

City of Gloucester Coastal Climate Change Vulnerability Assessment and Adaptation Plan

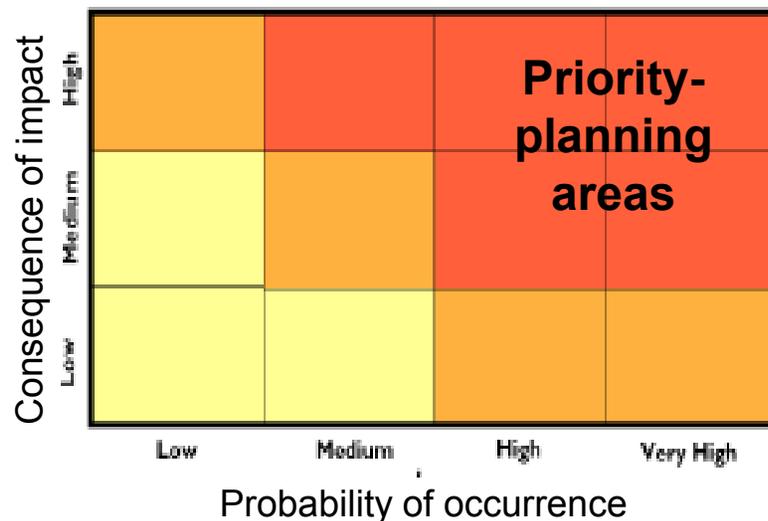
Public Meeting June 16, 2015



- Project Overview
- Methodology
- Review of Flood Modeling Results
- Municipally-Owned Infrastructure Subject to Flooding
- Infrastructure Adaptation Options

- **Develop appropriate sea level rise and storm surge scenarios**
- **Understand vulnerability of municipal infrastructure and natural resources to sea level rise and storm surge**
- **Develop potential short-, mid- and long-term adaptation strategies**

- **Produce high quality maps and graphics and GIS layers**
- **Undertake a public outreach and education program**
- **This project is not related to the recent FEMA flood mapping efforts or flood insurance rates**



Phase I

Sea Level Rise/Storm Surge Projections

Scenario Development

Phase II

Mapping Inundation Modeling Results

Vulnerability/Risk Assessment

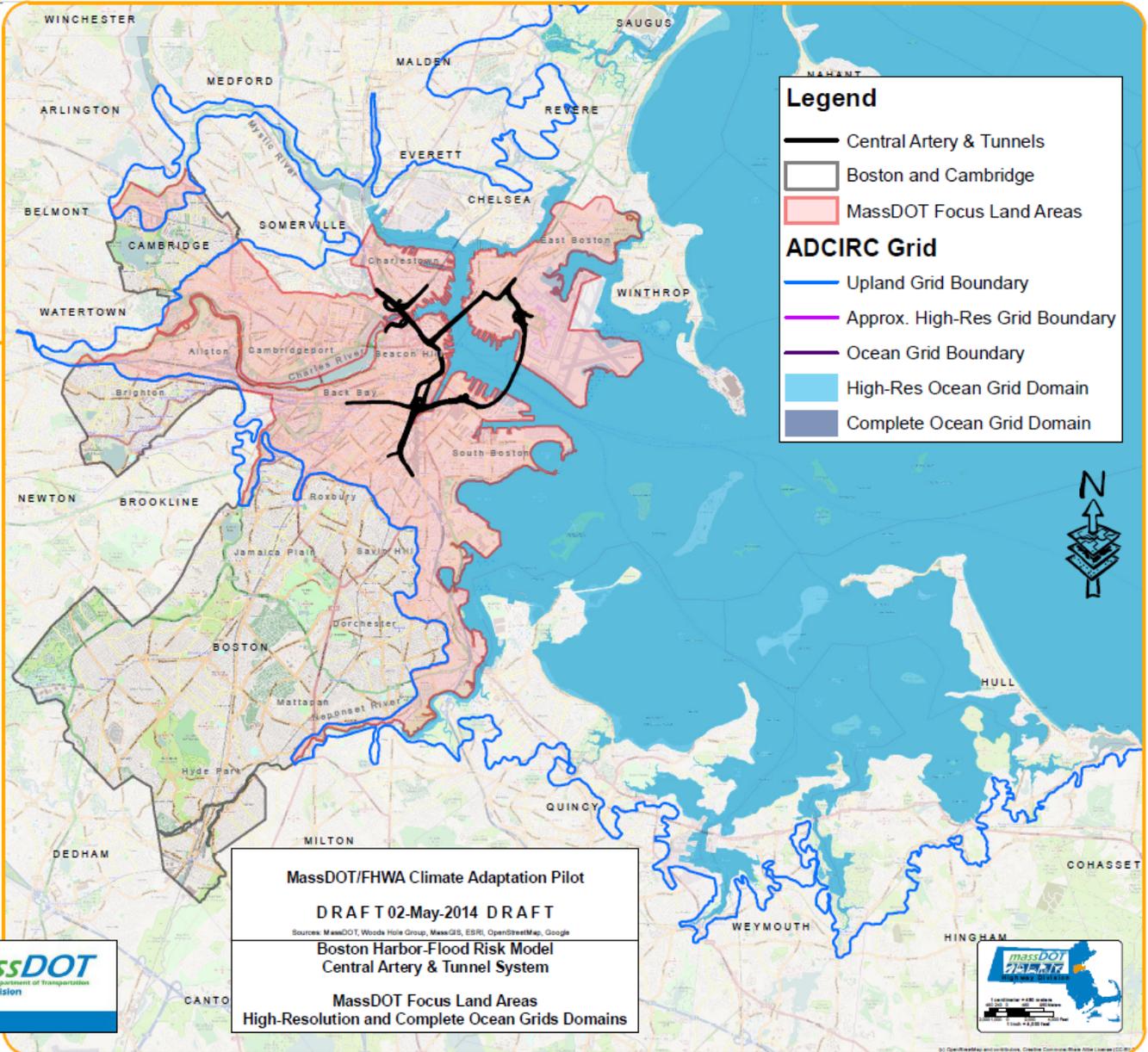
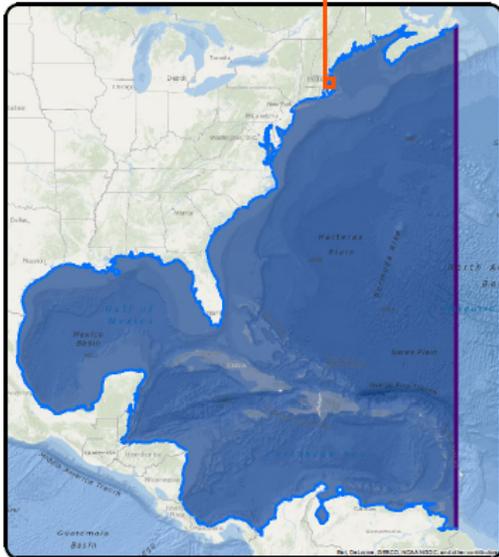
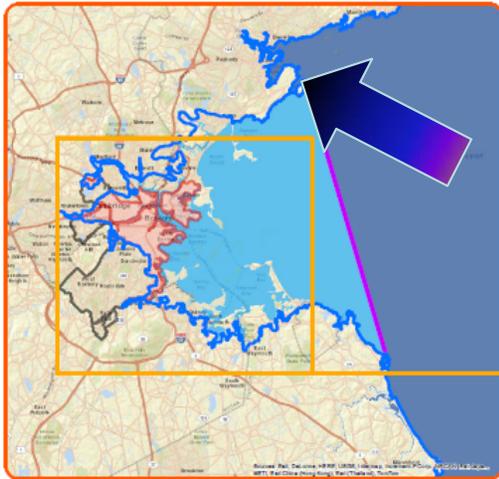
Phase III

Develop Adaptation Strategies

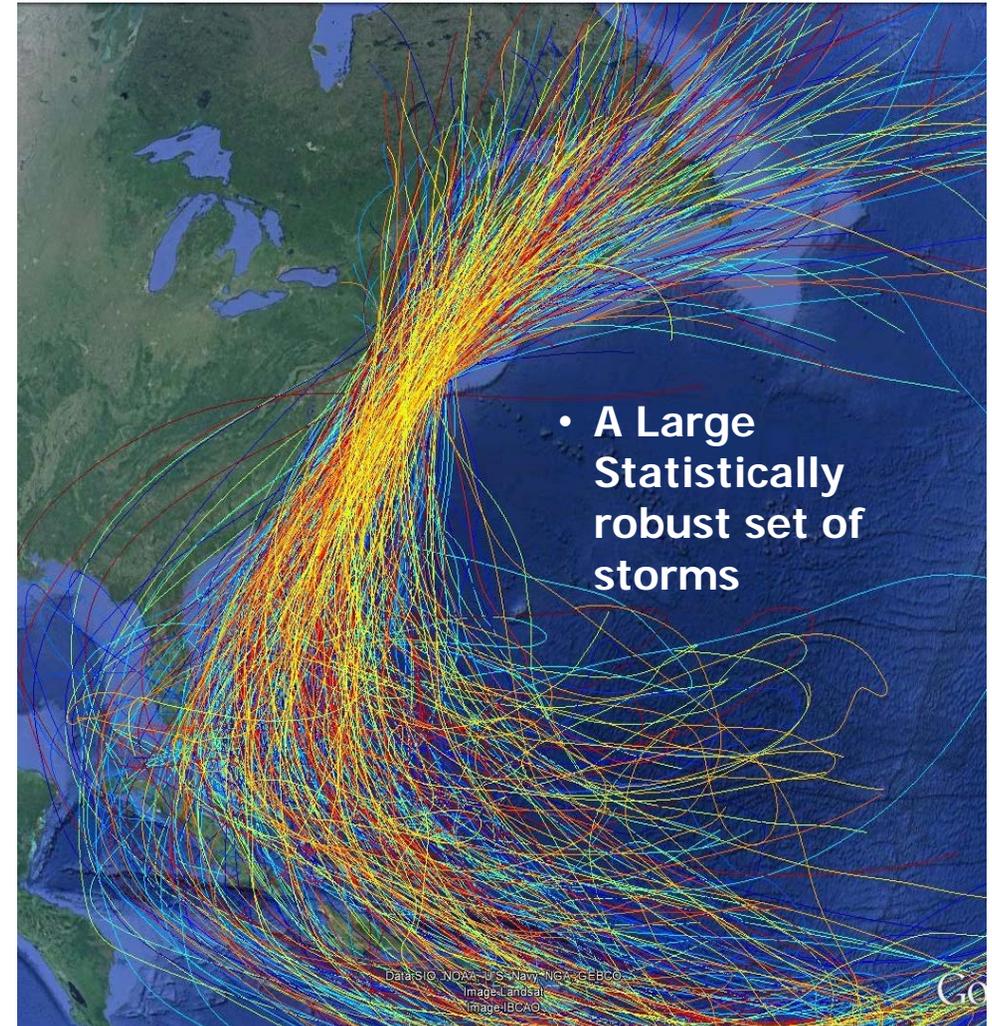
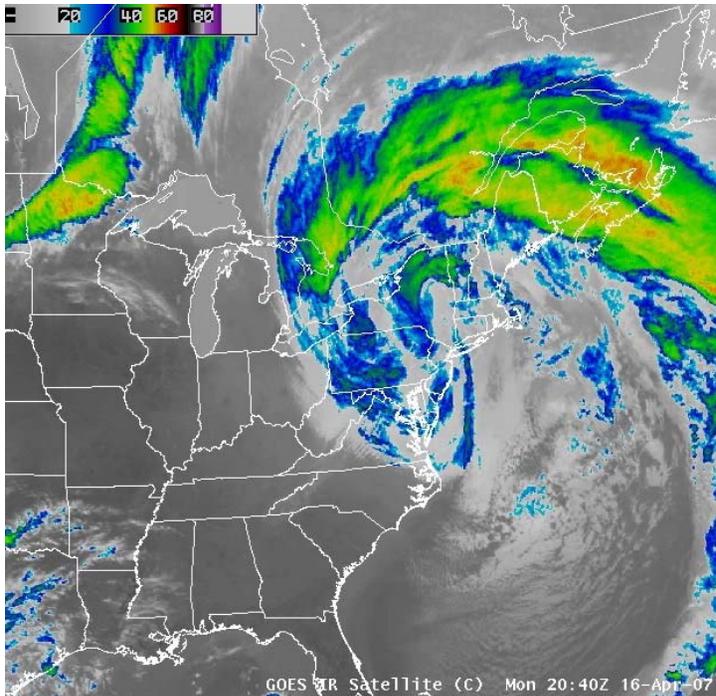
Public Outreach

- **2013 - Present**
- **2030 – 15 years out – Near term**
- **2070 – 55 years out – Long term**

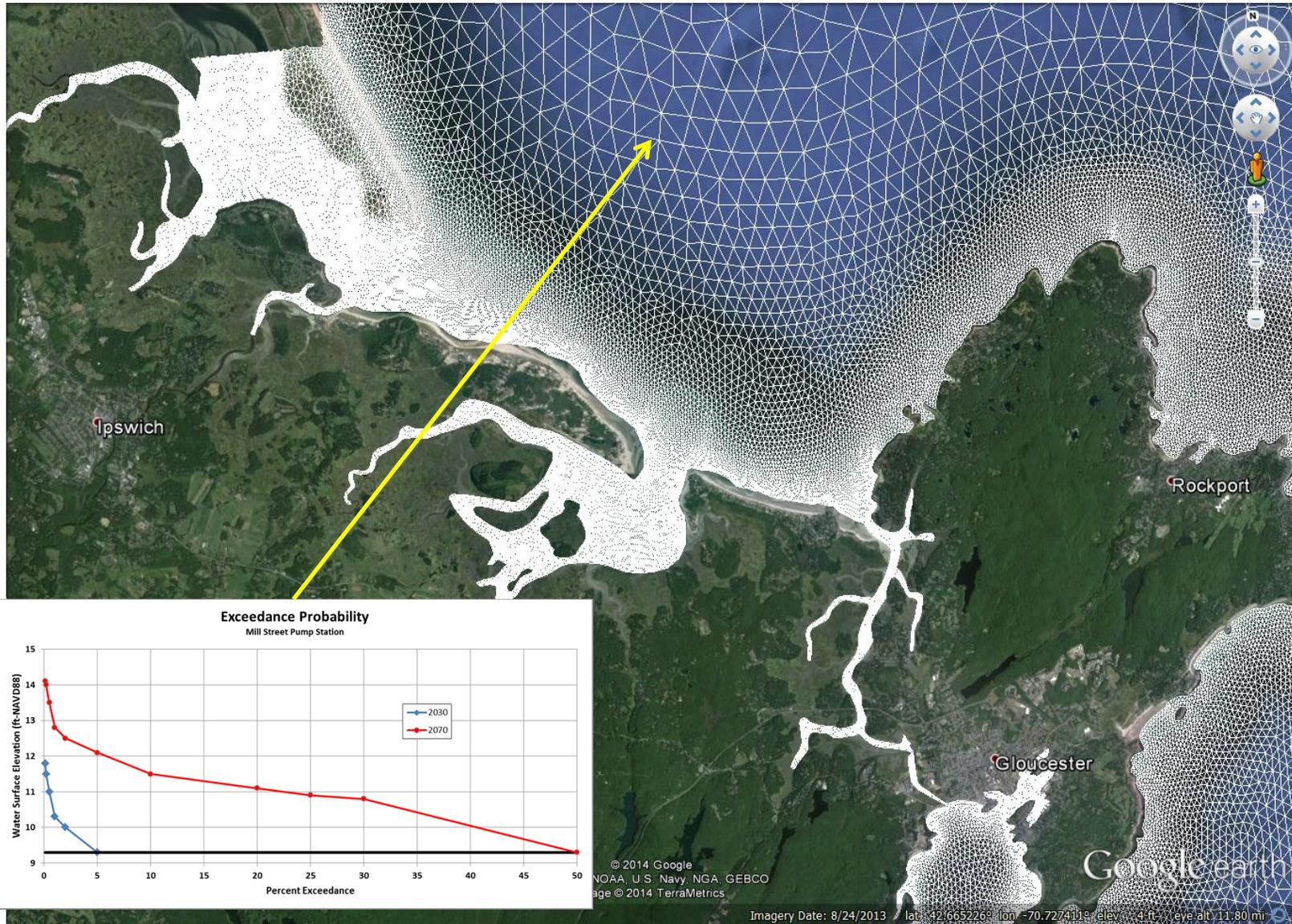
Hydrodynamic Water Surface Model



- Includes both tropical and extra-tropical storm sets



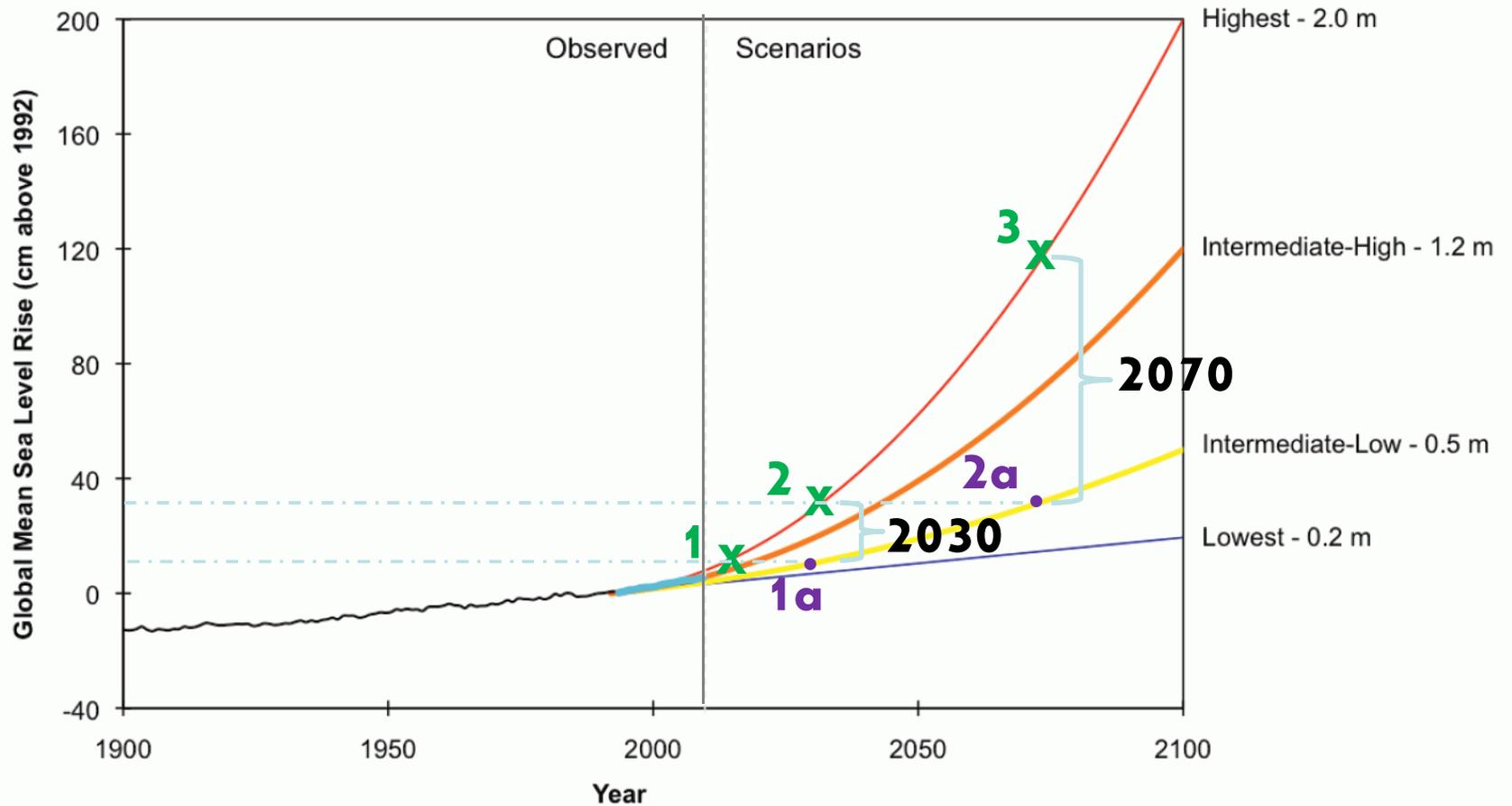
Gloucester ADCIRC Model Grid



A Probability-Based Model

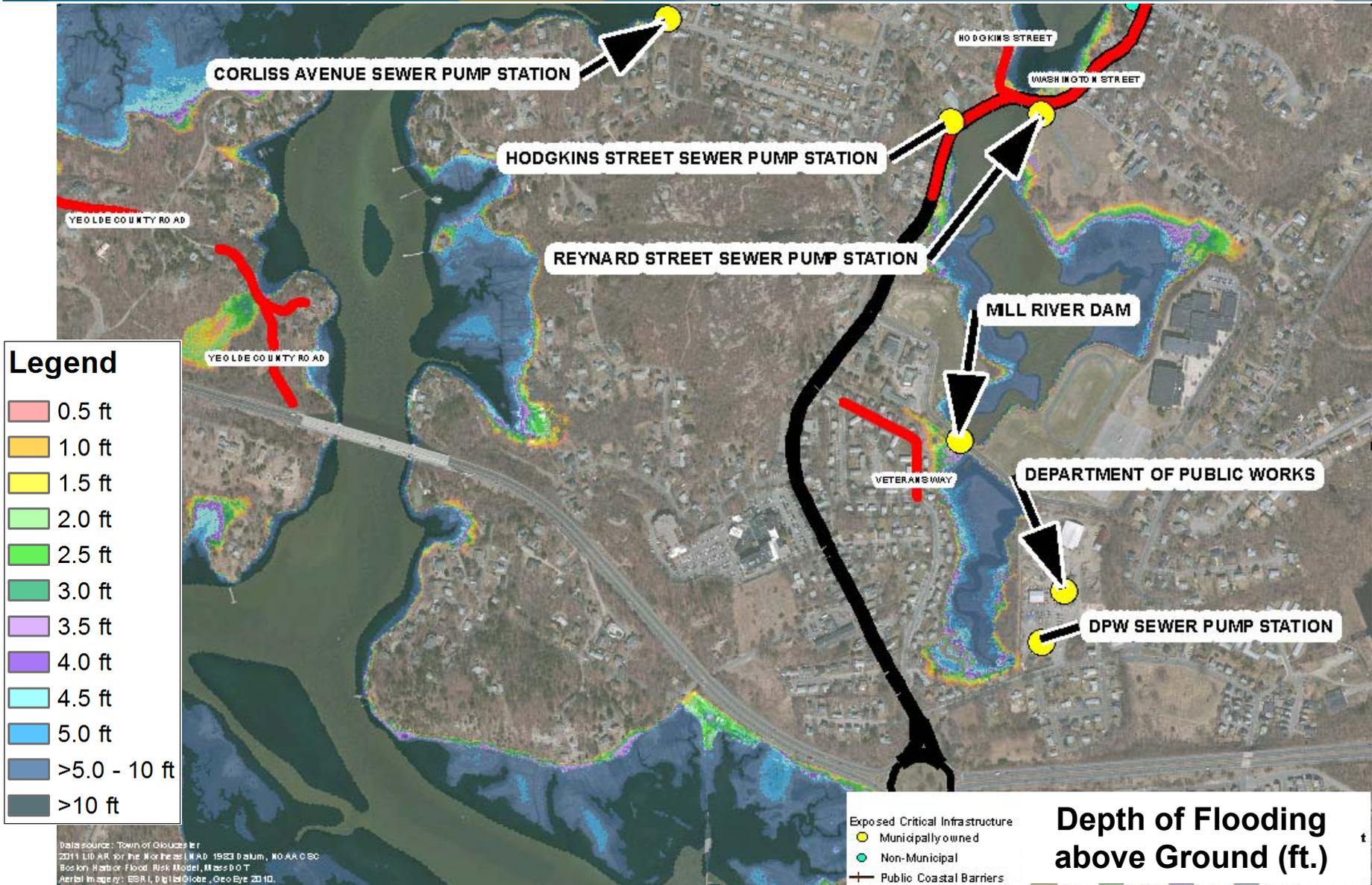
**Not “worst-case” scenarios
but
“worst-likely” scenarios**

NOAA Technical Report *Global Sea Level Rise Scenarios for the United States National Climate Assessment*, December 2012

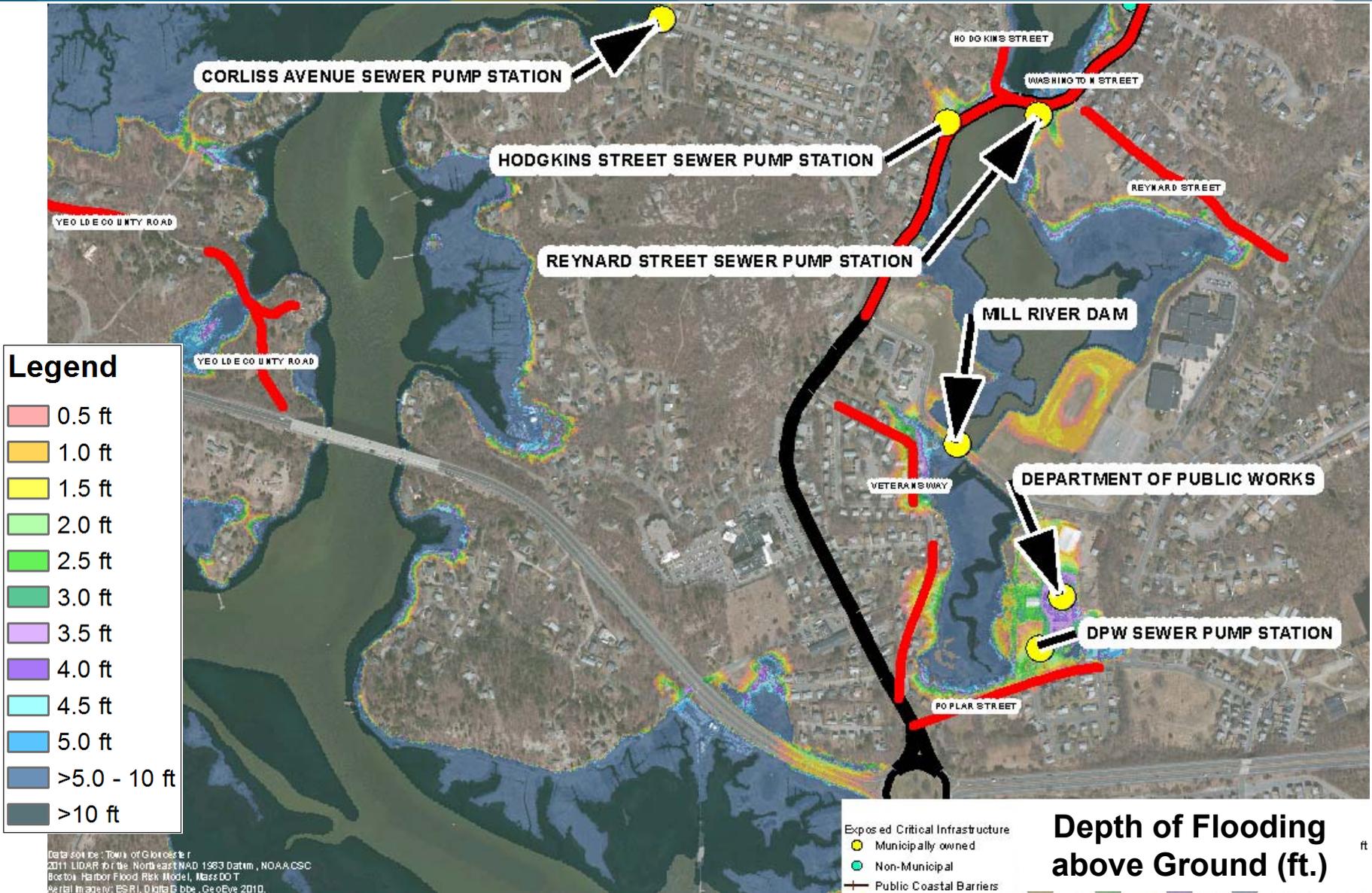


Impacts to Municipal Infrastructure due to Sea Level Rise and Storm Surge

Route 128 at Washington Street 2030: 1% Annual Probability (≈100 yr Recurrence)

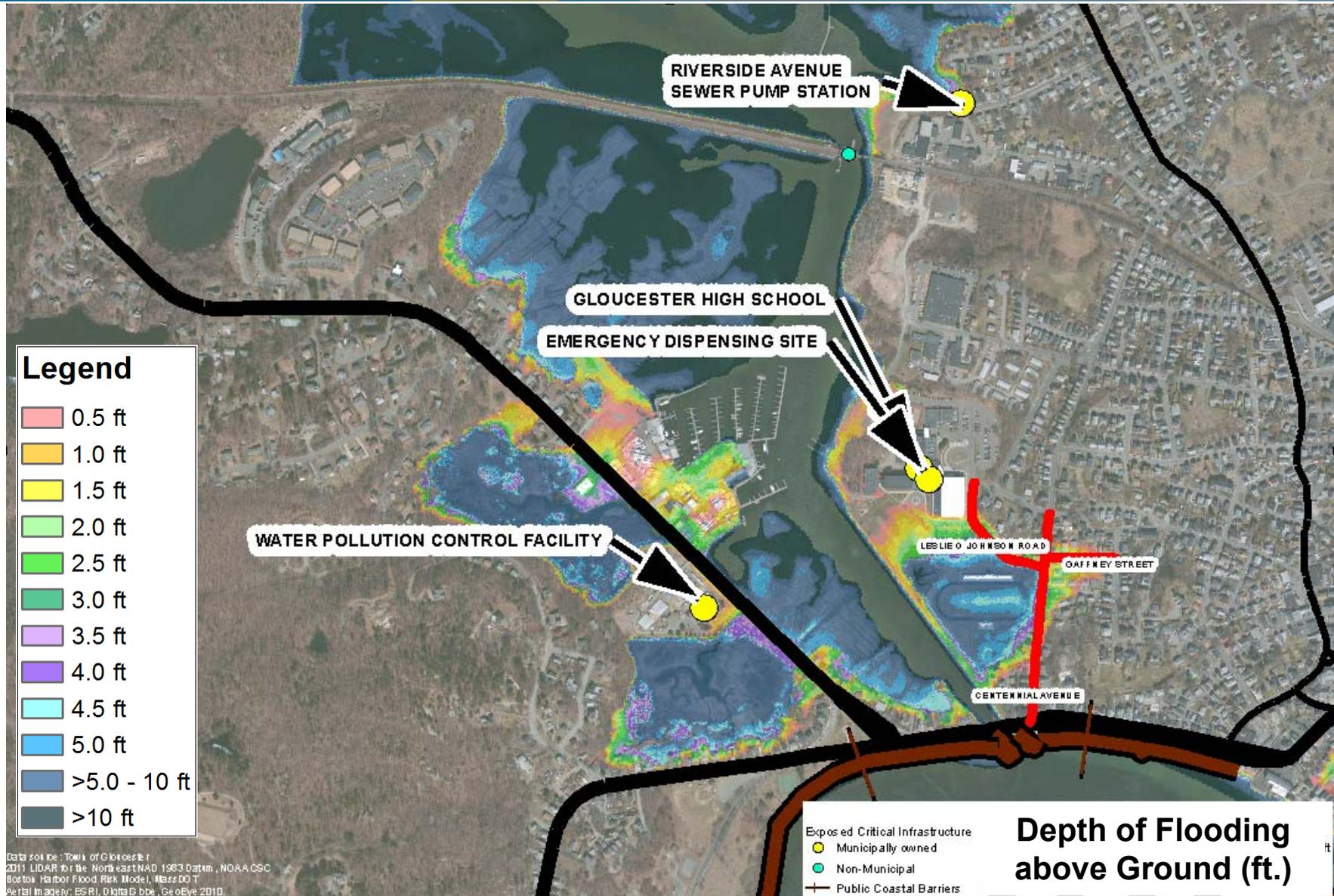


Route 128 at Washington Street 2070: 1% Annual Probability (≈100 yr Recurrence)



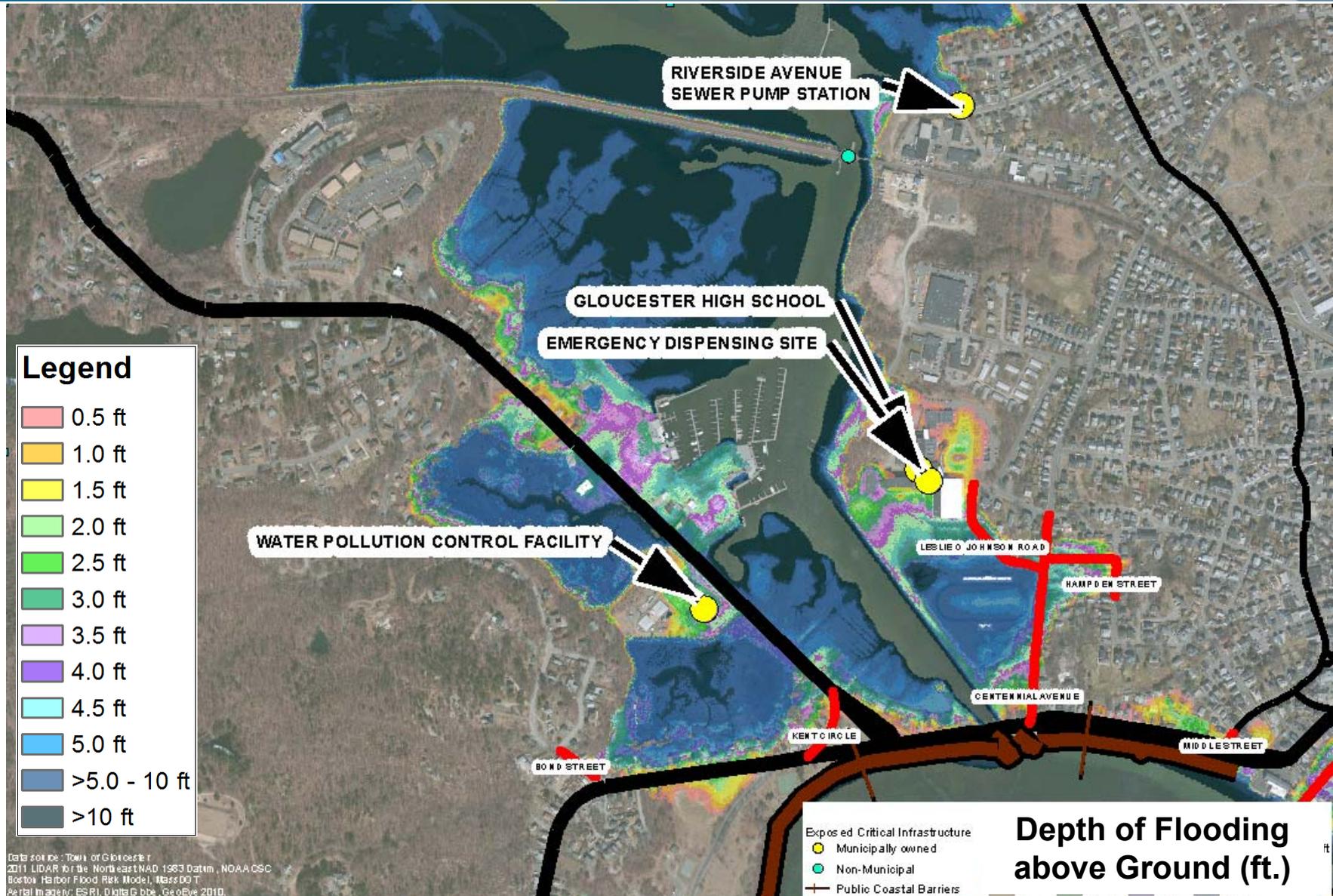
Essex Ave at Western Ave

2030: 1% Annual Probability (≈100 yr Recurrence)

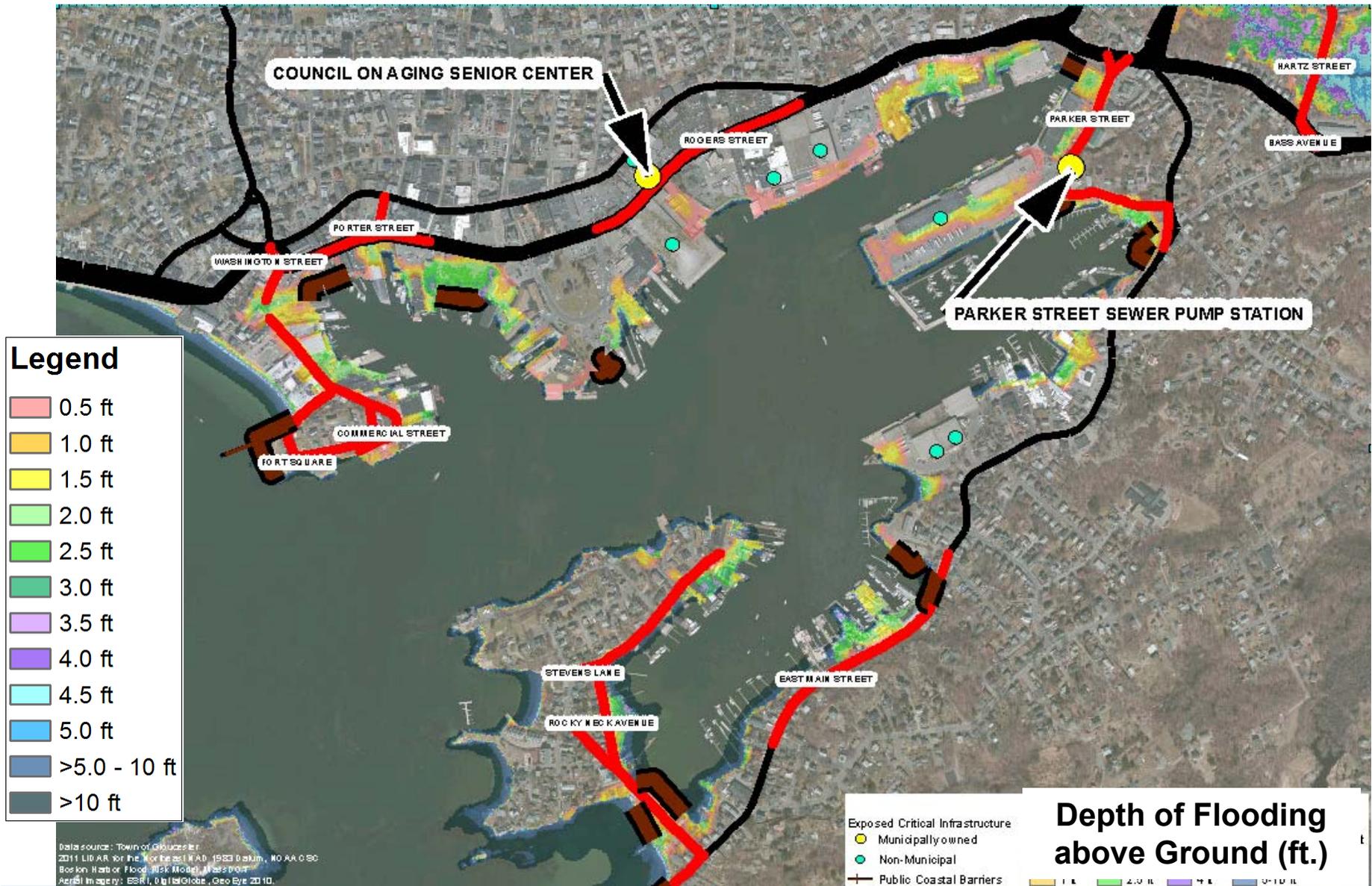


Essex Ave at Western Ave

2070: 1% Annual Probability (≈100 yr Recurrence)

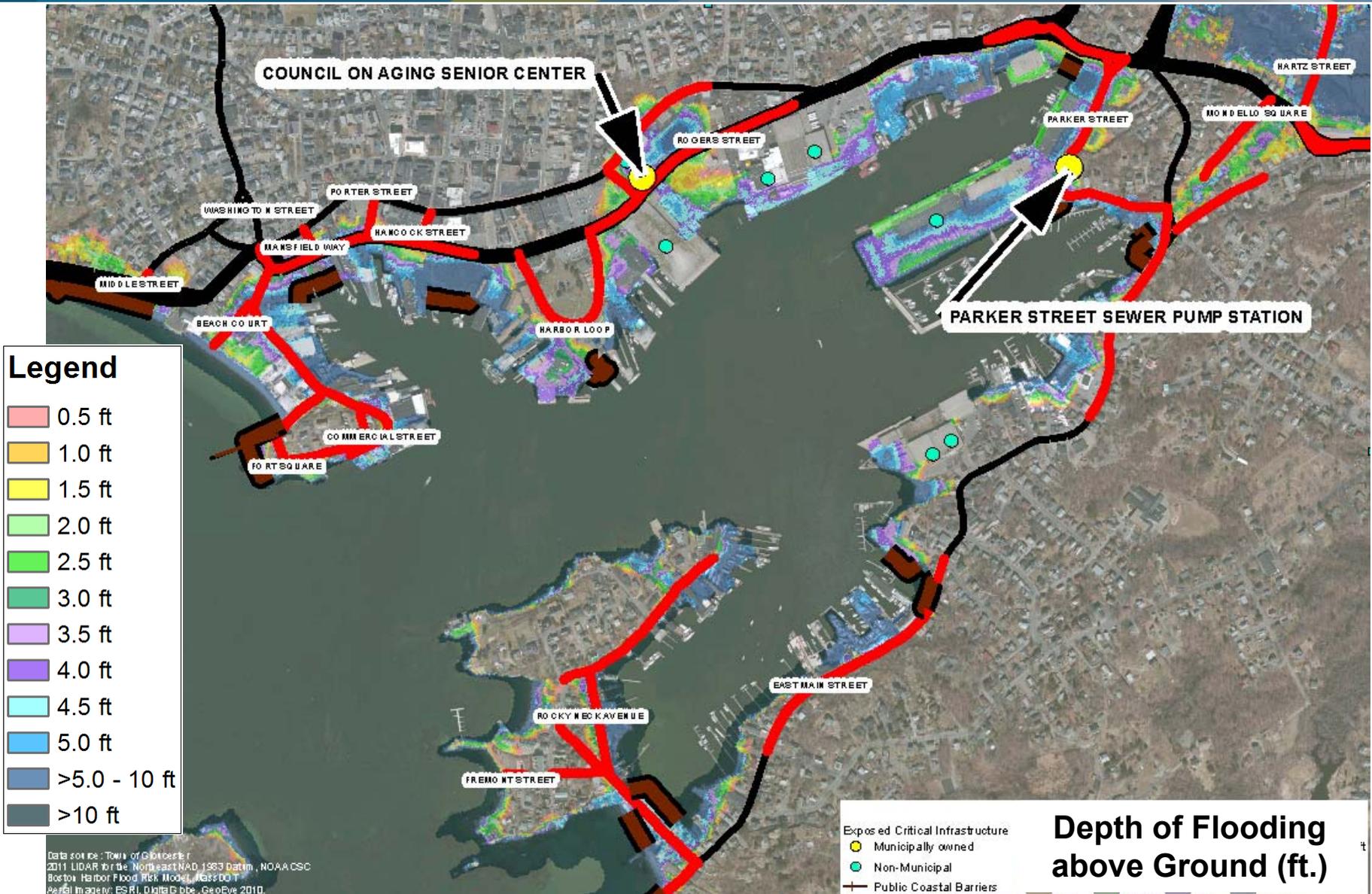


Gloucester Inner Harbor 2030: 1% Annual Probability (≈100 yr Recurrence)



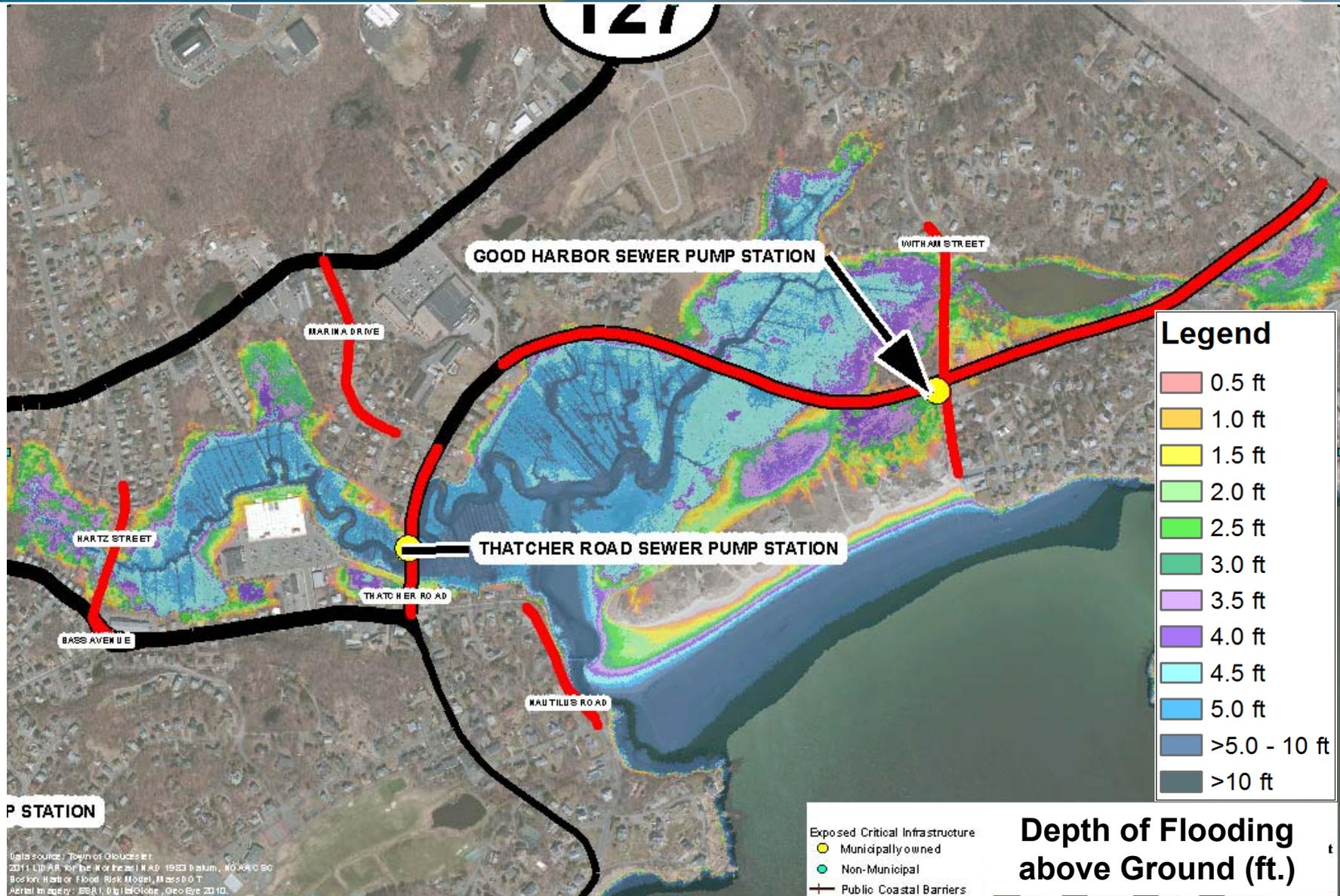
Gloucester Inner Harbor

2070: 1% Annual Probability (≈100 yr Recurrence)



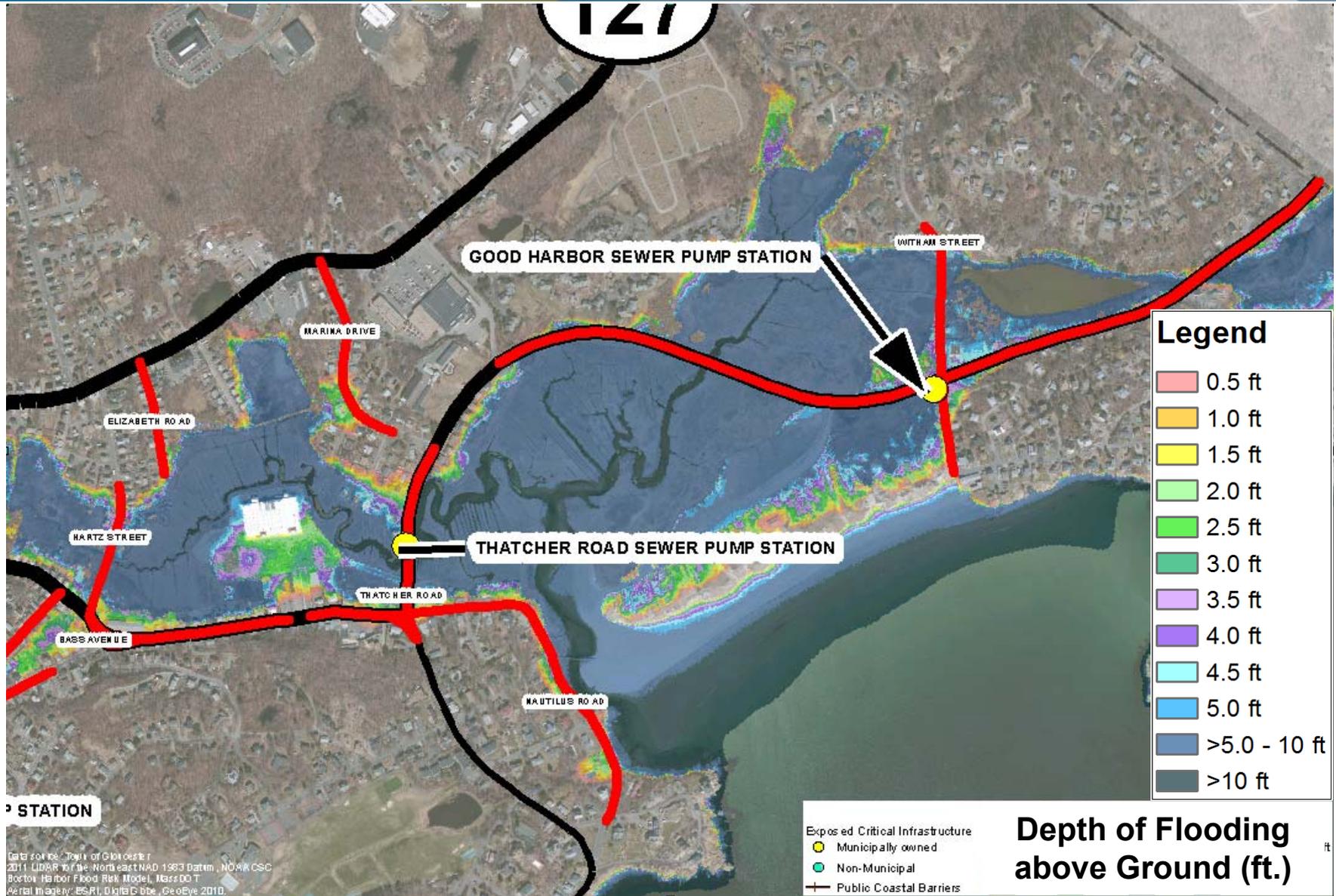
Thatcher Road

2030: 1% Annual Probability (≈100 yr Recurrence)

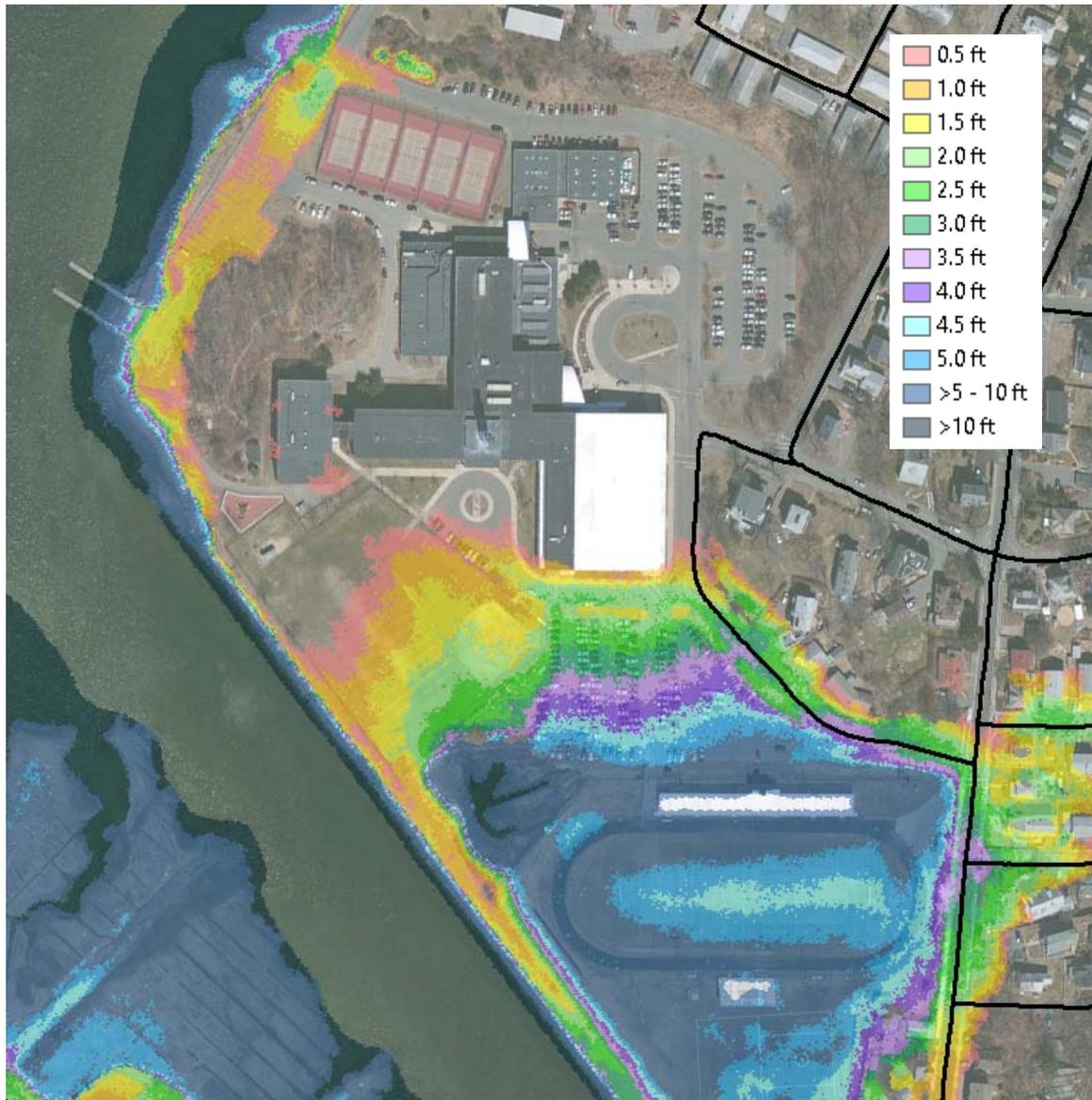


Thatcher Road

2070: 1% Annual Probability (≈100 yr Recurrence)



Gloucester High School – 2030 1%



1% Flood Elevation

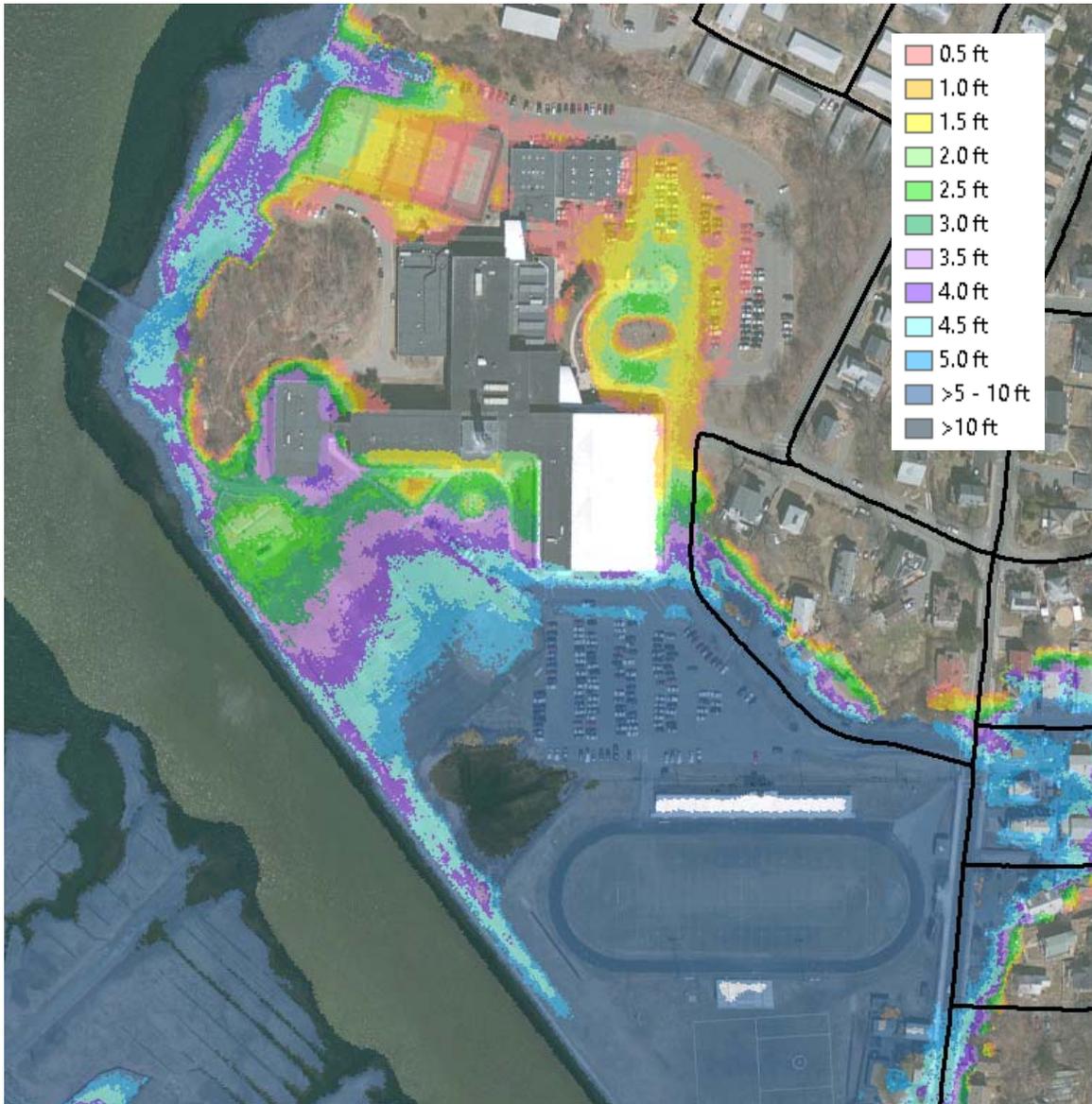
- 9.8 ft NAVD88

First Floor Elevation

- 12.7 ft NAVD88



Gloucester High School – 2070 1%



1% Flood Elevation

- 12.8 ft NAVD88

First Floor Elevation

- 12.7 ft NAVD88

Impacts to Natural Resources due to Sea Level Rise

Key Findings

- Conversion of uplands to wetlands, if no action is taken
 - 2030: - 45 acres
 - 2070: - 215 acres*
- Conversion of high marsh (irregularly flooded) to low marsh (regularly flooded), tidal flats (no vegetation), tidal creeks, or open water
 - 2030: - 185 acres *
 - 2070: - 750 acres*

(near total loss, breakdown of marsh diversity)

*2070 losses are additional to 2030 losses (not cumulative)

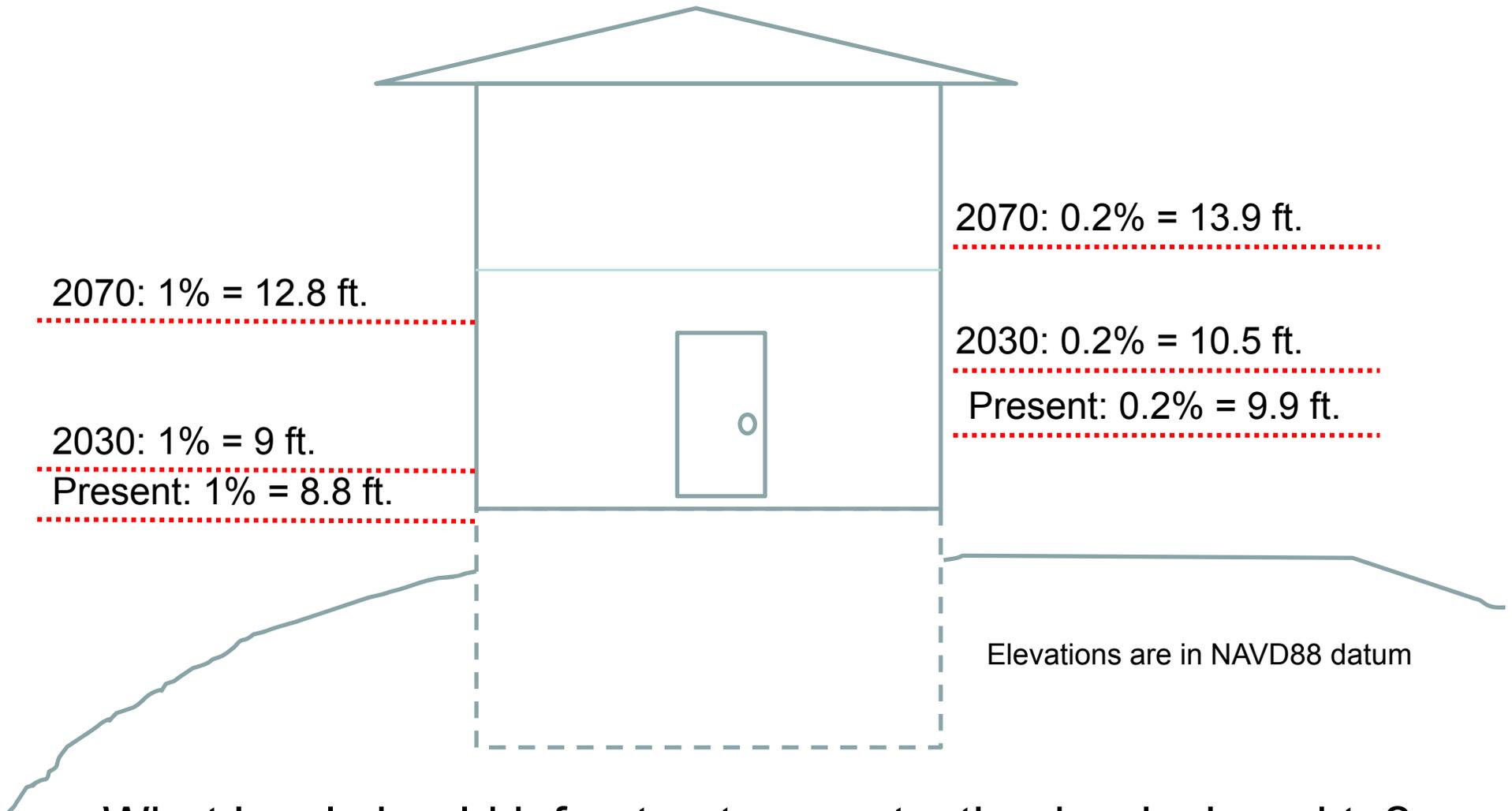
Vulnerability Assessment based on Risk

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

$$R = P \times C$$

Consequence of Flooding based on:

- Area of service loss
- Duration of service loss
- Cost of damage
- Impacts to public safety and emergency services
- Impacts to economic activities
- Impacts to public health and the environment



What level should infrastructure protection be designed to?



COASTAL STRUCTURES

- **Seawalls & Revetments**

- 14 structures \leq 8.8 ft NAVD

- \geq 1% annual probability of flooding in Present time

- **Highest Risk:**

- Lanes Cove

- Inner Harbor

- Public Landing

- Town Landing

- Robinson Landing

- Harbor Cove Wharf

- State Fish Pier

○ Seawalls & Revetments

- Incrementally raise waterfront elevation over time
- Aim for less than 1% annual probability of flooding

	Present	2030	2070
Additional height needed	0.0 - 2.8 ft	0.2 – 3.0 ft	4.0 – 6.8 ft

- Due to mixed ownership of abutting structures in Inner Harbor, raising only City structures will not accomplish overall flood protection goals.
- Need private participation.



FACILITIES

Facilities/Buildings

- All are at or above 1% Flood Elevation in 2030
- Some facilities subject to extreme flooding in 2030
 - Water Pollution Control Facility
 - Pump Stations at highest risk:
 - Thatcher Rd, Good Harbor
 - Senior Center
- A number of facilities buildings subject to some degree of flooding in 2070

ANNUAL CHANCE OF FLOODING

Present = 0.5% (1 in 200)

2030 = 1% (1 in 100)

2070 = 100%

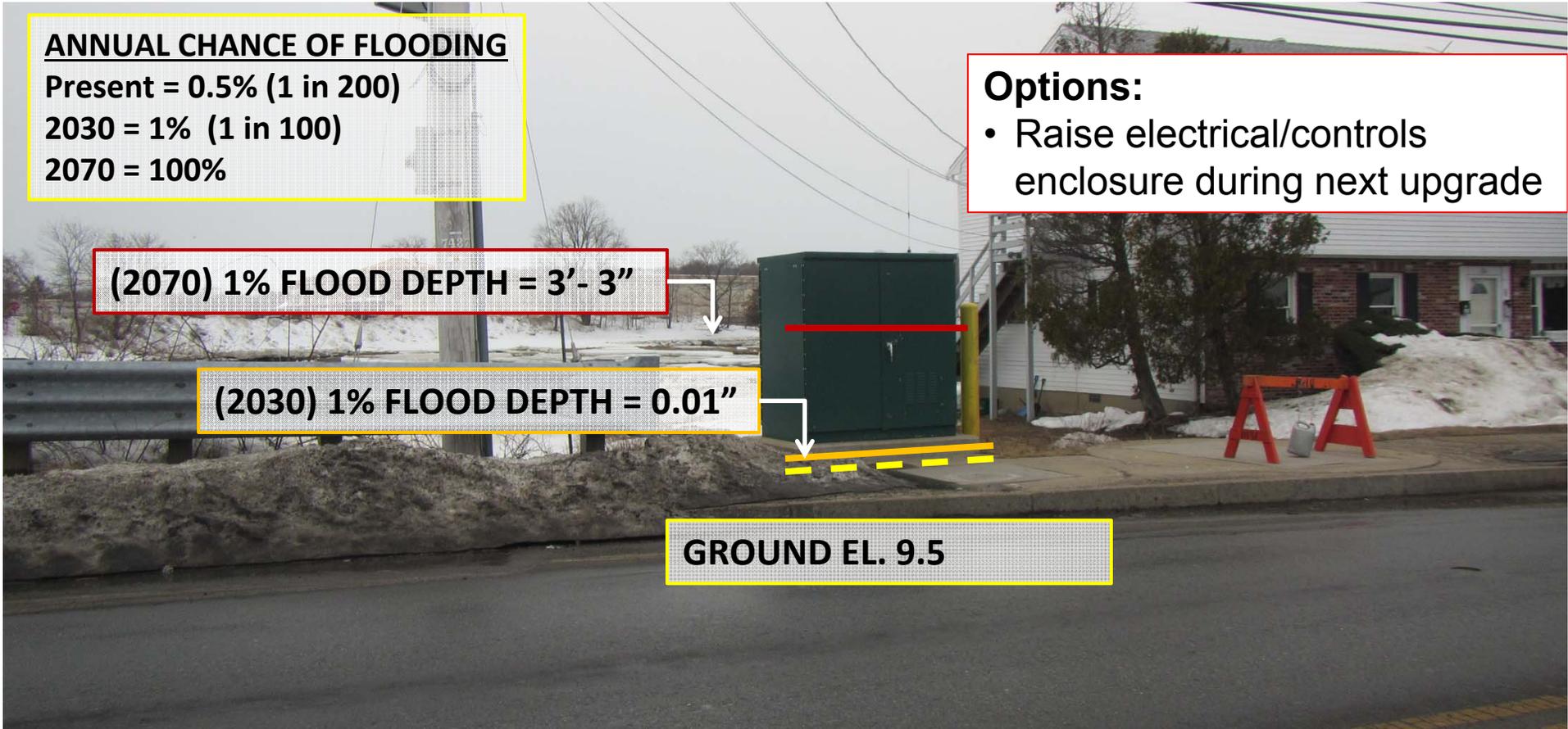
Options:

- Raise electrical/controls enclosure during next upgrade

(2070) 1% FLOOD DEPTH = 3'- 3"

(2030) 1% FLOOD DEPTH = 0.01"

GROUND EL. 9.5



ANNUAL CHANCE OF FLOODING

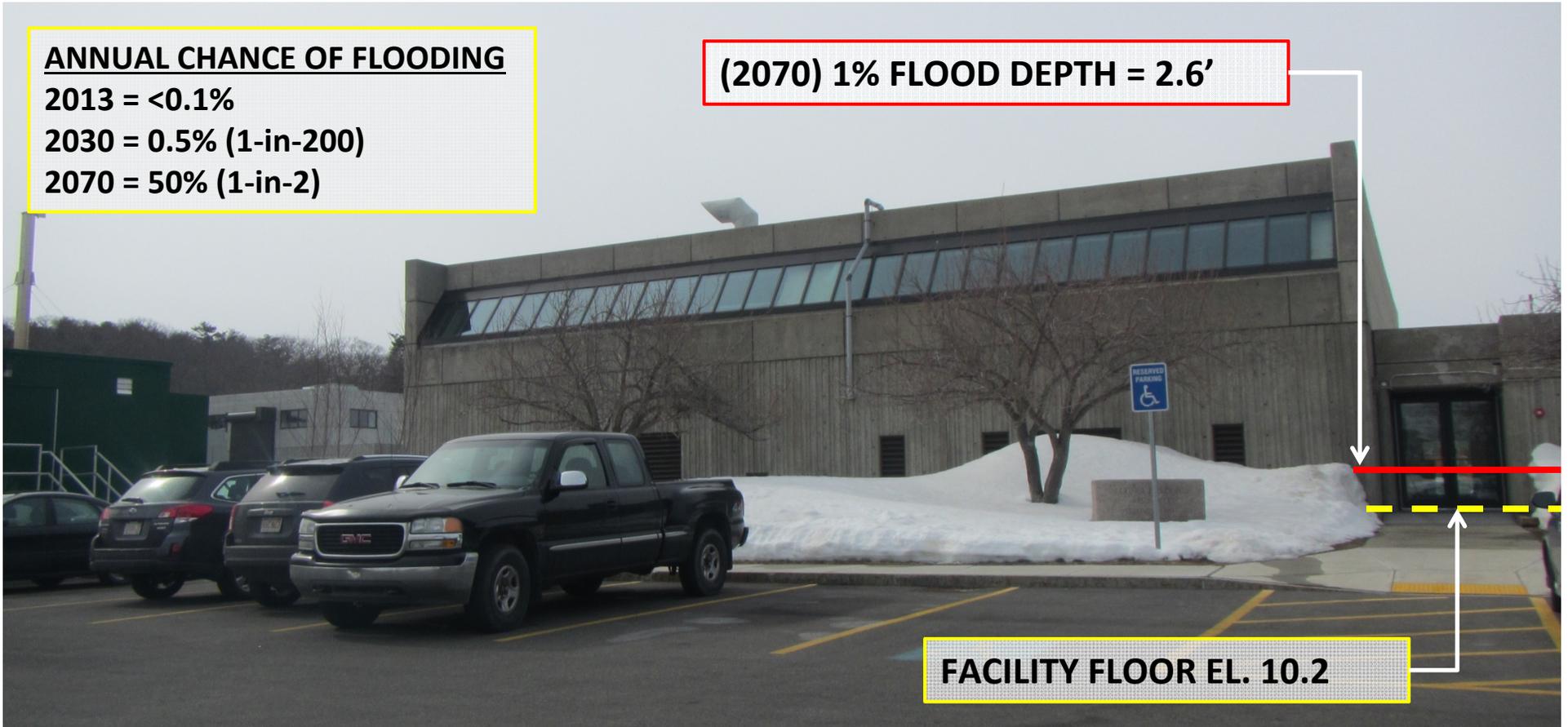
2013 = <0.1%

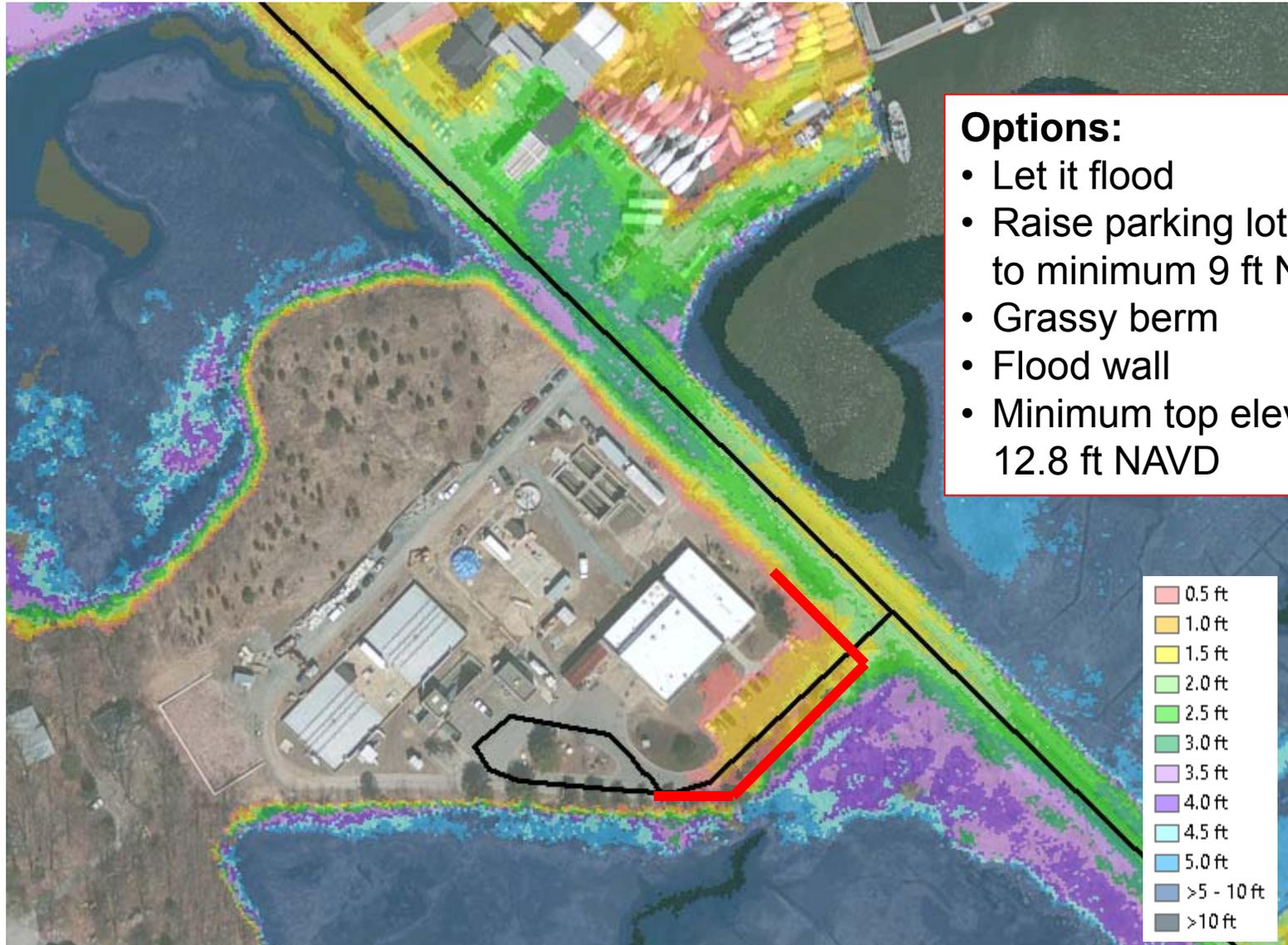
2030 = 0.5% (1-in-200)

2070 = 50% (1-in-2)

(2070) 1% FLOOD DEPTH = 2.6'

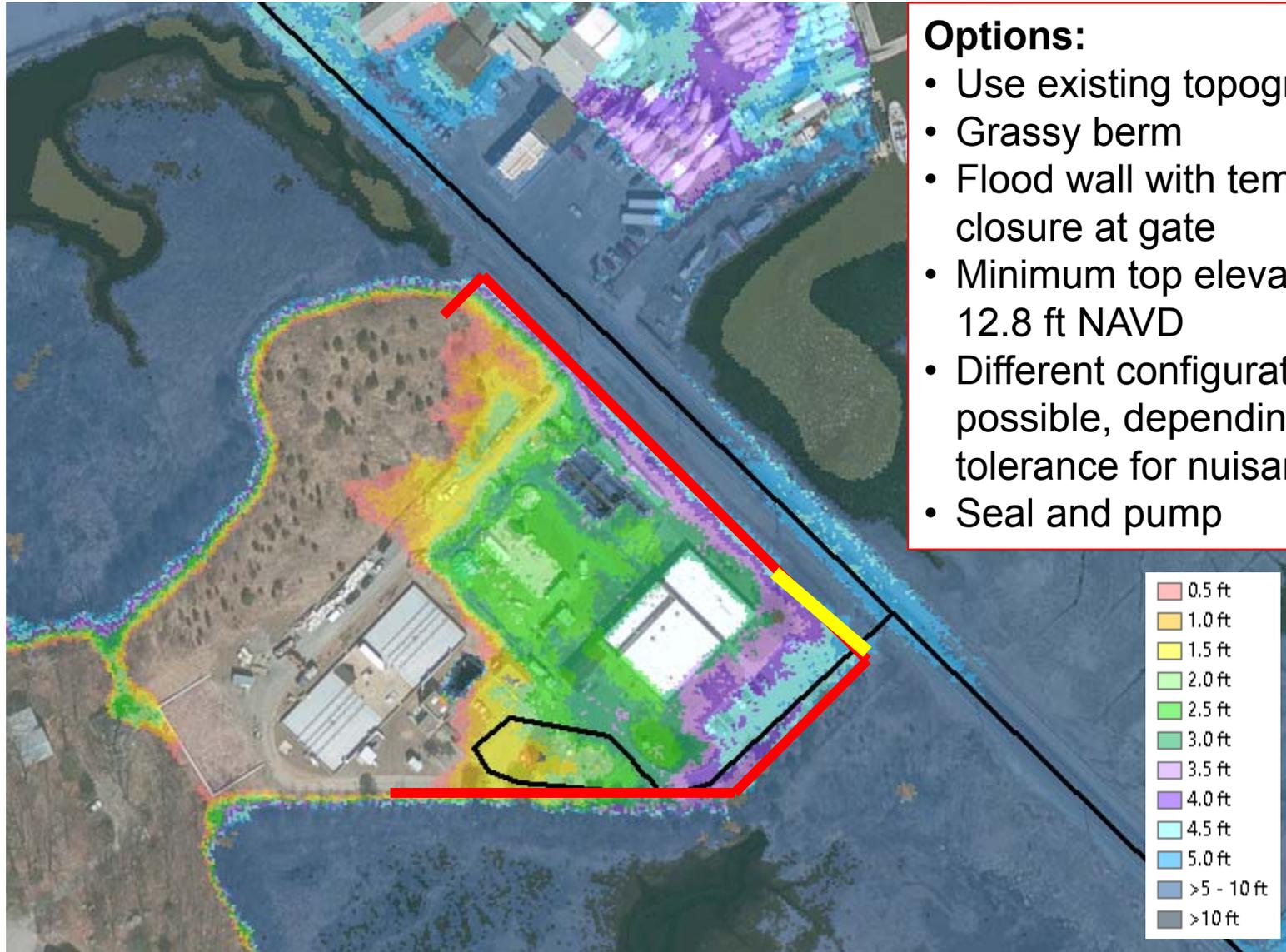
FACILITY FLOOR EL. 10.2





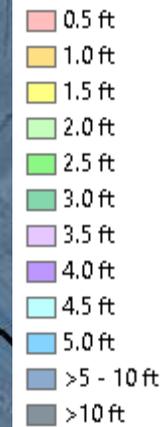
Options:

- Let it flood
- Raise parking lot and driveway to minimum 9 ft NAVD
- Grassy berm
- Flood wall
- Minimum top elevation = 12.8 ft NAVD



Options:

- Use existing topography
- Grassy berm
- Flood wall with temporary closure at gate
- Minimum top elevation = 12.8 ft NAVD
- Different configurations/height possible, depending on tolerance for nuisance flooding
- Seal and pump



ANNUAL CHANCE OF FLOODING

Present = 0.2% (1 in 500)

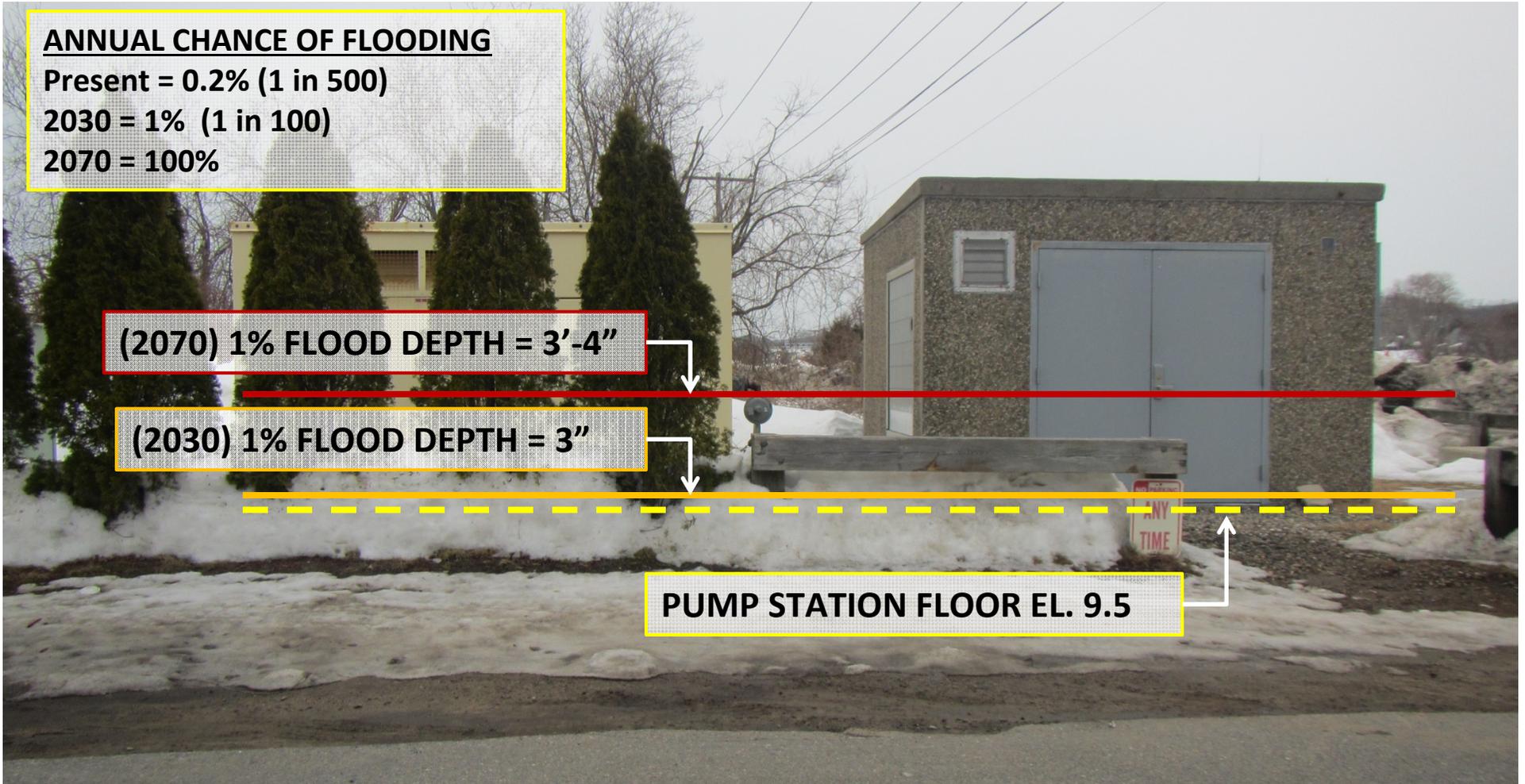
2030 = 1% (1 in 100)

2070 = 100%

(2070) 1% FLOOD DEPTH = 3'-4"

(2030) 1% FLOOD DEPTH = 3"

PUMP STATION FLOOR EL. 9.5



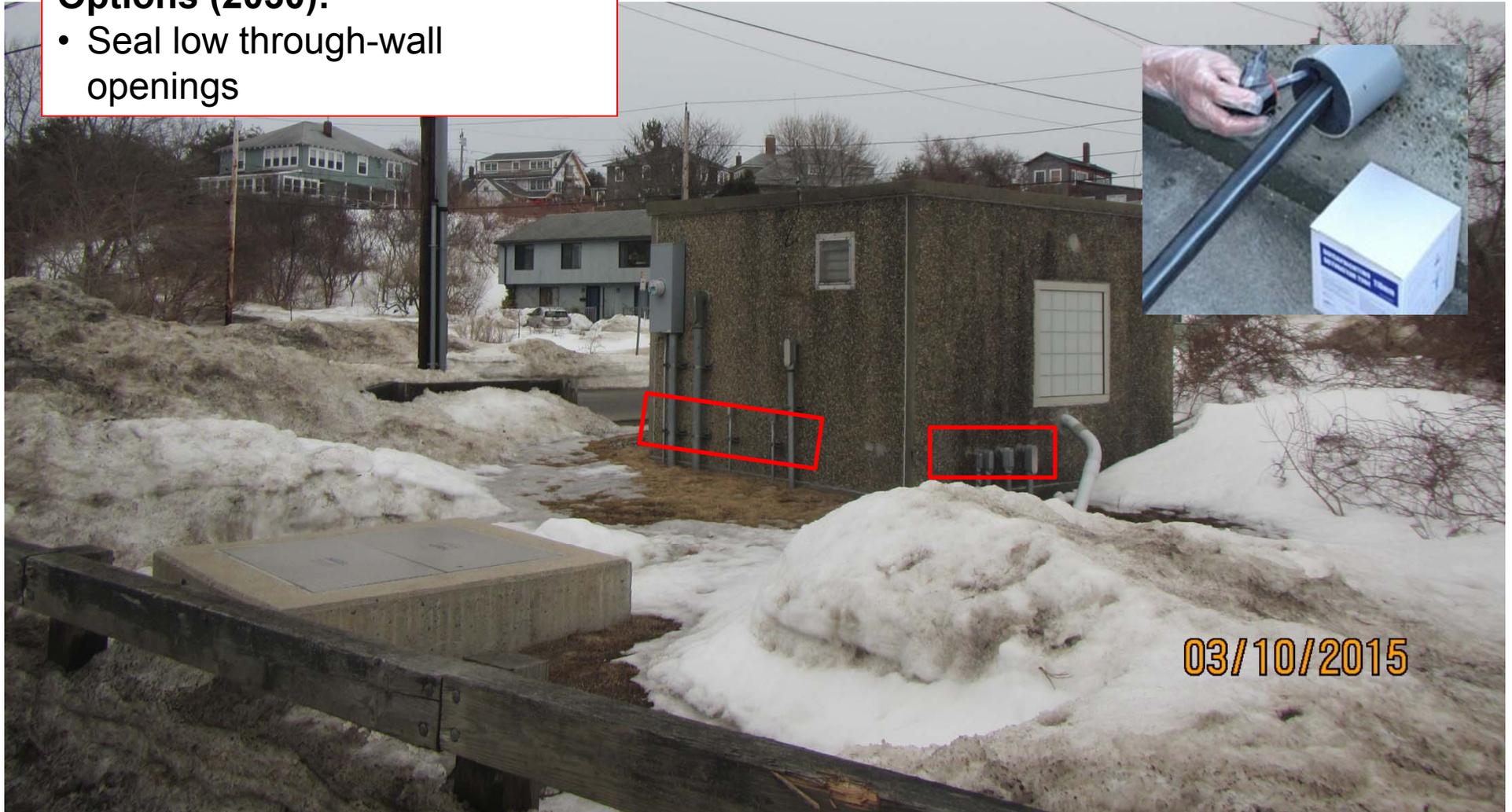
Options (2030):

- Temporary/demountable flood panel across large openings



Options (2030):

- Seal low through-wall openings



Options (2070):

- Perimeter 3.5 ft ± flood wall with temporary access closure
- Minimum top elevation = 12.8 ft NAVD
- Pump connected to existing generator

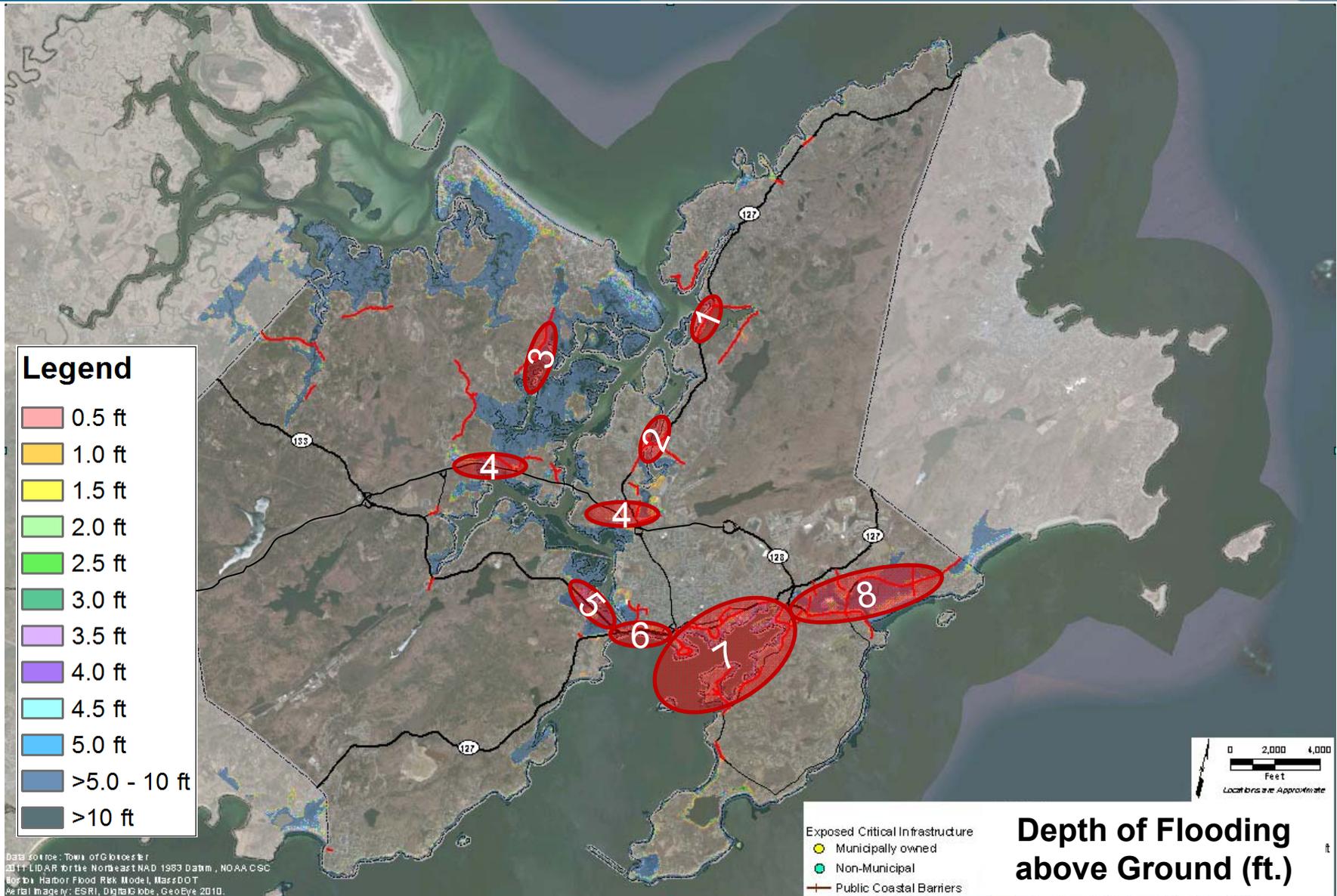




ROADWAYS

- **Key roads at-risk**
 - Most major evacuation routes
 - Rt. 133, Rt. 128, Rt. 127, Rt. 127A, Atlantic St
 - Inner Harbor roads
- **Longer-term strategies required**
 - Long planning/implementation timelines
 - Infrastructure is long-lived
 - Can be costly to implement
 - Challenging aesthetics

2070: 1% Annual Probability – Flooded Streets (≈100 yr Recurrence)



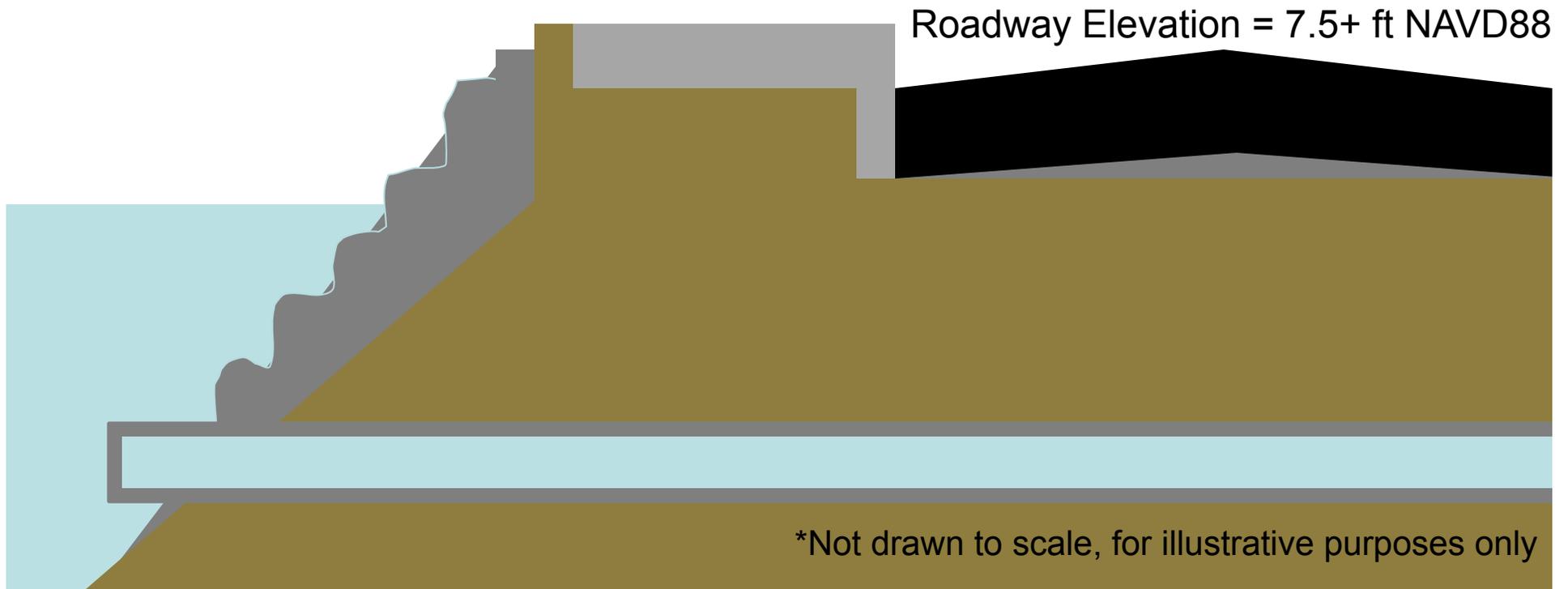
Existing Conditions

13.9 ft NAVD88 (2070 @ 0.2%)

12.8 ft NAVD 88 (2070 @ 1%)

10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)



Low Cost / Near Term Option: 1-2 ft Wall at Edge of Sidewalk

13.9 ft NAVD88 (2070 @ 0.2%)

12.8 ft NAVD 88 (2070 @ 1%)

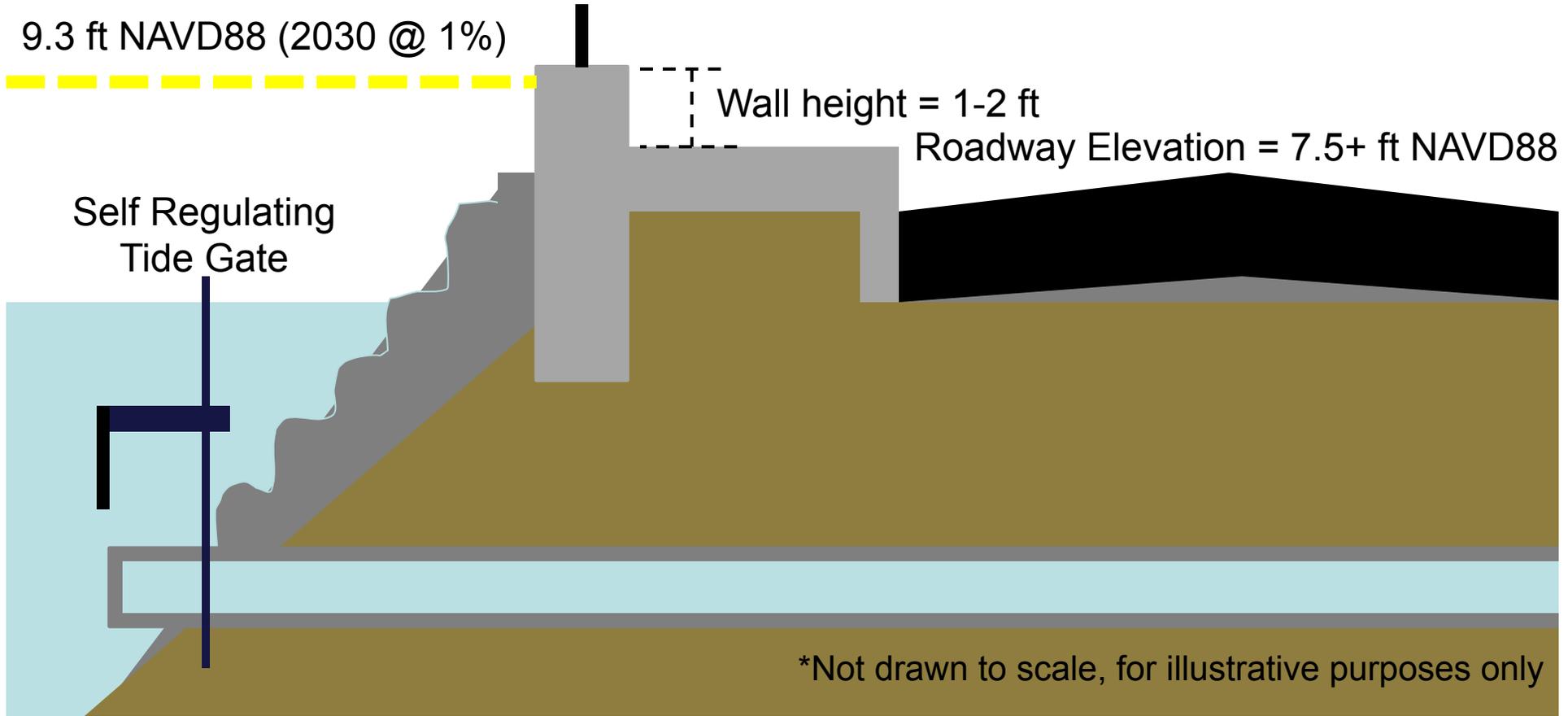
10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)

Wall height = 1-2 ft

Roadway Elevation = 7.5+ ft NAVD88

Self Regulating
Tide Gate



*Not drawn to scale, for illustrative purposes only

Low Cost / Medium Term Option: 3.5 ft Wall at Edge of Sidewalk

13.9 ft NAVD88 (2070 @ 0.2%)

12.8 ft NAVD 88 (2070 @ 1%)

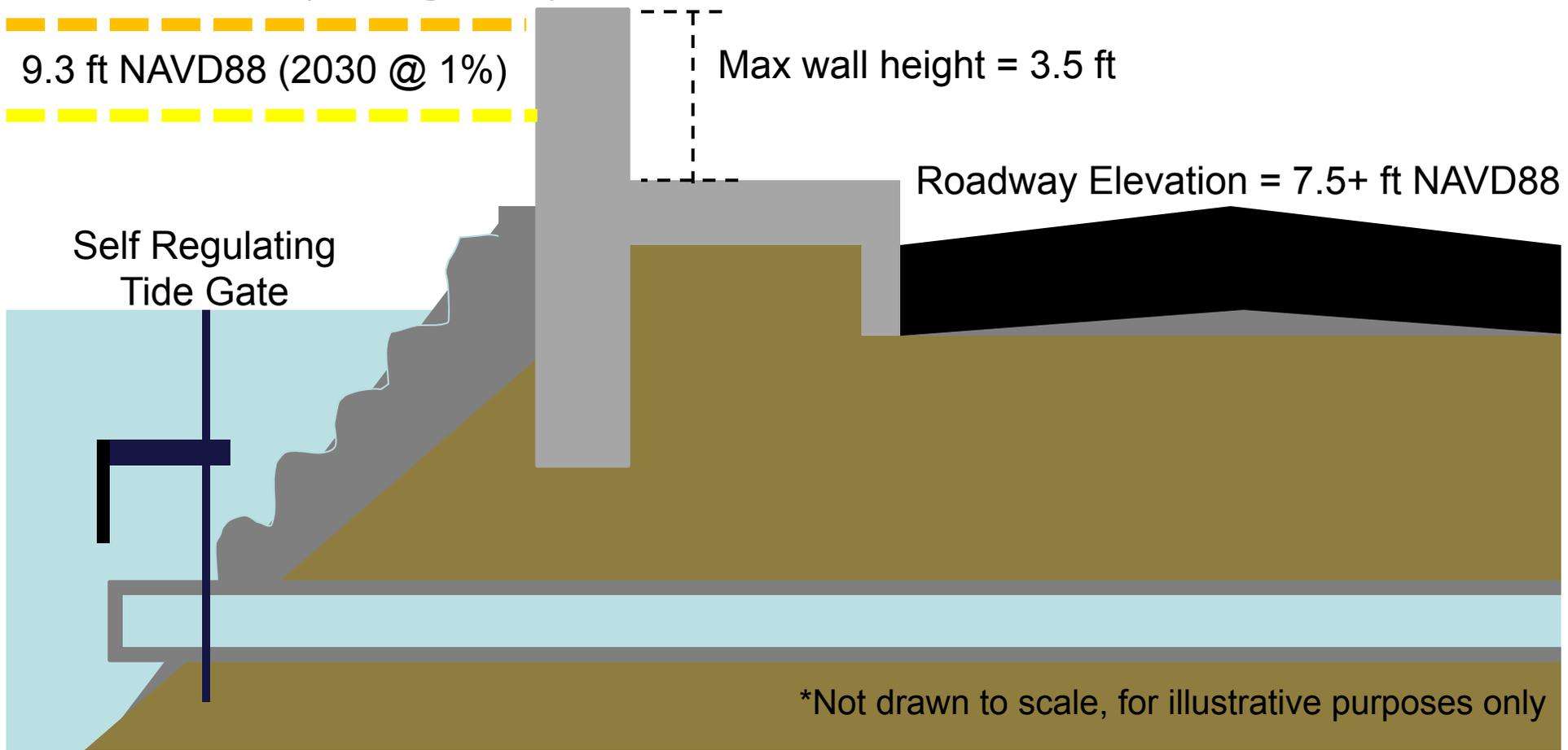
10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)

Max wall height = 3.5 ft

Roadway Elevation = 7.5+ ft NAVD88

Self Regulating
Tide Gate



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Long Term Option: Over Long Term, Increasing Wall Height

13.9 ft NAVD88 (2070 @ 0.2%)

12.8 ft NAVD 88 (2070 @ 1%)

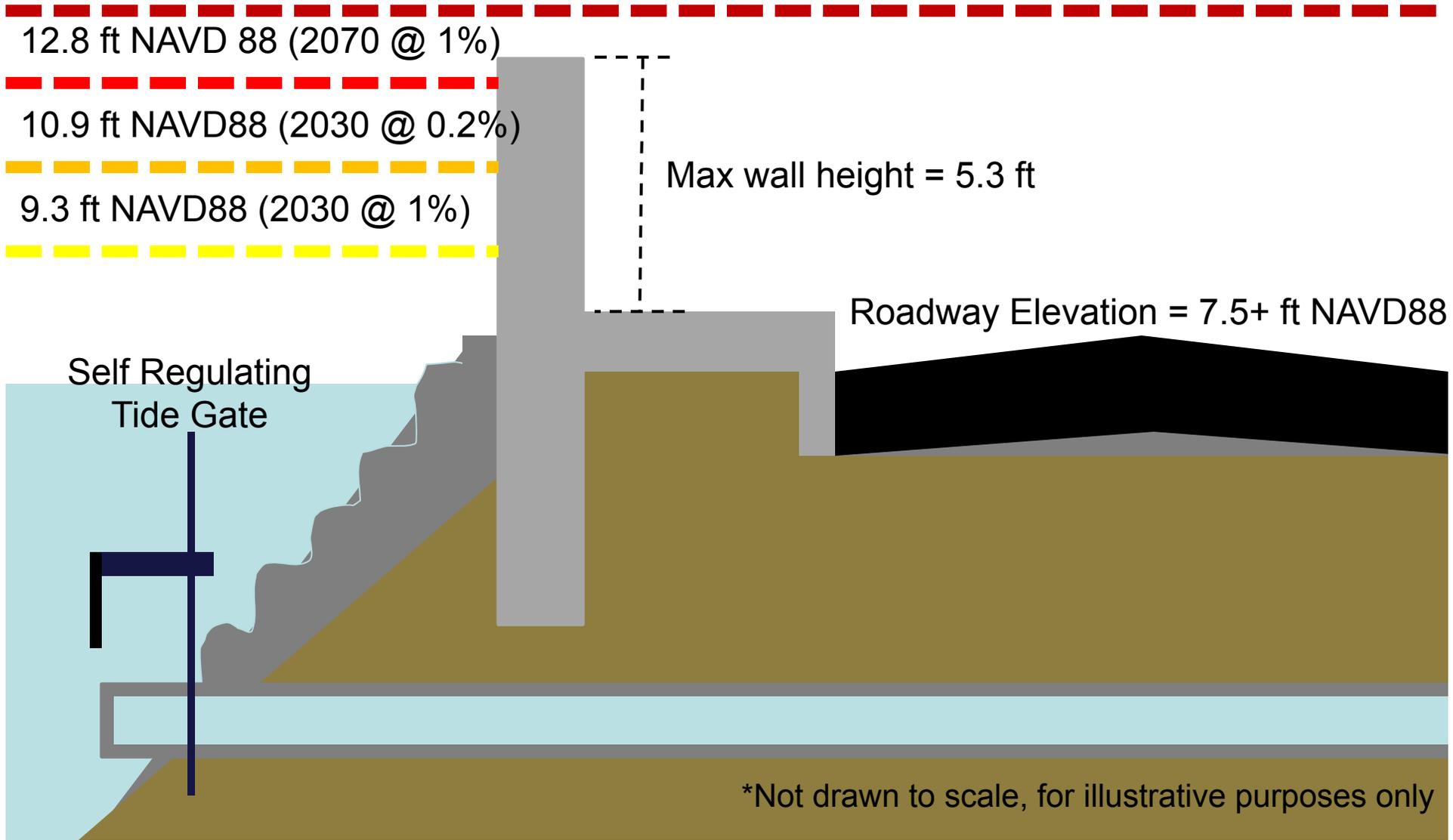
10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)

Max wall height = 5.3 ft

Roadway Elevation = 7.5+ ft NAVD88

Self Regulating
Tide Gate



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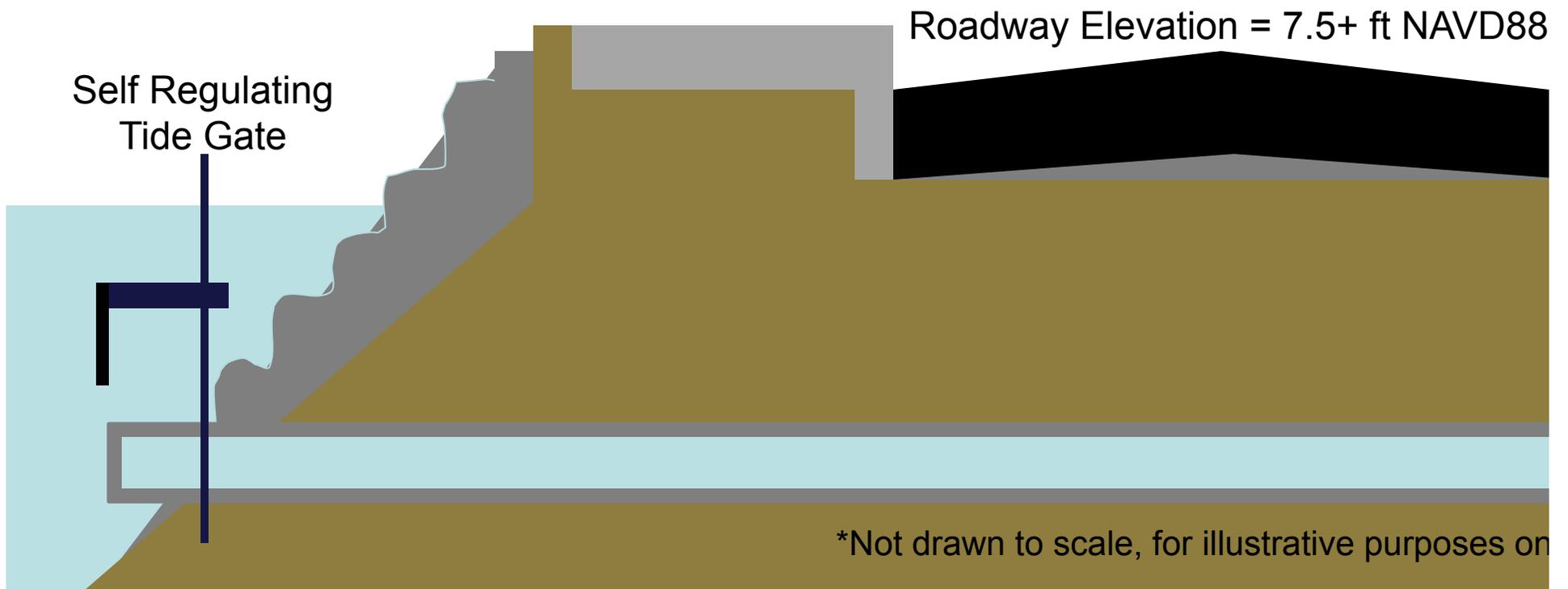
Existing Conditions

13.9 ft NAVD88 (2070 @ 0.2%)

12.8 ft NAVD 88 (2070 @ 1%)

10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)



Medium Term Option: Raise Road and Sidewalk to 9.5 ft ± NAVD

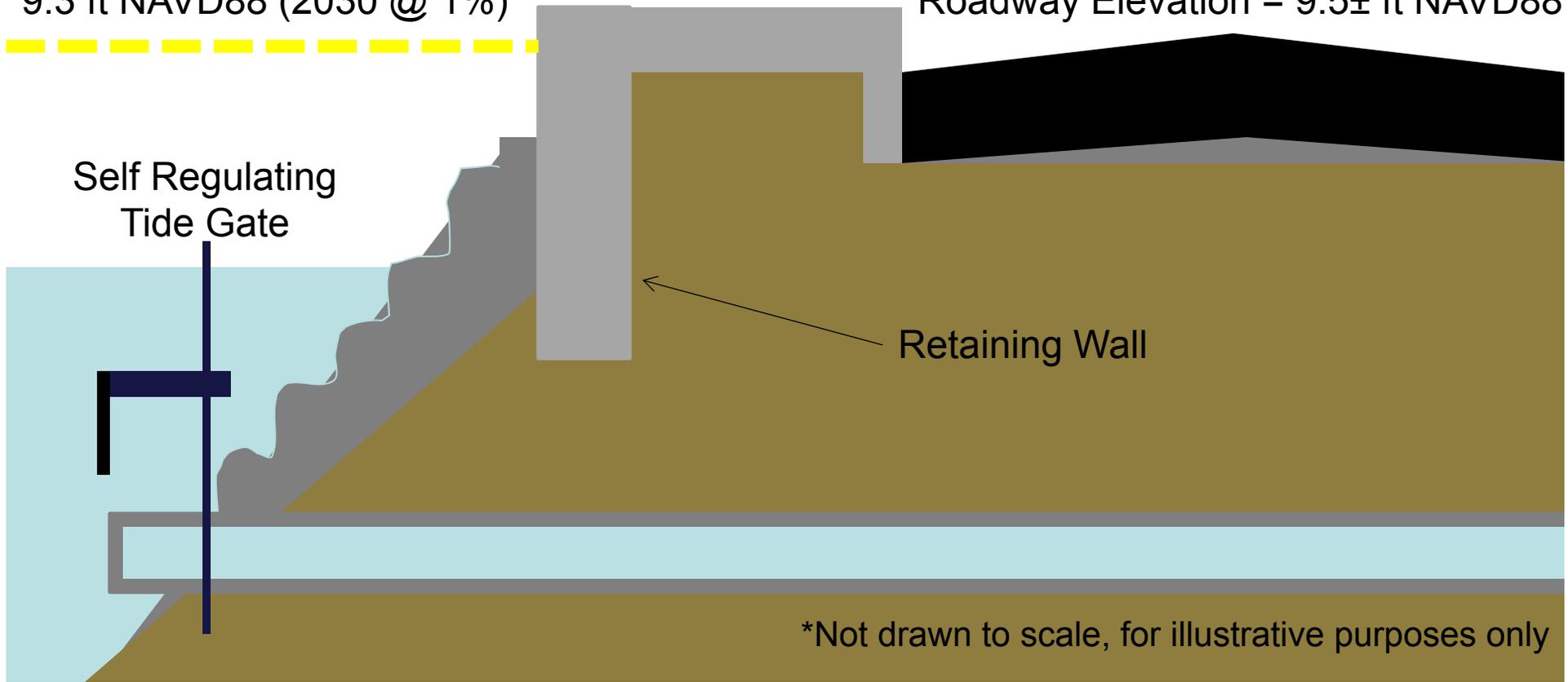
13.9 ft NAVD88 (2070 @ 0.2%)

12.8 ft NAVD 88 (2070 @ 1%)

10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)

Roadway Elevation = 9.5± ft NAVD88



*Not drawn to scale, for illustrative purposes only

Alternative Medium Term Option: Raise Road and Sidewalk to 11 ft ± NAVD

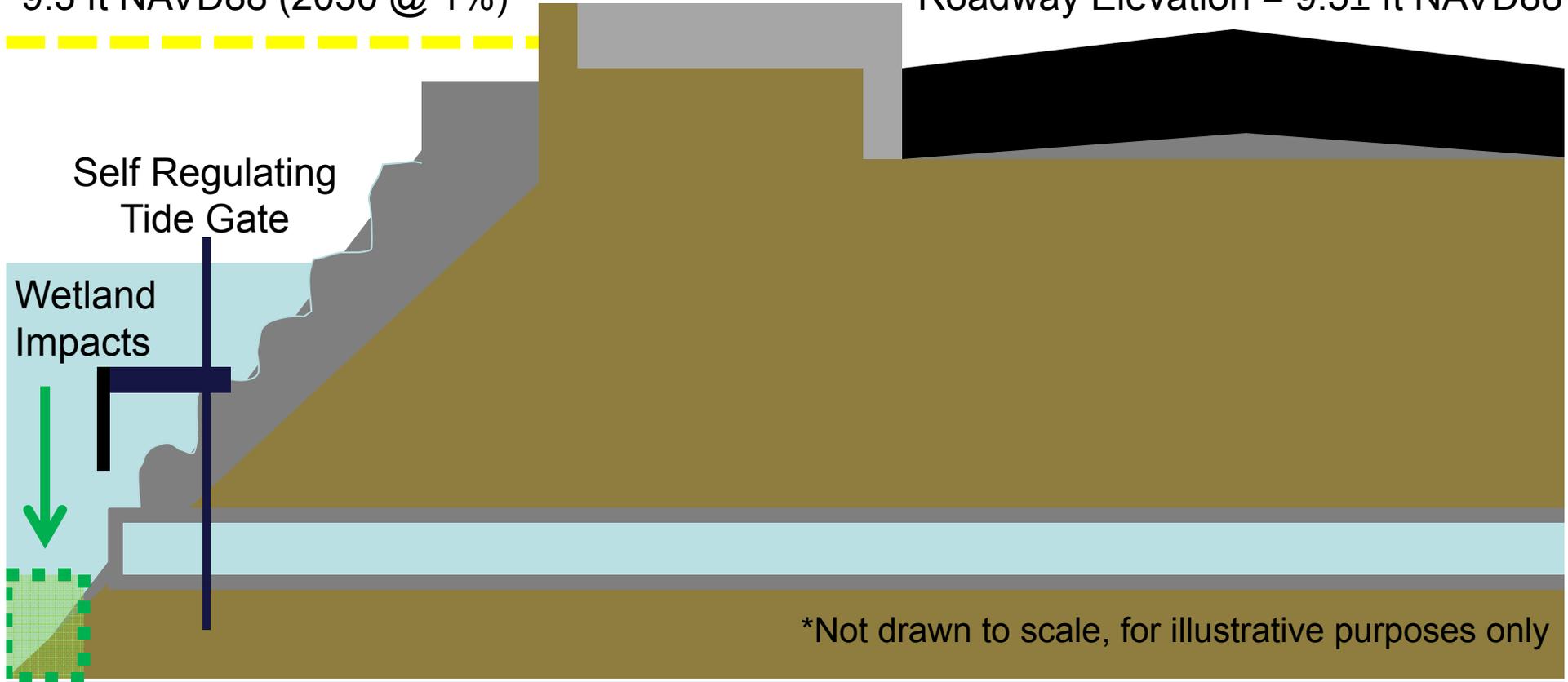
13.9 ft NAVD88 (2070 @ 0.2%)

12.8 ft NAVD 88 (2070 @ 1%)

10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)

Roadway Elevation = 9.5± ft NAVD88



*Not drawn to scale, for illustrative purposes only

Provides Flexibility to Increase Level of Protection

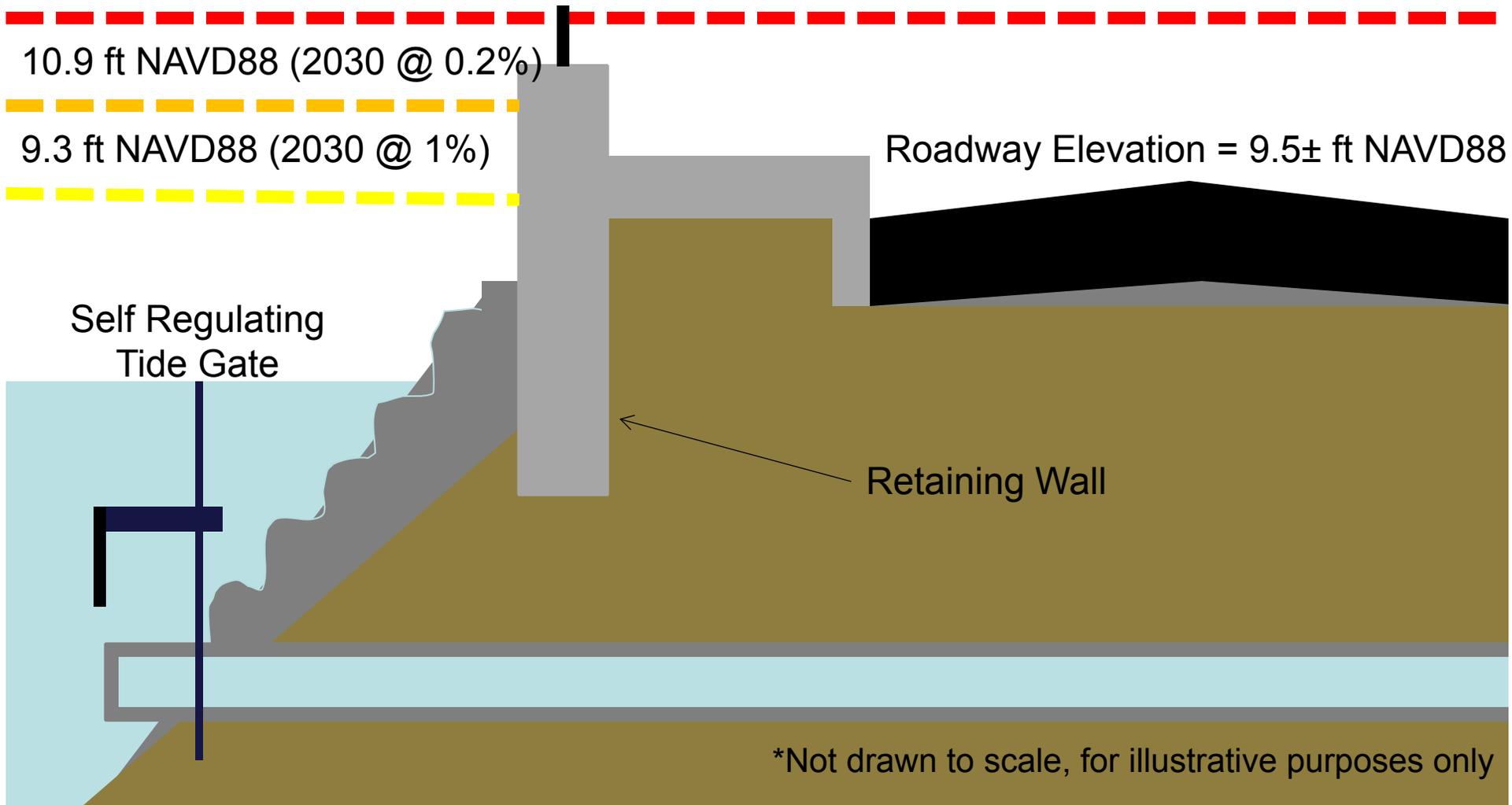
13.9 ft NAVD88 (2070 @ 0.2%)

12.8 ft NAVD 88 (2070 @ 1%)

10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)

Roadway Elevation = 9.5± ft NAVD88



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Provides Flexibility to Increase Level of Protection

13.9 ft NAVD88 (2070 @ 0.2%)

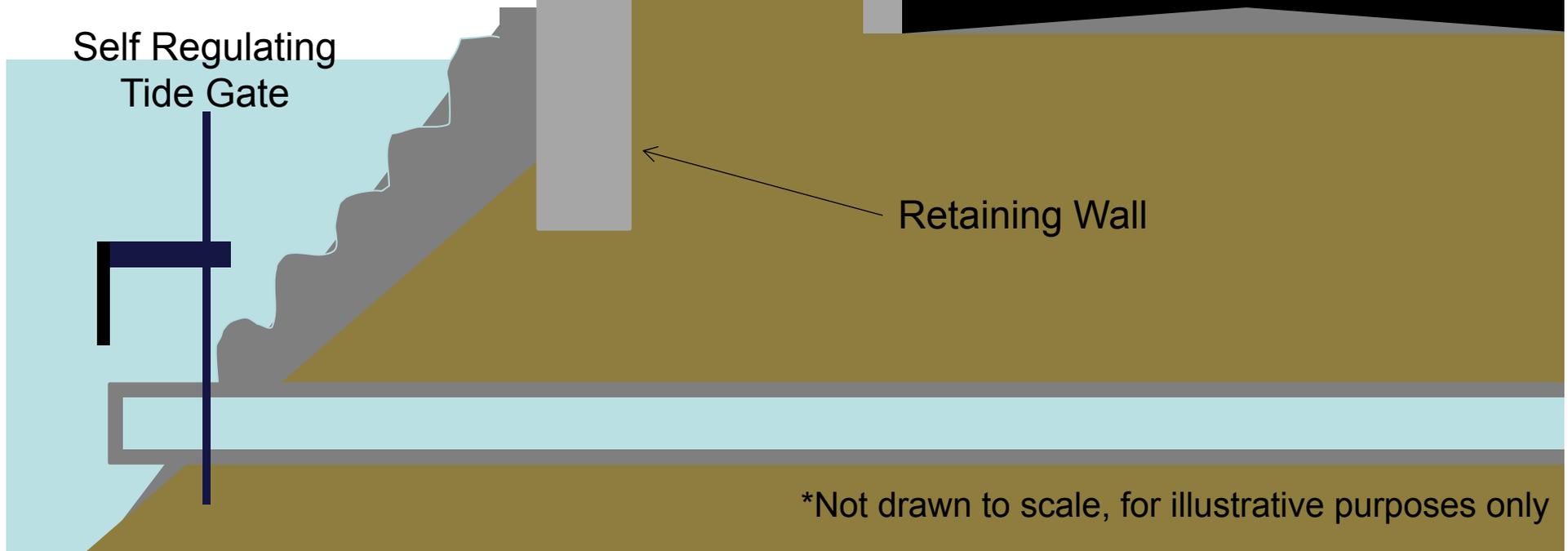
12.8 ft NAVD 88 (2070 @ 1%)

10.9 ft NAVD88 (2030 @ 0.2%)

9.3 ft NAVD88 (2030 @ 1%)

Max wall height = 3.5 ft

Roadway Elevation = 11± ft NAVD88



*Not drawn to scale, for illustrative purposes only



Concrete Permanent Flood Wall



Glass Flood Wall



Self-Regulating Tide Gate



Decorative Permanent Flood Wall

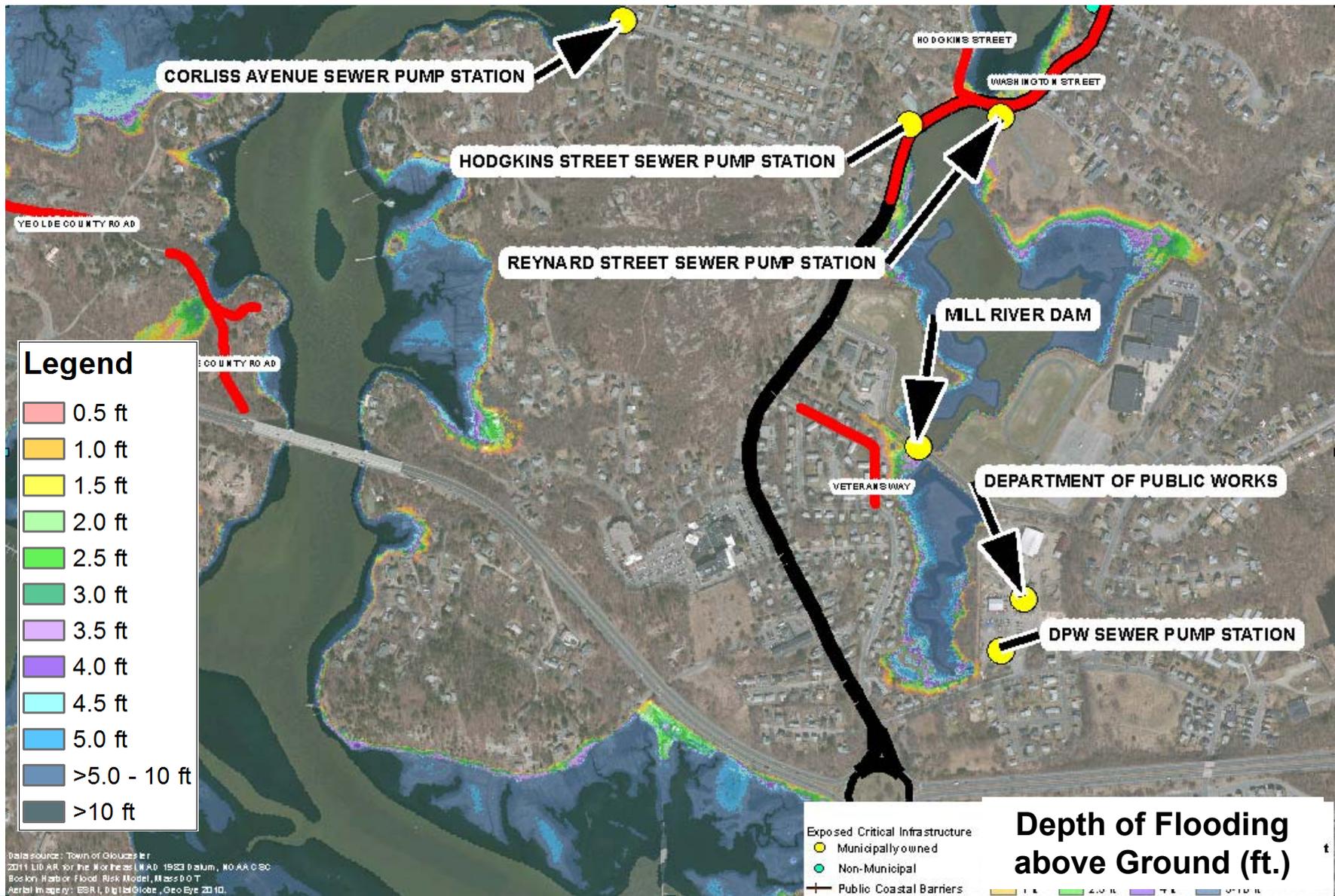
Examples of Glass-Topped Flood Walls





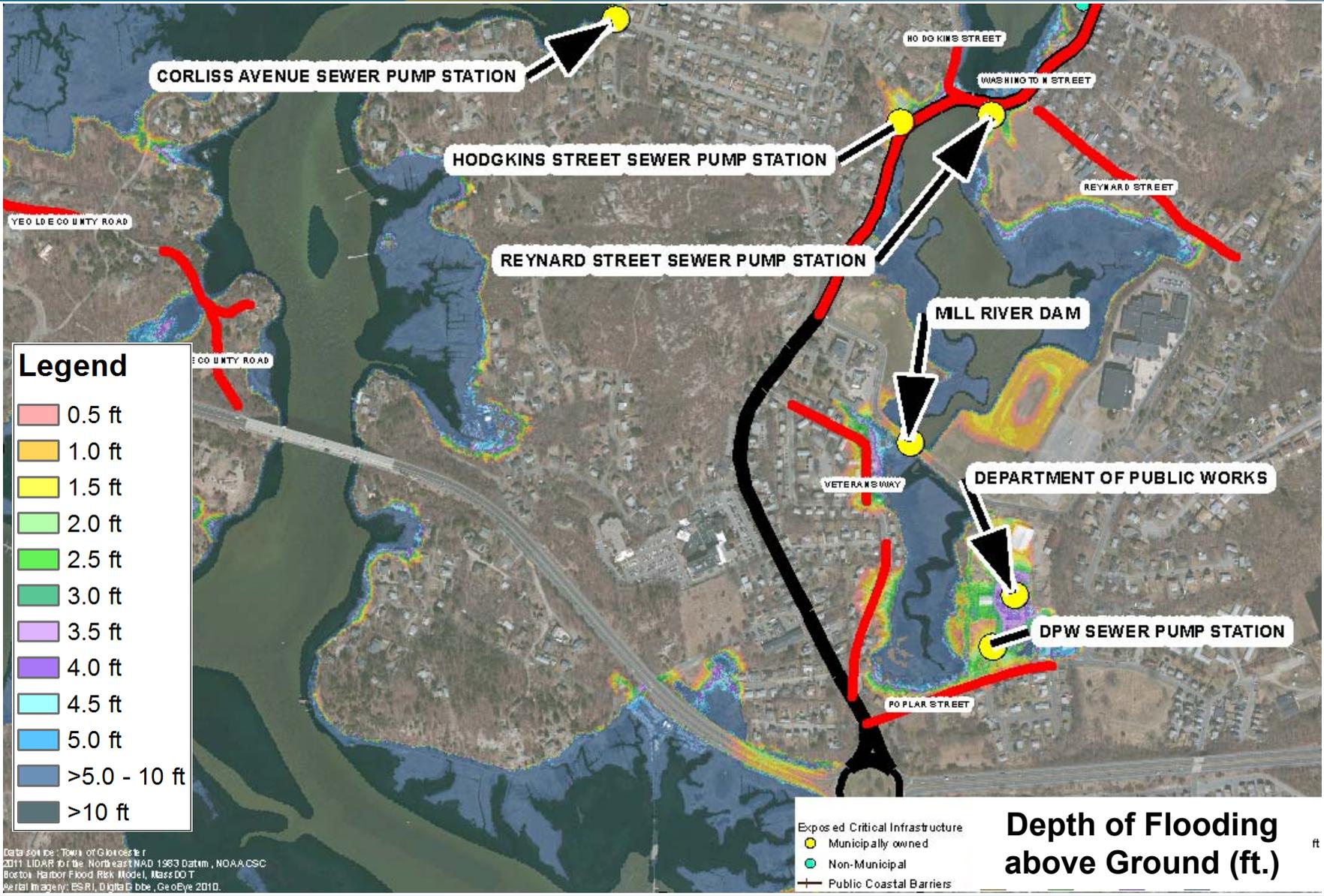
Mill Pond Floodplain

2030: 1% Annual Probability (≈100 yr Recurrence)



Mill Pond Floodplain

2070: 1% Annual Probability (≈100 yr Recurrence)



2030



Length = 650 ft
Height = 1-2 ft
Elevation = 9.3 ft NAVD
Freeboard to be added

2070



Length = 830 ft
Height = 3-6 ft
Elevation = 12.8 ft NAVD
Freeboard to be added

Recommendations:

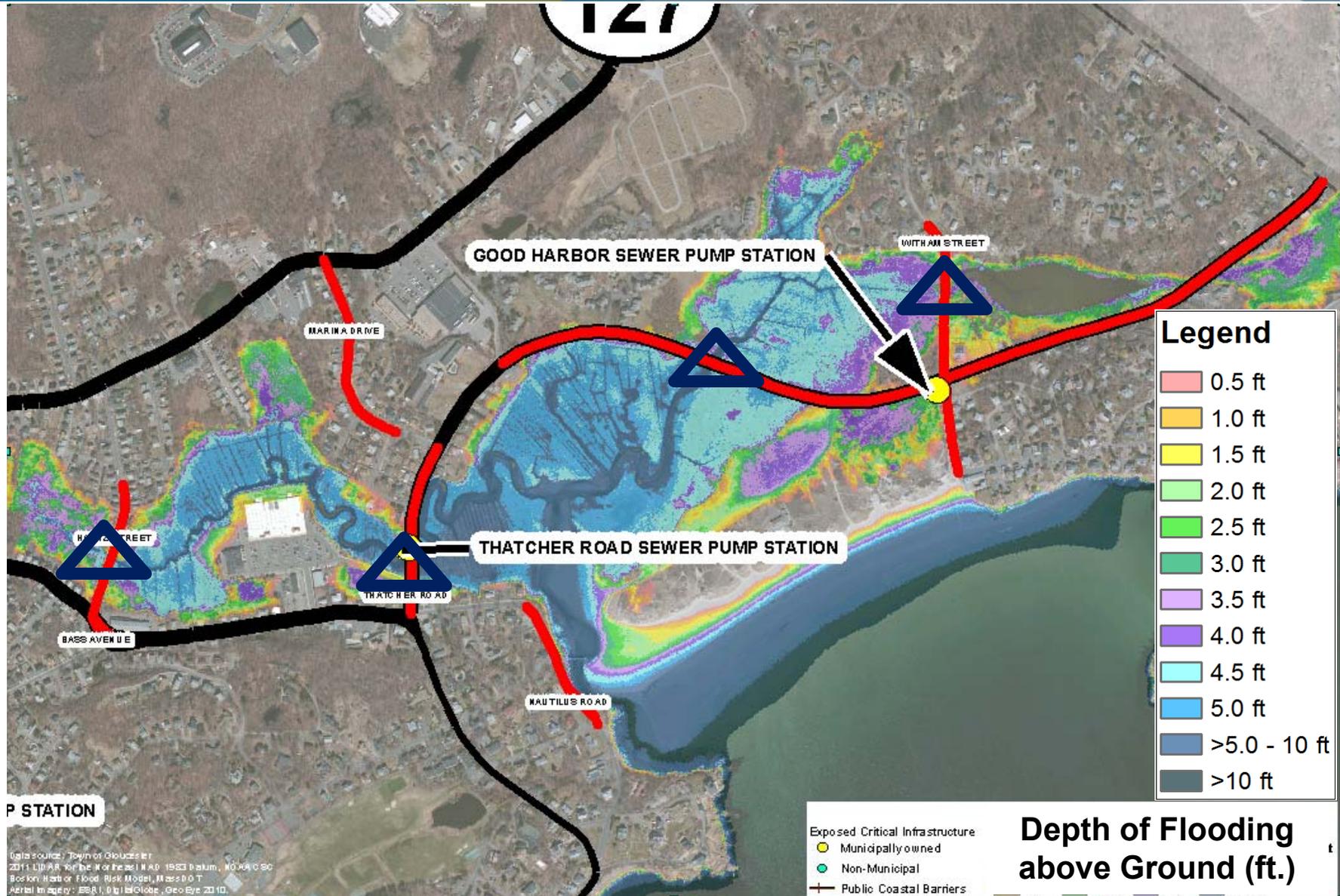
1. Raise road/barrier
2. Replace existing with self regulating tide gate or other control structure
3. Potentially add pumping

Protects City Assets:

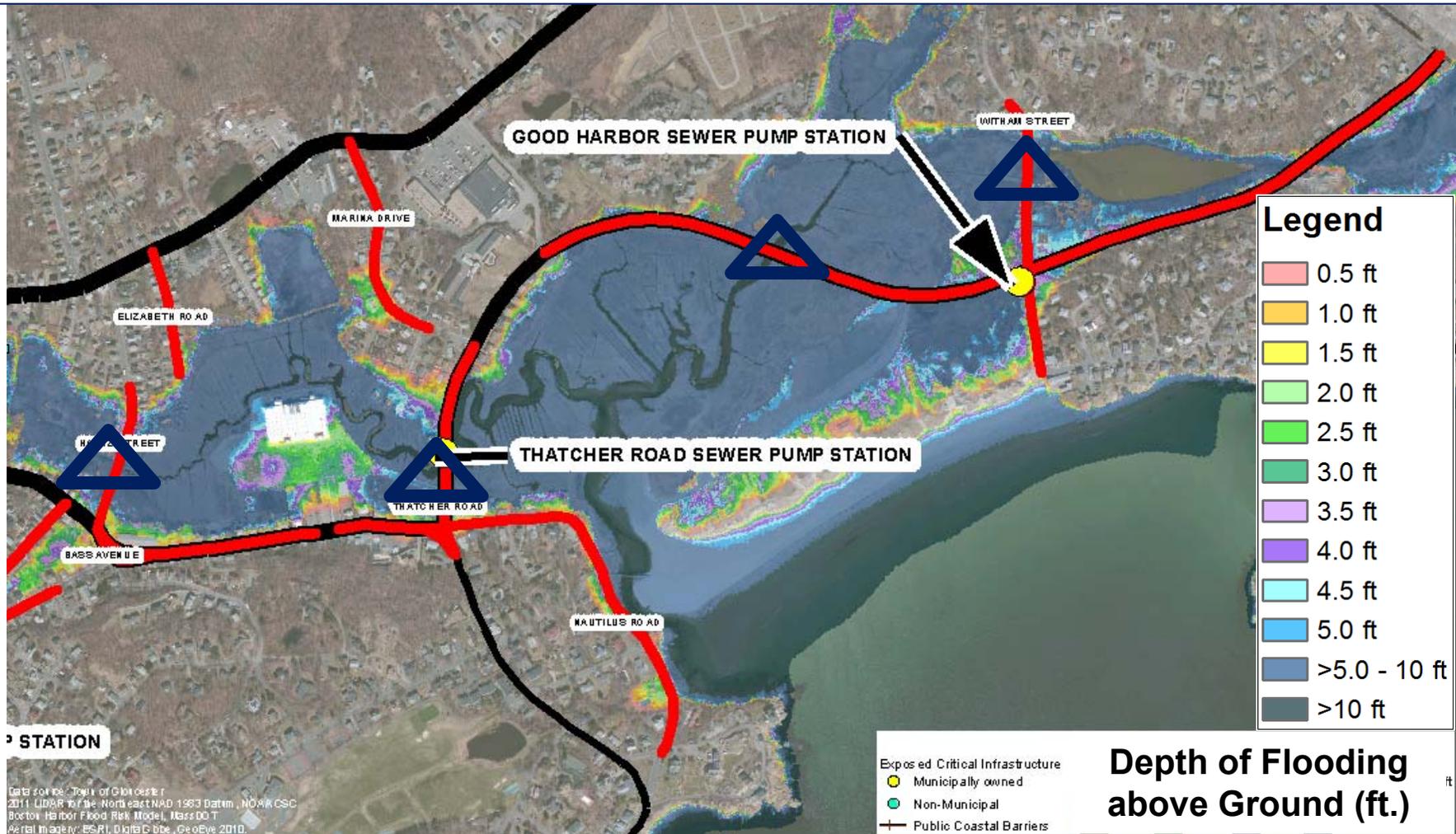
- DPW
- DPW PS
- Reynard St PS
- Hodgkins St PS
- Hodgkins St
- Veterans Way
- Poplar St
- Reynard St

Thatcher Road

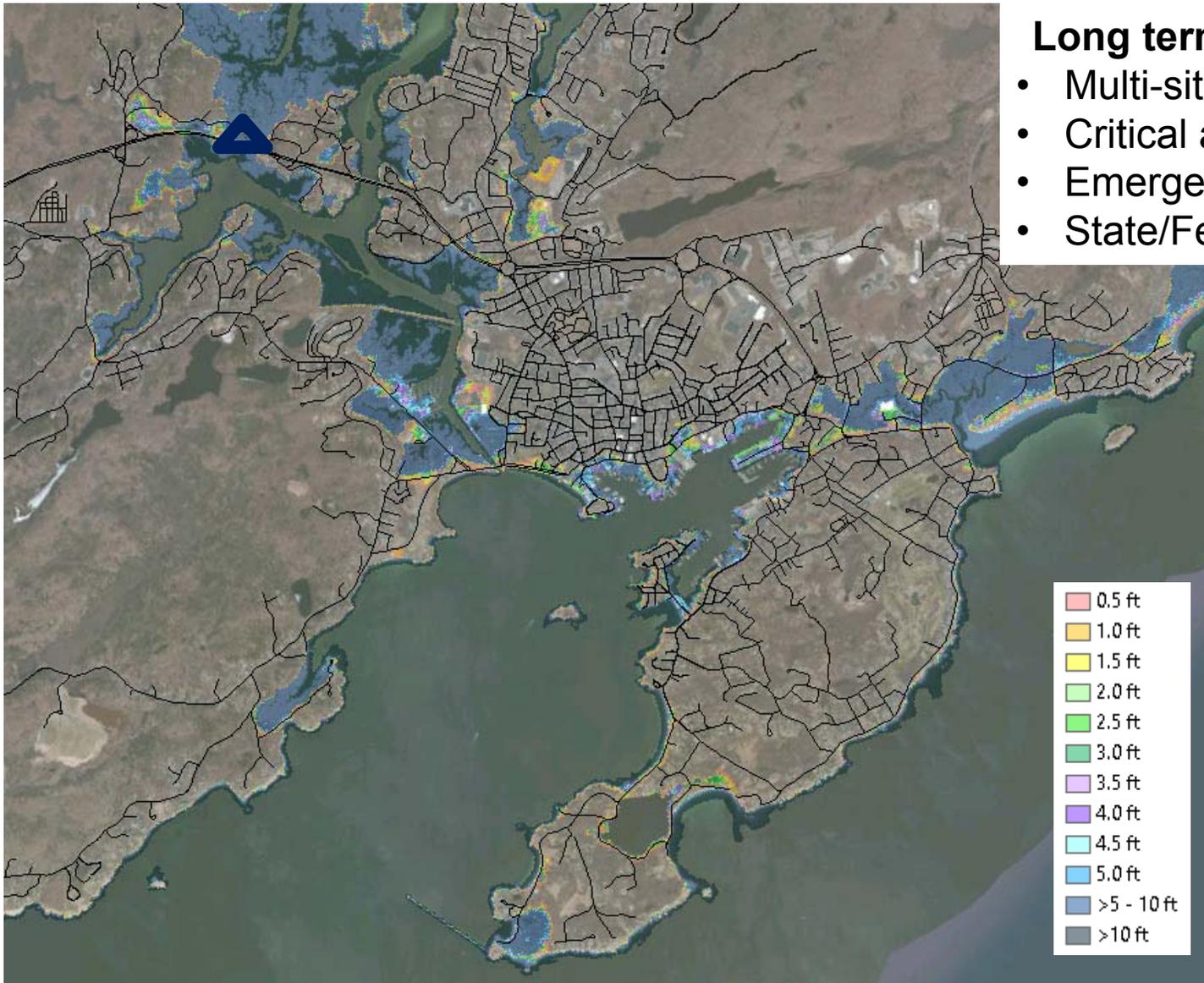
2030: 1% Annual Probability (≈100 yr Recurrence)



Raise Roads/Walls: Maintain access during/after a storm, protect upland properties
Tide Gates: Improve flood management and marsh health



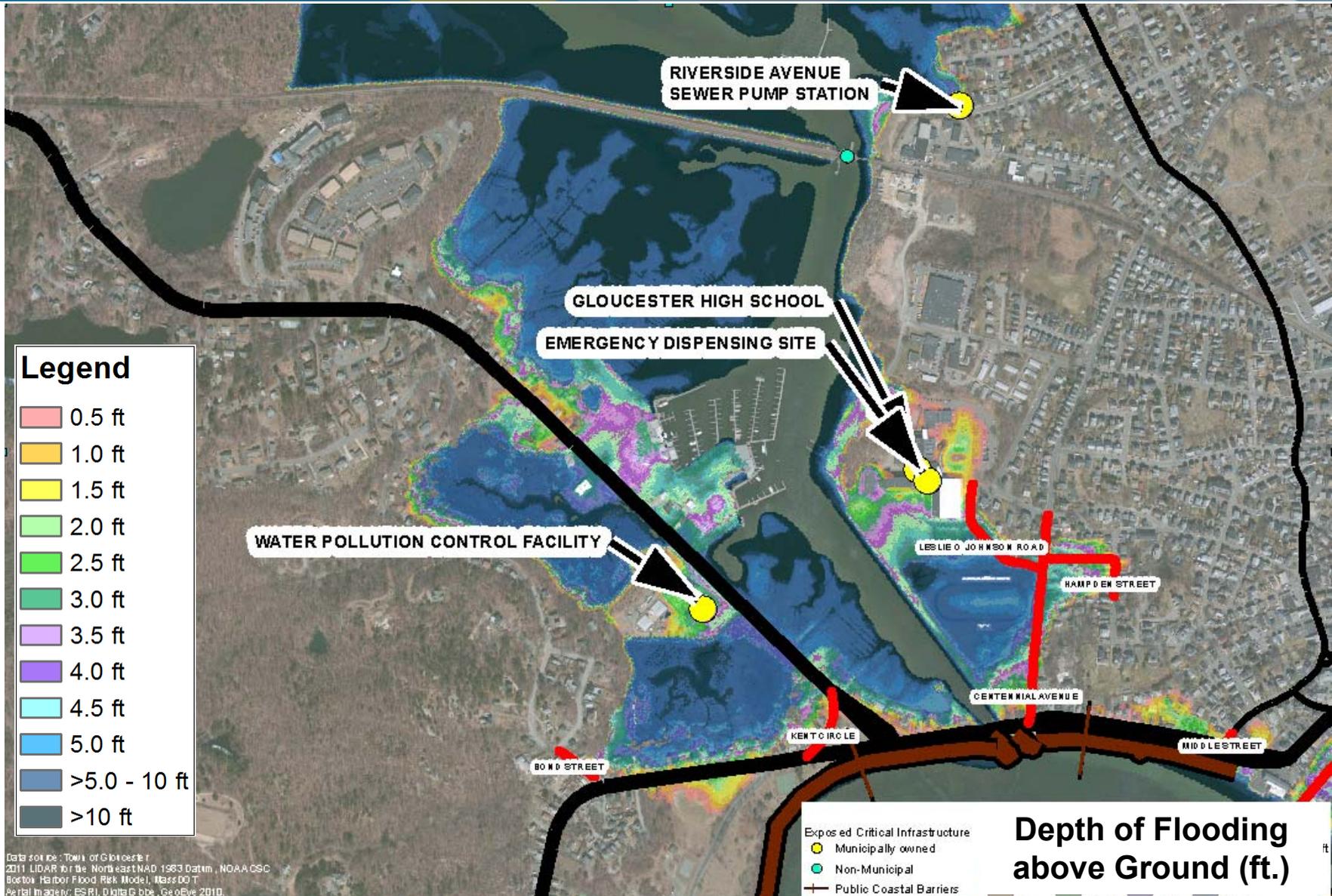
REGIONAL RISK MITIGATION

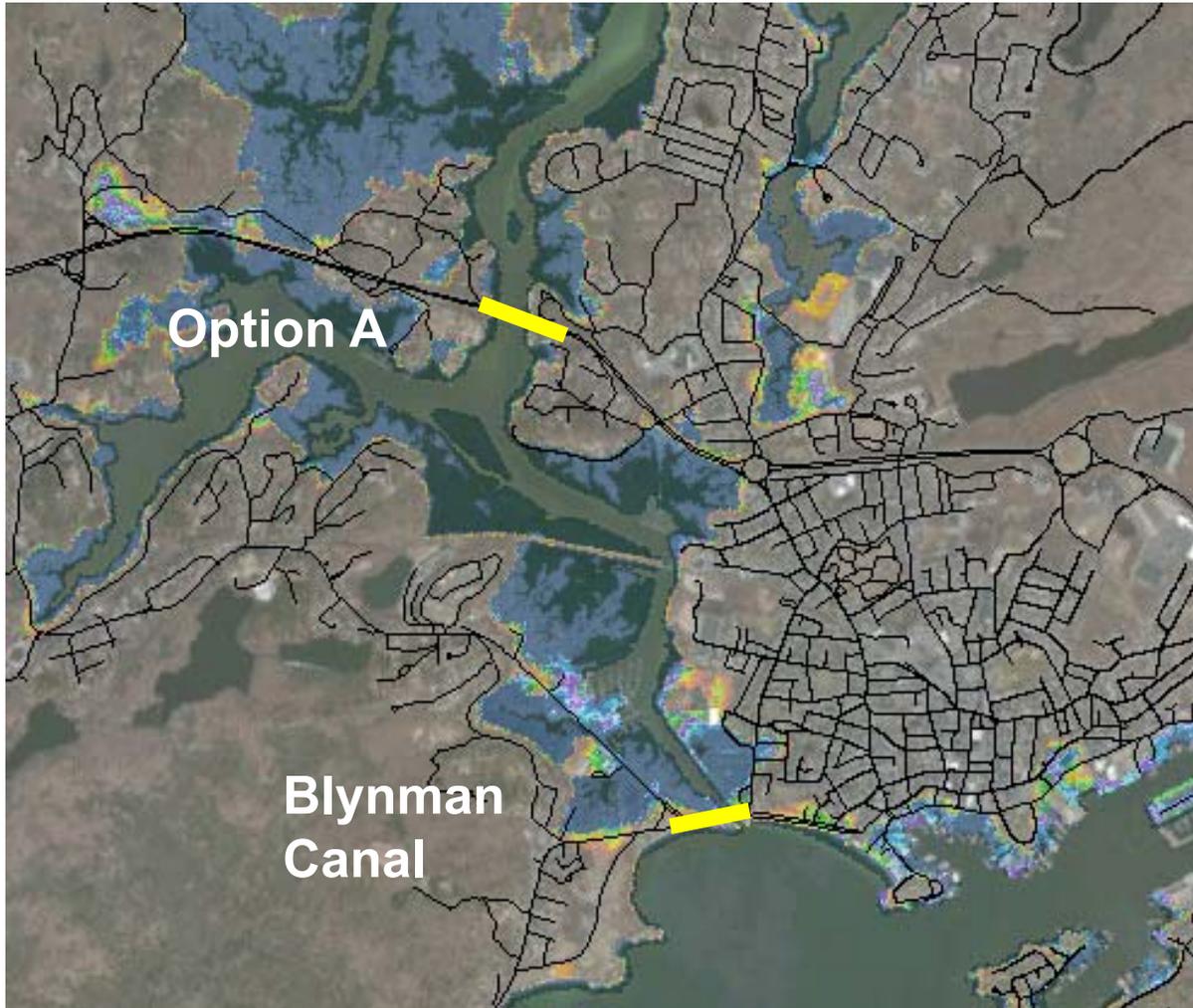


Long term strategy:

- Multi-site flood mgmt system
- Critical asset protection
- Emergency routes
- State/Federal funding

Lower Annisquam Floodplain 2070: 1% Annual Probability (≈100 yr Recurrence)



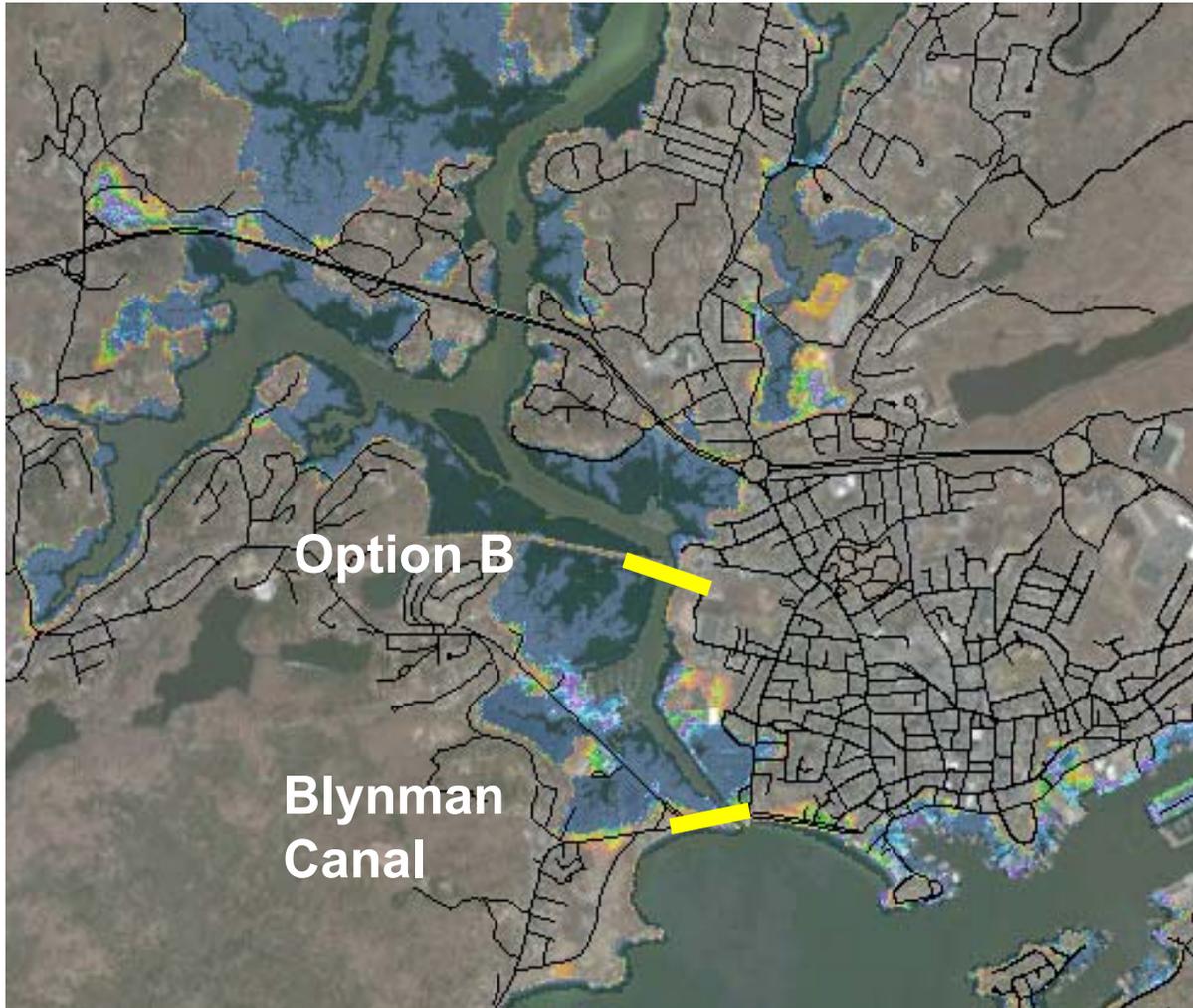


Recommendation:

Install lock gates at Blynman Canal, and Rt 128 at Annisquam River or Rail causeway, in concert with strategically raising roadway elevations and/or adding roadside walls

Protects City Assets:

- Water Pollution Control Facility
- High School/Emergency Dispensing Site
- Riverside Ave PS (if A2)
- Leslie O Johnson Rd
- Gaffney St
- Centennial Ave
- Kent Circle
- PLUS Rt 133, Rt 127



Recommendation:

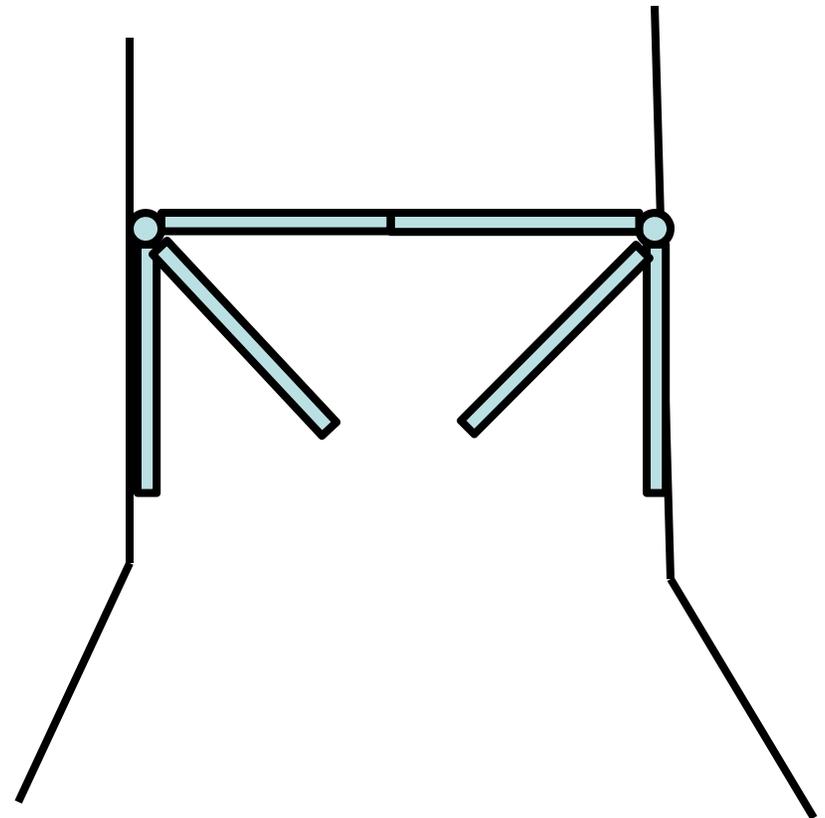
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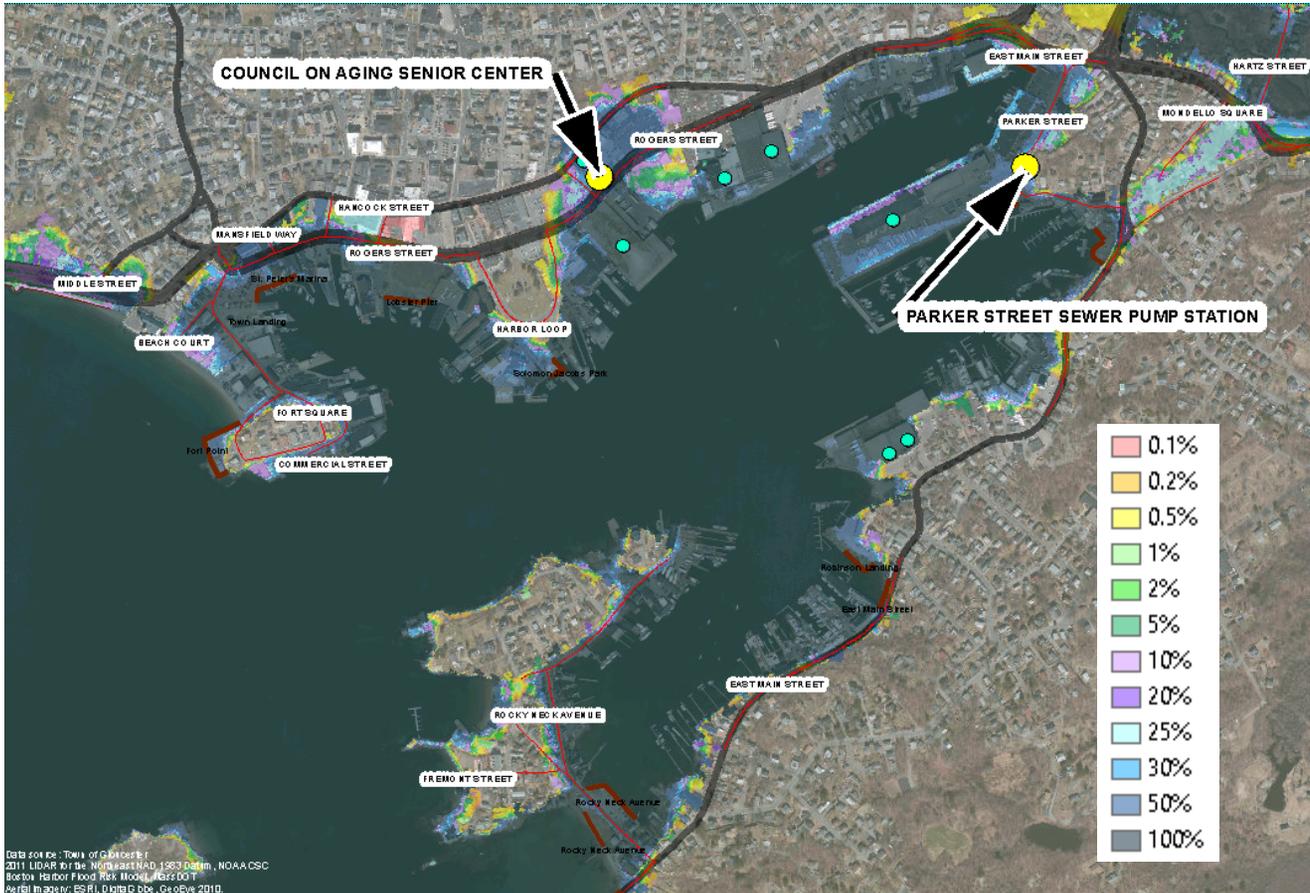
- Water Pollution Control Facility
- High School/Emergency Dispensing Site
- Riverside Ave PS (if A)
- Leslie O Johnson Rd
- Gaffney St
- Centennial Ave
- Kent Circle
- PLUS Rt. 133, Rt. 127



Rt. 127/Western Ave. at Blynman Canal



Lock Gate conceptual diagram



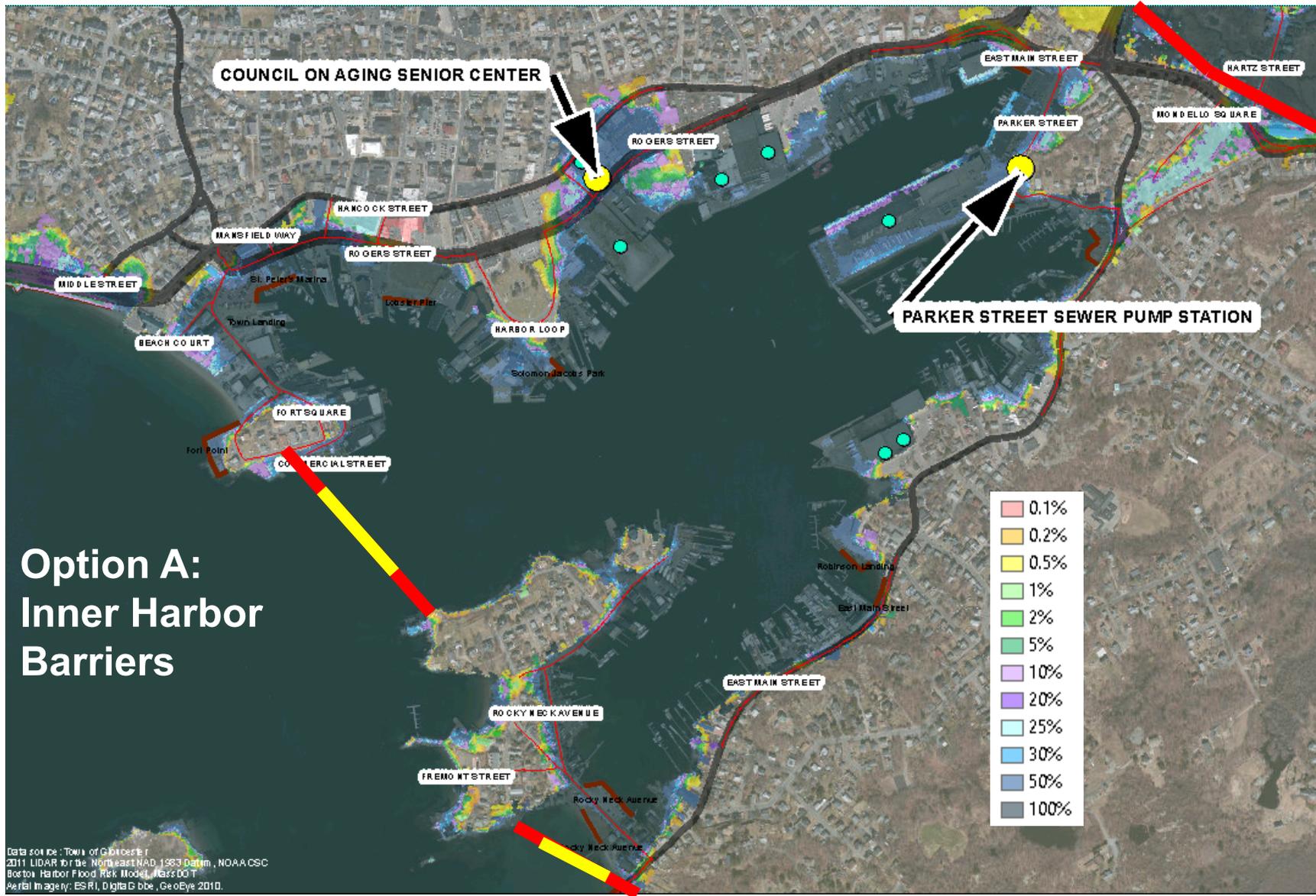
No Silver Bullet

- Largely private
- Public roads
- Mixed-owner barriers, non-continuous
- Senior Center
- Parker St PS

Incremental strategy

- Raise/floodproof public facilities over time (risk-based)
- Incentivize private floodproofing, raising wharves, raising and extending seawalls (e.g. betterments)

Inner Harbor - Hurricane Barrier



Outer Harbor – Hurricane Barrier



**Option B:
Outer Harbor
Barrier**

Hurricane Barrier Examples

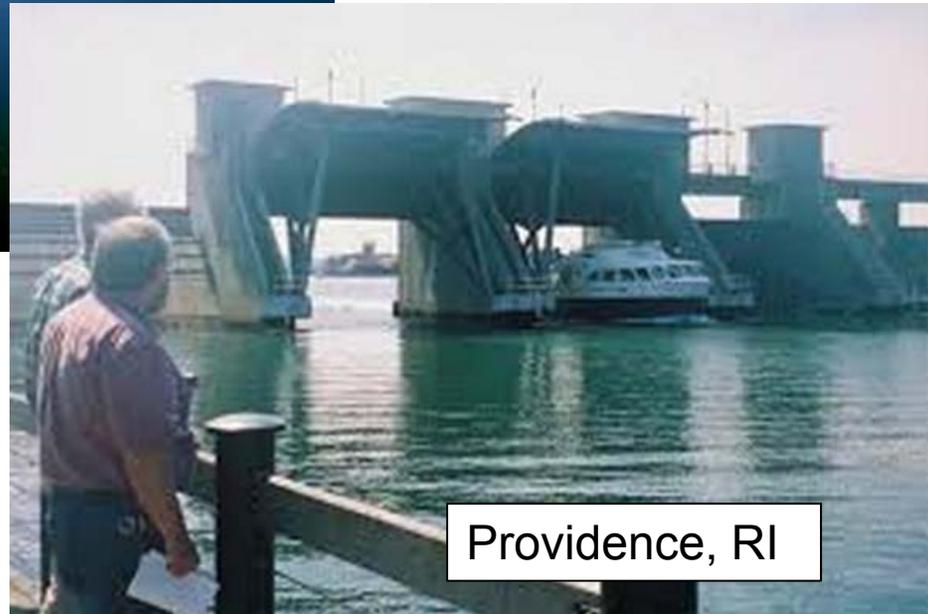
New Bedford, MA



Stamford, CT



Providence, RI



Folding Panel Barrier



Post-and-Beam Barrier



Door Flood Panel

