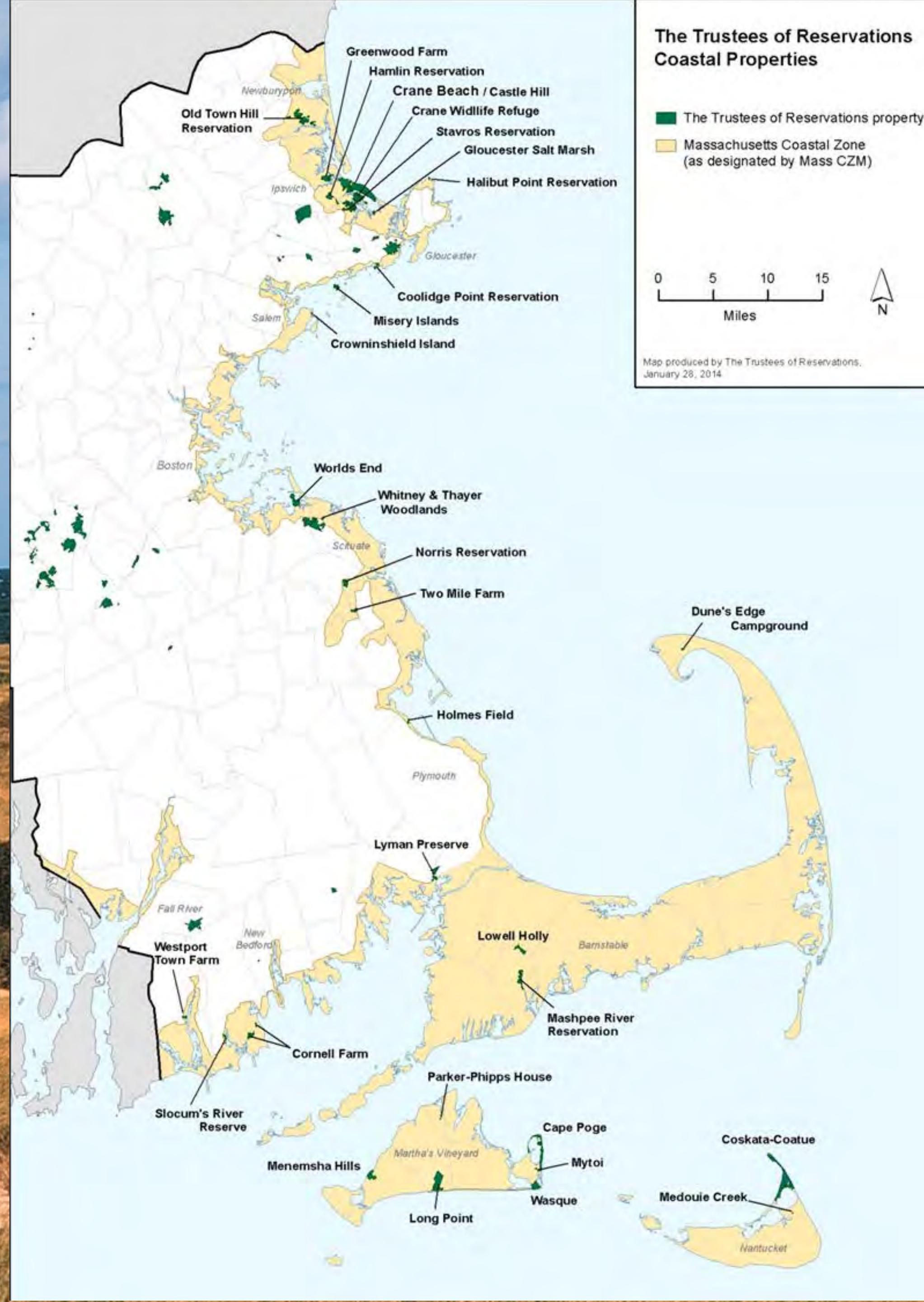
The Trustees

COASTAL VULNERABILITY ASSESSMENT



Coastline Ownership

OWNER	Miles	% of Shoreline
Federal	191	8%
State	98	4%
Municipal/Local	252	10%
Trustees-held CRs	44	2%
Trustees Reservations	76	3%
Other Non-Profit/Land Trust	106	4%
Other Private (mostly CRs)	33	1%
Total Miles of Shoreline	800	33%

Total Shoreline	2450	100%

trustees

Open Space Ownership

COASTLINE

OWNER	% of Open Space
Federal	24%
State	12%
Municipal/Local	32%
Trustees Reservations	10%
Trustees-held CRs	6%
Other Non-Profit/Land Trust	13%
Other Private (mostly CRs)	4%
Total Open Space	**100%**

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The Trustees of Reservations

MISSION

- Founded in 1891, The Trustees of Reservations preserve, for public use and enjoyment, properties of exceptional scenic, historic, and ecological value in Massachusetts and work to protect special places across the state.

- 50,000 acres, including 25,000+ acres on 116 reservations
- Open to the public.
- Nonprofit conservation organization
- 1M+ visitors annually, 40,000+ member household

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The Trustees of Reservations

COASTAL RESOURCES

- 32 Reservations (8,000 acres)
- 39 Parking Areas
- 103 Buildings
- 106 Other Structures
- 60 miles of trail (320 segments)
- 158 Cultural Resources points
- 48 State-listed Species
- Over 100 Vegetation Communities

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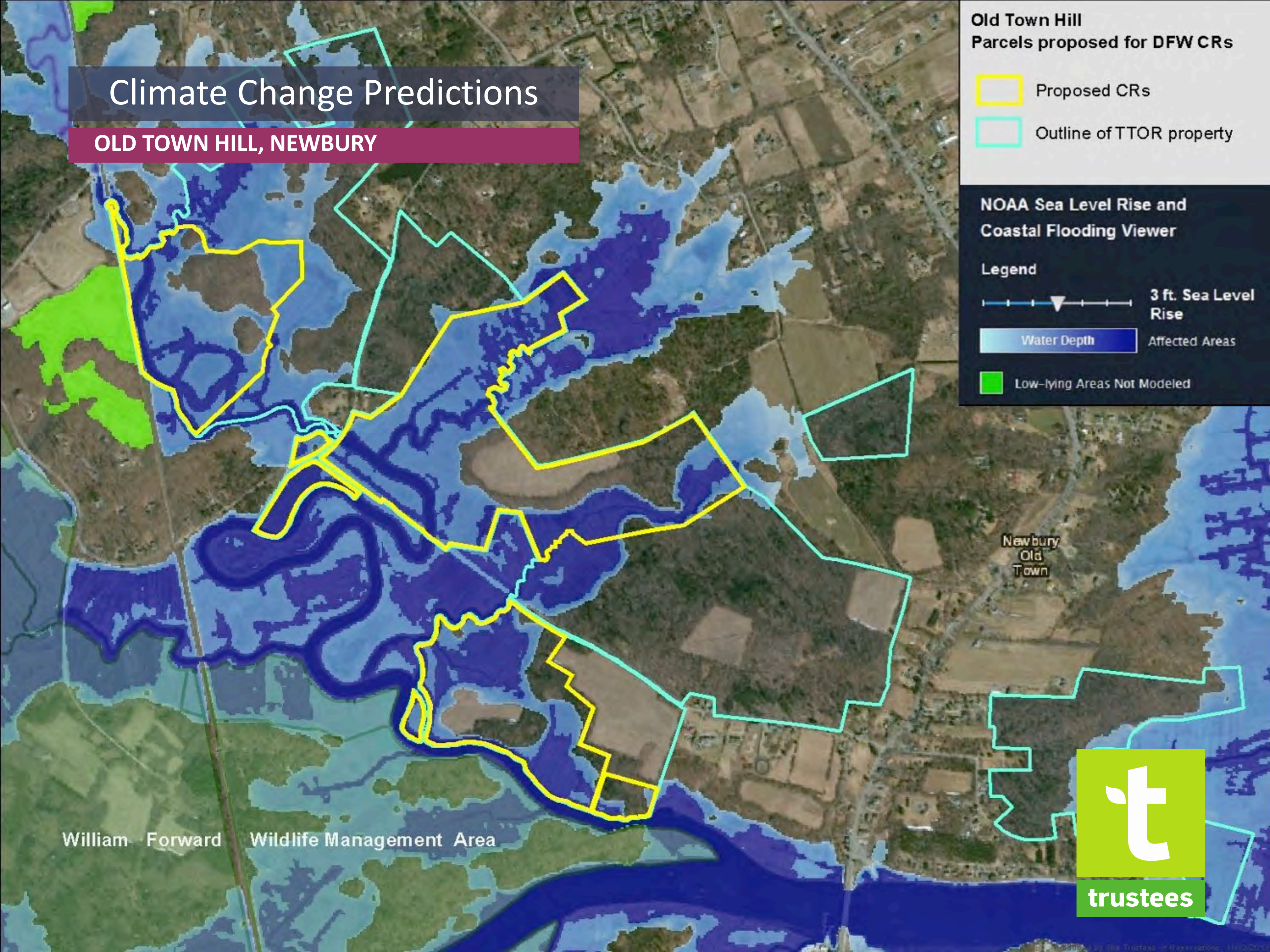
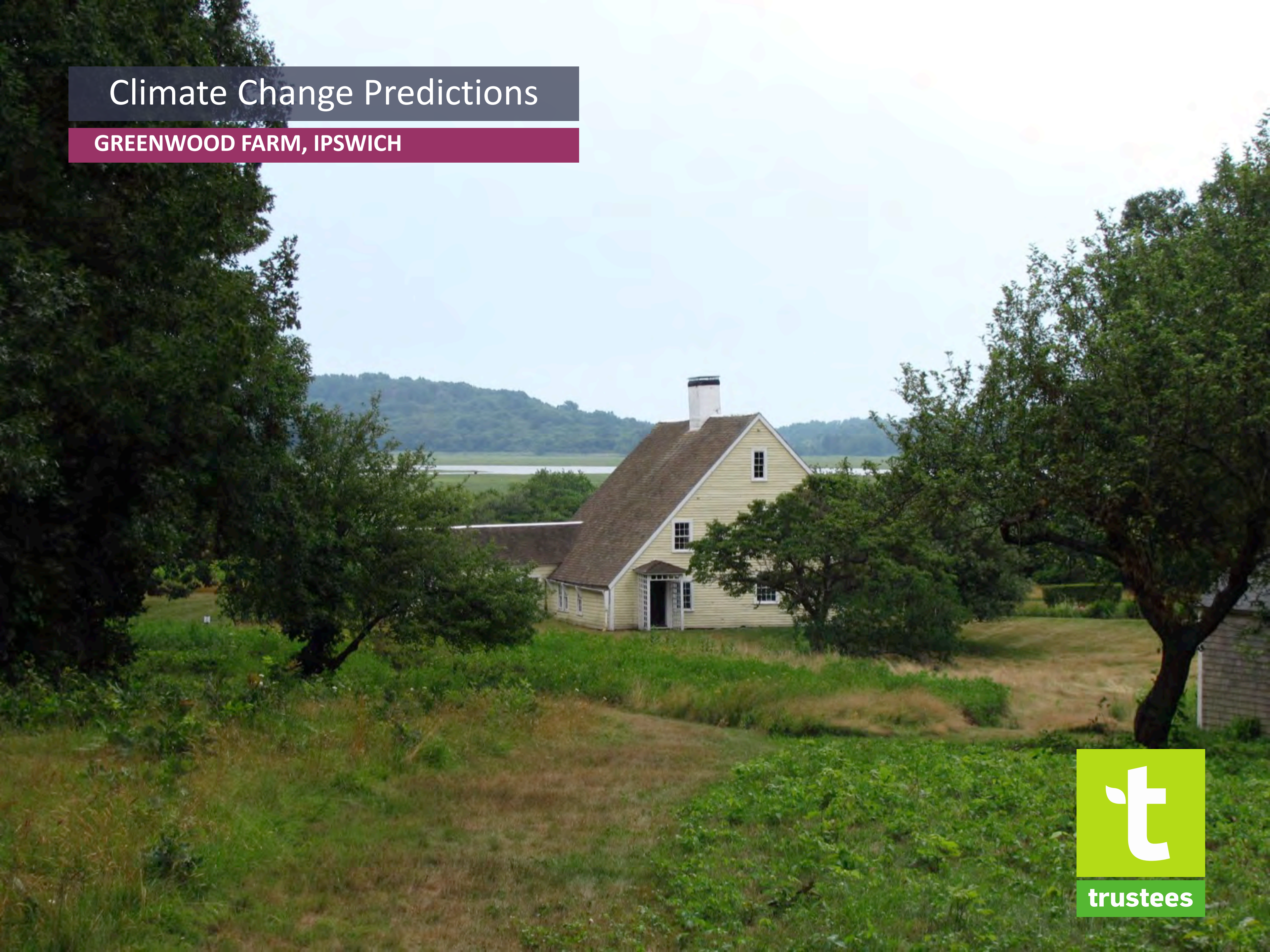
Climate Change Predictions

OLD TOWN HILL, NEWBURY



Climate Change Predictions

GREENWOOD FARM, IPSWICH




Castle Neck
IPSWICH – SALT MARSH / ESTUARY
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Halibut Point

GLOUCESTER – ROCKY SHORELINE

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Coskata- Coatue

NANTUCKET – BARRIER BEACH

Public Programs

WORLDS END, HINGHAM

Financial

CRANE BEACH, IPSWICH

Vulnerability Assessment

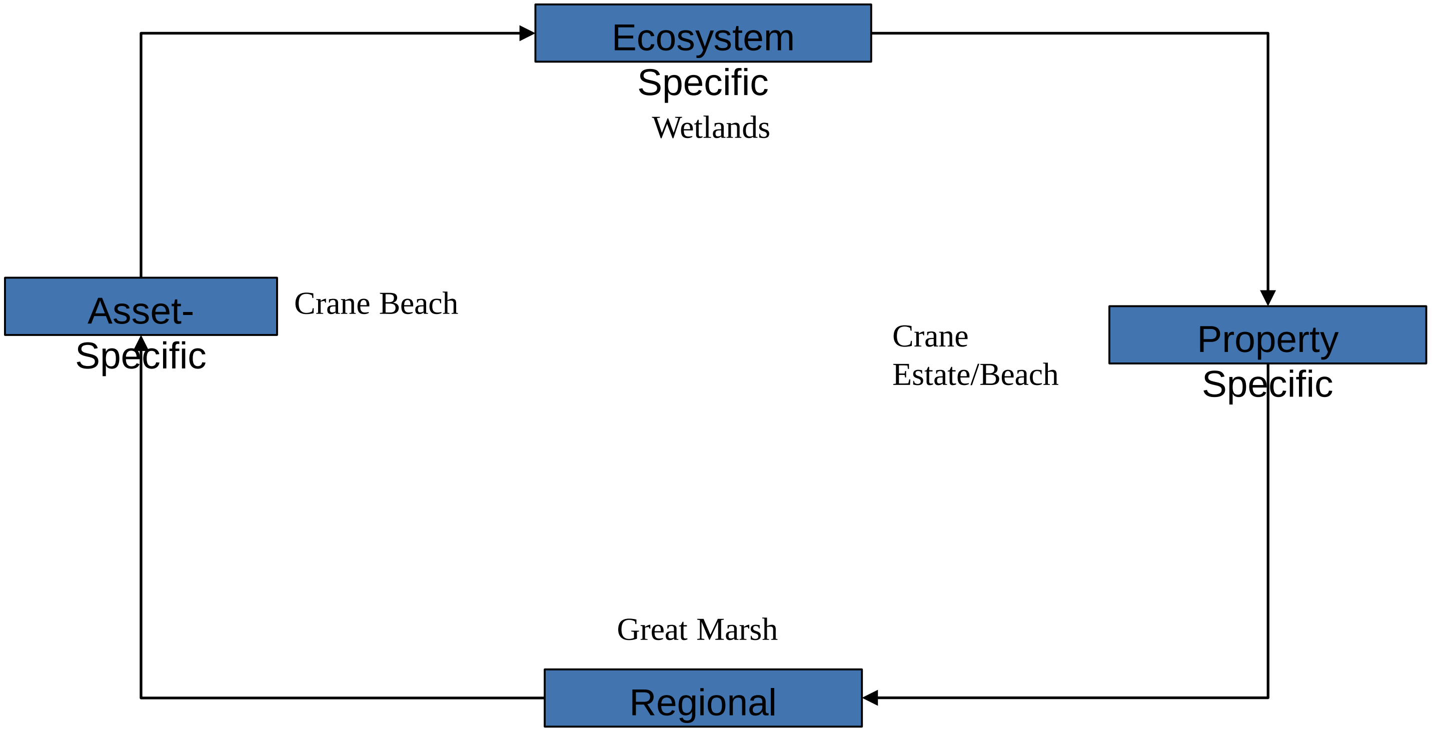
OBJECTIVES

Modeling Vulnerability

Assigning Value and Calculating Risk

Identifying Top 5 Priorities and Strategies

What is vulnerable, what do we value and how are they connected at different spatial scales? What impact do vulnerabilities (and adaptations) on TOR properties have on neighboring properties and communities?



Project Background

OBJECTIVES

Modeling Vulnerability

- GIS Data Development
- Vulnerabilities for years 2030 and 2070
- Probability-based approach for inundation

Primary Sources)

- MassDOT model results (Woods Hole Group)
- North Atlantic Coast Comprehensive Study (USACE)
- Sea Level Affecting Marshes Model (SLAMM) results (CZM – Woods Hole Group)

WOODS HOLE GROUP | 30 YEARS

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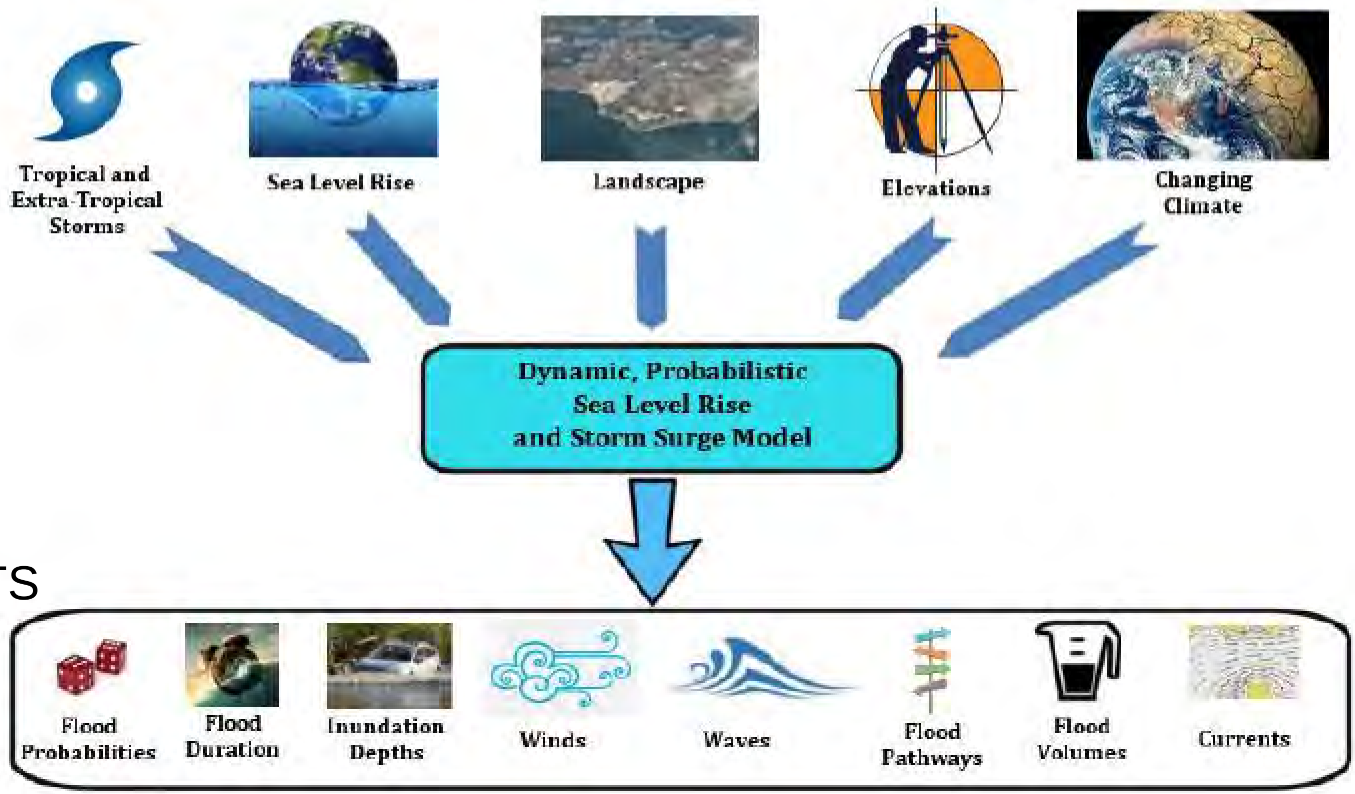
Step 2: Vulnerability Assessment – Modeling Overview

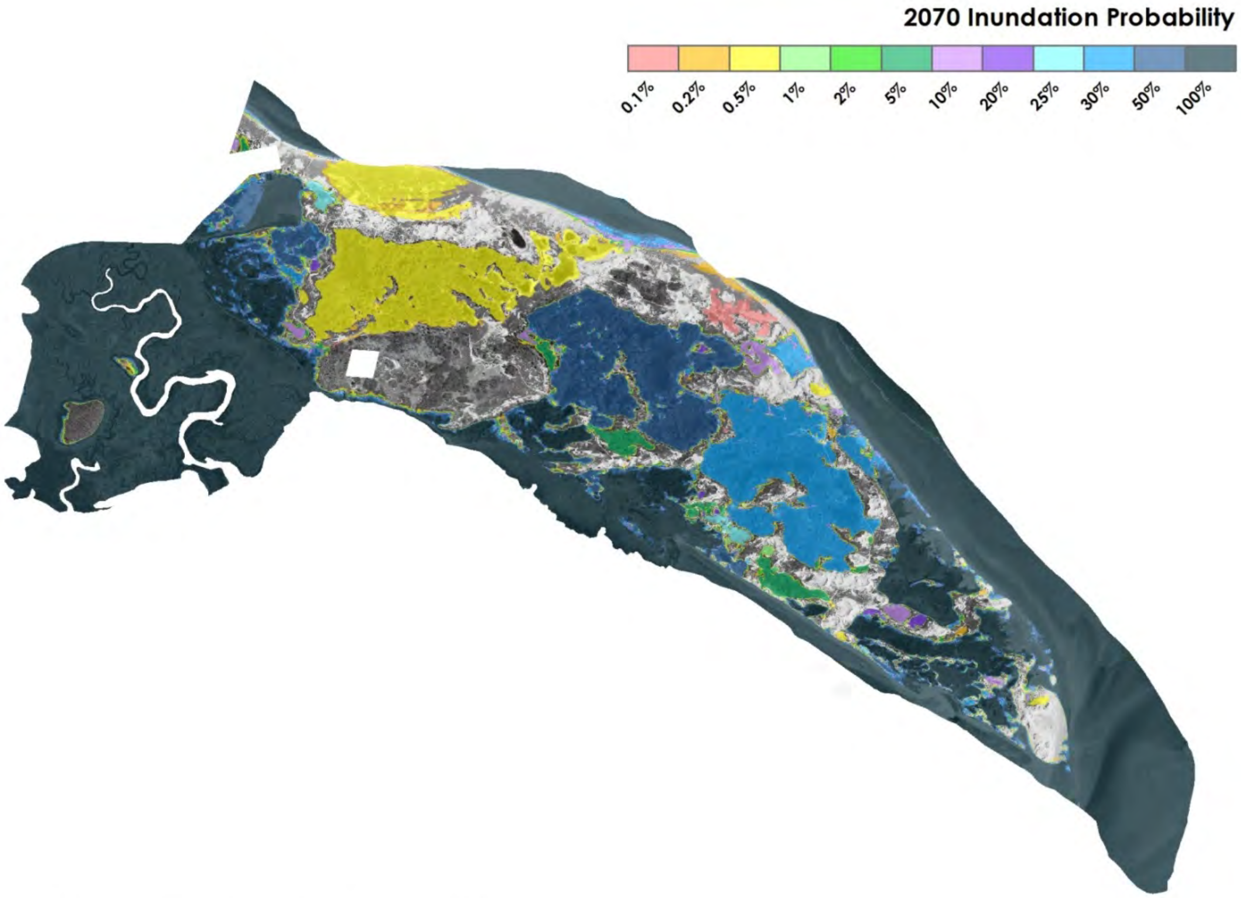
INPUTS

OUTPUTS



Inundation Probability

CRANE BEACH



2070 Inundation Probability

WOODS HOLEGROUP | YEARS

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Probabilistic Model

WHY THIS APPROACH?

Allows user to determine the decision making level of vulnerability

Capability to differentiate among, rank and prioritize locations based on probabilities

- other approaches present only 2 options – inundated or not inundated

Fixed sea level rise may not always be the most conservative.

Allows for combining vulnerability with consequence into an index

WOODS HOLE GROUP | 30 YEARS

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Assigning Value and Calculating Risk

- Assign consequence scores (values) to each coastal resource
- Coastal Vulnerability Index (CVI)

- For each asset:
- CVI = probability of flooding x consequence
- Rank all assets and prioritize adaptation projects

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OBJECTIVES

Mission-based Criteria Used in Scoring Asset Values

- Natural Resource Integrity and Significance
- Cultural Resource Integrity and Significance
- Visitor Experience Integrity and Significance
- Public Programs
- Revenue Impact
- Operational Support

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OBJECTIVES

1,300+ Assets and Resources Scored for Consequence Values

- Roads, Trails, and Entrances
- Infrastructure
- Buildings
- Cultural Resource Features and Landscapes
- Vegetative / Natural Community
- Priority Habitat

WOODS HOLE GROUP | 30 YEARS

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OBJECTIVES

Assigning Value and Calculating Risk

- Assign consequence scores (values) to each coastal resource
- Coastal Vulnerability Index (CVI)

- For each asset:
- CVI = probability of flooding x consequence
- Rank all assets and prioritize adaptation projects

WOODS HOLE GROUP | 30 YEARS

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Coastal Vulnerability Index

EXAMPLE

Asset	Property	Vulnerability (Probability of Inundation to Critical Depth)		Consequence	CVI (by Year)
		2030	2070		
Beach A	Property E	1%	5%	5	Prob x Consequence
Habitat B	Property F	2%	8%	2	Prob x Consequence
Habitat C	Property E	5%	15%	5	Prob x Consequence
Building D	Property G	6%	25%	3	Prob x Consequence

WOODS HOLE GROUP | 30 YEARS

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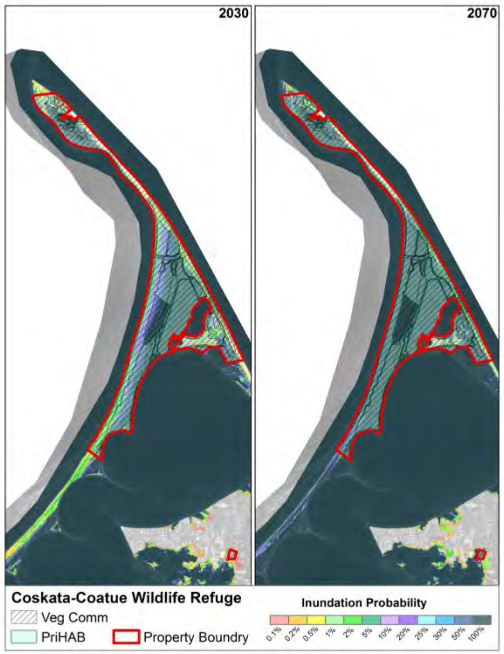
Coskata-Coatue Wildlife Refuge



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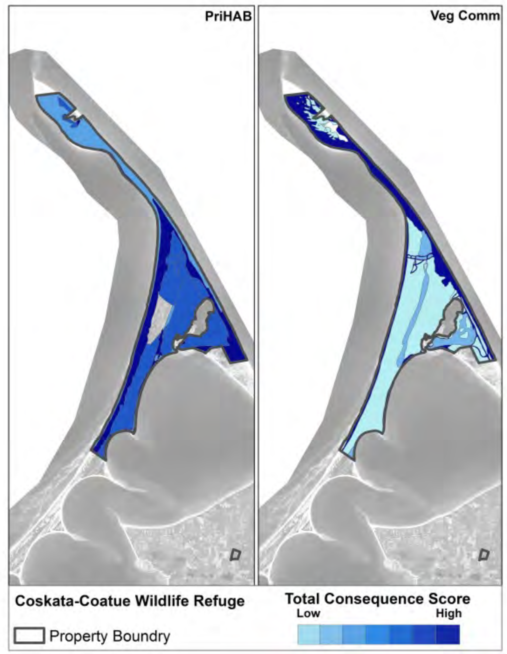

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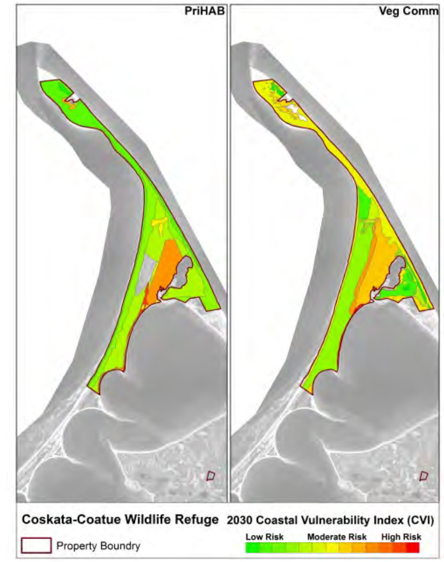

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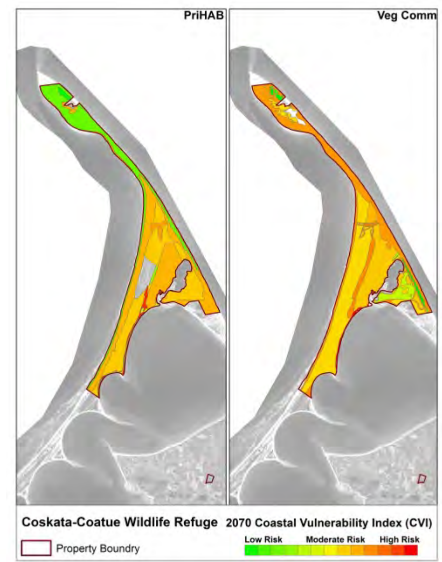
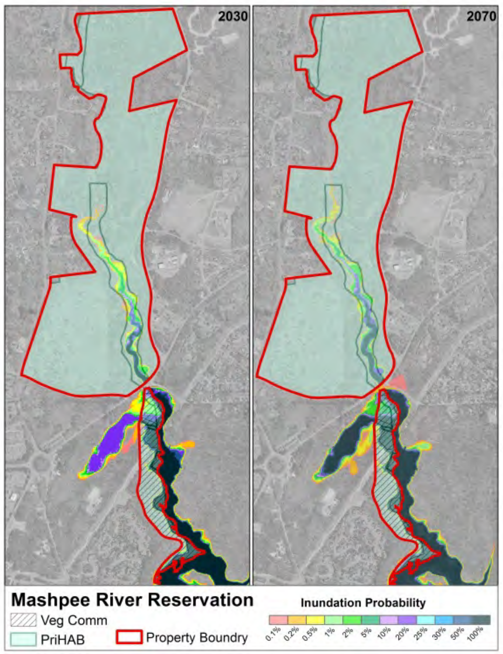


Mashpee River Reservation



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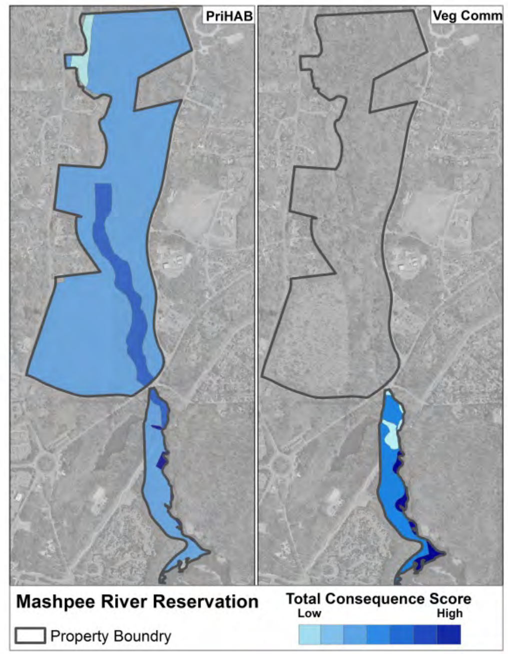

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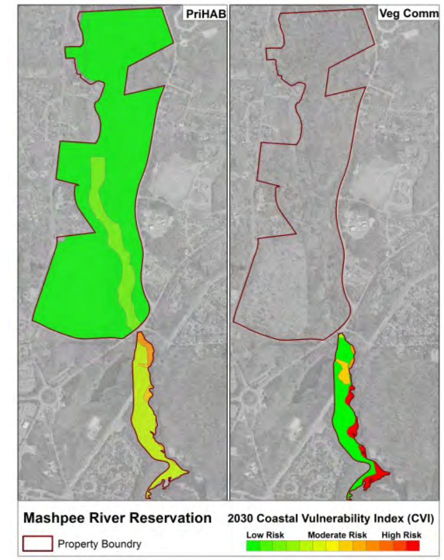

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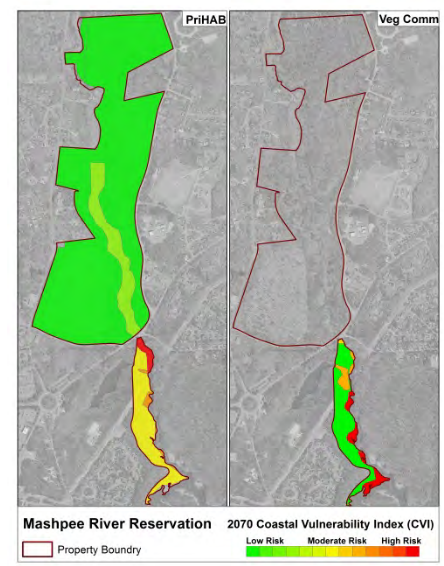

Top 25 Asset CVIs – Infrastructure

FID	Dataset	Property	Name	_IN	_SIG	_IN	_SIG	QUA	_SIG	_IC_	_IM	UP	TOTAL_CON	2070AVG	2030AVG	CVI2070AVG	CVI2030AVG
37	Infrastruct	Crane Beach	Argilla Road Culvert	0	0	0	0	3	2	5	5	5	44.4	100.0	100.0	4444	4444
82	Infrastruct	Wasque	Wasque Pt. Beach Stairs	0	0	0	0	5	5	4	5	0	42.2	100.0	100.0	4222	4222
90	Infrastruct	World's End	Damde Meadows Bridge	0	0	0	0	4	3	4	3	5	42.2	100.0	100.0	4222	4222
30	Infrastruct	Crane Beach	Crane-side Ferry Dock	0	0	0	0	2	1	5	5	5	40.0	100.0	99.6	4000	3985
89	Infrastruct	World's End	Damde Meadows Education Shed	0	0	0	0	4	4	5	3	0	35.6	100.0	100.0	3556	3556
41	Infrastruct	Crane Wildlife Refuge	Choate-side Ferry Dock	0	0	0	0	3	3	4	2	4	35.6	100.0	93.0	3556	3305
0	Infrastruct	Cape Poge Wildlife Refuge	Dike Bridge	0	0	0	0	5	5	5	5	0	44.4	100.0	70.7	4444	3141
2	Infrastruct	Cape Poge Wildlife Refuge	Dike Bridge Causeway	0	0	0	0	5	5	5	5	0	44.4	100.0	61.4	4444	2730
38	Infrastruct	Crane Beach	Fox Creek Bridge	0	0	0	0	3	2	0	5	5	33.3	88.8	80.0	2959	2667
40	Infrastruct	Crane Wildlife Refuge	Choate House Culvert	0	0	0	0	0	0	3	2	3	17.8	100.0	100.0	1778	1778
73	Infrastruct	Old Town Hill	Adam's Field Causeway Culvert	0	0	0	0	2	2	0	0	3	15.6	100.0	100.0	1556	1556
74	Infrastruct	Old Town Hill	Newman Road Culvert	0	0	0	0	2	2	0	0	3	15.6	100.0	100.0	1556	1556
75	Infrastruct	Old Town Hill	Newman Road Bridge	0	0	0	0	2	2	0	0	3	15.6	100.0	100.0	1556	1556
76	Infrastruct	Old Town Hill	Hay Street Bridge	0	0	0	0	2	2	0	0	3	15.6	93.4	82.3	1453	1281
70	Infrastruct	Norris Reservation	Gordon Pond Dam	0	0	3	3	3	4	0	0	0	28.9	81.1	31.1	2342	900
77	Infrastruct	Old Town Hill	Boardwalk	0	0	0	0	2	2	0	0	0	8.9	100.0	100.0	889	889
27	Infrastruct	Coskata-Coatue Wildlife Refuge	Coskata Life Saving Cottage	0	0	5	5	1	3	2	0	0	35.6	100.0	16.0	3556	570
54	Infrastruct	Long Point Wildlife Refuge	Off-season Road Culvert	0	0	0	0	3	5	1	2	0	24.4	100.0	20.0	2444	489
34	Infrastruct	Crane Beach	Store Septic Tank	0	0	0	0	0	0	0	4	4	17.8	100.0	25.0	1778	444
61	Infrastruct	Lyman Reserve	Red Brook Aluminum Bridge	0	0	0	0	0	2	0	0	0	4.4	100.0	91.2	444	405
25	Infrastruct	Coolidge Reservation	Coolidge Point Jetty	0	0	0	0	1	1	0	0	0	4.4	100.0	73.4	444	326
91	Infrastruct	World's End	Culvert	0	0	0	0	2	1	0	0	3	13.3	10.0	20.0	133	267
1	Infrastruct	Cape Poge Wildlife Refuge	Cape Poge Sand Planks	0	0	0	0	3	2	2	3	0	22.2	46.0	11.8	1021	262
72	Infrastruct	Norton Point Beach	Norton Pt. Air Station	0	0	0	0	5	5	2	5	2	42.2	100.0	5.0	4222	211
97	Infrastruct	World's End	Culvert	0	0	0	0	2	1	0	0	3	13.3	22.5	15.0	300	200

Results of CVI Analysis

TRENDS

Vegetation communities and priority habitats have the highest CVIs. Combination of larger areas (higher potential for some portion to be inundated) and location close to waters edge – many are wetlands or beaches

Certain properties have a higher density of elevated CVIs

Buildings, cultural resources and parking lots tend to have lower CVIs, but there are some with high probability of inundation, but lower consequence score

Irregularly flooded marshes are shifting to regularly flood marshes

Top 5 Properties

LARGEST CONCENTRATION OF HIGH RISK

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OBJECTIVES

Identifying Top 5 Priorities and Strategies

- Use CVI to prioritize adaptation alternatives
- Adaptation planning matrix of next steps

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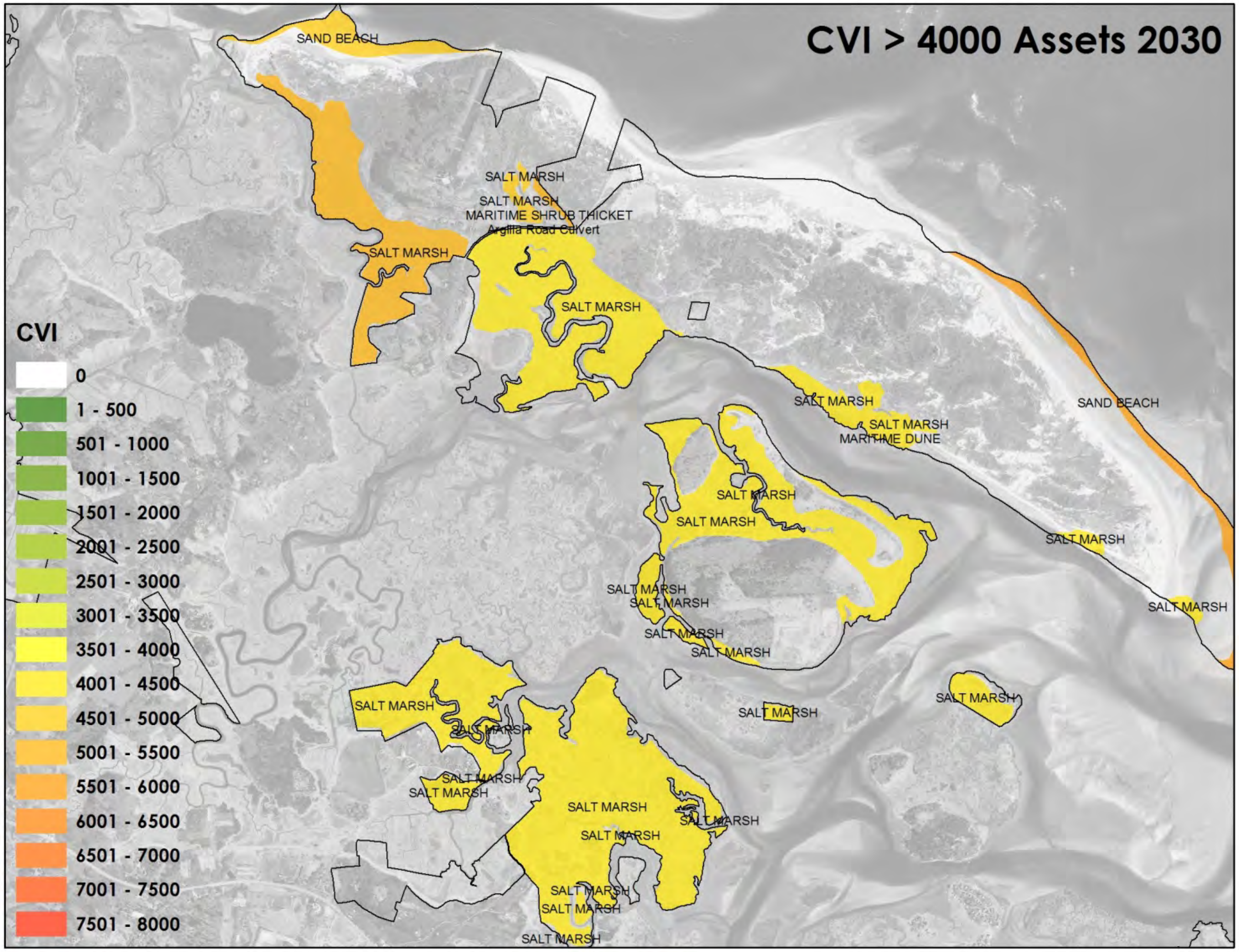
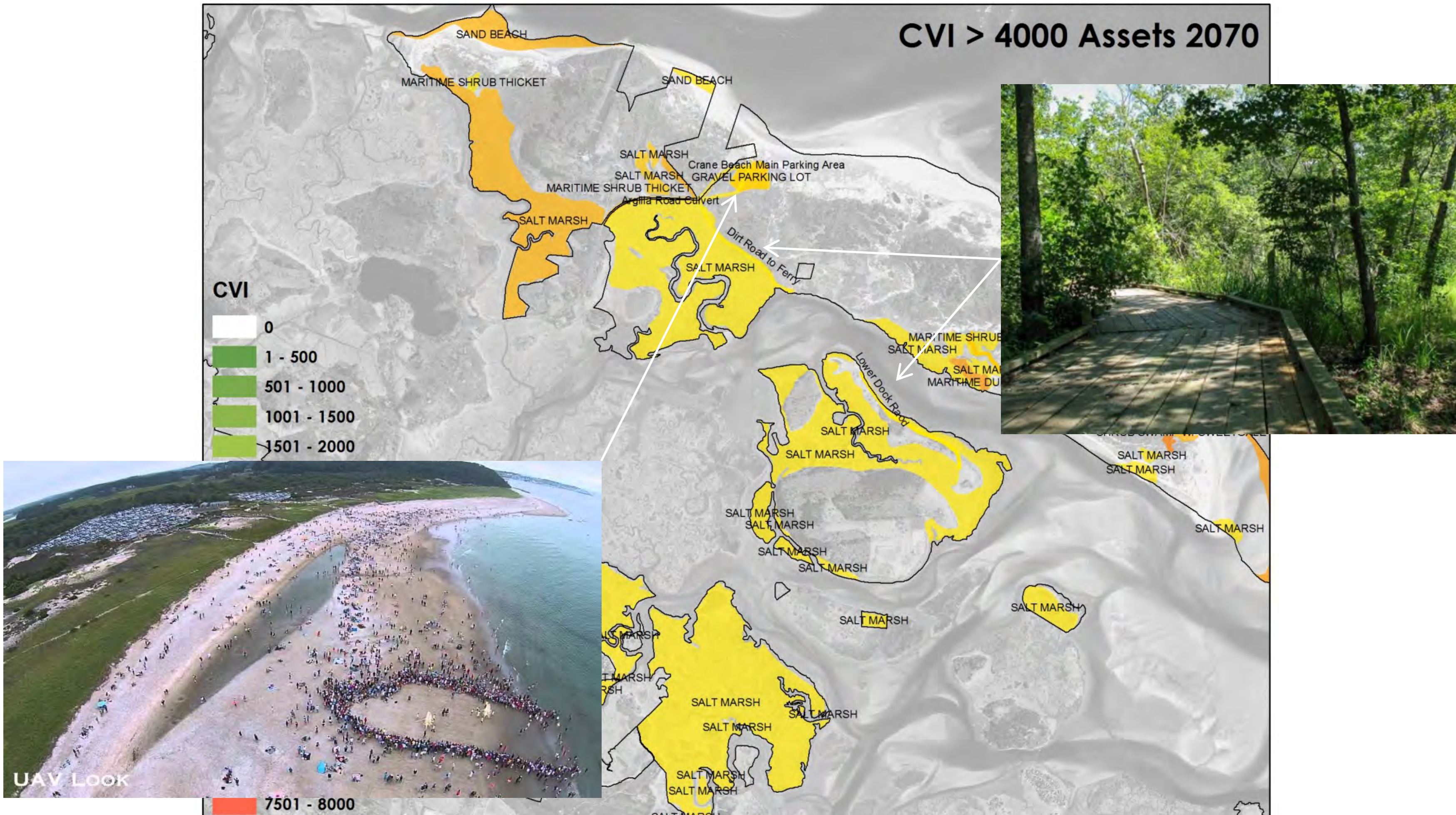
Examples of Site Vulnerability and Adaptation Evaluation (Conceptual)

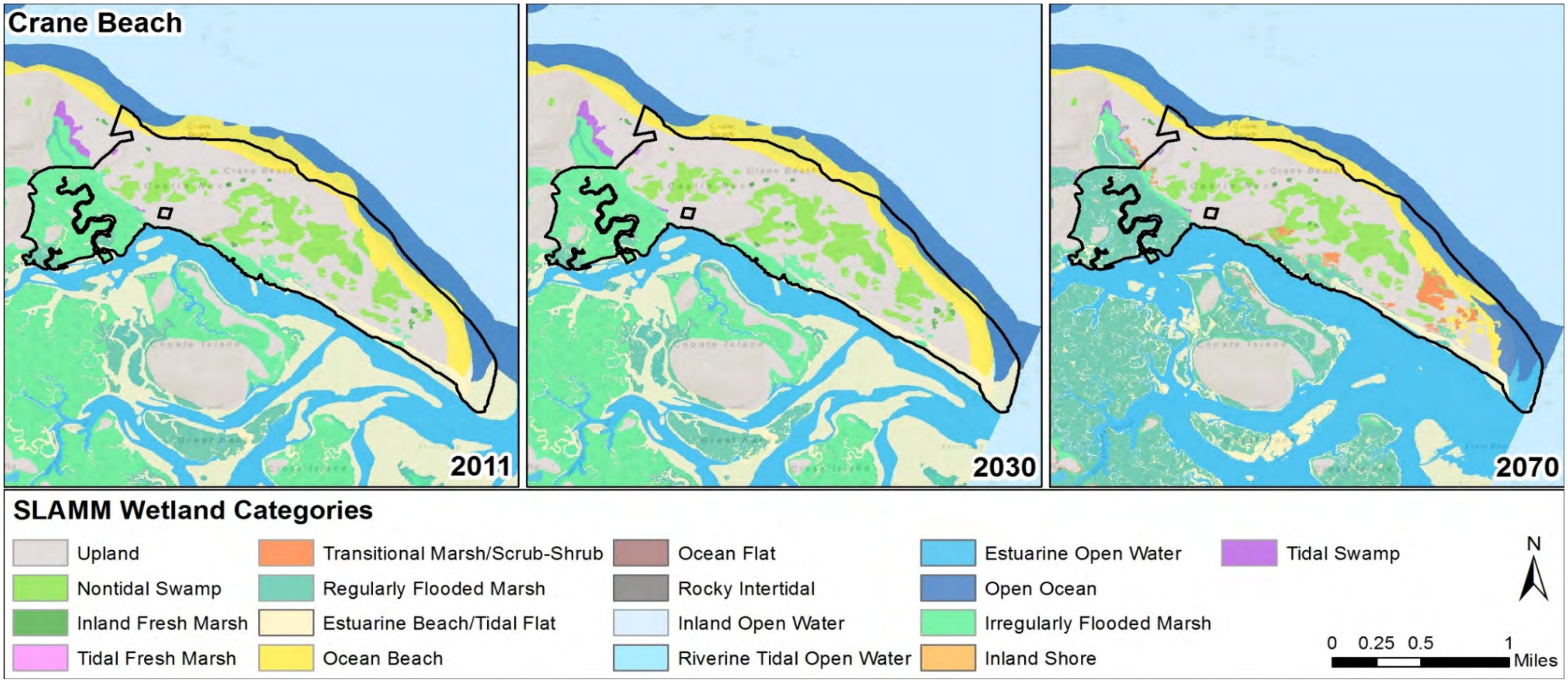
Elevated CVIs – Crane Estate 2030



Elevated CVIs – Crane Estate 2070

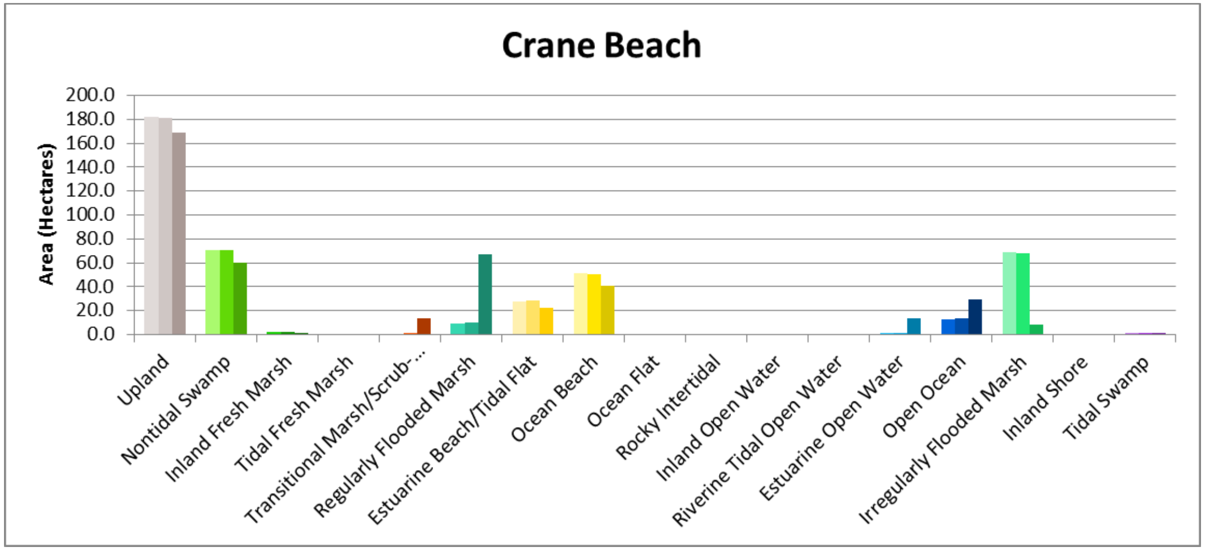


SLAMM Modeling– Example Results

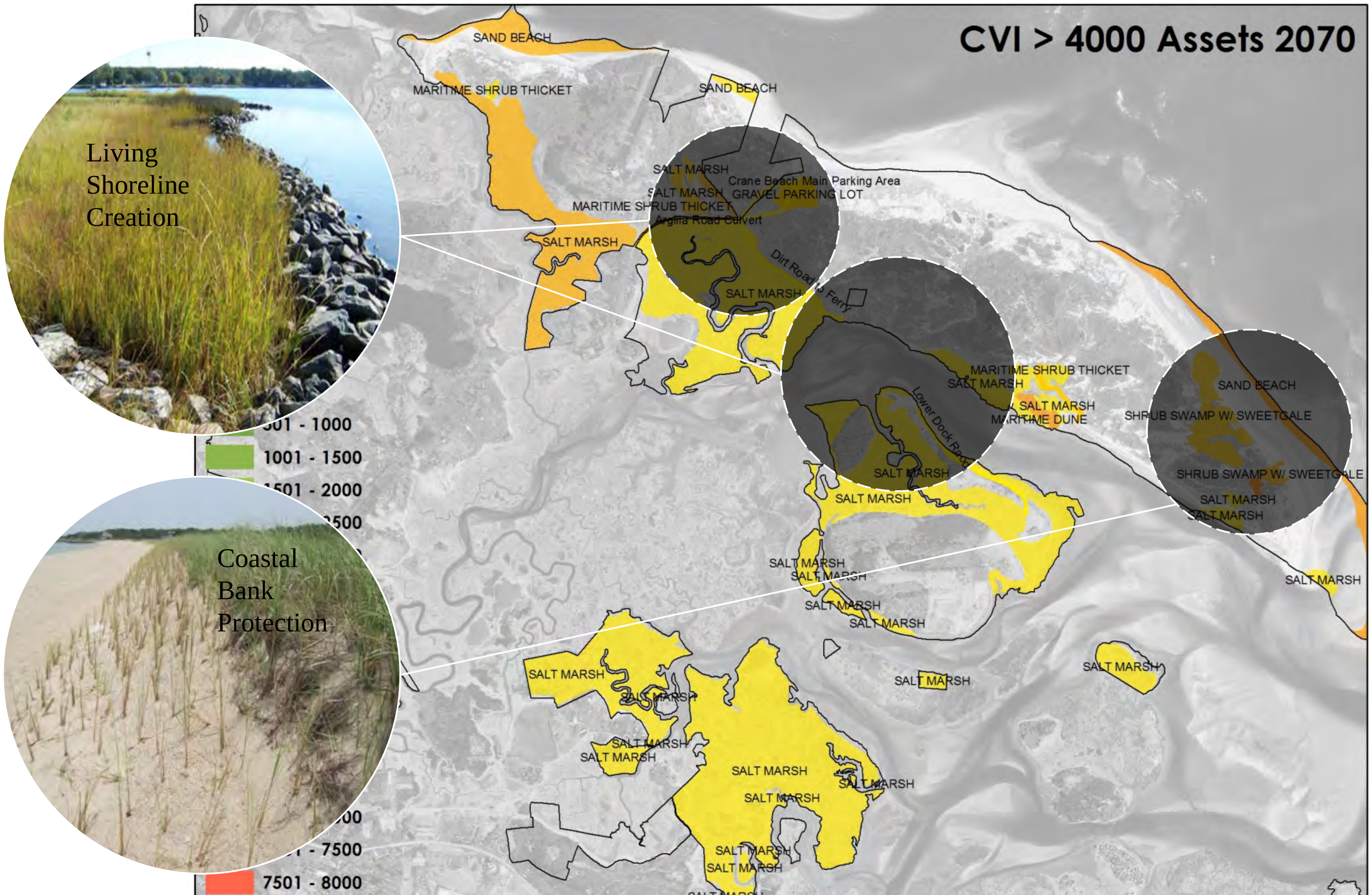


SLAMM Modeling– Example Results

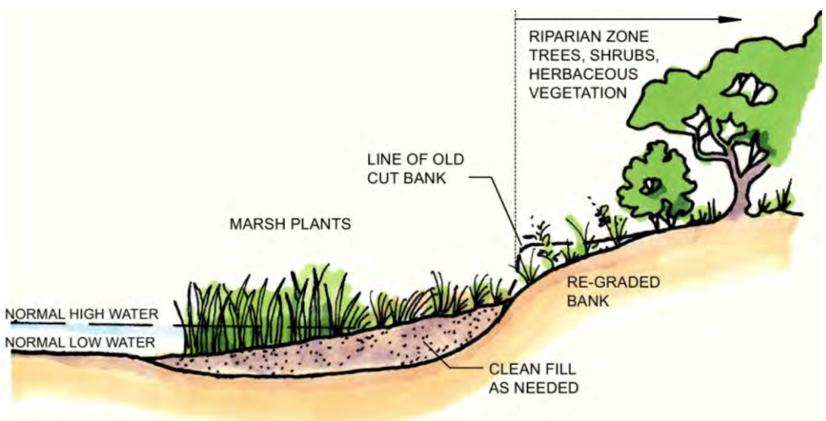
Wetland Type	2011	2030	2070
Upland	182.5	181.2	169.0
Nontidal Swamp	70.3	70.3	60.3
Inland Fresh Marsh	2.4	2.3	1.2
Tidal Fresh Marsh	0.0	0.0	0.0
Transitional Marsh/Scrub-Shrub	0.0	0.1	13.7
Regularly Flooded Marsh	9.4	10.3	66.7
Estuarine Beach/Tidal Flat	27.7	28.1	22.5
Ocean Beach	51.1	50.5	41.1
Ocean Flat	0.0	0.0	0.0
Rocky Intertidal	0.0	0.0	0.0
Inland Open Water	0.0	0.0	0.0
Riverine Tidal Open Water	0.0	0.0	0.0
Estuarine Open Water	0.1	0.6	13.2
Open Ocean	12.8	14.0	28.9
Irregularly Flooded Marsh	69.1	67.6	8.5
Inland Shore	0.0	0.0	0.0
Tidal Swamp	0.5	0.5	0.3

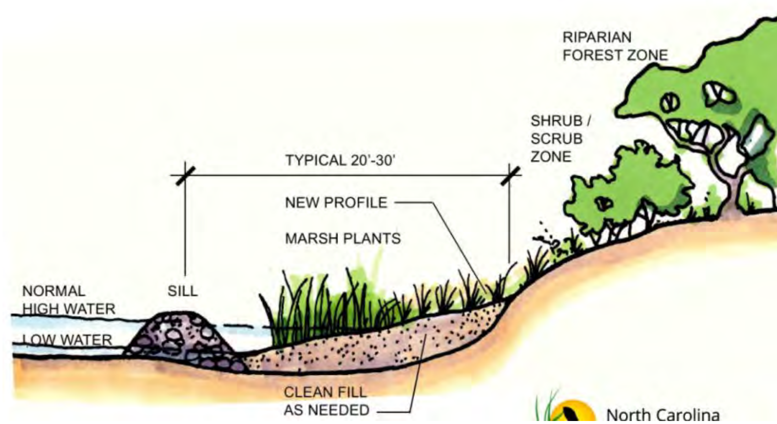


Example Adaptation Projects – Crane Estate



Adaptation Options – Living Shoreline/Marsh Creation/Enhancement





Adaptation Options – Coastal Bank Protection

SITE 5
HIGH PINES

High Pines, a headland located approximately a mile south of the Powder Point Bridge, represents a critical anchor point for the Duxbury barrier beach. While High Pines consists of large sand dunes on the surface, below the surface lies glacial till that makes this area more resilient than the connecting ribbons of sand to the north and south. However, it is still important to actively maintain the High Pines area since this is a critical connector for the entire barrier beach system.

Currently, the High Pines area experiences ongoing erosion at the base of the wind-blown sand dunes facing the Atlantic Ocean. These dune scarps have been maintained through time, and as part of the proposed resiliency approach should be continually maintained and enhanced to ensure stability of the High Pines anchor point.

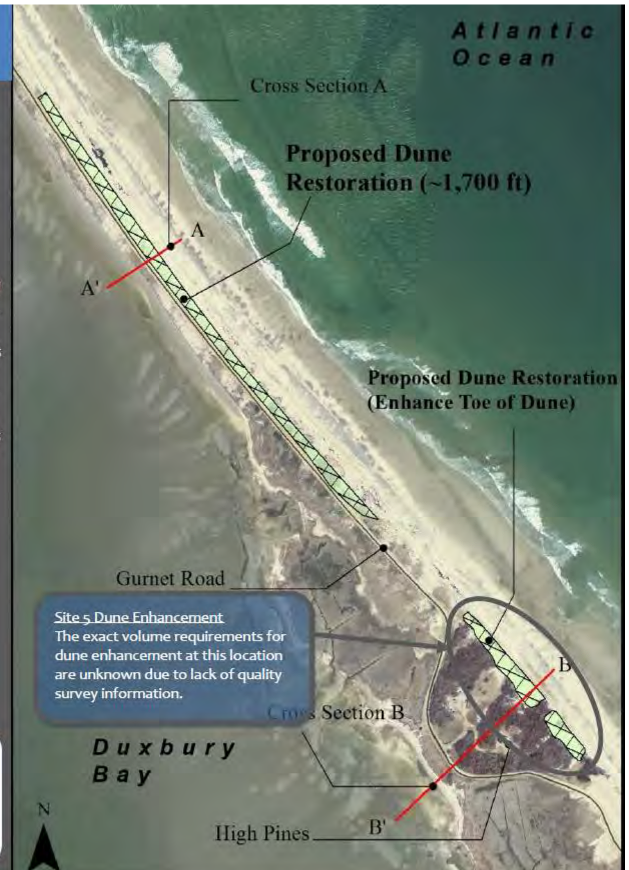
Cross Section B-B'

PRIORITY AND TIMING

3 LOWER PRIORITY

MID-TERM

The Duxbury Beach Reservation technical committee ranked this site as a lower priority site, due to the overall resiliency of the underlying glacial till and less critical nature of the erosion (wider dune and beach).



Adaptation Options – Marsh Restoration

Adaptation Planning Matrix

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

Mean Higher High Water (MHHW) Timeline	Annual (1-year) Storm Surge Timeline	100-year Storm Surge Timeline	Approximate Maximum Water Surface Elevation (ft, NAVD88)	Morrissey Blvd. Entrance: Upland Flooding Potential	Morrissey Blvd. Entrance: Recommended Engineering Adaptations	Morrissey Blvd. Entrance: Estimated Adaptation Cost*	Bayside Expo Center: Upland Flooding Potential	Bayside Expo Center: Recommended Engineering Adaptations	Bayside Expo Center: Estimated Adaptation Cost*	Mt. Vernon Street: Upland Flooding Potential	Mt. Vernon Street: Recommended Engineering Adaptations	Mt. Vernon Street: Estimated Adaptation Cost*	Ocean View Drive: Upland Flooding Potential	Ocean View Drive: Recommended Engineering Adaptations	Ocean View Drive: Estimated Adaptation Cost*
2010			4.0	No Flooding Expected	No Action Required	N/A	Poor Drainage of Bayside Expo Parking areas during heavy rainfall events. No Flooding of areas from Dorchester Bay waters.	Minor flood proofing of structures Installation of a pump house and pumped based-drainage system for parking area+	Capital Cost: $ 2.0 Million Annual Maintenance Costs: $ 10,000	No Flooding Expected	No Action Required	N/A	No Flooding Expected	No Action Required	N/A
			5.0												
2050			6.0												
	2010		7.0	Flooding of Morrissey Blvd. approximately 1/4 mile south of campus entrance. No flooding of campus entrance or campus facilities						Area has experienced poor storm water drainage. Storm water outfall at 2010 MHHW elevation may not adequately drain in future	Improve storm water removal and drainage lines. Modify storm water outfall or add pump house.	Capital Cost: $ 250,000 Annual Maintenance Costs: $ 2,000			
	2050		8.0												
2100			9.0												
		2010	10.0	Flooding of campus entrance. Initially from Patten's Cove (tidal pond to the west of entrance), and subsequently from Savin Hill Cove.	Tidal control structure installation at entrance to Patten's Cove. Soft solution (beach nourishment and vegetation enhancement) along Savin Hill Cove.	Capital Cost: $500-750,000 Annual Maintenance Costs: $10,000	Flooding of Bayside Expo areas from Dorchester Bay. Water overtops harbor walk in places.	Modular seawall installation at critical locations along Harbor walk Seawall extension along Harbor walk as needed	Capital Cost#: $1.0-1.5 million (1,000 foot length) Annual Maintenance Costs: $15,000				Flooding of streets around Ocean View Drive, expanding to buildings around the region.	Flood proofing of structures. Increasing crest height of revetment along Harbor walk or installation of a modular seawall.	Capital Cost#: $2.0-2.5 million (2,300 foot length) Annual Maintenance Costs: $20,000
		2050	11.0							Flooding from Dorchester Bay via low-lying pathways to the east of Mt. Vernon Street	Provide clean fill in low lying areas or increase storm damage protection through targeted soft coastal engineering solutions	Capital: $300-500,000 Annual Maintenance: $5,000			
	2100		12.0												
			13.0	Widespread flooding of UMASS Boston Campus, Morrissey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing	Widespread flooding of UMASS Boston Campus, Morrissey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing	Widespread flooding of UMASS Boston Campus, Morrissey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing	Widespread flooding of UMASS Boston Campus, Morrissey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing
		2100	14.0												
			15.0												
			16.0												

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

- Depends on length of seawall installed.

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