHB, 2018).

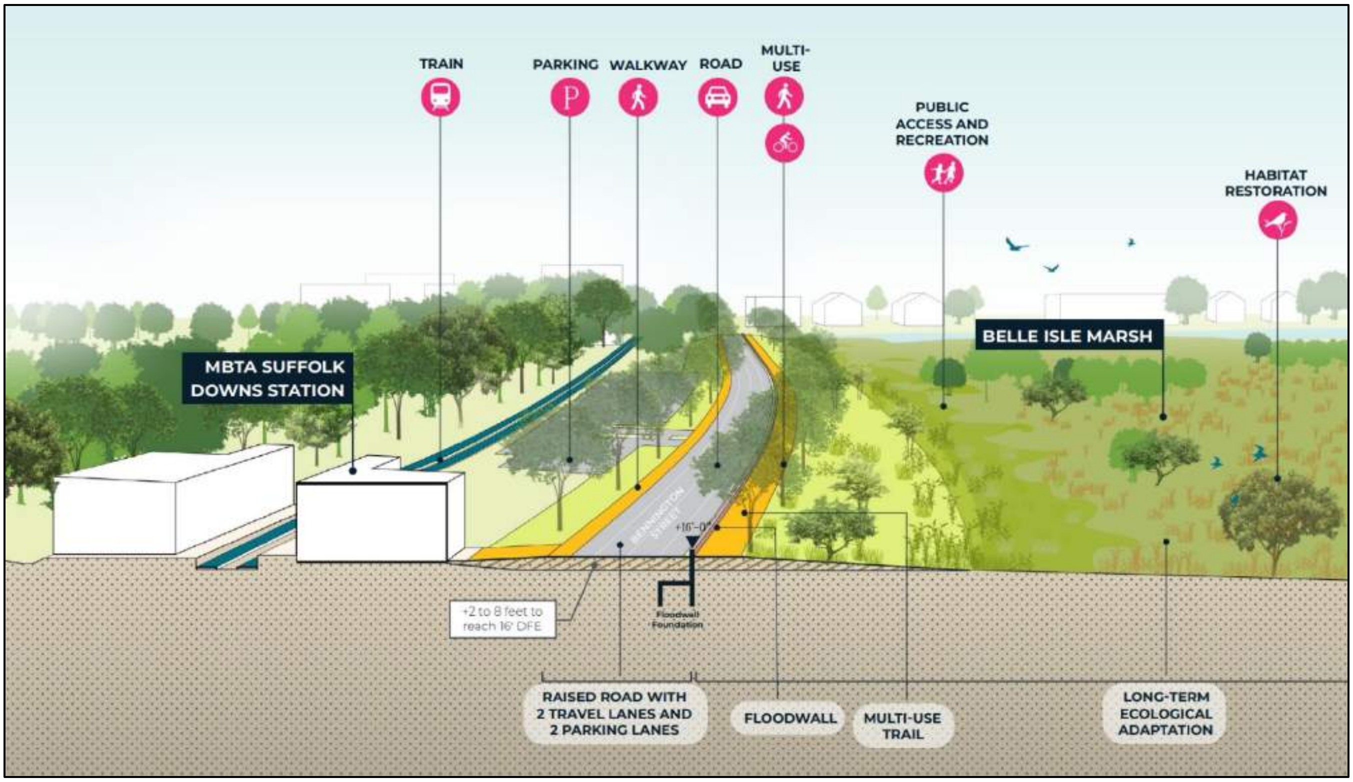

Figure 14. Bennington St adaptation strategies of Climate Ready Boston Phase II. Concept design includes a lane diet, elevated roadway, floodwall, and multi-use trail (City of Boston, 2022).

5.0 Conclusions

A comprehensive collection of public literature surrounding and relating to Belle Isle Marsh was reviewed to provide an integrated understanding of sea level rise and ongoing coastal planning for the regions of East Boston, Revere, and Winthrop to date. Throughout the multiple references cited, a total of five independent groups have undergone sea level rise planning in the region. Additionally, this Belle Isle Marsh Climate Vulnerability Assessment is providing additional modeling analysis of the impacts of sea level rise in the region. The range of sea level rise scenarios considered across the region are shown in Figure 15, along with the best available sea level rise science for the Commonwealth of Massachusetts (ResilientMA, 2022).

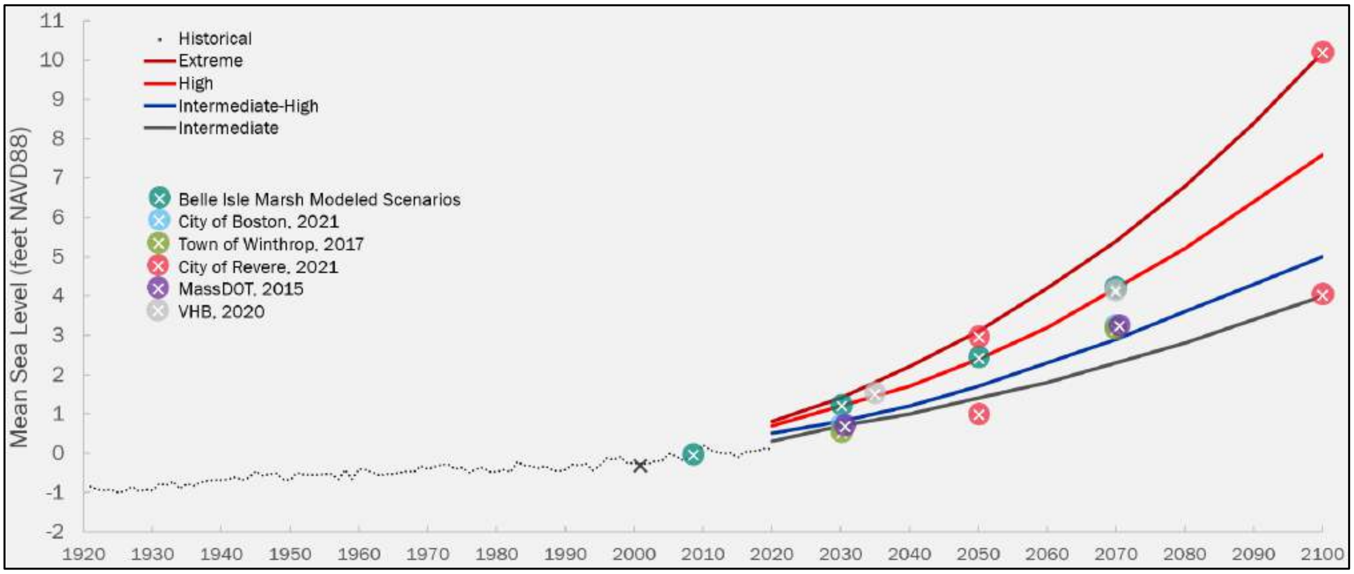

Figure 15. Sea level rise scenarios of planning studies of the region. Relative sea level rise projections represent ResilientMA modeled scenarios and utilize a baseline year of 2008 (1999-2017).

Flood projection results across the region tell a story of existing stormwater and coastal flood hazards becoming increasingly exacerbated by sea level rise and climate change. As sea level rises, events that today have a 1% annual chance of flooding will become increasingly frequent, and will become an annual event in areas of East Boston, Revere, and Winthrop under 2070 sea level rise projections. Belle Isle Marsh will gradually become more frequently inundated, reducing the coastal flood resilience and ecological benefits of the resource. Flood entry points are projected in Boston (Saratoga St, MBTA railyard, Casket Company, Sales Creek tide gate/Suffolk Downs, Bennington St), Revere (Bennington St, public schools, Pearl Ave, Belle Isle Ave), and Winthrop (Main St, Pleasant St, Morton St, Argyle St, and Revere St). Sea level rise is projected to exacerbate infrastructure damage and increasingly disrupt the functions of these communities. Critical infrastructure including evacuation routes and public transportation may experience disruption during major storm events.

Adaptation and resilience planning across the region is aligned with the desire to incorporate nature-based solutions where feasible. Adaptation projects are developed with the primary goal of flood protection, while aiming to generate multiple co-benefits. The most consistent strategy for adaptation across all groups is the consideration of raising the elevation of the perimeter of Belle Isle Marsh, preferably through constructing a vegetated berm. This option has been considered independently by and is shared across the MBTA/MassDOT, City of Boston, City of Revere, Town of Winthrop, and HYM Investment Group. Discussion of managed retreat and marsh migration was not addressed in most planning reports, and only found in the experimental scientific paper by Douglas et. al. (2018).

Community values were assessed by each jurisdiction, primarily through the MVP Community Resilience Building workshops. Communities across the region have a shared interest in maintaining and enhancing public safety and flood protection, protecting habitat and water quality in Belle Isle Marsh, and increasing community awareness and collaboration in coastal hazard planning.

6.0 References

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Douglas et. al. 2018. Improving the environment while protecting coasts: A holistic accounting of ecosystem services of "Green Infrastructure and Natural and Nature-Based Features (NNBF)"in an urbanized coastal environment.

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Appendix A. Belle Isle Marsh – Marsh Management Plan - Task 1: Review Existing Conditions – Summary Memo

MEMORANDUM

DATE January 18, 2021 **JOB NO.** 2020-0076

TO Catherine Pedemonti
Mystic River Watershed Association
20 Academy Street, Suite 306
Arlington, MA 02476-6401

FROM Elise Leduc
Woods Hole Group
eleduc@woodsholegroup.com

Task 1: Review Existing Conditions – Summary Memo - FINAL

This document summarizes information gathered from a site visit and initial conversations with project partners, past restoration activities, and site studies and existing information related to the Belle Isle Marsh site. The intent of this task was to develop a better understanding of work conducted to date and ensure availability of data essential for fully understanding the physical processes and natural resources within the system (updating our field data collection plan in Task 2 as needed). Existing data and studies were reviewed to ascertain what data are already available and where gaps exist.

Document reviewed as part of this task include:

- Rumney Marshes ACEC Designation (1998)
- Rumney Marshes ACEC – Salt Marsh Restoration Plan (May 2002)
- Belle Isle Marsh Reservation ACEC & IBA Management Assessment (Jan 2020)
- Belle Isle Marsh Water Quality Monitoring Program (1988)
- Belle Isle Marsh Restoration – Environmental and Engineering Evaluations (August 1991)
- Belle Isle Marsh Reservation – Preliminary Research and Master Plan Phase – Feasibility Study (1978)
- Sales Creek Information from Beals & Thomas

Significant findings from each of these documents is summarized below.

A. Define the project study area

The Belle Isle Marsh portion of the Rumney Marshes Area of Critical Environmental Concern (ACEC) consists of 422 acres and spans three Towns: Boston, Revere and Winthrop. The ACEC boundaries are displayed with a blue dashed line in Figure 1. Ownership within this area includes state-, municipal- and privately-owned parcels.

While the management scope of the final Resource Management Plan will consider the entire ACEC, for the purposes of the field-based data collection (Task 2) and hydrodynamic modeling (Task 3), our focus will be on the large state- and municipally-owned salt marsh parcels, shown in green and labeled with current ownership information in Figure 1. This excludes any private residential parcels along the perimeter of the marsh, as well as the upper portions of Sales Creek. The field study boundaries were further refined to exclude extreme upland areas of those of those parcels (e.g., the cemetery in Winthrop, the Beachmont Veterans Memorial School in Revere). The final boundary determined for the field study component of the project is displayed by a yellow line in Figure 1.

Figure 1. Belle Isle Marsh study area boundaries for the development of a Resource Management Plan.

B. Site Visit – September 23, 2020

A Professional Wetland Scientist (PWS) from Woods Hole Group attended a site walk with representative from Mystic River Watershed Association (MyRWA), the Massachusetts Department of Conservation and Recreation (DCR), the Nature Conservancy (TNC), and Friends of Belle Isle Marsh.

The visit involved a tour around the entire Belle Isle Marsh Area, stopping at various access points. The following is a summary of site conditions at each access point:

1. **Belle Isle Reservation Park** (from main parking lot):
    - There is a pipe under the parking lot access relatively close to the road, which allows the fresh water wetland to the south to drain into the tidal river to the north. DCR unclogs the north end of this pipe approximately 2x/year.

- Area seen from southwestern boardwalk closest to main parking lot, there is an approximately 30-acre area of mostly Phragmites, interspersed with upland patches of forest. One forested path, just west of the brackish pool, is comprised largely of birches.
- There is a small brackish open water pool in the salt marsh by a small southern walkway (by self-guided tour post #3).
- The central grassland meadow consists of approximately 12.5 upland acres. This area contained some purple loosestrife in southwest corner, but DCR staff mentioned that controlling the invasive crown vetch has been a bigger problem. The state has implemented targeted mowing to control it. Japanese knotweed is also actively removed; due to regular removal, Japanese knotweed is not currently a significant problem at the site. This upland area is a historic landfill. It was capped and landscaped. A drainpipe exits near the northeast corner.
- The long southeastern boardwalk crosses a mixed vegetation salt marsh area and an earthen berm. The earthen berm was described as originally having been built in the 1930s, and it has since breached in a number of areas. DCR staff mentioned that the state is currently discussing how to manage the resulting impounded area; consideration has been given to whether to further breach the berm to allow for better hydrologic connectivity.
- The salt marsh adjacent to the tidal creek extending south along the eastern portion of the property has experienced significant dieback and erosion and the creek has significantly widened over the last 4 or 5 years. DCR staff noted that this edge erosion is happening along many of the larger tidal channels as well.
- DCR staff noted that current management of the salt marsh largely consists of annual salt marsh sparrow monitoring. No major active salt marsh restoration has occurred recently or is planned.

2. **Key Parcel**:
    - This area was the site of a planned multi-agency restoration project to breach the berm and restore the salt marsh within the interior but the project was ultimately dropped
    - A breach in the northeast corner of the berm was the only place water could enter into the bermed area for a long time, but the southern part of the berm breached during a storm in 2018.
    - Prior to the breach, the inner area had been largely unvegetated (only a small bit of salt marsh had existing in the northeast section where tidal water was able to come in and out). Since the 2018 breach, the interior area has almost entirely re-vegetated over the last 2 years. The western half still has some significant pooling though.
    - A kestrel box has been installed on a pole along path out to the berm.
    - Footings from old WWII radio towers are still visible inside the bermed area
    - It was noted that the homes near the trailhead, as well as those near the Beachmont Yacht Club, flooded during the 2018 storm.

3. **John Joseph Kilmartin Pathway / Short Beach**
    - This area includes one of the largest wooded parcels in the town of Winthrop, with one of the highest tree canopies. Although it’s not vegetated with an ideal tree species assemblage (the property includes a lot of non-natives) it is still an incredibly important wildlife habitat.

- A number of the large aspens near the parking area are starting to die. It's unclear whether this is due to old age, salt water intrusion, or other factors.
- DCR recently restored a ~1 acre meadow on eastern side of the walking path.
- Due to a history of dumping, much of this site is underlain by chunks of concrete, asphalt and other debris. Some of this material is exposed at the overlook location.
- A number of swallow nest boxes are installed out on the salt marsh near the overlook.
- The parking area off Winthrop Ave is owned and maintained by DCR.
- Flooding from Short Beach is a problem. During events with significant storm surge or heavy waves flooding can either go around southern end of concrete seawall or splash over the main portion of the road itself. Storm drains in the road drain back to the ocean, but if sheet flow is heavy enough it continues west across the road, between the houses, and into the upper portions of the marsh.
- At southern end of this parcel there is a boardwalk bridge over tidal creek to the cemetery in Winthrop. At this point, property ownership changes from DCR to Town of Winthrop.

4. **Belle Isle Marsh Marine Ecology Park**
    - This area is owned and managed by the Town of Winthrop. There is now a large parking area at the corner of Morton and Winthrop Streets that provides access to an extensive boardwalk system that connects between the Morton Street Pavilion and the cemetery.
    - The boardwalk was only recently built (after the 2018 storms) and cost approximately ~$1.8-2 million.

5. **Morton Street Pavilion**:
    - This parcel consists of a large wooden pavilion constructed on a ~1.5 acre parcel that is owned by DCR but was leased to the Town of Winthrop for 5 years. The property will revert back to DCR ownership/maintenance next year.
    - All of Morton Street was flooded during the 2018 storms.
    - The area of salt marsh just west of this parcel has degraded significantly to mudflat. Only scattered hummocks of vegetated salt marsh remain.
    - There is some ponding at the upland edge of salt marsh immediately west of the upland parcel even at low tide.

6. **Excel Academy / CVS**:
    - There is a trailhead at back of Excel Academy. The trail is owned/maintained by DCR.
    - This parcel is adjacent to an MBTA railroad maintenance yard.
    - There is a concrete structure at end of trail (and another across the river). These structures mark where the MWRA sewer line runs under the river (on its way to Deer Island).
    - Just upstream of concrete structures there is a series of old wooden bridge piles.
    - Boston Natural Areas Network had previously conducted some restoration activities just north of main trail (along MBTA fence line). They added rip rap to create a path/viewpoint, included interpretive signs, and planted some salt marsh plants. However, much of this was destroyed in the 2018 storms.

7. **Lawn Ave Parcel**:
    - This parcel includes a path out to an elevated overlook platform.
    - The salt marsh surrounding this area has some of the highest salt marsh plant diversity of the entire Belle Isle Marsh system: *Spartina alterniflora, S. patens, Distichlis spicata*, seaside goldenrod, and high tide bush (DCR staff noted that this is the only high tide bush on the site).
    - The thickets in the upland areas are frequently used as long-eared owl roosts in the winter.
    - DCR staff noted that because this is one of the least trafficked portions of the reservation by humans there are lots of wildlife.
    - DCR runs a bird banding station here (mist nets for song birds and baited traps for raptures).
    - From the overlook, large pannes can be seen in the southeastern corner of bermed-in area.
    - High salt marsh area between pannes and the *Phragmites* is where all the salt marsh sparrow nests are built.
    - In 2016, there was a significant horseshoe crab breeding population using the pannes for egg laying.

8. **Sales Creek**:
    - This portion of the water way is not tidal.
    - Occasionally (approximately once in the last decade), there is a significant release of fresh water when heavy rains flood that back area.
    - The water control structure at Bennington Street is owned and managed by DCR.

Some additional general site history was also discussed during the site visit:

- The Reservation was built between 1975 and 1983. The park was designed by Jim Falk.
- The surrounding neighborhoods in Winthrop and Revere contribute stormwater runoff to the marsh. Both have EPA permits.
- At 1141 Bennington St., several parcels of privately owned land and Austin Avenue border the salt marsh. Austin Avenue provides access to the MBTA maintenance yard by an easement; DCR also has an easement to utilize a section of Austin Avenue. In March 2019, a fire destroyed the structures at 1141 Bennington Street. A proposal for housing on this location has been prepared but, as of the date of this memo, has not yet been submitted to the City of Boston. The salt marsh-Austin Avenue interface is characterized by broken fencing, overgrown vegetation, street runoff, and rock and gravel intrusion from occasional work along Austin Avenue. Ongoing illegal dumping occurs into the salt marsh at this location.
- There is currently a significant amount of future development planned for this area. A large HYM development of apartments in Boston and Revere is set to be constructed over the next 10-20 years. The area in Revere is fully permitted and construction has already started. The Boston area is in the last stages of permitting. Together, these apartments will house an additional 60,000 – 70,000 people immediately adjacent to Belle Isle Marsh. The potential impact to the site could be enormous. There are also concerns about the lifetime of those apartments given sea level rise. HYM has only vouched for the site through 2070 with regards to sea level rise and climate change.

The following sections summarize the main findings of previous studies and reports that were reviewed as part of this task.

C. Rumney Marshes ACEC Designation (1998)

The Area of Critical Environmental Concern (ACEC) designation pointed to this area's significance for flood control, prevention of storm damage, protection of land containing shellfish and fisheries, prevention of pollution, protection of wildlife habitat and protection of public water supplies as a reason for listing it as an ACEC. The larger Rumney Marshes ACEC includes both the Saugus and Pines River Estuary and Belle Isle Marsh. The designation further cited the relatively undisturbed nature of these resource areas within an otherwise heavily developed area as clear indication of their value. The landward boundary was defined by the 100-year flood elevation, except where specified otherwise. The Belle Isle Marsh portion of the system includes Belle Isle Creek, the marshes of this system and tributary streams, including Sales Creek.

Criteria for ACEC designation included:

1. Threats to public health through inappropriate use – Salt marshes play an important role in the prevention of flood damage by providing vital flood storage capacity. The loss of this flood storage capacity would have significant implications with regard to public health, safety and welfare.
2. Productivity – These areas contain some of the most productive and extensive salt marsh systems in the greater Boston area, containing salt marsh, tidal flats, and shallow subtidal channels. These areas were described by the U.S. Fish and Wildlife Service as "one of the most biologically significant estuaries in Massachusetts north of Boston."
3. Uniqueness of the area – This relatively undisturbed estuary and marsh complex is quite unique given its close proximity to a major metropolitan center.
4. Imminence of threat to resources – Given the existing developmental pressure along the fringes of these areas, the chronic and cumulative impacts can ultimately have significant adverse impacts on the natural system.

D. Rumney Marshes ACEC – Salt Marsh Restoration Plan (May 2002)

The salt marsh restoration plan was developed to "identify how salt marsh restoration might help address some of the effects of cumulative salt marsh loss - such as, a decline in water quality, loss of flood storage, and decreased habitat for wildlife, fish, and shellfish throughout the ecosystem." In addition to addressing potential restoration actions, this document also included significant background information on the site's history and ACEC designation, existing wildlife, and threats to the site. Information on these topics from this report are summarized below.

<u>ACEC Designation</u>:

The Rumney Marshes Area of Critical Environmental Concern (ACEC) was characterized by the U.S. Fish and Wildlife Service as one of the most biologically significant estuaries in Massachusetts north of Boston. The entire ACEC is 2,634 acres in size and is located in the municipalities of Boston, Revere, Winthrop, Lynn and Saugus. The ACEC is comprised of two marsh systems, Rumney Marsh and Belle Isle Marsh. These two areas are now disconnected but were formally portions of a much larger salt marsh complex. The purpose of the ACEC Program is to identify, designate and preserve critical environmental resource areas, and facilitate and support long-term stewardship.

<u>History</u>:

Rumney Marsh and Belle Isle Marsh, now separated by channelized buried creeks and filled land, were once interconnected by the Chelsea River, Mill Creek, and Sales Creek. In total, the two marsh systems drain an area of approximately 65 square miles. The majority of the uplands and filled wetlands within this region are now heavily developed urban land, which contribute large volumes of polluted run-off and other non-point source pollution to the Belle Isle Marsh watershed. The role of salt marshes in such a landscape is critical for attenuation of peak run-off velocities, water quality improvement, flood storage, and maintenance of fish and wildlife habitat.

Belle Isle Marsh Description:

Belle Isle Marsh is the smaller of the two Rumney Marshes ACEC components and is located approximately 1.5 miles south of Rumney Marsh proper and just north of Logan Airport. The ACEC at Belle Isle Marsh is 359 acres and is located in Boston, Revere and Winthrop. The primary surface water feature in Belle Isle Marsh is Belle Isle Inlet, which travels through the center of the Belle Isle Marsh from Bennington Street to the Saratoga Street Bridge (approximately two miles). The two major tributaries of Belle Isle Inlet are Sales Creek to the west and Short Beach Creek to the east. Sales Creek flows into Belle Isle Inlet from the west side of Bennington Street. Sales Creek formerly connected with the Chelsea River, but the upper portions of this system are is now partially buried and channelized. Remnants of Sales Creek are present within the Suffolk Downs Racetrack and within small portions of remaining creek just north of the track stables. Due to the importance of the hydrologic connections among these remaining sections of Sales Creek to the marsh, the remaining sections of Sales Creek were also included in the ACEC boundary. Wetland types mapped in 1998 in Belle Isle Marsh included 174 acres of salt marsh, 55 acres of tidal flats, 27 acres of other vegetated wetlands, and 6 acres of open water (a total of 262 acres of wetland).

Birds/Wildlife:

Among the mammal species indigenous to the area are raccoon, muskrat, meadow vole, skunk, red fox, and harbor seal[1]. Muskrat and meadow vole reside in the marsh proper with visitors of raccoon, red fox, and opossum. Reptiles and amphibians are limited in the marshes because of the small amount of available habitat and are found mostly on the fringes of the ACEC in the uplands or in freshwater areas.

Fish/Shellfish/Invertebrates:

Like all estuarine systems, Belle Isle Marsh is critical resource areas for both resident and transient fish species. Year-round resident fish species in the salt pannes and creeks of Belle Isle Marsh include mummichogs (*Fundulus heteroclitus*), killifish (*Fundulus spp*.), three-spined sticklebacks (*Gasterosteus aculeatus*), and four-spined sticklebacks (*Apeltes quadracus*). These species play a crucial role in the salt marsh food web. As prey species for larger fish and birds and consumers of detritus, vegetation, and smaller fish, they represent an important link in the maintenance of trophic structure relationships. Soft-shell clam (*Mya arenaria*) and blue mussel (*Mytilus edulis*) are the most common shellfish found within Rumney Marsh and Belle Isle Marsh.

Threats/Impacts:

Both Rumney Marshes and Belle Isle Marsh were once much more extensive. Human impacts to the marshes have included filling, dumping and digging of ditches. Surveys by the Army Corps have determined that approximately 11.5 acres of salt marsh were filled within the ACEC between 1978 and 1989, despite the existence of rigid wetland regulations.

This 2002 Restoration Plan listed the following as threats to the Rumney Marshes ACEC, including Belle Isle Marsh: loss of habitats, increase in invasive plant species and loss of native salt marsh plants, impaired water quality, flooding, increase in mosquitoes, increased risk of fire, and loss of recreational and educational opportunities, open space and scenic quality.

[1] This species list was taken from a 2002 report but underrepresents the suite of mammals presently (2021) utilizing the Reservation; the Belle Isle Marsh Reservation Park Supervisor notes that mink, long-tailed weasel and eastern coyote are also present at the site. Red fox, however, have been extirpated from the park for about a decade.

Grid ditching for mosquito control conducted during the 1930s, attempted to drain water from virtually the entire marsh surface, eliminating salt pannes and small tidal creeks, essential habitat areas for killifish and wading birds. Mosquitoes continued to breed on the moist marsh surface, but killifish were no longer present to consume mosquito larvae, one of their preferred food sources. As a result, mosquito populations increased. Open Marsh Water Management (OMWM) is an innovative technique for mosquito control, which involves the systematic plugging of grid ditches and the re-establishment of salt pannes and small meandering tidal creeks in order to bring killifish back onto the marsh surface. Implementation of OMWM has been extremely effective in both controlling mosquitoes and restoring lost ecological functions to salt marshes. The Northeast Massachusetts Mosquito Control and Wetlands Management District has implemented a number of OMWM projects in Rumney Marsh and Belle Isle Marsh to specifically address continuing mosquito problems.

Other alterations to natural hydrology (e.g., tide gates and crossings of tidal creeks by roads) have also had significant adverse effects on salt marsh wildlife by restricting tidal flow and freshwater run-off and fragmenting formally contiguous marshes.

Extensive areas of former salt marsh are now dominated by invasive plant species, most notably the common reed, *Phragmites australis*. At disturbed sites, common reed frequently forms dense monotypic stands, which can outcompete native species. In addition to its habitat impact, monotypic stands of common reed typically contain several years' worth of dead plant material, both on the ground and standing, which can lead to an increased brush fire risk. The 2002 Salt Marsh Restoration Plan states that in Belle Isle Marsh, previous use of the marsh for dredged material disposal around 1930 created a large *Phragmites* dominated area which can potentially be restored with proper excavation.

<u>Restoration Projects (Implemented and Planned)</u>:
In 1998, the Rumney Marsh Salt Marsh Restoration Task Group compiled a list of potential restoration projects totaling approximately 273 acres of potentially restorable salt marsh. Additionally, between 1993 and 2002, 142 acres of this total salt marsh acreage have been restored within the ACEC at 14 sites. Additional areas of potentially restorable salt marsh have also been identified. The 2002 acreage of potentially restorable salt marsh was estimated to be approximately 131 acres at 16 sites. Highlights from some of the proposed and complete restoration projects are listed below:

> *<u>Proposed Restoration project</u>*: The "Belle Isle Fish Co." project proposed to restored approximately 1.5 acres of salt marsh located off Saratoga Street in Boston behind Osco drug store just west of the Saratoga Street Bridge.
>
> > Site/Project Description: "The Belle Isle Fish Company site (BIFCO) is owned and managed by the City of Boston as publicly accessible conservation land. The site is bounded by Belle Isle Inlet to the east, the MBTA Orient Heights Maintenance Yard on the west, and the MDC's Belle Isle Reservation to the north and south. In the early 1990s, the site was investigated as a potential mitigation area for Central Artery/Tunnel wetland impacts. During the course of this investigation, substantial soil contamination was discovered on-site. Because of this, the site was dropped from consideration for CA/T mitigation. In accordance with the Massachusetts Contingency Plan (MCP), the City of Boston was left with the responsibility of cleaning up the site. Boston's Environment Department and Parks Department have been working jointly since 1998 to develop a site remediation and salt marsh restoration plan for BIFCO. As of February 2002, the city had submitted a Phase III Release Action Plan to DEP and began preparation of construction specifications. The overall project plan involves the removal of approximately 7,000 cubic yards of fill, capping of contaminated hot spots, and restoration of salt marsh in the excavated area and creation of coastal bank and grassland habitat on the capped area. The site will be managed as a

natural area for passive recreation and eventually will be incorporated as a key component of the East Boston Greenway, connecting Saratoga Street to the MDC Reservation. Though not a large salt marsh restoration, the project will provide significant benefits to Belle Isle Inlet by reconnecting large areas of fragmented marsh and helping to improve surface water run-off from the adjacent industrial area. Depending on the availability of funding, construction of the project is scheduled for the winter of 2002-2003."

Completed Restoration project: "Radio Tower Dike/OMWM Area" project located east of Belle Isle Inlet, near Short Beach Creek restored 5 acres of salt marsh. This diked salt marsh was the site of a 5-acre OMWM project completed by the Northeast Massachusetts Mosquito Control and Wetlands Management District in 1993.

Proposed Restoration project: "Sales Creek/Bennington Street" project proposed to restore 6 acres of wetland at the Intersection of Sales Creek and Bennington St.

Site/Project Description: "A standard flapper type tide gate prevents tidal flow from going upstream into Sales Creek, although some leakage may occur at Bennington Street and at a culvert under Route 1A which drains to Chelsea Creek. It may be possible to modify the standard flapper type tide gate at Bennington Street, to include a Self-Regulating Tide Gate to introduce controlled tidal flow to Sales Creek to help control *Phragmites* and improve its ecology, habitat values, and flushing characteristics."

E. Belle Isle Marsh Reservation ACEC & IBA Management Assessment (Jan 2020)

This assessment provides a history of the ownership and use of the Belle Isle Marsh area, as well as a description of the different segments of the site. The Belle Isle Marsh Reservation is a fragmented reservation, requiring a vehicle to get to and access the various satellite areas of the park. This 2020 assessment provides a detailed description of each of the reservation areas and habitats types, as well as documentation of the various fauna that utilize the site. The assessment ends with a summary of some of the historic, ongoing and potential future threats to the marsh (e.g., significant housing developments nearby, off-leash dogs, sea level rise and climate change, etc.). Although the details from this 2020 document are not reproduce here, the information in this document will be drawn from heavily in the development of the Belle Isle Marsh Resource Management Plan.

F. Belle Isle Marsh Water Quality Monitoring Program (1988)

This document was developed as part of developing a water quality monitoring program for Belle Isle Marsh. The goals of the program included:

1. Detect present day water quality problems and any changes in water quality in the future, and
2. Be simple enough to be carried out by non-scientific personnel after training.

Although funding was tight, the program was initiated through a partnership with Mass Audubon and MWRA and was partially funded by a CEIP fund grant. Details of the monitoring program and results from the initial year of implementation are documented below.

Need for Water Quality Monitoring:

Salt marshes used to dominate the coastline from Rowley to Cape Cod, but many of these areas have been developed or turned into dumpsites. Belle Isle Marsh has remained open space, but open space does not guarantee productive space. Coastal ecosystem health is directly related to the quality of water. The salt marsh is an essential place for reproduction and growth of many fish and bird species.

Water Quality Parameters:

The initial year of water quality monitoring included sampling for the following parameters:

1. Salinity – measures the concentration of salt in the water and provides information about how far freshwater extends into the estuary.
2. Dissolved Oxygen – measures the concentration of oxygen in the water. Aquatic organisms require oxygen for respiration. Low dissolved oxygen concentrations reduce benthic species diversity and can have other adverse impacts. Massachusetts state regulations require a minimum of 6mg/L of dissolved oxygen.
3. Turbidity – measures water clarity. High turbidity can limit photosynthesis and can clog the gills of fish and filter feeding organisms.
4. Temperature – Dissolved oxygen concentrations are related to temperature, so it's important to measure both. Elevated temperatures can lead to low dissolved oxygen concentrations and potentially fish kills.
5. Coliform Bacteria – Coliform bacteria are organisms that are indigenous to the digestive tracts of warm-blooded animals. They are used as an indicator of sewage.
6. Biochemical Oxygen Demand – Bacteria degrade organic matter by using up oxygen from the water column. This measurement provides a relative idea of how much organic matter is present in a sample.

In addition, pH was also considered, but equipment was unavailable to measure this.

Sample Sites:

The initial year of sampling included 8 different sampling sites:

A. Sales Creek (Trailer Park)
B. Sales Creek (Cerretani's)
C. Sales Creek (Pumping Station)
D. Bennington Street Bridge
E. Island Bridge
F. MDC Property
G. Saratoga Street Bridge
H. Rosie's Pond

The locations of these sites are shown in Figure 2.

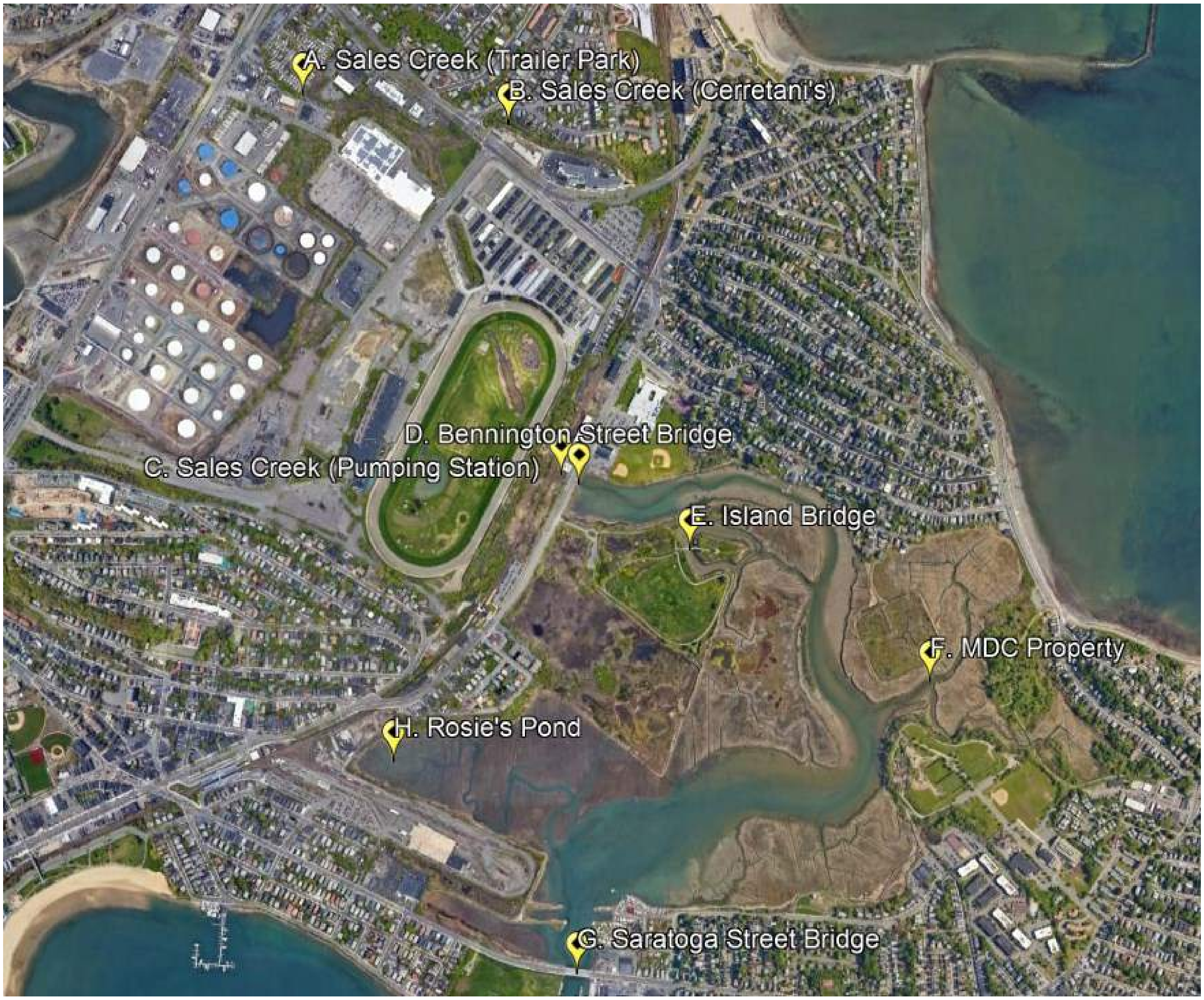

Figure 2. **Map of 1988 water quality sampling stations.**

Monitoring Methods:

All samples were collected within an hour of high tide (in many cases, this is the only time water is available for sampling). The Bennington Street Bridge and the Island Bridge were sampled three times a week. All other sites were sampled once a week. Sampling spanned 11 weeks in 1988.

Results:

The 1988 report concluded that, at the time, there were many water quality problems in Belle Isle Marsh. Quantitative results from the 1988 water quality monitoring are provided in Tables 1 through 4. Additional summaries about the data for each water quality parameter are provided below:

1. Salinity: At high tide, the entire marsh is seawater with salinities consistently between 29 and 31 ppt. However, at low tide, in dry weather conditions, the salinity in many areas of the marsh are greatly reduced. The input of fresh water from Sales Creek is felt deep within the marsh. During wet weather, salinity values are much lower throughout the marsh. This is especially true when the pumping station is

in operation; at these times, a large portion of the marsh becomes freshwater (e.g., salinity at the Island bridge was reduced to 4 ppt).

2. Water clarity: In general, water clarity decreases as water comes in from the harbor and disperses around the marsh. After operation of the pumping station, water clarity was reduced to zero and remained in this condition at most sites in the marsh for several days after.
3. Dissolved oxygen: DO concentrations varied greatly throughout the site, with concentrations decreasing as you move upstream. The lowest DO concentrations were near the pumping station. After wet weather, dissolved oxygen concentrations decreased throughout the marsh. Low dissolved oxygen concentrations are probably responsible for the fish kills experienced within Belle Isle Marsh.
    a. Fish Kills: During the summer of 1988, there were three incidences of extensive fish kills. The first occurred in the isolated pools of water out in the lower marsh during a hot, dry period of weather. These isolated pockets of water heat up and the degradation of organic matter in the pools results in dangerously low oxygen levels. An occurrence like this is natural during hot dry summer conditions. The other two fish kills were higher causes for concern. Both resulted after the operation of the pumping station and significant discharge into the marsh, which had a high organic matter content.
    b. In general, dissolved oxygen decrease after wet weather due to the influx of organic matter (including large amounts of dog waste in the park).
4. Coliform Bacteria: High levels of coliform were found at the Bennington Street sample site at all times, but were higher after wet weather, so much so that they were too high to count, even with a dilution factor of 100. Sales Creek was determined to be the major source of coliform, with the storm drain that empties into this area also contributing varying amounts. Based on further analysis, it was determined that the majority of the problem already exists in Sales Creek before it enters Suffolk Downs (i.e., the source of the high coliform from upstream of Suffolk Downs). Most other sample sites throughout Belle Isle Marsh had coliform levels that fell within the normal range. It appears that Boston Harbor did not significantly contribute to the coliform counts within Belle Isle Marsh.
5. Other Water Quality Issues:
    a. The storm drain that empties into the Bennington Street site has a continuous oil slick associated with it, cause by street runoff. Oil also emanates from the creosote piling on the Island Bridge. Oil and gas also originate from boat use in the estuary.
    b. Aquatic species diversity in the marsh is extremely low. There are several species that should be abundant in the salt marsh, but do not exist there. Fiddler crabs, for instance, are not present in the marsh[2].

<u>Recommendations</u>:

1. Continue water quality monitoring in the long-term
2. Additional environmental chemistry testing for sediments contaminants
3. Compilation of a complete flora and fauna map for the reservation

[2] This is no longer the case. The Belle Isle Marsh Reservation Park Supervisor notes that presently (2021) there are a number of fiddler crab colonies across the Belle Isle Reservation.

Table 1. Summary of 1988 Water Quality Testing Results.

Site	Turbidity (m)	Salinity (ppt)	D.O. (mg/l)	Temperature (C)
Saratoga	2.96	29.73	9.3	13.5
	(2 – 4)	(28 – 31.5)	(7.1 – 11.1)	(9 – 18)
MDC Property	0.52	27.42	5.53	22.17
	(0.5 – 1)	(26 – 30)	(5.1 – 6.9)	(19 – 22)
Island	0.77	27.22	5.32	20.97
	(0 – 1.5)	(4 – 31)	(3.5 – 7.1)	(17 – 24)
Bennington	0.44	26.56	3.72	22.34
	(0 – 1)	(0 – 31)	(2.3 – 5.7)	(16.5 – 28)
Osco	--	10	4.16	29.5
		(1 – 20)	(1.9 – 7.1)	(24 – 37)
Rosies	--	27.8	5.98	25.6
		(20 – 32)	(4.0 – 9.8)	(21 – 28)

Unshaded cells represent the mean value; shaded cells represent the range.

Table 2. Mean total and fecal coliform counts from 1988 testing.

Site	Total Coliform Count (cells/100ml; mean)	Total Coliform Count (cells/100ml; range)	Fecal Coliform Count
Bennington Street	53,314	(3,400 – TNTC)	TNTC
Storm Drain	5,886	(1,700 - 13,000)	1,100
Island Bridge	20,800	(1,300 – 110,000)	7,000
MDC Property	7,287	(0 – 40,000)	--
Sales Creek	62,267	(2,600 – TNTC)	TNTC
Rosie's Pond	5,590	(20 – 18,000)	--
Saratoga Street	2,575	(160 – 10,000)	0
Carratani's	75,000	(n=1)	--
Trailer Park	13,000	(n=1)	700
Bennington Street (immediately after pumping station was put into operation)	TNTC		

TNTC = Too numerous to count, minimum value would be 200,0000

Table 3. Water quality conditions at Bennington Street before and after operation of pumping station from 1988 sampling.

	Turbidity (m)	D.O. (mg/l)	Salinity (ppt)	Coliform (cells/100ml)
Before	0.25	2.8	27	25,000
After	0	2.3	0	TNTC

Table 4. **Biochemical oxygen demand taken from Sales Creek and Belle Isle Marsh from the 1988 sampling.**

Site	Reading (mg/l)
Sales Creek 1 (Cerretani's)	8.3
Sales Creek 2 (Trailer Park)	9.1
Pumping Station	8.5
Bennington Street Storm Drain	4.6
Storm Drain 2*	6.0

*This site empties into the inlet approximately 500 feet down from the Sales Creek input; it is runoff from several baseball fields and a playground.

G. Belle Isle Marsh Restoration – Environmental and Engineering Evaluations (August 1991)

This document proposed a restoration plan to increase the amount of salt marsh and vegetation diversity within the bermed area of Belle Isle Marsh and to reduce the amount of *Phragmites*. An area of approximately 25 acres has been altered through the construction of a bermed dredged material disposal site, which is believed to have occurred in the 1930s. This berm eliminated tidal flooding to the area behind it, but a series of subsequent breaches have resulted in reclamation of approximately 10 acres of salt marsh and salt marsh mixed with low *Phragmites*.

As part of the settlement of the federal lawsuit against the Commonwealth of Massachusetts over the pollution of Boston Harbor, funds were placed in the Massachusetts Bays Environmental Trust. The agreement specified that $100,000 should be used for the Belle Isle Marsh cleanup, restoration, or study of the sublethal effects of contaminants on the marsh flora and fauna. A working group convened in 1989 to determine how to best utilize these funds to benefit Belle Isle Marsh. The recommendation of this working group was to focus on restoring the area behind the berm.

<u>Vegetation Mapping</u>: Vegetation across Belle Isle Marsh was mapped and described in 9 main sections. The majority of Belle Isle Marsh was high marsh, which extends roughly from mean high water (MHW) to the level of the highest spring tides. On the high marsh, salt meadow grass (*Spartina patens*) is dominant and spike grass (*Distichilis spicata*) is second most dominant. Large areas of high marsh are also dominated by short salt marsh cordgrass (*Spartina alterniflora*). Low marsh areas were dominated by tall salt marsh cordgrass. The largest area of *Phragmites* is located behind the berm adjacent to Belle Isle Park. Baseline vegetation surveys were conducted by Mass Audubon (North Shore) to describe the existing plant community and set up a series of permanent transects so that changes in plant community could be documented over time. Data was collected on species composition, relative frequency, relative cover, and relative importance for each species.

<u>Benthic Surveys</u>: Baseline surveys of benthic fauna were also conducted by Mass Audubon. Benthic samples were taken from ten station in Belle Isle Marsh in August 1990. Samples taken from the main channels and the ditches found oligochaetes and the polychaete, *Streblospio benedictii*, to be the dominant taxa, accounting for 89-93% of all individuals found in those locations. The dominance of these two taxa is characteristic of the intertidal fauna in Boston Harbor. Samples from the salt pannes found a reduced number of organisms.

<u>Fish Surveys</u>: Fish data were collected using steel minnow traps and seines. Data indicated that the most abundant fish in the mosquito ditches were mummichogs (*Fundulus heteroclitus*). Other fish observed included three- and four-spined sticklebacks, striped killifish, and juvenile eels. Winter flounder are also commonly caught by recreational fishermen in the inlet.

General Tide Information: The maximum predicted astronomical high water at the NOAA gauge in Boston Harbor was 12 feet mean low water (MLW), the mean spring high water level was 10.3 feet MLW, and the mean high water level was 9.5 feet MLW. Actual tides within Belle Isle Marsh were not measured but were most likely less than these maximums due to the restriction at Saratoga Street. Behind the berm near existing openings, based on the presence of salt marsh vegetation, evidence of tidal flooding is present up to elevation 11.8 MLW.

Proposed Restoration Alternatives (for area behind berm): This report suggestioned 3 alternatives for restoring tidal flooding to the bermed area:

1. Partial or complete removal of the berm;
2. Construction of channels through the berm and on the surface of the bermed area; and
3. Complete removal of the berm and grading the marsh surface to the level of pre-existing salt marsh.

All options would improve hydraulic conveyance and tidal circulation, but Option 2 was selected as the preferred alternative due to the effectiveness and cost constraints of the other two options.

Historical and Archaeological Resources: This document included an assessment from Thomas Mahlstedt, who was Chief Archaeologist for the Metropolitan District Commission at the time, regarding potential historical resources within the proposed restoration area. The assessment assumed that fall harvesting of salt marsh hay continued at Belle Isle Marsh throughout the 18th and 19th centuries. The only possible, although highly unlikely, historic period archaeological remains would be evidence of the hay harvesting activities. Remains of the wooden post structures, known as staddles, which held the marsh hay until the marsh and estuary frozen enough to cart the hay to the local markets, may exist in the marshland or may have been buried by the landfill. Even if buried, they are likely to have been crushed by the weight of the overburden, so they would not retain a high degree of integrity.

Mahlstedt's assessment also described how Belle Isle Park is not a natural landform. A refuse dump was created in the vicinity in the 1920s when Breed's Isle, as it was still called by some, was selected to relieve Boston's growing waste problem. At that time, the wetlands were systematically filled. Based on cores, it appears that much of what was placed in this area is likely to be disposed earthen fill, perhaps from nearby dredging, rather than refuse.

Suffolk Downs Racetrack was built in 1935 on the landfill. The MBTA blue line trolley and Bennington Street were also built on the landfill. East of the road the Suffolk Downs Drive-in Theatre was built on the fill in the 1950s. After it was closed in 1971, the former theater property was abused and used as a general dumping ground. The Friends of Belle Isle Marsh lobbied to have this area preserved as open space, and ultimately the land was purchased by MDC in the 1980s. In 1986, extensive landscaping was conducted on the former drive-in site. Deep trenches were excavated from the fill to create the island-like configuration that is present today. The spoil from this dredging was placed over the drive-in site and contoured and graded to create a rolling hill meadow aesthetic. The spoil was then capped with a membrane of impervious PVC plastic, over which loam was spread, graded and planted. Benches, winding walkways, a small parking area, signs and an observation tower completed the development of the park.

Although Mahlstedt could not confirm the presence or absence of archaeological (prehistoric) resources, he noted that the survival of prehistorical archaeological remains has been found in similar nearby settings, and are therefore possible at this site.

H. Belle Isle Marsh Reservation – Preliminary Research and Master Plan Phase – Feasibility Study (1978)

This document summarized the results of an initial investigation into the feasibility of constructing the "Master Park Concept". The report concluded that the overall concept was feasible. The initial Master Plan Concept included the following:

1. Passive recreation
2. Altering the flat landscape of the old Suffolk Downs Drive-In Theater facility to create more natural, rolling terrain
3. Formation of an island connected by bridges
4. Reduce the existing concrete driveway and add stone dust walking trails
5. A fishing pier near Belle Isle Inlet
6. A small park structure for public toilets and park management staff
7. A lookout tower
8. Parking for approximately 50 cars
9. A general inventory of existing plant species, and a determination of which undesirable species should be removed; replanting with desired species where necessary
10. Park furnishing and other appurtenances.

Plan L2, included with the study, has a full depiction of the initial Master Plan Concept; while Plan L10 presents the revised Master Plan Concept that could be constructed with a more reasonable budget (and appears to largely match what is in place today). The revised plan included only a single bridge to the created island, and a reduced network of roads and paths. In addition, the proposed fishing pier and toilet facility were removed from the plan.

At the time, existing conditions included significant debris around the site, which had been used as an unsanctioned dumping ground since the closure of the drive-in, and areas of burned marsh. The old theater area and parking lot were located on filled materials. This area was surrounded by relatively undisturbed tidal marsh. Even in the 1970s, there was an area of significant *Phragmites* to the north, between the parking area and Bennington Street, which had been cut off from tidal flushing. The vegetation survey conducted during the feasibility assessment found no endangered or rare plants or animals on the site.

A subsurface soil evaluation was also conducted. The findings showed that there was a layer of anthropogenically placed fill, underlain by a stratum of naturally occurring soft organic soils, which is further underlain by a deep deposit of sand and clay. Given this subsurface material, the report provided the following recommendations:

- All permanent structures requiring good vertical alignment (e.g., bridges, piers, observation towers, etc.) should be pile supported;
- The deep tidal channels should have slopes no steeper than 4H:1V; and
- Future settlement should be considered in areas where sites grades are to be raised.

The report also included an analysis of the Belle Isle Inlet at Saratoga Street. Serious shoaling conditions in this tidal waterway were experienced in the past. The report mentions that dredging had been considered in the past (but not performed) and noted that the clam beds in this area would suffer from a major dredging operation.

I. Sales Creek Information from Beals & Thomas

Although DCR does not own or manage land around Sales Creek, because this waterbody flows directly into Belle Isle Marsh and is part of the ACEC, the project team reached out to the property owners of that site to see if they (or their consultants) would be willing to share existing conditions information regarding the wetlands and topography of the Sales Creek System. A wetland scientist from Beals & Thomas provided the following information:

1. Wetland delineations for the Sales Creek system
2. Invasive species inventories and maps for the Sales Creek system
3. Site photos showing the existing conditions of Sales Creek
4. Topographic data for the Sales Creek area

Reference Information on Above Sources:

Rumney Marshes ACEC Designation (1998):

EOEA. 1998. *Designation of Portions of the Cities of Boston, Lynn, and Revere, and the Towns of Saugus and Winthrop as the Rumney Marshes Area of Critical Environmental Concern with Supporting Findings*. Signed by James S. Hoyte, Secretary of Environmental Affairs, Massachusetts Executive Office of Environmental Affairs, August 22, 1988.

Rumney Marshes ACEC – Salt Marsh Restoration Plan (May 2002)

MWRP and MDEM. 2002. *Rumney Marshes Area of Critical Environmental Concern Salt Marsh Restoration Plan*. Prepared by Massachusetts Restoration Program and Massachusetts Department of Environmental Management on behalf of the Rumney Marshes ACEC Salt Marsh Restoration Task Group. May 2002.

Belle Isle Marsh Reservation ACEC & IBA Management Assessment (Jan 2020)

Riley, S. 2020. *Belle Isle Marsh Reservation Area of Critical Environmental Concern & Important Bird Area Management Assessment*. January 2020.

Belle Isle Marsh Water Quality Monitoring Program (1988)

Colarusso. 1998. *Belle Isle Marsh Reservation Water Quality Monitoring Program*. Submitted by Philip Colarusso, August 15, 1988.

Belle Isle Marsh Restoration – Environmental and Engineering Evaluations (August 1991)

USACE. 1991. *Belle Isle Marsh Restoration Environmental and Engineering Evaluations*. Prepared for Commonwealth of Massachusetts Executive Office of Environmental Affairs by New England Division U.S. Army Corps of Engineers funded by Massachusetts Environmental Trust. August 1991.

Belle Isle Marsh Reservation – Preliminary Research and Master Plan Phase – Feasibility Study (1978)

Moriece and Gary, Inc. Landscape Architects. 1978. Belle Isle Marsh Reservation – Preliminary Research and Master Plan Phase – Feasibility Study. Prepared for Commonwealth of Massachusetts Metropolitan District Commission. May 26, 1978.

Appendix B: Belle Isle Marsh Climate Vulnerability Assessment – Task 2.3 Future Conditions

MEMORANDUM

DATE June 29, 2022 **JOB NO.** 2020-0076-01

TO Catherine Pedemonti
Mystic River Watershed Association
20 Academy Street, Suite 306
Arlington, MA 02476

FROM Conor Ofsthun, Grace Medley
Woods Hole Group, Inc.

Belle Isle Marsh – Climate Vulnerability Assessment – MVP Task 2.3 Future Conditions

1.0 Introduction

This Technical Memorandum is prepared for the Town of Winthrop and Mystic River Watershed Association (MyRWA) in support of the FY22 Municipal Vulnerability Preparedness grant titled "Belle Isle Marsh – Climate Vulnerability Assessment." Belle Isle Marsh is threatened presently by several anthropogenic and environmental stressors. Climate change protections are anticipated to amplify such vulnerabilities, primarily due to coastal storms and sea level rise (SLR). The Climate Vulnerability Assessment aims to evaluate the current and future vulnerabilities of Belle Isle Marsh and the surrounding communities to flood risk, leading towards the development of mutually beneficial nature-based solutions (NBS) to protect the marsh and surrounding communities in the face of SLR and storms. This memo evaluates and documents the present and projected future flood risk of Belle Isle Marsh and surrounding communities. This is followed by the identification of flood pathways and vulnerable reaches to help prioritize areas for adaptation.

This memo will focus on the region threatened by coastal storm-related flooding by way of Belle Isle Marsh, namely the Cities of Boston, Revere, and the Town of Winthrop (Figure 1). Belle Isle Marsh is an extensive open space, and therefore this project is primarily focused on the boundary between the marsh and development. The mean higher high water (MHHW) line, representing the average elevation of the higher high-water mark occurring on each tidal day over an 18-year period, is provided in the below graphic. This serves as an approximation of the marsh-development boundary. Surrounding Belle Isle Marsh is a mixture of local, state, and private land. Flood risk does not recognize jurisdictional boundaries; cross-jurisdictional coordination and implementation will be key drivers of successful adaptation planning.

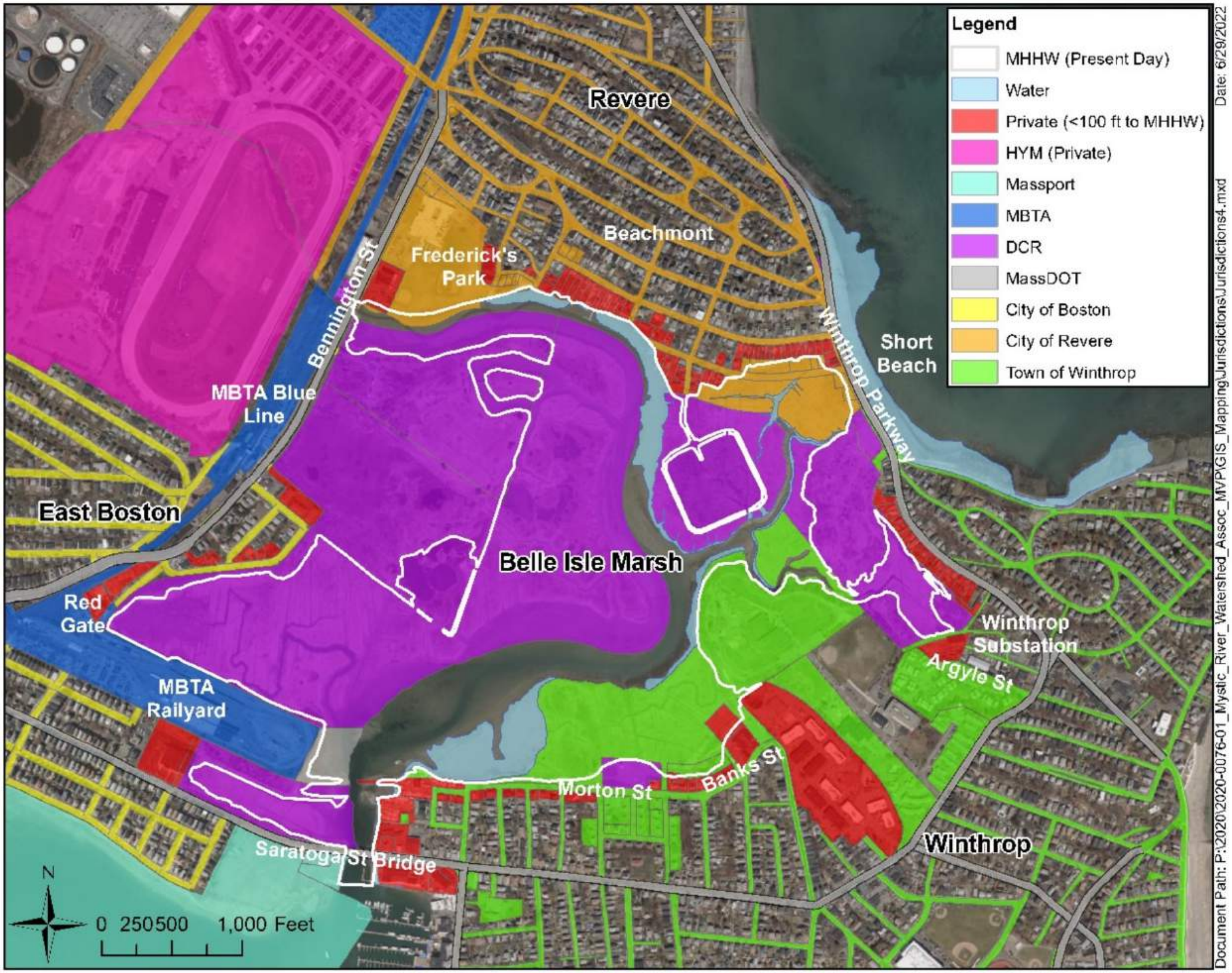

Figure 1. Belle Isle Marsh MHHW shoreline, public land, and private parcels within 100 ft of the MHHW.

2.0 Sea Level Rise and Storm Modeling

To evaluate flood risk from sea level rise and coastal storms, this analysis relied on the latest probabilistic sea level rise hazard maps derived from the Massachusetts Coast Flood Risk Model (MC-FRM). The MC-FRM was developed by Woods Hole Group to assess the potential impacts of climate-related coastal flooding on transportation infrastructure in coastal Massachusetts (MassDOT & FHWA, 2015; Bosma, 2021). MC-FRM has been and is currently being used for numerous coastal planning and design projects throughout Massachusetts and is recommended by the Commonwealth of Massachusetts *Climate Resilience Design Standards* tool (https://resilientma.mass.gov/rmat_home/designstandards/) as the basis for resilient coastal design. The model integrates the latest sea level rise projections developed specifically for the Commonwealth of Massachusetts, large coastal hydrodynamic and atmospheric datasets (winds, waves, surge) of historical coastal storms (hurricanes, tropical storms, nor'easters) that have affected the region, and state-of-the-science projections for future storm intensification and frequency. Using this information to simulate the spectrum of hydrodynamic processes, the model projects the coastal flood risk at a high-resolution spatial scale throughout the Commonwealth of Massachusetts. This is accomplished by simulating thousands of probabilistic storm scenarios under current and future time horizons. Note that MC-FRM does not incorporate stormwater runoff or piped stormwater infrastructure.

The SLR inputs for MC-FRM are derived from the Massachusetts-specific probabilistic projections downscaled from global climate models (DeConto and Kopp, 2017). These local projections incorporated the best available information on the impacts of a range of greenhouse gas emissions, ocean thermal expansion, and ice sheet melt, and provide a range of sea level rise scenarios based on these parameters. From among four scenarios (Intermediate, Intermediate-High, High, Extreme), the State selected the High scenario for planning purposes in Massachusetts. Flood levels derived from the High scenario are conservative and are considered appropriate for application where there is a low tolerance for risk. The High scenario projections are very unlikely to underpredict SLR across a spectrum of potential greenhouse gas emissions scenarios that do not meet the targets of the Paris Agreement (both rising or slowly declining scenarios) even when accounting for contributions from ice sheet melt. The High scenario used in MC-FRM projects mean sea level in Boston to be no more than 1.3 feet above the 2008 baseline (updated 1999-2017 tidal epoch) by 2030, no more than 2.5 feet above the baseline by 2050, and no more than 4.3 feet above the baseline by 2070. The extreme (maximum physically plausible) scenario was not considered in the model (Figure 2).

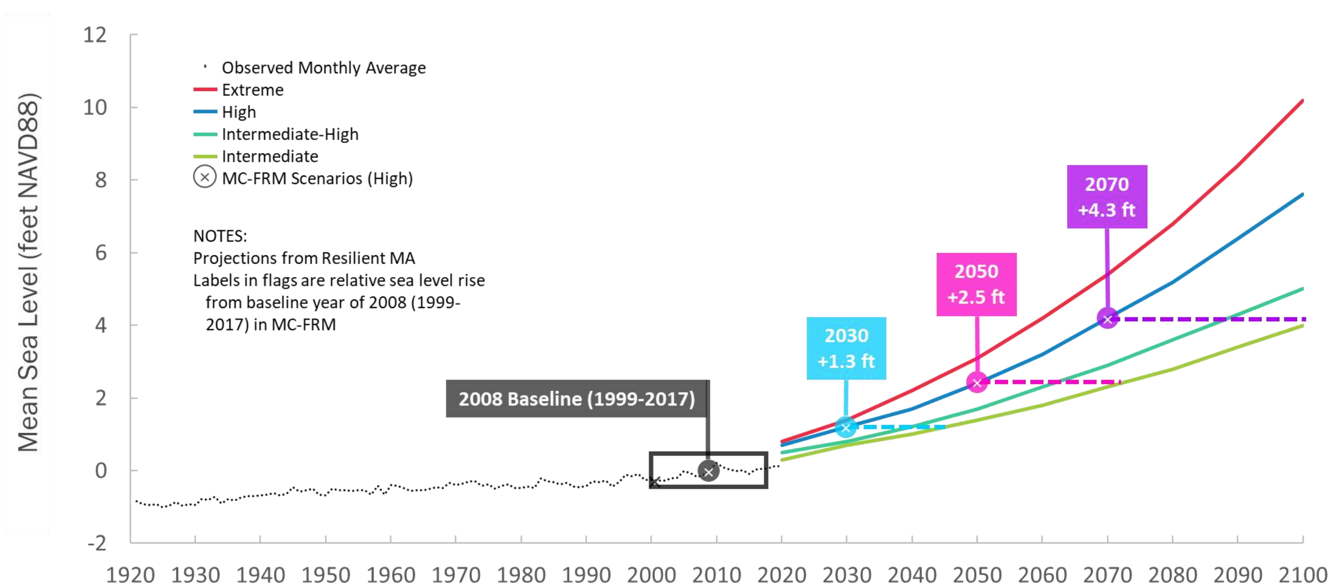

Figure 2. Observed relative mean sea level (ft NAVD88) and State projections for Boston Harbor tide gauge.

3.0 Flood Risk Hazards

To assess flood risk of Belle Isle Marsh and the surrounding communities of Boston, Revere, and Winthrop, site-specific MC-FRM results were extracted and processed to develop GIS-based maps. The probability of inundation during storms was mapped for present day, 2030, 2050, and 2070 planning horizons, as depicted in Figure 6, Figure 7, Figure 8, and Figure 9, respectively. These maps present coastal storm flood risk as a percent annual chance of occurrence. These include the high (100% annual chance or 1-year recurrence), moderate (>10% annual chance or 10-year recurrence), and low (>1% annual chance or 100-year recurrence) probability of coastal storm-related flood risk for each time horizon. Key results highlighting marsh and community coastal flood risk are summarized by planning horizon below. An in-depth analysis into marsh migration and SLR impacts on Belle Isle Marsh habitat has been prepared as a component of the on-going parallel project managed by MyRWA, and is appended as Appendix A. Additionally, no quantitative breakdown of flood risk to assets and infrastructure is provided, as this analysis is more focused on the boundary between the marsh and communities. For such details, see municipality led assessments of flood risk, as referenced in the Task 2.2 literature review memo.

<u>Present Day – 0.0 ft SLR</u>

Present day flood hazards are primarily experienced during severe coastal storm events such as the January 4th and March 2-4th, 2018. These nor'easters featured high water levels in Belle Isle Marsh and flooding in the surrounding communities (Lombard et al, 2021). The National Oceanic and Atmospheric Administration (NOAA) tide gauge in Boston Harbor recorded the highest total water level on record of 9.66 ft during the January 2018 event, equating to approximately a 2% annual chance event. Similarly, the tide gauge recorded the third highest total water level on record of 9.16 ft during the March 2018 event. Such events present a risk to low-lying communities including residential neighborhoods along Morton St/Banks St in Winthrop (Figure 3), Bennington St in East Boston and Revere, the Beachmont neighborhood of Revere (Figure 4), and Winthrop Parkway along Short Beach in Revere and Winthrop (Figure 5). Despite such vulnerabilities to the communities, the habitat of Belle Isle Marsh remains generally resilient to storm impacts. Marsh vegetation is well-equipped to manage infrequent storm surge events. However, the timing of storm events can affect wildlife, such as during the spring nesting season of saltmarsh sparrows. It has been observed that a storm surge event can disturb the saltmarsh sparrow nests and eggs in high marsh areas, harming reproductive success rates.

Figure 3. Flooding of Morton St in Winthrop during January 4th, 2018 nor'easter. Source: Boston.com (left) and Winthrop, 2018 (right).

Figure 4. Flood waters from both Belle Isle Marsh and the Winthrop Parkway impact the Beachmont neighborhood during the January 4th, 2018 nor'easter. Source: WBUR, image sourced from a video courtesy of Sandra Castellarin and Christine LaVigueur.

Figure 5. Wave overtopping and flooding of the Winthrop Parkway during the March 2018 nor'easter. Source: WBUR, photo courtesy of Sandra Castellarin.

2030 – 1.3 ft SLR

Under 2030 storm scenarios, flood risk extends deeper into all surrounding communities. Critically vulnerable areas include the three main thoroughfares which serve as emergency evacuation routes: Bennington St, Winthrop Parkway, and Saratoga St. These three roadways may all experience flooding during a 10% annual chance event, limiting access for citizens and emergency responders to East Boston, Revere, and especially Winthrop, which could temporarily lose access to the only two roadways connecting the town to adjacent areas. Along Bennington St, Fredericks Park and the Revere Public Schools are seen as a low-lying area which is projected to experience a wide extent of flooding, temporarily closing schools, and likely causing damage to public infrastructure. Certain residential communities adjacent to the marsh will experience more frequent and possibly more damaging high-water events under future time horizons. Under a 1% annual chance event, it is important to note that flood waters may be able to overtop Belle Isle Marsh by the MBTA railyard, Rosie's Pond, and the former site of the Casket Company (i.e., Red Gate Property). This area represents a major threat to East Boston, because once sufficiently overtopped the topography causes flood waters to travel downhill into a much wider area in the community.

The marsh is anticipated to continue to weather storm events, however high tide events will increasingly encroach on low elevation areas. The L-Berm, which impedes most tidal penetration to the upland Belle Isle Marsh Reservation Park, is anticipated to be partially to completely overtopped during a spring high tide in 2030. However, the frequency of this overtopping is low, and is not anticipated to have short-term effects on the established habitat types. With sea level rise, there is a relative increase in the salinity of the salt marsh as more saline ocean water is introduced farther into the system during higher tides. Additionally, groundwater levels are anticipated to rise alongside SLR, further impacting vegetation and infrastructure (e.g., basements).

2050 – 2.5 ft SLR

Under 2050 storm scenarios, flood risk begins to increase dramatically. Storms that are statistically predicted to occur annually are projected to overtop very large areas in Revere's Beachmont neighborhood and Winthrop's Morton St/Banks St neighborhood. Furthermore, annual chance flooding is projected to impact the critical assets and infrastructure of Bennington St, Revere Public Schools, Winthrop Parkway, and Saratoga St bridge. The MBTA maintenance railyard is projected to be almost entirely inundated under a 10% annual chance storm. Flooding of East Boston across the MBTA railyard and Red Gate property increases in likelihood from a 1% annual chance storm in 2030 to a 10% annual chance storm in 2050. A new flood pathway appears under the 100% annual chance storm north across Bennington St and the Revere Public schools impacting areas farther into Revere's residential and industrial areas. Large areas of East Boston and Revere are projected to be flanked from several directions such as Constitution Beach, Chelsea Creek, and Revere Beach in addition to storm surge overtopping of Belle Isle Marsh.

The Winthrop Parkway is projected to be overtopped annually under the 2050 SLR scenario. The wide extent and frequency of this overtopping will not only affect the public, but will likely begin to impact the function of Belle Isle Marsh habitat in this area. Overtopping events may carry large volumes of sand and cobble which would deposit on the low marsh platform and disturb habitat. It is possible that habitat types may convert, such as from low marsh to high or transitional marsh, or even from low marsh to a sandy overwash area, more comparable to a dune system than a salt marsh. Spring high tide flooding is anticipated to begin encroaching on transitional marsh and upland areas in Winthrop and Revere. Flood depths will increase by a couple of feet and marsh habitat will be inundated for a longer period of time each day. Steep slopes at the boundary between Boston and Belle Isle Marsh prevent high tide from flooding from extending into upland areas on a daily basis.

2070 – 4.3 ft SLR

Under 2070 storm scenarios, every foot of boundary between Belle Isle Marsh and inland development is anticipated to be inundated by the annual (100%) chance storm event. This represents flooding across over 4.5 miles of salt marsh coastline. Flooding impacts are severe, and are anticipated to disrupt the normal functioning of major assets and entire communities. Previously discussed vulnerabilities are worsened, as the MBTA railyard, Blue Line, Bennington St, Revere Public Schools, Winthrop Parkway, and Saratoga St Bridge are all projected to flood at least annually if no adaptive measures are taken. Flooding simultaneously is anticipated to converge on communities from Constitution Beach, Chelsea Creek, and Revere Beach (Figure 10). New vulnerabilities develop, such as the projected flooding of Winthrop's electrical substation by Argyle St and Bayou St under a 10% chance storm. Unless adaptation efforts are made, previously vulnerable and newly vulnerable residential areas will be impacted to the point of possibly becoming uninhabitable. Furthermore, spring tidal flooding is anticipated to inundate the existing marsh and many upland areas of all three adjacent municipalities. Belle Isle Marsh habitat will be severely impacted by the increased frequency and depth of tidal flooding, and is expected to experience habitat conversion as the marsh wants to naturally migrate inland and upland with SLR. However, under existing development conditions, marsh migration is not anticipated to occur successfully due to the near immediate presence of developed, impervious surfaces adjacent to the marsh. Open space areas such as the Belle Isle Marsh Reservation park, Fredericks Park, and the cemetery in Winthrop may serve future marsh habitat.

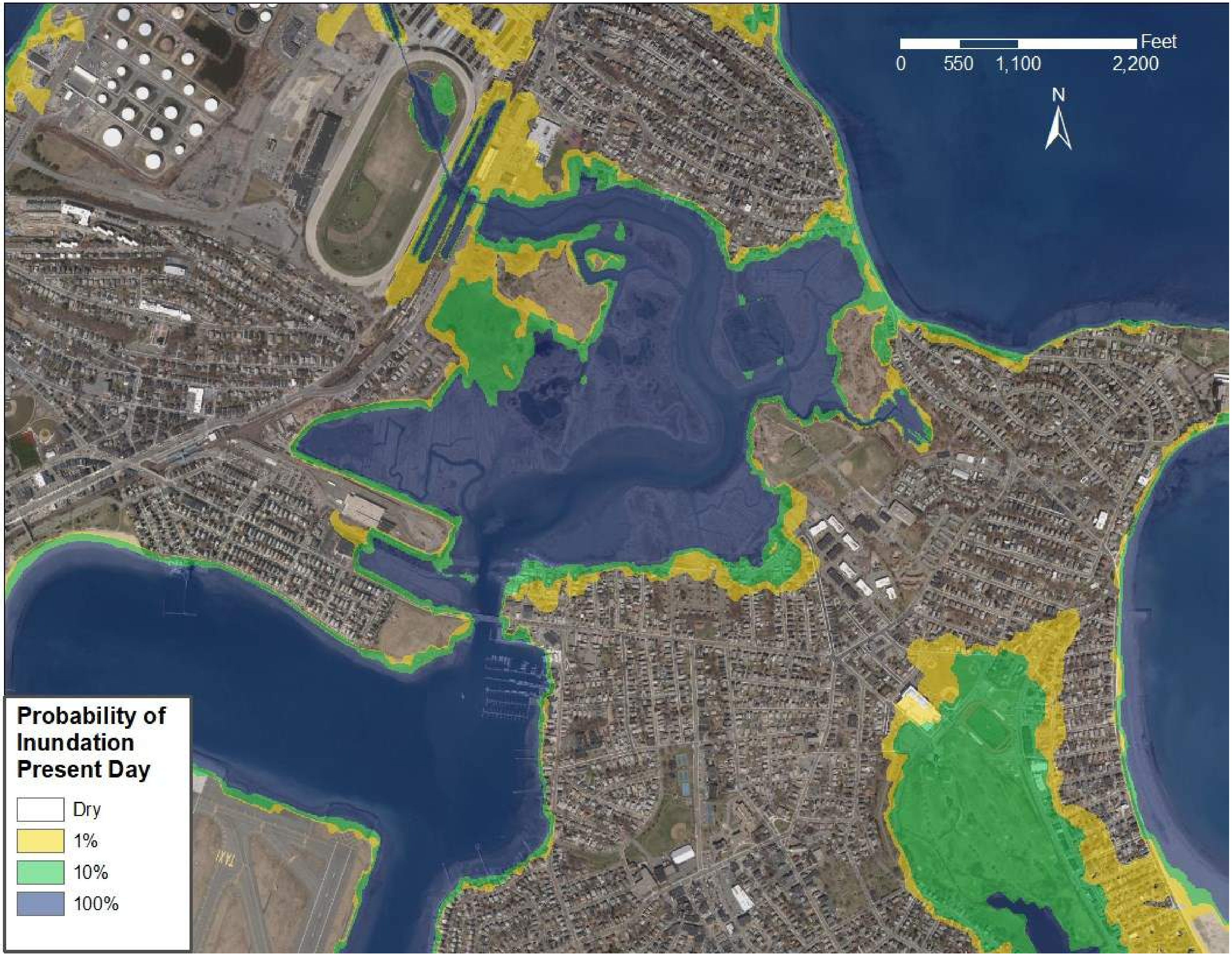

Figure 6. Annual chance flood extent of Belle Isle Marsh and the surrounding communities – Present Day

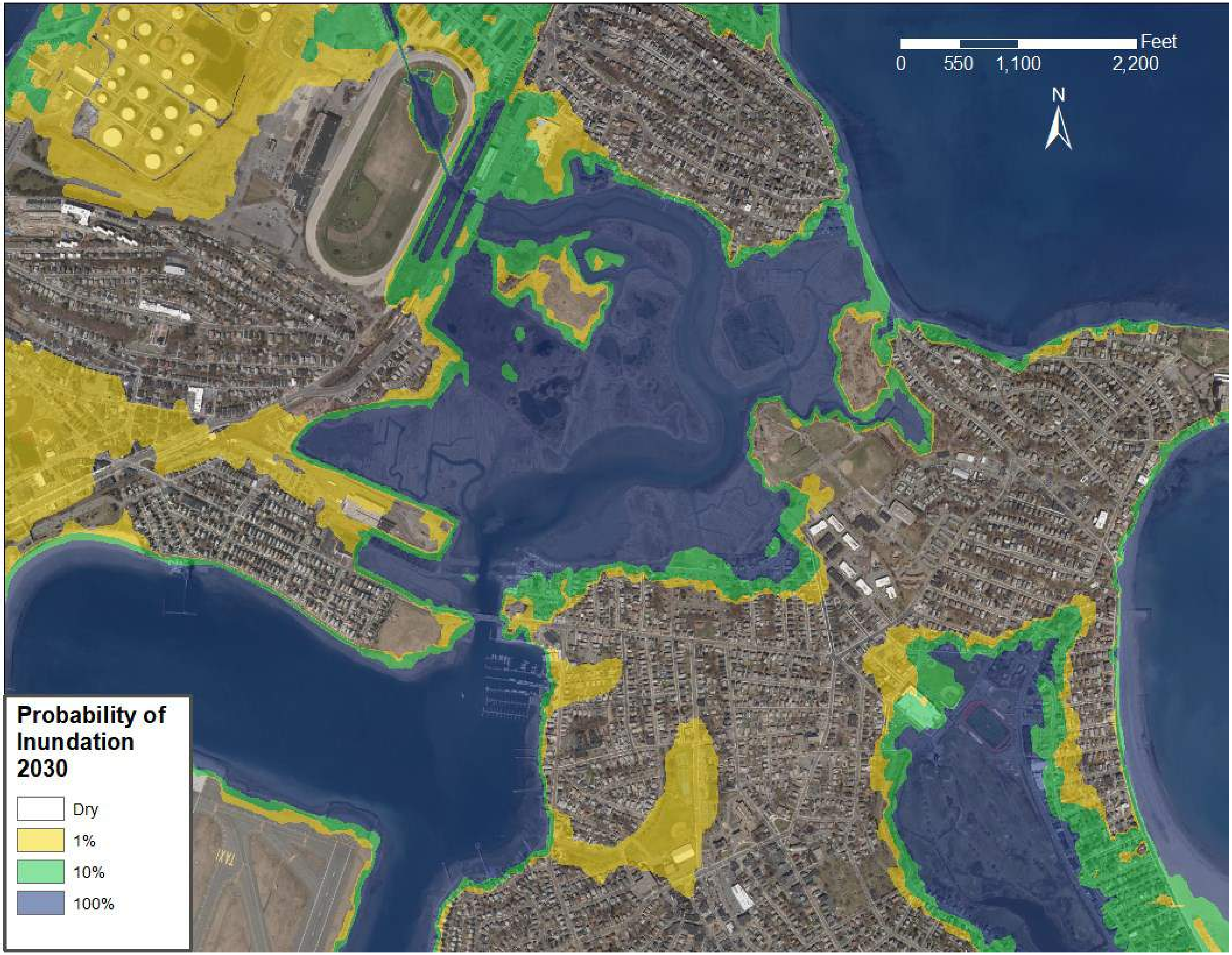

Figure 7. Annual chance flood extent of Belle Isle Marsh and the surrounding communities – 2030

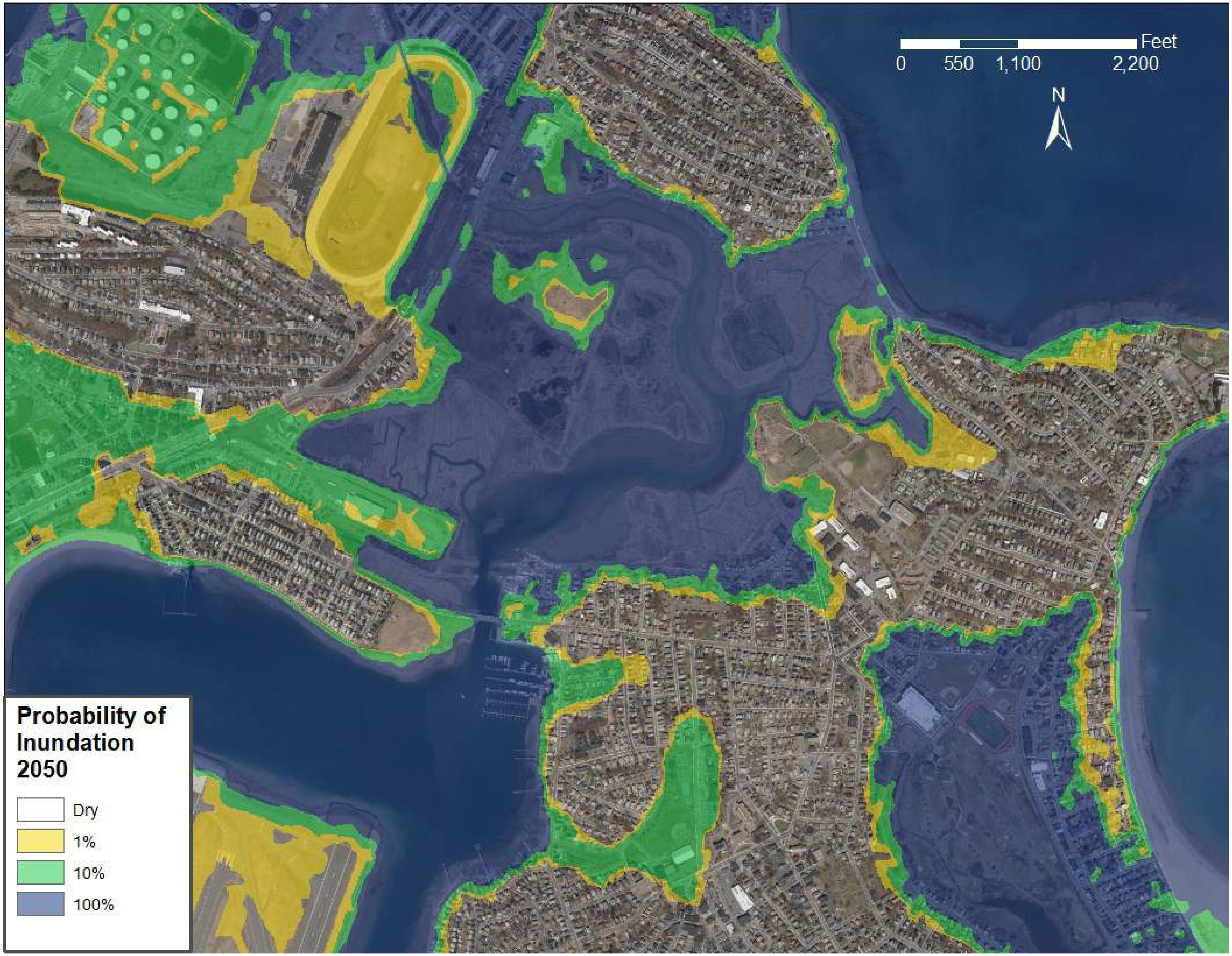

Figure 8. Annual chance flood extent of Belle Isle Marsh and the surrounding communities – 2050

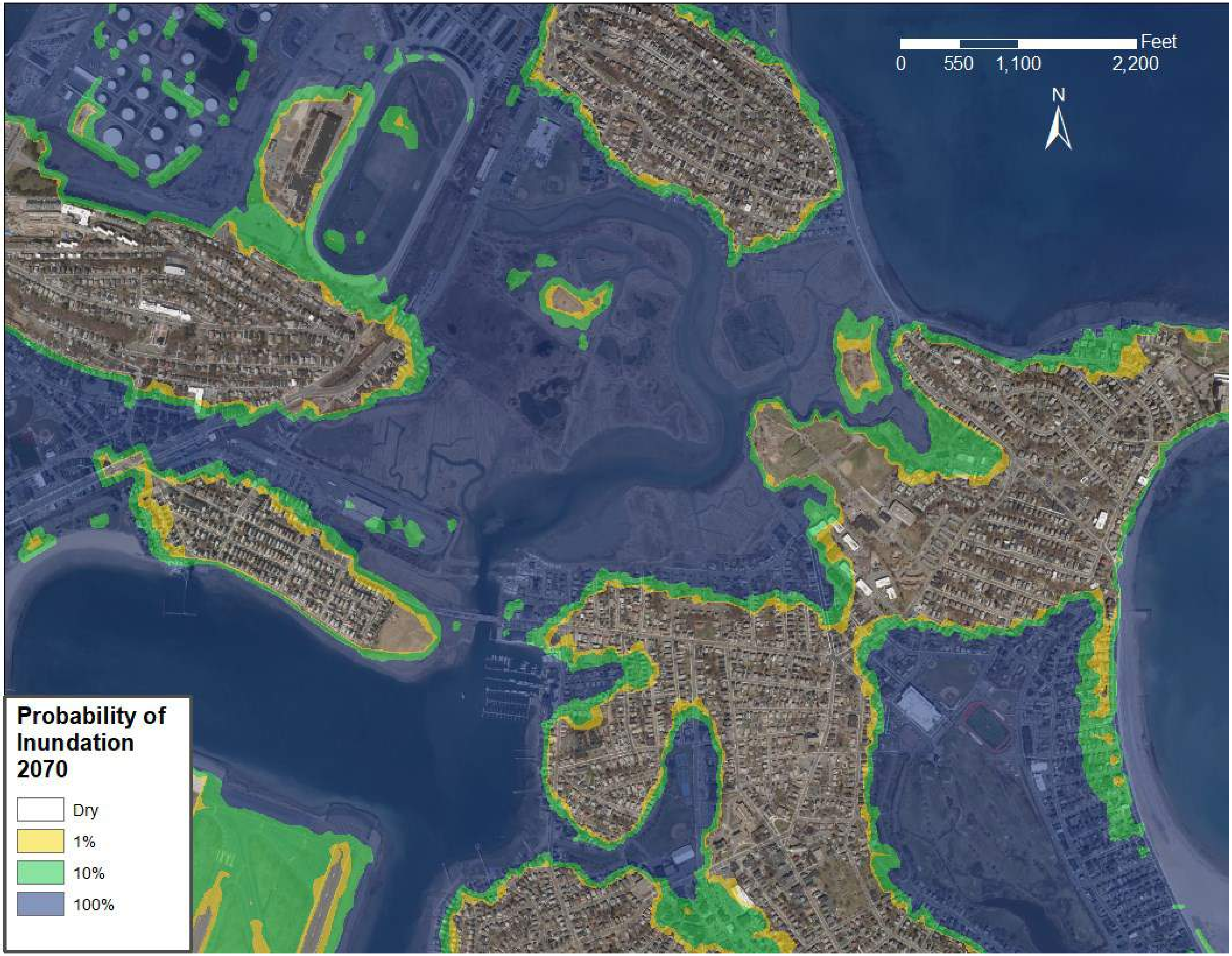

Figure 9. Annual chance flood extent of Belle Isle Marsh and the surrounding communities – 2070

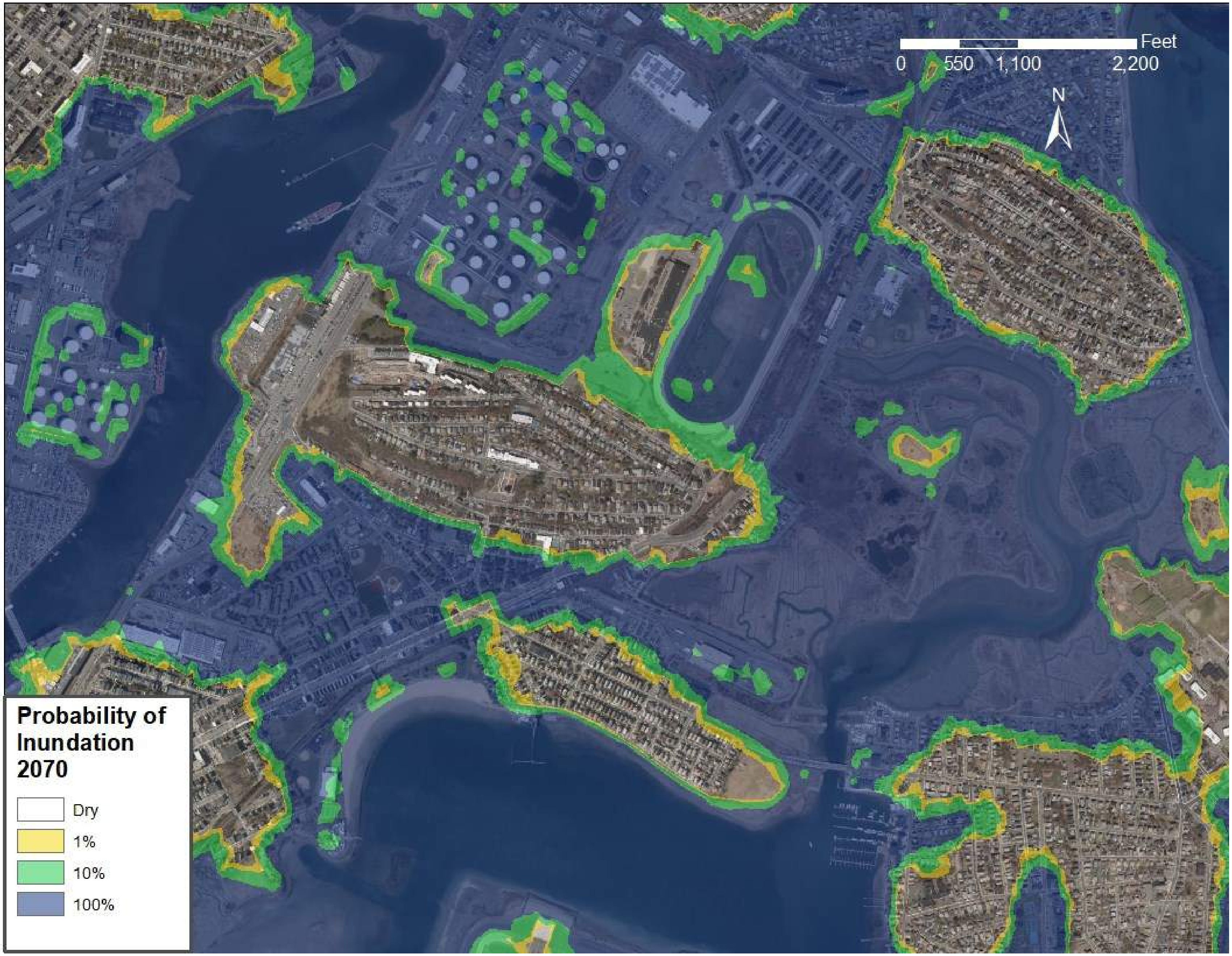

Figure 10. Annual chance flood extent in East Boston and Revere – 2070

4.0 Flood Pathways

To proceed in the development of a management approach to the Belle Isle Marsh area, a detailed analysis of potential flood pathways for both present day conditions, as well as future conditions was completed. Flood pathways are an important starting point in the development of adaptation strategies, as they identify local points of flood conveyance whose protection would benefit regional areas. The flood pathways analysis utilizes detailed, probabilistic, flood risk results from the MC-FRM to identify the flooding dynamics that are expected to occur under present and future climate conditions. To accomplish this, MC-FRM results were re-analyzed in terms of flood water elevations, and their relationship to local topography, to determine the progression of flooding that would occur within the study area under increasing annual exceedance probability of inundation. The flood pathway may continue to convey water for hours or more (depending on severity) until an ebbing tide drops below the critical elevation of the pathway. This flood pathway analysis was conducted for present-day climate conditions and climate conditions expected for 2030, 2050, and 2070. Maps of flood pathways for the entire study area are compiled in Appendix A, while maps which focus on specific locations are provided within this section. Note that the open ocean color associated with flood progression is meant to represent flooding which overtops Short Beach and the Winthrop Parkway.

Present Day – 0.0 ft SLR

Figure 11 and Figure 12 highlight the flood pathways for present day conditions. The figures show the progression of flooding sequentially from dark blue to pink. The first major entry point of note occurs at the corner of Morton St and Banks St in Winthrop. A storm surge water level of 7.3 ft (NAVD88) would result in inundation of Banks St. This would be the first area to experience flooding from a coastal storm event, resulting in inundation of the low-lying neighborhood. Other key entry points for flooding from Belle Isle Marsh include Bennington Street, specifically through Fredericks Park in Revere at 8.5 ft, and the MBTA railyard and maintenance facility, specifically through the Red Gate property at 10.5 ft and the railyard at 11.1 ft. These areas will serve as corridors for flooding in future years as SLR exacerbates the effects of even the higher annual exceedance of probability storms (i.e., smaller storms).

2030 – 1.3 ft SLR

Under 2030 SLR projections, three new critical flood pathways develop (Figure 13 and Figure 14). A major entry point of flooding is the Winthrop Parkway, where water is projected to overtop Short Beach from the open ocean to flood Belle Isle Marsh. A storm of this severity and storm surge height is extremely unlikely in present day but beginning in 2030, becomes a likelier possibility. Storm waves have presently been observed to overtop the seawall at Short Beach. The elevation required for storm surge (sheet flow) overtopping of Winthrop Parkway is 11.5 ft. As such, a storm surge elevation of 11.5 ft (without the addition of waves) will begin to flow over the wall in certain spots. Also impacting Winthrop is the arising of a flood pathway at the intersection of Bayou St and Argyle St. Flood waters from an extreme event (<1% annual chance) which exceed the 13 ft critical elevation may begin to encroach on and damage the critical electrical substation located in this area. Within East Boston, two other major flood pathways which include critical areas of Bennington St and Saratoga St become threatened by storm surge. While Bennington Street has a flood pathway in the present day, the new pathway overtops the L-Berm and breaks through Bennington Street to the south, running west towards Ashley St. Additionally, Saratoga St is overtopped by flooding which first enters Belle Isle Marsh under the bridge, and then flanks this critical roadway. While Saratoga St in East Boston is anticipated to flood first, it is important to note that the Saratoga St bridge may also become inaccessible by a flood pathway across Main St in Winthrop.

2050 – 2.5 ft SLR

The flood pathways in the present day are consistent through 2030 and largely remain the same, however, by 2050 a new major pathway develops. As storms increase in intensity in 2050, storm surge is projected to inundate Bennington St, creating a flood pathway through Waldemar Ave/Tomasello Way that connects to storm surge flooding from Chelsea Creek to the west. In this scenario, the flood pathway inundates the Suffolk Downs racetrack and the adjacent Irving Oil Terminals (Figure 15).

<u>2070 – 4.3 ft SLR</u>

Flood pathways for 2070 are ubiquitous around Belle Isle Marsh (see Appendix A), and no specific zoom-in graphic is provided here. All established floodways would be anticipated to continue to serve as the early warning signs of vulnerability, however by 2070, nearly the entire boundary of Belle Isle Marsh is projected to be overtopped under extreme storm scenarios. It is important to note that under the 2050 and 2070 SLR scenarios, flooding through Belle Isle Marsh is not the only flood pathway for most areas of East Boston and Revere. Flood waters are simultaneously projected to overtop Constitution Beach, Chelsea Creek, and Revere Beach. Adaptation strategies for such a scenario will need to consider all possible flood pathways.

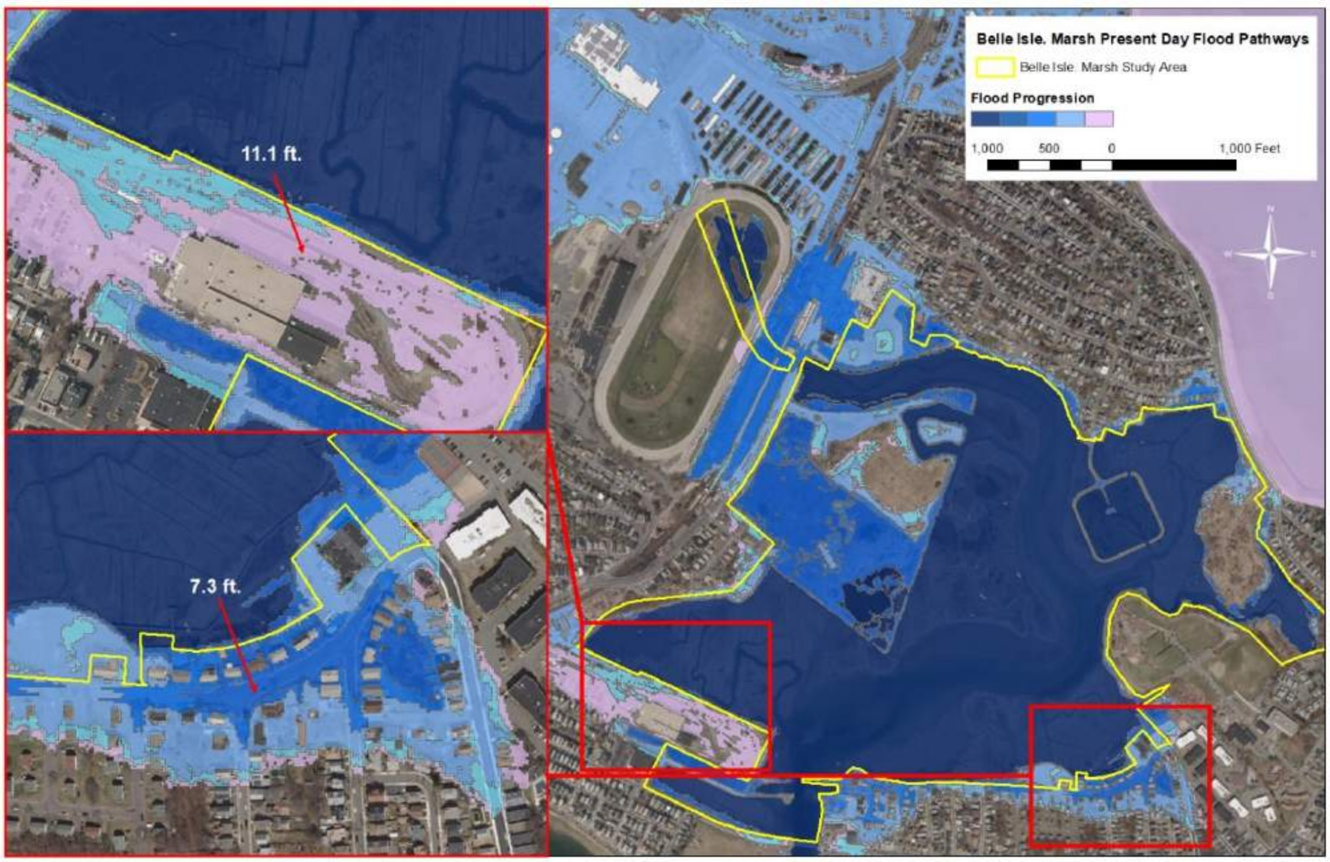

Figure 11. Present day storm flood pathways conditions and critical elevations.

Figure 12. Present day storm flood pathways and critical elevations (continued).

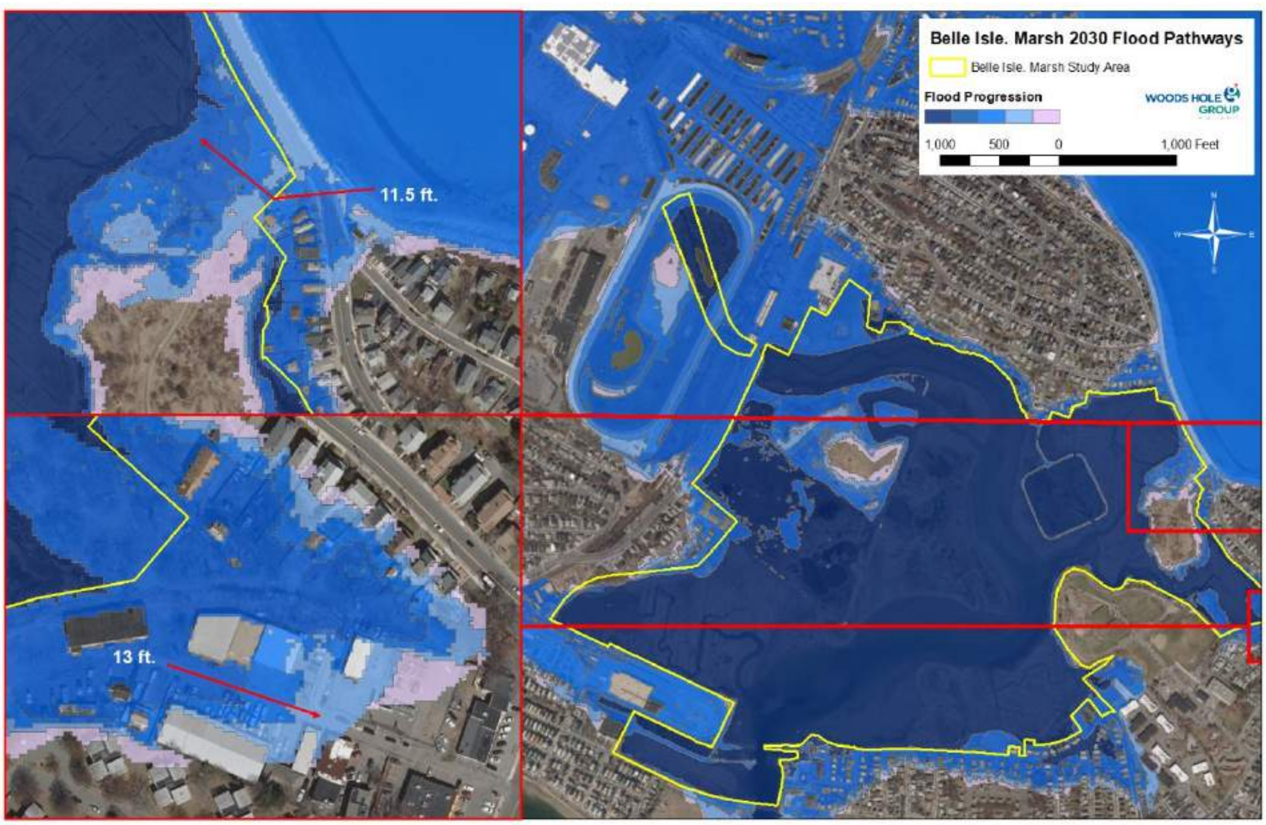

Figure 13. 2030 storm flood pathways and critical elevations, including overtopping Winthrop Parkway in top left.

Figure 14. 2030 storm flood pathways and critical elevations, including overtopping of Saratoga Street in East Boston.

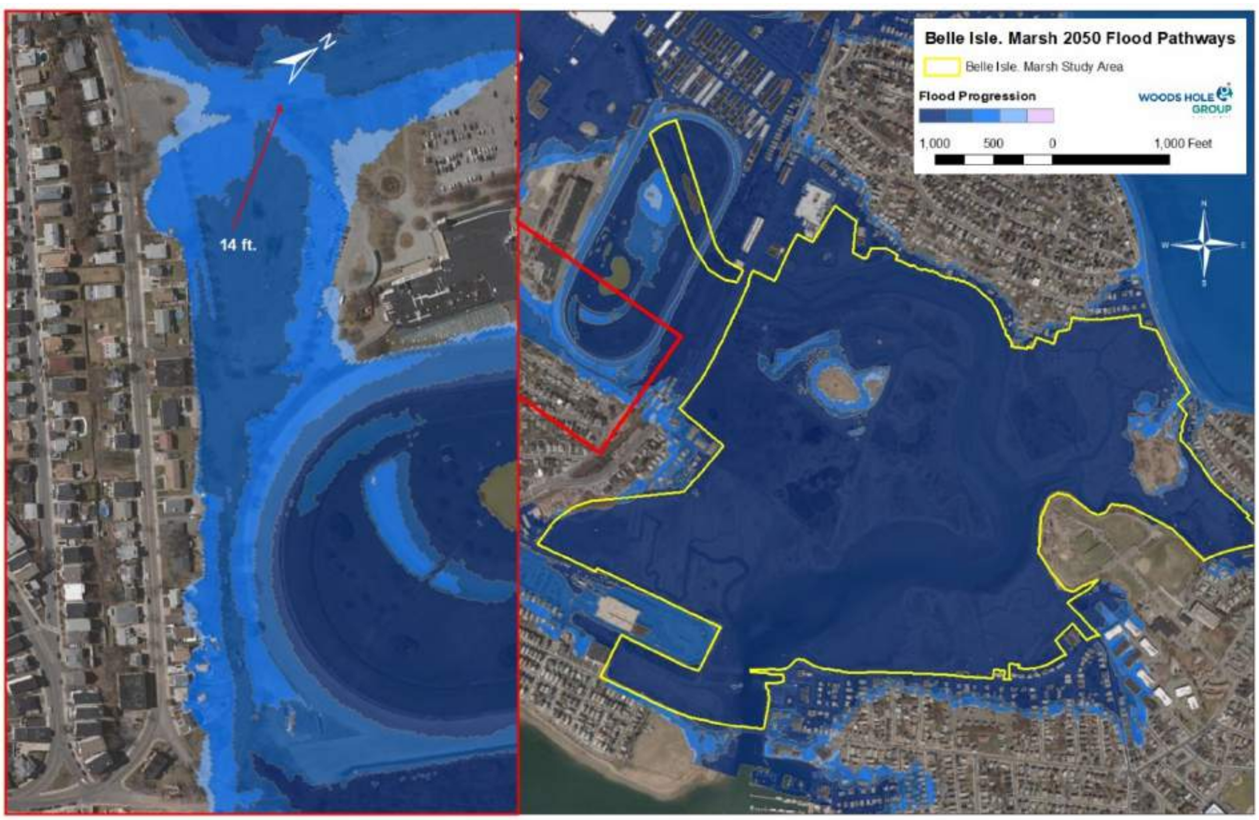

Figure 15. 2050 storm flood pathways and critical elevation at Waldemar Ave/Tomasello Way.

5.0 Conclusions

Future sea level rise and storm projections represent a significant flood risk to Belle Isle Marsh and the surrounding communities of East Boston, Revere, and Winthrop. Flood risk increases with larger, lower probability storm events, as well as with increasing sea level rise. Flood pathways and the critical elevations which serve as tipping points for greater flood hazards were identified in all three municipalities. The following lists these flood pathways in order of increasing critical flood elevation:

Banks St / Morton St, Winthrop	*Critical Elevation = 7.3 ft NAVD88*
Fredericks Park / Bennington St, Revere	*Critical Elevation = 8.5 ft NAVD88*
Casket Company / MBTA / Rosie's Pond, Boston	*Critical Elevation = 10.5 ft NAVD88*
MBTA Maintenance Railyard, Boston	*Critical Elevation = 11.1 ft NAVD88*
Winthrop Parkway / Short Beach, Winthrop	*Critical Elevation = 11.5 ft NAVD88*
Argyle St / Bayou St, Winthrop	*Critical Elevation = 13.0 ft NAVD88*
Saratoga St, Boston	*Critical Elevation = 13.0 ft NAVD88*
Waldemar Ave / Tomasello Way, Boston	*Critical Elevation = 14.0 ft NAVD88*

The above list will support the prioritization of areas for adaptation. Additionally, prioritization will consider assets and vulnerabilities which influence planning and adaptation. For example, critical infrastructure, such as evacuation routes (Winthrop Parkway, Bennington St, Saratoga St/Main St), public transportation infrastructure (MBTA Blue Line and maintenance railyard), and electrical utilities (Winthrop substation), may be prioritized when progressing a project into engineering design and implementation.

The purpose of this memo was to evaluate flood hazards and identify areas of vulnerability which will be the focus of nature-based or hybrid adaptation strategy identification. This will be followed by strategy identification of nature-based and hybrid solutions to mitigate risk in the most critical areas. Adaptation values, priorities, and goals will be summarized to inform targeted solutions to mitigate flood risk while enhancing habitat value.

6.0 References

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Town of Winthrop. 2018. Winthrop Community Resilience Workshop.

Appendix A. Flood Pathway Maps under Present Day, 2030, 2050, and 2070 Sea Level Rise Scenarios

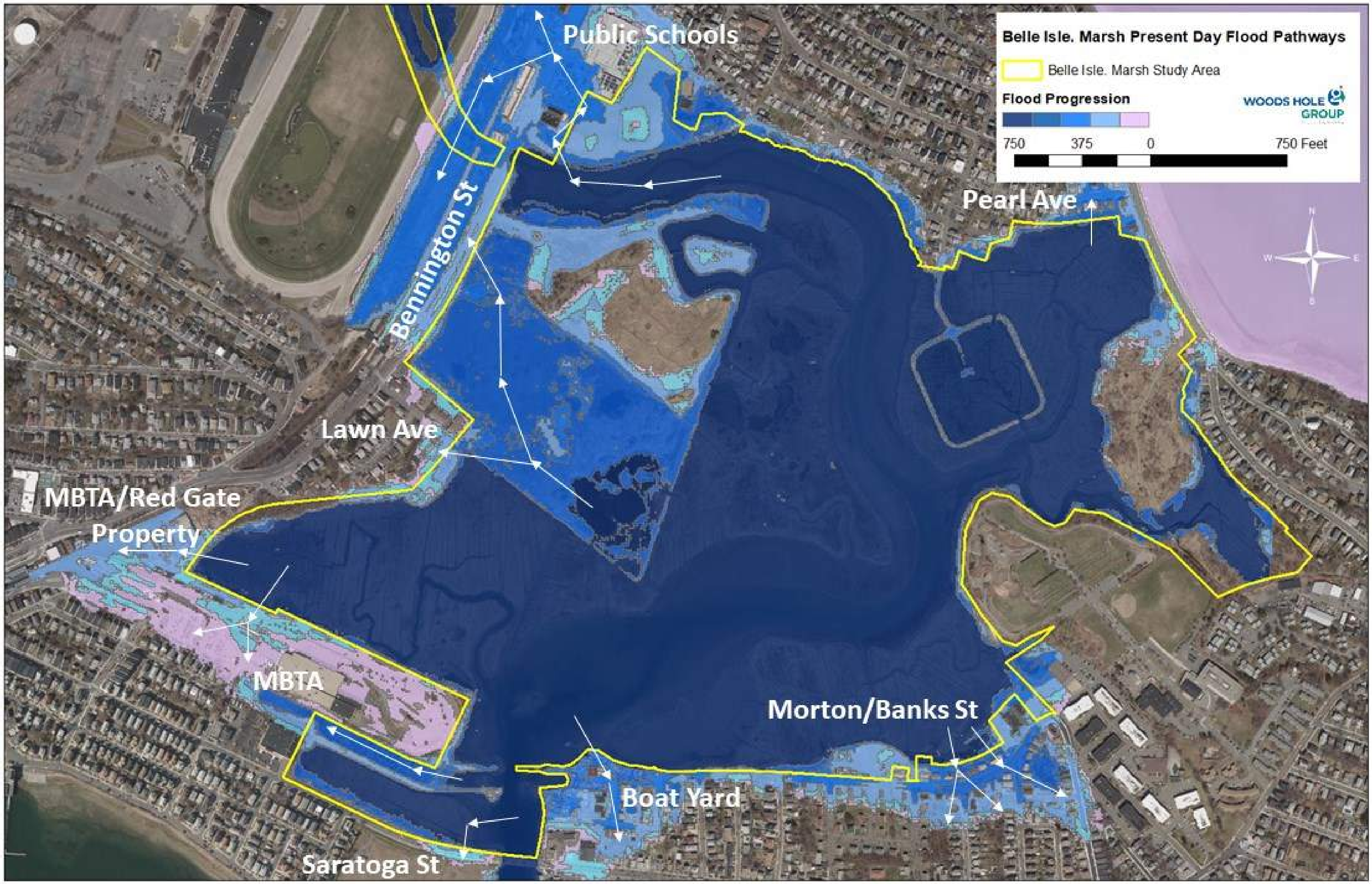

Figure 16. Present Day Flood Pathways

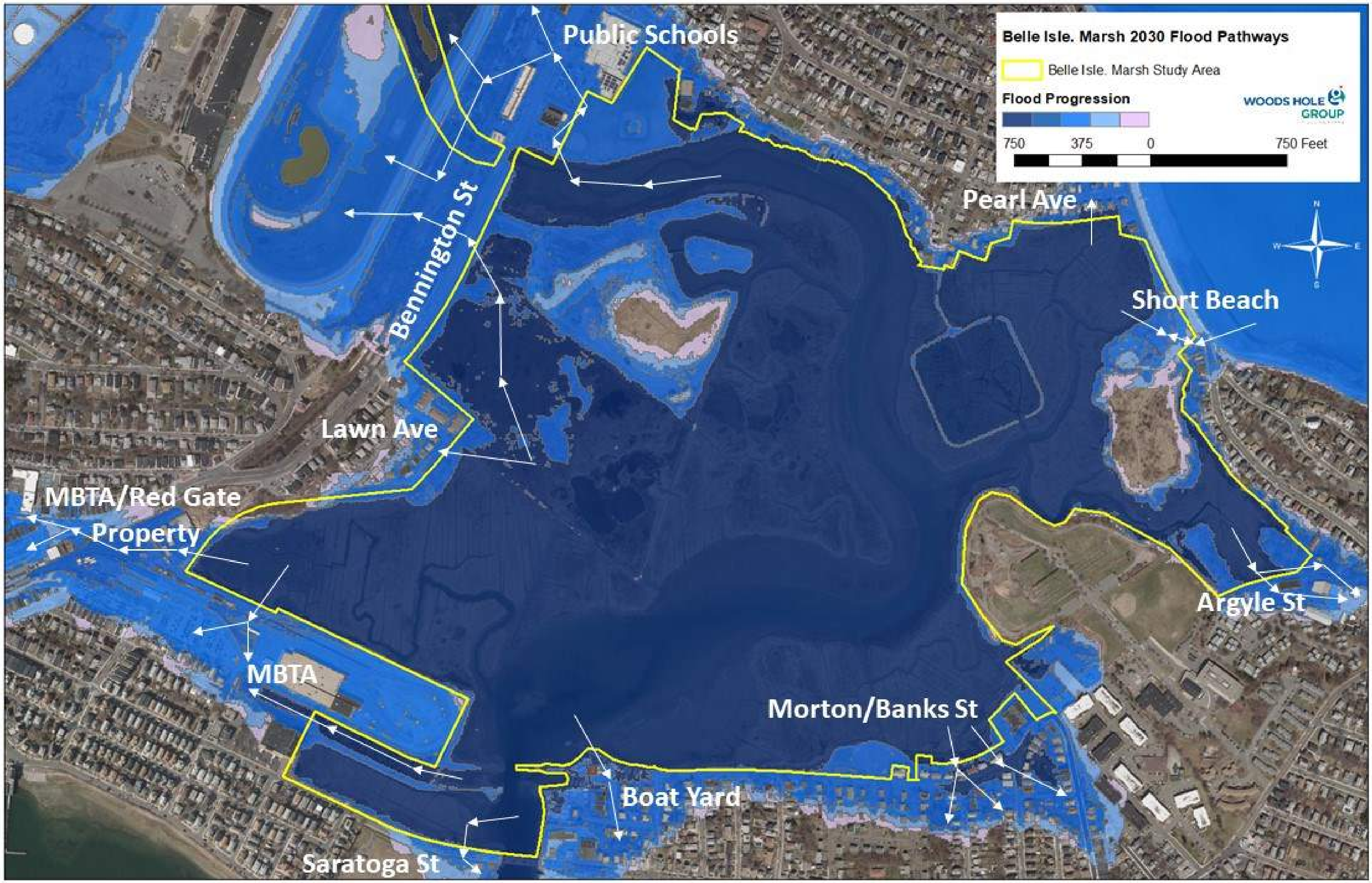

Figure 17. *2030 Flood pathways*

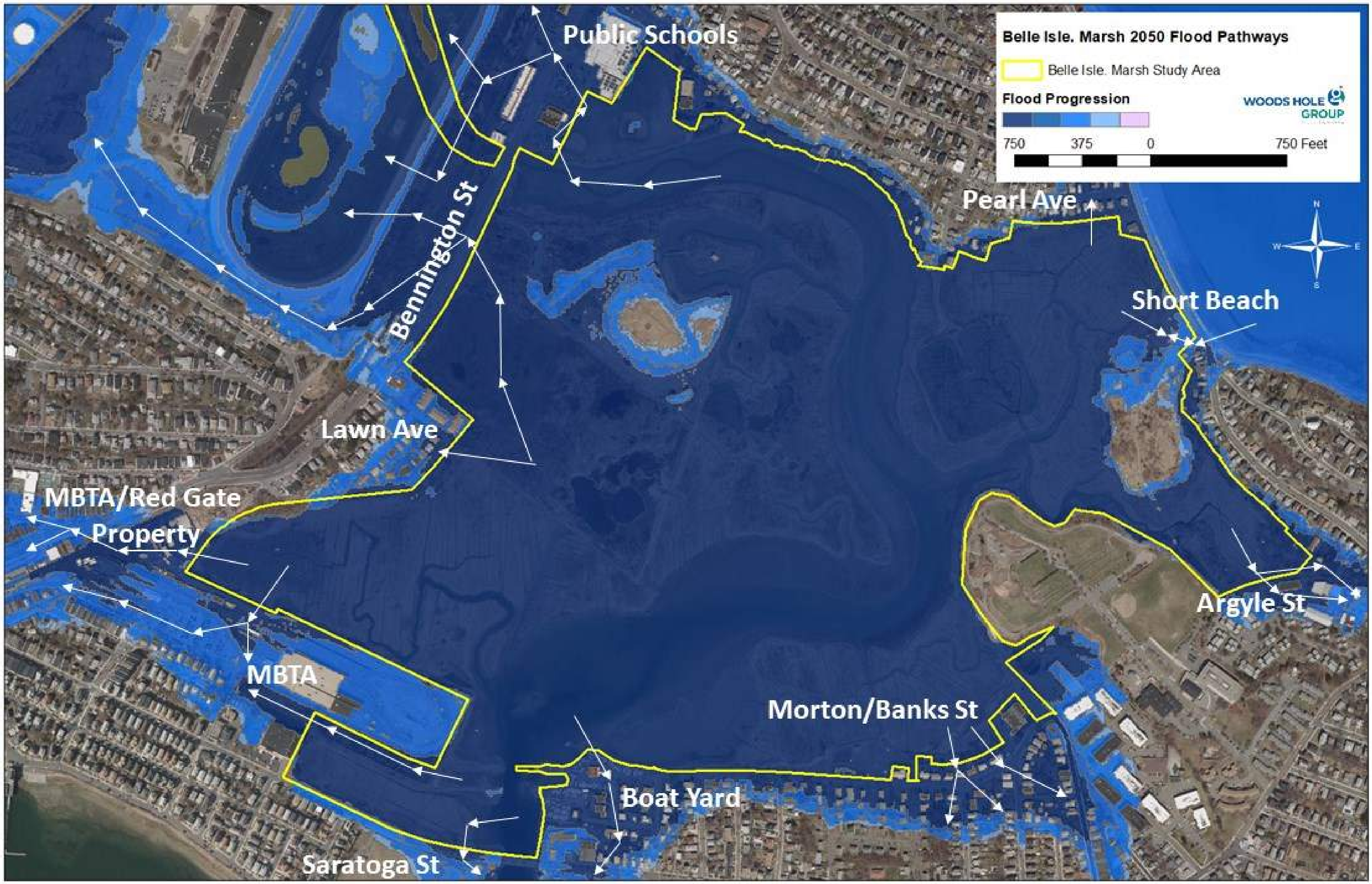

Figure 18. 2050 Flood Pathways

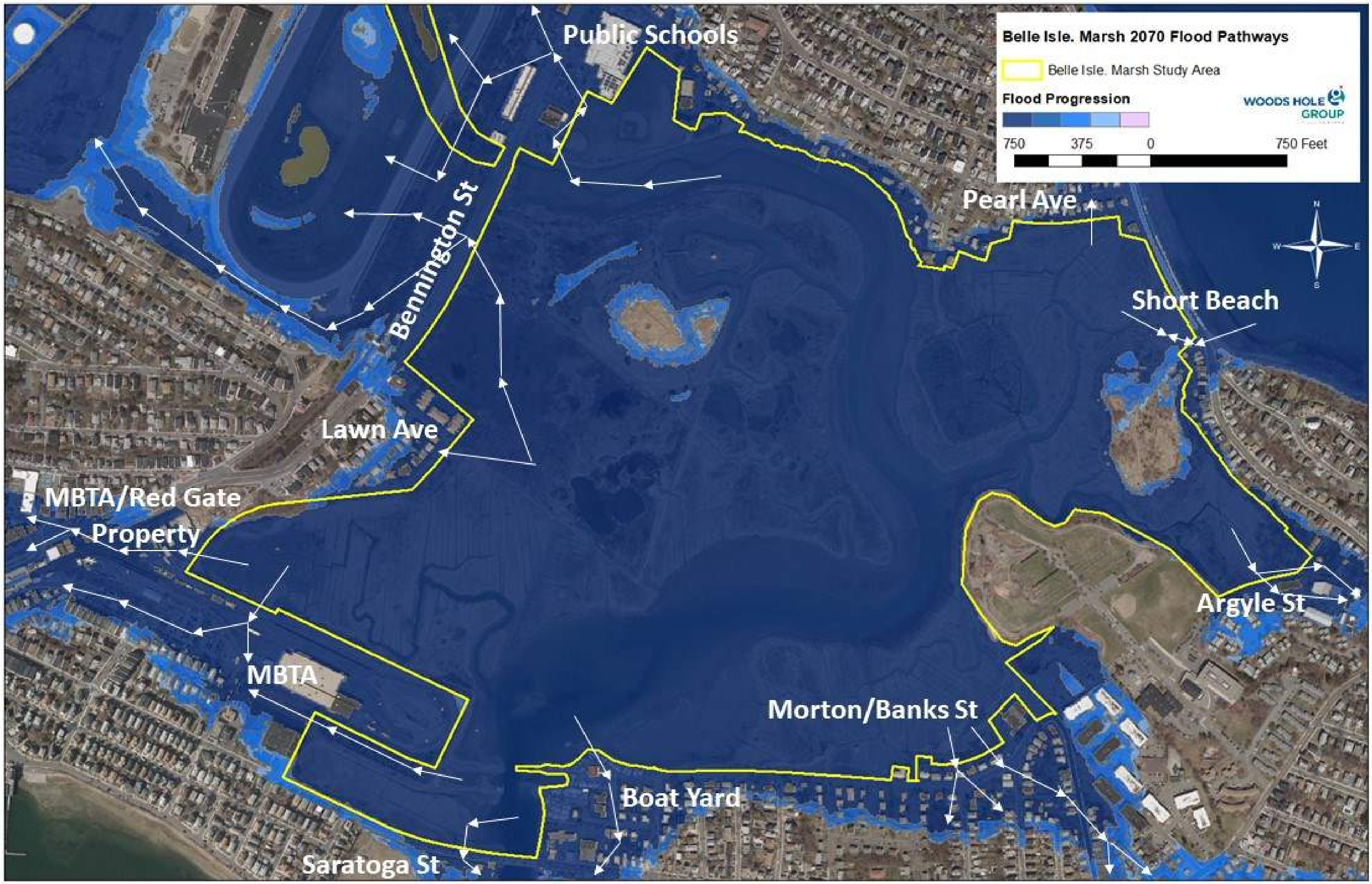

Figure 19. 2070 Flood Pathways

Appendix B. Belle Isle Marsh – Marsh Management Plan - Task 4: Sea Level Rise Affecting Marsh Migration – Summary Memo

MEMORANDUM

DATE May 5, 2022 **JOB NO.** 2020-0076

TO Catherine Pedemonti
Mystic River Watershed Association
20 Academy Street, Suite 306
Arlington, MA 02476

FROM Conor Ofsthun, Grace Medley
Woods Hole Group, Inc.

Belle Isle Marsh – Sea Level Rise Affecting Marsh Migration

1.0 Introduction

Woods Hole Group (WHG) was tasked with utilizing the Sea Level Affecting Marshes Model (SLAMM) to evaluate projected future wetland habitat conditions of Belle Isle Marsh, located in north Boston Harbor, and surrounded by the communities of East Boston, Revere, and Winthrop. SLAMM was developed specifically to evaluate the potential impacts to coastal wetlands from sea-level rise, and incorporates important parameters, such as elevation, wetland classifications, sea-level rise, tide range, and accretion and erosion rates for various habitat types. The Project area for SLAMM evaluation was identified as encompassing Belle Isle Marsh and the immediately adjacent upland developed land (Figure 1). This memorandum summarizes the model setup, supporting data collection, and model results. These results will be utilized to help develop potential recommendations and adaptations of Belle Isle Marsh for sustained and improved future marsh health.

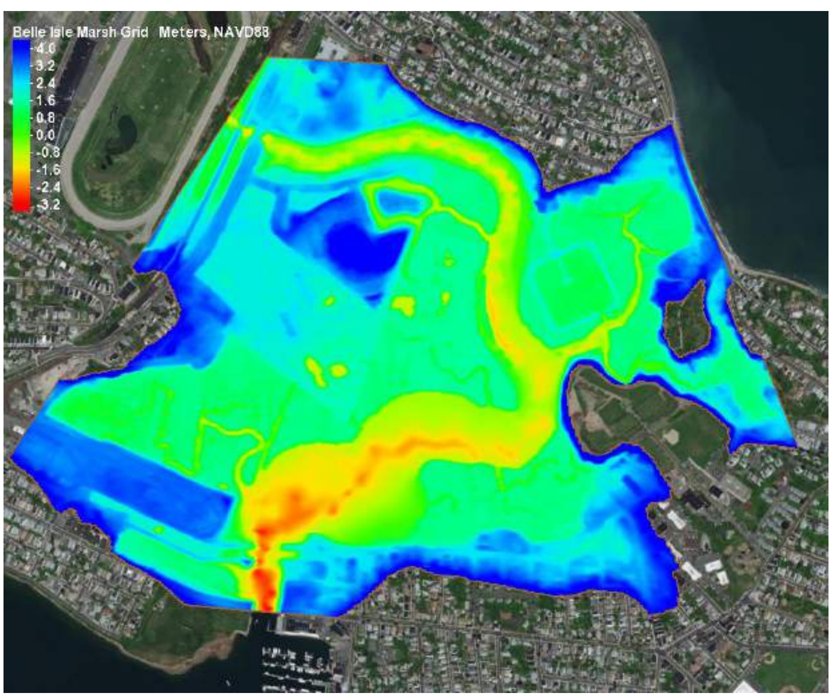

Figure 1. Belle Isle Marsh Project Area footprint, presented with topobathymetric elevations in meters, NAVD88.

2.0 Methodology

The Sea Level Affecting Marshes Model (SLAMM) was commissioned by the Environmental Protection Agency (EPA) in the 1980s and has subsequently undergone a number of updates. SLAMM 6.7, the most current version available, was used to model coastal wetland changes for the Belle Isle Marsh study area. Improvements made to SLAMM 6.7 since its prior iteration include the ability to utilize custom sea level rise (SLR) curves, improved marsh erosion modeling, and incorporation of carbon sequestration into the model. SLAMM was designed to simulate the dominant processes involved with wetland conversion due to sea level rise.

The SLAMM model was chosen for this project because it utilizes the driving physical processes that result in wetland and shoreline changes predicted to occur over a long-term time frame. The SLAMM model utilizes a number of data inputs and parameters including LiDAR elevation data, mapped wetland classifications, sea level rise, tide range, accretion, and erosion rates, resulting in a more comprehensive output result compared to some other ecological models currently available. Outputs from the simulations include both graphical (map) and tabular forms. This undertaking of SLAMM modeling for Belle Isle Marsh builds upon the efforts of the 2016 Massachusetts statewide study Modeling the Effects of Sea-Level Rise on Coastal Wetlands (Woods Hole Group, 2016). Specifically, the following key improvements were made to focus on Belle Isle Marsh:

- Achieve finer resolution utilizing a 1-meter model grid compared to the 5-meter statewide grid;
- Improve the wetland habitat mapping by acquiring wetland delineation boundaries to update the 2011 National Wetlands Index layer from the statewide modeling;
- Refine elevation input with site-specific elevation collected on-site by RTK Global Positioning System (GPS); and
- Improve accuracy of water level data: site specific water level information, including tidal range and the elevation of mean high water (MHW), will be used as inputs to the model (collected in Task 2.3).

2.1 Data Inputs

This section summarizes the various data which were researched, acquired, or assumed as inputs into the SLAMM model.

2.1.1 Elevation

High resolution elevation data is one of the most important inputs for SLAMM, as this dataset is used to determine where salt intrusion is expected to occur, as well as the frequency of salt inundation for wetlands and marshes in combination with tidal range data. Elevation data are also used to define the elevation range of wetlands, beaches, and tidal flats and when these areas should transition into a different land-cover type or even open water due to increased frequency of inundation. For the Belle Isle Marsh study area, 2018 United States Army Corps of Engineers (USACE) LiDAR Digital Elevation Model (DEM) was obtained from the National Oceanic and Atmospheric Administration (NOAA) Digital Coast database. NOAA maintains a public database containing a large variety of elevation data throughout Massachusetts. Due to the methods of data collection, a raw DEM often falls short when capturing bathymetry below the water surface, elevations of marsh platforms in areas of dense vegetation, and narrow channel thalweg profiles. In these cases, it is important to both ground-truth and correct the DEM with elevation data collected in-situ. In December of 2020 and March of 2021, Woods Hole Group collected Real Time Kinematic (RTK) survey data points at various locations around the marsh in order to characterize the site. These points were used as part of the modeling effort to ground truth and adjust the 2018 USACE topobathymetric LiDAR set sourced from NOAA Digital Coast. The LiDAR DEM was adjusted in the following ways: bathymetry from the survey was added, marsh platforms, channel thalwegs and linear features (berms) were adjusted to better align with the survey data. Bathymetric data was unavailable for the salt pools and pannes, therefore reasonable estimates to represent these regions based on water surface elevation data from the instrumentation deployment were applied to the DEM. The combined topobathymetric DEM used in the SLAMM modeling is presented in Figure 2. The DEM was then converted to a horizontal coordinate system consistent with additional data inputs described below, the Massachusetts State Plane Coordinate System (2001). The vertical coordinate system of the elevation data was the North American Vertical Datum 1988 (NAVD88). Both the horizontal coordinate system and the vertical datum are in meter units.

The SLAMM model processes all elevation data in refence to Mean Tide Level (MTL), not NAVD 1988, however. In order to correct this, a correction factor of -0.130 meters was used. This value was calculated using the Vertical Datum Transformation Tool (VDatum), which was developed by NOAA (NOAA 2021a). SLAMM allows for this correction factor to be entered as either a data input file or as a model parameter value; in this case, it was entered as a model parameter value and not as a separate, additional data input.

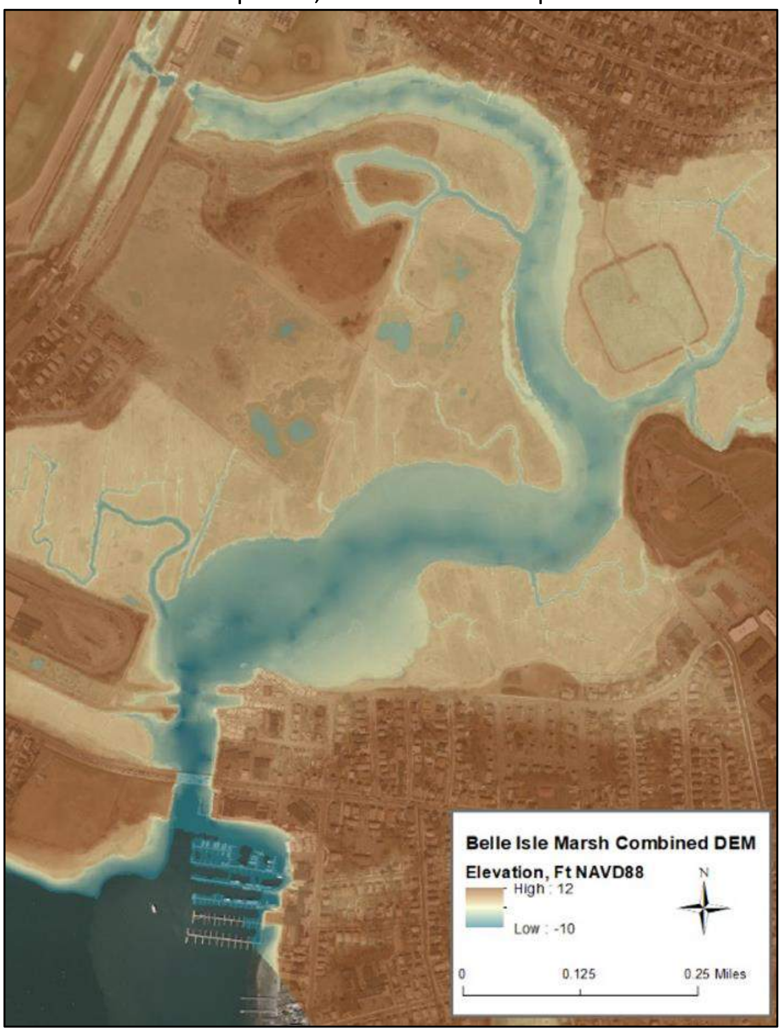

Figure 2. Combined Topobathymetric DEM used for hydrodynamic modeling, overlain on 2018 Orthoimagery for Massachusetts. All elevations are reported in ft, NAVD88.

2.1.2 Slope

In addition to being directly fed into the model as an input, the elevation data was also used to develop a slope file, which was then used as an additional input into the SLAMM model. For each raster cell of the elevation data, percent slope (units specified in the SLAMM technical documentation) was calculated using ESRI ArcMap tools. The slope file is a recharacterization of elevation data to define the change of elevation over horizontal distance, providing a quick approach of identifying a hill or bank.

2.1.3 Wetland Classifications

In addition to the elevation dataset, SLAMM also requires a classified wetland dataset documenting existing wetland conditions in the study area. This is the starting point for SLAMM's conversion algorithms, which assume wetlands inhabit a range of vertical elevations as a function of the tide range. In order to utilize the most recent wetlands data with as fine a resolution as possible, wetland classifications for the site were first mapped in the field to supplement existing publicly available wetlands layers from sources such as the National Wetlands Inventory (NWI). Another advantage in mapping wetlands in the field is that this process simplifies the process of cross-walking (i.e. translating) the observed wetland classifications into SLAMM wetland classifications. For instance, SLAMM distinguishes between regularly-flooded and irregularly flooded salt marsh but MassDEP wetlands layer only contains "salt marsh", which is difficult to accurately break down into different marsh types. Mapping wetland areas in the field allows for the surveyor to be more detailed and descriptive in identification of the various wetland areas.

Wetland classifications present at Belle Isle Marsh were determined by two Woods Hole Group Professional Wetlands Scientists (PWS) using an RTK-GPS in December 2020. GPS points were then brought into ESRI ArcMap software to create a wetlands classification data layer for the study area (Figure 3). Wetland classifications used in the field were then cross-walked to the designated SLAMM wetland categories and SLAMM wetland codes (Table 1), as designated in the SLAMM technical documentation. The wetland classification layer also utilized the Massachusetts State Plane Coordinate System (2001) in meters.

Table 1. Cross-walking of field designated wetland classifications into SLAMM wetland categories and Codes.

Field Designated Classification	SLAMM Wetland Category	SLAMM Wetland Code
Beach	Tidal Flat	11
Forest	Undeveloped Dry Land	2
High Salt Marsh	Irregularly-Flooded Marsh	20
Low Salt Marsh	Regularly-Flooded Marsh	8
Mudflat	Tidal Flat	11
Open Water (Channel)	Estuarine Open Water	17
Open Water (Panne)	Estuarine Open Water	17
Phragmites	Transitional Salt Marsh	7
Rocky/Structure	Undeveloped Dry Land	2
Shrubs	Transitional Salt Marsh	7
(All uncategorized areas within footprint)	Undeveloped Dry Land	2

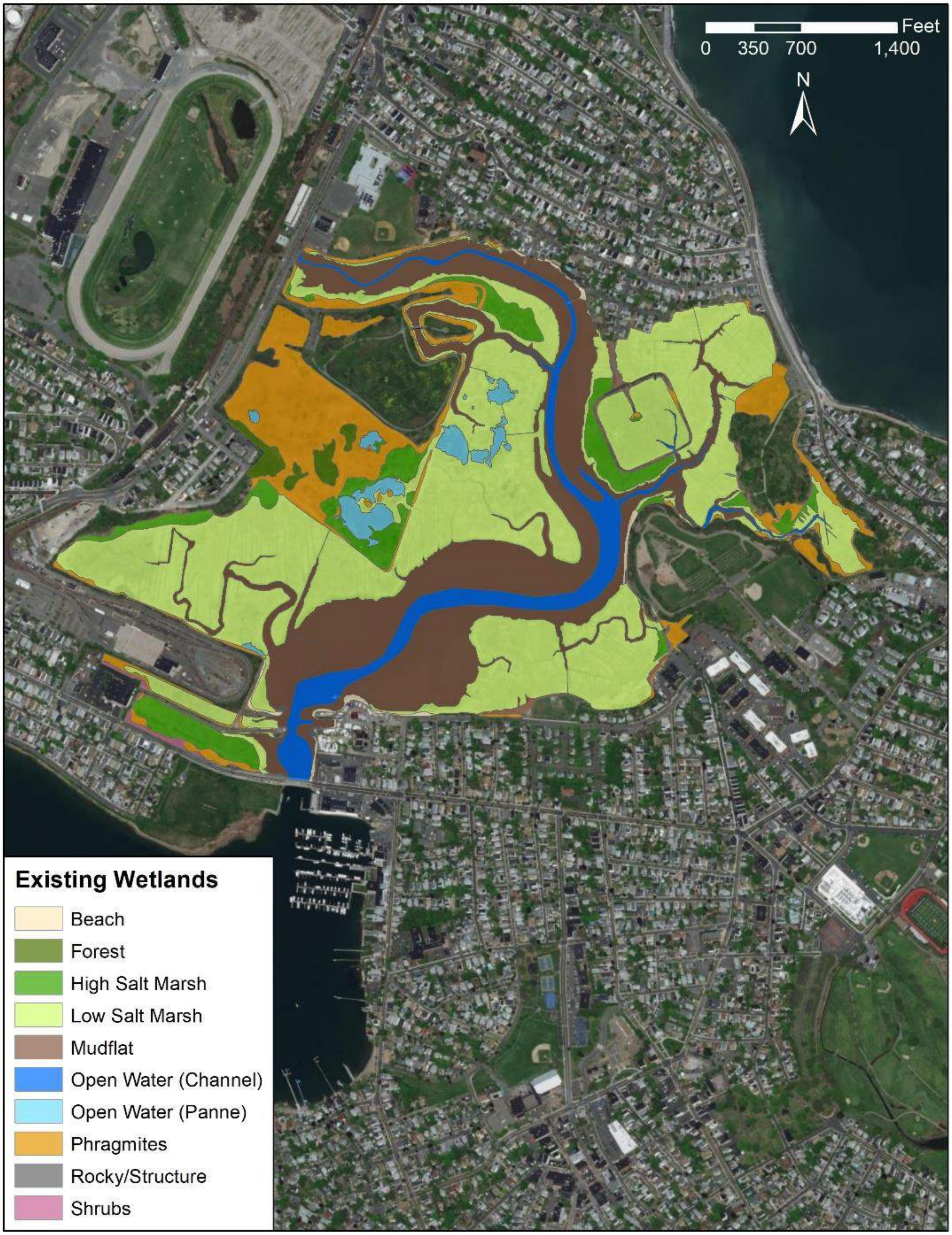

Figure 3. Existing wetland conditions for input to SLAMM modeling.

2.1.4 Dikes (Optional)

SLAMM allows for a number of optional data inputs including one for the locations of any dikes or dams within the study area. Elevations of these structures can be entered in the applicable raster cells and then during the model simulation, SLAMM evaluates potential inundation pathways using an internal connectivity algorithm. This file was not included for the Belle Isle Marsh simulation as there are no dikes or dams (at least not in the traditional sense) within the study area. The anthropogenic berms and other elevational flow control features within the BIM system (e.g., the key, etc.) in some ways act as flow impediments similar to a dike or a dam, but are not sufficiently represented by this optional SLAMM data input, which is intended to represent a more traditional dam structure.

2.1.5 Percent Impervious (Optional)

Impervious surface may be entered into SLAMM as a percent impervious raster file (any dry land with a percent impervious greater than 25% is assumed to be “developed dry land”). While an Impervious Surface raster layer is available from MassGIS, these data were not incorporated into the Belle Isle Marsh simulation. Incorporating these data would “protect” developed upland areas, meaning they would not be allowed to convert to another land-cover type. While in reality, salt marsh migration, for example, would stop at an impervious boundary, this does not inform stakeholders about where salt marshes would migrate if given the opportunity. As such, SLAMM models were conducted without percent impervious data so stakeholders can proactively understand and potentially manage the Belle Isle Marsh system for future salt marsh migration, and therefore persistence of the marsh system, if desired.

2.1.6 VDATUM (Optional)

SLAMM processes all elevation data in refence to Mean Tide Level (MTL), not the NAVD88 vertical datum utilized by the required data inputs. SLAMM allows for an elevation correction factor be entered as either a spatial dataset or as a singular value. In this simulation, the correction factor was entered as a model parameter and not as a spatial dataset.

2.1.7 Uplift/Subsidence (Optional)

This data input links a GIS layer specifying uplift/subsidence to the model simulation, allowing vertical land movement to be specified where applicable. Land movement could affect marsh migration because of the relative sea level change. The sea level rise estimates utilized for this project already include this site specific vertical land movement, and therefore this is already directly incorporated into the analysis.

2.1.8 Salinity (Optional)

Salinity data in raster form, representing cell-by-cell salinity values for the initial conditions, as well as specified outyears, can be input into the SLAMM simulation. However, SLAMM can traditionally be run without this data and based on pervious sensitivity testing and SLAMM usage (Woods Hole Group, 2016), this is unlikely to significantly affect the project results.

2.1.9 Storm Surge (Optional)

Storm surge is another optional data input, which SLAMM can utilize to calculate effects on infrastructure and the extent of storm surge. Considering the Massachusetts Coastal Flood Risk Model (MC-FRM) will be used to assess probability of inundation, as well as depth of inundation during a 1% chance event, and is a much more sophisticated inundation model, storm surge data was not included in this simulation. Additionally, episodic storm events do not have a significant impact on the wetland changes, which will be much more significantly influenced by the more permanent sea level rise changes.

2.1.10 Distance to Mouth (Optional)

These data are required for the optional Submerged Aquatic Vegetation (SAV) model, which predicts areas that will contain SAV and total coverage of SAV for each user specified time step. The SAV model will not be run for the Belle Isle Marsh simulation; therefore, distance to mouth data were not required or utilized.

2.2 Model Parameters

In addition to data input files, SLAMM also requires inputs for multiple parameters including marsh erosion, marsh accretion, tidal range data, historical sea level rise, etc. In addition, the global study area can be divided up into sub-sites, if parameter inputs vary between sub-sites. Due to the varied nature of the study area, seven separate subsites were delineated based on the varied barriers to tidal flow and resulting attenuation of the tidal range (Figure 4). All data parameters for each subsite are summarize in Table 2 discussed in detail below.

Figure 4. Sub-sites delineated for SLAMM based on the hydraulic conditions present within Belle Isle Marsh.

Table 2. Data parameters for all Belle Isle Marsh sub-sites.

Parameter	Site							
Description	**Global (Avg.)**	**Sub-Site 1**	**Sub-Site 2**	**Sub-Site 3**	**Sub-Site 4**	**Sub-Site 5**	**Sub-Site 6**	**Sub-Site 7**
NWI Photo Date (yr)*	2020	2020	2020	2020	2020	2020	2020	2020
DEM Date (yr)*	2018	2018	2018	2018	2018	2018	2018	2018
Direction Offshore	South	South	South	South	South	South	South	South
Historic SLR Trend (mm/yr)	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87
MTL - NAVD88 (m)	-0.130	-0.130	-0.130	-0.130	-0.130	-0.130	-0.130	-0.130
Great Diurnal Tide Range (m)	1.8	3.1	2.4	0.9	0.0	2.0	0.9	3.2
Salt Elevation (m)	0.9	1.5	1.2	0.4	0.0	1.0	0.5	1.6
Marsh Erosion (mm/yr)	0	0	0	0	0	0	0	0
Marsh Accretion (mm/yr)	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87

**The model start date is assumed at 2020 to match the study's decadal perspective. The 2-year difference between NWI and DEM inputs is considered small, and is not anticipated to significantly affect the results.*

2.2.1 Description

This model parameter allows users to enter the name of the site or subsite. For this simulation, the site was divided up into seven (7) sub-sites (Figure 4), numbered one through seven.

2.2.2 NWI Photo Date

SLAMM is commonly run using the NWI wetland data layer and therefore requires the date of the photo used to delineate wetland classifications in order to accurately model future out years. However, other wetland classification layers can be imported from other sources. In this case, a field survey was conducted in 2020 to delineate wetland classifications at the site. The NWI wetland file was updated per the field survey results, and therefore 2020 was utilized as the start date for the wetland types.

2.2.3 DEM Date

The elevation data used for the Belle Isle Marsh SLAMM simulation was captured in 2018 as a Lidar survey by the U.S. Army Corps of Engineers. An RTK GPS field survey was conducted in 2020 at points of interest to verify the accuracy of the Lidar data. Where RTK GPS recorded elevations varied from the Lidar survey, the GPS was utilized as a correction factor and an updated, combined DEM file was developed. The year 2018 was used as the start date for the DEM file which varies by 2 years from the wetland resource file, however this small difference in time is expected to be insignificant given the decadal timescale the study is focused on.

2.2.4 Direction Offshore

This input allows users to specify the direction of water from the shoreline in order for the model to better determine how inundated areas will change in land-cover over time. The water body to the south of Belle Isle Marsh is the most influential.

2.2.5 Historic Sea Level Rise Trend

SLAMM utilizes historic rates of sea-level rise to estimate subsidence or uplift within the simulation (unless a raster file representing land movement has been included in the simulation). Since a raster file for land movement data was not included, the historic rate of sea level rise was determined using NOAA Boston tide gauge data. Averaged over 79 years from 1921 to 2020, historic sea level rise for Boston is 2.87 mm per year (NOAA 2021b). This is different than the sea level rise projections used in the SLAMM execution (see Section 2.3.1).

2.2.6 MTL Minus NAVD88

SLAMM requires an elevation correction from NAVD88 to MTL. For this simulation, VDatum was used to calculate a correction factor of -0.13 meters.

2.2.7 Great Diurnal Tide Range

One of the most influential SLAMM parameters is tidal range (WHG, 2016). Data are entered in meters as "great diurnal tide range", equivalent to Mean Higher High Water (MHHW) subtract Mean Lower Low Water (MLLW). Tidal range data were obtained from tide gauges installed within Belle Isle Marsh in 2020. One tide gauge was installed in each sub-site, for a total of seven (7) gauges. Tide gauge data indicated that there are several areas within the Belle Isle Marsh study area that are tidally restricted (Table 3); salt elevation is described below, a significant factor when determining future wetland change. By incorporating data on tidally restricted areas, hydraulics within the SLAMM model are improved and avoids overestimating tidal range in restricted areas, while maintaining full tide range along open coast within the same model simulation. Essentially, the SLAMM model results are improved by actual observational variations in the tidal regime. These values can also be further refined by using even more detailed tidal information from the numerical modeling developed as a part of the wider Belle Isle Marsh, Marsh Management Project.

Table 3. Tidal range data for tide gauges installed in Belle Isle Marsh.

Sub-Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Tide Gauge	**BI-4**	**BI-7**	**BI-2**	**BI-5**	**BI-6**	**BI-3**	**BI-1**
MHHW (ft)	5.2	5.2	1.5	5.6	5.2	5.1	5.1
MHW (ft)	4.7	4.6	1.0	5.6	4.6	4.6	4.6
MTL (ft)	0.0	0.9	-0.1	5.6	1.7	3.3	-0.3
MLW (ft)	-4.7	-2.8	-1.3	5.5	-1.2	2.1	-5.1
MLLW (ft)	-4.9	-2.8	-1.3	5.5	-1.2	2.1	-5.4
Great Diurnal Tide Range* (ft)	10.1	8.0	2.8	0.1	6.4	3.0	10.5
Great Diurnal Tide Range (m)	3.1	2.4	0.9	0.04	2.0	0.9	3.2
Salt Elevation (m)**	1.5	1.2	0.4	0.02	1.0	0.5	1.6

**Great Diurnal Tide Range is the height difference between high and low tide, calculated as MHHW minus MLLW.*
***Salt elevation is defined by SLAMM as half the Great Diurnal Tide Range, and is often referred to as the Diurnal Tide Level.*

2.2.8 Salt Elevation

Salt elevation is another highly sensitive parameter (WHG, 2016) and is the elevation at which dry land and freshwater wetlands begin, which is often the elevation inundated by salt less than every 30 days. This value was calculated by dividing the great diurnal tide range in half, as suggested in the SLAMM technical documentation (Table 3).

2.2.9 Marsh Erosion

Horizontal erosion rate can be specified for marsh, swamp, and tidal flat wetland classifications. However, these specified erosion rates are only incorporated into the model for marsh or swamp when there is at least a 9 km fetch length to an open ocean or other inland water source that is present at the study area. Tidal flat erosion is incorporated regardless of fetch length. Given that the fetch length within the Belle Isle Marsh study area is less than 9 km, the SLAMM processor will not utilize a specified erosion rate for marsh or swamp. Based on the SLAMM fetch requirement, lack of marsh erosion data, and relative unimportance of this parameter as determined through a sensitivity analysis (WHG, 2016), marsh horizontal erosion rate was left at 0 mm per year for this particular evaluation.

Horizontal erosion or accretion of beaches can also be specified by utilizing the Bruun rule in SLAMM. However, implementation of this rule would only result in a horizontal erosion rate that is proportional to sea level rise rate, and not take into account other coastal processes that effect shorelines. As such, the Bruun rule was not applied for the Belle Isle Marsh SLAMM simulation. Additionally, the Bruun rule is most applicable to traditional, open coast coastal beaches which are not present within Belle Isle Marsh.

2.2.10 Marsh Accretion

SLAMM allows for vertical accretion rates (mm/yr) to be entered for a variety of wetland types, including irregularly- and regularly-flooded marsh, tidal flat, tidal fresh marsh, tidal swamp, and swamp. However, there is little site-specific accretion data available for Massachusetts marshes. In the case of Belle Isle Marsh, there is not any available data on vertical accretion rates. Additionally, accretion rates were also not available for any similar, nearby salt marshes that could reasonably serve as a proxy for Belle Isle Marsh. For this reason, an accretion rate of 2.87 mm per year was assumed to allow the Belle Isle Marsh to keep pace with the historical sea level rise trend for the area. This approach has been utilized in past for statewide runs as well as the current simulation. Additionally, a sensitivity analysis indicated that this parameter has minimal influence on Belle Isle Marsh results. The model was run under two conditions, one assuming the vertical accretion rate matches that of historic sea level rise, and another assuming no vertical accretion. The results were nearly equivalent under both conditions, indicating that either condition is acceptable. The reason marsh accretion may have played an insignificant role in migration predictions is that future predicted rates of sea level rise far outpace that of historic sea level rise, and overtake any reasonable assumptions of natural vertical accretion.

2.2.11 Beach Sedimentation Rate

SLAMM additionally allows for input of beach sedimentation, entered as a vertical measurement in mm per year. However, no traditional, open coast beaches exist within the Belle Isle Marsh complex. Short Beach is located nearby, but the Winthrop Parkway acts as a barrier that is assumed to hold the line against erosion which could otherwise encroach on Belle Isle Marsh. Furthermore, the effect of beach erosion is more adequately addressed by horizontal erosion rates, rather than sedimentation. Past analysis of this parameter indicates that only negative values resulted in changes in SLAMM output.

2.2.12 Irregular Flood Collapse

When an irregularly flooded marsh is converted into a regularly flooded marsh due to sea level rise and increased inundation, there can be a resulting loss of elevation. This elevation loss can then be entered into SLAMM to aid in the simulation. However, these data are not available for Belle Isle Marsh and collection of these data are outside the scope of this project.

2.2.13 Regular Flood Collapse

When a regularly flooded marsh is converted into tidal flats due to sea level rise and increased inundation, there can be a resulting loss of elevation. However, these data are not available for Belle Isle Marsh and collection of these data are outside the scope of this project.

2.2.14 Wave-Erosion Model

In the cases where marsh erosion is a significant occurrence, SLAMM can utilize wind direction, fetch length, and water depth to calculate erosion rates. For Belle Isle Marsh, fetch length is less than 9 kilometers, eliminating the need for an erosion model. Essentially, waves are generally small within BIM due to the relatively protective nature of the overall marsh complex and surrounding upland area.

2.3 Model Execution

This section summarizes decisions made in the execution of the SLAMM model.

2.3.1 Sea Level Rise Projections

SLAMM includes a variety of global sea level rise (SLR) projection scenarios from the Intergovernmental Panel on Climate Change (IPCC). However, the most recent update to SLAMM allows users to enter custom SLR projections for specified outyears. SLR projections used in the Belle Isle Marsh SLAMM simulation are listed in Table 4 and are consistent with the current best available, Massachusetts-specific, science, adopted by the Commonwealth of Massachusetts for planning and adaptation. In the case of this simulation, SLR projection outyears match the future time frames for which SLAMM models will be generated. Although the linear approach is not directly accurate (due to the acceleration of SLR expected), given the temporal gap is only 10 years between specified values, this assumption is not expected to cause significant limitations.

Table 4. Sea level rise projections used in the Belle Isle Marsh SLAMM simulation (projections are in reference to 2008).

Outyear	SLR (ft)	SLR (m)
2030	1.29	0.39
2040	1.79	0.55
2050	2.49	0.76
2060	3.29	1.00
2070	4.29	1.31
2080	5.29	1.61
2090	6.49	1.98
2100	7.69	2.34

2.3.2 Soil Saturation

Soil saturation is intended to predict where low elevation upland areas will become inundated by ground water as the water table rises with sea level rise. This requires water table level estimates which were not available for this study. Furthermore, this algorithm frequently causes “streaks” within model outputs according to SLAMM technical documentation and past projects completed by WHG and was therefore not utilized in this simulation.

2.3.3 Connectivity Algorithm

The connectivity algorithm within SLAMM determines whether dry lands or freshwater wetlands will be subject to saline inundation based on an uninterrupted low-elevation pathway to estuarine or ocean water. The “average” cell elevation based on a 4-side search rule was used to estimate whether each portion of the map has regular connectivity to tidal water. Without utilizing this algorithm, isolated low areas would be converted to tidal wetlands, which is not consistent with expected hydrological or ecological response. Using the connectivity algorithm, therefore, produces more realistic results, and is implemented in this study.

2.3.3 Model Time Steps

This analysis produced projected wetland area outputs for decadal time steps from 2020 through 2100. While GIS and tabular results are only presented for 2030, 2050, 2070, and 2100, using a 10-year interval for the model refines the accuracy of results because each wetland cell has more opportunities to experience small changes.

2.3.4 Model Limitations and Uncertainties

As with all models, there are a number of limitations within SLAMM that must be considered when interpreting the results. For instance, the erosion parameters for horizontal marsh and swamp are only triggered when there is a minimum fetch length of 9 kilometers. While this works well for open ocean coasts or expansive inland water systems, given the numerous enclosed bays and estuaries present in Massachusetts, including Belle Isle Marsh, the majority of coastal wetlands do not meet this criterion. In essence, this means even where data are available to document marsh erosion rates, entering these values as input parameters would not be utilized and would not affect the results.

SLAMM is limited in its installation of tide range in respective zones. While the input of varying tide ranges is beneficial to representing existing conditions, and limiting an overprediction of wetland habitat, it does have a drawback because tide range does not adapt with changes which may occur as sea level rises. Specifically, results behind the L-berm were at risk of error as the tidal range is in reality expected to change over time. To account for the simplicity of SLAMM, the model was paused at the outyears of interest (2030, 2050, and 2070), and the tidal range of the L-berm was revised to reflect the range observed in the EFDC hydrodynamic model (developed in support of the Marsh Management Plan).

Uncertainties are also inherently present when modeling future changes in wetland ecosystems. However, the largest uncertainty present may be sea level rise projections. Although the projections used in this model have been well researched and accepted, they remain projections. Despite limitations and uncertainty, sea level change is only trending in the direction of rising, and therefore even if projections are not exact, they are expected to be born out in time. For instance, if projections are slower than expected, the 2070 results may not occur until 2100; while if projections are faster than expected, the 2070 results may occur in 2050. The SLAMM results presented in this report still provide a valuable tool to identify future coastal wetland migration and provide valuable information to help prioritize marsh systems that may be the most vulnerable to climate change.

3.0 Results

This section presents habitat distribution maps under present day, 2030, 2050, 2070, and 2100 sea level rise scenarios (Figure 5, Figure 6, Figure 7, Figure 8, and Figure 9, respectively). Changes in total habitat type acreages referenced throughout this section are detailed in Table 5. A summary of the existing conditions, and projected habitat changes within Belle Isle Marsh from present day through year 2100 is described below. The impervious surface layer (obtained from MassGIS) is overlain on habitat distribution maps and provided as Appendix A. This layer is used to illustrate where marsh migration may be impeded by development in the future.

Table 5. Area (acres) of each wetland classification present within the Belle Isle Marsh study area for present day, 2030, 2050, 2070, and 2100 and change in area (acres) for select year to year comparisons.

SLAMM Code	Wetland Classification	Area (acres)					Change in Wetland Area (acres)					2020 to 2100 % Change
		2020	2030	2050	2070	2100	2020 to 2030	2030 to 2050	2050 to 2070	2070 to 2100	2020 to 2100	
2	**Upland**	159	156	135	102	35	-3	-21	-33	-137	-124	-78%
7	**Transitional Marsh**	35	33	40	39	13	-2	7	-1	-26	-22	-63%
8	**Regularly Flooded Marsh**	121	122	141	169	124	1	19	28	28	3	2%
11	**Tidal Flat**	67	57	54	41	159	-10	-3	-13	118	92	137%
17	**Estuarine Open Water**	22	36	41	65	90	14	5	24	25	68	309%
20	**Irregularly Flooded Marsh**	17	17	10	5	1	0	-7	-5	-4	-16	-94%

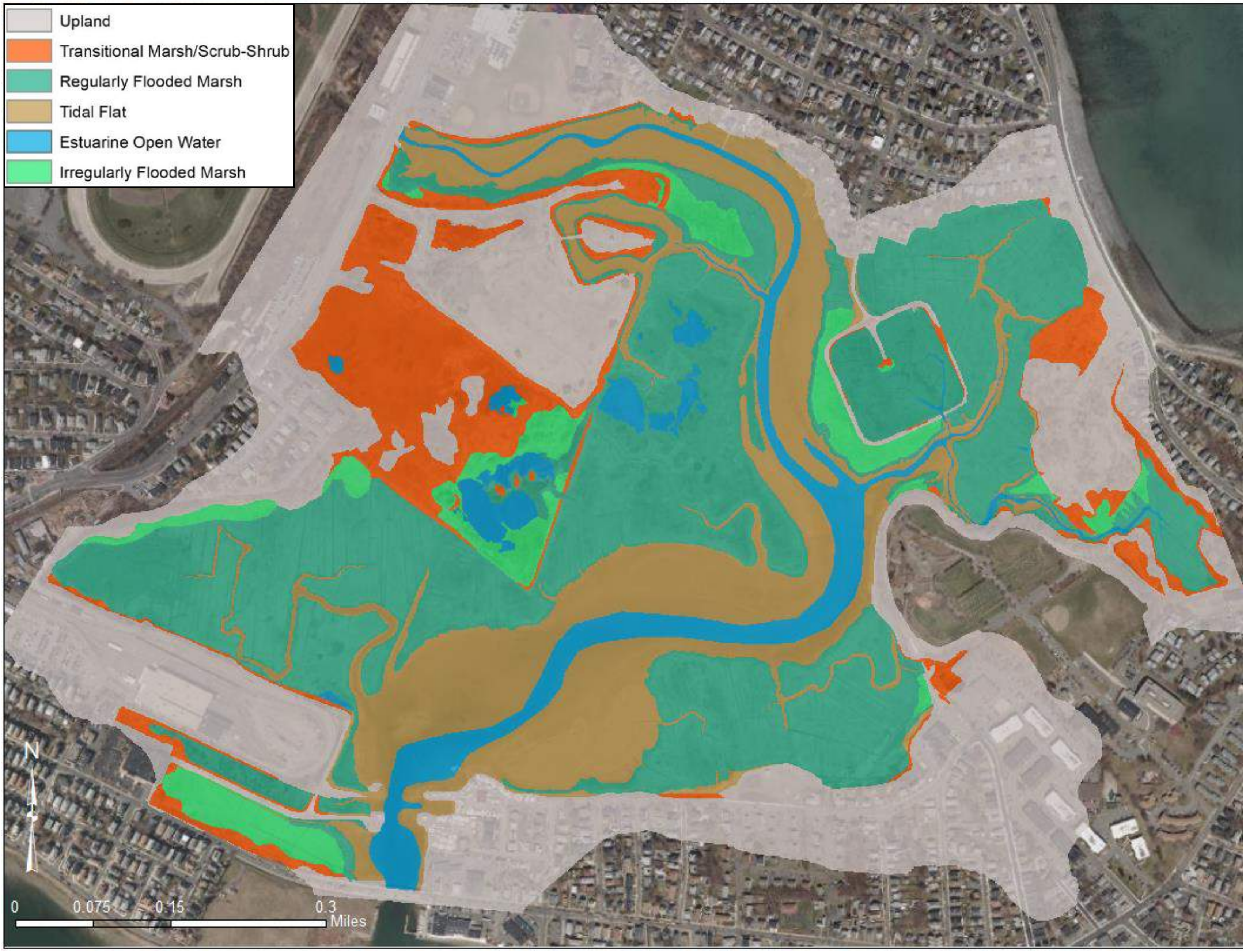

Figure 5. Initial wetland conditions used in SLAMM modeling for Belle Isle Marsh and the surrounding area.

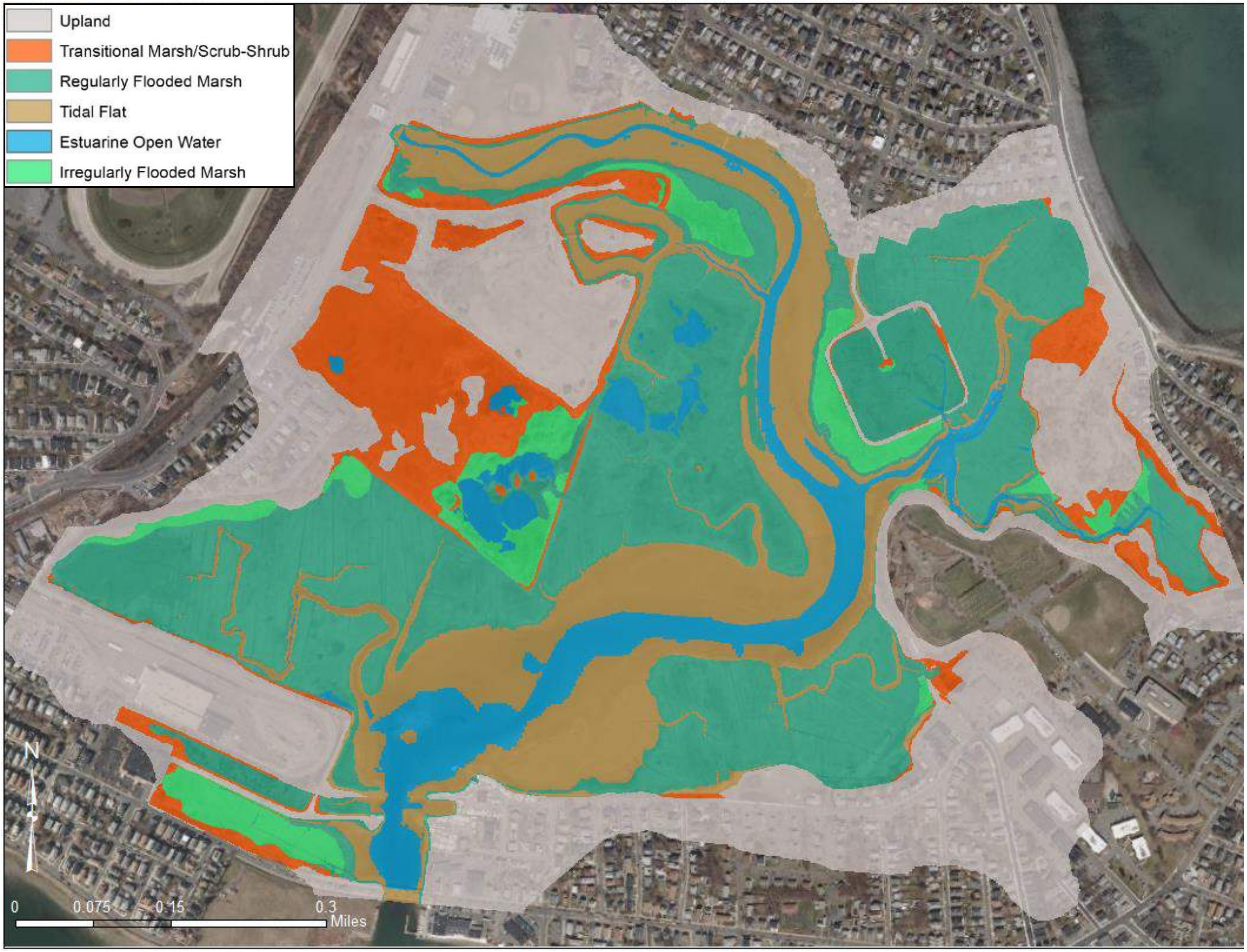

Figure 6. SLAMM modeling results for Belle Isle Marsh and the surrounding area during 2030.

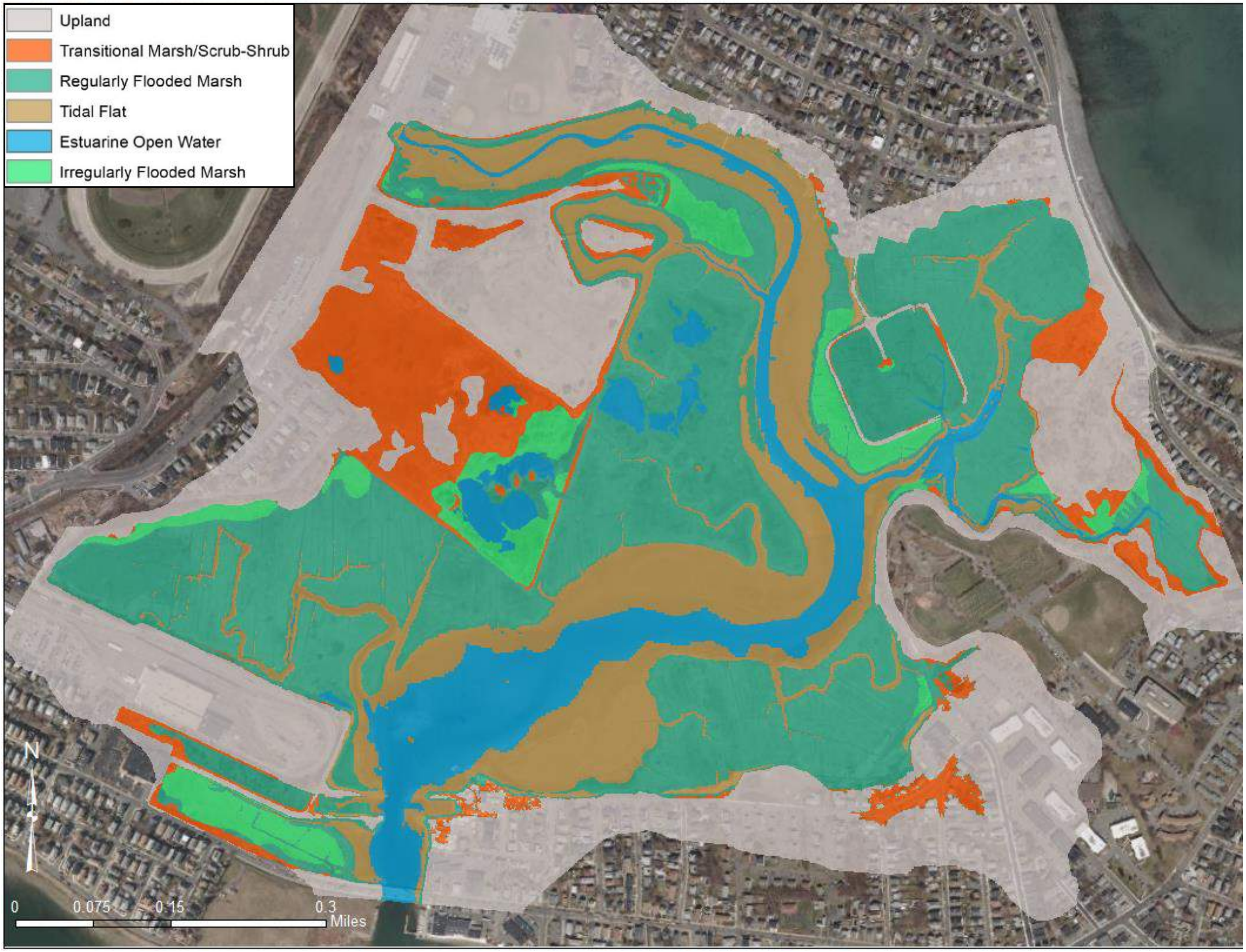

Figure 7. SLAMM modeling results for Belle Isle Marsh and the surrounding area during 2050.

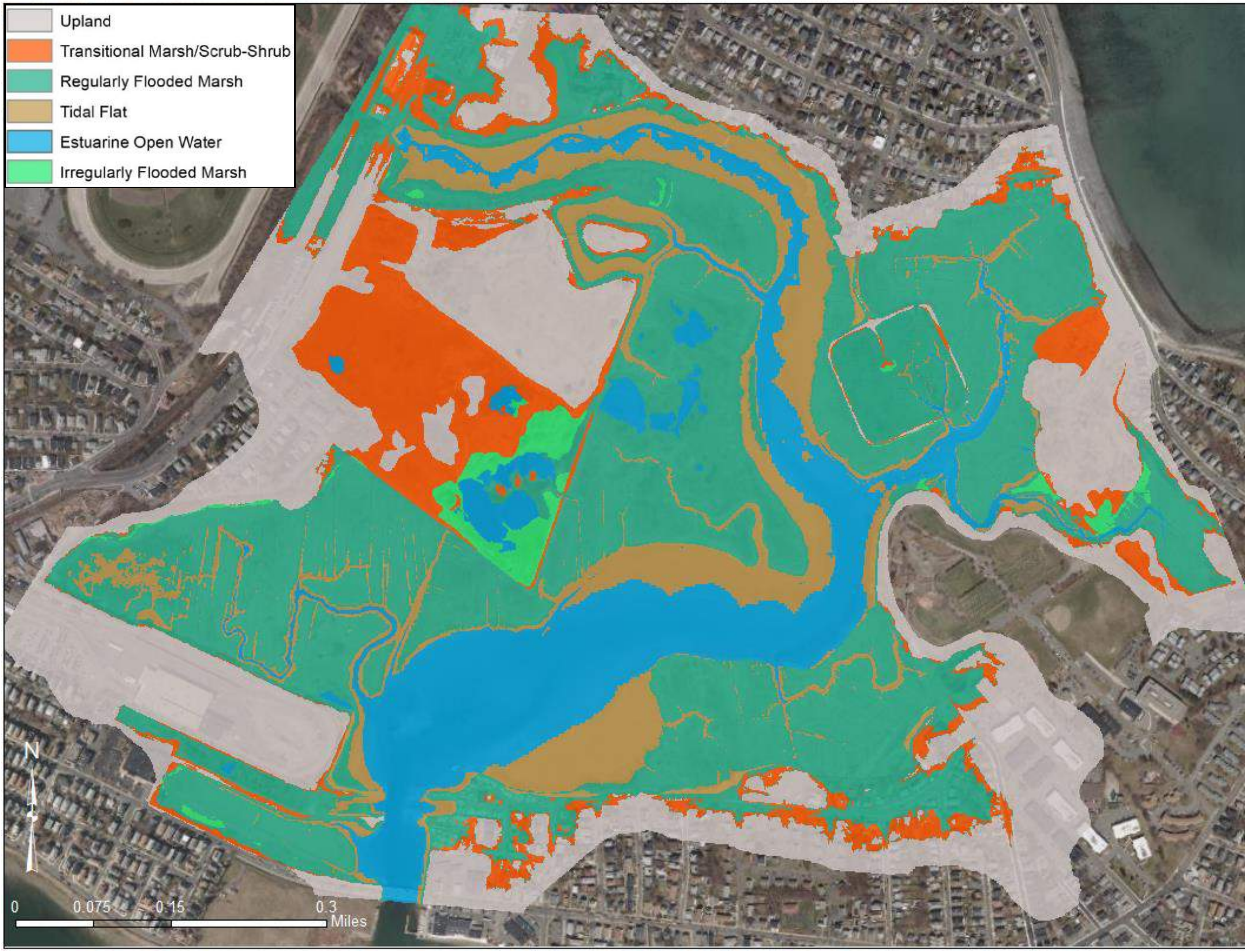

Figure 8. SLAMM modeling results for Belle Isle Marsh and the surrounding area during 2070.

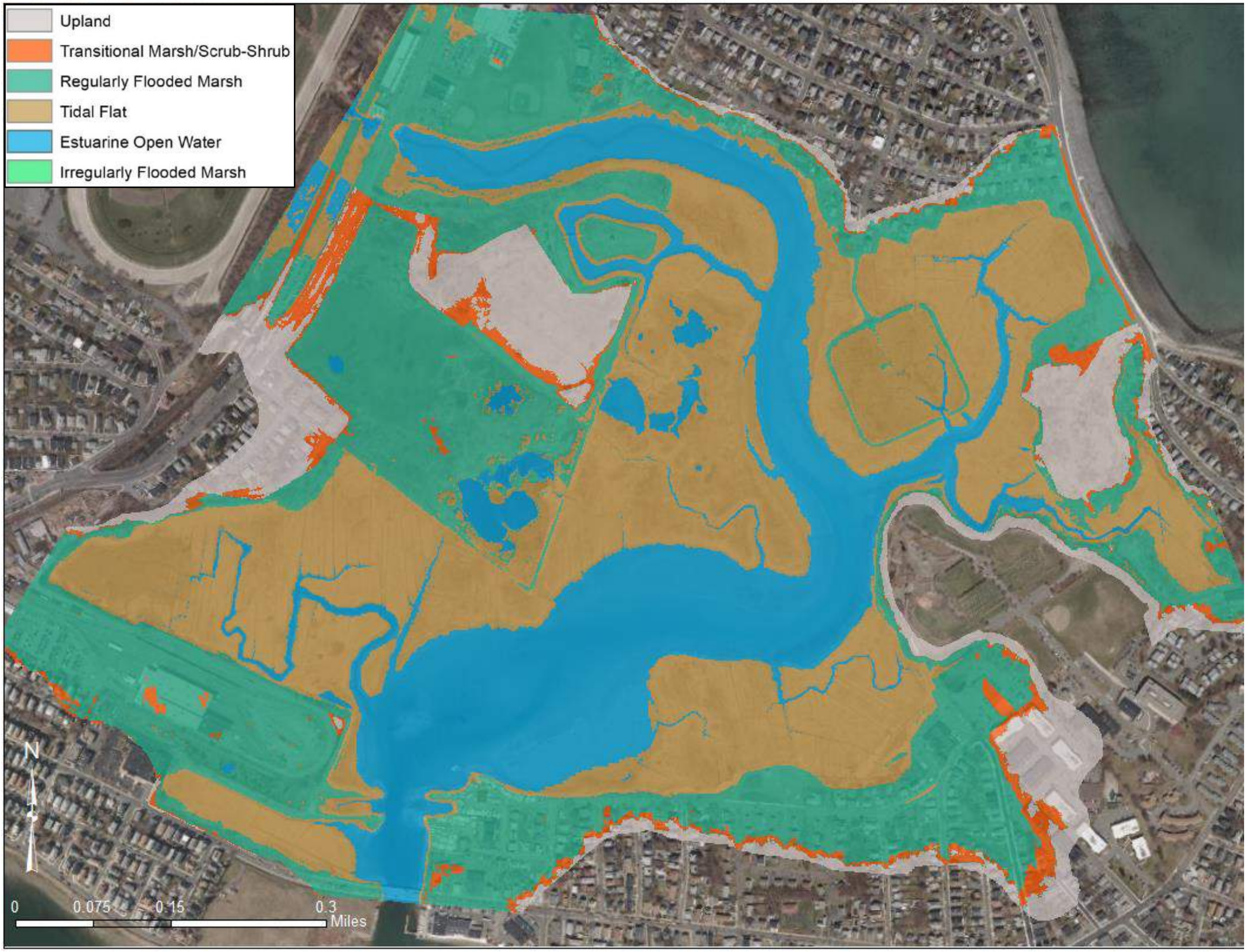

Figure 9. SLAMM modeling results for Belle Isle Marsh and the surrounding area during 2100.

3.1 Existing Conditions

The Belle Isle Marsh is an estuarine wetland system, encompassing of a whole range of wetland resource areas, which occupy specific elevation ranges . From low to high elevation, the basic resource areas modelled in SLAMM are: estuarine open water (subtidal), tidal flat (mudflat), regularly flooded marsh (low marsh), irregularly flooded marsh (high marsh), transitional marsh, and upland. Existing conditions are presented in Figure 5 and summarized by habitat below.

<u>Estuarine Open Water</u>

The marsh inlet connects to Boston Harbor at its southern end. The inlet is in a permanently fixed position, defined by the Main St bridge connecting East Boston to Winthrop. The main channel connects from the inlet north to the Sales Creek tide gate at the boundary of Bennington St and Suffolk Downs. The subtidal (i.e. always inundated) extent of the main channel reaches maximum widths over 100 feet. As indicated by tide gauge observations, tidal penetration is nearly unrestricted within the main channel. The tide range at the inlet was measured at 9.7 ft, and the tide range at the very northern boundary with Sales Creek was measured at 9.4 ft, representing an maximum attenuation by ~0.3 ft within the main channel.

<u>Tidal Flat</u>

Adjacent to subtidal habitat is the tidal flat (i.e. mudflat) habitat, which is frequently submerged. Tidal flats serve as habitat for benthic invertebrates and shellfish, and serve as foraging space for several bird species such as least tern and piping plovers. Mudflat habitat exists in both the main channel and secondary channels (i.e. tidal creeks).

<u>Low Marsh</u>

Adjacent to mudflat, a low marsh platform characterizes a large extent of the marsh. The low marsh supports *Spartina alterniflora* cordgrass and may provide storm surge attenuation benefits. This topic is targeted for future study as a task of a Belle Isle Marsh Municipal Vulnerability Preparedness project.

<u>High Marsh</u>

Adjacent to low marsh exists the high marsh habitat. High marsh habitat, dominated by *Spartina patens* (saltmeadow-hay grass) exists in the upper end of the daily tidal range, and is limited in extent throughout Belle Isle Marsh. The saltmarsh sparrow is the only species of breeding bird endemic to salt marshes of the Northeast. The saltmarsh sparrow nests on or near the ground, just above high tide levels in the cordgrass of high marsh.

<u>Transitional Marsh</u>

Transitional marsh and upland areas occupy the remaining space within the Belle Isle Marsh project area. Transitional marsh is defined as the area just above high marsh, and often represents space within which marsh habitat would migrate upland and inland as sea level rises.

<u>Upland</u>

Upland areas are developed areas surrounding Belle Isle Marsh on all sides, including residential and major development in East Boston, Revere, and Winthrop. Critical infrastructure in these areas include MBTA railyard and Blue Line infrastructure, Suffolk Downs, critical evacuation roadways such as Main St, Bennington St, and the Winthrop Parkway, community supporting resources such as Revere Public Schools, and a power station in Winthrop.

Unique areas within Belle Isle Marsh include salt pannes and bermed areas. Salt pannes exist within the high marsh and transitional habitat, most significantly nearby Belle Isle Marsh Reservation park and behind the L-berm.

Salt pannes were observed to fill with seawater during the highest tides, but are otherwise disconnected from the hydraulic system of the marsh and serve as retention areas for rainwater. Shorebirds utilize salt pannes for feeding on fish and insects. The L-berm and the Key berm areas are reaches of Belle Isle Marsh which were historically filled for purposes of upland development. The L-berm acts as a barrier to tidal penetration between the main channel and the upland Belle Isle Marsh Reservation park salt panne, meadows and forest. The Key berm is a square shaped area in the eastern marsh, which was constructed to protect a World War II radio tower, and now restricts tidal circulation to the low marsh within.

During present day, wetland delineation conducted in the field (and utilized as the initial wetland conditions in SLAMM) indicates that Belle Isle Marsh is dominated by upland (159 acres), closely followed by regularly flooded marsh (121 acres) and then by estuarine beach/tidal flat (67 acres). Less prevalent habitats present include transitional marsh/scrub-shrub, estuarine open water, and irregularly flooded marsh. Note that additional SLAMM wetland categories, such as nontidal swamp or ocean flat, are not present during present day conditions, nor are they predicted to occur in the future based on SLAMM modeling.

3.2 Year 2030 – 1.29 ft of Sea Level Rise

Following 1.29 ft of sea level rise by year 2030, changes predicted to occur in Belle Isle Marsh include a decrease in all habitats besides estuarine open water, which is projected to significantly increase by 14 acres (Figure 6 and Table 5). Estuarine open water increases most within the main channel as it increasingly occupies space currently defined as tidal flat. Additionally, subtidal habitat begins to reach penetrate further into tidal creeks. Tidal flats see the greatest loss to 1.29 ft of SLR of any habitat type (-10 acres). Low marsh habitat persists through year 2030 with no significant change. The bermed areas of Belle Isle Marsh, within the Key and upland of the L-Berm, do not see significant change. There is little change to low marsh and high marsh, except for the migration of about 1 acre of high marsh into inland transitional areas. However, this migration would be impeded by impervious surfaces under current development conditions. Upland habitat is projected to decrease by 3 acres, indicating marsh habitat begins to migrate upland and inland with SLR.

3.3 Year 2050 – 2.49 ft of Sea Level Rise

Following 2.49 ft of SLR by year 2050, a continued increase in estuarine open water is projected, with a gain of 5 additional acres (Figure 7 and Table 5). Open water gains correspond to a loss of tidal flat (-3 acres). While subtidal habitat expands, mudflat is unable to migrate into low marsh habitat due to the steep scarp which exists between mudflat and the low marsh platform. As a result, subtidal habitat encroaches on low marsh habitat, and increases the opportunity for limited wave and tidal current action to impact and potentially erode the edge of marsh. There is a modeled gain of 19 acres of low marsh as it migrates into high marsh areas south of the MBTA railyard in East Boston. There is also a projected gain of 7 acres of transitional marsh (7 acres). Low marsh and transitional marsh gains correspond to a loss of high marsh (-7 acres) and a loss of upland area (-3 acres).

The two bermed areas do not change significantly, neither does the tidal creek and low marsh habitat abutting Winthrop. Expansion of estuarine open water will not be impeded by any current existing impervious areas. However, migration of approximately 1,300 square feet (sf) of tidal flat and 2,000 sf of regularly flooded marsh will be impeded by impervious surface.

3.4 Year 2070 – 4.29 ft of Sea Level Rise

Following 4.29 ft of SLR by year 2070, wetland areas that increase include regularly flooded marsh (28 acres) and estuarine open water (24 acres) (Figure 8 and Table 5). These habitats expand into adjacent areas, where losses are projected in upland (-33 acres) transitional marsh (-1 acres), irregularly flooded marsh (-5 acres), and tidal flat (-13 acres). Near the inlet, subtidal habitat in the main channel overtops almost all tidal flat and abuts low marsh. As a result, wave action will further interact with low marsh habitat and potentially increase edge erosion. Low marsh is shown to persist through year 2070, maintaining most of its existing extent indicating that the marsh platform exists near the top of its viable elevation range. Low marsh habitat struggles to migrate inland in East Boston, likely due to the steep banks circumscribing the marsh by the MBTA railyard and former casket company parcel. Low marsh habitat migrates into low elevation residential neighborhoods of Winthrop and Revere. Additionally, transitional habitat migrates into Bennington St, Suffolk Downs, and Revere Public Schools. High marsh struggles to migrate into transitional habitat. By 2070, a much greater degree of wetland migration will be prevented by development. Transitional marsh and regularly flooded marsh will be prevented from migrating and these wetland types will be lost to sea level rise without the ability to shift location. No significant change is projected in the bermed areas of the Key and L-berm in 2070.

3.5 Year 2100 – 7.69 ft of Sea Level Rise

Following 7.69 ft of SLR by year 2100, wetland areas see the most extreme change of any timestep. Habitat acreage increases are seen in subtidal habitat (25 acres) and tidal flat (118 acres). Habitat acreage losses are projected in low marsh (-45 acres), high marsh (-4 acres), transitional marsh (-26 acres), and upland (-67 acres) (Figure 9 and Table 5). The subtidal habitat is anticipated to continue its expansion within the main channel and tidal creeks. Tidal flats are anticipated to finally make the jump onto what today is the low marsh platform, and as a result this habitat reverses its downward trend and expands dramatically in area. Low marsh within the Key berm converts to tidal flat as well. The low marsh is pushed out of its existing footprint and migrates almost entirely into and throughout adjacent jurisdictions, what is today the L-berm area, and developed/impervious land of East Boston, Revere, and Winthrop. Belle Isle Marsh almost entirely converts to a subtidal and mudflat wetland system with the L-berm are representing the only remaining viable marsh habitat within the Reserve. High marsh habitat is further squeezed out of functional space, as it struggles to migrate into transitional areas. Transitional habitat migrates further into the developed areas of East Boston, Revere, and Winthrop, and would also be expected to expand far beyond the project area boundary.

Multiple iterations of SLAMM analysis, paired with hydrodynamic modeling performed as a parallel task to SLAMM, was required to achieve reasonable projections of marsh migration behind the L-berm. Hydrodynamic model water level results were obtained behind the L-berm at the 2030, 2050, and 2070 planning horizons and manually input to represent tidal conditions at the L-berm. This allowed for the recognition that from the perspective of land elevation and tidal penetration, the L-berm can serve as future marsh habitat in long-term sea level rise scenarios. In this project, the tipping point for converting the L-berm to low marsh habitat occurs around 2080.

3.6 SLAMM Summary

Belle Isle Marsh habitat migration with sea level rise is characterized in two phases:

- **Present day to 2070:** Changes that occur from 2020 to 2070 include gains in estuarine open water (43 acres), low marsh (48 acres), and transitional marsh (4 acres). The most significant corresponding losses occur in tidal flat (-26 acres) and upland (-57 acres). High marsh losses are observed at a smaller scale (-12 acres), however, this represents over 70% of its current footprint. The increases in low marsh and transitional marsh are only able to become reality if development retreats and open space is provided for this migration.
- **2070 to 2100:** Changes that occur from 2070 to 2100 include gains in estuarine open water (25 acres) and tidal flat (118 acres). Significant corresponding losses occur in low marsh (-45 acres), high marsh (-4 acres), transitional marsh (-26) and upland (-67 acres). This represents a near complete conversion of the existing marsh habitat to open water and mudflat. Low, high, and transitional marsh habitat attempt to migrate inland and upland but will meet the barriers in existing development, except in the L-berm area where open space currently exists in the Reserve.

Subtidal habitat is found to continuously expand, increasing by 309% in acreage by year 2100. The main channel specifically increases in width by up to 100's of feet, potentially increasing marsh vulnerability as wave and tidal current forces may increase.

The year 2080 was found to represent a tipping point between the tidal flat and low marsh relationship. Low marsh was noted to persist through 2070. The Massachusetts Statewide SLAMM model (WHG 2016) projects low marsh to generally be converted to tidal flats under a 4.29 ft SLR scenario. However, at Belle Isle Marsh, low marsh habitat exists within the high end of its viable elevation range. With small amounts of marsh accretion (~2.8 mm/yr), the low marsh will be maintained through about year 2080 (5.29 ft SLR). This persistence of low marsh results in a loss of tidal flat, as tidal flats are squeezed between increasingly widening and deepening channels. Beyond 2080, the effects of sea level rise on low marsh reach a tipping point, where tidal inundation overtops the low marsh platform at an increased frequency and it converts nearly entirely to tidal flat, converting the marsh into a primarily subtidal/mudflat condition. It is anticipated that low marsh will continuously encroach on upland developed areas, especially the areas of the MBTA Blue Line/Suffolk Downs, Revere Public Schools, residential areas of Revere, and residential areas of Winthrop, especially along Morton St.

High marsh habitat most notably struggles to migrate into transitional areas, and there is a projected 94% loss of high marsh acreages from present day through 2100. This result is critical to the saltmarsh sparrow as the high marsh is the only viable nesting habitat for saltmarsh sparrow. The population has declined 85% since 1995 and is predicted to become extinct by year 2050.

Transitional marsh is observed to over time migrate into East Boston especially in the MBTA railyard, the Town of Revere by Sales Creek tide gate, and Winthrop residential areas. Through year 2070, the perimeter of the marsh in many reaches is too steep in elevation for habitat to migrate inland and upland with SLR. However, by 2100, low marsh and transitional habitats are projected to nearly entirely migrate out of the current marsh area and into low-lying areas of the surrounding communities. This is indicated by the estimated 78% loss in upland acreage between present day and 2100. If developed areas were not present, marsh habitat could potentially persist, migrating inland and upland in relation to sea level rise. However, under the current heavily developed conditions surrounding Belle Isle Marsh, marsh habitat is not likely to successfully migrate with sea level rise, and Belle Isle Marsh would no longer support extensive vegetated marsh habitat.

4.0 Next Steps

Belle Isle Marsh habitat is threatened by sea level rise. Tidal flat and the critical high marsh habitat are projected to decrease in acreage through 2070, while low marsh habitat may persist. However, by year 2100, the entire Belle Isle Marsh system is expected to convert to a predominantly subtidal and tidal flat habitat. In order to protect Belle Isle Marsh and for inland development to continue benefiting from storm damage and flood protection, management practices should focus on the following key areas:

- Areas where marsh elevation is not accreting, and is not sloped to promote gradual marsh migration,
- Areas where marsh migration is predicted to occur but would be impeded by existing development,
- Areas where steep slopes prevent the gradual migration of marsh habitat inland and upland,
- Areas where tidal flows are attenuated or nearly fully restricted by topography, which consequently limit the accretion, migration, and expansion of habitat, and
- Areas where increased open water fetch may create vulnerabilities in marsh edge erosion.

The Belle Isle Marsh complex contains a wide variety of habitat types and unique anthropogenic influences which have resulted in areas with distinct characteristics and function. As a result, marsh-wide generalizations do not bring clarity to developing management actions. The marsh was divided into eleven management areas for developing restoration alternatives which can address the specific concerns of each unique area. Belle Isle Marsh Management Areas are depicted in Figure 10, and the vulnerability results are organized by area in Table 6. Table 6 environmental vulnerability presents results from literature reviews, data collection, and EFDC existing conditions modeling in addition to the above SLAMM exercise. Next steps will utilize vulnerability results in combination with owner and stakeholder values, priorities, and goals to develop restoration alternatives. The top 2-3 restoration alternatives will then be modeled in EFDC to assess effectiveness and refine design.

Table 6. Environmental Vulnerability of Belle Isle Marsh Management Areas

No.	Management Areas	Environmental Vulnerability
1	Lower Main Channel	Sea level rise causes habitat conversion: • Subtidal habitat expansion, • Wave energy and tidal current velocities may increase and exacerbate marsh erosion. Tidal current velocities pull sediment loose and cause calving and erosion of marsh edge. Increased velocities would exacerbate this issue. Marsh habitat is squeezed between development and the ocean (i.e. coastal squeeze) Saratoga Bridge is a source of minor tidal constriction
2	Upper Main Channel	Sea level rise causes habitat conversion: • Subtidal habitat expansion, • Transitional marsh wants to migrate into developed areas of East Boston and Revere, • Upland areas vulnerable to marsh migration, tidal inundation, and especially storm flooding. Flooding of supporting and surrounding assets and infrastructure predicted to increase in frequency and damage • Wave energy and tidal current velocities may increase and exacerbate marsh erosion. Tidal current velocities pull sediment loose and cause calving and erosion of marsh edge. Increased velocities would exacerbate this issue. Marsh habitat is squeezed between development and the ocean (i.e. coastal squeeze) Sales Creek Tide Gate is point source for widely collected freshwater discharge and coliform bacteria. Upstream sediment impoundment reduces ability of marsh to capture sediment and increase in elevation with sea level rise. Pump station pump events dramatically freshen the system and decrease water clarity Extensive phragmites in the Reservation park area. Phragmites does support rare and common nesting birds
3	Excel Academy	Sea level rise causes habitat conversion: • Subtidal habitat expansion, • Mudflat losses through 2080, then jumps onto the low marsh platform and expands greatly • Low marsh persists through 2080, then converts to mudflat

<table>
<tr><td></td><td></td><td>High marsh habitat losses anticipated at all time horizons
Transitional marsh wants to migrate into developed areas of East Boston
Upland areas vulnerable to marsh migration, tidal inundation, and especially storm flooding. Flooding of supporting and surrounding assets and infrastructure predicted to increase in frequency and damage
Marsh habitat is squeezed between development and the ocean (i.e. coastal squeeze)
Runoff washes unmanaged into the marsh from nearby municipalities. Nutrients and chemicals decrease dissolved oxygen, degrade and alter plant structures, and lead to marsh degradation </td></tr>
<tr><td>4</td><td>West Marsh / Rosie’s Pond</td><td> Sea level rise causes habitat conversion:
Subtidal habitat expansion,
Mudflat losses through 2080, then jumps onto the low marsh platform and expands greatly
Low marsh persists through 2080, then converts to mudflat
High marsh habitat losses anticipated at all time horizons (saltmarsh sparrow nesting and foraging habitat)
Transitional marsh wants to migrate into developed areas of East Boston
Upland areas vulnerable to marsh migration, tidal inundation, and especially storm flooding. Flooding of supporting and surrounding assets and infrastructure predicted to increase in frequency and damage
Marsh habitat is squeezed between development and the ocean (i.e. coastal squeeze)
Marsh migration is not feasible in most low-lying areas due to steep slopes around the perimeter, backed by developmentRevitalize degraded wetland.
Runoff washes unmanaged into the marsh from nearby municipalities. Nutrients and chemicals decrease dissolved oxygen, degrade and alter plant structures, and lead to marsh degradation
Perched tides cannot properly drain in certain areas, leading to quasi-salt panned development, such as Rosie’s Pond in the western area by Austin St/MBTA railyard.
Mosquito ditches drain water from most of the marsh surface, eliminating salt pannes and small tidal creeks.
Marsh ditching during the past century has led to partial drying and lowering of the marsh bed.
This eliminated killifish habitat, resulting in loss of ecological function and continued mosquito population issues. Improve stormwater and tide water conveyance.</td></tr>
<tr><td>5</td><td>Central Marsh</td><td> Sea level rise causes habitat conversion:
Subtidal habitat expansion,
Mudflat losses through 2080, then jumps onto the low marsh platform and expands greatly
Low marsh persists through 2080, then converts to mudflat
High marsh habitat losses anticipated at all time horizons</td></tr>
</table>

		Mosquito ditches drain water from most of the marsh surface, eliminating salt pannes and small tidal creeks. • Marsh ditching during the past century has led to partial drying and lowering of the marsh bed. • This eliminated killifish habitat, resulting in loss of ecological function and continued mosquito population issues. Improve stormwater and tide water conveyance.
6	L-Berm	Sea level rise causes habitat conversion: • Subtidal habitat expansion, • High marsh habitat losses anticipated at all time horizons (saltmarsh sparrow nesting and foraging habitat) • Salinity is increasing around deciduous trees in the transitional zone/coastal thickets, causing die off and "ghost forests" Marsh habitat is squeezed between development and the ocean (i.e. coastal squeeze) L-berm is a barrier to tides and drainage, as is the upland fill material placed behind the L-berm Marsh migration is not feasible in most low-lying areas due to steep slopes around the perimeter, backed by development Extensive phragmites in the Reservation park area behind the L-Berm. Phragmites does support rare and common nesting birds. Japanese Honeysuckle established in transitional marsh/coastal thickets. Multiflora Rose and other invasive trees (Black Locust, Eastern Cottonwood, Tree of Heaven, Quaking Aspen and Norway Maple) in upland habitat/mid-canopy woodland do not maximize habitat value. Runoff washes unmanaged into the marsh from nearby municipalities. Nutrients and chemicals decrease dissolved oxygen, degrade and alter plant structures, and lead to marsh degradation
7	Grassland Meadow / Main Park	Main Park is squeezed between development and the ocean (i.e. coastal squeeze)
8	Morton St Marsh / Belle Isle Marine Ecology Park	Sea level rise causes habitat conversion: • Subtidal habitat expansion, • Mudflat losses through 2080, then jumps onto the low marsh platform and expands greatly • Low marsh persists through 2080, then converts to mudflat • High marsh habitat losses anticipated at all time horizons • Transitional marsh wants to migrate into developed areas of Winthrop • Upland areas vulnerable to marsh migration, tidal inundation, and especially storm flooding. Flooding of supporting and surrounding assets and infrastructure predicted to increase in frequency and damage Marsh habitat is squeezed between development and the ocean (i.e. coastal squeeze)

		Runoff washes unmanaged into the marsh from nearby municipalities. Nutrients and chemicals decrease dissolved oxygen, degrade and alter plant structures, and lead to marsh degradation Mosquito ditches drain water from most of the marsh surface, eliminating salt pannes and small tidal creeks. • Marsh ditching during the past century has led to partial drying and lowering of the marsh bed. • This eliminated killifish habitat, resulting in loss of ecological function and continued mosquito population issues. Improve stormwater and tide water conveyance.
9	The Key	Sea level rise causes habitat conversion: • Low marsh persists through 2080, then converts to mudflat • High marsh habitat losses anticipated at all time horizons Key berm constricts tides to anthropogenically influenced marsh
10	East Marsh / Short Beach	Sea level rise causes habitat conversion: • Subtidal habitat expansion, • Mudflat losses through 2080, then jumps onto the low marsh platform and expands greatly • Low marsh persists through 2080, then converts to mudflat • High marsh habitat losses anticipated at all time horizons • Transitional marsh wants to migrate into developed areas of Revere and Winthrop • Upland areas vulnerable to marsh migration, tidal inundation, and especially storm flooding. Flooding of supporting and surrounding assets and infrastructure predicted to increase in frequency and damage Marsh habitat is squeezed between development and the ocean (i.e. coastal squeeze) Runoff washes unmanaged into the marsh from nearby municipalities. Nutrients and chemicals decrease dissolved oxygen, degrade and alter plant structures, and lead to marsh degradation Mosquito ditches drain water from most of the marsh surface, eliminating salt pannes and small tidal creeks. • Marsh ditching during the past century has led to partial drying and lowering of the marsh bed. • This eliminated killifish habitat, resulting in loss of ecological function and continued mosquito population issues. Improve stormwater and tide water conveyance.
11	Revere St Marsh / John Kilmartin Pathway	Sea level rise causes habitat conversion: • Subtidal habitat expansion, • Mudflat losses through 2080, then jumps onto the low marsh platform and expands greatly • Low marsh persists through 2080, then converts to mudflat • High marsh habitat losses anticipated at all time horizons

		• Transitional marsh wants to migrate into developed areas of Winthrop • Upland areas vulnerable to marsh migration, tidal inundation, and especially storm flooding. Flooding of supporting and surrounding assets and infrastructure predicted to increase in frequency and damage Marsh habitat is squeezed between development and the ocean (i.e. coastal squeeze) Runoff washes unmanaged into the marsh from nearby municipalities. Nutrients and chemicals decrease dissolved oxygen, degrade and alter plant structures, and lead to marsh degradation Mosquito ditches drain water from most of the marsh surface, eliminating salt pannes and small tidal creeks. • Marsh ditching during the past century has led to partial drying and lowering of the marsh bed. • This eliminated killifish habitat, resulting in loss of ecological function and continued mosquito population issues. Improve stormwater and tide water conveyance.

Figure 10. Belle Isle Marsh Management Areas

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Appendix C: Belle Isle Marsh Climate Vulnerability Assessment – Task 2.4 Strategy Identification

MEMORANDUM

DATE June 30, 2022 **JOB NO.** 2020-0076-01

TO Catherine Pedemonti
Mystic River Watershed Association
20 Academy Street, Suite 306
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FROM Conor Ofsthun, Nasser Brahim
Woods Hole Group, Inc.

Belle Isle Marsh – Climate Vulnerability Assessment – MVP Task 2.4 Strategy Identification

1.0 Introduction

This Technical Memorandum is prepared for the Town of Winthrop and Mystic River Watershed Association (MyRWA) in support of the FY22 Municipal Vulnerability Preparedness grant titled "Belle Isle Marsh – Climate Vulnerability Assessment." As discussed in previous task memorandums, present and future flood risk to Belle Isle Marsh and the surrounding communities is significant. Coastal storm-induced flooding is a significant concern amongst the members of East Boston, Revere, Winthrop, as well as those who work in and/or utilize the services of these areas. Additionally, SLR threatens to not only cause an up-shift in the high-water levels experienced during storms, but also threatens to impact the natural function of the marsh. SLR gradually causes normal high tides to inundate higher elevation marsh habitat, which leads to the conversion of wetland resource areas. This threatens the wildlife that relies on specific marsh habitat and diminishes the environmental co-benefits received by the community from the marsh. The Climate Vulnerability Assessment aims to evaluate the current and future coastal flood hazards affecting Belle Isle Marsh and the surrounding communities, and develops a series of mutually beneficial natural nature-based solutions (NBS) that will both enhance the health of the marsh while providing the surrounding communities resiliency in the face of SLR and storm hazards.

This memo is organized as follows. First, to establish a basis for adaptation strategy identification, a consolidated list of priorities and values are used to inform adaptation goals. To achieve such goals, a toolbox of adaptation strategies is discussed. Adaptation strategies will vary depending upon existing habitat, topography, development, and criticality of the vulnerable area or infrastructure. This is followed by the identification of management reaches and development of strategies specific to each reach. Adaptation strategies consider a range of potential nature-based and hybrid solutions to both optimize marsh health and longevity and protect inland communities and supporting infrastructure in the short- and long-term.

This work builds upon all other on-going tasks in support of this project, including: modeling of present and future marsh tidal hydrodynamics (Task 2.1), literature review of climate vulnerability plans by abutting public and private landowners (Task 2.2), analysis of flood probabilities and pathways with sea level rise (Task 2.3), quantification of storm surge and wave mitigation by marsh elevation and vegetation (Task 2.5), and community and stakeholder discussion and feedback (Task 2.6 and Task 2.7).

2.0 Priorities and Values

Priorities and values were developed through a combination of literature research, discussions with stakeholders and the public, and outcomes of the on-going parallel project managed by MyRWA. Priorities and values are explored to provide a basis for developing adaptation goals. Through research and discussion, priorities and values common to the greater project team include:

- Flood Protection
    - Storm surge and sea level rise protection are needed for surrounding communities
    - Wave attenuation benefits of marsh and transitional/upland habitat
    - Low-lying flood pathways are recognized to present a risk to communities
    - Erosion control and protection of infrastructure/development is needed
    - Stormwater conveyance and discharge requires enhancement
    - Managed retreat may need to be considered to ensure space for floodwater accommodation and to reduce damage or disruption to community assets
- Habitat Quality and Biodiversity
    - Habitat diversity and connectivity, food web support, and biodiversity support long-term ecological resilience
        - Marsh habitat supports critical flora and fauna biodiversity, and it is a sanctuary among an urban setting
        - Marsh habitat is a breeding ground for threatened/endangered species (e.g., saltmarsh sparrow)
        - Preserve rare habitat, wildlife, and biodiversity, both wetland and upland
        - Enhance wildlife corridors within an urban setting
        - Restore the natural condition of the marsh
    - High marsh habitat is a critical nesting habitat for saltmarsh sparrow, and is limited and threatened within the marsh
        - High marsh habitat in the region is the only viable habitat for saltmarsh sparrow nests. Saltmarsh sparrow is predicted to become a listed federally threatened & endangered species by 2023.
        - Sea level rise threatens saltmarsh sparrow. They are predicted to go extinct by 2050 without intervention
    - Transitional/upland habitat serves wildlife and communities
        - Provides an elevation buffer between ocean and development, and acts as open space for future marsh migration
        - Forest has been found to support long-eared owls. Trees in transitional areas are dying from increased salinity
        - Grassland meadow, especially the 12-acre area in the main park, is considered an important and rare habitat. This is the only natural meadow for miles. Supports the important Meadow Vole and critical pollinator species
        - Fresh water pools support species of concern and endangered species.
    - Enhancing and preserving water quality
        - Sediment and nutrient cycling
        - Chemical and metal retention
        - Pathogen removal
    - Carbon storage for climate change mitigation
- Community Support and Engagement
    - Emphasize multi-jurisdictional and inclusive approach to developing solutions
    - Maintain and enhance aesthetic and recreational value

        - Socio-economic services to humans such as aesthetics, natural heritage, recreation/ecotourism, education, physical and psychological health
        - Belle Isle is a popular space for visitors to find relief from the stresses of the city and pandemic
        - Balance human and wild qualities of Belle Isle
    - Emphasize community engagement
        - Engage historically underserved communities
    - Provide ongoing educational science and monitoring programs

3.0 Adaptation Goals

The intersection of priorities and values with marsh vulnerability and flood risk led to the identification of adaptation goals. Goals will be used to inform short-term and long-term adaptation strategy recommendations. Adaptation goals are listed below:

- Expand and enhance transitional/upland areas for flood protection and accommodation
    - Target low-lying flood pathways
    - Create gently sloped or terraced features which can serve as existing or future marsh habitat
    - Attain critical elevation for flood protection under design storm scenario
    - Retreat assets and infrastructure which are flexible to relocation/removal
- Address marsh erosion
    - Target areas with poor drainage and degraded marsh habitat, such as Rosie's Pond
    - Focus on edge erosion, especially in Winthrop
    - Maximize marsh habitat where it is squeezed between ocean and development. For example, marsh creation or enhancement could return habitat to previously eroded areas. Additionally, inland assets could be retreated, such as reducing a two-lane road to one-lane, to create space for new marsh habitat.
    - Living shoreline stabilization as a regenerative buffer against storm waves. For example, an oyster reef can dissipate wave energy while providing habitat for oysters shelter for marine life, and enhancing water quality through filtration.
- Enhance vegetation to maximize wave attenuation
    - Enhance low marsh habitat quality for *Spartina alterniflora*
    - Expand transitional scrub such as high tide bush *Iva frutescens*
    - Reconsider pros/cons of phragmites serving as habitat and storm buffer
- Build elevation capacity for resilience to sea level rise
    - Increase elevation of existing habitat areas
    - Create high/transitional marsh habitat for marsh migration
- Expand high marsh area for saltmarsh sparrow and spring tide flood protection
- Maximize social benefit of Belle Isle Marsh, while minimizing human impact to resources
    - Increased, low impact public access.
    - Visitor management
    - Education and outreach

4.0 Management Reaches

The transition between the boundary of Belle Isle Marsh to upland development varies dramatically across jurisdictions, and properties. To better address the unique issues throughout the region, the shoreline has been broken down into thirteen (13) reaches circumscribing the marsh and totaling a length of over 4.5 miles (**Error! Reference source not found.**). These reaches were determined based on a general uniformity of shoreline type (i.e., asset/infrastructure type, habitat type) and extent and severity of flood risk, determined by previous tasks.

Given the number and extent of reaches, it is important to prioritize reaches which may require more urgent attention to mitigate flood risk. Following the flood risk and future conditions analyses of prior project tasks, the following five priority reaches were selected to facilitate stakeholder discussions of critical flood pathways and adaptation on June 16th, 2022:

- Morton St / Marine Ecology Park
- Fredericks Park
- Bennington St
- Rosie’s Pond
- Short Beach

Figure 1. Belle Isle Marsh Management Reaches

5.0 Strategy Identification

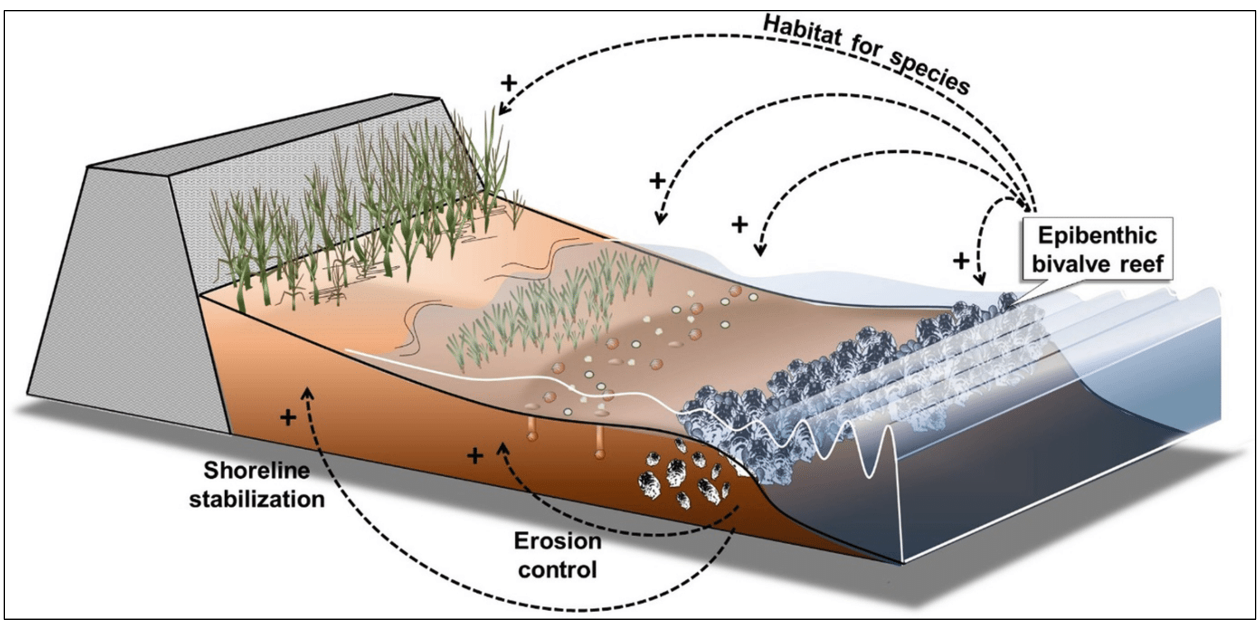
The following summarizes a series of strategies aimed at achieving the above adaptation goals. NBS can be effective in reducing erosion and the risk of storm surge and flooding, such as raising the marsh elevation, installing fiber rolls/native vegetation, or installing a vegetated berm. However, NBS are not necessarily feasible or effective in all cases. In such cases, hybrid solutions may be necessary which combine "green," nature-based solutions with "grey," hard infrastructure. The following is a "toolbox" of adaptation alternatives that summarizes various approaches to preserving the marsh and providing resiliency to the shoreline and inland communities affected by flooding by way of the marsh. This is followed by a focusing of adaptation alternatives along management reaches.

5.1 Adaptation Toolbox

- No Action
    - No action may be preferable in areas with little to no flood risk.
    - No action may be preferable in areas where NBS are infeasible.
- Salt Marsh Restoration for Marsh Resilience
    - Marsh restoration includes the dredging, grading, cutting, or filling of marsh platforms and channels, and enhancing vegetation to create and/or restore salt marsh habitats.
        - Restore marsh in degraded and eroded areas.
        - Enhance areas where perched tides (i.e., ponding) degrade marsh habitat
        - Maximize areas of high salt marsh (i.e., areas vegetated by Spartina patens, Distichilis spicata, Juncus gerardii, etc.) to provide habitat for saltmarsh sparrow and low marsh migration with sea level rise.
        - Increase the transitional/upland natural buffer area between marsh and development. A larger buffer area would help filter particles and pollutants before they reached the marsh
    - Open Marsh Water Management (OMWM)
        - This technique employs the filling of ditches and creation of runnels to reverse the impacts of historic mosquito ditching.
        - May prevent further subsidence, reduce the rate of marsh loss, and possibly even gradually elevate the marsh bed through sediment trapping, all of which serve to enhance the marsh as a storm surge buffer.
        - Co-benefits include mosquito control. Creates an appropriate habitat for the natural enemies of the mosquitoes; and reduces flooding in areas that are not wet on an ordinary basis which reduces the environment that would support mosquitoes but not their predators. Consider plugging grid ditches, strategically re-establishing salt pannes and improving small meandering tidal creeks, to enhance killifish and bird foraging habitat.
- Engineered Sill for Marsh Toe Protection
    - Rock sill for wave dissipation and sediment stabilization, see below image from Watson Park, Braintree, MA for an example of a recently constructed marsh with rock sill.

- Oyster sill for water quality enhancements in addition to wave dissipation and sediment stabilization
- Hybrid sill structure constructed of materials which encourage marine growth and oyster reef establishment

- Living Breakwater for Marsh Toe Protection
    - Living breakwater/oyster restoration can be installed to improve water quality through filtration, dampen wave energy, protect marsh edge, and encourage sediment accretion. See below schematic by the Nantucket Conservation Foundation showing the major functions of an oyster reef



- Thin Layer Deposition (TLD)
    - Raise marsh habitat elevation to build saltmarsh resilience in the face of sea level rise. *Note that TLD alone is not sufficient to mitigate storm flooding, and is intended to be part of a holistic approach to adaptation.*
    - Maintain the benefits provided by the marsh into the future, including shoreline stabilization, storm surge and wave attenuation, elevation buffer between ocean and development, and filtration of polluted water.
    - Consider 1) where the material would come from, and 2) how it would be transported to the site and spread across the marsh.
    - Note that TLD has not been successfully permitted in Massachusetts. However, several resource agencies are interested in exploring and piloting this approach in the future.
- Living Levee
    - Re-grade slopes to be gently sloping or terraced from low marsh to critical flood elevation
    - Facilitate future marsh migration by properly designing high and transitional marsh and upland areas
    - Plant vegetation for habitat enhancement as well as storm surge and wave attenuation
    - Attain critical crest elevation for storm flood protection through construction of vegetated earthen berm
    - Consider incorporation of an engineered core which can serve multiple purposes such as inhibiting flooding through permeable material, and providing a hardened "last line of defense"
- Beach nourishment and dune restoration
    - Along historically classified beach and dune habitat areas, import sediment for nourishment, dune restoration, and plant beach grass vegetation.
    - Stabilize shorelines, provide flood protection, increase public access, and enhance habitat
- Stormwater management
    - Collect and treat stormwater in rain gardens
    - Convey stormwater flows to the harbor to reduce ponding-related die off and edge erosion
- Hard infrastructure
    - Seawalls, revetments, and breakwaters may be employed to stabilize shorelines and attain critical design elevations for flood protection
- Public access trails and signage
    - Create or convert elevated trail systems to provide flood protection in addition to public access
- Flood Control – Saratoga St Water Level Control Structure
    - A water level control structure at the Belle Isle Marsh inlet could control tide and storm surge levels within the marsh to allow for storm protection (short-to-mid-term) and marsh resiliency (long-term). It is important to note that multiple flood pathways threaten Belle Isle Marsh and surrounding communities, and a water level control structure would not be a fix-all.
    - The control structure would likely consist of a series of combination slide/flap gates to allow for full control of the tides. It could be integrated into the Saratoga St. Bridge or potentially into the future East Boston to Winthrop greenway extension.
- Managed retreat
    - Managed retreat can create space for marsh migration, a storm buffer or storm management features, and public access ways.
    - Assets and infrastructure which can be relocated or removed should be investigated

- Assets and infrastructure which endure repetitive damage or loss due to coastal storms should consider managed retreat
  - Discourage development in areas of future marsh migration.
- Monitoring Program
  - Install long-term tide gauge to observe king tide, storm surge, and sea level change within the marsh. This can help inform design criteria for restoration and development.
  - No action and nature-based solutions should be accompanied by a Monitoring and Adaptive Management plan to record the following:
    - Environmental conditions
    - Success or failure to meet goals
    - Triggers for re-assessment (i.e. marsh erosion, lack of vegetation establishment, change in species, etc.)
    - Adaptive management strategies to alter or abandon an approach which is not successful
  - Adaptive management of implemented projects would entail planning phases of monitoring, observation of success and failures, and augmenting the project to capitalize on success and repair the project where components have failed.
- Hybrid Approach
  - Combine the above techniques to create a mosaic of adaptation strategies which serve multiple goals

The living levee alternative is a relatively new approach to both riverine and coastal flooding. In the State of Massachusetts, a project was recently designed and constructed (Spring 2022) at Watson Park in Braintree, MA which exemplifies the balance of habitat enhancement and flood protection achieved by this approach. The Watson Park Shoreline Erosion Mitigation and Coastal Resiliency Project was funded by the MA Office of Coastal Zone Management (CZM) and Town of Braintree. The living levee concept encompasses marsh habitat restoration (stabilized by a sill structure), regrading and planting the coastal bank, and constructing a vegetated berm/pedestrian pathway with an engineered core to provide protection to a specified design flood elevation. The conceptual diagram is provided, Figure 2 and representative before and after photos are provided in Figure 3.

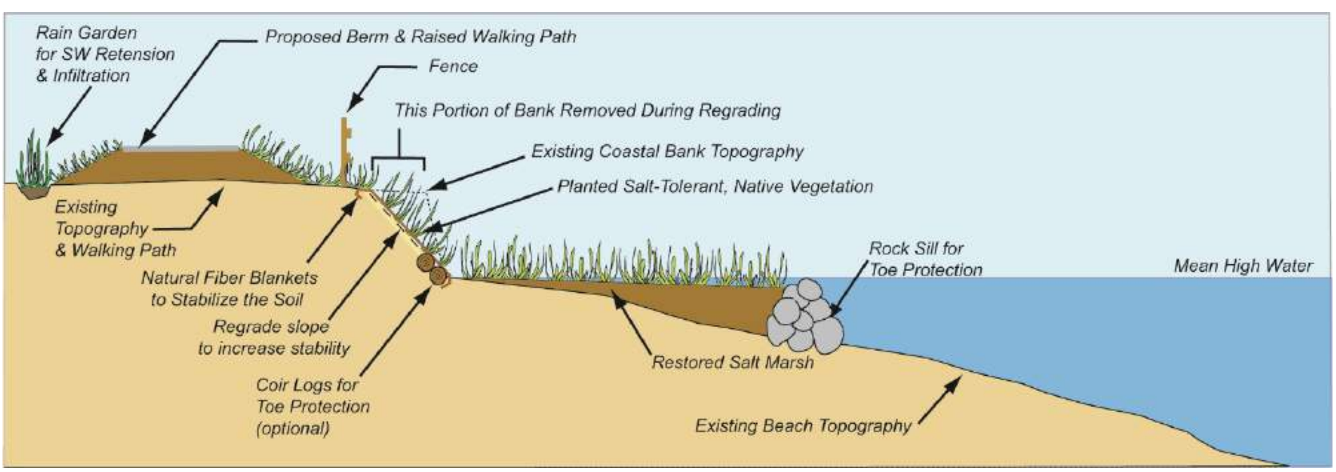


Figure 2. Watson Park Shoreline Erosion Mitigation and Coastal Resiliency Project – Conceptual Diagram

Figure 3. Watson Park Shoreline Erosion Mitigation and Coastal Resiliency Project – Before (left) and After (right), Spring 2022

5.2 Adaptation Strategies along Management Reaches

Tables 1 through 13 summarize adaptation goals specific to each management reach, proposes short-term and long-term alternatives, and identifies monitoring or management which may be necessary. Short-term solutions tend to represent the alternative that is more feasibly implemented in the near-term, while long-term alternatives will typically require a greater lead time for planning. Figure 4 through Figure 16 plan view diagrams roughly approximate the footprint of potential adaptation strategies at each management reach. Tables and figures provide a list of multiple adaptation strategies, some of which may stand on their own, while others may enhance one another if implemented in parallel.

Excel Academy

Table 1. Excel Academy Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Reduce flood risk to Saratoga St. Flood pathway tipping point at approximately 13 ft NAVD88. Reduce flood risk to MBTA railyard and East Boston by mitigating the flood pathway alongside the CVS/Excel Academy. Build marsh health and elevation capacity for resilience to sea level rise.	Mitigate marsh erosion with stabilization approaches such as installing oyster reefs. Construct a living levee around perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Look for opportunities to build flood protection and habitat enhancement into forthcoming East Boston-Winthrop Greenway extension spanning the main channel connecting East Boston Greenway with Belle Isle Marine Ecology Park.	Thin layer deposition (TLD) to build marsh elevation and maintain environmental benefits under SLR. *Note that TLD alone is not sufficient to mitigate storm flooding and is intended to be part of a holistic approach to adaptation.* Proposed pedestrian bridge to connect East Boston Greenway with Belle Isle Marine Ecology Park could be paired with a water level control structure. This would allow water level control within the marsh, preserving marsh habitat under SLR and reducing risk to communities from flooding by way of Belle Isle Marsh. *Note that this water level control structure would not eliminate all flood pathways and would need to be a component of a complex approach to flood protection.*	Vegetation monitoring for living shoreline and marsh restoration approaches. An adaptive management structure would require ongoing monitoring and management of water levels.

Figure 4. Excel Academy Reach – Adaptation Strategies

MBTA Railyard

Table 2. MBTA Railyard Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Soften "bathtub" condition where a steep marsh boundary prevents marsh migration inland. Enhance high and transitional marsh. Reduce flood risk to MBTA railyard. Flood pathway tipping point at approximately 11.1 ft NAVD88.	The Marsh Management Plan proposes Rosie's Pond/West Marsh restoration, including creation of a new tidal creek. This may eliminate the need for the present main channel which, at one point, abuts the MBTA railyard. This portion of the channel could be closed, and converted to low/high marsh, improving protection from tidal inundation under future SLR scenarios.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Lane reduction of MBTA railyard perimeter road to create space for expanded living levee concept. Pair with grey infrastructure, such as a buried seawall or elevated berm to provide a last line of defense to critical infrastructure.	The MBTA is looking into elevated features around their property, such as a seawall. Coordinate all future efforts and look for opportunities to build in nature-based features and resilience.

Figure 5. MBTA Railyard Reach – Adaptation Strategies

Rosie’s Pond

Table 3. Rosie’s Pond Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Mitigate low-lying flood pathway which enters by the Red Gate property (formerly Casket Company) and extends deep into East Boston. Flood pathway tipping point at approximately 10.5 ft NAVD88. Revitalize degraded wetland and improve stormwater discharge. Build marsh health and elevation capacity for resilience to sea level rise.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Space for transitional and upland resilient landscaping would necessarily take place on the Red Gate property. Pair this project with the Marsh Management Plan proposed restoration of Rosie’s Pond to capture complete suite of ecotones from subtidal to upland habitat.	Thin layer deposition across low marsh platform to incrementally raise marsh elevation in parallel with observed sea level rise rates. *Note that TLD alone is not sufficient to mitigate storm flooding and is intended to be part of a holistic approach to adaptation.* Create open space at Red Gate property for future marsh migration. Relocate MBTA railway access road by converting the Orient Heights parking lot/Barnes Ave access road to the entrance way. *Note that current access road is used because it allows space to transport rail cars.*	Vegetation monitoring for living shoreline and marsh restoration approaches.

Figure 6. Rosie's Pond Reach – Adaptation Strategies

Lawn Ave

Table 4. Lawn Ave Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Maximize habitat value while reducing flood risk to inland residential properties. Build marsh health and elevation capacity for resilience to sea level rise.	Lawn Ave does not serve as a critical flood pathway for the greater community and is vulnerable to periodic flooding under SLR. Temporary flood management techniques and flood accommodation techniques may be most appropriate for the row of residences closest to the marsh in the near term to minimize damage. This may include temporary flood barriers along the roadway or in doorways, waterproofing or elevating vulnerable assets (electrical systems), identifying space for parking vehicles above flood levels, etc. Such approaches are relatively low investment and would avoid any necessary impacts to the marsh.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Lane reduction of Lawn Ave and Palermo St to create expanded space for living levee concept. Roadway could be converted to one-way travel without losing access to residential properties. Thin layer deposition across low marsh platform to incrementally raise marsh elevation in parallel with observed sea level rise rates. *Note that TLD alone is not sufficient to mitigate storm flooding, and is intended to be part of a holistic approach to adaptation.*	Vegetation monitoring for living shoreline and marsh restoration approaches. Track storm damage and FEMA reimbursement requests to understand the existence of repetitive loss properties which may be more effectively retreated, rather than repaired.

Figure 7. Lawn Ave Reach – Adaptation Strategies

Bennington St

Table 5. Bennington St Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Reduce flood risk to Bennington St and MBTA Blue Line. Flood pathways approach from both East Boston (overtopping L-Berm area) and Revere (Fredericks Park/ Revere Public Schools). Enhance present and future marsh habitat. Create space for marsh migration.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Bennington St lane reduction to create space for expanded living levee concept and improved marsh migration pathways. Develop tide gate management plan to leave tide gate open during all but storm surge conditions, promoting the migration of saltmarsh habitat inland.	Elevate Bennington St on a bridge to allow tidal exchange into the open space between the roadway and Blue Line tracks. *Note that this option would require engineering of new tide gate/pump station infrastructure to maintain protection of inland development.*	Vegetation monitoring for living shoreline and marsh restoration approaches. Coordinate lane reduction opportunities w/ ongoing MassDOT road diet and bike lane study. Long-term (+/- 25 years or permanent) tide gauge at Sales Creek tide gate to monitor local dynamics and long-term changes to tidal level, storm surge, and sea level rise.

Figure 8. Bennington St Reach – Adaptation Strategies

Fredericks Park

Table 6. Fredericks Park Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Mitigate low-lying flood pathway which enters at Fredericks Park and continues into Revere and East Boston. Flood pathway tipping point at approximately 8.5 ft NAVD88. Maintain open space for recreation.	Mitigate marsh erosion with stabilization approaches such as installing oyster reefs in subtidal habitat, and coir logs in low/high/transitional marsh habitat. Vegetation management for soil stabilization and sediment capture will also enhance erosion control. Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Given the limited space between the main channel and park, commit a portion of the park to the living levee footprint to allow enough width for establishing the full suite of marsh habitat types as well as an elevated berm feature for flood protection.	Re-envisioning of open space to create floodable park and space for natural marsh migration. Re-orienting baseball fields may allow for increasing the open space buffer between marsh and park features. Open space would benefit from marsh restoration by establishing marsh habitat and an earthen berm for flood protection.	Vegetation monitoring for living shoreline and marsh restoration approaches.

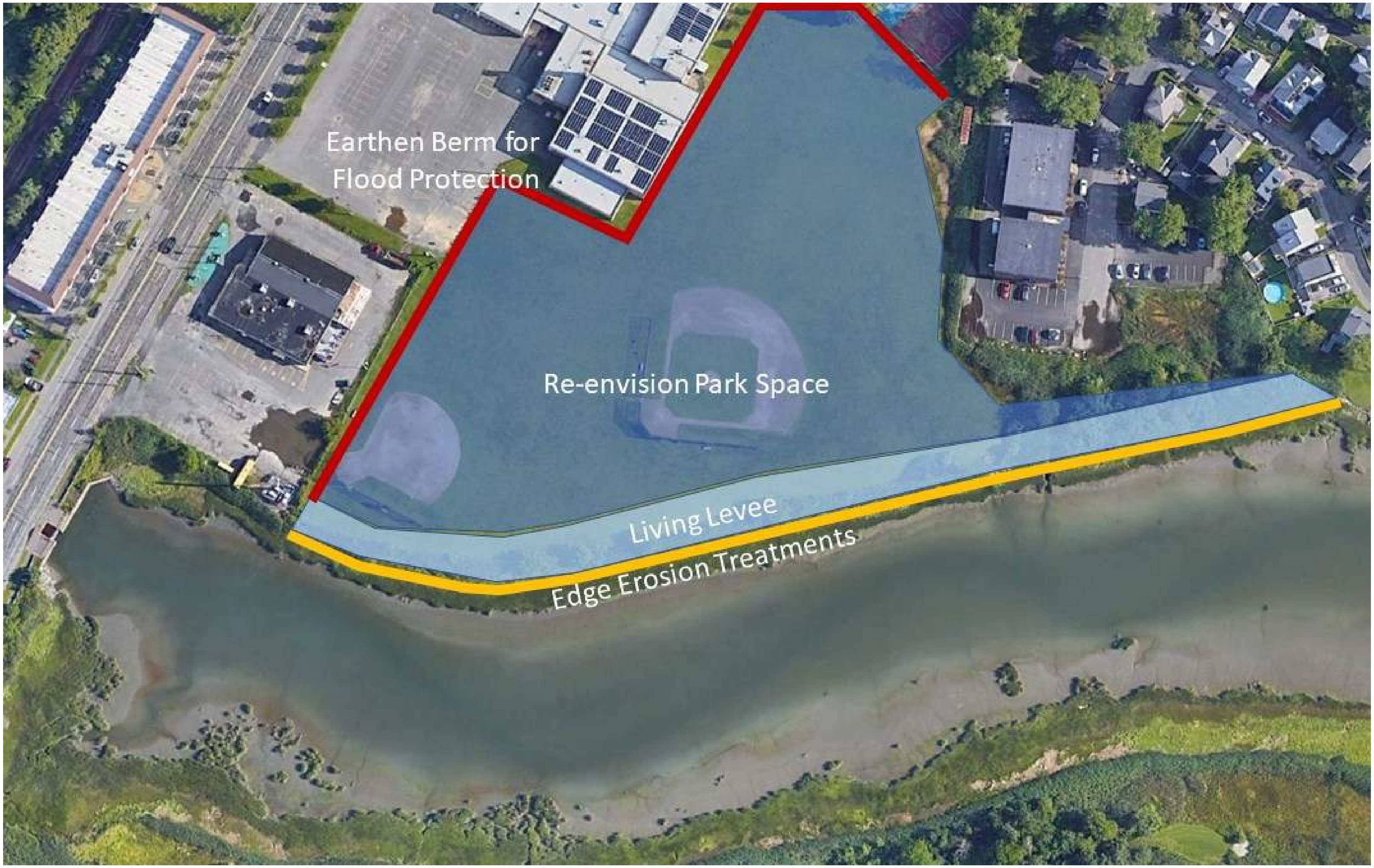


Figure 9. Fredericks Park Reach – Adaptation Strategies

Residential Revere

Table 7. Residential Revere Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Maximize habitat value while reducing flood risk to inland properties.	Given the limited space between the main channel, marsh, and residential properties, erosion control to maintain the benefits of what is present is paramount. Mitigate marsh erosion with stabilization approaches such as installing oyster reefs in subtidal habitat, and coir logs in low, high, and transitional marsh habitat. Vegetation management for soil stabilization and sediment capture will also enhance erosion control. Adaptation will likely be property-specific.	The space for constructing a living levee or any wide protection buffer is limited. Once SLR and flood risk becomes too severe, it is likely that the two top alternatives will be property-specific and will involve protection through hard armoring (e.g., seawall), or managed retreat of marsh-adjacent, low-lying structures.	Monitoring of oyster reef or vegetation management. Track storm damage and FEMA reimbursement requests to understand the existence of repetitive loss properties which may be more effectively retreated, rather than repaired.

Figure 10. Residential Revere Reach – Adaptation Strategies

Short Beach

Table 8. Short Beach Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Minimize risk of Winthrop Parkway overtopping and flooding Belle Isle Marsh. Tie-in ocean facing alternatives with upland development to mitigate all flood pathways. Additionally, mitigate the flood pathway from Belle Isle Marsh across Winthrop Ave. Flood pathway tipping point at approximately 11.1 ft NAVD88. Build marsh health and elevation capacity for resilience to sea level rise.	Sand and cobble nourishment of Short Beach to create buffer for Belle Isle and Winthrop Parkway from the open ocean. Should the nourishment project be pursued, and if it creates an appropriately large beach width, pair nourishment with construction of vegetated sand dune for elevation buffer to reduce runup and overtopping.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Consider retreating Winthrop Ave, directing traffic solely through Winthrop Parkway, to create space for an expanded living levee alternative on the marsh side. Extend existing seawall along the ocean-side of Winthrop Parkway further into adjacent neighborhoods to tie-in with critical flood elevation, providing protection from flooding due to water overtopping and sheet flow over the Winthrop Parkway. Thin layer deposition across low marsh platform to incrementally raise marsh elevation in parallel with observed sea level rise rates. *Note that TLD alone is not sufficient to mitigate storm flooding and is intended to be part of a holistic approach to adaptation.*	Vegetation monitoring for living shoreline and marsh restoration approaches.

Figure 11. Short Beach Reach – Adaptation Strategies

Residential North Winthrop

Table 9. Residential North Winthrop Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Maximize habitat value while reducing flood risk to inland properties.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Due to the low-lying nature of many properties, an elevated berm may be needed to provide adequate flood protection.	The space for constructing a living levee or any wide protection buffer is limited. Once SLR and flood risk becomes too severe, it is likely that the two top alternatives will either be protection through hard armoring (e.g., seawall), or managed retreat of marsh- adjacent/low-lying structures.	Monitoring of living levee and vegetation management. Track storm damage and FEMA reimbursement requests to understand the existence of repetitive loss properties which may be more effectively retreated, rather than repaired.

Figure 12. Residential North Winthrop Reach – Adaptation Strategies

Bayou St / Argyle St

Table 10. Bayou St / Argyle St Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Mitigate flood pathway into developed area and critical infrastructure. Flood pathway tipping point at approximately 13.0 ft NAVD88. Build marsh health and elevation capacity for resilience to sea level rise.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway.	Thin layer deposition across low marsh platform to incrementally raise marsh elevation in parallel with observed sea level rise rates. *Note that TLD alone is not sufficient to mitigate storm flooding and is intended to be part of a holistic approach to adaptation.* Flood proofing and/or protection of Winthrop substation critical infrastructure.	Vegetation monitoring for living shoreline and marsh restoration approaches. Look to FEMA BRIC program for grant funding to adapt critical infrastructure to SLR.

Figure 13. Bayou St / Argyle St Reach – Adaptation Strategies

Cemetery

Table 11. Cemetery Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Promote marsh migration.	No action. Limited existing upland development supports marsh migration.	Regrade shoreline to gentler slope for future marsh habitat. Vegetation management for marsh enhancement.	Vegetation monitoring of marsh migration.

Figure 14. Cemetery Reach Adaptation Strategies

Morton St / Marine Ecology Park

Table 12. Morton St / Marine Ecology Park Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Expand marsh area and enhance storm protection value. Mitigate flood pathway through Morton St to low-lying neighborhood in Winthrop. Flood pathway tipping point at approximately 7.3 ft NAVD88, located at the intersection of Morton St and Banks St. Build marsh health and elevation capacity for resilience to sea level rise.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Incorporate an upland, elevated berm to provide adequate flood protection. Extend from Morton St to Cemetery. Consider raising the intersection of Amelia Ave / Morton St to tie-in storm protection where the flood pathway is most narrow and could be most easily headed-off. *Note that this would leave three blocks of residential Winthrop unprotected, and these would ideally be addressed in the Winthrop Boat Yard alternatives. Additionally, note that stormwater cannot drain to the marsh from Morton St during king tide/storm conditions.*	Thin layer deposition across low marsh platform to incrementally raise marsh elevation in parallel with observed sea level rise rates. *Note that TLD alone is not sufficient to mitigate storm flooding and is intended to be part of a holistic approach to adaptation.*	Vegetation monitoring for living shoreline and marsh restoration approaches.

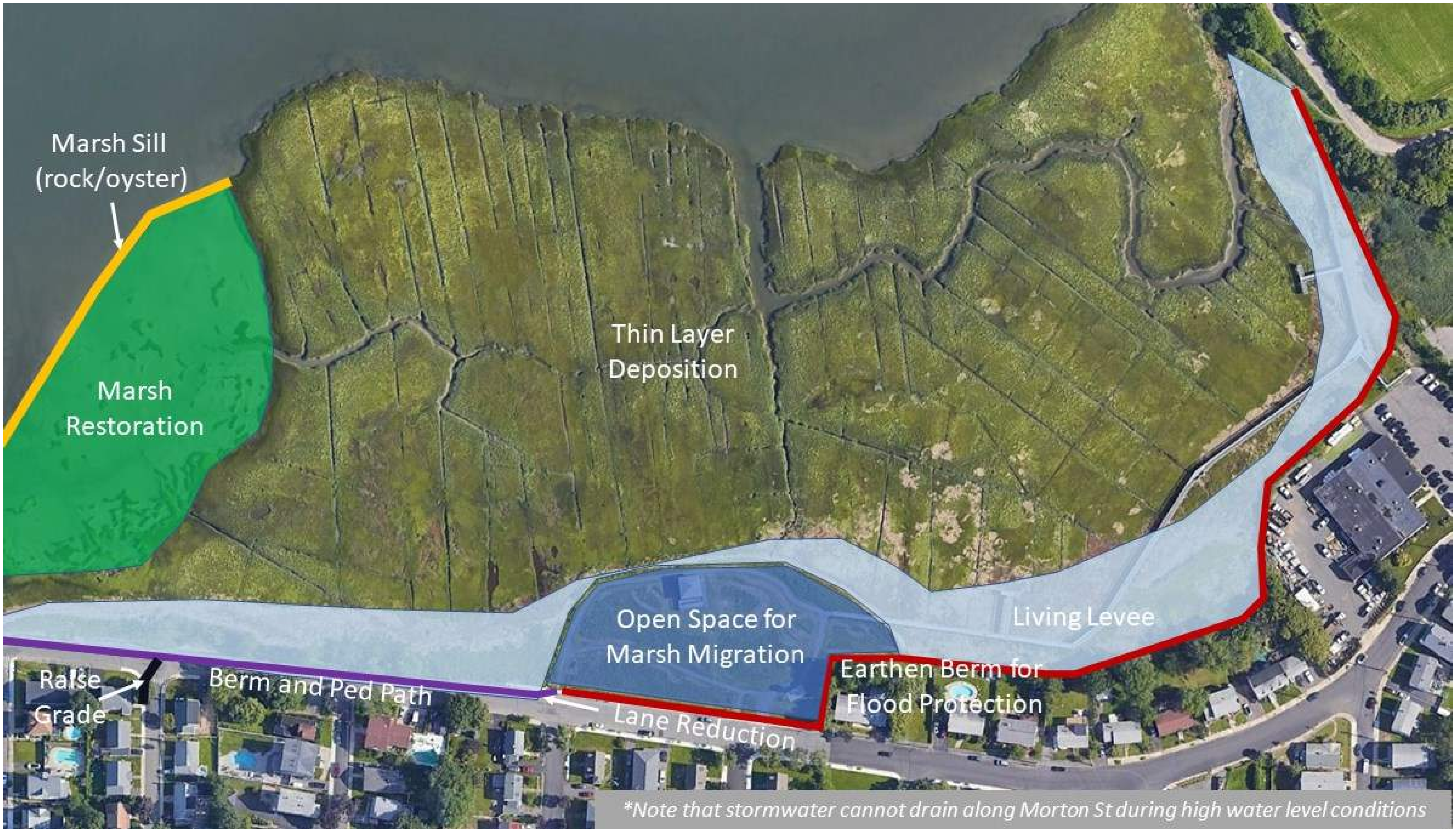


Figure 15. Morton St / Marine Ecology Park Reach – Adaptation Strategies

Winthrop Boat Yard / Main St

Table 13. Winthrop Boat Yard / Main St Reach – Adaptation Strategies

Desired Goal	Short-Term Approach	Long-Term Approach	Monitoring and Management
Address erosion by the Boat Yard/Morton St. Expand marsh area and enhance storm protection value. Mitigate flood pathway which stems at the boundary between marsh and Boat Yard. Ultimately, mitigate flooding which is projected to find a pathway into Winthrop beginning south of Main St.	Stabilize shoreline and reduce wave energy with an oyster reef. Construct living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Incorporate an upland, elevated berm to provide adequate flood protection. *Note that stormwater cannot drain to the marsh from Morton St during king tide/storm conditions.* Look for opportunities to build flood protection and habitat enhancement into forthcoming East Boston-Winthrop Greenway extension connecting East Boston Greenway with Belle Isle Marine Ecology Park.	The mudflat/degraded marsh would benefit from marsh enhancement to expand low/high marsh habitat, increase the buffer between development and the tides, increase wave attenuation, and provide stormwater runoff filtration. Consider use of a marsh sill (oyster reef or rock) to stabilize edge, filling of landside mudflat, and establishment of native vegetation. *Note that marsh restoration alone is not sufficient to mitigate storm flooding and is intended to be part of a holistic approach to adaptation.* Managed retreat of existing boatyard to avoid future flood pathways and allow for natural marsh migration. Utilize the new open space to create expanded living levee concept for flood protection and future marsh migration. Raise Main St to eliminate flood pathway from Boston Harbor across critical evacuation route and into Winthrop.	Vegetation monitoring for living shoreline and marsh restoration approaches.

Figure 16. Winthrop Boat Yard / Main St Reach – Adaptation Strategies

6.0 Conclusions

This memo identified adaptation priorities, values, goals, and a range of strategies to adapt Belle Isle Marsh and the surrounding communities to sea level rise and storm surge. Thirteen (13) management reaches were defined and a range of nature-based solutions and hybrid “green/grey” alternatives were proposed. Through on-going stakeholder and public discussions, the collection of strategies will be filtered into 10 composite management scenarios, from which the top 2-3 will be modeled to assess storm protection benefits and guide engineering design.

Appendix D: Belle Isle Marsh Climate Vulnerability Assessment – Task 2.5 High-resolution modeling of storm wave height and energy attenuation at Belle Isle Marsh under different restoration and climate scenarios

High-resolution modeling of storm wave height and energy attenuation at Belle Isle Marsh under different restoration and climate scenarios

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Executive Summary

This report uses high-resolution SWAN modeling to quantify the loss of coastal protection ecosystem services, specifically wave attenuation, at Belle Isle Marsh in Boston, MA, under a variety of climate and storm intensity scenarios and restoration conditions. Percent change in wave height and energy was determined across three different marsh habitats (low marsh, high marsh, and phragmites) for storms with 10-, 50-, 100-, and 500-year return intervals under 2020, 2030, 2050, and 2070 climate horizons.

Model results indicate an average increase across the marsh platform in wave heights of up to 30% and in wave energy up to 50% during storm events over the next 50 years at Belle Isle if no restorative action is taken. The marsh platform is less able to attenuate larger storms, particularly under climate horizons with increased sea-level rise and reduced vegetation. While phragmites contributes most to wave attenuation under no action scenarios, under a thin-layer deposition scenario, where six inches of elevation is added to marsh habitats, the attenuative capacity of both high and low marsh habitats increases. This increase is particularly visible under climate horizons where an increase in elevation increases low and high marsh habitat and discourages phragmites habitats. This suggests that thin-layer deposition allows marsh vegetation to work as coastal protection more effectively for a longer period of time.

Introduction

Belle Isle Marsh, the largest remaining salt marsh system in Boston Harbor, provides critical protection to abutting communities in the face of increasing sea levels and storm intensity. Without active intervention, however, the marsh is predicted to become largely mudflat in the coming decades. This report uses high-resolution SWAN modeling to quantify the loss of coastal protection ecosystem services, specifically wave attenuation, under a variety of climate and storm intensity scenarios, as well as under different restoration conditions.

Methods

Bathymetry and model set up

This study uses a third-generation directional spectral wave model, SWAN (Simulating Waves Nearshore; Booij et al., 1999), to simulate wave attenuation in varying vegetation and elevation scenarios, across four different climate horizons—present day, 2030, 2050, and 2070. Using 2018 topography from the United States Army Corps of Engineers (Figure 1A), water level in the model domain for each climate horizon was determined using Massachusetts Coastal Flood Risk Model (MC-FRM) estimates for MHW/MHHW from Woods Hole Group and their differences from present day water level estimates (Table 1). Bottom topography and vegetation grids were 1-m resolution.

To assess the utility of thin-layer deposition (TLD) as a climate adaptation strategy, model scenarios also considered the addition of 0.15 m (~6 inches) of elevation to marsh habitats.

Assuming rapid adoption of the strategy, present day elevations were augmented in the desired habitats (Figure 1B). Vegetation distribution also remained the same as present day maps, though water levels and wind speeds were varied for each climate horizon and return interval, as previously described. These augmented elevation model runs were compared to base vegetated model runs for analysis.

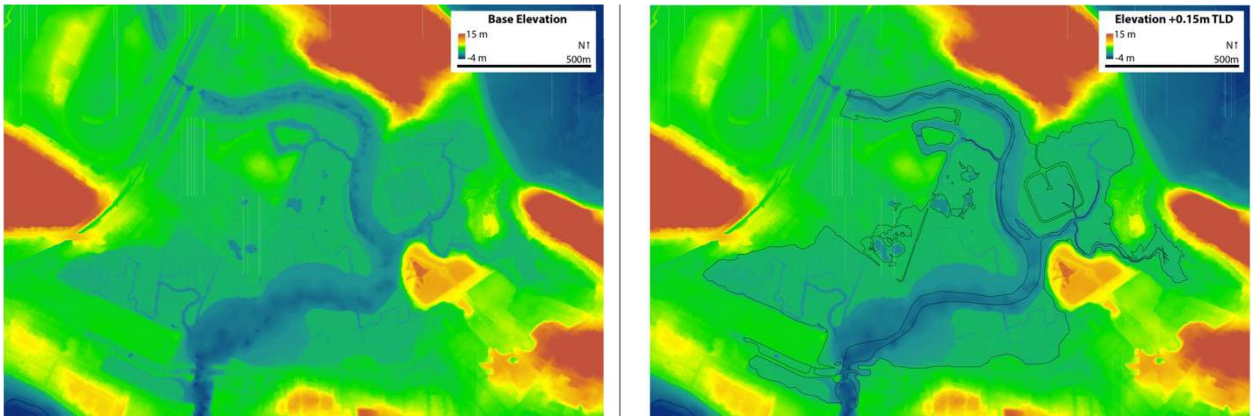

Figure 1. A) Bathymetry of base case model domain. B) Bathymetry of thin-layer deposition case model domain. Area of TLD is indicated by the solid black line.

Table 1. Model domain water levels for each climate horizon.

Climate Horizon	Water Level (m; NAVD88)
2020	0
2030	0.47
2050	0.84
2070	1.41

Winds and waves

Given that wave action in Belle Isle Marsh is predominantly from wind, waves in the model domain were forced using wind speeds indicative of storms of 10-, 50-, 100-, and 500-year return intervals. Using the 74-year wind speed dataset from Logan International Airport, average wind speeds were calculated for each return interval (Table 2). The wind direction mode of wind speed measurements greater than 20 m/s was 45°N. As such, the wind direction of 45°N was used as a constant for model runs. Results were analyzed for percent change in wave height and wave energy between model scenarios. Wave energy was determined from wave height using the equation:

$$E = \frac{1}{8}\rho g H^2$$

where E represents wave energy in J/m^2, ρ is the density of water (1024 kg/m^3 at 20°C), g is the acceleration of gravity (9.81 m/s^2), and H is the wave height.

Table 2. Model wind speeds and directions for specified storm return intervals.

Storm return interval	Wind speed (m/s)	Wind direction (°)
500-year storm	33.1 (30.3-35.9)	45
100-year storm	30.1 (27.9-32.2)	45
50-year storm	28.7 (26.7-30.6)	45
10-year storm	25.1 (23.8-26.3)	45

Vegetation

Projected vegetation extent from Sea Level Affecting Marshes Model (SLAMM) was used as a base for vegetation mapping. Present and future habitat extents were modeled by Woods Hole Group and details can be found in the Belle Isle Marsh SLAMM memo, provided as an appendix to Task 2.3 Future Conditions final memo. It is important to note that future projected vegetation distribution assumed that present day development and impervious surfaces were not a barrier to marsh migration. Vegetation was represented in the model through varying bottom friction values. Manning's values (Bunya et al., 2010; Dietrich et al., 2011) were converted to Madsen bottom friction coefficients (Madsen et al. 1988) using the method determined by Dietrich et al. (2011), where Madsen coefficients are calculated as a function of Manning's values and water depth (Table 2). Vegetation extent varied for each climate horizon per SLAMM projections. For analysis, SLAMM base vegetation cases were compared to scenarios where all marsh vegetation was replaced by mudflat.

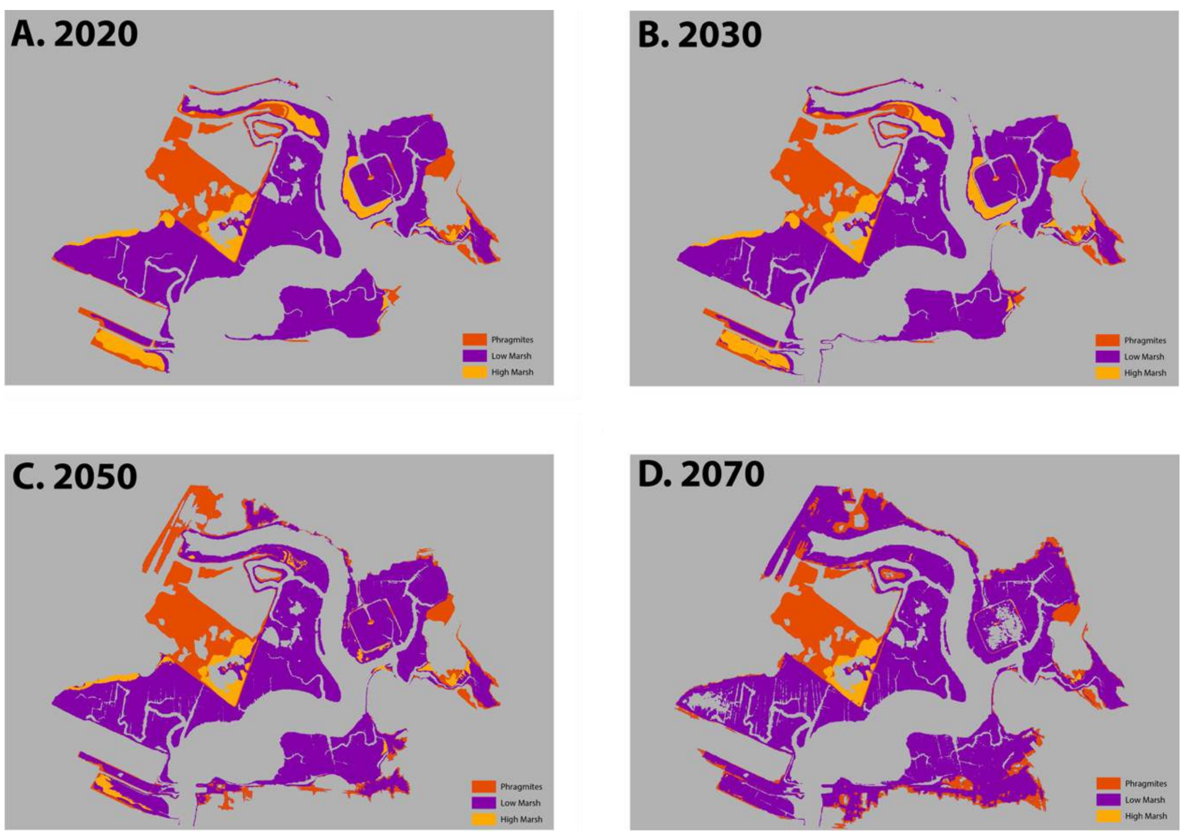

Figure 2. Vegetation distributions for key vegetation types (phragmites [red], low marsh [purple], and high marsh [yellow]) for SLAMM simulations for A) 2020, B) 2030, C) 2050, and D) 2070.

Table 3. Manning's values for vegetation types within the model domain.

Vegetation type	Manning's value
Upland (Rocky/Structure)	0.12
Transitional Marsh/Scrub-Shrub (Phragmites)	0.08
Regularly Flooded Marsh (Low Marsh)	0.035
Tidal Flat	0.03
Estuarine Open Water	0.025
Irregularly Flooded Marsh (High Marsh)	0.05

Results

Quantification of wave attenuation of various habitat types

To assess the wave attenuation capacity of various habitat types for storms of different intensities, SLAMM-vegetated scenarios for 2020, 2030, 2050, and 2070 climate horizons were compared to scenarios in which all marsh was replaced with mudflat (Figure 3; A1, A2). Model results indicate that the individual contribution of vegetation to wave attenuation is low, with maximum wave height and energy reduction below 4% and 7%, respectively. As storms increased in intensity, vegetated areas experienced a slight decrease in wave height and energy reduction, though it is important to consider, for example, that a 0.5% decrease in wave height is equivalent to a 0.5 cm reduction for a 1-m wave, whereas it is only equivalent to a 0.25 cm reduction for a 0.5-m wave.

Phragmites habitat provided the most attenuation, particularly in the 2050 climate horizon, where a combination of increasing water level and vegetation changes allowed for more phragmites habitat to be exposed to wave action. Average wave attenuation reduction for habitats other than phragmites, including high marsh, low marsh, and an average across the whole marsh, were largely below 1%.

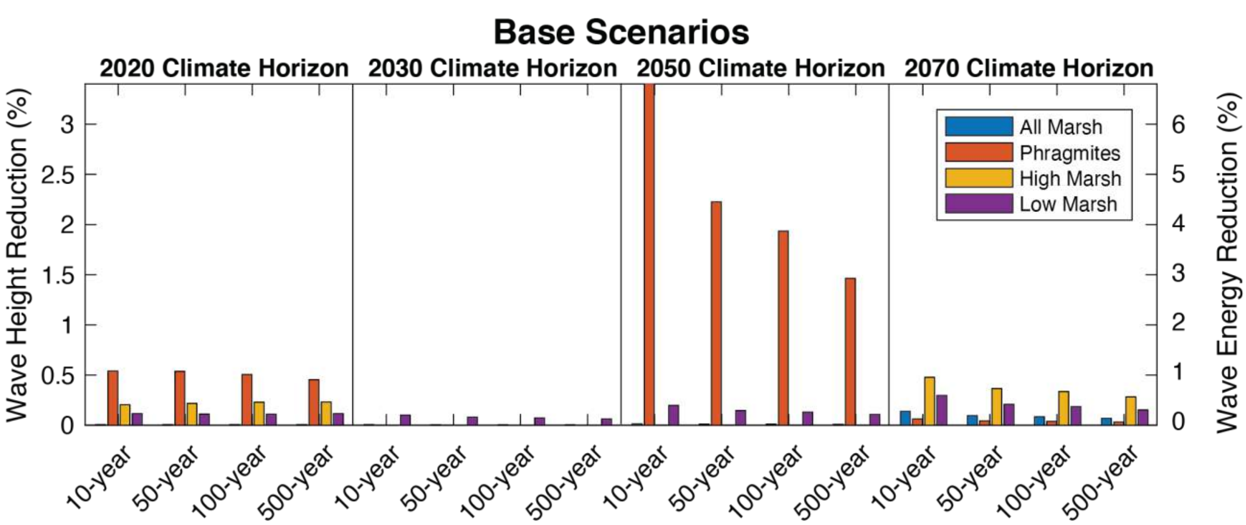

Figure 3. Comparison of average wave height/energy reduction for each key habitat type, across various model scenarios. Percent reduction is calculated between the SLAMM vegetation scenarios and a scenario in which all marsh vegetation is replaced by mudflat.

Loss of wave attenuation capacity over time

To quantify the loss of wave attenuation capacity over time, SLAMM-vegetated scenarios from 2030, 2050, and 2070 climate horizons were compared to the present day 2020 climate horizon (Figure 4; A5, A6). Calculating percent change between the 2020 and later horizons allows us to understand the amount of capacity lost as the marsh continues to convert to mudflat if no restorative action is taken. Compared to 2020 baseline conditions, marsh areas in 2030 will see an average of 15%-18% increase in wave height and an average of 26%-32% increase in wave energy across all storm intensity scenarios. By 2070, those averages jump to 26%-32% and 44%-53%, respectively. Phragmites areas will see the most increase in wave height and energy, from an average 18% increase in wave height during a 100-year storm in 2030 to an average 44% increase in wave height during a 500-year storm in 2070. Though phragmites has the highest average wave attenuation compared to other habitats, it is important to consider that a 44% increase for a 0.5-m wave adds an additional 22 cm to the wave height.

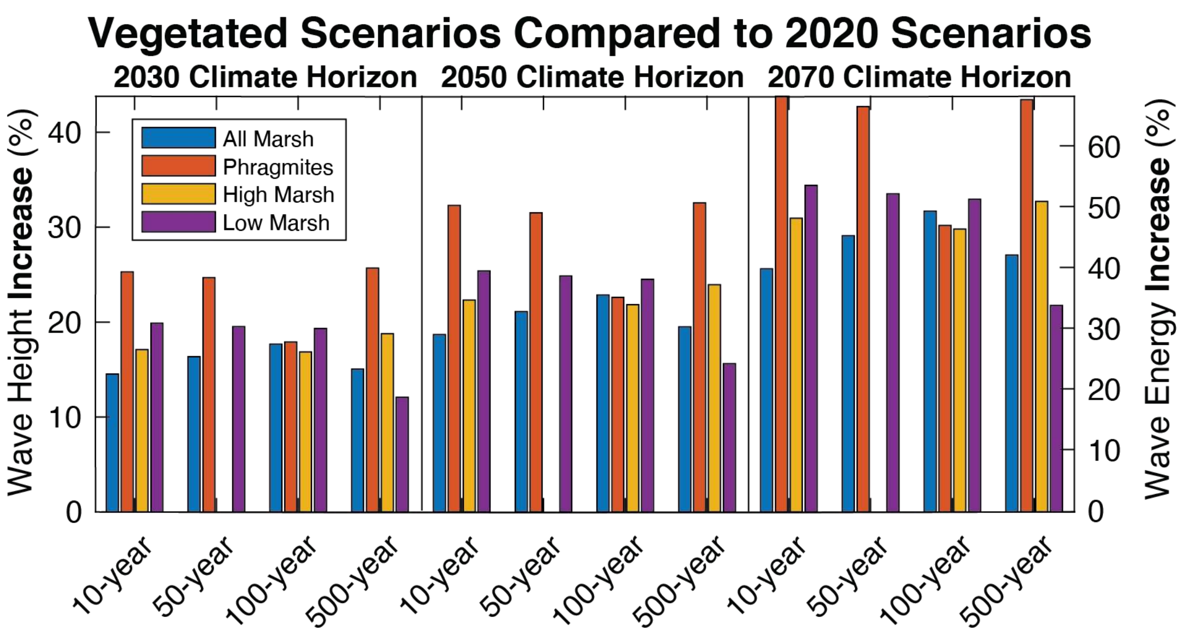

Figure 4. Comparison of average wave height/energy *increase* from the 2020 wave height/energy values to those of the 2030, 2050, and 2070 climate horizons, across study storm intensities.

Quantification of wave attenuation from TLD

To assess the impacts of a proposed restoration solution, thin-layer deposition (TLD), elevations of all marsh areas were increased by 0.15 m (6 in; Figure 1B). Percent reduction of wave height and energy was calculated between the scenarios with increased elevation and the base scenarios (Figure 3; A3, A4). Vegetation distributions were held constant from the 2020 SLAMM scenario.

Here, we see that increasing elevation by only 0.15 m has substantial impacts on wave attenuation. Whereas marsh vegetation overall contributed only an average of <0.1% reduction compared to bare mudflat, under the TLD scenario, the newly elevated marsh platform attenuates wave height an additional 4%-17% and wave energy an additional 9%-45% (Figure 5). Contributions of specific marsh habitats varies based on climate horizon; while low marsh vegetation contributes the most attenuation in all climate horizons, by 2050 and 2070, high marsh vegetation becomes a larger player, providing >100% more wave energy reduction than it would under similar, non-elevated scenarios. This suggests that TLD allows marsh vegetation to work as coastal protection more effectively for a longer time period.

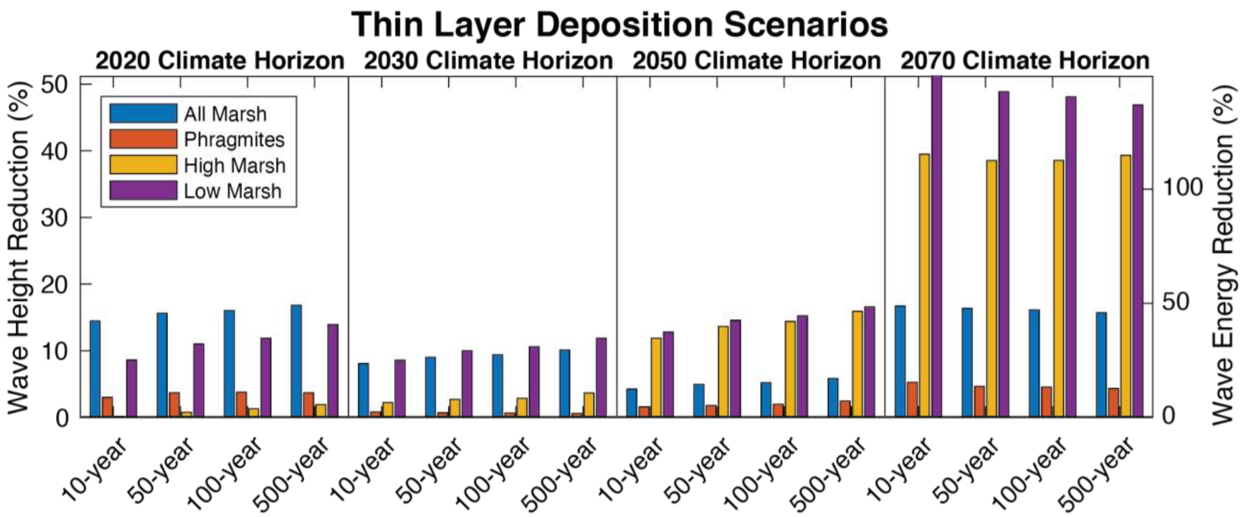

Figure 5. Comparison of average wave height/energy reduction for each key habitat type, after the addition of 0.15 m of elevation to all marsh surfaces. Percent reduction is calculated between the SLAMM vegetation scenarios with the additional elevation and SLAMM scenarios without additional elevation, shown in Figure 3.

Conclusions

Model results indicate an average increase across the marsh platform in wave heights of up to 30% and in wave energy up to 50% during storm events over the next 50 years at Belle Isle Marsh if no restorative action is taken. The marsh platform is less able to attenuate larger storms, particularly under climate horizons with increased sea-level rise and reduced vegetation.

While model results indicate that vegetation alone causes only a small amount of wave attenuation compared to mudflat (A7), it is important to consider that a limitation of SWAN modeling is that it only calculates the contribution of differing bottom friction to wave attenuation, and it does not incorporate the more complex role of vegetation within the system, including varying vegetation heights, densities, and sediment-trapping capabilities.

While phragmites contributes most to wave attenuation under no action scenarios, under TLD scenarios, the attenuative capacity of both high and low marsh habitats increases, particularly under climate horizons where an increase in elevation increases low and high marsh habitat and discourages phragmites habitats.

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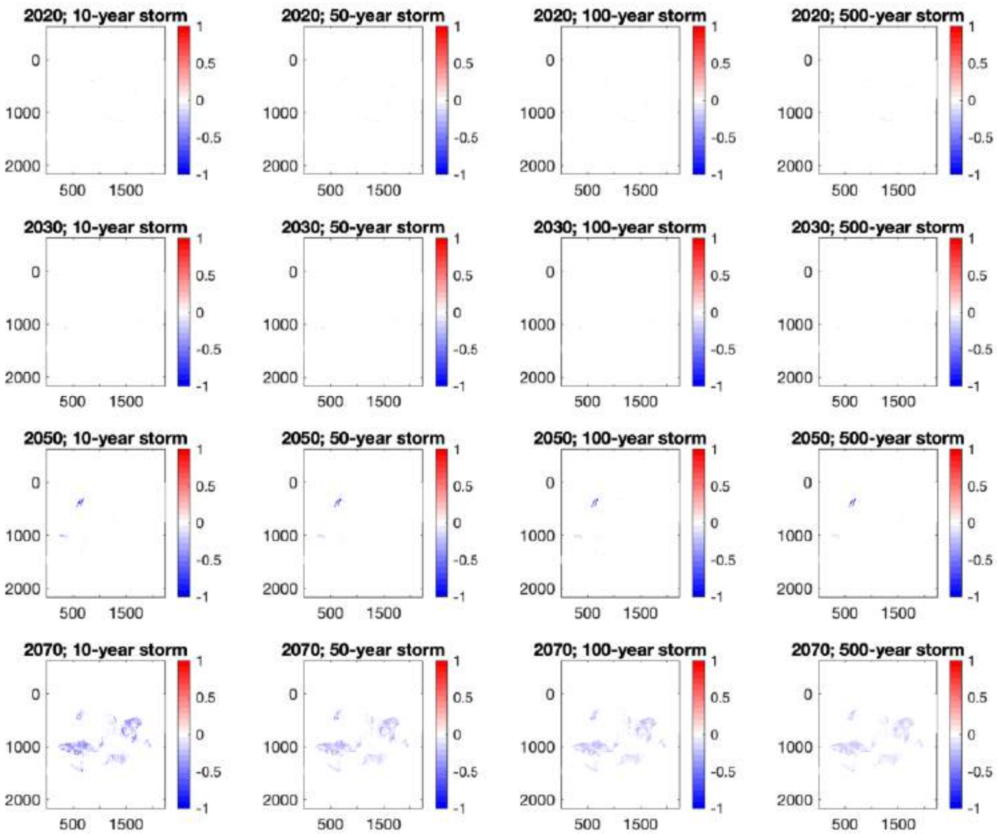
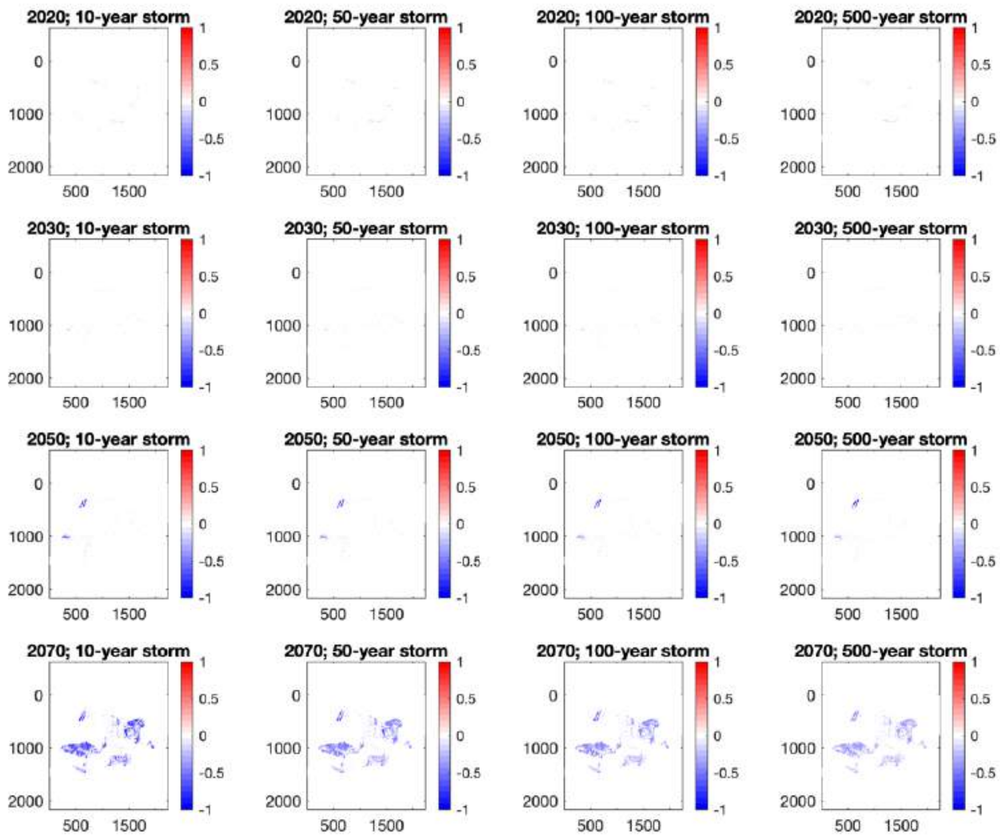
Appendix

A1. Base vegetation vs. mudflat cases: percent change in wave height



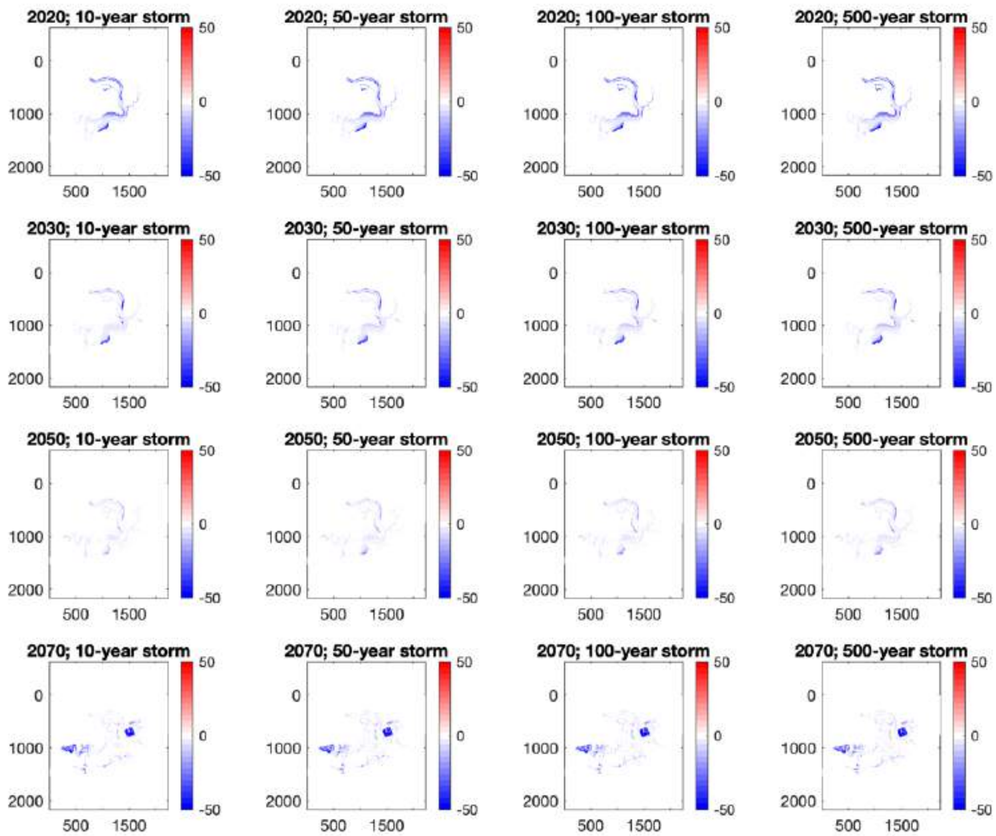
Year/Scenario	10-yr storm	50-yr storm	100-yr storm	500-yr storm
% Change, ALL marsh				
2020	-0.01	-0.01	-0.01	-0.01
2030	-0.01	-0.01	-0.01	-0.01
2050	-0.01	-0.01	-0.01	-0.01
2070	-0.14	-0.10	-0.08	-0.07
% Change, phragmites				
2020	-0.54	-0.54	-0.51	-0.45
2030	0.00	0.00	0.00	0.00
2050	-3.41	-2.22	-1.93	-1.46
2070	-0.06	-0.04	-0.04	-0.03
% Change, high marsh				
2020	-0.21	-0.22	-0.23	-0.23
2030	N/A	N/A	N/A	N/A
2050	0.00	0.00	0.00	0.00
2070	-0.48	-0.37	-0.34	-0.28
% Change, low marsh				
2020	-0.12	-0.11	-0.11	-0.12
2030	-0.10	-0.08	-0.07	-0.06
2050	-0.20	-0.15	-0.13	-0.11
2070	-0.30	-0.21	-0.19	-0.15

A2. Base vegetation vs. mudflat cases: Percent change in wave energy



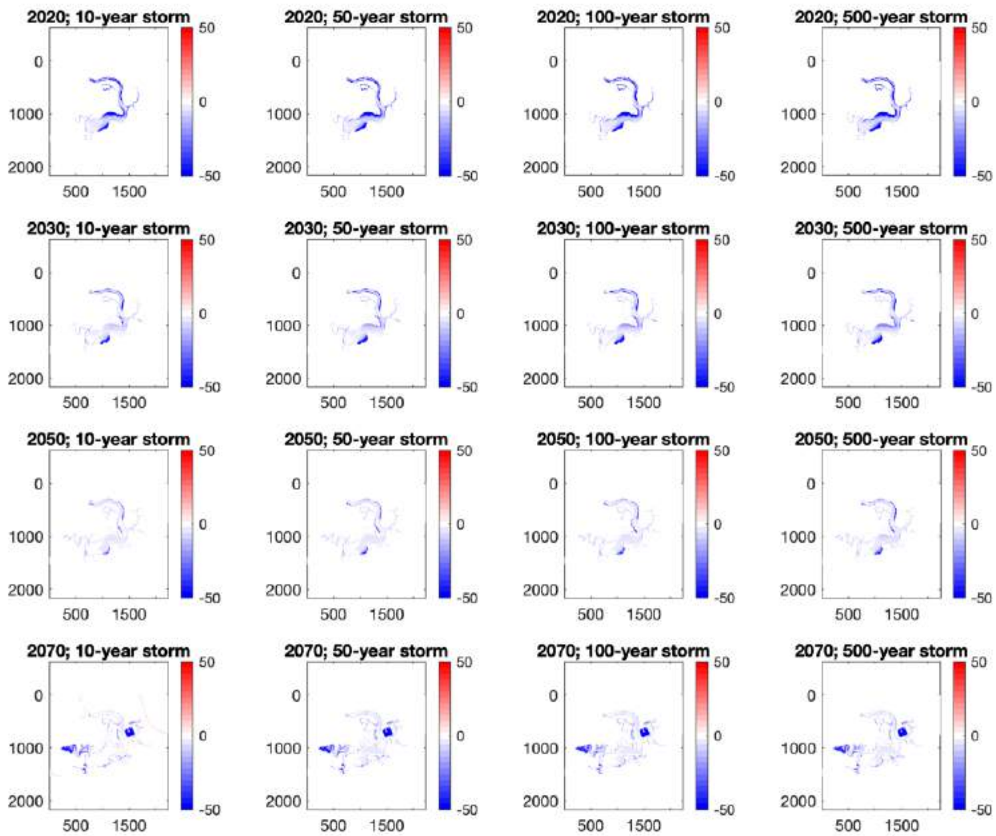
Year/Scenario	10-yr storm	50-yr storm	100-yr storm	500-yr storm
% Change, ALL marsh				
2020	-0.01	-0.01	-0.01	-0.01
2030	-0.01	-0.01	-0.01	-0.01
2050	-0.03	-0.02	-0.02	-0.02
2070	-0.28	-0.19	-0.17	-0.14
% Change, phragmites				
2020	-1.09	-1.08	-1.02	-0.91
2030	0.00	0.00	0.00	0.00
2050	-6.98	-4.52	-3.92	-2.96
2070	-0.13	-0.09	-0.08	-0.06
% Change, high marsh				
2020	-0.41	-0.44	-0.46	-0.46
2030	N/A	N/A	N/A	N/A
2050	0.00	0.00	0.00	0.00
2070	-0.96	-0.74	-0.67	-0.57
% Change, low marsh				
2020	-0.23	-0.23	-0.22	-0.23
2030	-0.20	-0.16	-0.15	-0.13
2050	-0.40	-0.29	-0.26	-0.22
2070	-0.59	-0.42	-0.37	-0.31

A3. Base vegetation vs. TLD cases: Percent change in wave height



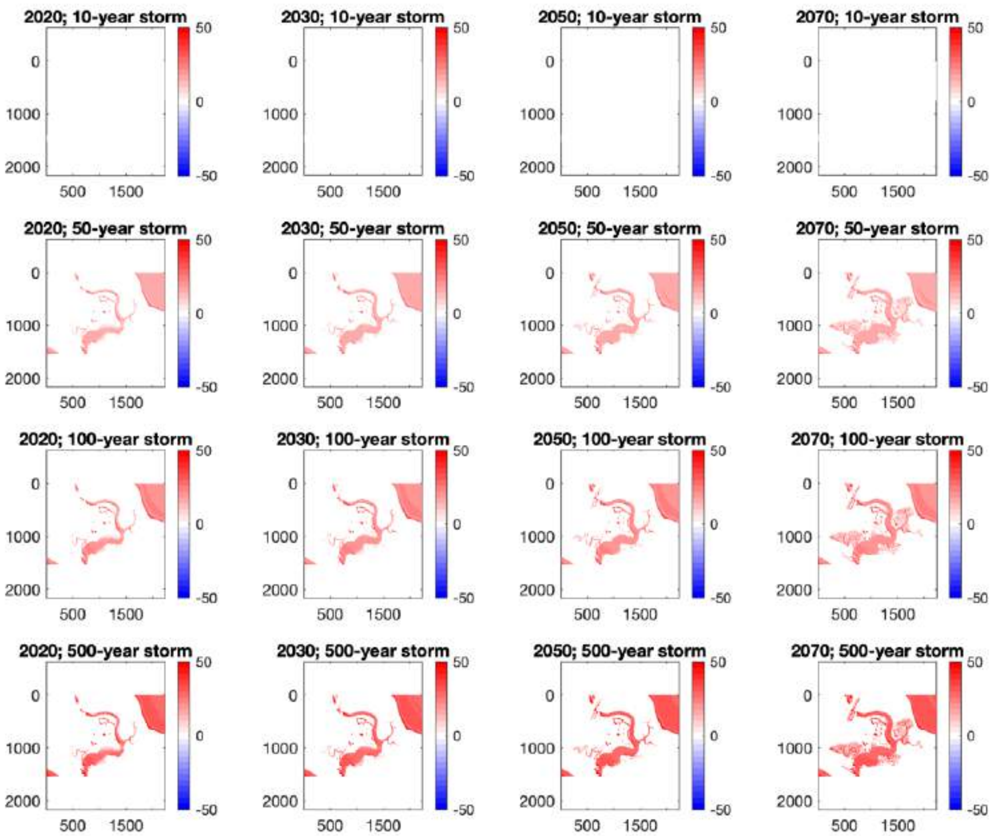
Year/Scenario	10-yr storm	50-yr storm	100-yr storm	500-yr storm
% Change, ALL marsh				
2020	-14.32	-15.48	-15.88	-16.68
2030	-7.95	-8.88	-9.25	-9.97
2050	-4.11	-4.80	-5.08	-5.70
2070	-16.58	-16.22	-15.96	-15.57
% Change, phragmites				
2020	-2.86	-3.56	-3.65	-3.55
2030	-0.67	-0.55	-0.51	-0.45
2050	-1.45	-1.65	-1.82	-2.32
2070	-5.11	-4.51	-4.41	-4.22
% Change, high marsh				
2020	0.14	-0.63	-1.16	-1.79
2030	-2.10	-2.56	-2.72	-3.54
2050	-11.74	-13.51	-14.25	-15.77
2070	-39.35	-38.39	-38.42	-39.16
% Change, low marsh				
2020	-8.48	-10.89	-11.76	-13.79
2030	-8.45	-9.86	-10.46	-11.75
2050	-12.66	-14.43	-15.10	-16.44
2070	-51.16	-48.71	-47.94	-46.73

A4. Base vegetation vs. TLD cases: Percent change in wave energy



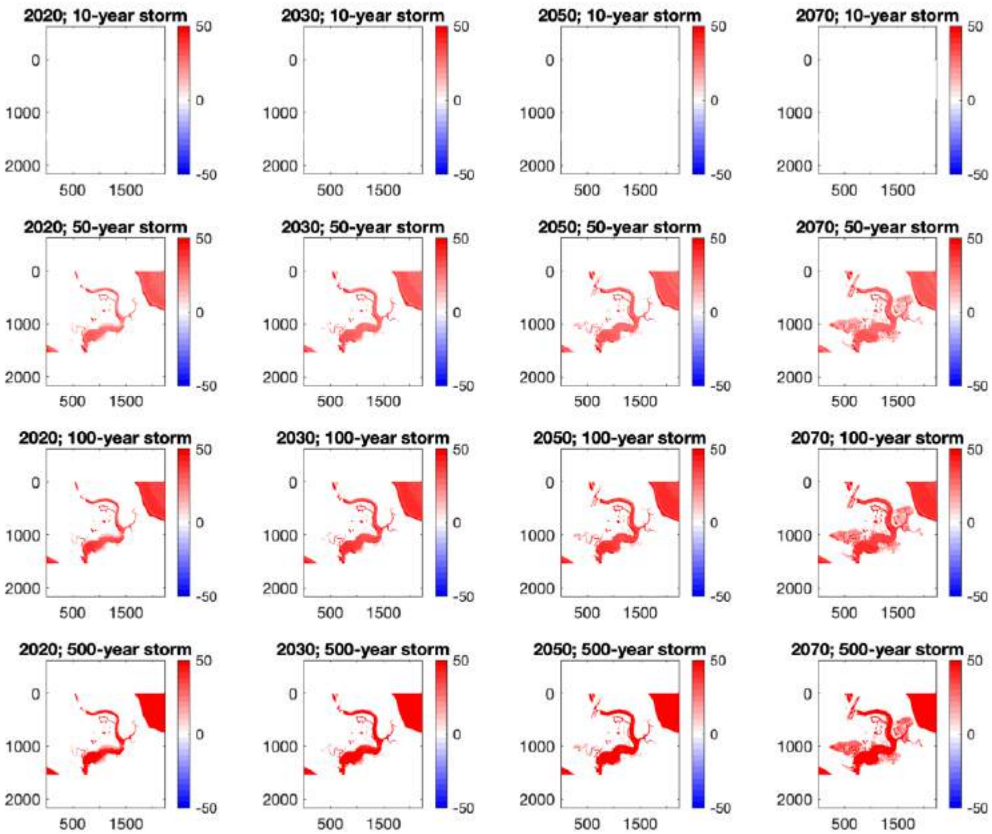
Year/Scenario	10-yr storm	50-yr storm	100-yr storm	500-yr storm
% Change, ALL marsh				
2020	-35.34	-37.93	-38.79	-40.50
2030	-19.76	-21.72	-22.51	-24.05
2050	-9.39	-11.05	-11.71	-13.15
2070	-47.28	-44.84	-43.90	-42.50
% Change, phragmites				
2020	-6.29	-7.72	-7.89	-7.62
2030	-1.34	-1.11	-1.02	-0.90
2050	-3.39	-3.63	-3.92	-4.90
2070	-12.00	-10.44	-10.17	-9.60
% Change, high marsh				
2020	0.27	-1.27	-2.35	-3.61
2030	-4.38	-5.31	-5.65	-7.44
2050	-26.76	-31.02	-32.88	-36.87
2070	-103.81	-100.04	-100.05	-102.35
% Change, low marsh				
2020	-20.52	-26.29	-28.40	-33.24
2030	-21.13	-24.41	-25.81	-28.90
2050	-32.74	-37.53	-39.32	-42.81
2070	-149.38	-138.62	-135.61	-130.98

A5. Wave height attenuation loss (%) compared to 2020 vegetation scenarios



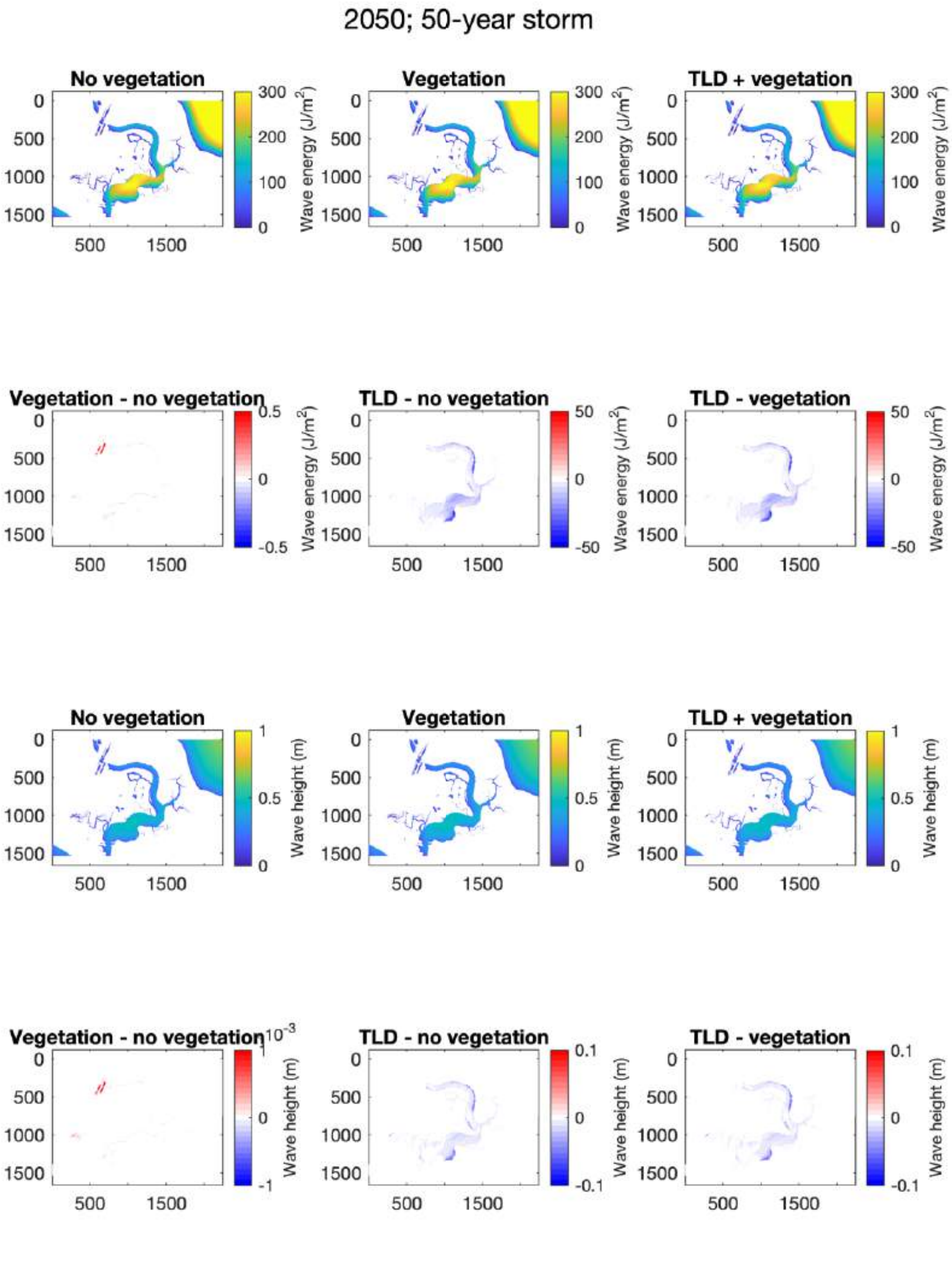
Year/Scenario	10-yr storm	50-yr storm	100-yr storm	500-yr storm
% Change, ALL marsh				
2020	N/A	N/A	N/A	N/A
2030	14.52	16.35	17.68	15.05
2050	18.67	21.09	22.85	19.50
2070	25.60	29.10	31.68	27.06
% Change, phragmites				
2020	0.00	0.00	0.00	0.00
2030	25.28	24.68	17.89	25.68
2050	32.29	31.51	22.60	32.56
2070	43.80	42.71	30.18	43.43
% Change, high marsh				
2020	0.00	N/A	0.00	0.00
2030	17.09	N/A	16.84	18.78
2050	22.32	N/A	21.84	23.94
2070	30.93	N/A	29.79	32.72
% Change, low marsh				
2020	0.00	0.00	0.00	0.00
2030	19.88	19.51	19.32	12.06
2050	25.38	24.84	24.51	15.61
2070	34.40	33.52	32.94	21.74

A6. Wave energy attenuation loss (%) compared to 2020 vegetation scenarios



Year/Scenario	10-yr storm	50-yr storm	100-yr storm	500-yr storm
% Change, ALL marsh				
2020	N/A	N/A	N/A	N/A
2030	26.55	29.74	32.02	27.51
2050	33.23	37.28	40.15	34.70
2070	43.54	48.93	52.78	45.97
% Change, phragmites				
2020	0.00	0.00	0.00	0.00
2030	44.17	43.20	32.21	44.74
2050	54.16	52.99	39.54	54.48
2070	68.41	66.99	50.33	67.91
% Change, high marsh				
2020	0.00	N/A	0.00	0.00
2030	31.25	N/A	30.83	33.86
2050	39.66	N/A	38.88	41.88
2070	52.29	N/A	50.68	54.35
% Change, low marsh				
2020	0.00	0.00	0.00	0.00
2030	35.47	34.71	34.51	22.36
2050	43.79	42.72	42.39	28.31
2070	56.09	54.43	53.94	38.01

A7. Relationships between base vegetation scenarios and TLD scenarios



Appendix E: Belle Isle Marsh Climate Vulnerability Assessment – Task 6.1 Alternatives Analysis and Selection

WOODS HOLE GROUP FOR EARTH, FROM SPACE
A CLS COMPANY

MEMORANDUM

DATE June 30, 2023 **JOB NO.** 2020-0076-01

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Rachel Kelly
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FROM Conor Ofsthun
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Belle Isle Marsh – Climate Vulnerability Assessment – MVP Task 6.1 Alternatives Analysis & Selection

1.0 Introduction

This Technical Memorandum is prepared for the Town of Winthrop and Mystic River Watershed Association (MyRWA) in support of the FY22-23 Municipal Vulnerability Preparedness grant titled "Belle Isle Marsh – Climate Vulnerability Assessment." As discussed in previous task memorandums, present and future flood risk to Belle Isle Marsh and the surrounding communities is significant. Coastal storm-induced flooding is a significant concern amongst the members of East Boston, Revere, Winthrop, as well as those who work in and/or utilize the services of these areas. Additionally, sea level rise (SLR) threatens to not only cause an up-shift in the high-water levels experienced during storms, but also threatens to impact the natural function of the marsh. SLR gradually causes normal high tides to inundate higher elevation marsh habitat, which leads to the conversion of wetland resource areas. This threatens the wildlife that relies on specific marsh habitat and diminishes the environmental co-benefits received by the community from the marsh. The Climate Vulnerability Assessment aims to evaluate the current and future coastal flood hazards affecting Belle Isle Marsh and the surrounding communities, and develops a series of nature-based solutions (NBS) that aims to minimize coastal flood damage to Winthrop, East Boston, and Revere and, where possible, maximize the habitat value of Belle Isle Marsh Reservation.

The adaptation strategies developed for each reach prioritize flood protection, green infrastructure, living shorelines, and natural and nature-based features to the maximum extent practicable. Where necessary due to site constraints, hard infrastructure may be warranted. Conversion of wetland resource areas is considered in certain instances to facilitate sea level rise resiliency, though it is recognized that permitting of such work does not meet Massachusetts Wetland Protection Act performance standards for salt marsh.

This Alternatives Analysis and Selection Memorandum evaluates a range of potential nature-based and hybrid solutions. Task 2.4 Strategy Identification developed the adaptation goals, adaptation toolbox, and adaptation strategies for thirteen (13) uniquely vulnerable reaches circumscribing Belle Isle Marsh. This alternatives analysis uses one prioritization matrix to evaluate which generalized strategies are preferred for adaptation, and a second prioritization matrix to compare adaptation strategies across each of the thirteen reaches. Through this analysis as well as consistent stakeholder engagement, this memorandum concludes in the selection of priority reaches and site-specific alternatives to be carried forward to subsequent tasks.

2.0 Adaptation Strategy Prioritization

Adaptation strategies were identified through a step-by-step process in coordination with stakeholders and the Community Advisory Group (CAG). Priorities and values were developed through a combination of literature research, discussions with stakeholders and the public, and outcomes of the on-going parallel project managed by MyRWA. The intersection of priorities and values with marsh vulnerability and flood risk led to the identification of shared adaptation goals. Adaptation goals subsequently led to the development of adaptation strategies that could feasibility achieve such goals. This process is detailed through the evolution of prior task deliverables and is summarized in Table 1.

Adaptation strategies look to both protect inland residential neighborhoods and critical infrastructure and optimize marsh health and longevity. The preferred approach will maximize the value of flood protection, habitat quality and biodiversity (through restoration), and community and public access. Furthermore, the preferred approach will be permittable, feasible to construct, provide long-term resilience (i.e., design life), and minimize necessary costs. A prioritization matrix evaluates how each adaptation strategy achieves, or falls short of, the above qualities, as shown in Table 2. The highest scoring strategies point towards a hybrid approach, incorporating components of a living levee and managed retreat (e.g., lane reduction).

Adaptation alternatives were developed primarily to achieve flood protection while maximizing co-benefits to marsh habitat where possible. Each alternative would carry various pros and cons. For instance, adaptation strategies such as an earthen berm, which are sited entirely outside of the marsh, will require steep slopes to achieve flood protection levels, essentially drawing a hard line between habitat and development. However, such projects would avoid impacting existing marsh habitat and would preserve critical functions such as serving as wildlife refuge and carbon storage today. Conversely, adaptation strategies such as a living levee, which are sited partially within the marsh, provide the opportunity to flatten slopes while still achieving flood protection levels. Such projects provide the opportunity for marsh migration with sea level rise and blend the boundary between habitat and development; however, this can come at the expense of adding fill to existing marsh habitat and potentially altering critical functions. Furthermore, projects which impact existing salt marsh will meet regulatory hurdles, as they do not meet the Massachusetts Wetland Protection Act performance standards for salt marsh. All projects which create and/or contain open space should be planted with appropriate native vegetation for habitat enhancement as well as wave attenuation.

Table 1. Development of priorities and values to adaptation goals, and lastly adaptation strategies.

Priorities and Values	
Flood Protection	Storm surge and sea level rise protection
	Wave attenuation
	Intercept flood pathways
	Erosion control
	Stormwater management
	Risk avoidance
Habitat Quality and Biodiversity	Habitat diversity and connectivity
	Food web support
	Biodiversity
	High marsh habitat
	Transitional and upland habitat
	Water quality
	Carbon storage
Community Support and Engagement	Regional approach
	Community outreach
	Educational and monitoring programs
	Recreational and open space

Adaptation Goals
Intercept flood pathways which affect communities and critical infrastructure
Reduce flood depth within communities
Expand and enhance transitional/upland areas for flood protection and accommodation
Address marsh erosion
Enhance vegetation to maximize wave attenuation
Build elevation capital for resilience to sea level rise
Expand high marsh area for saltmarsh sparrow and spring tide flood protection
Maximize social benefit of Belle Isle Marsh, while minimizing human impact to resources

Adaptation Strategies
No Action
Salt Marsh Restoration for Marsh Resilience
Engineered Sill for Marsh Toe Protection
Living Breakwater for Marsh Toe Protection
Thin Layer Deposition (TLD) (*not currently permittable*)
Living Levee
Beach Nourishment and Dune Restoration
Stormwater Management
Hard Infrastructure (seawall, revetment, raised roadway)
Public Access Trails and Signage
Flood Control Structure
Managed Retreat (e.g., Lane Reduction)
Monitoring Program
Hybrid Approach

Table 2. Prioritization scoring assessment of adaptation strategies for shoreline resilience at Belle Isle Marsh.

Adaptation Strategy	Project Goals			Implementation Feasibility				Composite Score (max 21)
	Flood Protection Value	Habitat Restoration Value	Community and Public Access Value	Permitting Feasibility	Construction Feasibility	Design Life	Cost Magnitude	
Hybrid Approach	High (3)	Medium (2)	High (3)	Medium (2)	High (3)	High (3)	High (0)	16
Earthen Berm	High (3)	Low (1)	Medium (2)	Medium (2)	Medium (2)	High (3)	Low (2)	15
Lane Reduction	High (3)	High (3)	Low (1)	High (3)	Low (1)	Medium (2)	Low (2)	15
Living Levee	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (2)	High (3)	Medium (1)	14
Salt Marsh Restoration	Low (1)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (1)	14
Beach Nourishment & Dune Restoration	High (3)	High (3)	High (3)	Medium (2)	Low (1)	Medium (2)	High (0)	14
Stormwater Management	Medium (2)	Low (1)	Low (1)	High (3)	Medium (2)	High (3)	Low (2)	14
Public Access	None (0)	None (0)	High (3)	High (3)	Medium (2)	High (3)	Low (2)	13
Elevate Roadway	High (3)	None (0)	Medium (2)	Medium (2)	Medium (2)	High (3)	High (0)	12
Monitoring Programs	None (0)	Low (1)	Medium (2)	High (3)	High (3)	None (0)	Low (2)	11
Hard Infrastructure	High (3)	None (0)	Low (1)	Low (1)	Medium (2)	High (3)	High (0)	11
Living Breakwater (Oyster Sill)	Low (1)	Medium (2)	Medium (2)	Low (1)	Low (1)	Medium (2)	Medium (1)	10
Engineered Sill	Low (1)	Medium (2)	Low (1)	Low (1)	Medium (2)	Medium (2)	Medium (1)	10
Thin Layer Deposition	Low (1)	High (3)	Low (1)	Low (1)	Medium (2)	Low (1)	High (0)	9
No Action	None (0)	None (0)	None (0)	High (3)	High (3)	None (0)	None (3)	9

3.0 Shoreline Site Prioritization

Thirteen reaches were identified surrounding Belle Isle Marsh according to unique shoreline types (e.g., developed vs. natural) as well as flood risk. Based upon adaptation strategy prioritization and the unique opportunities and constraints of each reach, a conceptual approach was developed at each reach. The top adaptation strategies included living levee, earthen berm, lane reduction, salt marsh restoration, stormwater management, and public access. Recognizing that one solution will not address all problems at hand, a hybrid solution composed of these adaptation strategies could provide the greatest benefit. While short-term and long-term approaches were separated in Task 2.4, the preliminary alternatives carried forward incorporate elements of each to achieve both immediate benefit and long-term resilience against sea level rise. A depiction of the thirteen reaches and conceptual adaptation footprints is depicted in Figure 1. A description of each shoreline sites jurisdictional considerations and adaptation project details is provided in Table 3. See Task 2.4 Memorandum for a complete description and detailed depiction of adaptation approaches at each of the shoreline sites.

Prioritizing shoreline sites and adaptation approaches involves evaluating each concept against key criteria. Key criteria are described below, and the evaluation at each site is summarized in Table 4.

Flood Exposure

Relative flood exposure was evaluated during prior tasks where previous municipal planning studies were reviewed and supplemented by a flood pathways analysis utilizing the Massachusetts Coast Flood Risk Model (MC-FRM) for present day through 2070 sea level rise scenarios (see memos supporting Tasks 2.2 and 2.3). Flood exposure tends to stem from storm surge which enters Belle Isle Inlet by way of Boston Harbor. The marsh is sheltered from open ocean wave exposure until sea level rise and storm scenarios predict overtopping of Short Beach. Stormwater-related flooding from precipitation was not included in the flood exposure assessment.

Asset Criticality

Asset criticality describes the presence of infrastructure that provide necessary functions to the region. Examples in the project area include evacuation routes (Bennington St, Saratoga St/Main St, Winthrop Parkway), public transportation (MBTA Blue Line, Orient Heights maintenance railyard), and utility infrastructure (pump stations, substations). The analysis of asset criticality is qualitative, and is only intended to provide a general picture of each site.

Permitting Feasibility

Permitting feasibility considers the regulatory hurdles or pathways for implementation. While each site is unique, several realities will play a role regardless of which site or project is pursued. Many aspects of the considered alternatives have historically met barriers to permitting, including thin layer deposition, and habitat conversion. Additionally, due to the designation of the reservation as an ACEC, special regulations apply according to the Code of Massachusetts Regulations (CMR). Furthermore, Belle Isle Marsh is within a designated Outstanding Resource Waters (ORW) area, entailing further special regulations. A detailed permitting pathway analysis and consultation with regulatory agencies will be necessary to more accurately map a route to successful permitting. Examples of regulations which will pertain to a project.

Water Quality Standards 314 CMR 9.06(3)

- According to Massachusetts Department of Environment Project (DEP) Water Quality Standards (314 CMR 9.06(3)), “Projects impacting an ACEC may not be permittable through MassDEP under the 401 Water Quality Standards without a variance.”

Massachusetts Wetlands Protection Act

- Pursuant to 310 CMR 10.24(5)b, projects in ACECs that will have an adverse effect on the interests of the Wetlands Protection Act are only allowed for maintenance dredging, Ecological Restoration Projects, Ecological Restoration Limited Projects, and for improvement dredging needed to restore navigation to areas previously navigable.
- Pursuant to 310 CMR 10.24(8)(b), an Ecological Restoration Project permitted as an Ecological Restoration Limited Project in accordance with 310 CMR 10.24(8) may result in the temporary or permanent loss of Resource Areas and/or the conversion of one Resource Area to another when such loss is necessary to the achievement of the project's ecological restoration goals.
- Pursuant to 310 CMR 10.32(3), a proposed project in a salt marsh, on lands within 100 feet of a salt marsh, or in a body of water adjacent to a salt marsh shall not destroy any portion of the salt marsh and shall not have an adverse effect on the productivity of the salt marsh. Alterations in growth, distribution and composition of salt marsh vegetation shall be considered in evaluating adverse effects on productivity.
- Pursuant to 310 CMR 10.32(5), a project which will restore or rehabilitate a salt marsh, or create a salt marsh, may be permitted in accordance with 310 CMR 10.11 through 10.14, 10.24(8), and/or 10.53(4).
- Pursuant to 310 CMR 10.32(6), no project may be permitted which will have any adverse effect on specified habitat sites of Rare Species, as identified by procedures established under 310 CMR 10.37.

The design development process should be developed to work collaboratively with stakeholders to arrive at a design that balances access, resilience and ecological interests within current regulations. The balanced design solution should minimize adverse effects on the environment and serve the long-term function of municipal, ecological, recreational, and historic resources. Depending upon the size of the project and proposed work, permitting may take 1-3 years. Permitting of any project is anticipated to require the preparation and filing of all local, state and federal application:

- Massachusetts Environmental Policy Act (MEPA) Review – It is anticipated that the project will trigger one or more thresholds for the filing of an Environmental Notification Form (ENF) with MEPA (i.e., 301 CMR 11.03(3)(b)1.f; 301 CMR 11.03(3)(b)5)). It is additionally anticipated that a mandatory Environmental Impact Report (EIR) will be required in the MEPA Certificate on the ENF. The ENF/EIR will contain detailed information describing and analyzing the project and its alternatives and will assess the potential environmental impacts and mitigation measures, incorporating relevant portions of technical memoranda prepared. Public notice must be placed in a local newspaper, and abutters notified.
- Conservation Commission Notice of Intent (NOI) – The project must submit a NOI application with the local Conservation Commission of the jurisdiction in which the project resides. The Conservation Commission will notify the Natural Heritage & Endangered Species Program (NHESP), Division of Marine Fisheries (DMF), and Department of Environmental Protection (DEP) to provide comment. The application requires submittal of engineering plans. Public hearings follow the application, with acceptance leading to acquisition of an Order of Conditions.
- Department of Environmental Protection (DEP) Combined Chapter 91 and Water Quality Applications – A combined DEP Chapter 91 and Water Quality Certification application will be required for preparation and submittal to DEP. Supporting this permit, a Sampling and Analysis Plan may additionally be required to sample and test dredge/cut and fill material. USACE and DEP will provide a determination on the suitability of material handling and placement. Public notices must be published in the local newspaper, and waterfront abutters must be notified.
- Massachusetts Coastal Zone Management Federal Consistency (CZM) – The project must prepare and file a request for federal consistency with MA CZM. A Federal Consistency Statement must be prepared to address consistency of the proposed project with the Coastal Program Policies of CZM.

- US Army Corps of Engineers (USACE) Review – The project must file an Individual Permit application with the USACE New England Division for the dredging project. Copies of the application must be provided to the Massachusetts Historical Commission (MHC), Board of Underwater Archaeological Resources (BUAR), and Tribal Historic Preservation Officers.
- Local Special Permit – A special permit application may be necessary according to local regulations.

Construction Feasibility

Construction feasibility refers to the logistical complexity or barriers which may impact implementation of a preferred alternative. For nature-based solutions, barriers to construction may arise from limited available space. In its current state, Belle Isle Marsh abuts densely developed uplands, many of which provide critical functions to the region (e.g., MBTA Blue Line, evacuation routes). However, building natural features such as high/transitional marsh or coastal dune/bluff which provide a level of flood protection often requires a wide footprint, so as to not revert to a solution which more resembles a wall. Unless existing natural resources can be modified or existing infrastructure can be retreated, there may not be the space required to feasibly construct a project. In many cases, impacting existing natural resources will trigger regulatory thresholds and reduce permitting feasibility, while impacting existing infrastructure impacts the cost and function of critical infrastructure.

Other barriers to construction may arise from ownership and jurisdiction. The shoreline of Belle Isle Marsh changes hands across three municipalities, state agencies, and private commercial and residential development. All owners will approach their shoreline with varying priorities and varying ability to implement flood protection measures. Despite this, flood risk pays no mind to ownership boundaries, and a flood pathway will in most cases need to be addressed by multiple landowners coming together for one project.

Community Benefit

Community benefit was evaluated qualitatively through the identification of opportunities to increase public access at Belle Isle Marsh directly (e.g., trails, open space, aesthetic value), opportunities to protect critical community functions (e.g., transportation services, educational services), and opportunities to support community engagement programs.

Habitat Restoration Value

Habitat restoration value refers broadly to the size and quality of habitat that can be restored or enhanced by a proposed nature-based solution. Alternatives are considered to provide high restoration value if they:

- Solely utilize nature-based features,
- Do not negatively impact existing natural resources,
- Increase the availability of rare or valuable habitat types needed in the area, e.g., high marsh habitat which supports saltmarsh sparrow nesting, or
- Increase the opportunity for marsh migration with sea level rise, e.g., retreat of waterfront infrastructure.

Alternatives are considered to not provide habitat value if they, for instance:

- Utilize hard infrastructure, such as revetments and seawalls, without any amendments to support wildlife,
- Negatively impact existing natural resources, or
- Draw a hard line between Belle Isle Marsh and upland development, halting marsh migration with SLR.

Figure 1. Belle Isle Marsh Management Reaches and Conceptual Adaptation Footprints.

Table 3. Jurisdictional considerations and potential adaptation approaches of shoreline sites.

Shoreline Site	Jurisdictional Considerations		Adaptation Project Details	
	Landowners	Opportunities & Constraints	Desired Goal	Proposed Near-Term Adaptation Approach
Excel Academy	Adaptation of this reach would require collaboration across several entities, including the MBTA, City of Boston, MassDOT, and DCR.	MassDOT aims to improve culvert. MBTA plans to protect property with an elevated feature (e.g., seawall). Winthrop and East Boston are coordinating a Greenway extension. Coordinate all future efforts and look for opportunities to build in NBS and resilience.	Reduce flood risk to Saratoga St. Flood pathway tipping point at approximately 13 ft NAVD88. Reduce flood risk to MBTA railyard and East Boston by mitigating the flood pathway alongside the CVS/Excel Academy. Build marsh health & elevation capacity for resilience to SLR.	Construct a living levee around perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Pair with grey infrastructure, such as a buried seawall or elevated, impermeable berm to provide a last line of defense to critical infrastructure. Stabilize marsh edge with natural materials (e.g., fiber roll array, oyster reef).
MBTA Railyard	Adaptation of this reach would require collaboration between the MBTA and DCR.	MBTA plans to protect property with an elevated feature (e.g., seawall). Coordinate all future efforts and look for opportunities to build in nature-based features and resilience.	Soften "bathtub" condition where a steep marsh boundary prevents marsh migration inland. Enhance high and transitional marsh. Reduce flood risk to MBTA railyard. Flood pathway tipping point at ~ 11.1 ft NAVD88.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Lane reduction of MBTA railyard perimeter road to create space for expanded living levee concept. Pair with grey infrastructure, such as a buried seawall or elevated, impermeable berm to provide a last line of defense to critical infrastructure.
Rosie's Pond	Adaptation of this reach would require collaboration between MBTA, DCR, and Redgate, a private real estate company.	MBTA is considering moving railyard entrance away from Austin Ave. An ideal project would be incorporated across the area from the Belle Isle Marsh, up through the Redgate property. Coordination with the future housing development would be necessary for successful implementation of a project.	Mitigate low-lying flood pathway which enters by the Red Gate property (formerly Casket Company) and extends deep into East Boston. Flood pathway tipping point at ~ 10.5 ft NAVD88. Revitalize degraded wetland and improve stormwater discharge. Build marsh health & elevation capacity for resilience to SLR.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway.

Shoreline Site	Jurisdictional Considerations		Adaptation Project Details	
	Landowners	Opportunities & Constraints	Desired Goal	Proposed Near-Term Adaptation Approach
Lawn Ave	Adaptation of this reach would require collaboration between DCR, the City of Boston, and the neighborhood residents.	Proposed lane reduction would require buy-in from neighborhood residents.	Maximize habitat value while reducing flood risk to inland residential properties. Build marsh health & elevation capacity for resilience to SLR.	Temporary flood management techniques and flood accommodation techniques may be most appropriate for the row of residences closest to the marsh in the near term to minimize damage. This may include temporary flood barriers along the roadway or in doorways, waterproofing or elevating vulnerable assets (electrical systems), identifying space for parking vehicles above flood levels, etc. **OR** Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Lane reduction of Lawn Ave and Palermo St to create expanded space for living levee concept. Roadway could be converted to one-way travel without losing access to residential properties.
Bennington St	Adaptation of this reach would require collaboration between the City of Boston, City of Revere, MBTA, MassDOT, and DCR.	Climate Ready East Boston is pursuing elevated berm/ living levee or elevated roadway/trail. Opportunity to build habitat value. Coordinate lane reduction with ongoing MassDOT road diet & bike lane study. Bennington St and Fredericks Park must both be adapted to avoid flanking.	Reduce flood risk to Bennington St and MBTA Blue Line. Belle Isle flood pathways approach from both East Boston (overtopping L-Berm area) and Revere (Fredericks Park/Revere Public Schools). Enhance present and future marsh habitat. Create space for marsh migration.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Bennington St lane reduction to create space for expanded living levee concept and improved marsh migration pathways. Develop tide gate management plan to leave tide gate open during all but storm surge conditions, promoting the migration of saltmarsh habitat inland.
Fredericks Park	Adaptation of this reach would require collaboration from Revere & DCR.	Bennington St and Fredericks Park must both be adapted for flood protection to avoid flanking. The City intends to maintain recreational function of the fields long-term.	Mitigate low-lying flood pathway which enters Fredericks Park and continues into Revere and East Boston. Flood pathway tipping point at approximately 8.5 ft NAVD88. Maintain open space for recreation.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Given the limited space between the main channel and park, commit a portion of the park to the living levee footprint to allow enough width for establishing the full suite of marsh habitat types as well as an elevated berm feature for flood protection and trail.

Shoreline Site	Jurisdictional Considerations		Adaptation Project Details	
	Landowners	Opportunities & Constraints	Desired Goal	Proposed Near-Term Adaptation Approach
Residential Revere	Adaptation of this reach would require collaboration between DCR, Revere, & the neighborhood residents.	Private ownership and limited open space constrain this project from being of significant scale.	Maximize habitat value while reducing flood risk to inland properties.	Mitigate marsh erosion with stabilization approaches such as installing oyster reefs in subtidal habitat, and coir logs in low, high, and transitional marsh habitat. Vegetation management for soil stabilization and sediment capture will also enhance erosion control. Educational approach to encourage homeowners to support marsh vegetation. "Living with sea level rise" program, similar to "Pollinator Friendly Yards."
Short Beach	Adaptation of this reach would require collaboration between DCR, Revere, Winthrop, & MassDOT.	Flood pathways stemming from both the open ocean and Belle Isle Marsh increase the complexity of this site. Short Beach is technically outside of the scope of this project, but must be adapted to provide protection to the Winthrop Parkway.	Minimize risk of Winthrop Parkway overtopping and flooding of Belle Isle Marsh. Tie-in ocean facing alternatives with upland to mitigate flanking. Additionally, mitigate the flood pathway from Belle Isle Marsh across Winthrop Ave. Flood pathway tipping point at ~ 11.1 ft NAVD88. Build marsh health & elevation capacity for resilience to SLR.	Sand and cobble nourishment of Short Beach to create buffer for Belle Isle and Winthrop Parkway from the open ocean. Should the nourishment project be pursued, and if it creates an appropriately large beach width, pair nourishment with construction of vegetated sand dune for elevation buffer to reduce runup and overtopping. On the marsh-side, construct a living levee to create elevation buffer for flood protection and gently, vegetated slopes to serve as present day high/transitional marsh habitat and future habitat migration pathway.
Residential North Winthrop	Adaptation of this reach would require collaboration between DCR, Winthrop, & residents.	Private ownership constrains this project from being of significant scale.	Maximize habitat value while reducing flood risk to inland properties.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Due to the low-lying nature of many properties, an elevated berm may be needed to provide adequate flood protection.
Bayou St / Argyle St	Adaptation of this reach would require collaboration from DCR, Winthrop, & residents and businesses.	A critical electrical substation sits inland from the marsh. It may be more cost effective to adapt it to flooding on-site.	Mitigate flood pathway into developed area and critical infrastructure. Flood pathway tipping point at ~ 13.0 ft NAVD88. Build marsh health & elevation capacity for resilience to SLR.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway.

Shoreline Site	Jurisdictional Considerations		Adaptation Project Details	
	Landowners	Opportunities & Constraints	Desired Goal	Proposed Near-Term Adaptation Approach
Cemetery	Adaptation of this reach would require collaboration between DCR & Winthrop.	Due to the limited space and steep slope between the cemetery and marsh, little opportunity for restoration exists without leveling wide swaths of the headland.	Promote marsh migration.	Conserve undeveloped spaces. Regrade shoreline to gentler slope for future marsh habitat. Vegetation management for marsh enhancement.
Morton St / Marine Ecology Park	Adaptation of this reach would require collaboration from DCR, Winthrop, & residents and commercial businesses.	Protection of Morton St would necessarily extend from Morton St to the Winthrop Boat Yard. Private ownership along Banks St constrain the project to within existing marsh habitat or Winthrop right-of-way (ROW).	Expand marsh area and enhance storm protection value. Mitigate flood pathway through Morton St to low-lying neighborhood. Flood pathway tipping point at ~ 7.3 ft NAVD88, located at the intersection of Morton St and Banks St. Build marsh health and elevation capacity for resilience to sea level rise.	Construct a living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and future habitat migration pathway. Incorporate an upland, elevated berm to provide adequate flood protection. Extend from Morton St to Cemetery. Consider raising the intersection of Amelia Ave / Morton St to tie-in storm protection where the flood pathway is most narrow and could be most easily headed-off. *Note that this would leave three blocks of residential Winthrop unprotected, and these would ideally be addressed at Winthrop Boat Yard shoreline. Note that stormwater currently cannot drain to the marsh from Morton St during king tide/storm conditions.*
Winthrop Boat Yard / Main St	Adaptation of this reach would require collaboration between DCR, Winthrop, & residents and businesses.	Protection of Morton St would necessarily extend from the Winthrop Boat Yard to Morton St. Protection of Main St from long-term sea level rise and storm scenarios would necessarily prevent flooding from both the north (Belle Ilse Marsh) and south (Boston Harbor).	Address the mudflat/degraded marsh by the Boat Yard/Morton St. Expand marsh area and enhance storm protection value. Mitigate flood pathway which stems at the boundary between marsh and Boat Yard. Ultimately, mitigate flooding which is projected to find a pathway into Winthrop south of Main St.	Marsh enhancement to expand low/high marsh habitat, increase the buffer between development and the tides, increase wave attenuation, and provide stormwater runoff filtration. Consider use of a marsh sill (oyster reef or rock) to stabilize edge, filling of landside mudflat, and establishment of native vegetation. *Note that marsh restoration alone is not sufficient to mitigate storm flooding and is intended to be part of a holistic approach to adaptation.* Construct living levee along perimeter of marsh to create elevation buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh and marsh migration pathway. Incorporate an upland, elevated berm to provide adequate flood protection and trail. *Note that stormwater currently cannot drain to the marsh from Morton St during king tide/storm conditions.*

Table 4. Detailed prioritization criteria for adaptation at Belle Isle Marsh.

Shoreline Site	Prioritization Criteria					
	Flood Exposure	**Asset Criticality**	**Permitting Feasibility**	**Construction Feasibility**	**Community Benefit**	**Habitat Restoration Value**
Excel Academy	The Excel Academy reach is the 7th lowest critical flood pathway. Under 2030 sea level rise projections, Saratoga Street may be overtopped by way of the marsh under 13.0 ft NAVD88 water levels.	Saratoga Street is an evacuation route, one of only two (the other being Winthrop Parkway) for the entire Town of Winthrop.	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	Due to the extent of degraded marsh area, it is considered feasible to design and construct a living levee along Saratoga Street and the MBTA railyard.	Merging habitat enhancement and flood protection project with the Greenway extension would provide infrastructure, environmental, & social benefits. Protection of an evacuation route is critical to Winthrop residents, including EJ communities.	Due to the degraded quality of high marsh adjacent to the MBTA railyard, restoration value is significant. However, the limited space available along Saratoga St would necessitate impacts to existing marsh areas, reducing the habitat value while providing for long-term marsh migration.
MBTA Railyard	This site is the 4th lowest flood pathway at an elevation of 11.1 ft NAVD88, vulnerable in the present day. Once overtopped, flood water may travel through the railyard and link up with flooding across Rosie's Pond, ultimately flowing to East Boston, impacting commercial, residential, and transportation infrastructure.	The Orient Heights maintenance railyard is critical to the function of the Blue Line, which provides public transportation to 69,000 people per weekday. Of these riders, 90% are using the Blue Line to travel to or from home, and a majority of riders reported utilizing no alternative means for making these trips (MBTA, 2017).	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	Little space exists between healthy low marsh and the active railyard. The steep slope between the two averages ~25 ft in width. Construction of a habitat enhancing adaptation project would likely require conversion of existing low marsh to higher elevation habitat, or lane reduction on behalf of the MBTA.	This project aims to protect critical transportation infrastructure for residents in the area, especially the many EJ communities which rely solely on public transportation.	Due to the limited space available between the railyard roadway and marsh, adaptation would necessarily impact existing marsh areas, reducing the habitat value.
Rosie's Pond	The upland area adjacent to Rosie's Pond is the 3rd lowest flood pathway at an	Austin Ave provides critical access for MBTA personnel and transportation of	May be permittable should work provide	Little space exists between the existing low marsh, Austin St, & the Redgate property.	This project aims protect greater East Boston from a low-lying flood pathway	Due to the limited space available, creating a gently sloped living levee

Shoreline Site	Prioritization Criteria					
	Flood Exposure	Asset Criticality	Permitting Feasibility	Construction Feasibility	Community Benefit	Habitat Restoration Value
	elevation of 10.5 ft NAVD88, vulnerable in the present day. Overtopping of Austin Ave and the inland Redgate property is projected to cross Bennington St and flow downhill into East Boston, flooding a very large residential and commercial area, & impacting roadways.	equipment and rail cars to the railyard. Farther inland, Bennington Street is a critical evacuation roadway in East Boston.	overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	Adaptation may require work w/in the marsh. Space for transitional and upland resilient landscaping would necessarily take place on the Redgate property. Austin St would remain a hard infrastructure barrier between marsh and upland unless alternative routes were pursued by the MBTA.	susceptible to future sea level rise and storms. Flood protection would necessarily need to be implemented along other flood pathways to East Boston to effectively benefit the community.	will necessarily extend across existing, healthy low marsh habitat, but long-term would provide marsh migration space.
Lawn Ave	Lawn Ave is not considered a critical flood pathway. Flooding of Lawn Ave is anticipated to have a 1% annual chance under 2030 sea level rise conditions. Flooding will impact an isolated neighborhood.	Lawn Ave is a residential area across from the Blue Line Suffolk Downs stop. The area supports ~30 residential homes or apartments, the Park Place apartment complex, and a few commercial businesses.	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	Between 30 and 125 ft of horizontal open space are available for an adaptation project. Should lane reduction be amenable to stakeholders, it is anticipated that a living levee would be feasible across this full reach.	Protection benefits are limited to local residents.	Should lane reduction be pursued, the opportunity exists to expand both high marsh and transitional marsh habitat, providing significant habitat restoration value.
Bennington St	Fredericks Park is the 2nd lowest flood pathway around Belle Isle Marsh, being overtopped by an 8.5 ft NAVD88 water level, vulnerable in the present day. Flooding travels along the	Bennington St is a primary roadway and evacuation route between Revere and East Boston. Parallel to Bennington St, the MBTA Blue Line connects the Suffolk Downs and Beachmont	May be permittable should work provide overriding benefit to habitat and Rare Species, where	This reach serves transportation, public access, and the Belle Isle Reservation. MassDOT is investigating the feasibility of lane reduction for Bennington St, creating	This project aims to protect a critical evacuation route for residents in the area, including multiple EJ communities.	Wave energy is low and soft solutions are more likely to be successful, reducing the need to rely on hard infrastructure. Existing *Phragmites* stands provide little habitat value,

Shoreline Site	Prioritization Criteria					
	Flood Exposure	Asset Criticality	Permitting Feasibility	Construction Feasibility	Community Benefit	Habitat Restoration Value
	western reach of the fields and crosses Bennington St. Flood risk is greatest to Bennington St and Revere Public Schools. Under 2030, Bennington St becomes at risk of overtopping along the full reach between Lawn Ave and Revere. Furthermore, the MBTA Blue Line becomes vulnerable to flooding once Bennington St is overtopped. Under future extreme storms, back-flooding becomes a risk from Chelsea Creek and Roughan’s Point.	stops, which provide public transportation primarily to residents of East Boston and Revere. Suffolk Downs is the site of a future residential apartment complex, expected to increase the population of this reach by tens of thousands. Sales Creek is the site of DCR’s Bennington St Pump Station.	impacted OR, if work is sited outside of such sensitive areas.	an opportunity for increased open space. The existing pedestrian/ bike path could be incorporated into the adaptation project (as proposed by Climate Ready East Boston), and the landward edge of the Reservation could be committed to the project footprint. Assuming the above is accomplished, there is anticipated to be enough space for adaptation.		therefore construction impacts are temporary, and long-term benefits are gained by providing habitat migration space between the marsh and roadway. Habitat upstream of the pump station is of poor quality, and would benefit significantly from re-introduced tides.
Fredericks Park		The Fredericks Park reach supports the Beachmont School, a public sports complex (baseball fields, basketball courts, etc.), and the Beachmont VFW. Inland of Fredericks Park is Bennington St, a critical evacuation route for Revere.	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	Revere can’t relocate this recreational area. As a result, the available space for a project is limited. ~40 to 65 ft of width exists between the main channel and the park. While erosion control or an earthen berm may fit in this area, a living levee would require a wider band for construction.	This project aims to protect a public school and a critical evacuation route (Bennington St) for residents in the area, including multiple EJ communities.	Restoring grass lawn to marsh habitat would provide significant habitat value.
Residential Revere	Site is not considered a critical flood pathway. Flooding has occurred in recent past (e.g., 2018 winter storms) and is anticipated to	Site is a narrow marsh-front area of Beachmont. Beachmont Yacht Club and over 65 residential homes or apartments	May be permittable should work provide overriding benefit to	Very limited space exists between the main channel and residential structures. Implementation of a project would	Protection benefits limited to local residents.	A narrow band of marsh habitat exists, limiting the opportunity for significant habitat enhancement.

Shoreline Site	Prioritization Criteria					
	Flood Exposure	**Asset Criticality**	**Permitting Feasibility**	**Construction Feasibility**	**Community Benefit**	**Habitat Restoration Value**
	occur during a 10-year storm. Flooding will impact a narrow band of marsh-front homes.	are present along Pearl Ave, Summer St, & Crystal Ave.	habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	necessarily occur within private land.		Vegetation management would be positive, but not expansive.
Short Beach	Short Beach and the Winthrop Parkway become a potential flood pathway by 2030, at risk to wave overtopping of Short Beach rather than flooding through the marsh. The elevation required storm surge overtopping at Winthrop Parkway is 11.5 ft NAVD88.	The Short Beach reach contains the ocean front beach (owned by DCR), marsh edge, Winthrop Ave and parking area, and the Winthrop Parkway. Winthrop Parkway is an evacuation route, one of only two (the other being Saratoga St) for the entire Town of Winthrop.	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	Little space exists between low marsh and the Winthrop Parkway. The sloped area is ~45 ft in width. Construction of a habitat enhancing adaptation project would require conversion of existing low marsh to higher elevation habitat, or lane reduction in Winthrop Ave.	This project aims to protect a critical evacuation route for residents in the area, including multiple EJ communities.	With lane reduction, near-term open space and long-term marsh migration space could be created. Along Short Beach, if sufficient beach width could be gained through nourishment, dune restoration would significantly improve habitat value.
Residential North Winthrop	Residential North Winthrop is not considered a critical flood pathway. Flooding has occurred in recent past (e.g., 2018 winter storms) and is anticipated to occur during a 10% annual chance storm. Flooding will impact a narrow band of marsh-front homes.	Residential North Winthrop is a narrow marsh-front area supporting approximately 28 residential homes or apartments, west of Bayou St.	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	Due to the limited space between the low marsh and residential structures, implementation of a project necessarily impacts existing marsh or occur within private land. ~55 ft of horizontal open space is available. Adaptation to interrupt the flood pathway from Short Beach could fit in the	Protection benefits limited to local residents.	Due to the limited space available, creating a gently sloped living levee will necessarily extend across existing, healthy low marsh habitat, but long-term would provide marsh migration space.

Shoreline Site	Prioritization Criteria					
	Flood Exposure	Asset Criticality	Permitting Feasibility	Construction Feasibility	Community Benefit	Habitat Restoration Value
				John Kilmartin Pathway area.		
Bayou St / Argyle St	Bayou St / Argyle St represent the 6th lowest flood pathway vulnerable to events more extreme than 100-year storm in 2030. Critical elevation is 13 ft NAVD88. The potential consequence of flooding is damage & disruption of a critical electrical substation.	Bayou St is a short public road accessing a few residential homes or apartments. Argyle St is the adjacent roadway across the corner of the marsh, and supports commercial businesses, as well as a critical electrical substation.	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	This reach varies from undeveloped upland to low marsh which abuts infrastructure. Where space exists, a project may be more easily constructed. However, adaptation in the narrower reaches would likely require conversion of existing low marsh to higher elevation habitat.	This project aims to protect a critical electric substation serving Winthrop residents.	Creating a gently sloped living levee will necessarily extend across upland vegetated space, but long-term would provide marsh migration space.
Cemetery	This site has the lowest flood risk of any reach. No coastal flood risk was identified even under the 2070 scenario, only fringe flooding of open space area is anticipated. No critical assets are at-risk. Local cultural impacts may develop.	The North Winthrop Cemetery is an active, open-space cemetery supporting funerals and burial grounds.	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	While significant open space exists the topography of the cemetery extends as a headland with a steep perimeter bank. This limits the horizontal space for an adaptation project to benefit the marsh.	Flood protection would provide cultural preservation benefits.	Due to the limited space and steep slope between the cemetery and marsh, adaptation would necessarily impact existing marsh areas, reducing the habitat value.
Morton St / Marine Ecology Park	Morton St and Banks St are the lowest developed areas along the perimeter of Belle Isle Marsh, vulnerable in the present day. A	Morton St and Banks St are primarily residential roadways supporting approximately 17 marsh-front residential	May be permittable should work provide overriding benefit to	Due to the limited space between the low marsh and residential structures, implementation of a project would impact	Protection benefits to public access (Marine Ecology Park and Winthrop Greenway), local roadways,	If lane reduction were acceptable along Morton St, migration space could be created while minimizing

Shoreline Site	Prioritization Criteria					
	Flood Exposure	Asset Criticality	Permitting Feasibility	Construction Feasibility	Community Benefit	Habitat Restoration Value
	storm surge water level of 7.3 ft (NAVD88) would result in inundation of Banks St. This would be the first area to experience flooding from a coastal storm event, resulting in inundation of the low-lying neighborhood. Flooding primarily impacts residents.	homes or apartments, a few commercial businesses, and the Belle Isle Marsh Marine Ecology Park, an open space park and boardwalk developed by DCR and Winthrop. This is anticipated to be the site of a future Greenway extension.	habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	existing marsh or occur within private land. Opportunity does exist within the Marine Ecology Park which is a higher elevation open space area. ~50 ft of horizontal open space is available adjacent to Morton St. Lane reduction would support a significant project.	businesses, and residents.	impacts to the existing marsh habitat. However, due to the limited space available along Banks St, creating a gently sloped living levee may need to extend across existing, healthy low marsh habitat, but long-term would serve marsh migration.
Winthrop Boat Yard / Main St	Under 2030 sea level rise conditions, flooding of Main St by way of Morton St and Boston Harbor is projected to occur during a 1% annual chance storm.	This reach supports approximately 7 marsh-front homes or apartments, the Belle Isle Boat Yard (w/commercial marine businesses), as well as Main St, Winthrop and its residential and commercial buildings. Main Street (Saratoga Street in Boston) is an evacuation route, one of only two (the other being Winthrop Parkway) for the entire Town of Winthrop.	May be permittable should work provide overriding benefit to habitat and Rare Species, where impacted OR, if work is sited outside of such sensitive areas.	~45 ft of horizontal open space is available for a project adjacent to Morton St. With lane reduction, a significant project could be constructed. Along the boat yard property, very limited space is available between mudflat/open water & the developed land. Adaptation would be limited to erosion control measures, unless some level of retreat from the shoreline were implemented.	Protection benefits to public access (Marine Ecology Park and Winthrop Greenway), local roadways, businesses, and residents. Additional protection benefits for Main St, which represents a critical evacuation route for residents, including EJ communities.	Marsh restoration within the degraded mudflat area would provide significant habitat value. Additionally, if lane reduction were acceptable along Morton St, migration space could be created while minimizing impacts to the existing marsh habitat.

4.0 Priority Site Selection

Detailed prioritization criteria described in Table 4 were assigned a score to characterize the value provided by each site and approach, including the relative flood exposure, existence of critical assets and infrastructure, project permitting feasibility, construction feasibility, community benefit, and habitat restoration value (Table 5).

Following extensive discussions with the landowners and abutters group, as well as individual consultation with municipalities, it was determined that four sites would be carried forward to conceptual design:

- Frederick's Park – Revere
- Bennington St – Boston
- Winthrop Boat Yard / Main St – Winthrop
- Morton St / Marine Ecology Park – Winthrop

The four priority adaptation sites represent flood pathways to East Boston, Revere (Beachmont), and Winthrop. Frederick's Park and Bennington St sites are addressed as one because future flood risk spans both reaches. Winthrop Boat Yard / Main St and Morton St / Marine Ecology Park sites are also addressed as one, because long-term flood risk spans both reaches.

Table 5. Site prioritization scoring assessment at Belle Isle Marsh.

Shoreline Site	Relative Flood Exposure	Asset Criticality	Permitting Feasibility	Construction Feasibility	Community Benefit	Habitat Restoration Value	Composite Score (max 18)
Fredericks Park	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	14
Bennington St	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	14
Winthrop Boat Yard / Main St	High (3)	High (3)	Medium (2)	Low (1)	Medium (2)	High (3)	14
Short Beach	Medium (2)	High (3)	Medium (2)	Low (1)	High (3)	High (3)	14
Morton St / Marine Ecology Park	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	13
Rosie's Pond	Medium (2)	High (3)	Medium (2)	Low (1)	High (3)	Medium (2)	13
Excel Academy	Low (1)	High (3)	Medium (2)	High (3)	Medium (2)	Medium (2)	13
Bayou St / Argyle St	Low (1)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	13
MBTA Railyard	Medium (2)	High (3)	Medium (2)	Low (1)	High (3)	Low (1)	12
Lawn Ave	Medium (2)	Low (1)	Medium (2)	Medium (2)	Low (1)	Medium (2)	10
Residential North Winthrop	Medium (2)	Low (1)	Medium (2)	Medium (2)	Low (1)	Low (1)	9
Residential Revere	Medium (2)	Low (1)	Medium (2)	Low (1)	Low (1)	Low (1)	8
Cemetery	None (0)	Low (1)	Medium (2)	Low (1)	Low (1)	Low (1)	6

5.0 Priority Alternative Conceptual Design

The following section discusses conceptual design alternatives at each priority site.

5.1 Bennington St and Frederick's Park Reach

Mitigating flood risk to Bennington St and Frederick's Park, as well as inland infrastructure such as the MBTA Blue Line, requires attaining a critical design elevation adjacent to the marsh edge. Alternatives carried forward along Bennington St closely follow the City of Boston's Coastal Resilience Solutions for East Boston Phase II plan (2022). Frederick's Park represented more of a blank slate, though any alternative would necessarily tie-in with Bennington St and must maintain public use of the ballfields.

Four alternatives were developed to provide a range of options to landowners which come with varying pros/cons relating to flood protection, habitat enhancement, and public access value. These alternatives are depicted in Figure 2 through Figure 5, and detailed below:

- No Action
- Vegetated Berm and Elevated Pedestrian Pathway
- Living Levee and Elevated Roadway
- Living Levee and Elevated Pedestrian Pathway

Note that rain gardens at Frederick's Park are currently proposed under each alternative, although assessment is required to understand the stormwater volumes to be managed, the results of which will determine the sizing of rain gardens or the need for additional flood storage and conveyance. No impervious surfaces are proposed under any alternative, and the lane reduction at Bennington St will result in an increase in pervious open space surfaces.

No Action

This alternative proposes no mitigation, adaptation, or restoration actions to be taken. Bennington St and Frederick's Park would be subject to ongoing coastal processes – erosion, flooding, storm surge, waves, and sediment transport, coupled with sea level rise. Based on the evaluation of existing and future flood risk, Frederick's Park would increasingly be overtopped, leading to flooding of the park, school, and Bennington St. Such flooding has already occurred under present day conditions. Under severe storm conditions, Bennington St is projected to flood from both Frederick's Park and the upper limit of the Belle Isle main channel, as well as across the *Phragmites* dominated habitat in an area referred to as the L-Berm. Wetland habitat would be projected to migrate into Frederick's Park as regular inundation increasingly occurs with sea level rise.

Vegetated Berm and Elevated Pedestrian Pathway

In anticipation of the permitting difficulties with filling wetland resources to support a living levee, a minimized impact design is proposed to align all features outside of existing wetland resources. This alternative considers reducing Bennington St to two lanes to create space for a vegetated berm and pedestrian pathway landward of the reservation. Raising Bennington St remains an option in this alternative. The earthen berm would continue along the shore of Frederick's Park and tie-in to Orchard St to provide immediate flood protection for the roadway and fields/school while creating a public access trail. The berm would be vegetated with native species.

While this alternative may increase permitting feasibility, it may limit habitat restoration value compared to the following living levee concepts. Working outside of the marsh reduces the available width within which a critical elevation can be attained and, as a result, the vegetated berm would have steep side slopes which are less supportive of marsh vegetation and therefore habitat migration.

Stormwater management infrastructure will be necessary so as to not impound precipitation-based or overtopping flood water upland. In Frederick's Park, rain garden infiltration basins are proposed along the field-side of the berm to reduce the amount of surface runoff that flows directly from the playing fields into the river. No impervious surfaces are proposed.

Elevated Roadway and Living Levee

A living levee concept at this reach involves attaining a critical design elevation for flood protection through the expansion and enhancement of the full range of habitat types at this marsh site:

- Low Marsh & High Marsh
- Transitional Marsh
- Upland Habitat

This means grading existing resource areas and/or occupying uplands to create a gentle slope across ecotones and up to the critical design elevation. Existing wetland habitat would be impacted, and such impacts would have to be minimized or mitigated. The long-term goal would be to provide a net-ecological benefit to the area.

Habitat restoration is maximized wherever possible to provide immediate benefit, as well as facilitate future marsh migration. This includes restoring areas of eroding fringe marsh, expanding high marsh habitat for saltmarsh sparrow nesting, and enhancing/expanding transitional marsh and upland open space areas for marsh migration. Where proposed, low marsh restoration areas would be planted with predominately *Spartina alterniflora*, with a mix of other native high marsh species in the higher elevation areas (e.g., *S. patens*, *Distichlis spicata*, and *Juncus gerardii*). Newly created upland open space will additionally require a planting plan. Considerations may include New England Coastal Salt Tolerant Grass Mix, little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardi*), indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), seaside goldenrod (*Solidago sempervirens*), and marsh elder (*Iva frutescens*).

Because the existing shoreline condition varies along the reach, proposed adaptation varies accordingly. Along Bennington St, the Reservation supports primarily *Phragmites* stands and freshwater ponds. Restoration opportunities exist primarily in vegetation management, and would require close collaboration with DCR. While *Phragmites* is an invasive species and is progressively engulfing the ponds, the area does support sensitive species. Impacts to sensitive species should aim to be avoided, minimized, or mitigated through design and construction approaches. In the long-term, the gently sloped levee would serve as transitional marsh habitat to support marsh migration. Proposed atop the living levee is a pedestrian pathway in the City's right-of-way to support public access and aesthetic views. Elevating Bennington St is proposed under this alternative, which brings the added benefit of eliminating the risk of back-flooding via Sales Creek to the critical evacuation route.

Along Frederick's Park, an eroding fringing marsh habitat would be enhanced through expansion of low marsh habitat stabilized by a stone sill. Open space currently serving the park would be converted to high marsh and transitional marsh habitat for present and future saltmarsh sparrow nesting habitat. The pedestrian pathway is proposed to continue atop the living levee from Bennington St and along Frederick's Park, tying-in at Orchard St. The foundation of the living levee could be made impermeable, to mitigate seepage during high water levels.

Stormwater management infrastructure will be necessary so as to not impound precipitation-based or overtopping flood water upland. In Frederick's Park, rain garden infiltration basins are proposed along the field-side of the berm to reduce the amount of surface runoff from the playing fields into the river. No impervious surfaces are proposed. Conceptual cross-sections of this alternative are included in Figure 6 and Figure 7.

Living Levee and Elevated Pedestrian Pathway

This alternative proposes similar components to the prior concept, with the only difference being Bennington St would not be raised and back-flooding from Sales Creek must be addressed elsewhere. This alternative proposes to construct a living levee along Bennington Street and Frederick's Park to Orchard St with a gradual slope into the marsh to support marsh migration.

Figure 2. Bennington St and Frederick's Park – No Action

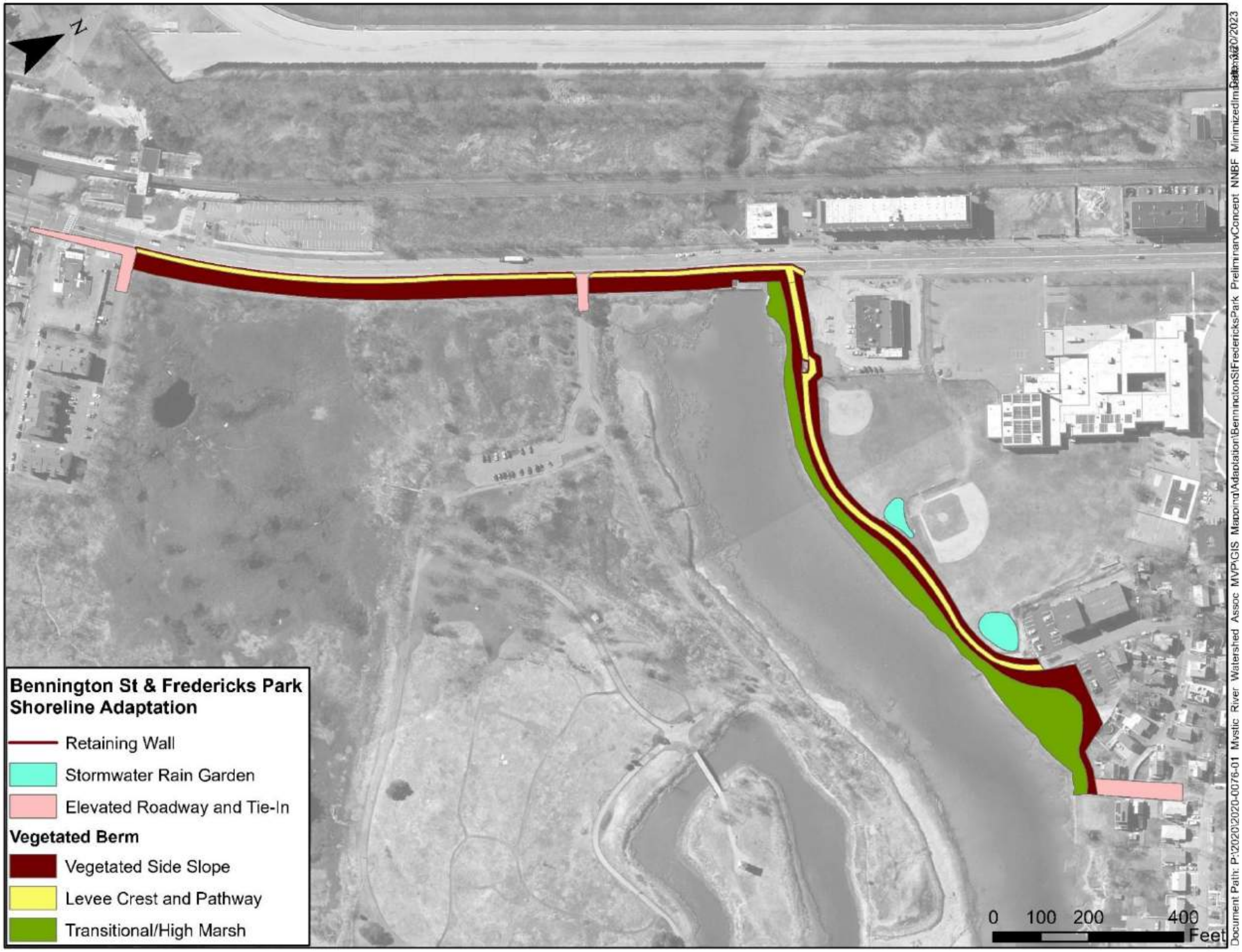

Figure 3. Bennington St and Frederick's Park – Vegetated Berm and Elevated Pedestrian Pathway (Minimized Impact Design).

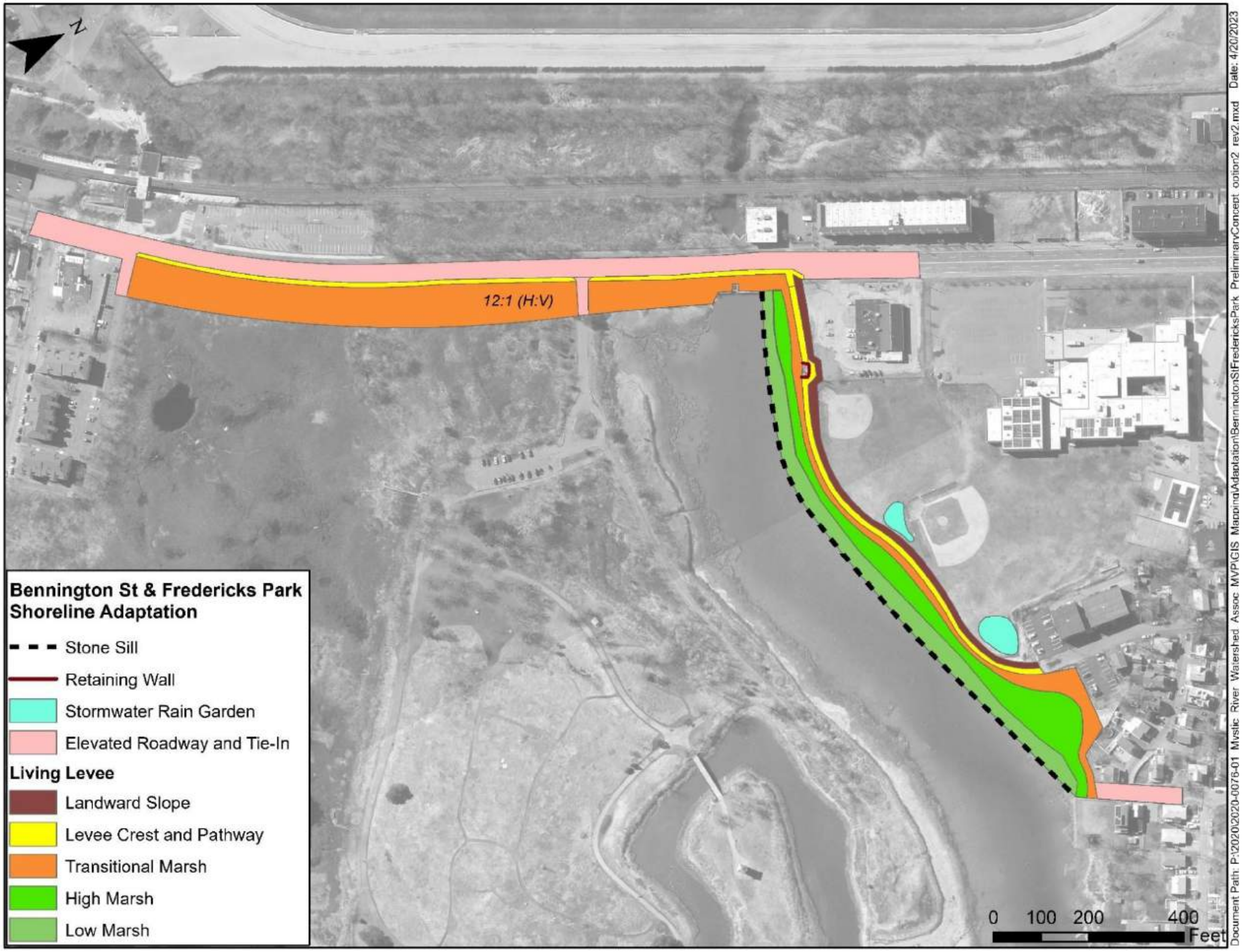

Figure 4. Bennington St and Frederick's Park – Living Levee and Elevated Roadway.

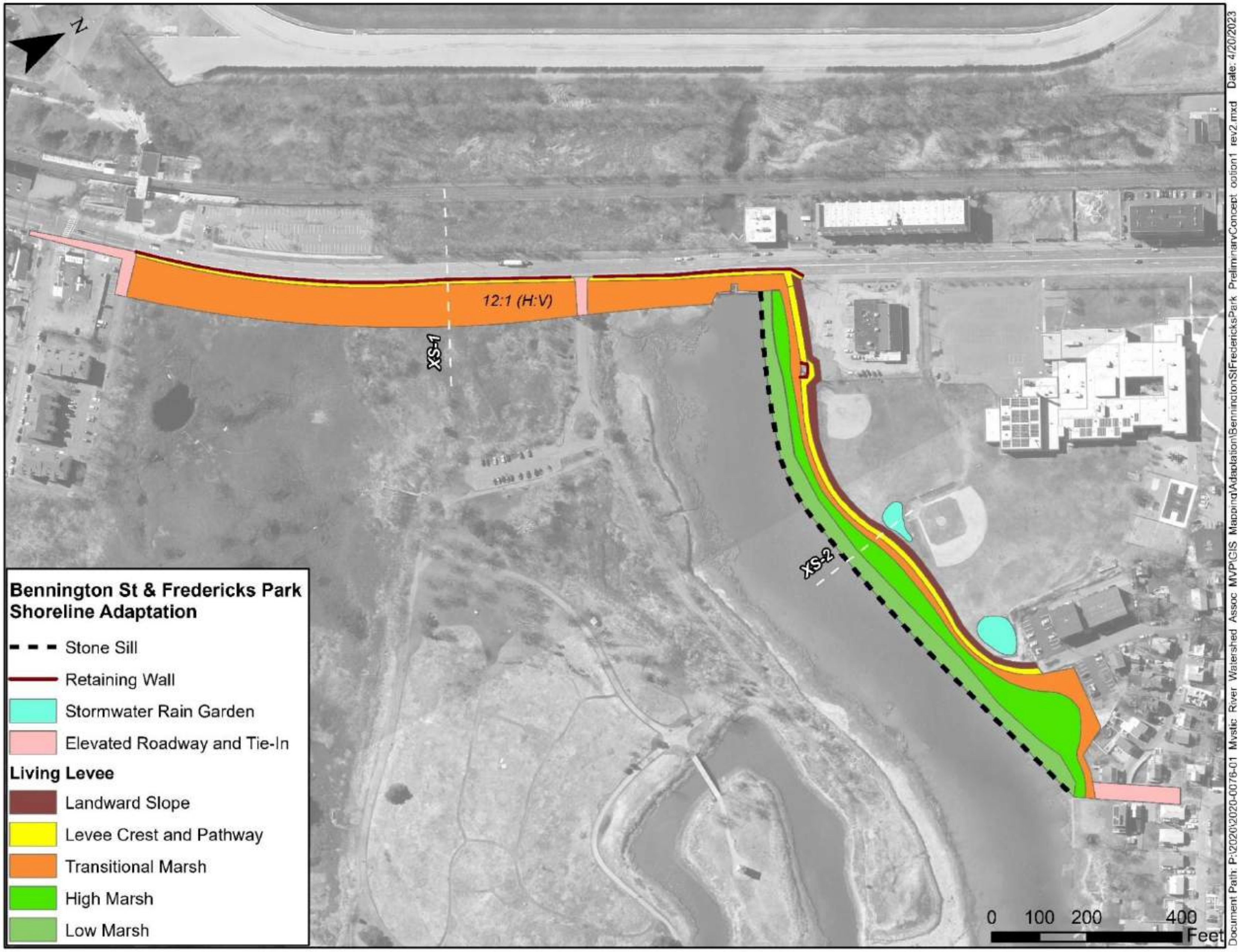

Figure 5. Bennington St and Frederick's Park – Living Levee and Elevated Pedestrian Pathway.

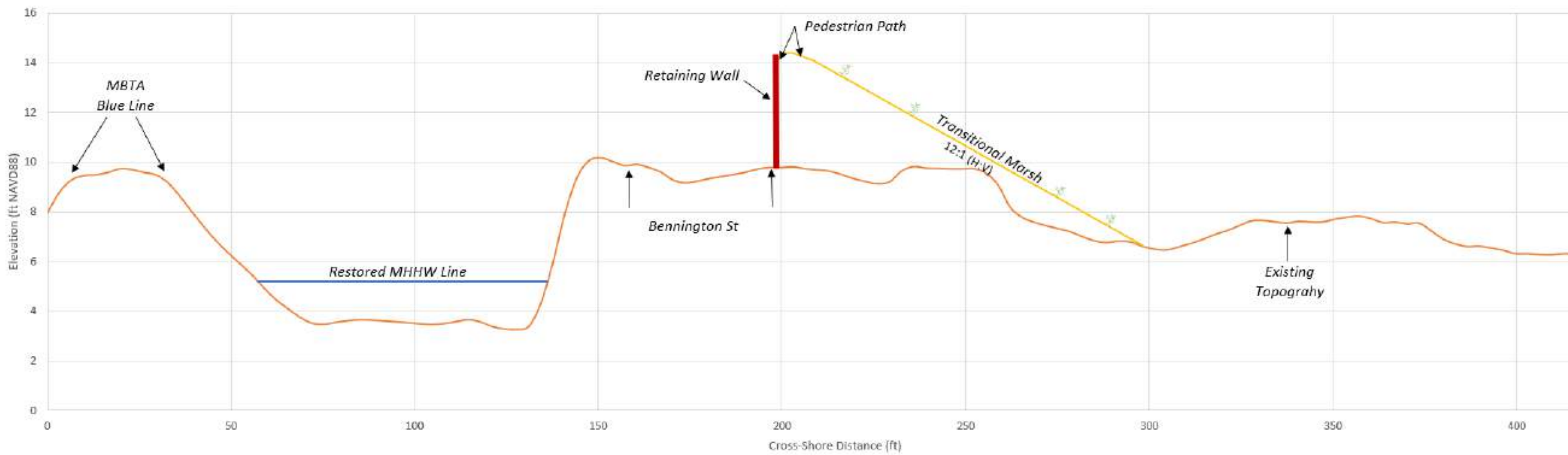

Figure 6. Bennington St – Living Levee and Raised Pathway Conceptual Cross-Section (XS-1).

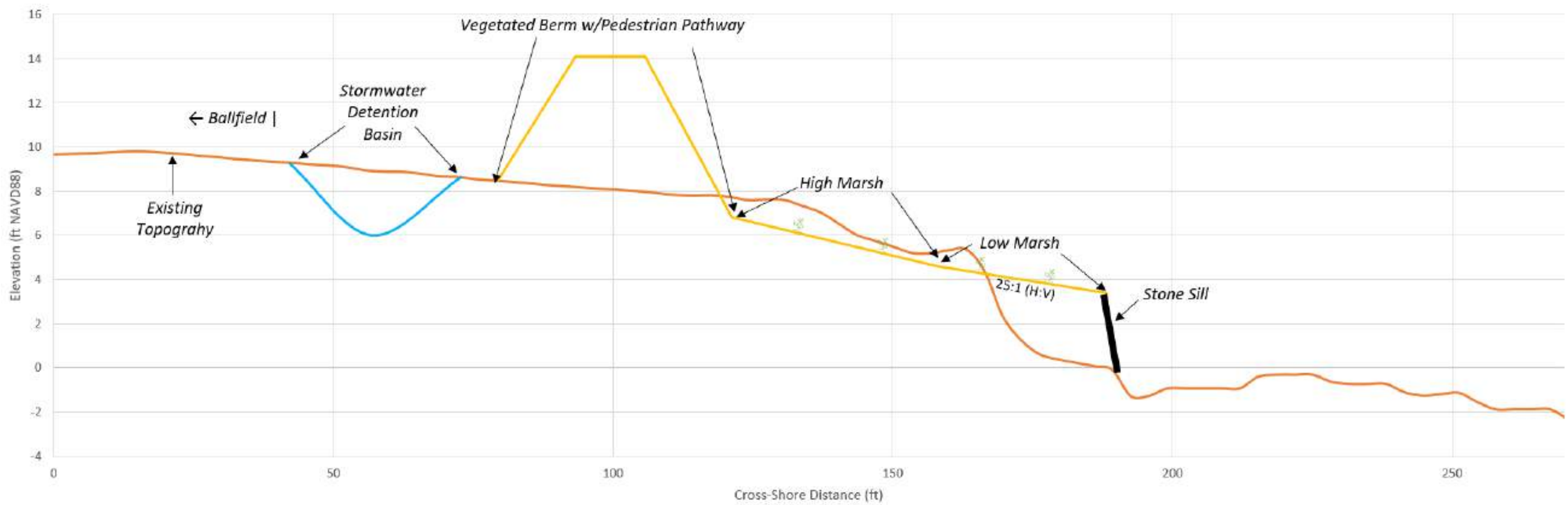

Figure 7. Frederick's Park – Living Levee and Raised Pathway Conceptual Cross-Section (XS-2).

5.2 Morton St Reach

Mitigating flood risk to Morton St reach involves attaining a critical design elevation adjacent to the marsh edge. Four alternatives were developed to provide a range of options to landowners which come with varying pros/cons relating to flood protection, habitat enhancement, and public access value. Note that adaptation alternatives vary in alignment and the protection of residential areas in Winthrop. The four alternatives are depicted in Figure 8 through Figure 11, and detailed below:

- No Action
- Vegetated Berm and Elevated Roadway (Minimized Impact Design)
- Living Levee and Elevated Pedestrian Pathway
- Living Levee and Elevated Roadway

While not currently incorporated into concepts, it is recognized that stormwater management infrastructure will be necessary to not impound precipitation-based or overtopping flood water in neighborhoods. Flood storage and infiltration will be prioritized. No impervious surfaces are proposed under any alternative.

No Action

This alternative proposes no mitigation, adaptation, or restoration actions to be taken. The reach would be subject to ongoing coastal processes – erosion, flooding, storm surge, waves, and sediment transport, coupled with sea level rise. Based on the evaluation of flood risk, the area will increasingly experience flooding, often first stemming at the intersection of Banks St and Morton St, and ultimately overtopping much of the marsh front. Under future sea level rise scenarios, back-flooding from Boston Harbor over Main St is anticipated to additionally impact this neighborhood. Marsh habitat is currently degraded in many locations due to oversaturation and the smothering of vegetation by wrack material. The waterfront is eroded, and composed of various materials as many sites, such as the Belle Isle Marine Ecology Park, used to be the site of local filling and dumping. Wetland habitat would be projected to migrate into the Morton St residential neighborhood as daily and monthly inundation increasingly occurs with sea level rise.

Vegetated Berm and Elevated Roadway (Minimized Impact Design)

In anticipation of the difficulties with filling wetland resources to support a living levee, a minimized impact design is proposed to align all features outside of existing wetland resources. This alternative considers removing one lane along a portion of Morton St to create space for a vegetated berm and pedestrian pathway landward of existing marsh habitat. Creation of an earthen berm would provide flood protection for the neighborhood while creating public access and open space. The berm would be vegetated with native species. Where open space along the marsh edge is unavailable, this alternative considers raising roadway elevations within the Winthrop right-of-way to attain critical elevations to buffer against a targeted design storm water level. The vegetated berm could tie-in to elevated roadways at Banks St, Willis Ave/Pleasant Ct, and Main St.

While this alternative may increase permitting feasibility, it may limit habitat restoration value compared to the following living levee concepts. Working outside of the marsh reduces the available width within which a critical elevation can be attained, and as a result the vegetated berm would have steep side slopes which are less supportive of marsh vegetation and therefore habitat migration.

Living Levee and Elevated Pedestrian Pathway

A living levee concept at Morton St involves attaining a critical design elevation for flood protection through the expansion and enhancement of the full range of habitat types at this marsh site:

- Low Marsh & High Marsh
- Transitional Marsh
- Upland Habitat

This means grading existing resource areas and/or occupying uplands to create a gentle slope across ecotones and up to the critical design elevation. Existing wetland habitat would be impacted, and such impacts would have to be minimized or mitigated. The long-term goal would be to provide a net-ecological benefit to the area.

Habitat restoration is maximized wherever possible to provide immediate benefit, as well as facilitate future marsh migration. This includes restoring areas of eroding fringe marsh, restoring areas of ponding and marsh degradation, expanding high marsh habitat for saltmarsh sparrow nesting, and enhancing/expanding transitional marsh and upland open space areas for marsh migration. Where proposed, marsh restoration areas would require a planting plan. Low marsh would be planted with predominately *Spartina alterniflora*, with a mix of other native high marsh species in the higher elevation areas (e.g., *S. patens*, *Distichlis spicata*, and *Juncus gerardii*). Upland vegetation may include New England Coastal Salt Tolerant Grass Mix, little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardi*), indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), seaside goldenrod (*Solidago sempervirens*), and marsh elder (*Iva frutescens*).

Because the existing shoreline condition varies along the reach, proposed habitat restoration varies accordingly. At the crescent-shaped mudflat area, low marsh creation is proposed through the filling of mudflat with sediment consisting of a sand/silt mix that will be specified to mirror the site-specific grain size while supporting marsh plant establishment. The toe of fill material is proposed to be stabilized by a stone sill. Inland and adjacent to the low marsh restoration area, high marsh habitat and transitional marsh habitat are proposed at a gentle slope to facilitate marsh migration. Expansion of high marsh and transitional habitat is proposed to occupy portions of existing low marsh habitat through fill and portions of Morton St through lane reduction. Morton St would drop from a two-way road to a one-way road, though it is recognized that the Town relies on Morton St as emergency parking during snow events and this parking would need to be accommodated. At the crest of the living levee, a pedestrian pathway is proposed to support public access and aesthetic views of the marsh. As the East Boston Greenway is proposed for extension into Winthrop, this project would ideally be integrated with this effort to provide community connectivity. The foundation of the pedestrian pathway should be made impermeable, to mitigate seepage and flood risk during high water levels. A conceptual cross-section is included in Figure 12.

Along Banks St, the elevated pedestrian pathway is proposed to follow the alignment of the existing boardwalk. Integrated flood protection into the existing boardwalk will require creative engineering solutions to ensure that inland properties are protected, while also minimizing impacts to existing habitat. Alternatively, the crest elevation of the living levee could be aligned within private property, should the public be willing to grant easements for the protection of their assets. A conceptual cross-section is included in Figure 13.

Along the Belle Isle Boatyard shoreline, a living levee does not seem feasible, and the already armored shoreline is proposed to be bolstered and elevated by a seawall or bulkhead and revetment. Furthermore, Main St would require protection, proposed through being raised to cut off flood pathways.

Living Levee and Elevated Roadway

This alternative proposes similar components to the prior concept, with the only difference being that no berm is proposed along Banks St residential parcels and instead the most seaward roadways (Main St, Morton St, Banks St) are proposed to be raised for flood protection. Local connecting roadways such as Willis Ave, Pleasant Court, Pleasant St, or others must be raised to tie-in critical elevations. Barriers to implementation may require consideration of alternative roadway elevation alignments, exposing various parcels to flooding. The flood pathway is most narrow at Amelia Ave / Morton St, representing an alternative reach to tie-in storm protection.

This alternative continues to propose a living levee along Morton St to create an elevated buffer for flood protection and gentle, vegetated slopes to serve as present day transitional marsh habitat and a future habitat migration space. The concept incorporates land reduction and an upland, elevated berm with a pedestrian pathway to achieve critical elevation.

Figure 8. Morton St – No Action.

Figure 9. Morton St – Vegetated Berm and Raised Roadway (Minimized Impact Design).

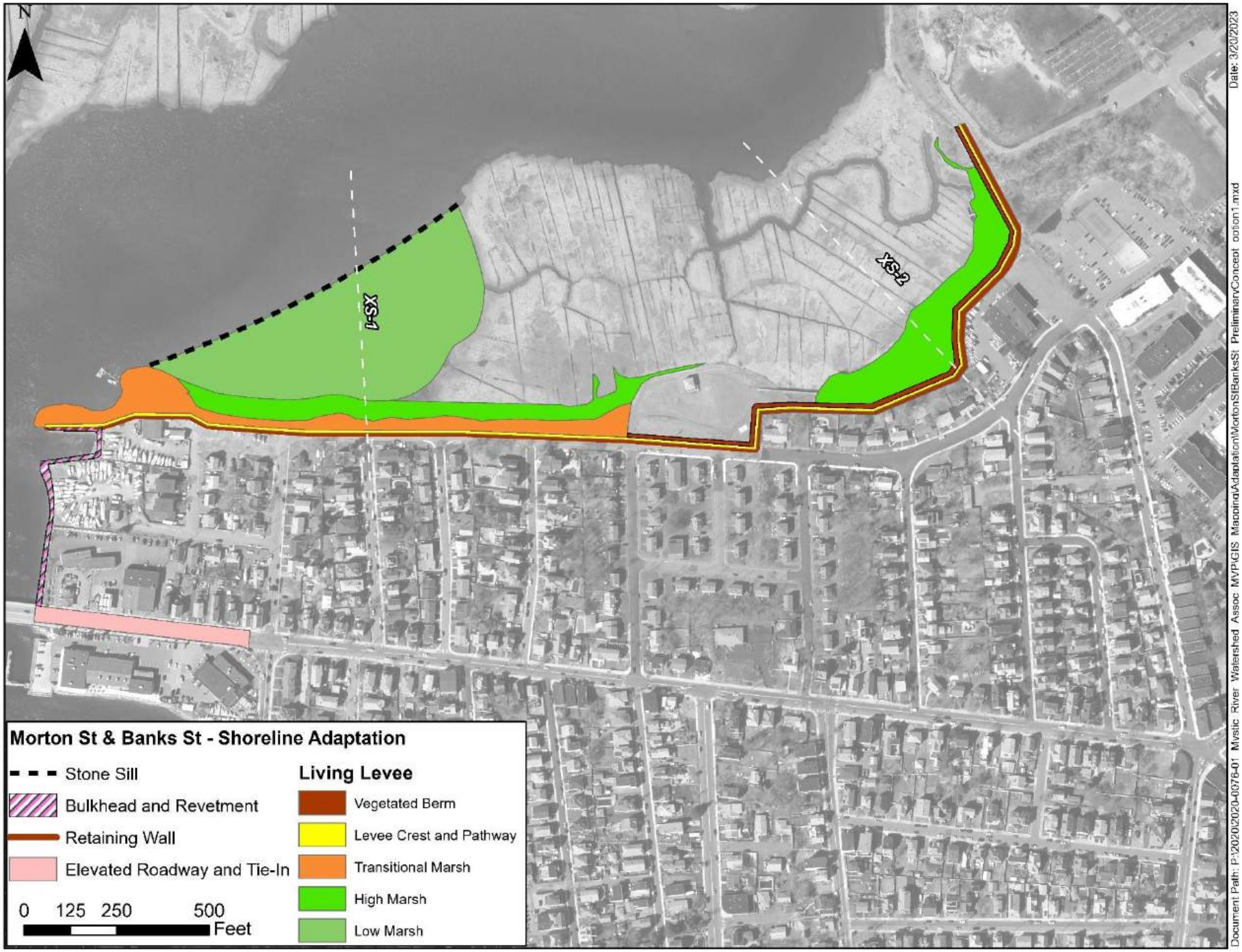

Figure 10. Morton St – Living Levee and Elevated Pedestrian Pathway.

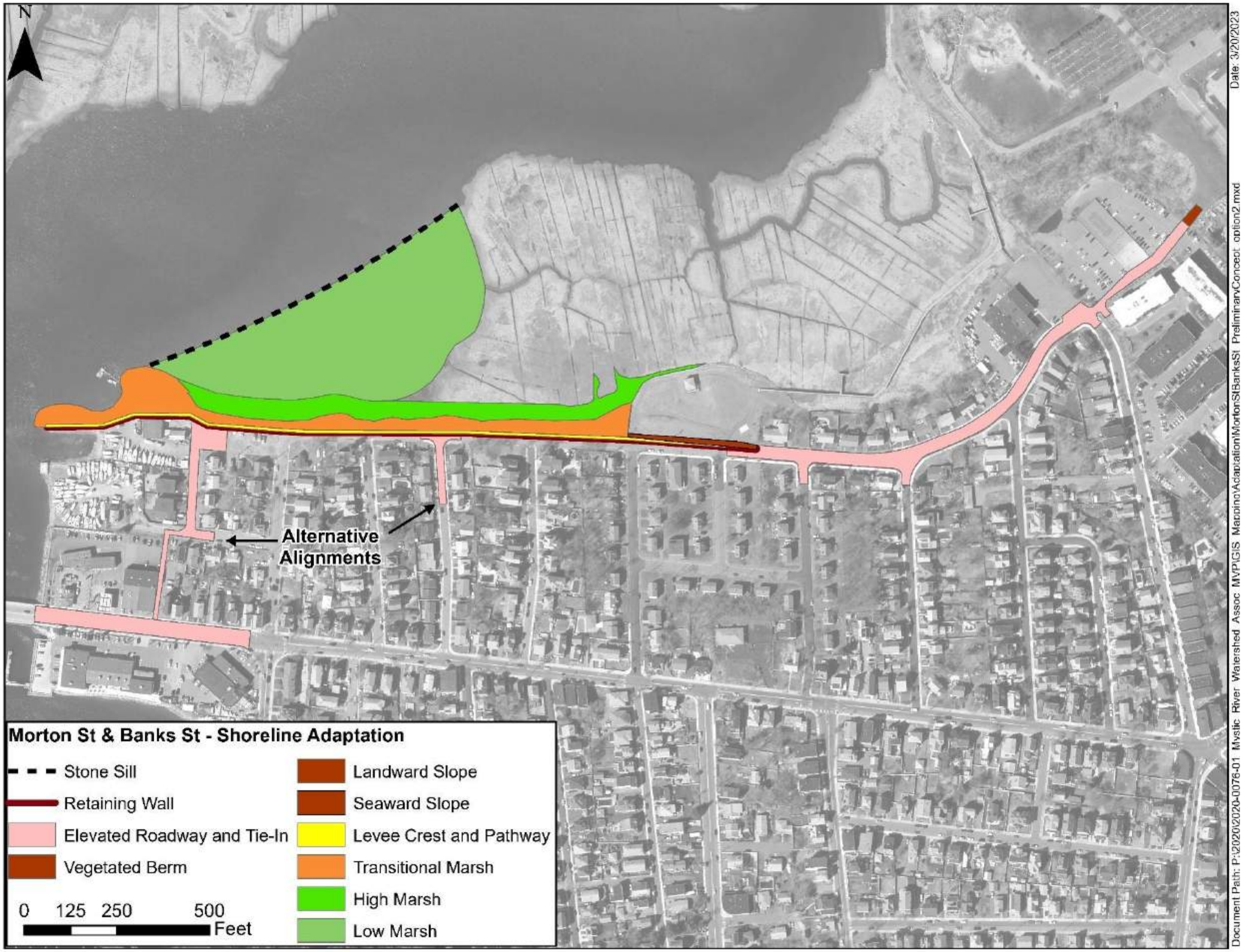

Figure 11. *Morton St – Living Levee and Elevated Roadway.*

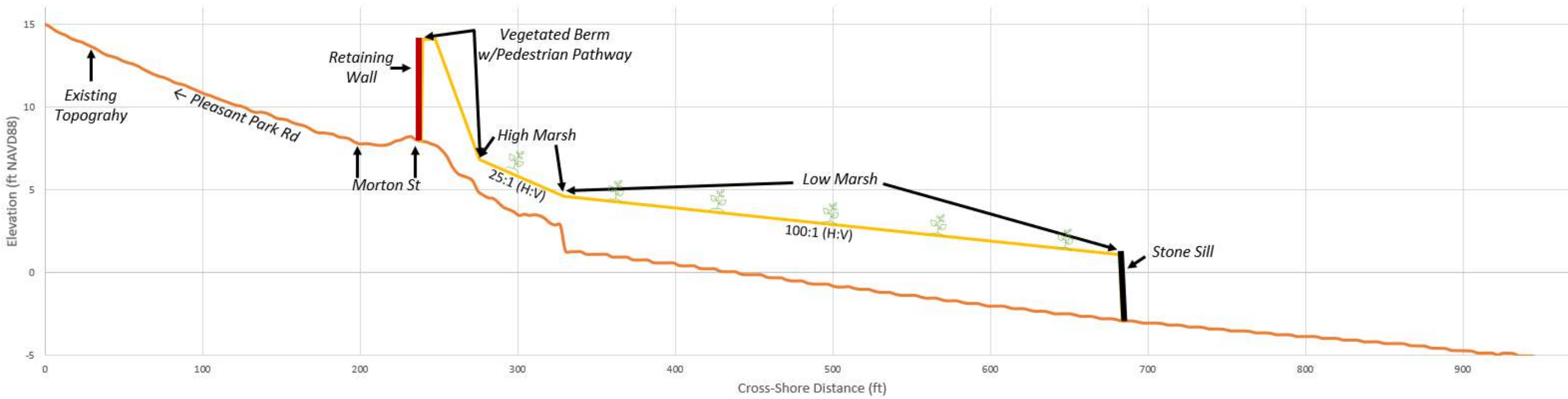

Figure 12. Morton St – Living Levee and Raised Pathway Conceptual Cross-Section (XS-1).

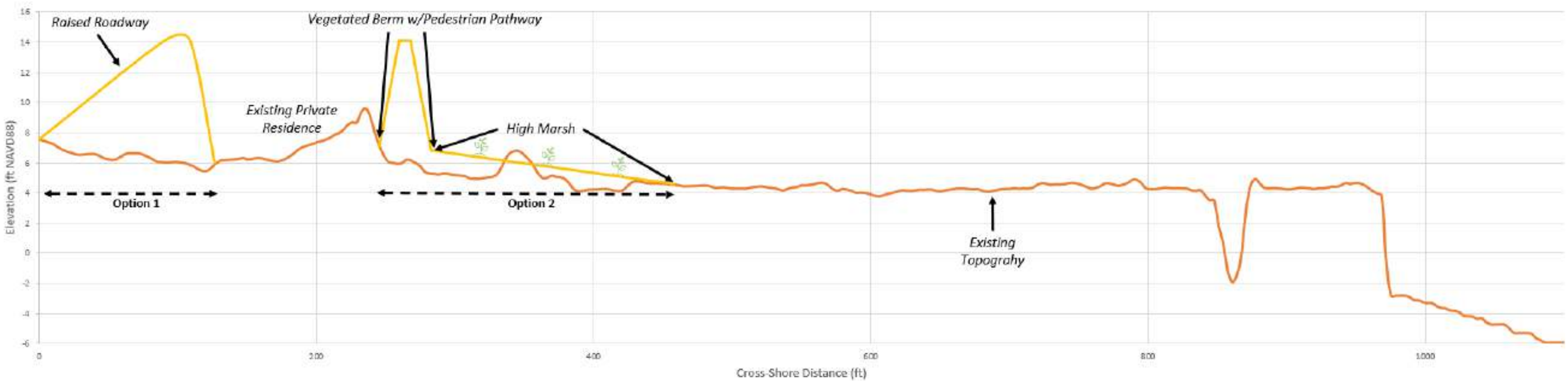

Figure 13. Banks St – Living Levee and Raised Pathway or Raised Roadway Conceptual Cross-Section (XS-2).

6.0 References

City of Boston. 2022. *Coastal Resilience Solutions for East Boston and Charlestown (Phase II) – Final Report*. August 2022.

MBTA. 2017. *Massachusetts Bay Transportation Authority: Climate Change Vulnerability Assessment for the Blue Line (Draft).* Prepared by MBTA and MassDOT. March 30, 2017.

Appendix F: Belle Isle Marsh Climate Vulnerability Assessment – Task 6.2 Cumulative Impact Modeling and Analysis

MEMORANDUM

DATE June 30, 2023 **JOB NO.** 2020-0076-01

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Belle Isle Marsh – Climate Vulnerability Assessment – MVP Task 6.2 Cumulative Impact Modeling and Analysis

1.0 INTRODUCTION

Nature based solutions are becoming a mainstream alternative to grey infrastructure for the purposes of coastal flood protection. Nature-based berms, living levees and living shorelines have been shown to provide wave attenuation and flood protection benefits, as well as enhance habitat. Flood protection through nature-based features provides an opportunity to tie in coastal resiliency and community benefits to ongoing saltmarsh restoration projects. This project looks at Belle Isle Marsh as a source for regional flood protection through the design and integration of a series of nature-based flood protection measures. The marsh was broken down into thirteen reaches for which nature-based solutions to flood risk and habitat vulnerability were developed. Following a process of analysis, stakeholder and community collaboration, and concept development, four priority reaches were determined for preliminary design and performance modeling. Following Task 6.1, wherein the prioritization process is detailed, this Task 6.2 memorandum describes the development of priority site preliminary design, performance modeling utilizing the Massachusetts Coast Flood Risk Model (MC-FRM), and the conclusions/implications for project feasibility and next steps.

2.0 PRIORITY SITE ALTERNATIVES

The primary goal of priority site alternatives is to use nature-based solutions to provide coastal flood protection while creating a soft edge between development and Belle Isle Marsh, supporting present and future habitat value.

Four priority sites selected for further analysis included:

- Bennington St (East Boston)
- Frederick's Park (Revere)
- Belle Isle Boatyard/Morton St (Winthrop)
- Belle Isle Marine Ecology Park/Banks St (Winthrop)

Bennington St and Fredericks Park are immediately adjacent to one another, as are the Morton St and Banks St sites. While these sites were initially segmented because of unique shoreline development constraints, flood pathway analysis shows that under future sea level rise scenarios, flood extents will cross these areas. In order to address flood pathways, the sites were merged into two priority sites as follows:

- **Bennington St to Frederick's Park Shoreline**
- Belle Isle Boatyard/Morton St to Belle Isle Marine Ecology Park/Banks St, herein referred to as **Morton St Shoreline**

Several alternative designs may feasibly protect communities from flooding by way of Belle Isle Marsh. As discussed in Task 6.1 Alternatives Analysis/Selection, hybrid concepts which incorporate a living levee (to facilitate marsh migration and achieve design flood elevations) and lane reduction (to increase available open space and support gentle side slopes) will provide the greatest total benefit to flood protection, habitat enhancement, and public access. The alternatives developed at this phase include:

- Bennington Street & Fredericks Park
  - No Action
  - Vegetated Berm and Elevated Pedestrian Pathway
  - Living Levee and Elevated Roadway
  - Living Levee and Elevated Pedestrian Pathway

- Morton Street
  - No Action
  - Vegetated Berm and Elevated Roadway (Minimized Impact Design)
  - Living Levee and Elevated Pedestrian Pathway
  - Living Levee and Elevated Roadway

See MVP Task 6.1 Alternatives Analysis and Selection Memo for a depiction and detailed description of these alternatives.

3.0 MASSACHUSETTS COAST – FLOOD RISK MODEL

The flood protection design alignments were modeled for effectiveness using the Massachusetts Coast Flood Risk Model (MC-FRM), through which extent of flooding, depths of flooding and potential impacts to neighboring properties were assessed. The methods and results of this assessment are presented below.

3.1 Storm Scenarios and Parameters

Four representative storms under three different time horizons were simulated for existing and alternative conditions using the Massachusetts Coast Flood Risk Model (MC-FRM). This consisted of the four (4) future projected storm scenarios in addition to existing conditions. Modeled storm scenario maximum still water elevations are summarized in Table 1. Annual exceedance probability (AEP) the annual chance a particular storm water level will be met or exceeded for a given time horizon.

Table 1. Modeled Storm Scenarios – Annual Exceedance Probability Storm Water Levels

AEP	Storm Level	Time Horizon	Sea Level Rise Scenario	Maximum Water Level (ft NAVD88)
5%	**20-year Storm**	**2050**	2.5 ft	11.1
2%	**50-year Storm**	**2030**	1.3 ft	10.0
1%	**100-year Storm**	**Present**	0 ft	8.6
1%	**100-year Storm**	**2070**	4.3 ft	13.6
0.2%	**500-year Storm**	**2050**	2.5 ft	13.0

The MC-FRM (Figure 9) is a high-resolution, probabilistic flood risk model created specifically to assess physics-based, coastal forced, flooding conditions under present and future climate conditions for the entire coast of Massachusetts. The model uses a two-way coupled version of the Advanced Circulation (ADCIRC) and Unstructured Simulating Waves Nearshore (UnSWAN) models to fully simulate a variety of storm conditions (e.g., tropical and extra-tropical cyclones, etc.). The MC-FRM incorporates the state standard sea level rise conditions over time as presented by Massachusetts Coastal Zone Management and Resilient MA (https://resilientma.mass.gov/changes/sea-level-rise). Storm intensification due to climate change is also incorporated within the MC-FRM. The model has, and is currently, being used for numerous coastal planning and design projects throughout Massachusetts and is recommended by the Commonwealth of Massachusetts *Climate Resilience Design Standards* as the basis for resilient coastal design.

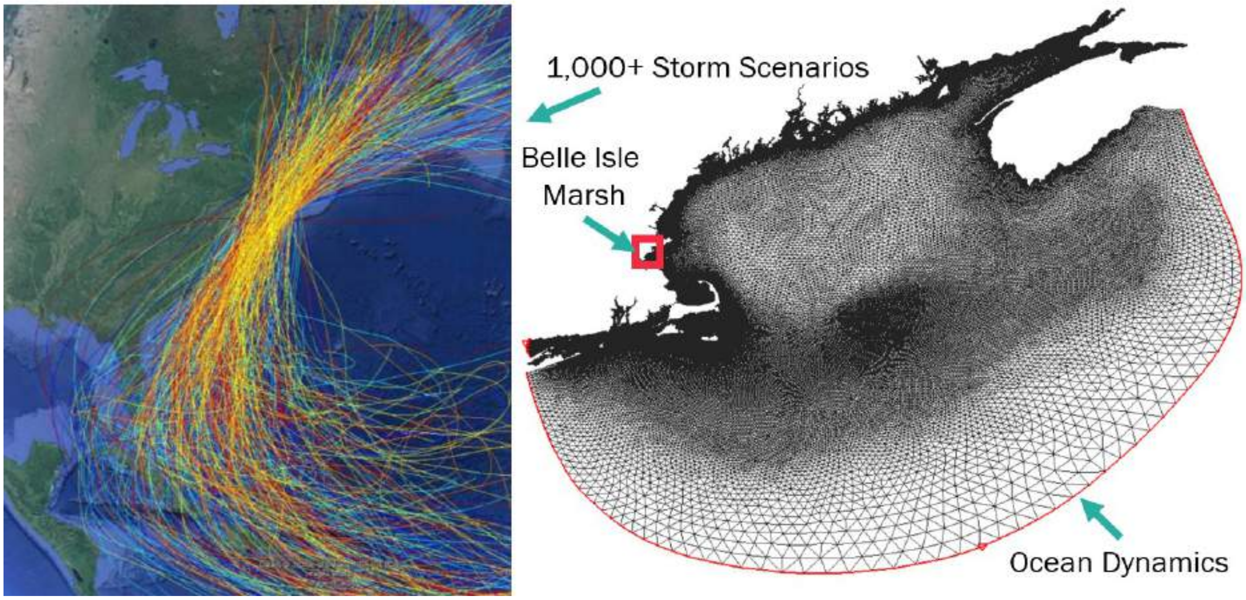

Figure 1. **Storm tracks for a percentage of the storms incorporated into the MC-FRM (left panel). MC-FRM regional modeling mesh with the location of Belle Isle Marsh identified with a box (right panel).**

The MC-FRM provides a probabilistic distribution of water levels for locations throughout Massachusetts based on thousands of storms. From these thousands of storm events, individual storms corresponding closely to specific return-periods water surface elevations can be selected to evaluate the performance of flood resiliency projects. To model the difference between existing and proposed conditions, an alternative scenario was developed by applying the topographic changes and elements of the design to the MC-FRM modeling mesh. The alternative scenario mesh was then run under the same storm scenario as the existing conditions, to identify regions where the design influences the hydrodynamics. Modeled water-level information from the MC-FRM for each storm and alternative scenario were used to create comparison maps of flood extent, increases/decreases in flooding to neighboring properties, and depth reduction maps.

3.2 Adaptation Grids

A series of modeling grids were created by applying the design elements to the MC-FRM grid by changing the elevations of the topography to reflect the design. Changes in topography result from elevating marsh platforms, elevating roads, and elevating stretches of coastal bank (berms, living levees) and are added to the grid as such. The goal of the design elements is to mitigate flooding without adding any adverse effects (channelization of flood waters) to neighboring properties.

Bennington Street/Frederick's Park

One alignment was created for the Bennington Street/Frederick's Park region (Figure 2). One of the concept scenarios covered by this alignment raises a section of Bennington Street to 14.1 ft NAVD88, with a nature-based berm (14.1 ft NAVD88) continuing in front of Frederick's Park and terminating at the end of Orchard Street in Revere, creating a single continuous alignment. Due to the resolution of the model, the modeling grid that raises Bennington Street, and the grid that constructs a berm and reduces the street to one lane of traffic each way will achieve the same result when comparing flood extents and depth reduction. As such, these are treated as a single alignment scenario, and will be discussed below as the “Elevate Bennington Street to Frederick’s Park” scenario. The second alignment scenario raises Bennington Street through the intersection with Winthrop Ave in Revere and adds the nature-based berm continuing in front of Frederick’s Park and terminating at the end of Orchard Street in Revere. This scenario will be discussed below as the “Elevate Bennington Street to Winthrop Ave” scenario. All the above scenarios include a 14.1 ft NAVD berm in front of Frederick’s Park that terminates at Orchard Street.

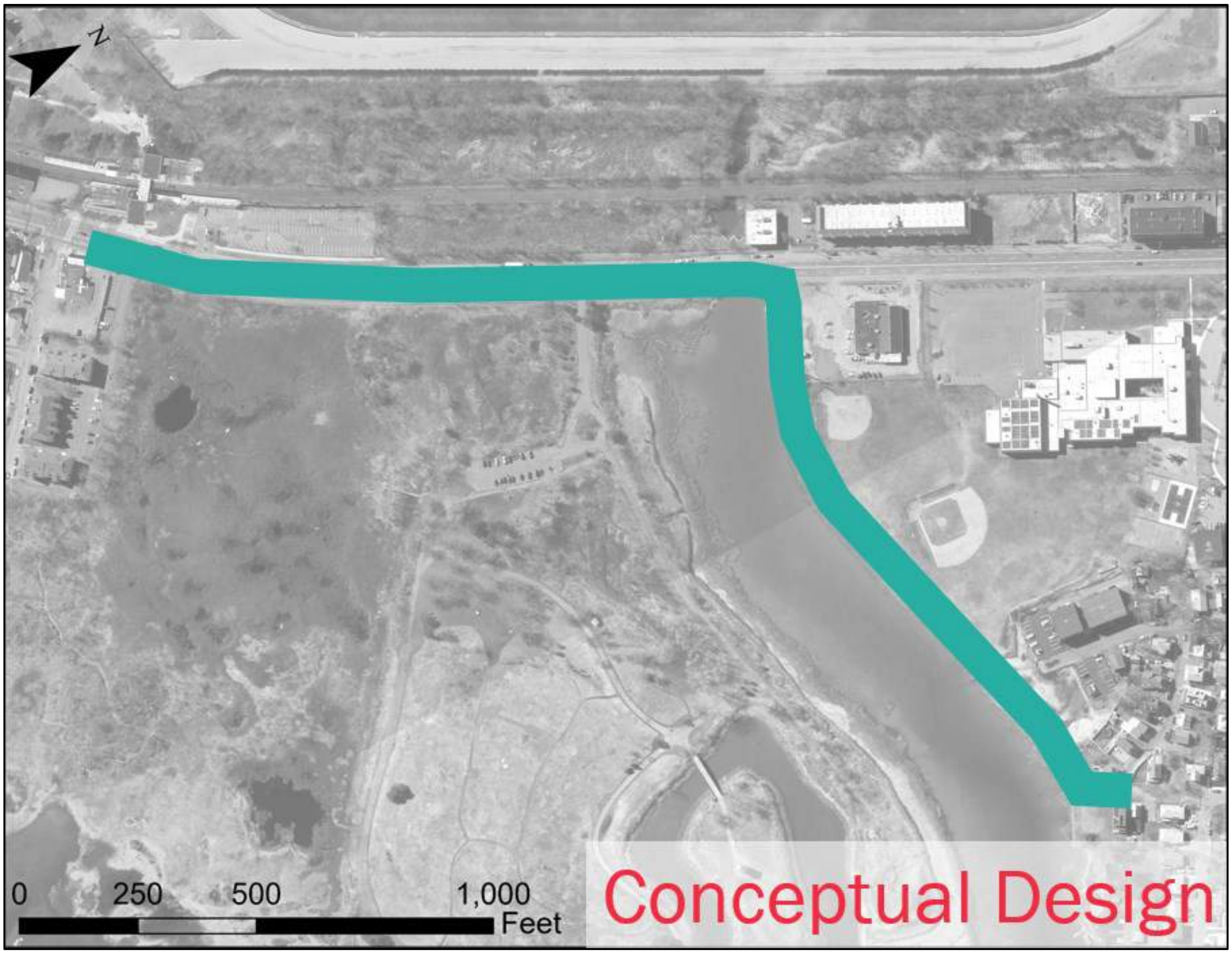

Figure 2. Conceptual design alignment for Bennington Street/Frederick’s Park.

Morton Street

Two alignments were created for the Morton Street region (Figure 3). The first alignment (described below as “Layout 1”) builds a 14.1 ft NAVD88 berm from the Saratoga Street Bridge, along the shoreline of Belle Isle Marsh perpendicular to Morton Street, and ties into higher elevations near the end of Kennedy Drive. This functions essentially as a “protect all” scenario, creating a fully protected region from flooding originating from Belle Isle Marsh up to the largest storm event simulated. The second scenario (described below as “Layout 2”) proposes to build a 14.1 Ft NAVD88 elevation berm, that ties into a raised Morton Street, creating a raised 14.1 ft NAVD88 alignment that extends to Winthrop Street. This scenario creates a protected inland Morton Street side, with retreat or adaptation required for the line of houses that line the shore of Belle Isle Marsh in the Morton Street region.

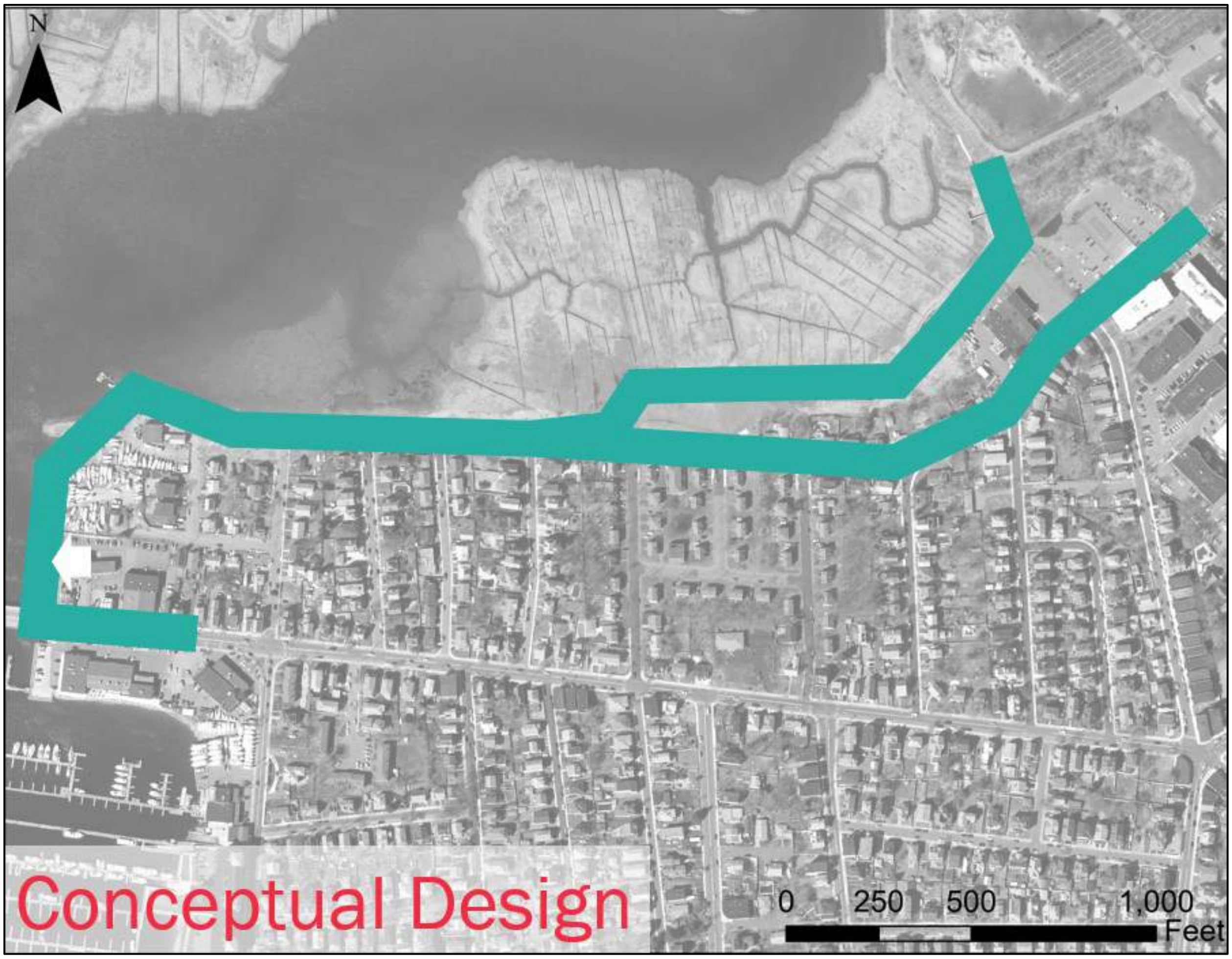

Figure 3. Conceptual design alignments for the Morton Street region.

3.3 Modeling Results

The MC-FRM was used to simulate coastal flooding events and the resulting extent of flooding under existing and alternative design conditions. A series of figures will be presented in the following section using the model simulation results. Extent of flooding, with the alternative design conditions (extent shown in light blue) and the additional extent of flooding under existing conditions without design improvements (extent shown in dark blue) under the flooding scenario simulated. The areas shown in dark blue therefore represent the areas where flooding would be mitigated under the storm scenario simulated as a result of the design improvements. Flood extent results help identify the strengths and weaknesses of each design alternative, identifying scenarios and areas where flood extent mitigation is achieved, as well as scenarios and areas where the design improvements are flanked through adjacent lower-lying flood pathways or exceeded by flood water elevations.

Flood depth results are informative when considering the independent effectiveness of the design when other flood pathways become key players in regional flooding patterns. In the Bennington Street/Frederick's Park region, it was necessary to investigate depth reduction due to the significance of other regional flood pathways. Depth reduction maps are presented in the section below focusing only on the Bennington Street/Frederick's Park region. A brief comparative analysis is conducted on the significance of the Belle Isle Marsh flood pathway through Bennington Street versus the other major regional flood pathways.

Bennington Street/Frederick's Park

Under the largest representative storm simulated (a 1% annual exceedance probability storm in 2070) the elevated alignment along Bennington Street that continues in front of Frederick's Park at a crest elevation of 14.1 feet effectively prevents flooding *sourced from Belle Isle Marsh*. Under this storm scenario, flooding does occur from other major regional flood pathways originating in Chelsea Creek and Revere (Figure 4), and the alignment is effectively back flooded. It was determined that these flood pathways become key players in the near-term time-horizons during relatively small storm events, as frequently as the 25% annual exceedance probability storm event in 2030 time-horizon.

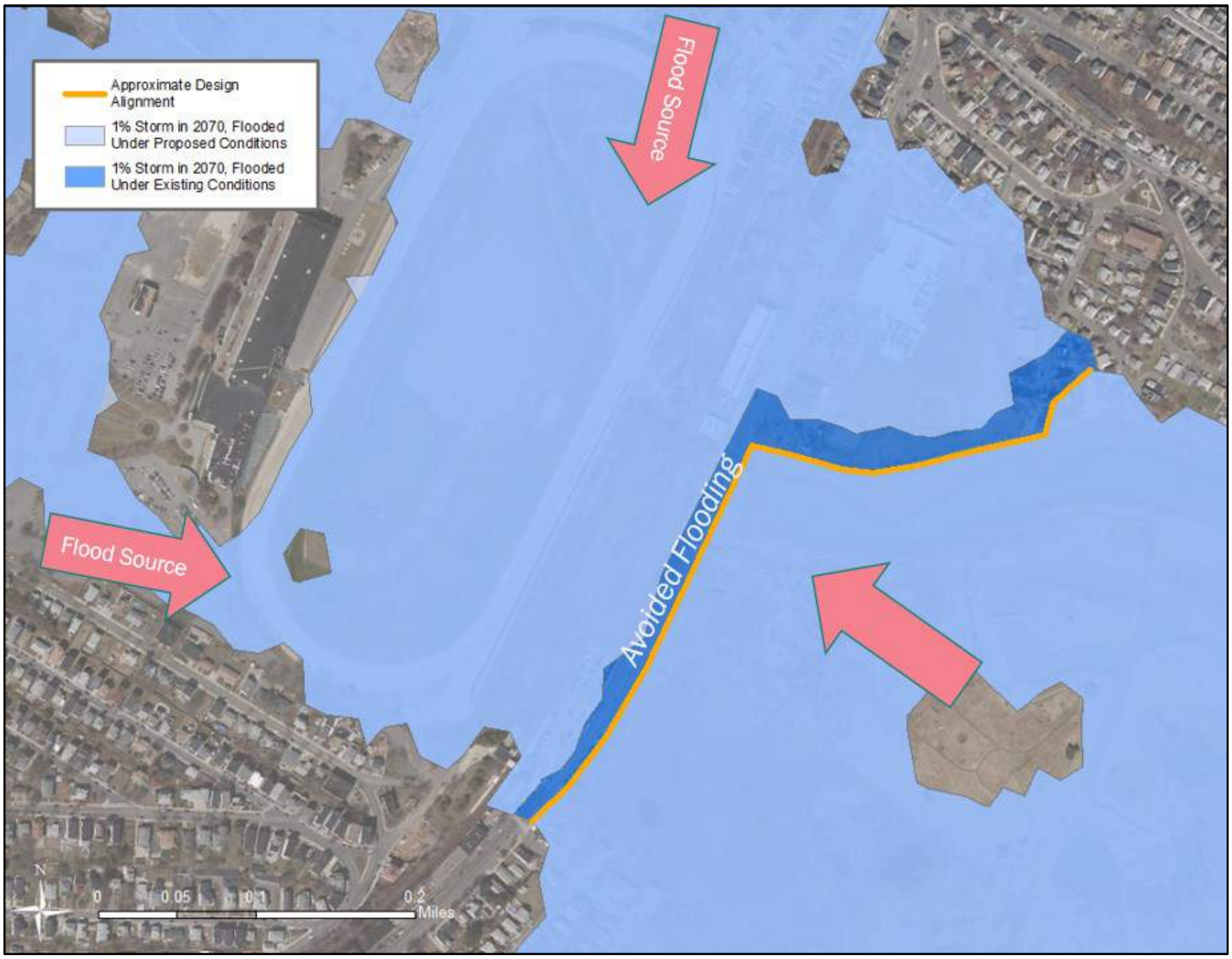

Figure 4. 1% Storm in 2070 results for existing and proposed conditions, with a berm build along Bennington Street/Fredericks Park. The light blue indicates areas that are flooded in both existing and proposed conditions, whereas the dark blue regions indicate areas of avoided flooding due to the design alternative. The orange line indicates the approximate location of the alignment crest.

When Bennington Street is raised and the elevated roadway (at a crest elevation of 14.1 ft) is extended towards Revere, the elevated road holds the potential to act as a flood barrier to Frederick's Park, from flooding originating through the Revere and Chelsea creek flood pathways (Figure 5). This elevated roadway extension, coupled with a nature-based flood protection berm along the Belle Isle Marsh bank in front of Frederick's Park, would effectively eliminate flooding occurring in all storms up to the 2070 1% event for Frederick's Park and Seacoast High School/ Beachmont Veterans Memorial School.

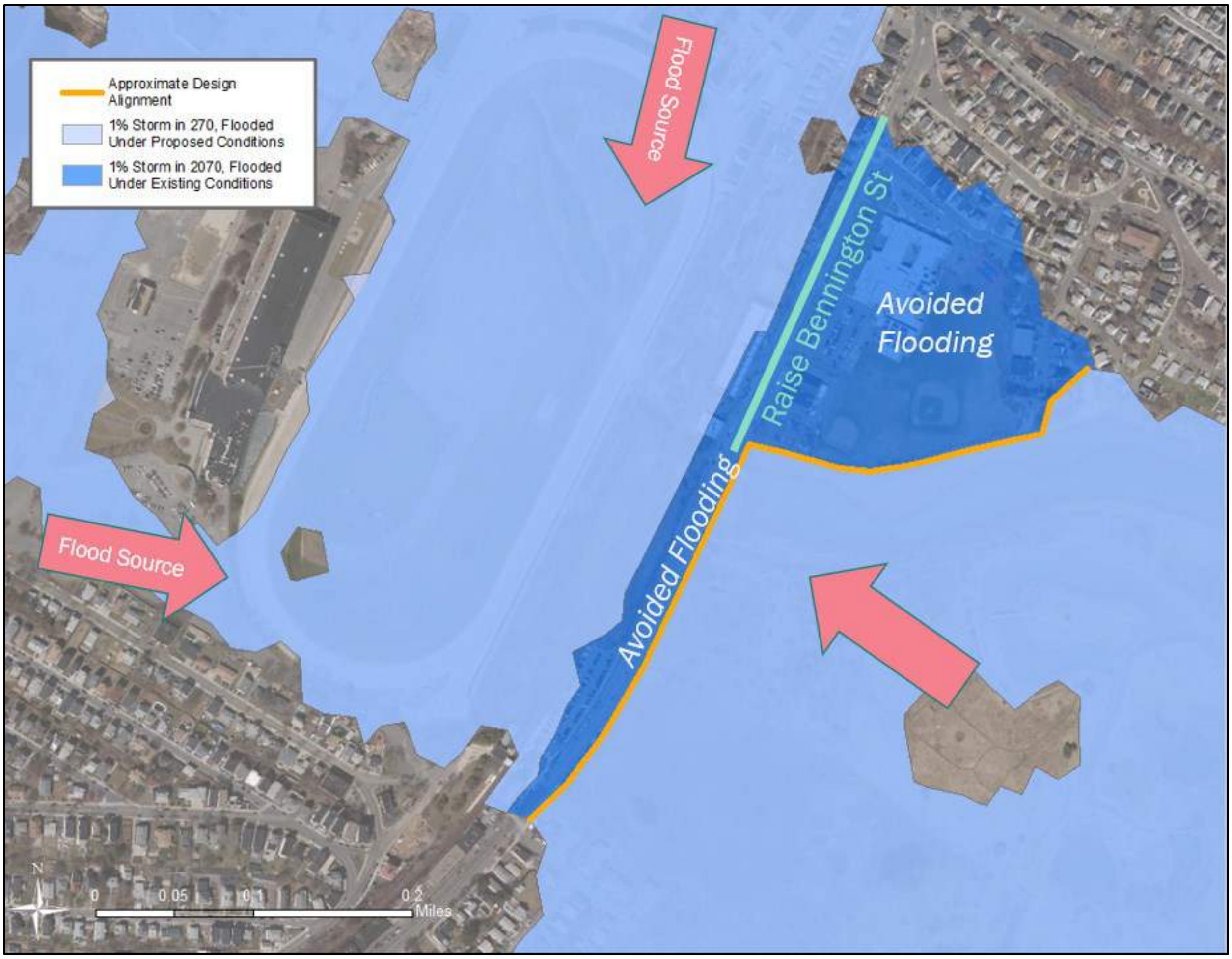

Figure 5. **1% Storm in 2070 results for existing and proposed conditions, with an extended elevated Bennington Street, and flood protection berm on the Belle Isle Marsh-facing side of Frederick's Park (crest elevation 14.1 feet). The light blue indicates areas that are flooded in both existing and proposed conditions, whereas the dark blue regions indicate areas of avoided flooding due to the design alternative. The orange line indicates the approximate location of the alignment crest.**

Under a smaller, more frequent scenario, such as the 1% present day storm event or the 25% storm in 2030 (water surface elevations between these two events are roughly equivalent in the model), the design alignment effectively eliminates flooding to Frederick's Park and Bennington Street (Figure 6).

Figure 6. **A 25% storm under the 2030 time horizon (equivalent to the 1% Storm in Present Day) results for existing and proposed conditions, with an extended elevated Bennington Street, and flood protection berm on the Belle Isle Marsh-facing side of Frederick's Park (crest elevation 14.1 feet). The light blue indicates areas that are flooded in both existing and proposed conditions, whereas the dark blue regions indicate areas of avoided flooding due to the design alternative. The orange line indicates the approximate location of the alignment crest.**

When considering the total cumulative impact of this design alignment when impacted by other flood pathways, it is important to consider the depth of flooding as a proxy for volumetric contributions of each flood pathway. An analysis was conducted that effectively “closed off” the Belle Isle Marsh flood pathway under a series of different scenarios to investigate the volumetric contribution of flooding coming from Belle Isle Marsh. This will highlight the independent benefit of the proposed design in the event other flood pathways are not mitigated.

Reduced flood extents have the potential to occur if the Revere and Chelsea creek pathways are blocked off and Belle Isle Marsh is kept open, for the 0.2 % storm event in 2050 (Figure 7), (approximate maximum water surface elevation of 11.1 ft NAVD88) and the 5% storm in 2050 (approximate maximum water surface elevation of 13.0 ft NAVD88) (Figure 8). These figures identify the flooding occurring from the Belle Isle Marsh flood pathway alone during these singular representative storm events.

Figure 7. Extents of flooding for the 0.2% Storm in 2050. The light blue indicates areas that are flooded in both existing and when the Revere and Chelsea Creek Flood pathways are closed (flooding contribution from Belle Isle Marsh), whereas the dark blue regions indicate areas of avoided flooding due to the Revere and Chelsea Creek flood pathways. The yellow line indicates flood pathways that are blocked in the model simulation.

Figure 8. **Extents of flooding for the 5% Storm in 2050. The light blue indicates areas that are flooded in both existing and when the Revere and Chelsea Creek Flood pathways are closed (flooding contribution from Belle Isle Marsh), whereas the dark blue regions indicate areas of avoided flooding due to the Revere and Chelsea Creek flood pathways. The yellow line indicates flood pathways that are blocked in the model simulation.**

When depth reduction is considered, blocking the Belle Isle Marsh flood pathway has the potential to reduce flood depths by as much as 0.7 feet during a representative 0.2% AEP storm event in 2050 (maximum water surface elevation of 13.0 feet) (Figure 9). As such, the independent benefit of flood mitigation along Belle Isle Marsh has the potential to reduce flood depths in large-extreme storms, when other flood pathways become key players in regional flooding patterns.

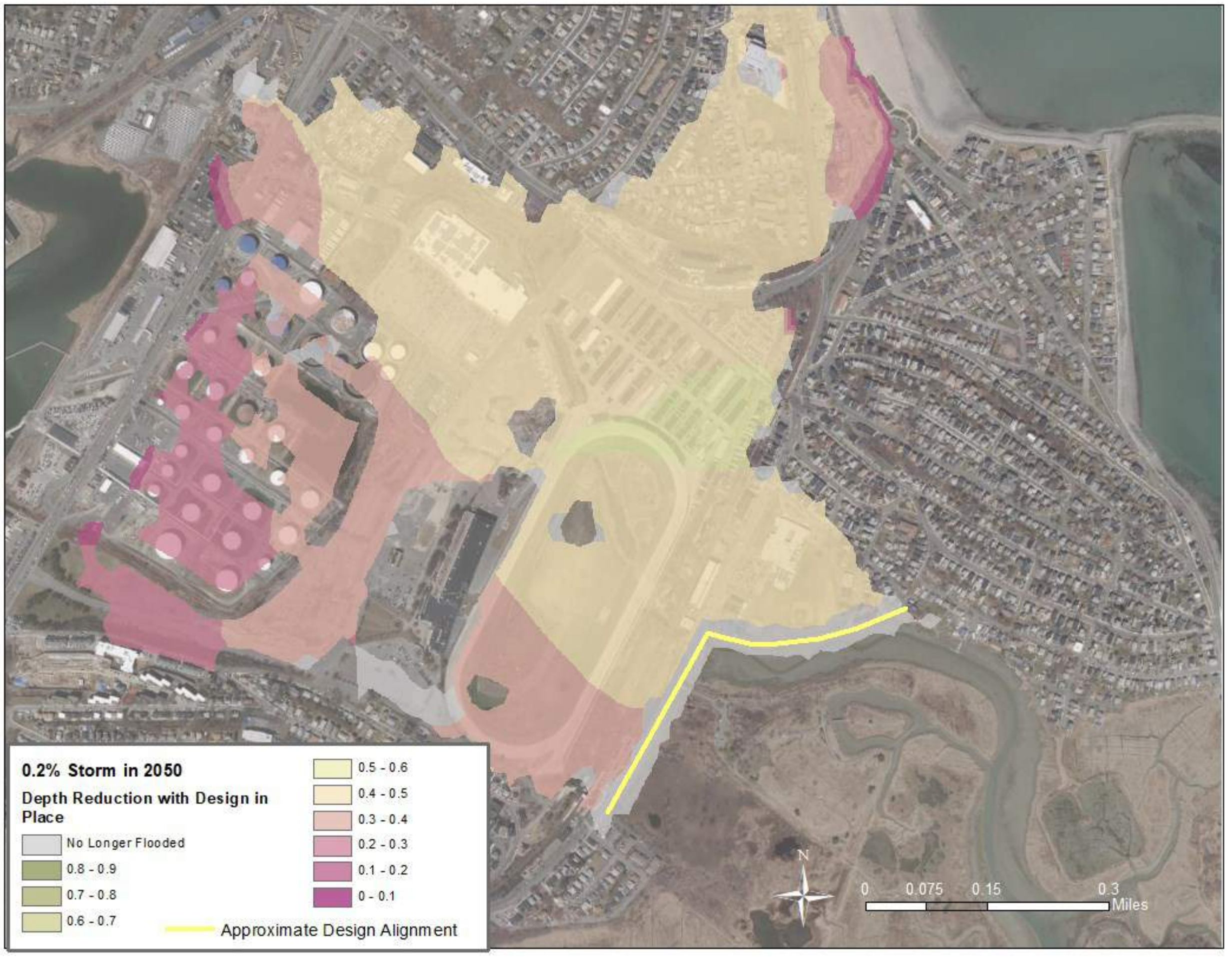

Figure 9. Depth reduction for a 0.2% Annual Exceedance Probability representative storm during the 2050 time horizon, for a scenario where the Belle Isle Marsh flood pathway is blocked. The yellow line indicates flood pathways that are blocked in the model simulation.

Morton Street

Under the largest storm scenario simulated (1% storm in 2070) the 14.1 berm along Belle Isle Marsh in the Morton Street area effectively eliminates flooding to the Morton Street neighborhood (Figure 10). When the design is backed out to raising only Morton Street, the line of houses that fringes Belle Isle Marsh is made susceptible to flooding (Figure 11). An additional 1 commercial, and 8 residential properties are protected by moving the conceptual design alignment from Morton Street to the edge of the marsh.

Figure 10. A 2070 1% event results for existing and proposed conditions, with a living levee constructed along the edge of Belle Isle Marsh in the Morton Street region (elevated crest elevation of 14.1 ft NAVD88). The light blue indicates areas that are flooded in both existing and proposed conditions, whereas the dark blue regions indicate areas of avoided flooding due to the design alternative. The orange line indicates the approximate location of the alignment crest.

Figure 11. A 2070 1% event results for existing and proposed conditions, with a living levee constructed along the edge of Belle Isle Marsh, tying into an elevated Morton Street (elevated crest elevation of 14.1 ft NAVD88). The light blue indicates areas that are flooded in both existing and proposed conditions, whereas the dark blue regions indicate areas of avoided flooding due to the design alternative. The orange line indicates the approximate location of the alignment crest.

Impacts to neighboring properties

As flood waters flow inland and interact with infrastructure (both existing and proposed), various patterns and potential redirection of flow magnitudes, directions, and volumes can occur. Proposed infrastructure can function as a barrier to flow, which can potentially alter the flow patterns and modify flow velocities and flow volumes in the vicinity of these changes. Redirected flood waters that cause additional flooding to adjacent neighborhoods will be shown through modeled results as a localized increase in the water surface elevation in areas adjacent to the project implementation site. Impacts to neighboring properties in the form of redirected flood waters due to the placement of the design alignments was investigated for the largest of the storms simulated for both priority sites (1% AEP storm event in 2070) (Figure 12).

Modeled results indicate that during the most extreme of the storm scenarios simulated, there are no localized increases in water surface elevations, and therefore no redirected flood waters. The assumption is made that results of flow redirection are the most extreme during the largest events, and if no difference is calculated in the largest of the events between existing and proposed water surface elevations, no differences will be observed in events of lesser magnitude.

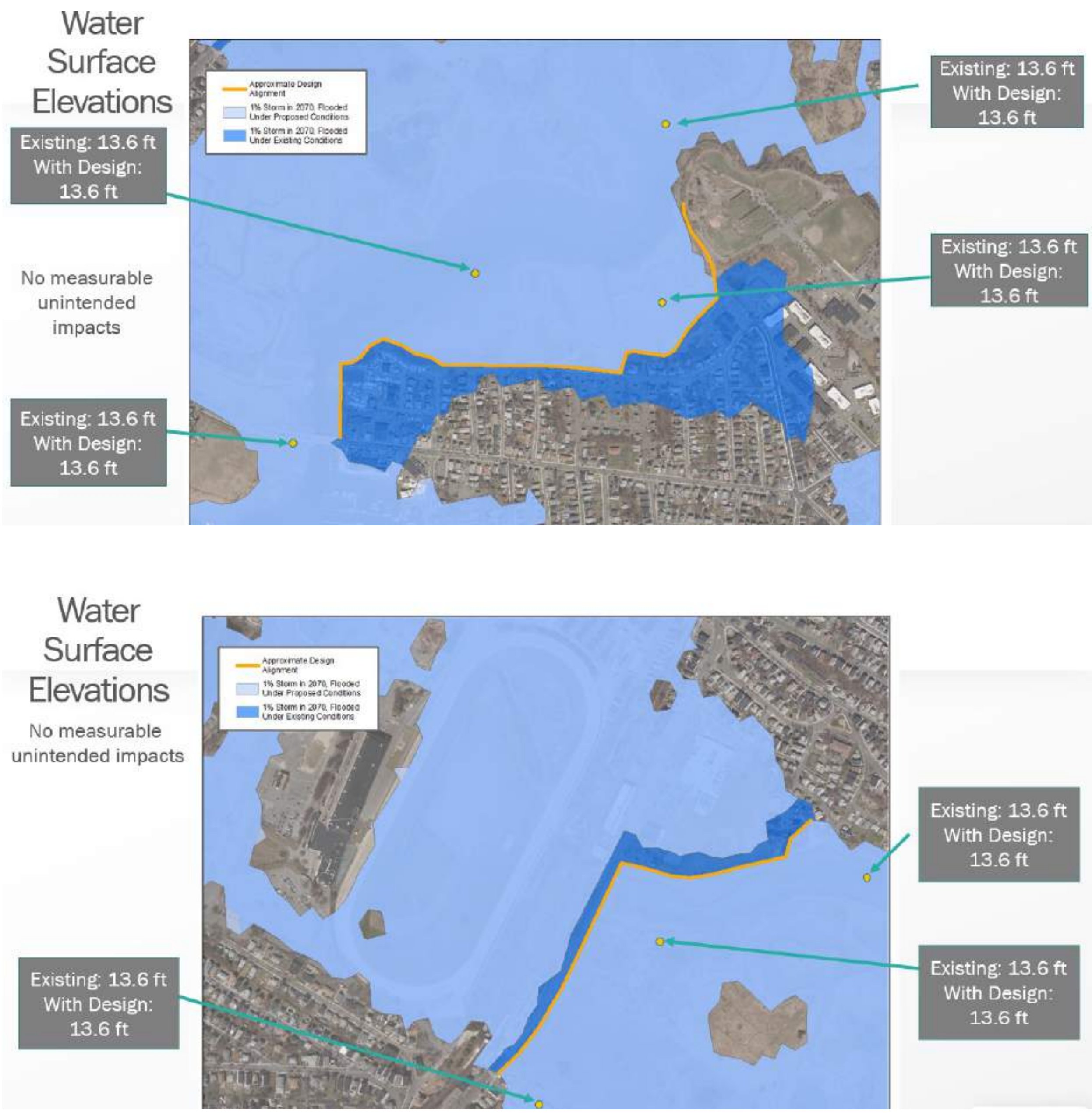

Figure 12. **Redirected flood waters in the form of localized water surface elevation increases shown by the model. The light blue indicates areas that are flooded in both existing and proposed conditions, whereas the dark blue regions indicate areas of avoided flooding due to the design alternative. The orange line indicates the approximate location of the alignment crest.**

4.0 CONCLUSIONS

The MC-FRM was used to model the performance of multiple conceptual design alignments for two priority locations in Belle Isle Marsh, as part of a regional effort to mitigate flood risk through nature-based solutions. The results of the modeling effort indicate the following:

- The Bennington Street/Frederick's Park alignment features independent benefits in eliminating flooding during storm events smaller than the 1% storm in present day, or the 25% storm in 2030 (equivalent water levels) but fails to eliminate flooding in larger events due to other dominant flood pathways.
- The Bennington Street/Frederick's Park alignment features independent benefits of depth reduction in storms that are larger than the 1% storm in present day, or the 25% storm in 2030 (equivalent water levels).
- The Morton Street project, if feasibly constructed, could provide protection to the community under a 1% storm in 2070. The alignment that features a living levee along the marsh edge protects an additional 1 commercial and 8 residential properties when compared to an alignment that raises Banks Street.
- There is no increase in water surface elevation, and therefore no increased flooding, to properties surrounding the alignments when the design is in place for both priority sites with all alignments considered.