Town of Wareham
Climate Change Flood Vulnerability Assessment and Adaptation Planning

Public Presentation

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Town of Wareham Primary Contact:
Ken Buckland
Town Planner
Planning Department

Project Manager:
Elise Leduc
Coastal Scientist
Woods Hole Group

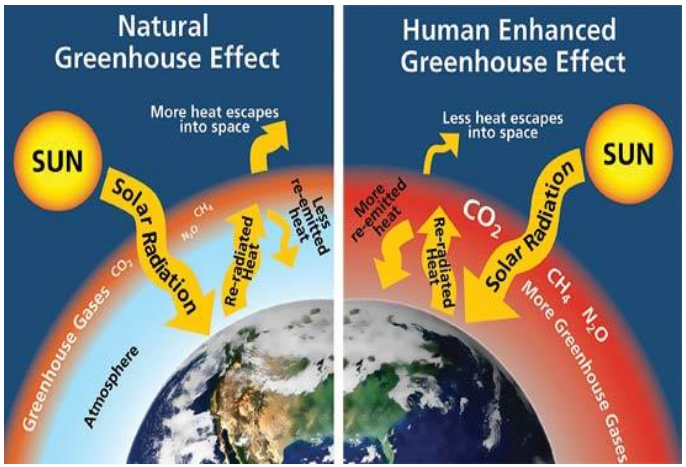
Vulnerability Assessment and Adaptation Planning

Presentation Outline

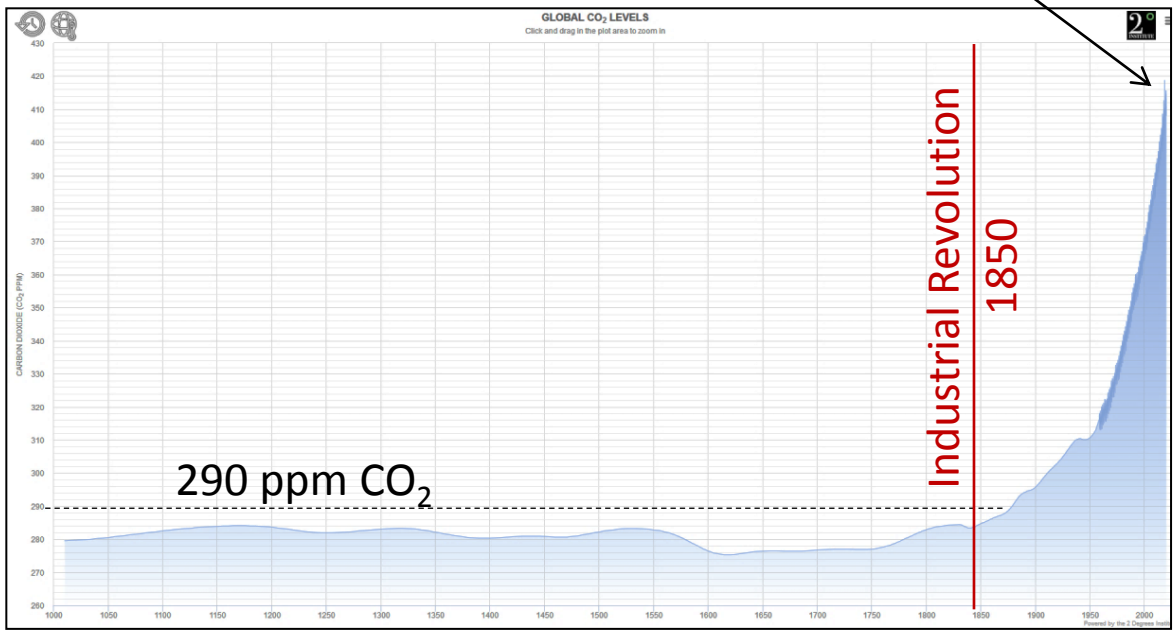
- Project Background and Need
  - Climate Change and Sea-Level Rise
  - Statewide MVP Program
- Analysis Methods
- Preliminary Vulnerability Assessment Results
  1. Municipal Asset Results
  2. Natural Resources Impacts
  3. Neighborhood Level Vulnerability Assessment
- Next Steps

Project Background and Need
Climate Change – What's happening and Why?

- Increasing concentrations of heat-trapping greenhouse gases, such as CO_2, are primarily responsible for the climate changes observed in the industrial era, especially over the last seven decades

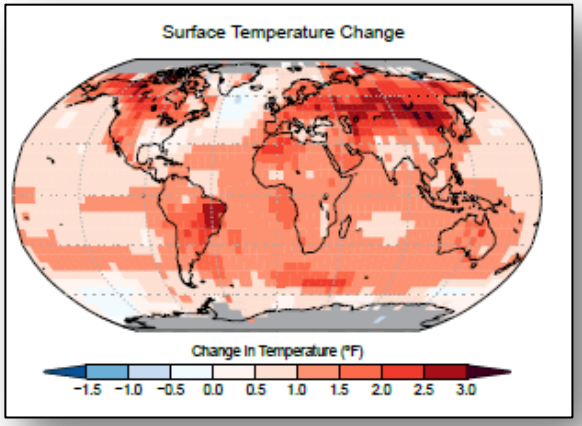


CO2 concentration > 400ppm
(9/23/19 from Mauna Loa Station)

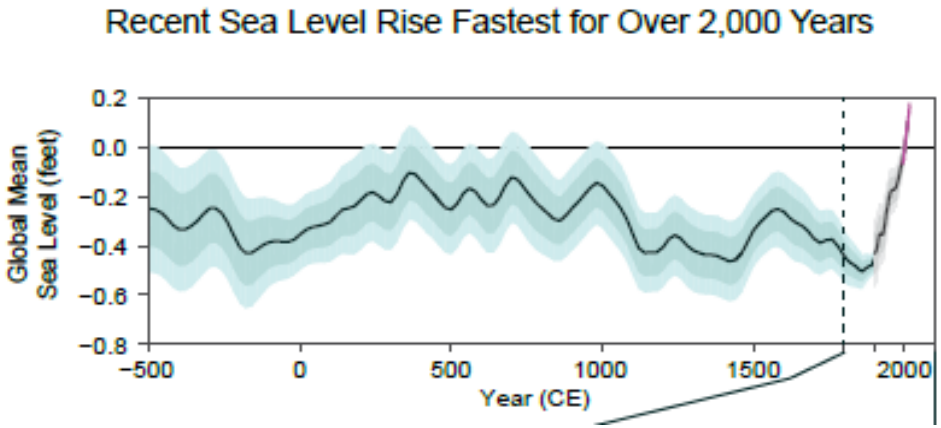


Project Background and Need
Climate Change – What's happening and Why?

- Thousands of studies by researchers worldwide have documented temperature increases at the Earth's surface and in the ocean

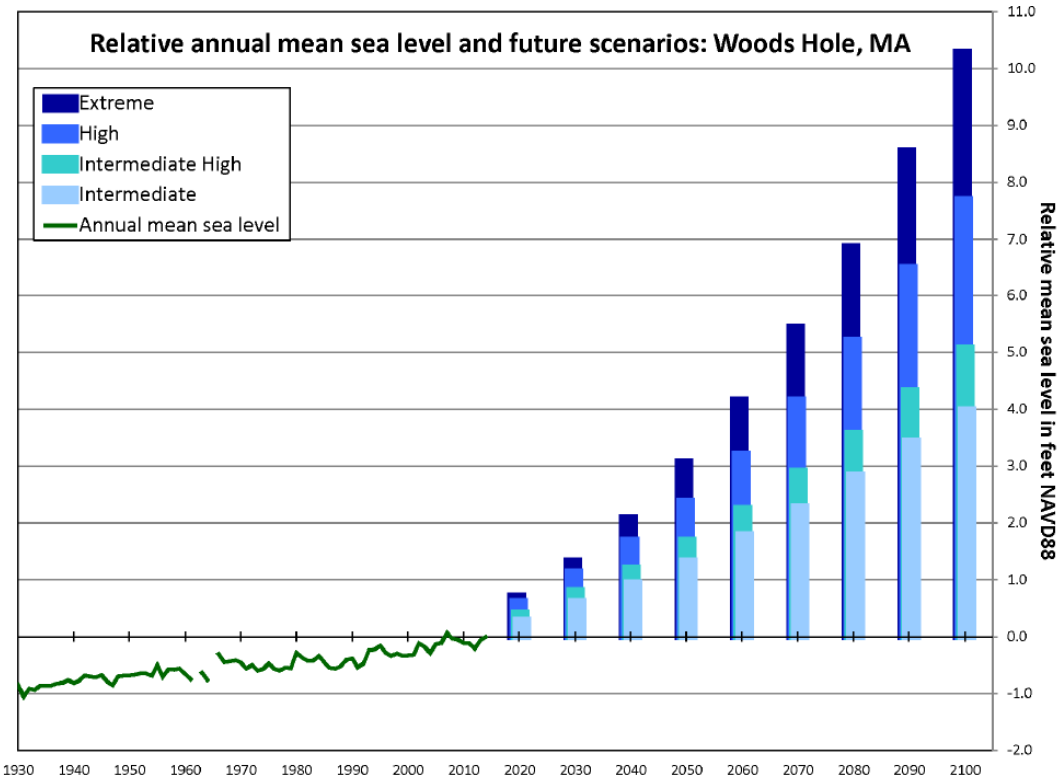


- Seas are warming, rising, and flooding is become more frequent along the U.S. coastline.



Project Background and Need
Climate Change – What's happening and Why?

- Warmer oceans and melting ice caps will continue to contribute to sea-level rise in the future



Statewide hydrodynamic modeling uses "High" Scenario

High	Extremely unlikely to exceed (99.5%) under RCP8.5	1.1	2.4	4.2	7.7
	• Unlikely to exceed (83%) under RCP8.5 when accounting for possible ice sheet instabilities • Extremely unlikely to exceed (95%) under RCP4.5 when accounting for possible ice sheet instabilities				

Project Background and Need

What is Municipal Vulnerability Preparedness?

1. Engage Community
2. Identify CC impacts and hazards
3. Complete assessment of vulnerabilities & strengths
4. Develop and prioritize actions
5. Take Action

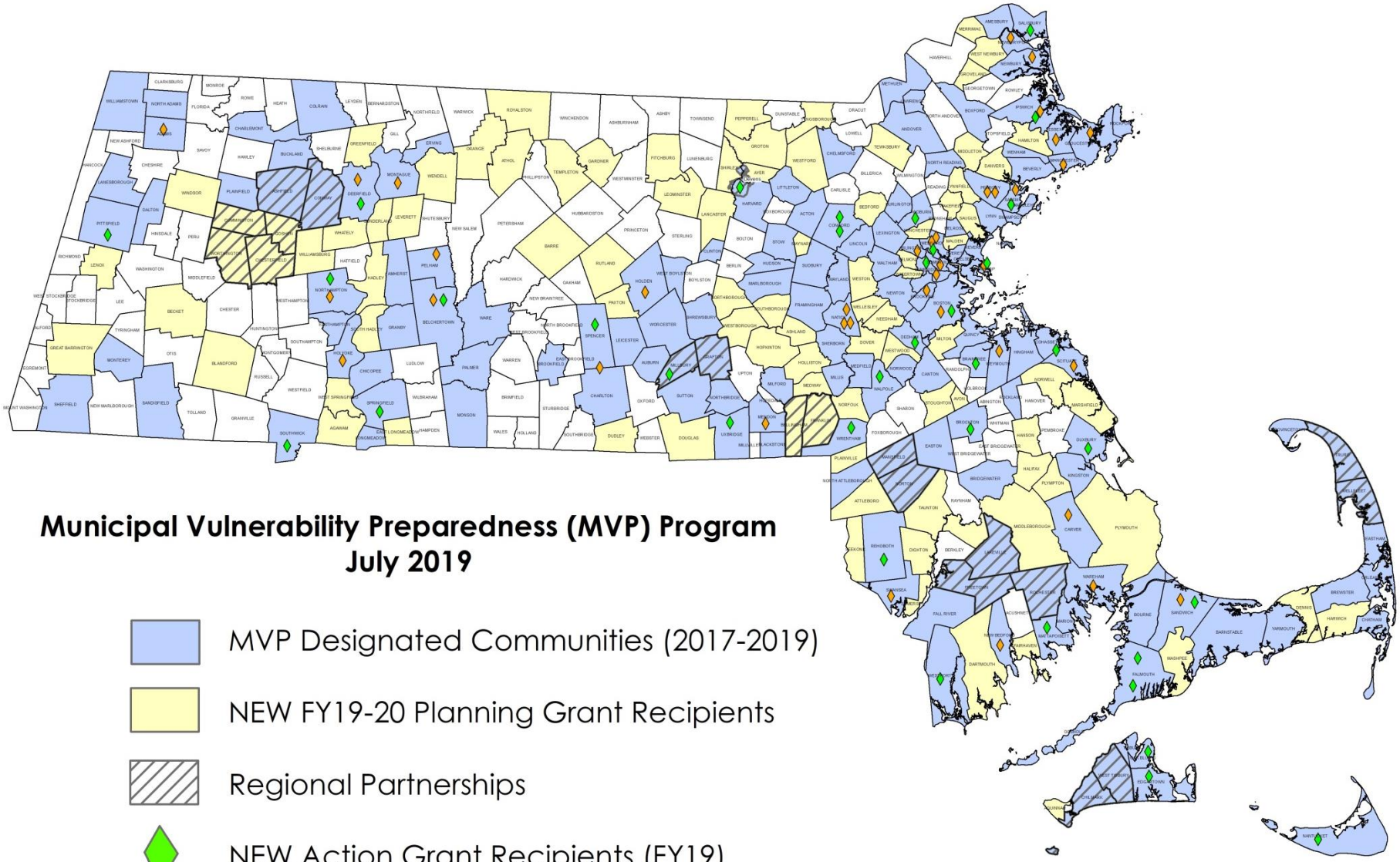
Potential Natural Hazards in Wareham

(included in pre-MVP workshop survey)

- **Coastal Flooding**
- Inland Flooding
- Coastal Erosion
- Sea-level Rise
- **Hurricane and Tropical Storm**
- Dam/Culvert Failure
- Earthquake
- Wildfires
- **Nor'easters/Snow Storms**
- **High Winds**
- Thunderstorms
- Extreme temperatures
- Tornadoes
- Drought
- Tsunami

MVP Workshop Top 10 Recommended Actions

1. Develop a comprehensive emergency evacuation and response plan
2. Develop incident command center and relocate Main St. fire station HQ
3. Install “quick connects” for wastewater pump station redundancy
4. Conduct an inflow/infiltration assessment for sewer system
5. Develop a beach management plan for nourishment
6. **Complete a flood risk assessment** to identify municipal features vulnerable to flooding.
7. Develop an acquisition plan for purchasing properties for protecting salt marsh and to allow for salt marsh migration as sea level rises.
8. Conduct a **bridge and road vulnerability assessment**.
9. Adopt zoning regulations to limit or restrict new construction in flood zones and other flood prone areas.
10. Establish a storm access route and public safety program for school accessibility.



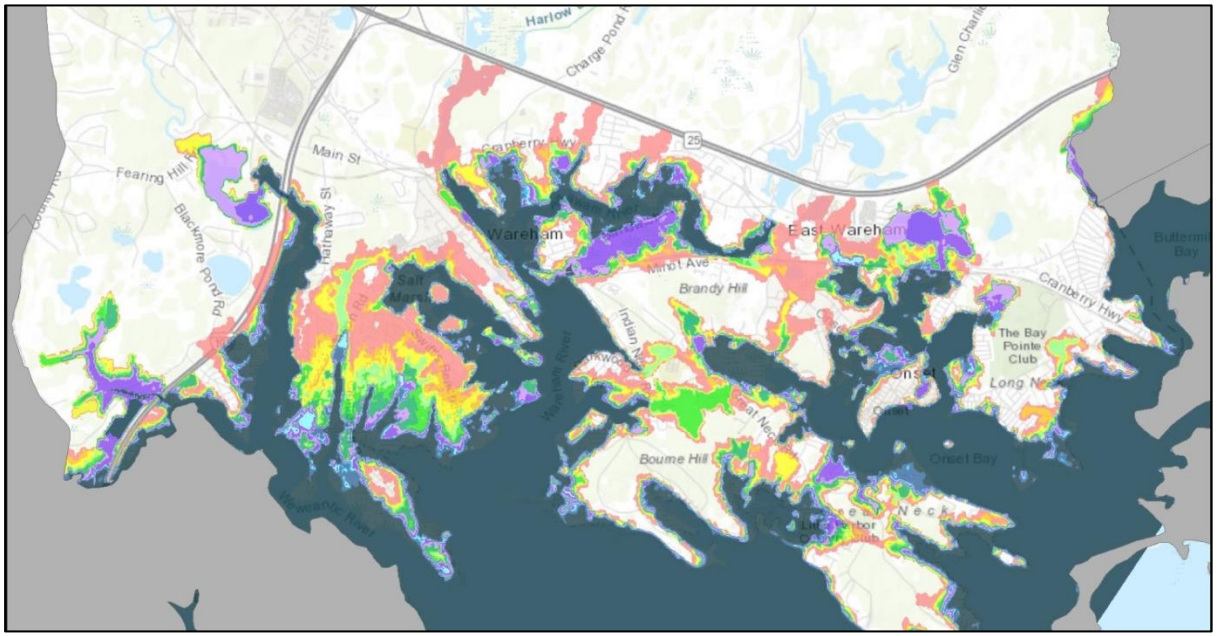
Municipal Vulnerability Preparedness (MVP) Program
July 2019

- MVP Designated Communities (2017-2019)
- NEW FY19-20 Planning Grant Recipients
- Regional Partnerships
- NEW Action Grant Recipients (FY19)
- Action Grant Recipients (FY18)

Project Background and Need

The Town applied for and received an MVP Action Grant

- Following the May 2018 MVP Workshop, the Town of Wareham was designated and MVP Certified Community
- MVP Action Grant for a **Climate Change Flood Vulnerability Assessment and Adaptation Planning** project awarded in summer 2018



Climate Change Flood Vulnerability Assessment

Project Goals and Objectives

- Provide data on likely future flooding scenarios
- Identify potential flooding impacts to municipally-owned infrastructure
- Identify potential flooding impacts to specific demographics
- Identify potential sea-level rise impacts to natural resources
- Identify and prioritize potential adaptation strategies to reduce risk
- Produce high-quality maps/graphics
- Public outreach and education

Climate Change Flood Vulnerability Assessment
Project Methods

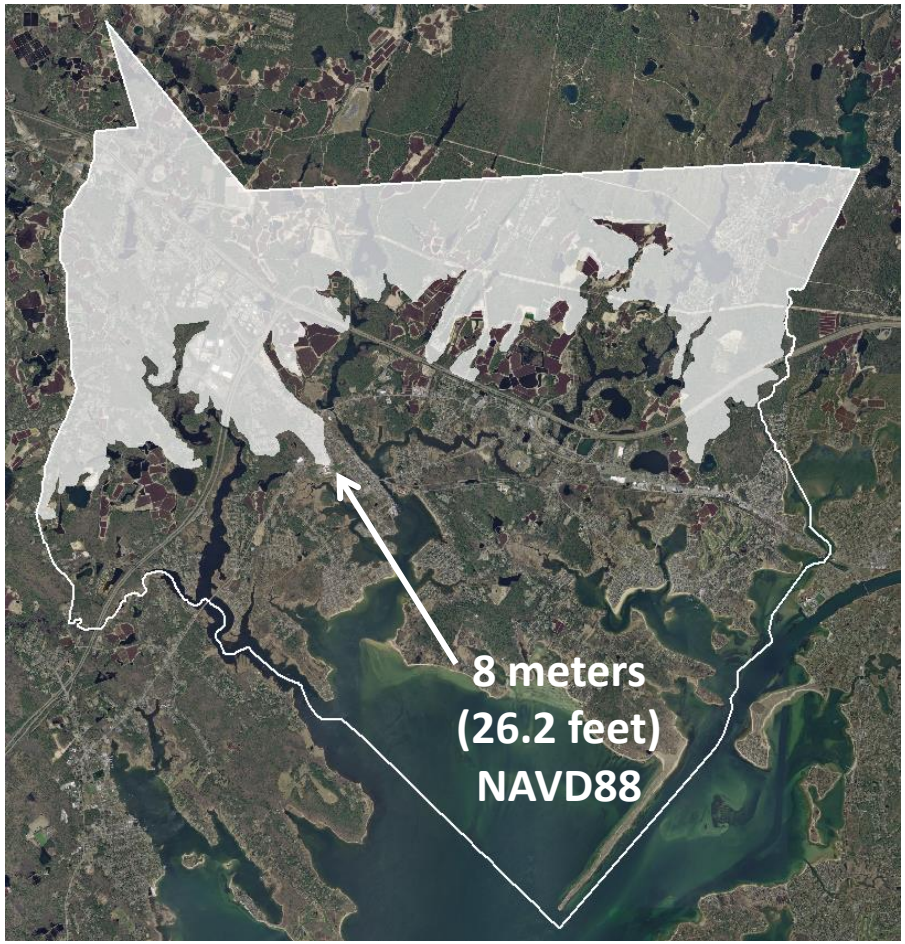
- Assess risk for each asset
  - Risk (R) = Probability of Flooding (P) x Consequence of Flooding (C)

- 5 step process:
  1. Determine critical assets
  2. Determine consequence of flooding score
  3. Determine critical elevations
  4. Obtain probability of exceedance data
  5. Calculate risk scores and rankings

Step 1: Determine critical assets

The following municipally owned assets within the model grid were included in the analysis:

- Buildings
- Above ground utilities (e.g., waste-water pumping stations)
- Onset Pier & boat ramps
- Recreational facilities (e.g., baseball fields, tennis courts, etc.)
- Selected coastal parking lots
- Roads/bridges



Step 2: Determine consequence of flooding

Rating	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impact on Public Safety & Emergency Services	Impact on Important Economic Activities	Impact on Public Health & Environment
5	Whole town/city	> 30 days	> $10m	Very high	Very high	Very high
4	Multiple neighborhoods	14 - 30 days	$1m - $10m	High	High	High
3	Neighborhood	7 - 14 days	$100k - $1m	Moderate	Moderate	Moderate
2	Locality	1 - 7 days	$10k - $100k	Low	Low	Low
1	Property	< 1 day	< $10k	None	None	None

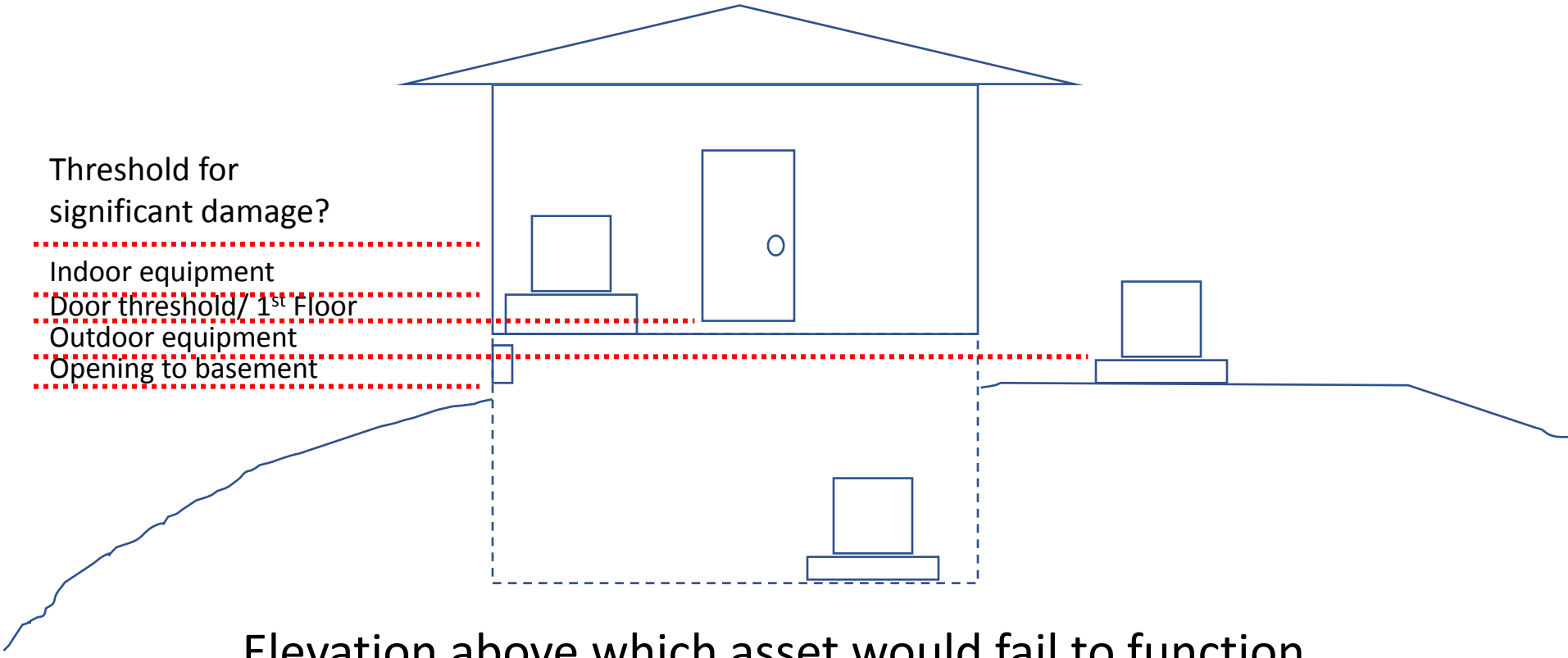
Risk (R) = Probability of Flooding (P) x **Consequence of Flooding (C)**

Step 2: Determine consequence of flooding

Asset Name	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impact on Public Safety & Emergency Services	Impact on Important Economic Activities	Impact on Public Health & Environment	Total Consequence Score
Onset Fire Department	5	3	4	5	2	5	80
Town Hall	5	3	4	3	4	3	73
Harbor Master Building & Restrooms	5	3	3	4	3	3	70
WPCF - Operational Building	5	2	3	2	3	5	67
Wareham High School	5	3	4	2	3	1	60
Apple Street Pump Station	3	2	4	2	2	4	57
Red Wood Park - Community Building	2	3	3	2	2	2	47
Fearing Tavern Museum	1	3	3	1	3	1	40
Onset Band Stand	1	2	3	1	3	1	37
Swifts Beach Basketball Court	1	2	1	1	2	1	27

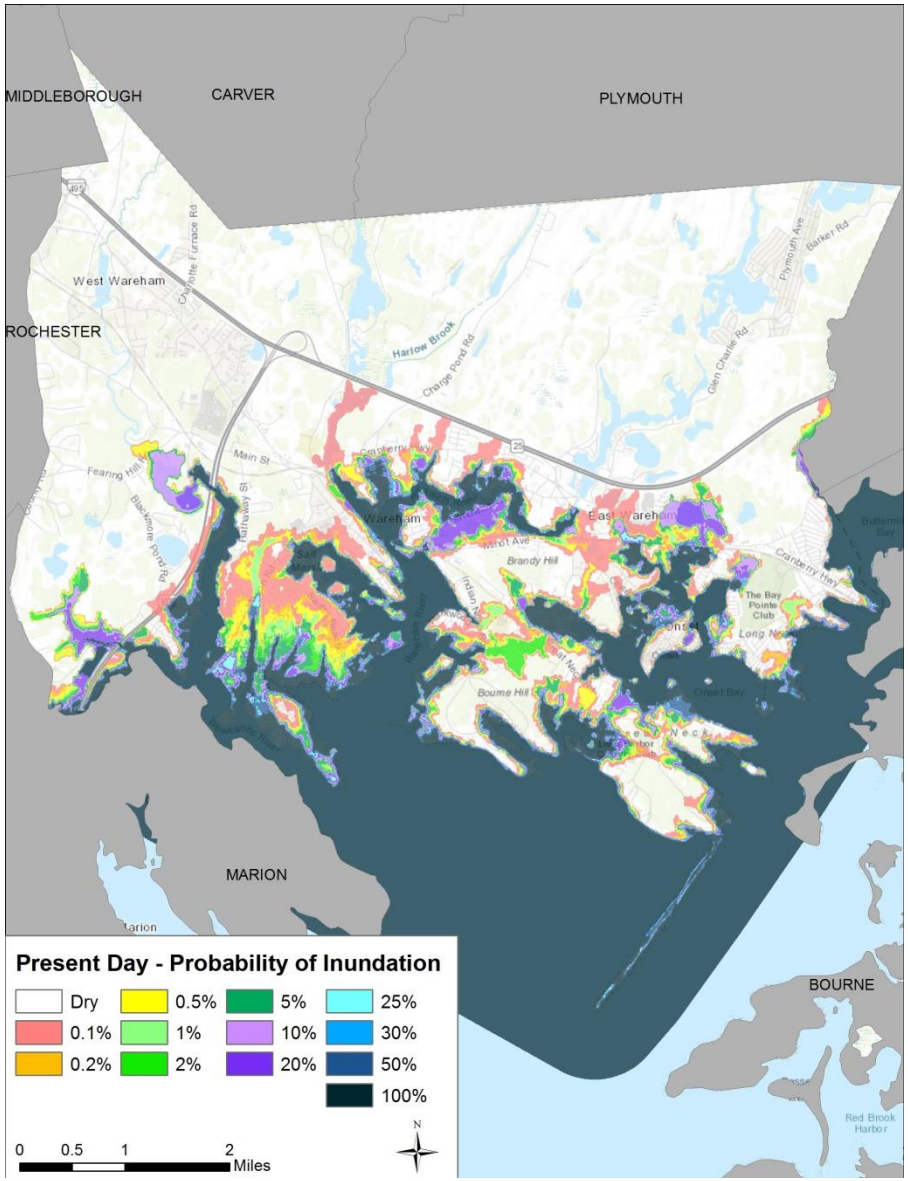
Risk (R) = Probability of Flooding (P) x **Consequence of Flooding (C)**

Step 3: Determine critical elevations



Elevation above which asset would fail to function

Step 4: Obtain Probability of Exceedance Data



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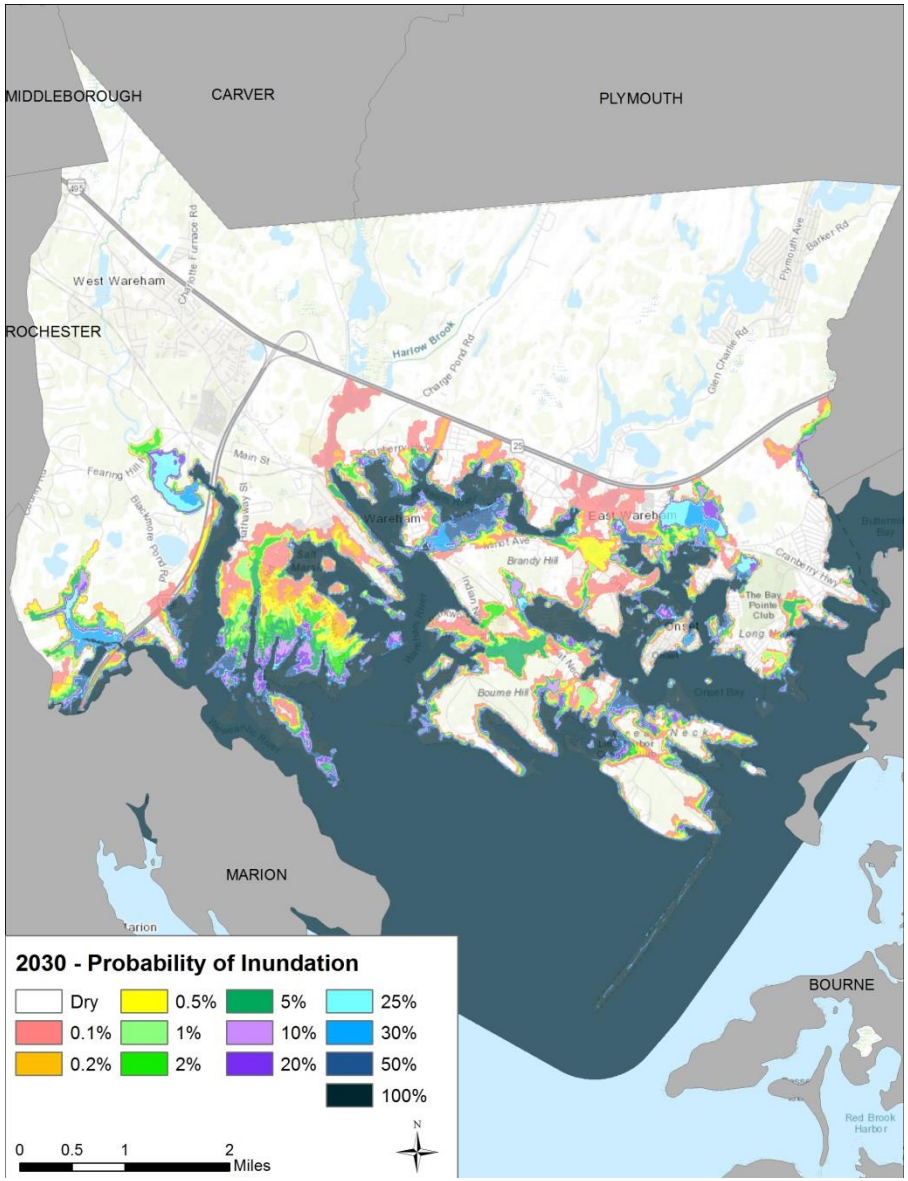

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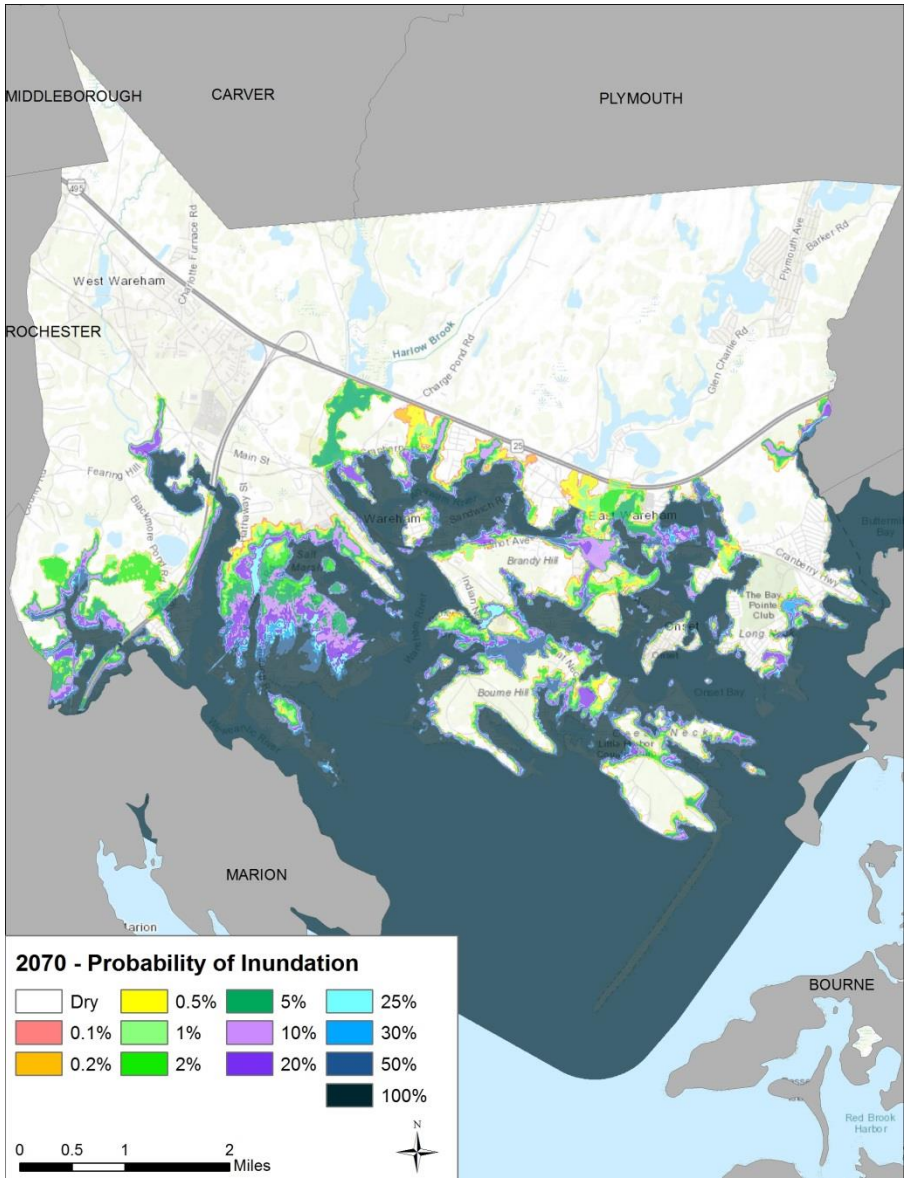

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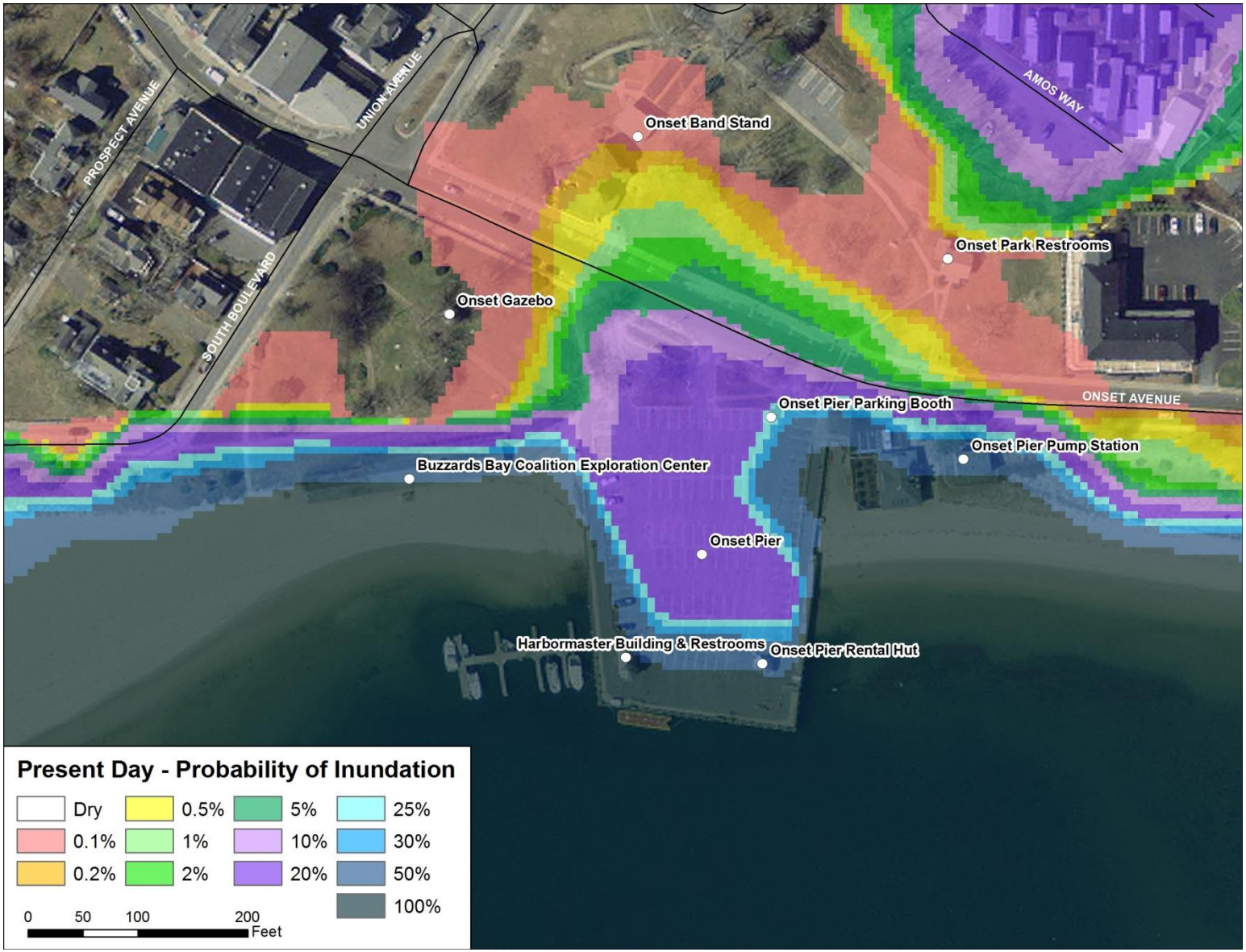

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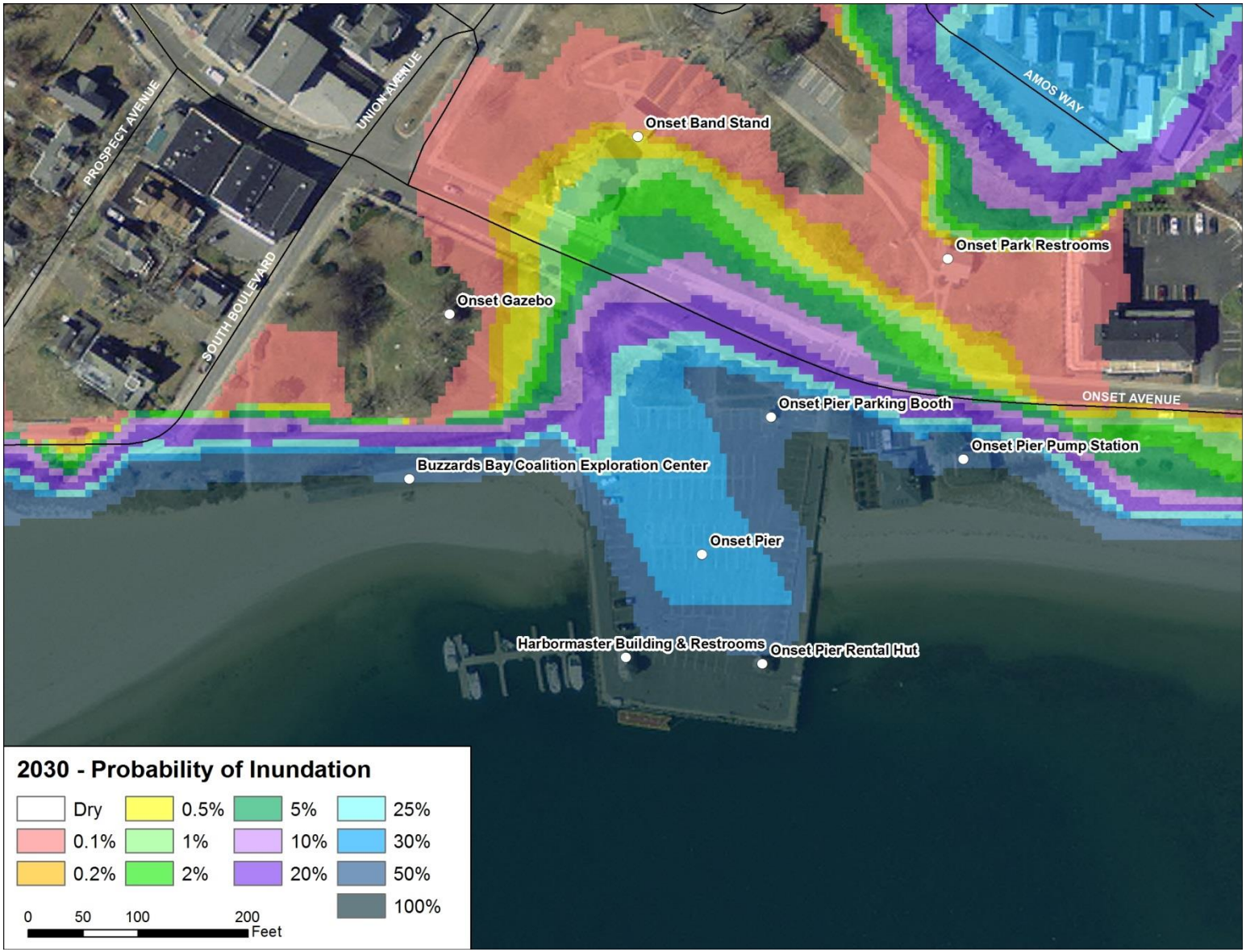

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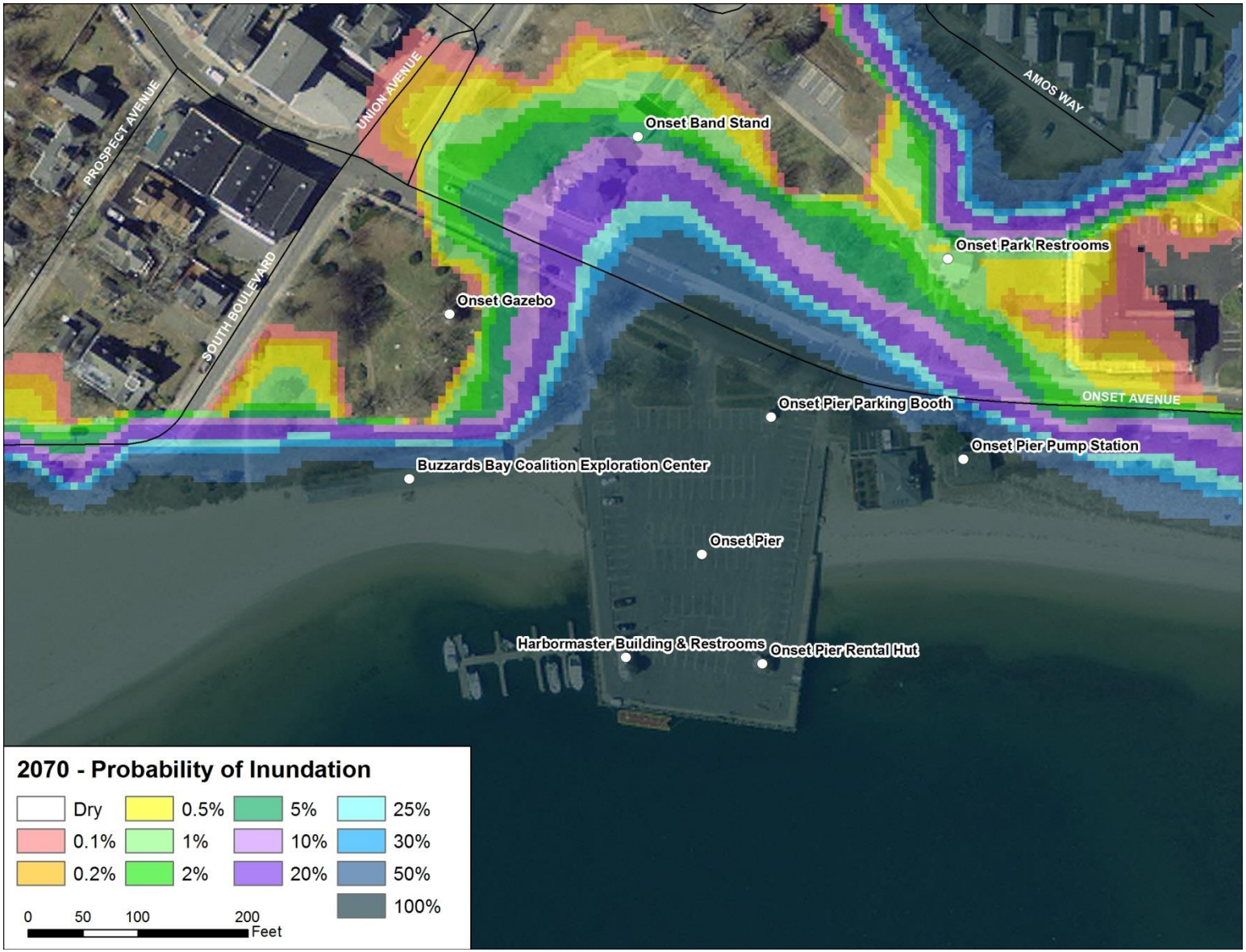
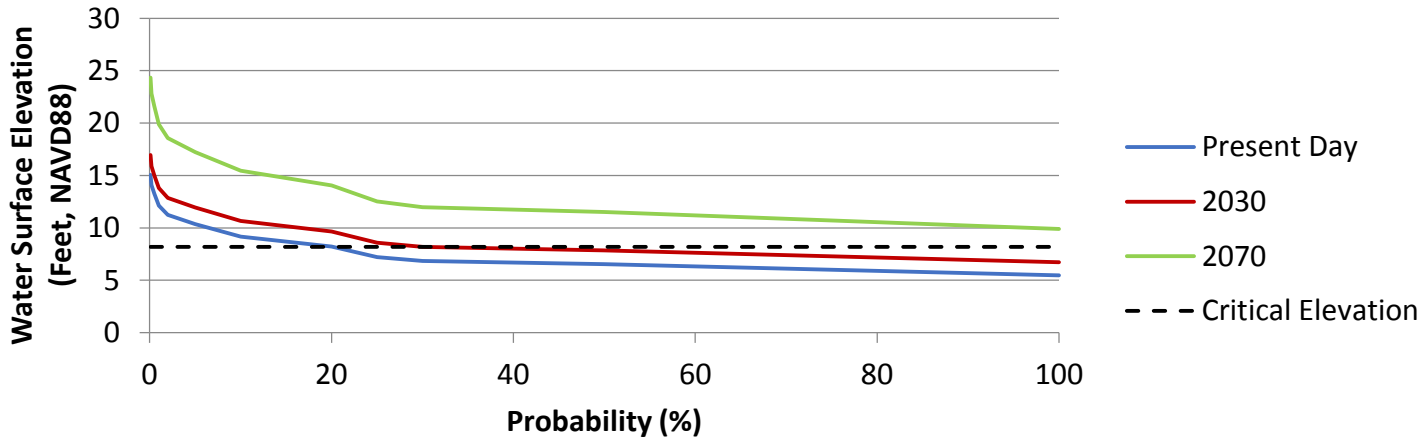


Step 4: Obtain Probability of Exceedance Data

Harbormaster building: Critical elevation = 8.2 feet (NAVD88)

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	15.1	6.9	16.9	8.8	24.3	16.1
0.2	14.1	5.9	15.9	7.7	22.8	14.6
0.5	13.3	5.1	15.0	6.8	21.6	13.4
1	12.1	3.9	13.8	5.6	19.9	11.7
2	11.2	3.0	12.9	4.7	18.6	10.4
5	10.4	2.2	11.9	3.7	17.2	9.0
10	9.2	1.0	10.7	2.5	15.5	7.3
20	8.3	0.1	9.7	1.5	14.0	5.8
25	7.21	dry	8.6	0.4	12.5	4.3
30	6.85	dry	8.19	dry	12.0	3.8
50	6.54	dry	7.86	dry	11.5	3.3
100	5.47	dry	6.72	dry	9.9	1.7



Step 5: Calculate Risk Scores and Rankings

Time horizon	Probability of Exceedance	Consequence Score	Risk Score	Weight	Composite Risk Score
Present	20	70	1400	0.5	2625
2030	25	70	1750	0.3	
2070	100	70	7000	0.2	

$$R_{comp} = (R_{present} \times W_{present}) + (R_{2030} \times W_{2030}) + (R_{2070} \times W_{2070})$$

Step 5: Calculate Risk Scores and Rankings

Top 20 ranked buildings and structures

Rank	Asset Name	Asset Type	Consequence Score	Present Probability (%)	2030 Probability (%)	2070 Probability (%)	Composite Risk Score
1	Arnold Pump Station	Sewer	57	30	100	100	3683
2	Train Station Parking Lot Restrooms	Admin	47	50	100	100	3500
3	Tremont Nail - Freight Building	Historical	33	100	100	100	3333
4	Harbormaster Building & Restrooms	Marine	70	20	25	100	2625
5	Onset Heights Pump Station	Sewer	57	20	50	100	2550
6	Riverside Pump Station	Sewer	57	20	50	100	2550
7	Avenue A Street Pump Station	Sewer	57	25	30	100	2352
8	East Boulevard Ejector	Sewer	60	20	30	100	2340
9	Tremont Nail - Shed	Historical	23	100	100	100	2333
10	Buzzards Bay Coalition Exploration Center	Rec	43	25	50	100	2058
11	Tremont Nail - Nail Factory	Historical	40	2	100	100	2040
12	Tremont Nail - Packaging Building	Historical	40	25	50	100	1900
13	Little Harbor Restrooms	Rec	40	20	50	100	1800
14	Leonard Pump Station	Sewer	57	10	20	100	1757
15	Onset Pier Parking Booth	Marine	37	25	50	100	1742
16	Briarwood Beach Pump Station	Sewer	57	5	20	100	1615
17	Indian Neck Pump Station	Sewer	57	5	20	100	1615
18	Onset Pier Rental Hut	Marine	40	10	25	100	1300
19	Emergency Medical Services	Emer.	77	2	5	50	958
20	Bay Street Ejector	Sewer	57	5	10	50	878

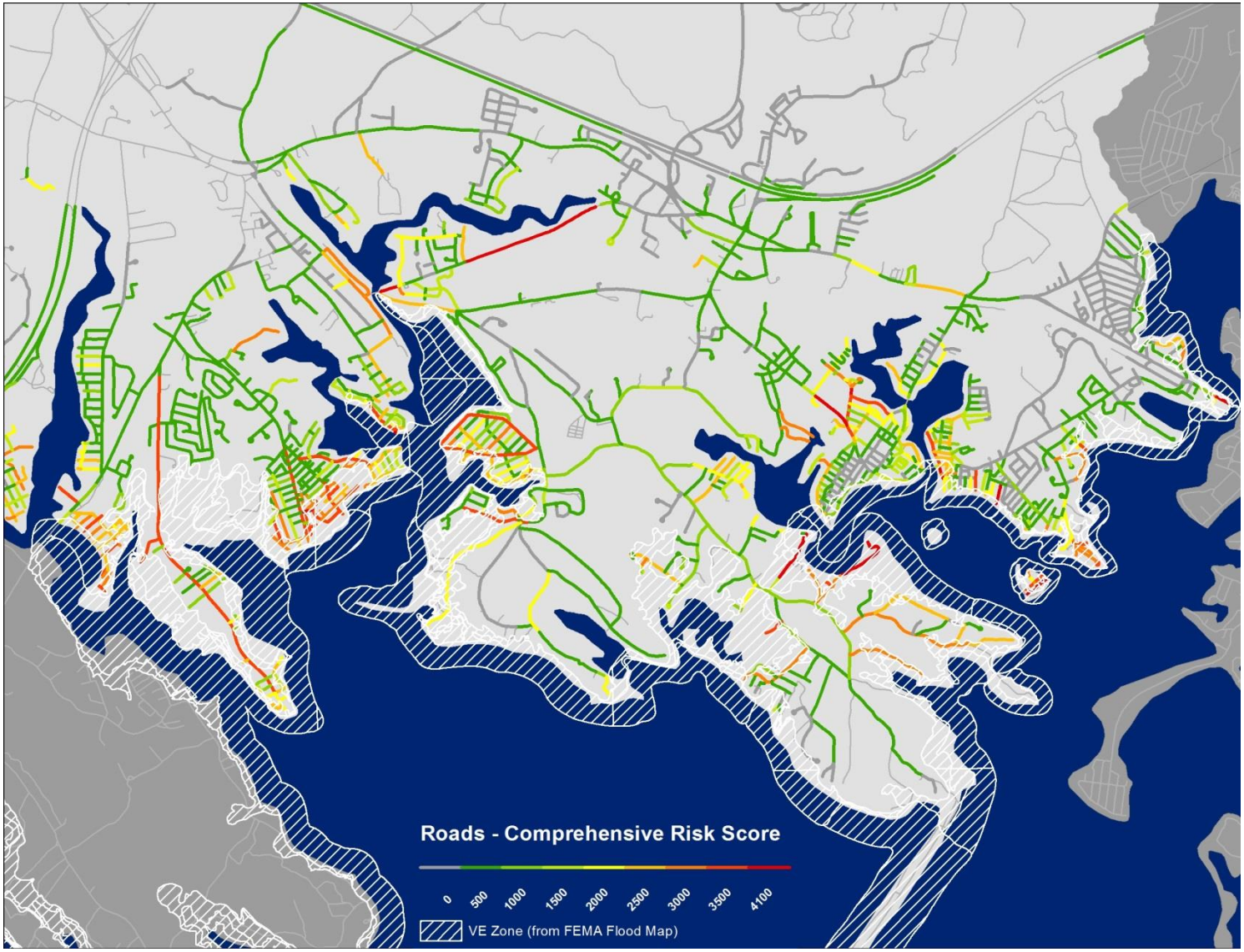
Step 5: Calculate Risk Scores and Rankings

Top 20 ranked roads

Rank	Asset Name	Consequence Score	Present Probability (%)	2030 Probability (%)	2070 Probability (%)	Composite Risk Score
1	Green Street	53	70.9	78	88.4	4082
2	Lydias Island Road (northeastern half)	43	89.5	91.5	100	3995
3	Onset Avenue (Osborne Ave to Barlow Ave)	63	52.7	70.1	76.2	3966
4	Circle Drive (western half from Swifts Beach Rd)	53	65.5	74.1	87.1	3861
5	South Water Street	53	64.8	72.7	90.4	3855
6	Sandwich Road (Apple St to Wareham River)	57	66.5	66.9	73.3	3852
7	Monument Avenue	43	81.1	84.1	99.1	3709
8	Over Jordan Road (northeastern half)	43	80	82.4	100	3671
9	Cranberry Highway (Water St to Cohasset Narrows Bridge)	73	33.1	56.5	75.3	3561
10	Sandwich Road (RR crossing to Mayflower Ave)	53	57.5	70.9	83.7	3561
11	Camp Street (North Blvd to Commonwealth Ave)	37	94.5	95.4	100	3515
12	Salt Creek Road	43	75.9	76	100	3499
13	Swifts Beach Road	57	51.1	67.4	75.3	3447
14	Oceanside Drive	50	62.6	73.2	76.9	3432
15	Old Colony Avenue	43	72	75.9	100	3413
16	Pinehurst Drive (southwestern portion of Pinehurst Dr to Pigs Pt Rd)	53	52.8	67.2	85.2	3392
17	Cleveland Avenue (seaward of Thrush Ave)	43	72.9	75.3	94.9	3381
18	Roby Street (Shore Ave to Circle Dr)	43	70.8	75.1	99.7	3374
19	Sias Point Road Extension (circle only)	43	70.9	74.8	98.3	3361
20	Circle Drive (eastern half to Roby St)	47	65.3	73.8	85.7	3357

Step 5: Calculate Risk Scores and Rankings

Top 20 ranked roads



Step 5: Calculate Risk Scores and Rankings

Top 20 ranked assets (overall)

Rank	Asset Name	Asset Type	Consequence Score	Present Probability (%)	2030 Probability (%)	2070 Probability (%)	Composite Risk Score
1	Onset Avenue (Osborne Ave to Barlow Ave)	Road	63	52.7	70.1	76.2	3966
2	Arnold Pump Station	Sewer	57	30	100	100	3683
3	Besse Park Parking Lot	Parking Lot	37	100	100	100	3667
4	Swifts Beach Parking Lot (West)	Parking Lot	37	100	100	100	3667
5	Swifts Beach Parking Lot (East)	Parking Lot	37	100	100	100	3667
6	Cranberry Highway (Water St to Cohasset Narrows Bridge)	Road	73	33.1	56.5	75.3	3561
7	Sandwich Road (RR crossing to Mayflower Ave)	Road	53	66.5	66.9	73.3	3561
8	Train Station Parking Lot Restrooms	Admin	47	50	100	100	3500
9	Tremont Nail - Freight Building	Historical	40	100	100	100	4000
10	Onset Avenue (Storer St to Wareham Ave)	Road	60	38.4	62.9	75.2	3187
11	Onset Avenue (Wareham Ave to 10th St)	Road	57	34.9	59.6	74.9	2851
12	12th Street Boat Ramp Parking Lot	Parking Lot	37	50	100	100	2750
13	Little Harbor Beach Parking Lot	Parking Lot	37	50	100	100	2750
14	Shell Point Parking Lot	Parking Lot	37	50	100	100	2750
15	Swifts Beach Basketball Court	Rec	27	100	100	100	2667
16	Harbormaster Building & Restrooms	Marine	70	20	25	100	2625
17	Onset Heights Pump Station	Sewer	57	20	50	100	2550
18	Riverside Pump Station	Sewer	57	20	50	100	2550
19	Onset Pier	Marine	57	20	50	100	2550
20	Sandwich Road (RR Crossing to Main St)	Road	57	29.9	49.7	74.4	2535

Vulnerability Assessment – Other Deliverables

Asset Specific Visualizations

- Asset Specific Visualizations
  - Harbormaster Building
  - Hynes Field Pump Station
  - Main Street

Harbormaster Building

2070 100-year flood depth = 11.7 feet (elevation = 19.9 feet NAVD88)

2030 100-year flood depth = 5.6 feet (elevation = 13.8 feet NAVD88)

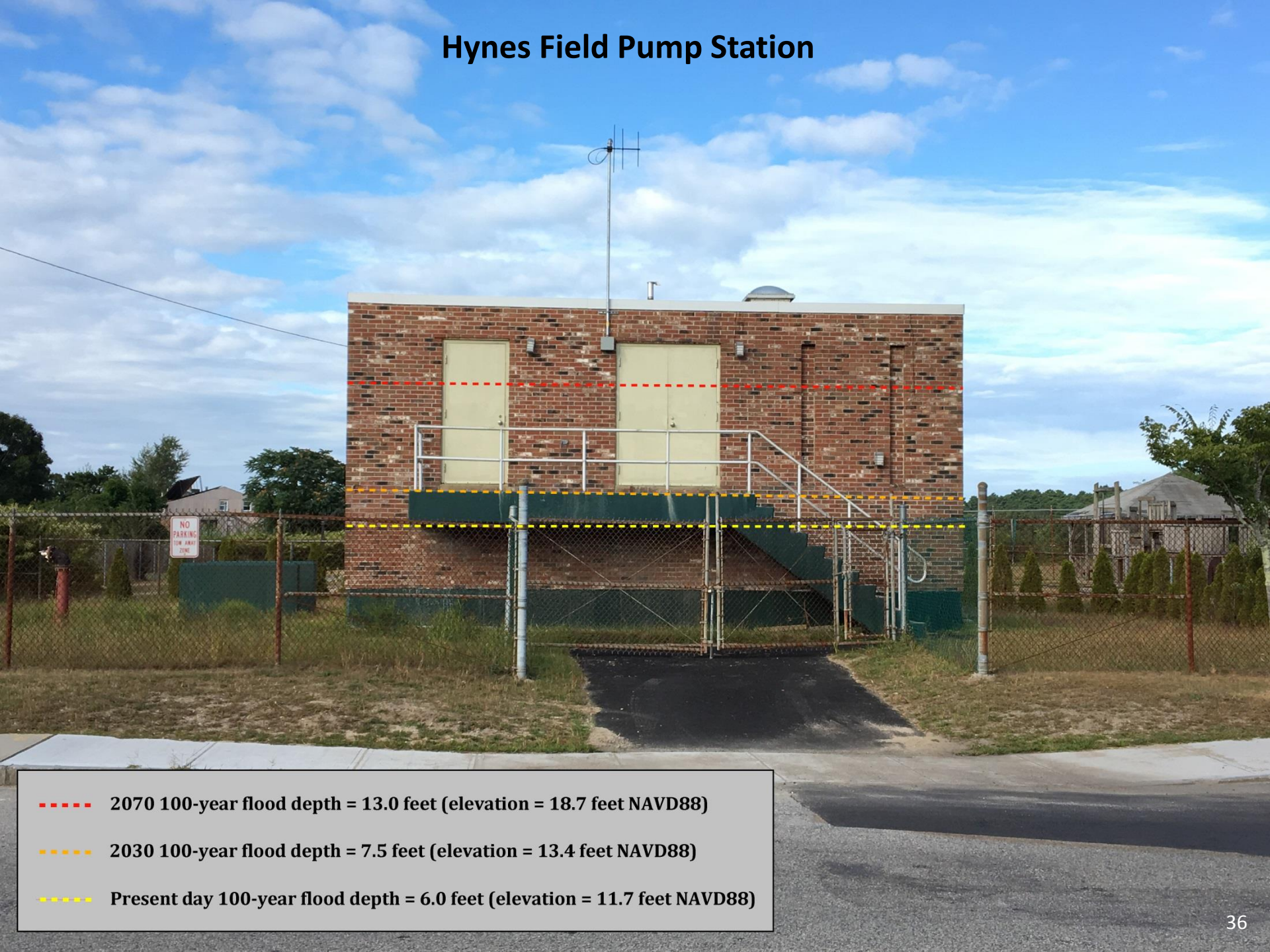
Present day 100-year flood depth = 3.9 feet (elevation = 12.1 feet NAVD88)


Present Day 100-year event
HARBORMASTER
ONSET PIER
BUOYS
UTILITIES


2030 100-year event
HARBORMASTER
ONSET PIER
BUOYS
UTILITIES


2070 100-year event

Hynes Field Pump Station



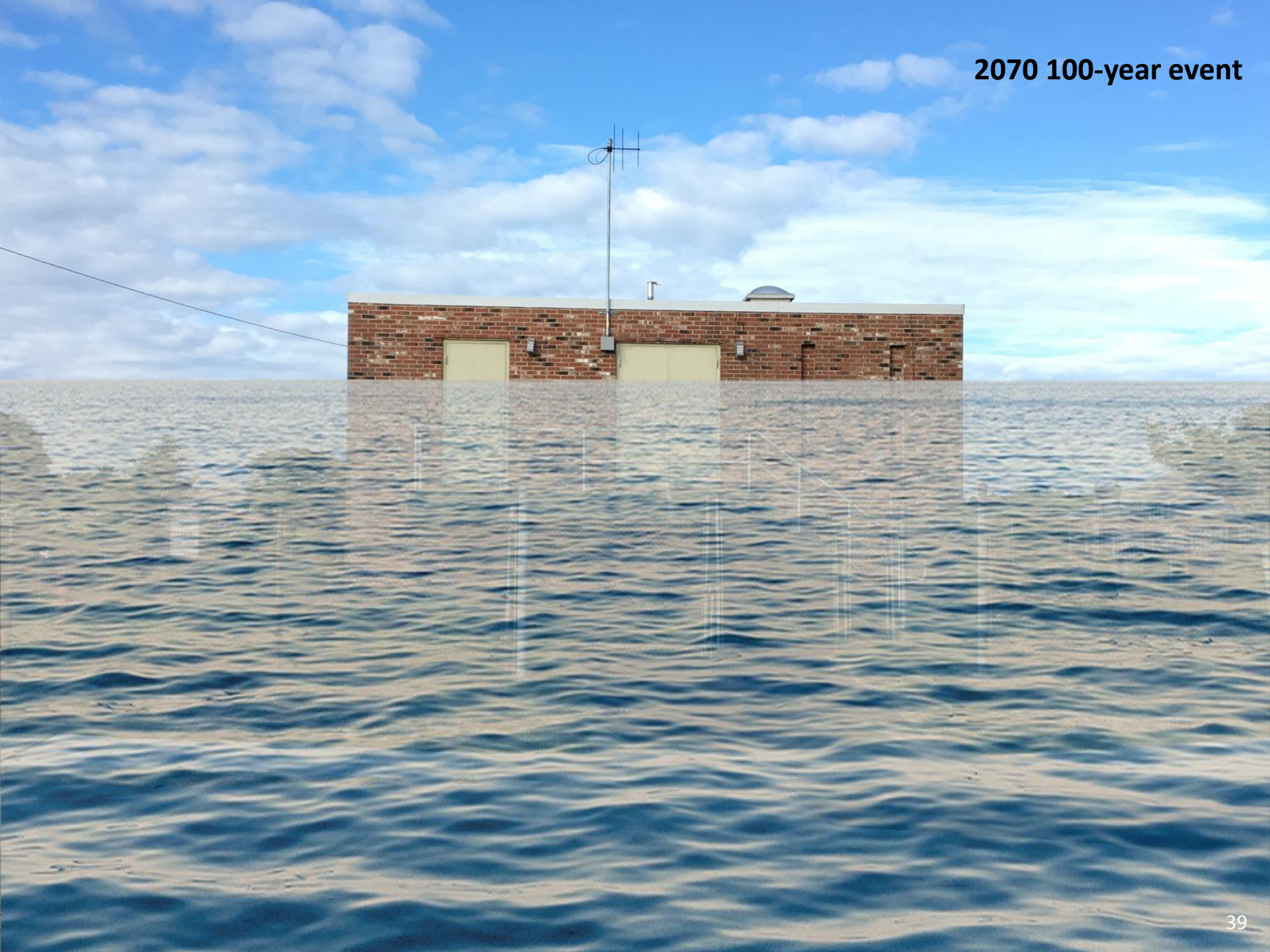
2070 100-year flood depth = 13.0 feet (elevation = 18.7 feet NAVD88)

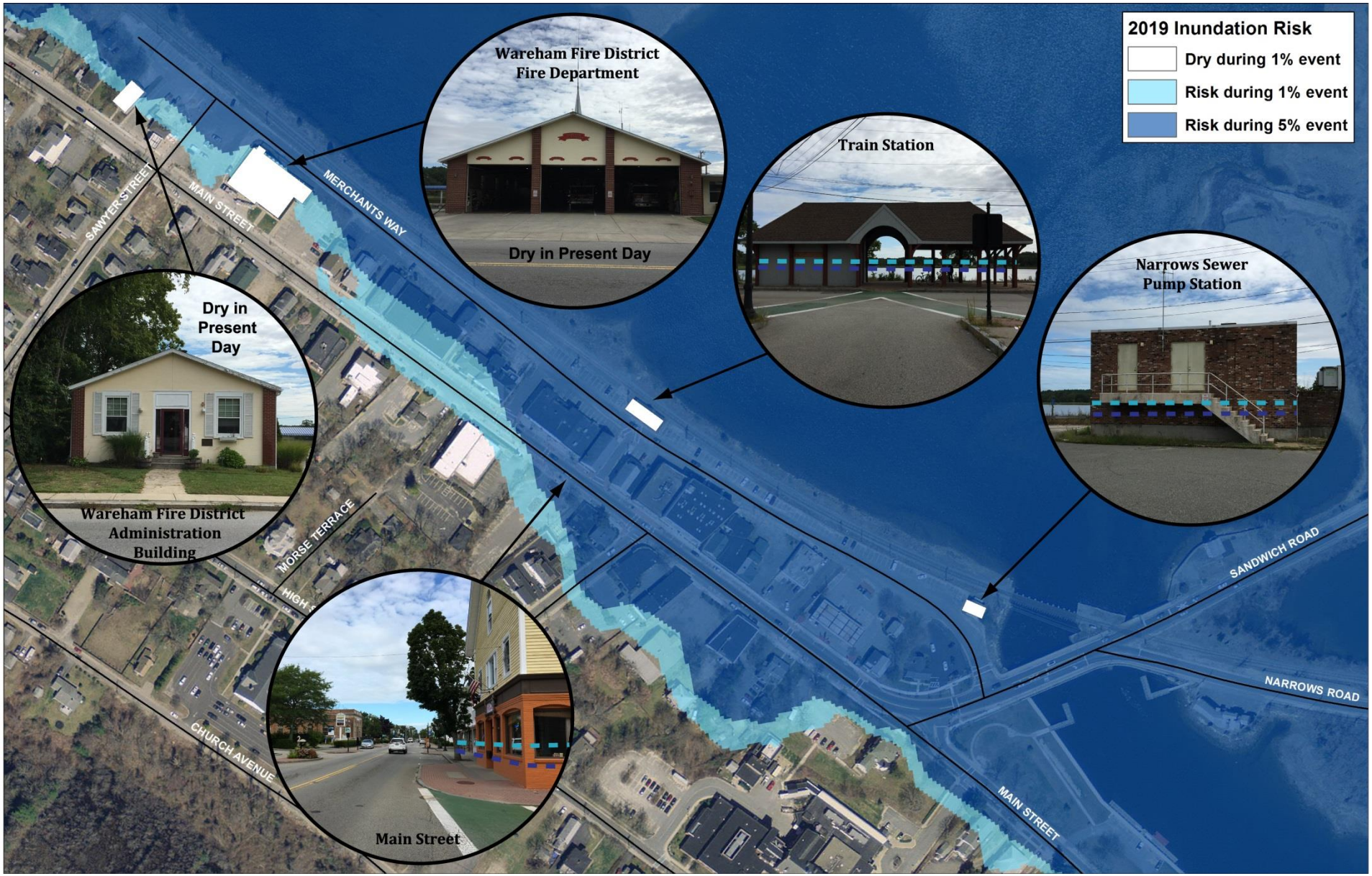
2030 100-year flood depth = 7.5 feet (elevation = 13.4 feet NAVD88)

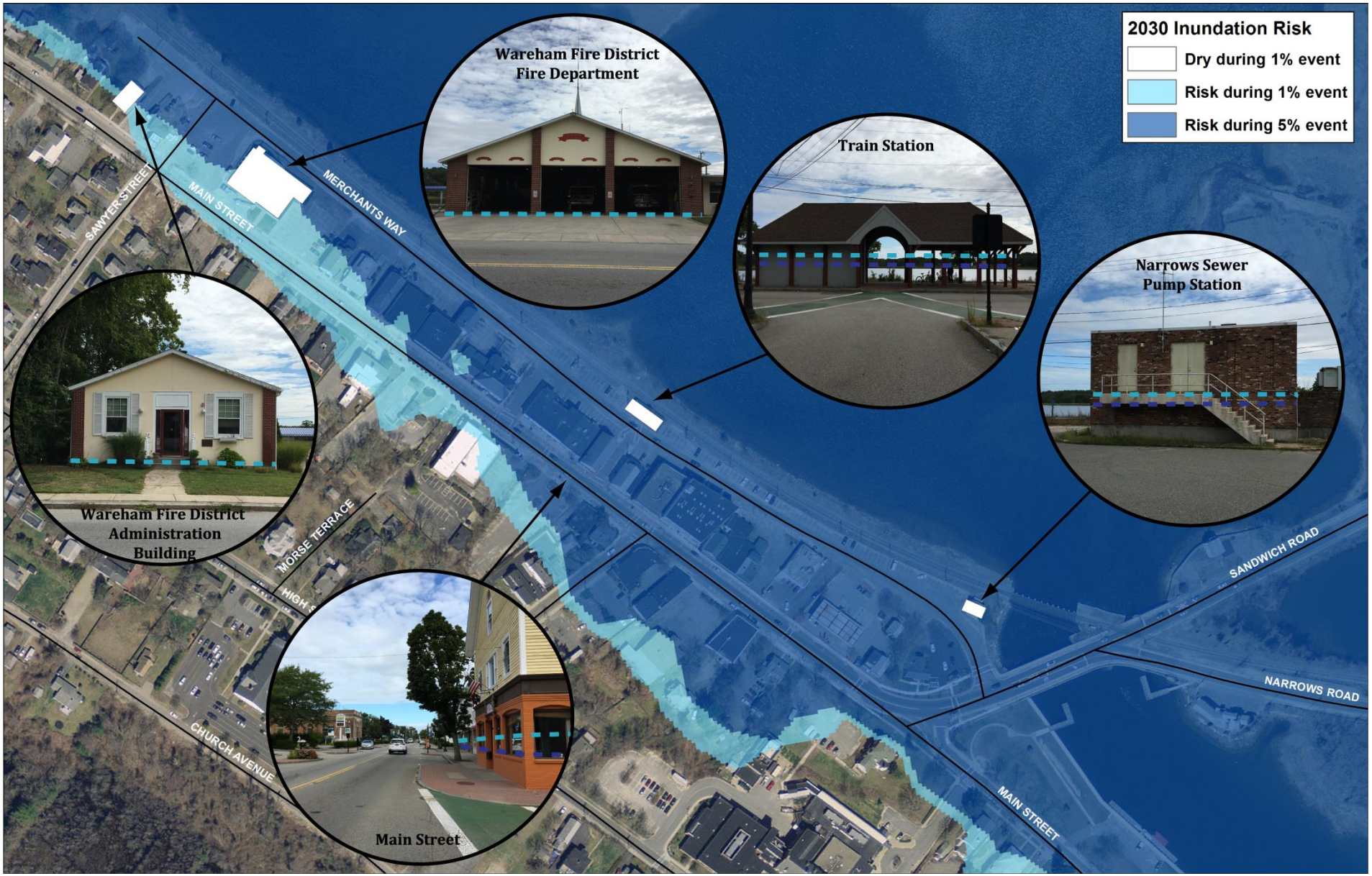
Present day 100-year flood depth = 6.0 feet (elevation = 11.7 feet NAVD88)


Present Day 100-year event


2030 100-year event


2070 100-year event


2019 Inundation Risk
Dry during 1% event
Risk during 1% event
Risk during 5% event
Wareham Fire District Fire Department
Dry in Present Day
Train Station
Narrows Sewer Pump Station
Dry in Present Day
Wareham Fire District Administration Building
Main Street
SAWYER STREET
MAIN STREET
MERCHANTS WAY
MORSE TERRACE
CHURCH AVENUE
SANDWICH ROAD
NARROWS ROAD
MAIN STREET


2030 Inundation Risk
Dry during 1% event
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Wareham Fire District Fire Department
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Wareham Fire District Administration Building
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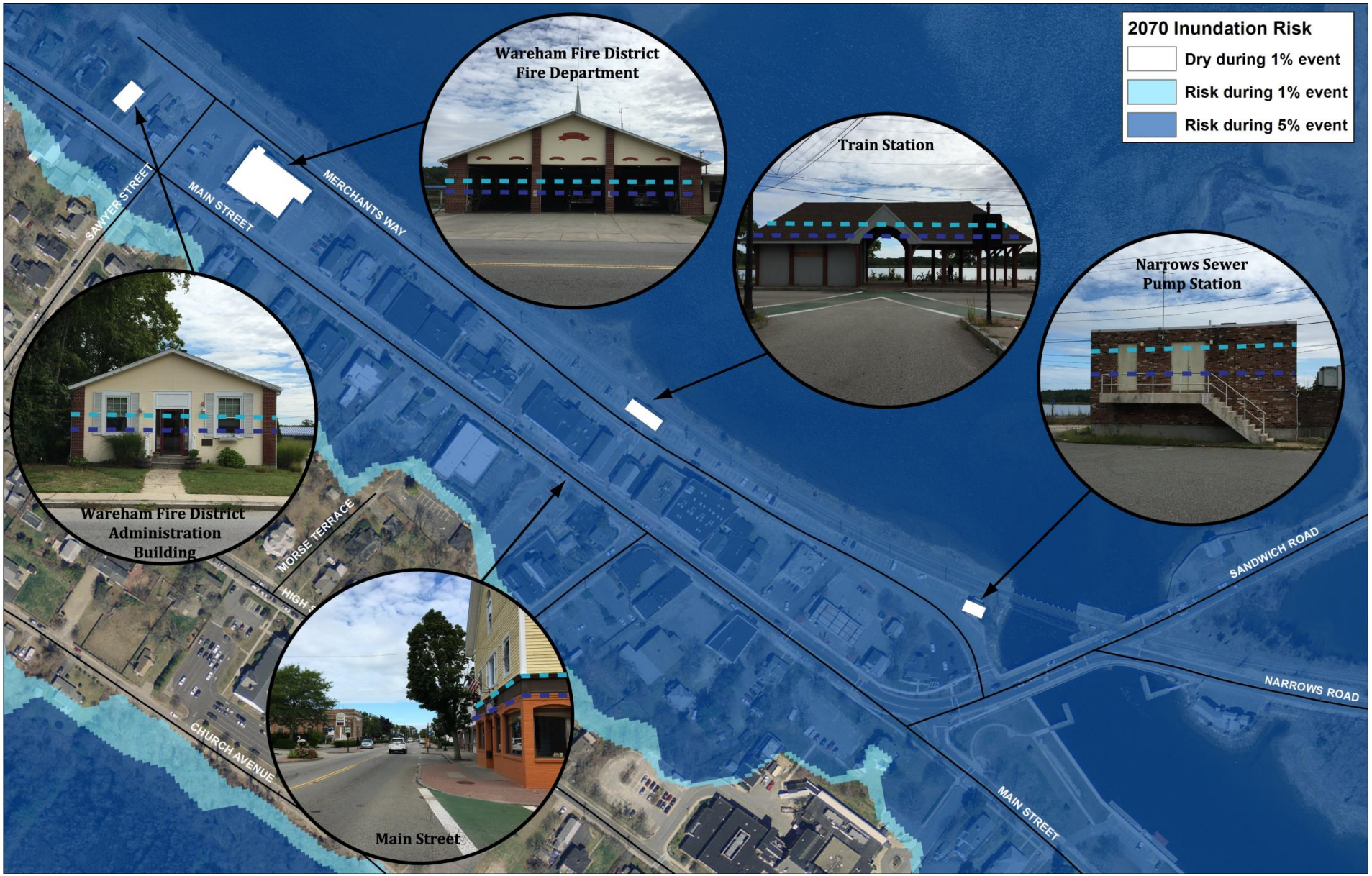
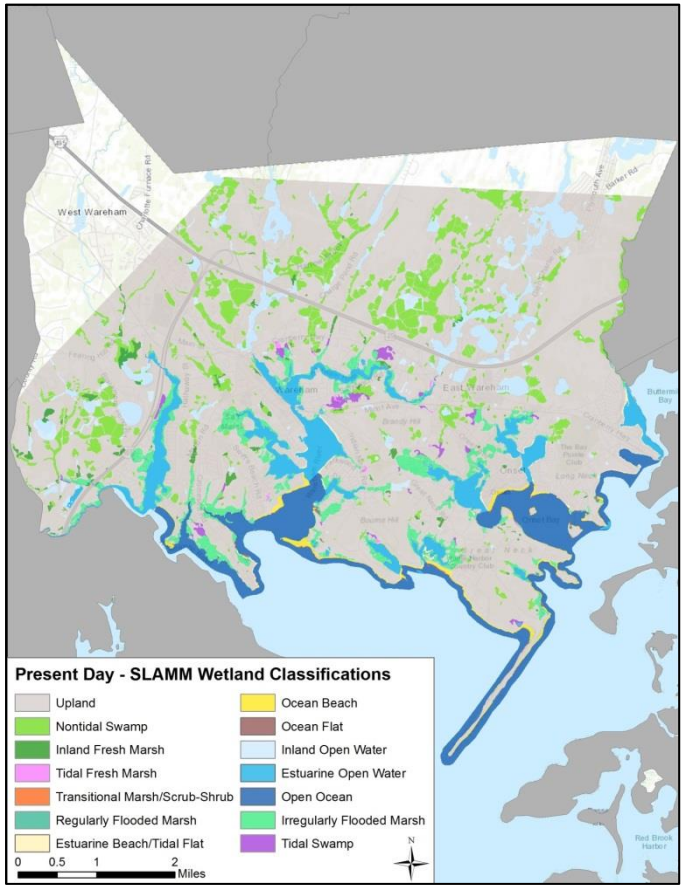
SAWYER STREET
MAIN STREET
MERCHANTS WAY
MORSE TERRACE
CHURCH AVENUE
SANDWICH ROAD
NARROWS ROAD
MAIN STREET

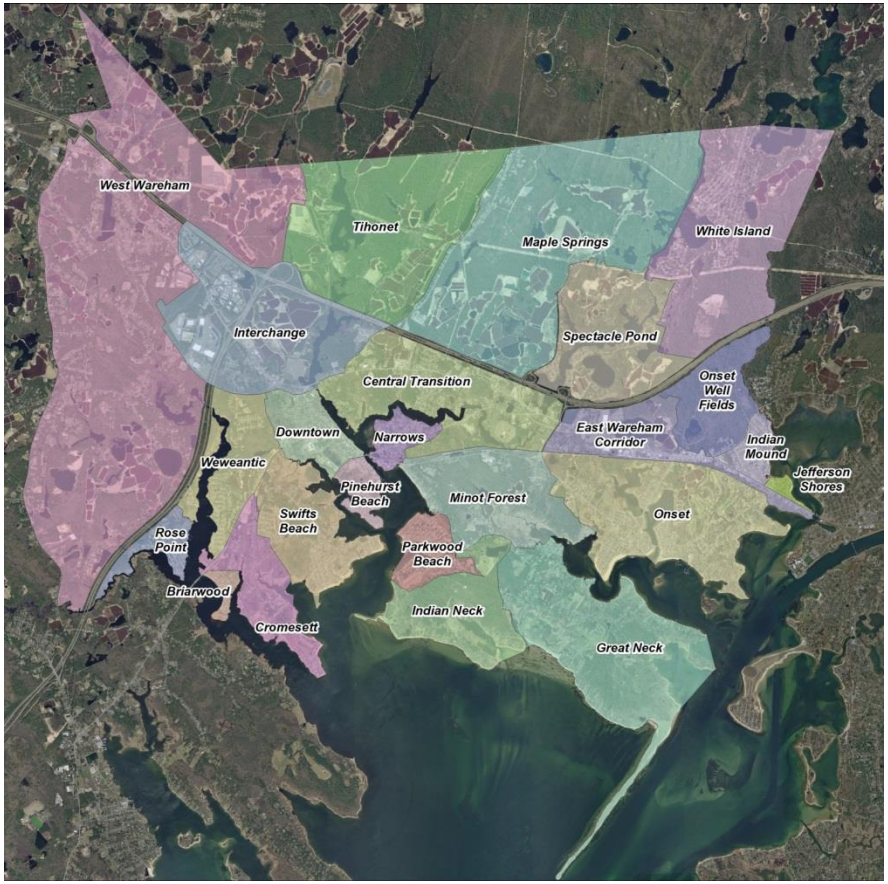

2070 Inundation Risk
Dry during 1% event
Risk during 1% event
Risk during 5% event
Wareham Fire District Fire Department
Train Station
Narrows Sewer Pump Station
Wareham Fire District Administration Building
Main Street
SAWYER STREET
MAIN STREET
MERCHANTS WAY
MORSE TERRACE
CHURCH AVENUE
SANDWICH ROAD
NARROWS ROAD
MAIN STREET

Other Vulnerability Assessment Evaluations

- Assessment of Impacts to Natural Resources: SLAMM Results

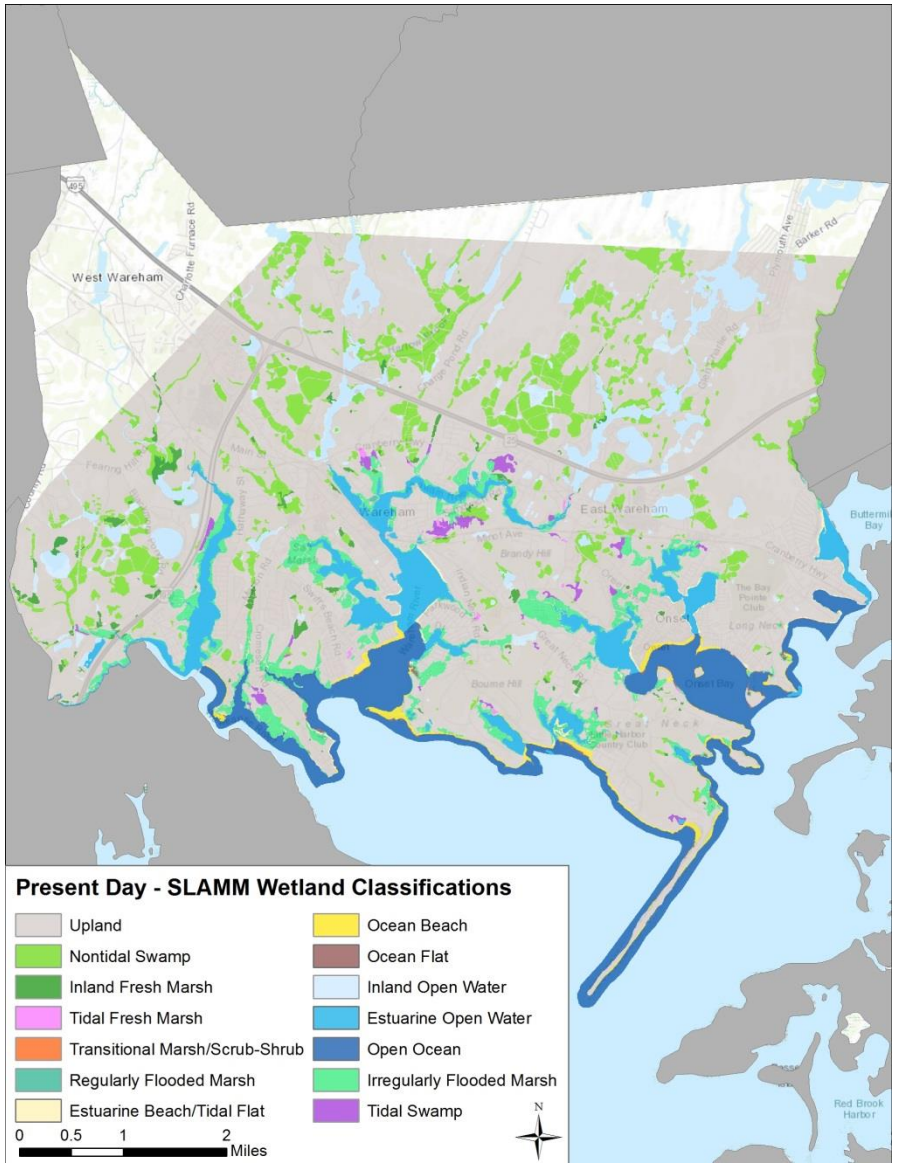


- Neighborhood Level Vulnerability Assessment



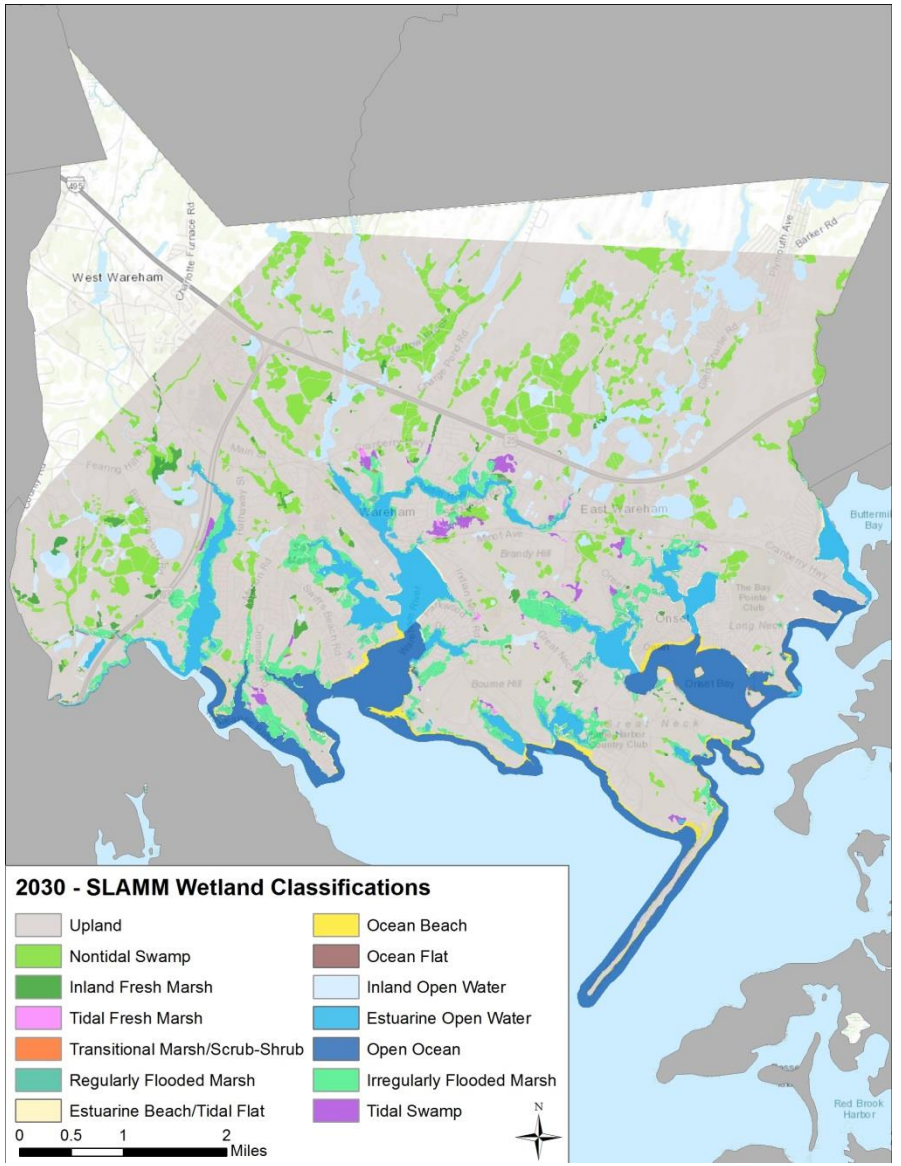
Assessment of Impacts to Natural Resources

SLAMM Results – Present Day



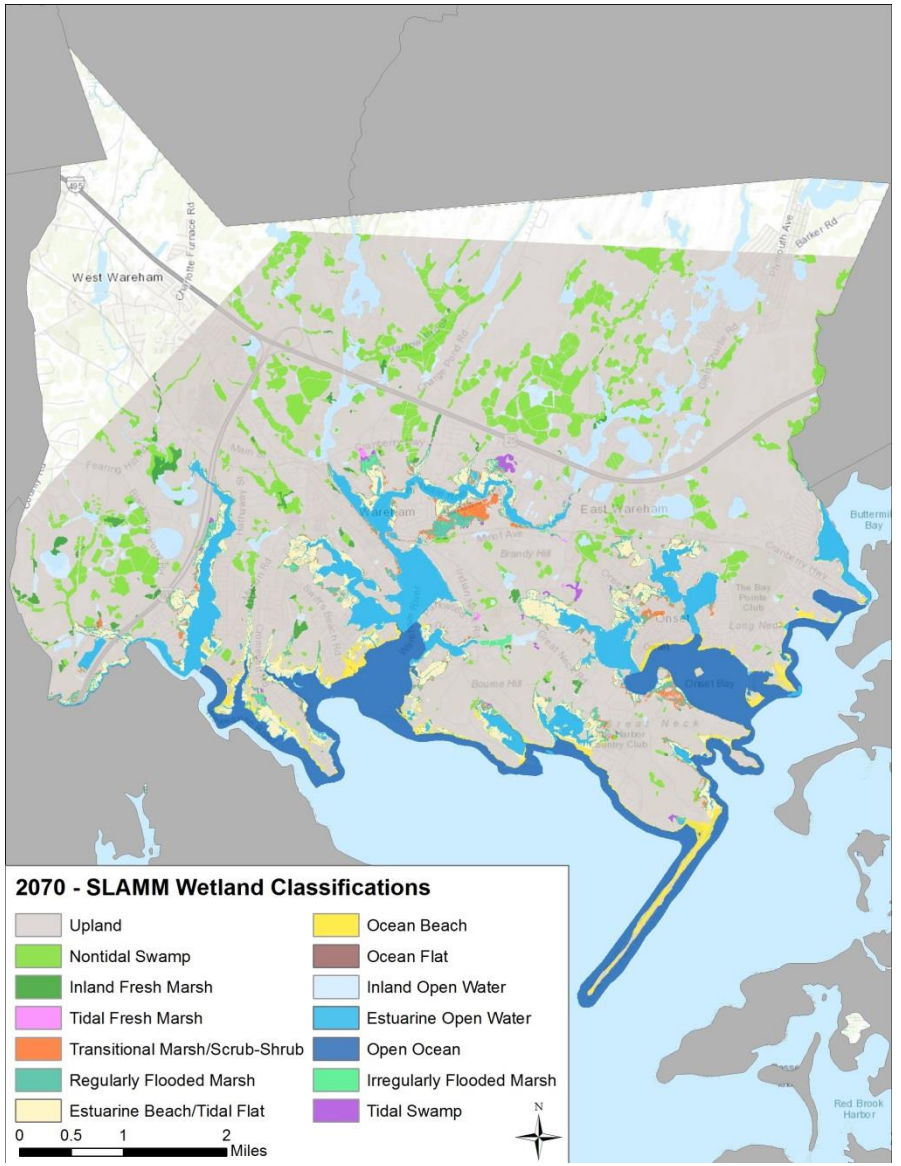
Assessment of Impacts to Natural Resources

SLAMM Results – 2030



Assessment of Impacts to Natural Resources

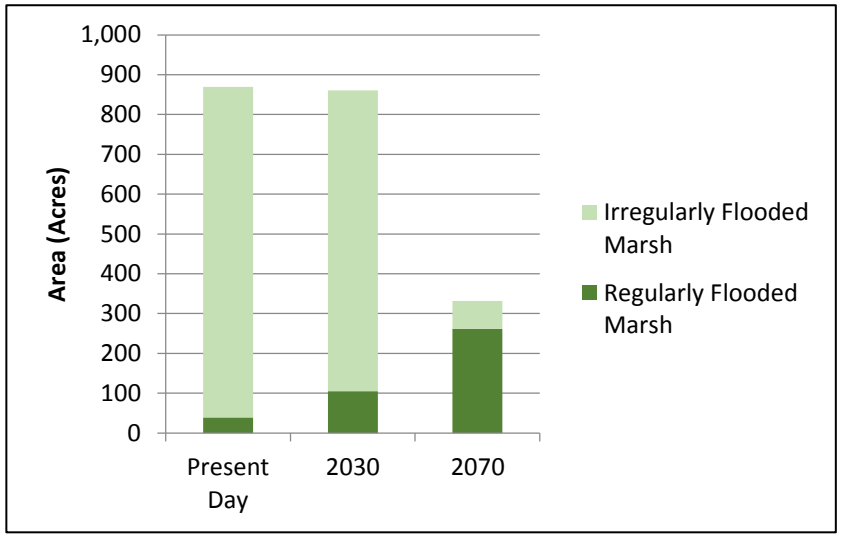
SLAMM Results – 2070

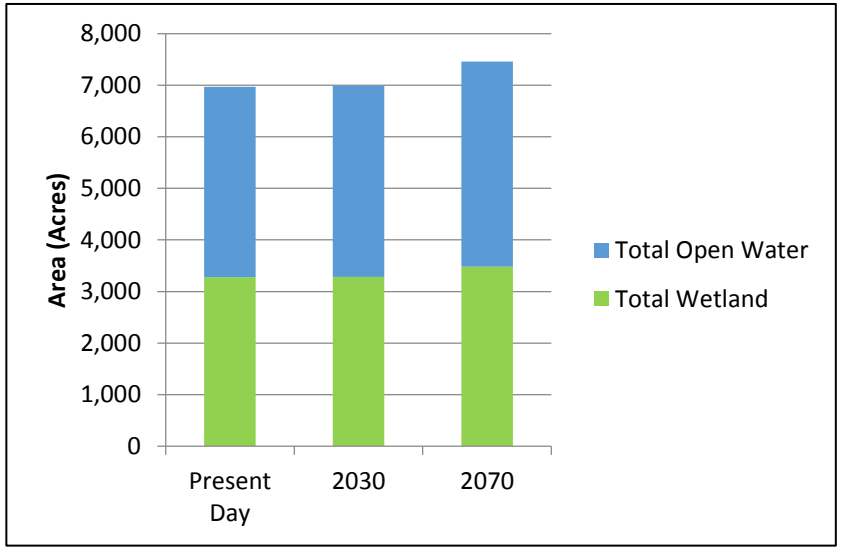


Assessment of Impacts to Natural Resources

SLAMM Results – Townwide Changes

	Area (acres)		
	Present Day	2030	2070
Upland	14,907.2	14,887.8	14,412.0
Nontidal Swamp	1,815.4	1,815.1	1,785.1
Inland Fresh Marsh	170.8	168.2	148.5
Tidal Fresh Marsh	15.8	14.2	6.9
Transitional Marsh/Scrub-Shrub	-	7.4	149.8
Regularly Flooded Marsh	39.1	104.8	261.5
Estuarine Beach/Tidal Flat	101.2	138.3	756.7
Ocean Beach	158.2	151.3	263.1
Ocean Flat	40.4	21.3	1.9
Inland Open Water	1,117.7	1,117.0	1,109.2
Estuarine Open Water	1,106.2	1,090.7	1,288.5
Open Ocean	1,461.0	1,494.1	1,581.3
Irregularly Flooded Marsh	830.3	755.7	70.4
Tidal Swamp	108.6	105.9	36.7





Assessment of Impacts to Natural Resources

SLAMM Results – Site-specific Changes

All public beaches:

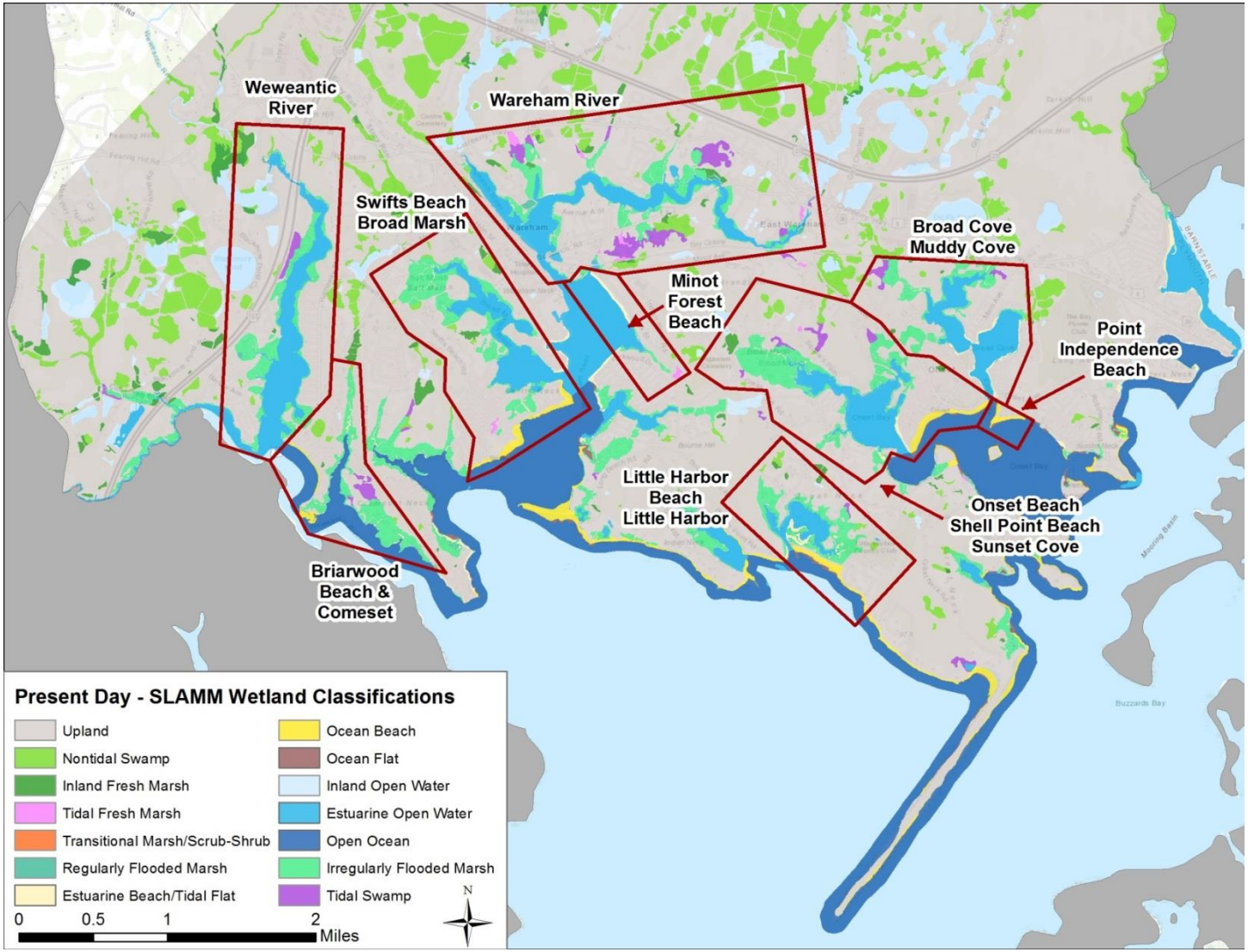
- Briarwood Beach
- Little Harbor Beach
- Minot Forest Beach
- Onset Beach
- Point Independence Beach
- Shell Point Beach
- Swifts Beach

Other major coastal wetlands:

- Broad Cove
- Broad Marsh
- Cromesett
- Little Harbor
- Muddy Cove
- Sunset Cove
- Wareham River
- Weweantic River

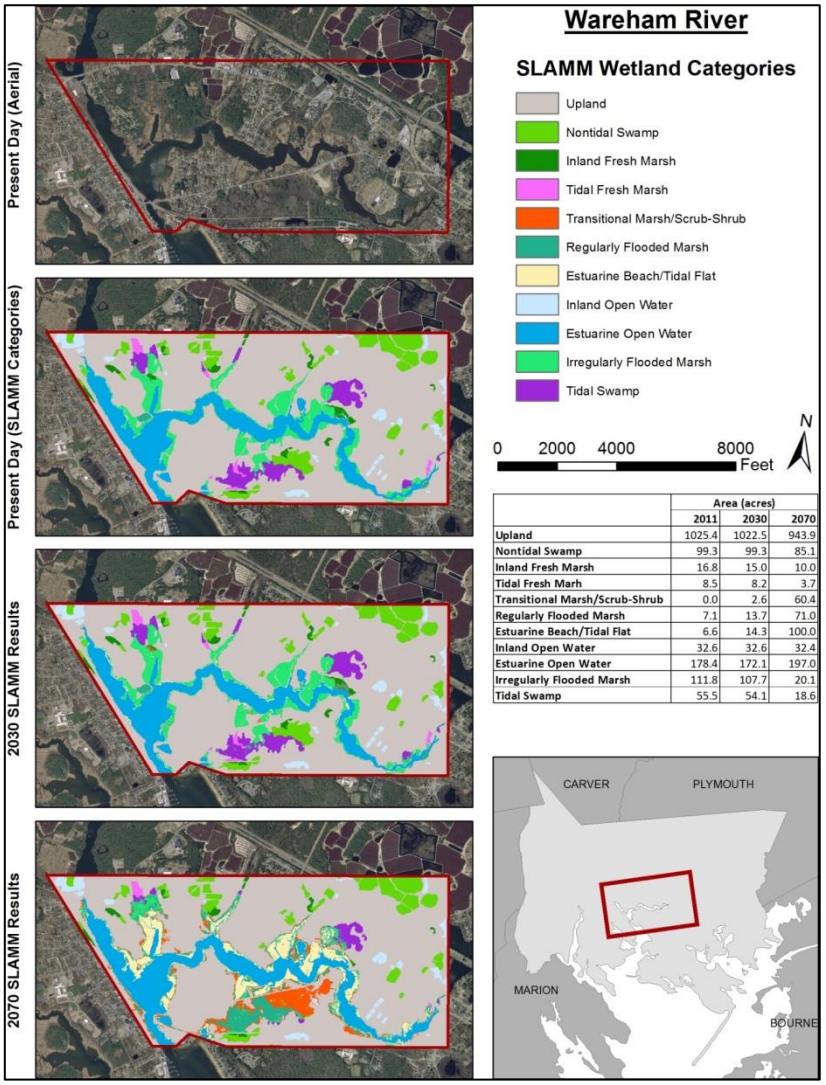
Assessment of Impacts to Natural Resources

Natural Resources Evaluation Areas

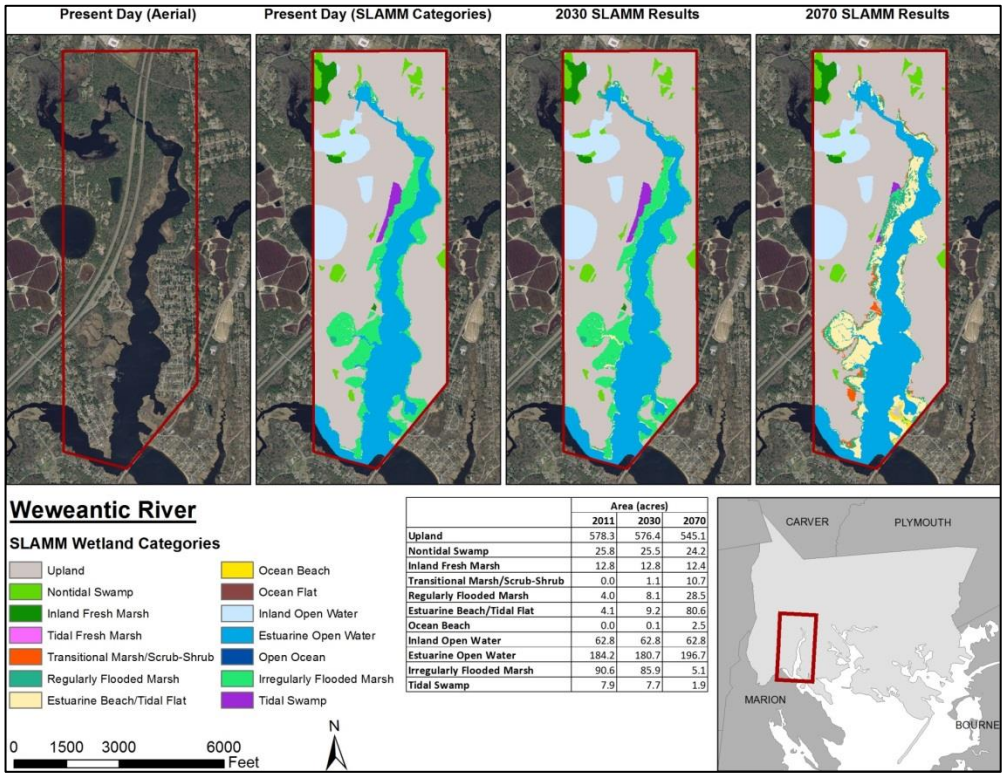


Assessment of Impact to Natural Resources

SLAMM Results – Site-specific Changes



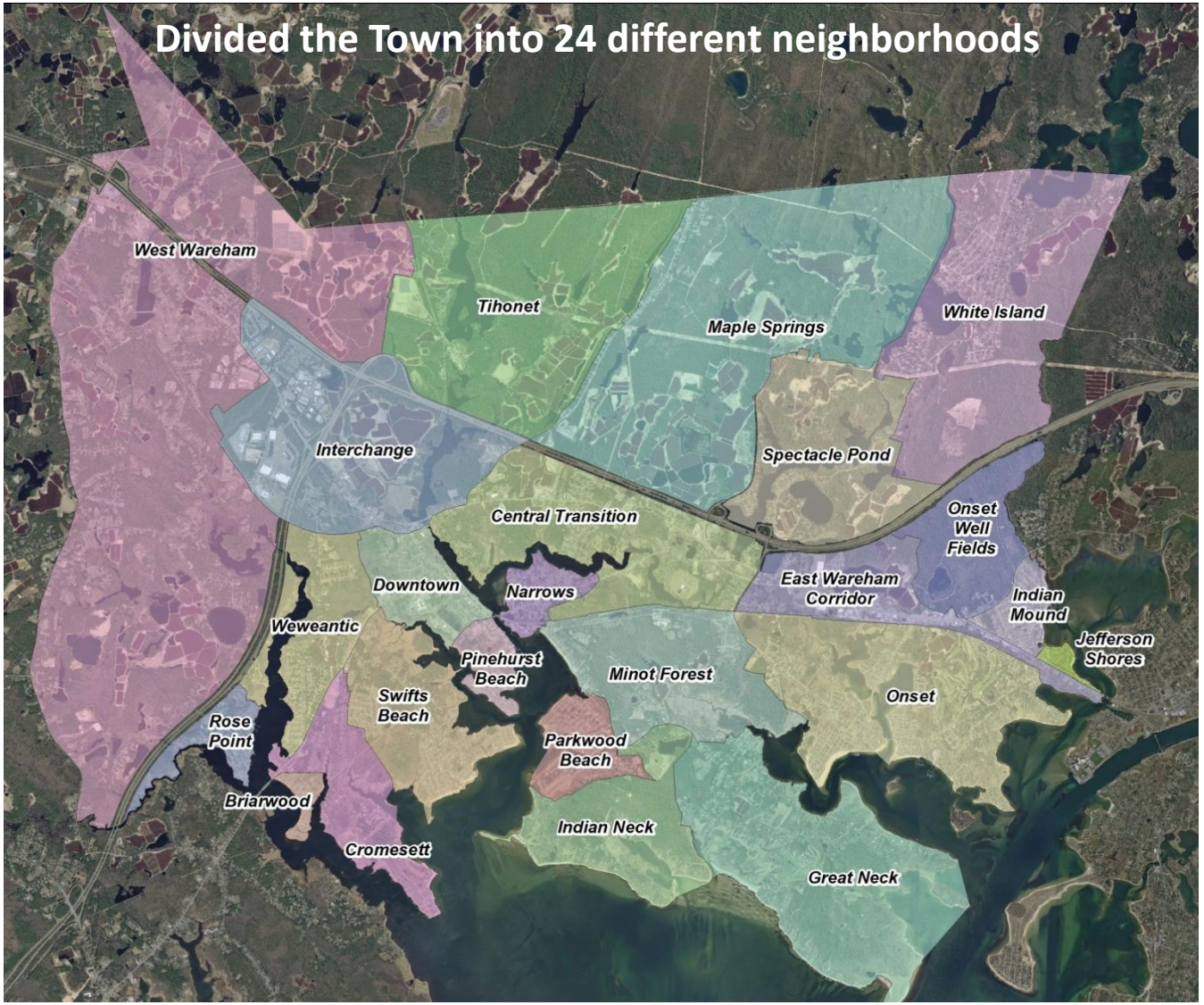
	Area (acres)		
	2011	2030	2070
Upland	1025.4	1022.5	943.9
Nontidal Swamp	99.3	99.3	85.1
Inland Fresh Marsh	16.8	15.0	10.0
Tidal Fresh Marh	8.5	8.2	3.7
Transitional Marsh/Scrub-Shrub	0.0	2.6	60.4
Regularly Flooded Marsh	7.1	13.7	71.0
Estuarine Beach/Tidal Flat	6.6	14.3	100.0
Inland Open Water	32.6	32.6	32.4
Estuarine Open Water	178.4	172.1	197.0
Irregularly Flooded Marsh	111.8	107.7	20.1
Tidal Swamp	55.5	54.1	18.6



	Area (acres)		
	2011	2030	2070
Upland	578.3	576.4	545.1
Nontidal Swamp	25.8	25.5	24.2
Inland Fresh Marsh	12.8	12.8	12.4
Transitional Marsh/Scrub-Shrub	0.0	1.1	10.7
Regularly Flooded Marsh	4.0	8.1	28.5
Estuarine Beach/Tidal Flat	4.1	9.2	80.6
Ocean Beach	0.0	0.1	2.5
Inland Open Water	62.8	62.8	62.8
Estuarine Open Water	184.2	180.7	196.7
Irregularly Flooded Marsh	90.6	85.9	5.1
Tidal Swamp	7.9	7.7	1.9

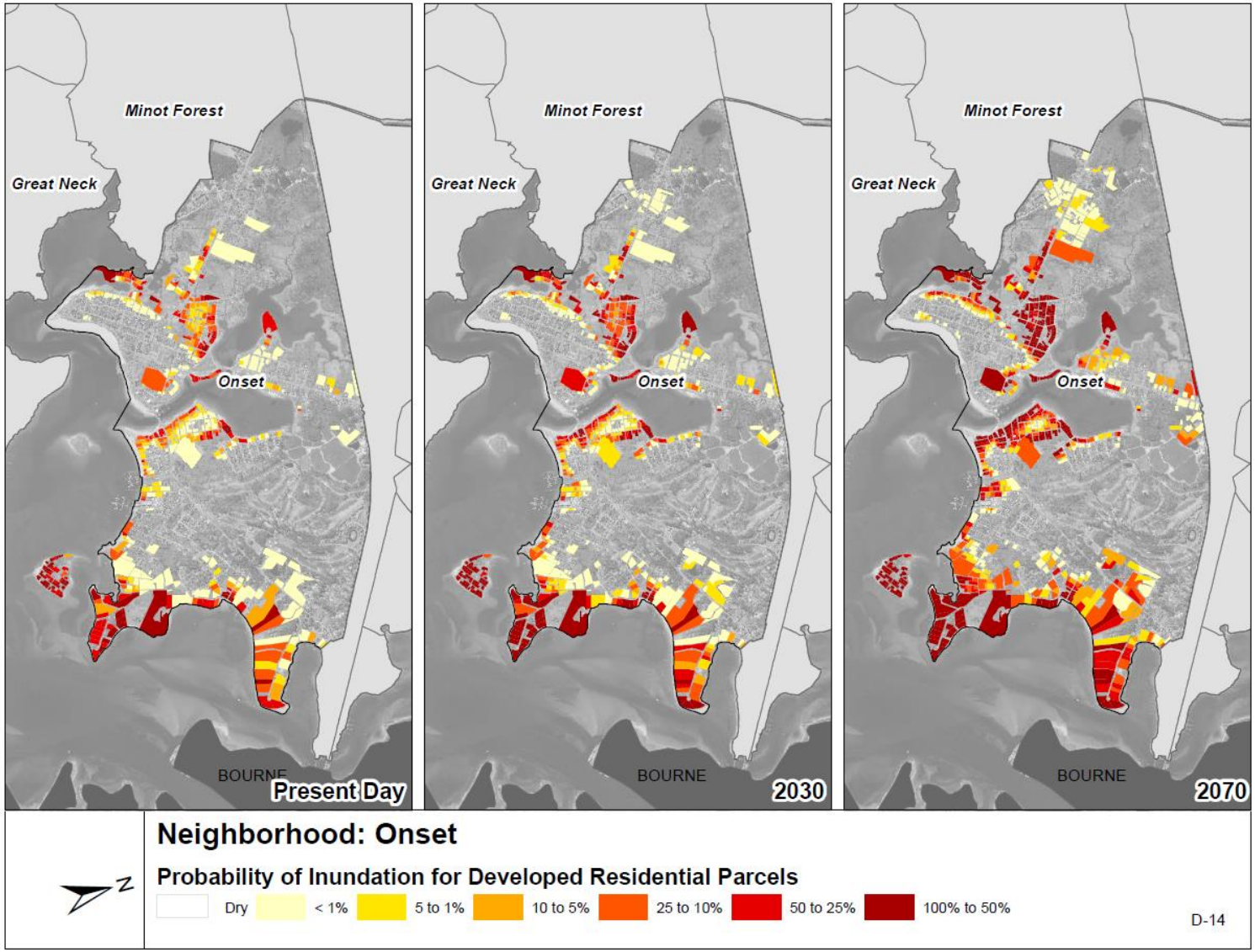
Neighborhood Level Vulnerability Assessment

Neighborhood Evaluation Areas



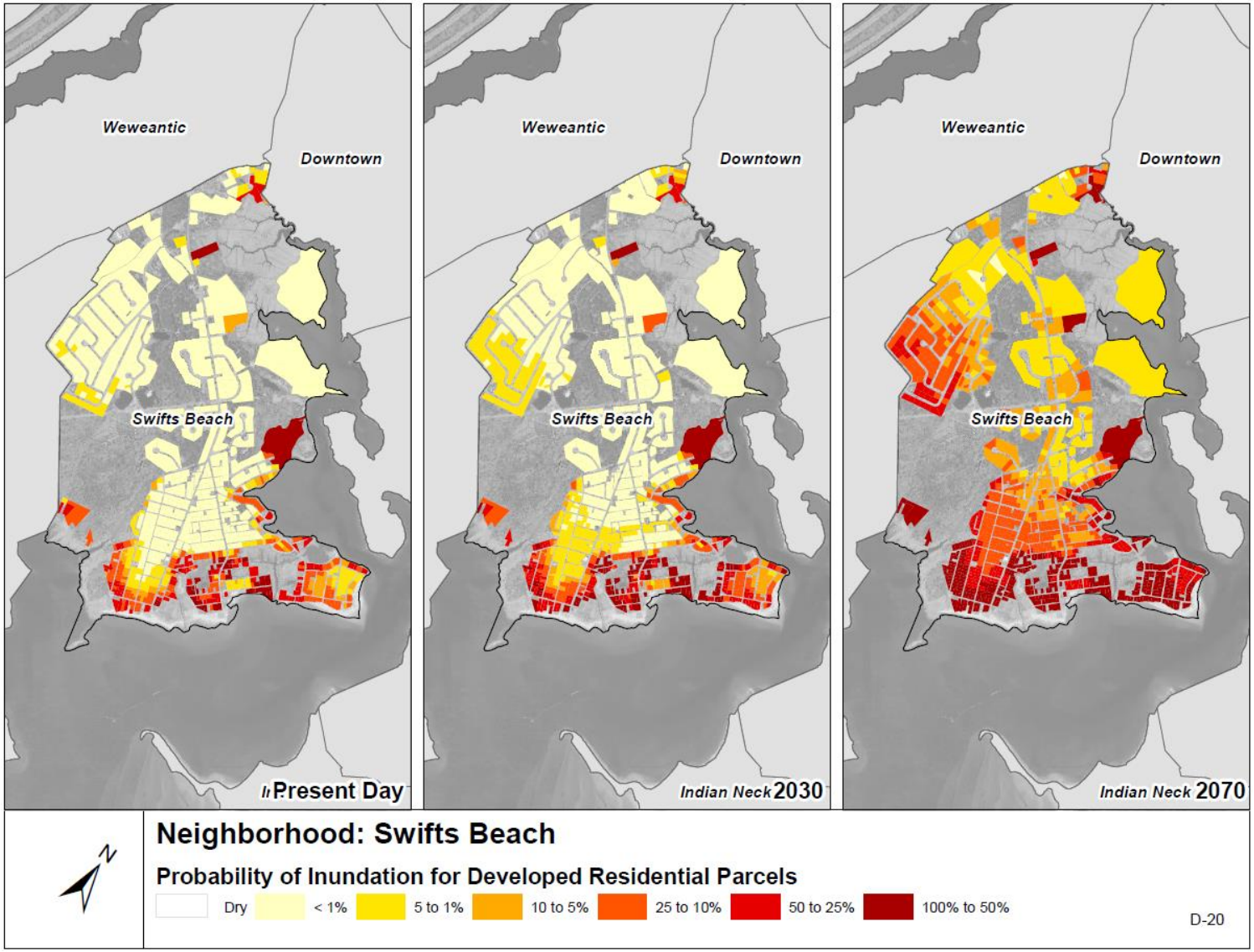
Neighborhood Level Vulnerability Assessment

Neighborhood Evaluation Areas



Neighborhood Level Vulnerability Assessment

Neighborhood Evaluation Areas



Neighborhood Level Vulnerability Assessment

Neighborhood Evaluation Areas

2030 Risk

Neighborhood Name	Total Parcels in Neighborhood	Number and Percent of Developed Residential Parcels Within Each Neighborhood at Risk of Inundation – 2030													
		100 to 50% Inundation Risk		50 to 25% Inundation Risk		25 to 10% Inundation Risk		10 to 5% Inundation Risk		5 to 1% Inundation Risk		< 1% Inundation Risk		Dry	
		#	%	#	%	#	%	#	%	#	%	#	%	#	%
Briarwood	134	47	35%	45	34%	26	19%	9	7%	7	5%	0	0%	0	0%
Central Transition	554	13	2%	67	12%	14	3%	9	2%	23	4%	32	6%	396	71%
Cromesett	285	12	4%	29	10%	32	11%	28	10%	76	27%	61	21%	47	16%
Downtown	296	1	0%	0	0%	2	1%	1	0%	18	6%	10	3%	264	89%
East Wareham Corridor	104	0	0%	2	2%	4	4%	3	3%	7	7%	12	12%	76	73%
Great Neck	482	36	7%	42	9%	55	11%	14	3%	51	11%	57	12%	227	47%
Indian Neck	68	8	12%	3	4%	4	6%	3	4%	11	16%	7	10%	32	47%
Indian Mound	479	0	0%	2	0%	4	1%	3	1%	5	1%	9	2%	456	95%
Interchange	112	0	0%	0	0%	0	0%	0	0%	0	0%	3	3%	109	97%
Jefferson Shores	71	2	3%	4	6%	4	6%	0	0%	12	17%	7	10%	42	59%
Maple Springs	118	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	118	100%
Minot Forest	275	4	1%	13	5%	14	5%	13	5%	19	7%	28	10%	184	67%
Narrows	161	5	3%	8	5%	9	6%	13	8%	12	7%	26	16%	88	55%
Onset	2042	160	8%	122	6%	145	7%	77	4%	169	8%	184	9%	1185	58%
Onset Well Fields	17	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	17	100%
Parkwood Beach	436	11	3%	35	8%	40	9%	23	5%	49	11%	63	14%	215	49%
Pinehurst Beach	405	21	5%	56	14%	154	38%	23	6%	51	13%	34	8%	66	16%
Rose Point	220	23	10%	35	16%	36	16%	16	7%	16	7%	22	10%	72	33%
Spectacle Pond	323	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	323	100%
Swifts Beach	1287	94	7%	118	9%	121	9%	83	6%	273	21%	519	40%	79	6%
Tihonet	29	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	29	100%
West Wareham	1067	7	1%	1	0%	0	0%	2	0%	5	0%	15	1%	1037	97%
Weweantic	392	14	4%	9	2%	18	5%	14	4%	35	9%	88	22%	214	55%
White Island	1010	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1010	100%

Next Steps

- Develop short, mid and long-term adaptation strategies to address flooding impacts
- Recommended strategies may include (but are not limited to):
  - Infrastructure repairs and upgrades
  - Land acquisition and management
  - Changes to policies and regulations
- Final report, communication materials, and presentation

Questions?