State Street Landing and Tucker's Wharf Resiliency Project

Coastal Flood Vulnerability and Conceptual Alternatives

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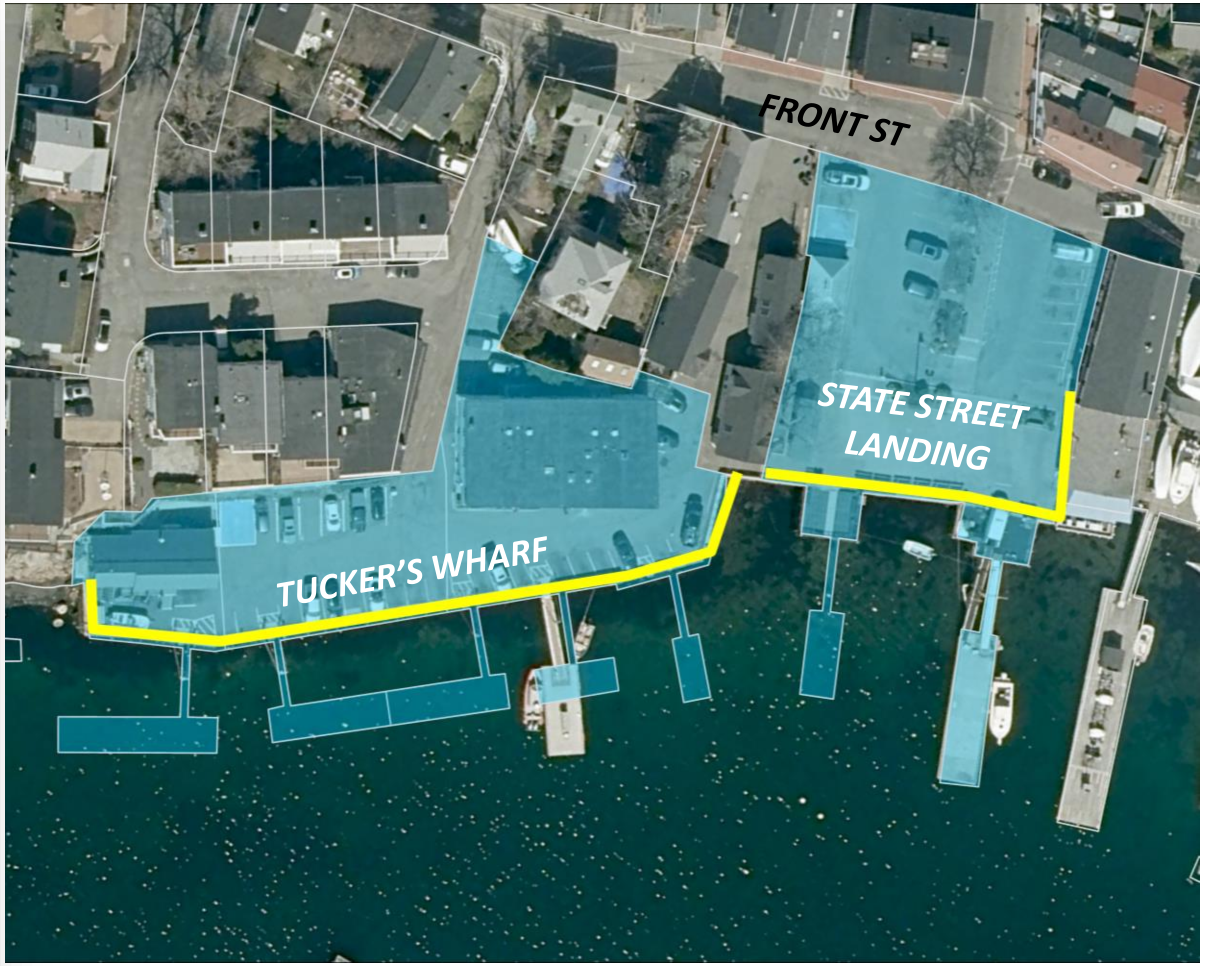

Project Overview

Where: State Street Landing and Tucker's Wharf

What: A project to develop resiliency alternatives for a Town-owned public wharf used for recreational and commercial water access, ending with a report and three concepts.

Why: Storms have inundated the site and damaged the seawall repeatedly in the recent past.

Who: Town of Marblehead, Salem Sound CoastWatch, Woods Hole Group, Collins Engineers, Massachusetts Office of Coastal Zone Management

When: Fall 2024 - June 30, 2025

Meeting Goals: *Review the results of the vulnerability assessment and receive feedback from the public on three conceptual alternatives.*

*Funding provided by Massachusetts Office of Coastal Zone Management with in-kind match funding provided by Salem Sound CoastWatch & Town of Marblehead

Scope of Work and Study Area

1) **Collect and Review Existing Information** - COMPLETE
   a) Gather licenses, drawings, and documentation
   b) Perform a site survey and draft existing conditions drawings
2) **Analyze the Site** - COMPLETE
   a) Perform a site-specific flood risk analysis
   b) Assess the seawall's condition and draft maintenance plan
3) **Draft Conceptual Alternatives** - COMPLETE
4) **Engage the Public** - ONGOING
5) **Refine Conceptual Alternatives** - ONGOING
   a) Incorporate performance analysis and public feedback
   b) Develop design drawings, cost estimates, and a permitting matrix

Vulnerability Assessment Tasks

- Asset Inventory
  - Critical Elevation Survey
- Review Flood Risk Modeling
  - Massachusetts Coast Flood Risk Model (MC-FRM)
  - Conduct Vulnerability Assessment
- Develop Design Flood Elevations (DFEs)
- Summary Memo

ACRONYMS:
MC-FRM – *Massachusetts Coast Flood Risk Model* - a hydrodynamic probabilistic model that describes coastal flood risk in Massachusetts in terms of annual chance of flooding under conditions predicted for 2030, 2050, and 2070 by a high sea level rise scenario.
DFE – *Design Flood Elevation* – an elevation recommended for a certain built feature in order to achieve a specific level of flood risk. DFEs can be calculated differently by a variety of sources, and then chosen for features such as a building or seawall based on risk tolerance and regulatory requirements.

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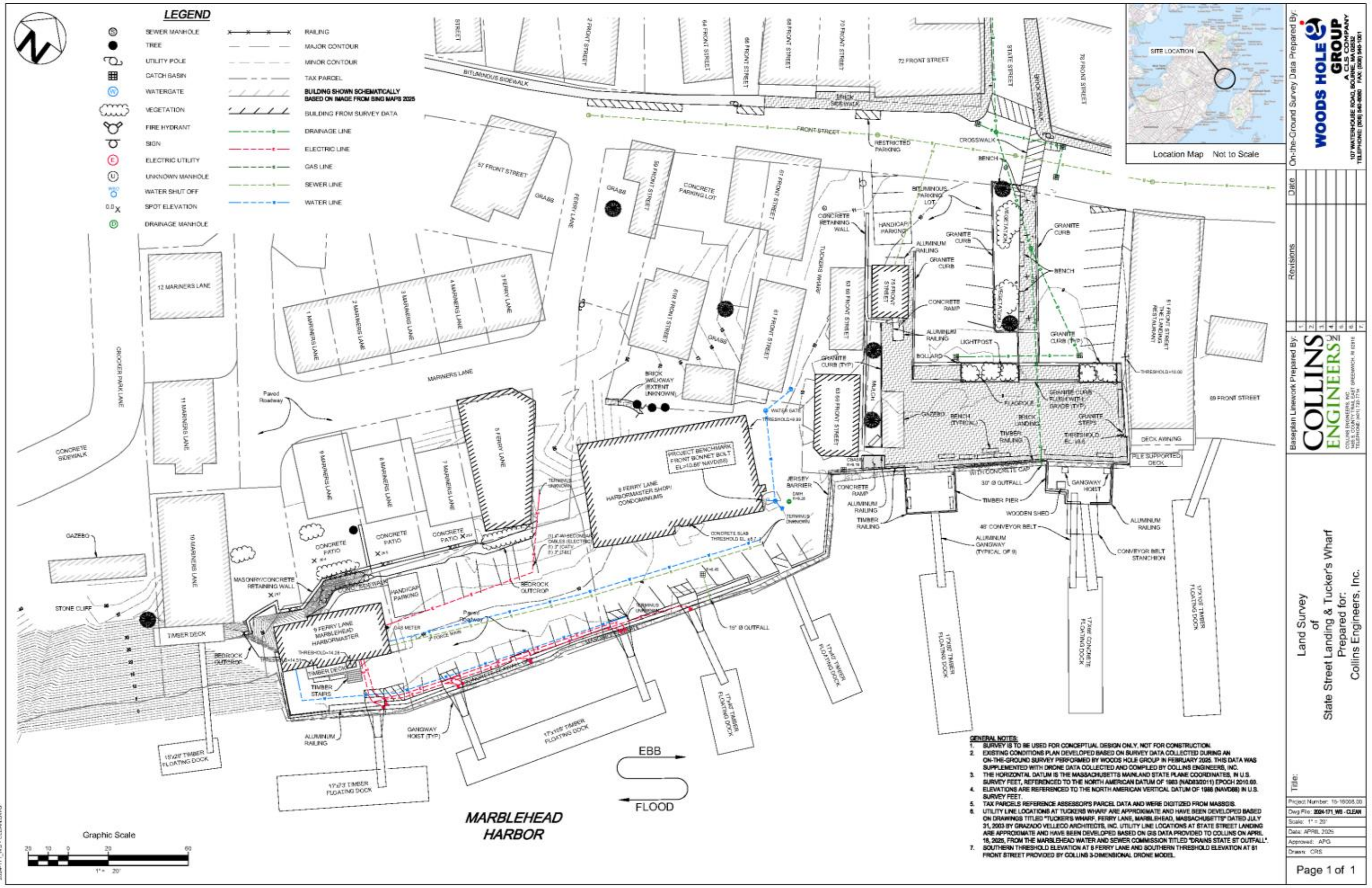
Asset Inventory and Topographic Survey

Documenting Elevations:

- Seawall
- Building Floors
- External Equipment (air conditioners, generators, etc.)

Asset	Critical Elevation (ft NAVD88)
HARBORMASTER’S OFFICE – FIRST FLOOR	14.4
HARBORMASTER’S OFFICE – AC UNIT	15.3
HARBORMASTER’S OFFICE – ELECTRICAL PANEL	16.9
CONDO BUILDING – FIRST FLOOR	13.3
CONDO BUILDING - BASEMENT	8.7
67 FRONT STREET	9.5
THE LANDING – STREET SIDE FINISHED FLOOR	10.3
THE LANDING – HARBOR SIDE FFE	9.8



Critical Elevation – the elevation where damage to an asset will begin if flood water reaches it.
NAVD88 – *North American Vertical Datum of 1988*– a control datum or “zero point” for elevations in North America. All elevations in this study reference NAVD88.

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Massachusetts Coast Flood Risk Model (MC-FRM)

INPUTS

SEA LEVEL RISE

TROPICAL / EXTRA-TROPICAL STORMS

LANDSCAPE

ELEVATION

CHANGING CLIMATE

PROBABILISTIC / HYDRODYNAMIC MODEL

Includes relevant physical processes: sea level rise, tides, storm surge, wind, wave setup / run-up / overtopping, future climate scenarios

FLOOD PROBABILITY

FLOOD DEPTH

FLOOD DURATION

FLOOD VOLUMES

FLOOD PATHWAYS

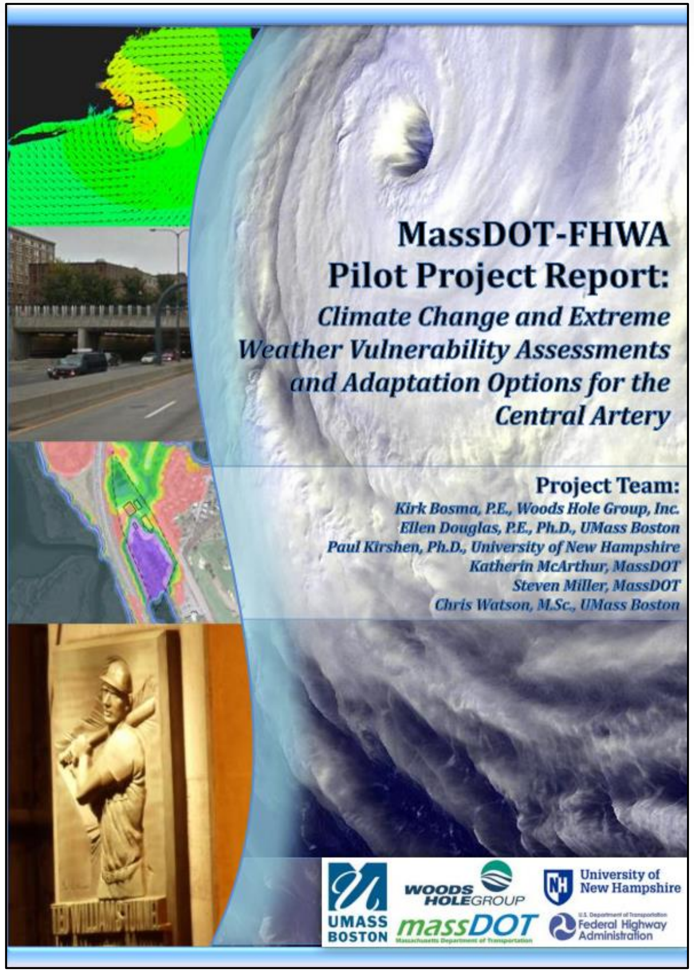
WINDS

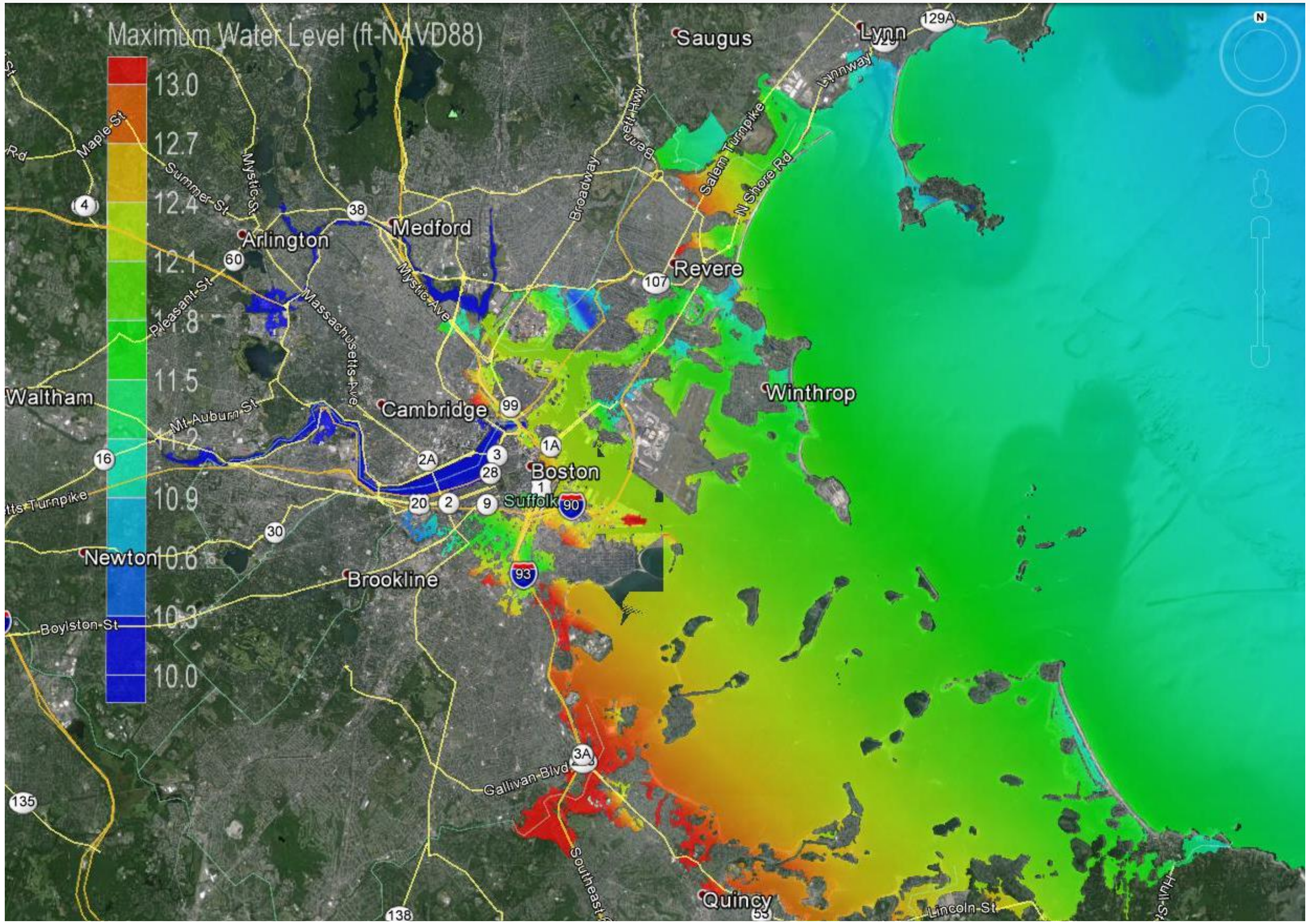
WAVES

CURRENTS

OUTPUTS

Why Hydrodynamic Modeling? Why Probabilistic?





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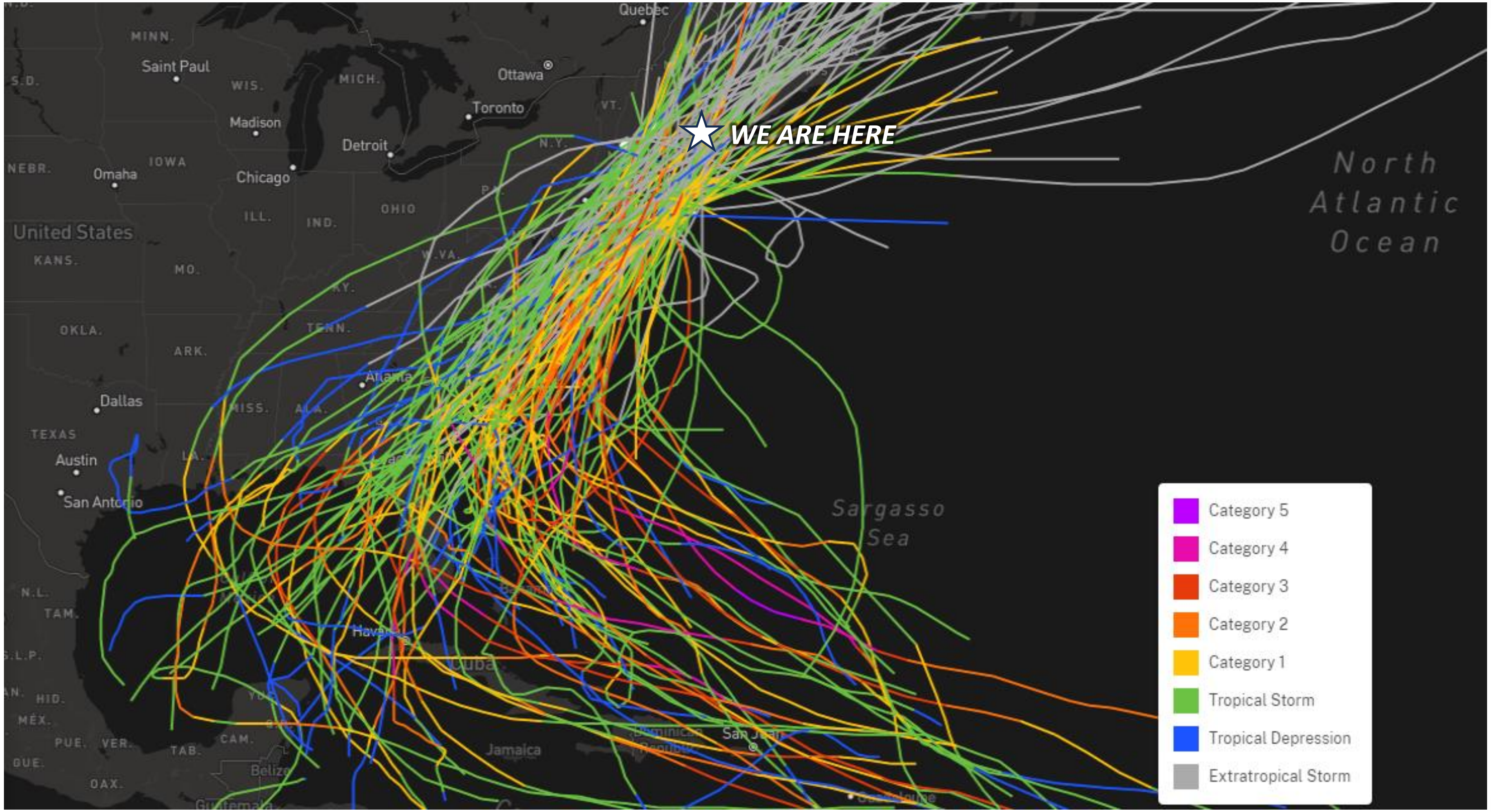
Tropical and Extratropical Storms



NOAA National Ocean Service

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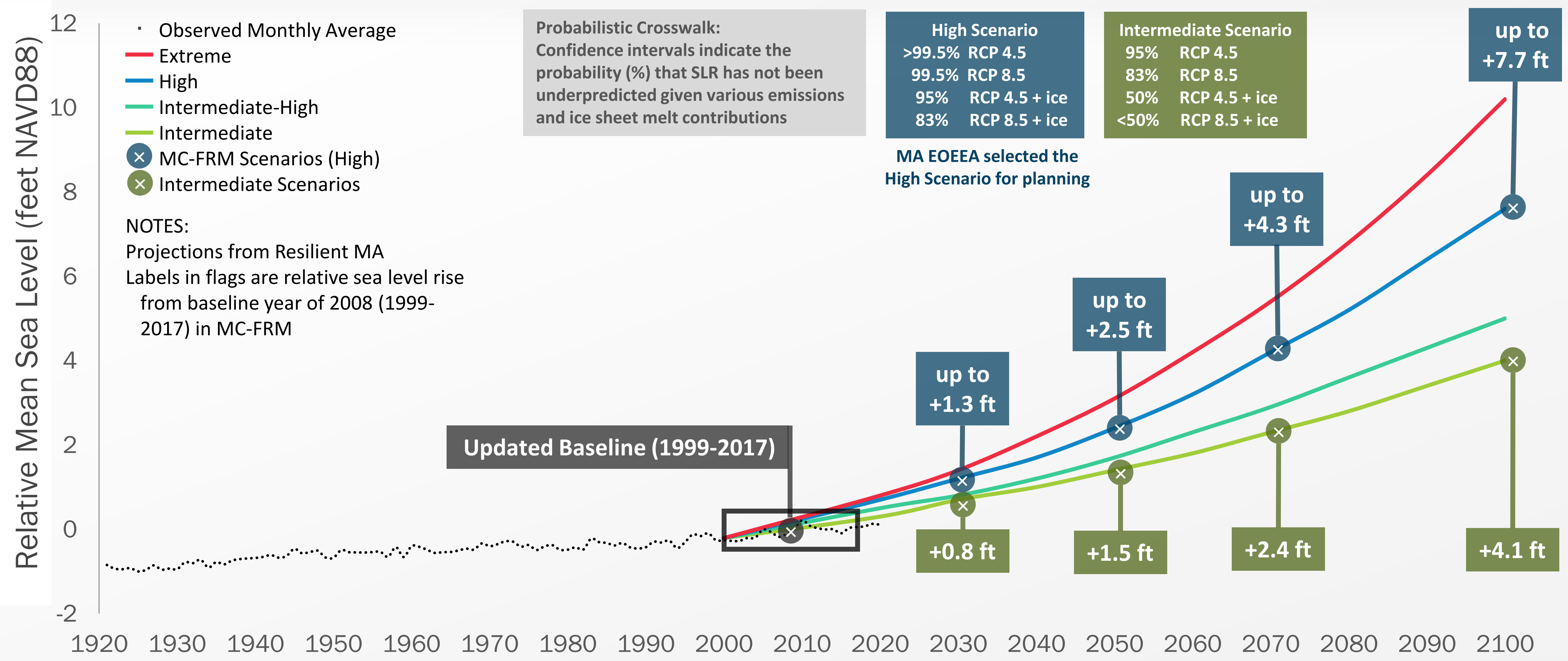
MA EOEEA Probabilistic Sea Level Rise Projections

MC-FRM NORTH (DeConto & Kopp, 2017)



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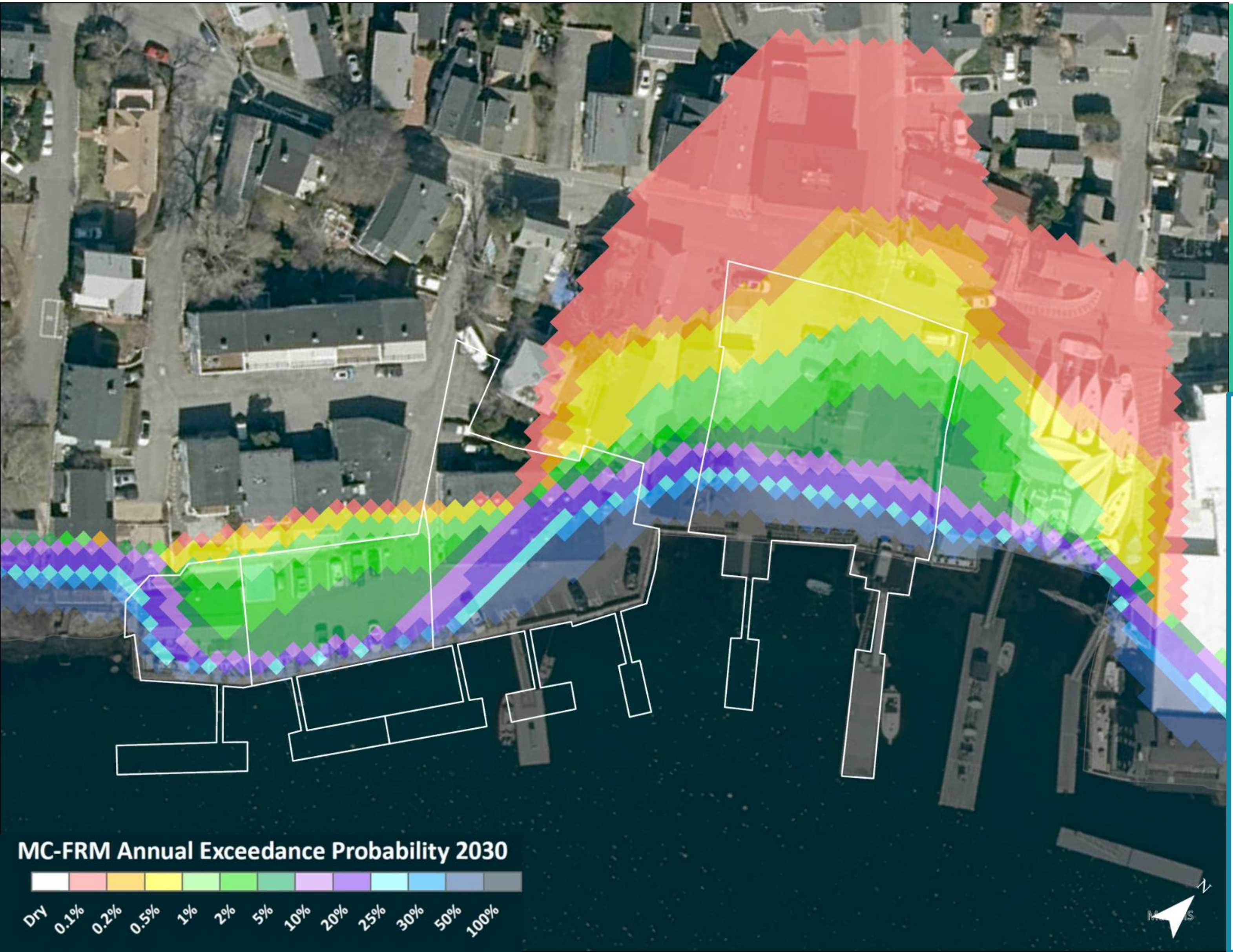
2030 MC-FRM Annual Exceedance Probability (AEP)

1.3’ Sea Level Rise (SLR) from 2008 baseline



- “as soon as 2030”
- Varying annual probability from 100% - 0.1% across the site
- Does not include wave overtopping or precipitation

MC-FRM – *Massachusetts Coast Flood Risk Model* - a hydrodynamic probabilistic model that describes coastal flood risk in Massachusetts in terms of annual chance of flooding under conditions predicted for 2030, 2050, and 2070 by a high sea level rise scenario.

AEP – *Annual (Coastal Flood) Exceedance Probability* – the probability that at least one storm event will flood an area or building in one year.

SLR – *Sea Level Rise* – a global phenomenon of rising average sea level due to climate change driven expansion of sea water and introduction of meltwater from glaciers and ice sheets. Sea level rise in this presentation references Boston Harbor, and has been locally adjusted to reflect land subsidence.

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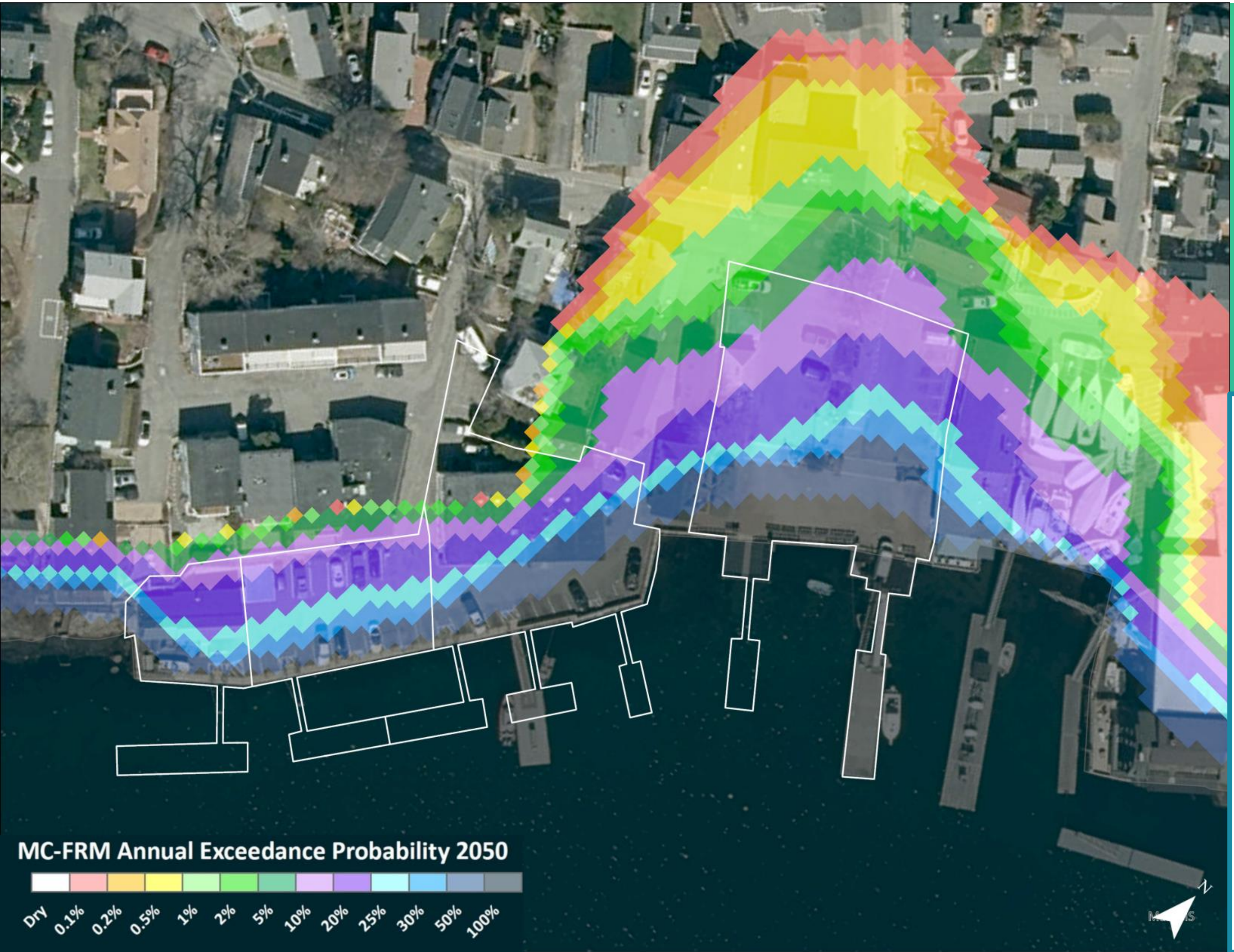
2050 MC-FRM Annual Exceedance Probability (AEP)

2.5' Sea Level Rise (SLR) from 2008 baseline



- "as soon as 2050"
- Varying annual probability from 100% - 1% across the site
- Does not include wave overtopping or precipitation

MC-FRM – *Massachusetts Coast Flood Risk Model* - a hydrodynamic probabilistic model that describes coastal flood risk in Massachusetts in terms of annual chance of flooding under conditions predicted for 2030, 2050, and 2070 by a high sea level rise scenario.
AEP – *Annual (Coastal Flood) Exceedance Probability* – the probability that at least one storm event will flood an area or building in one year.
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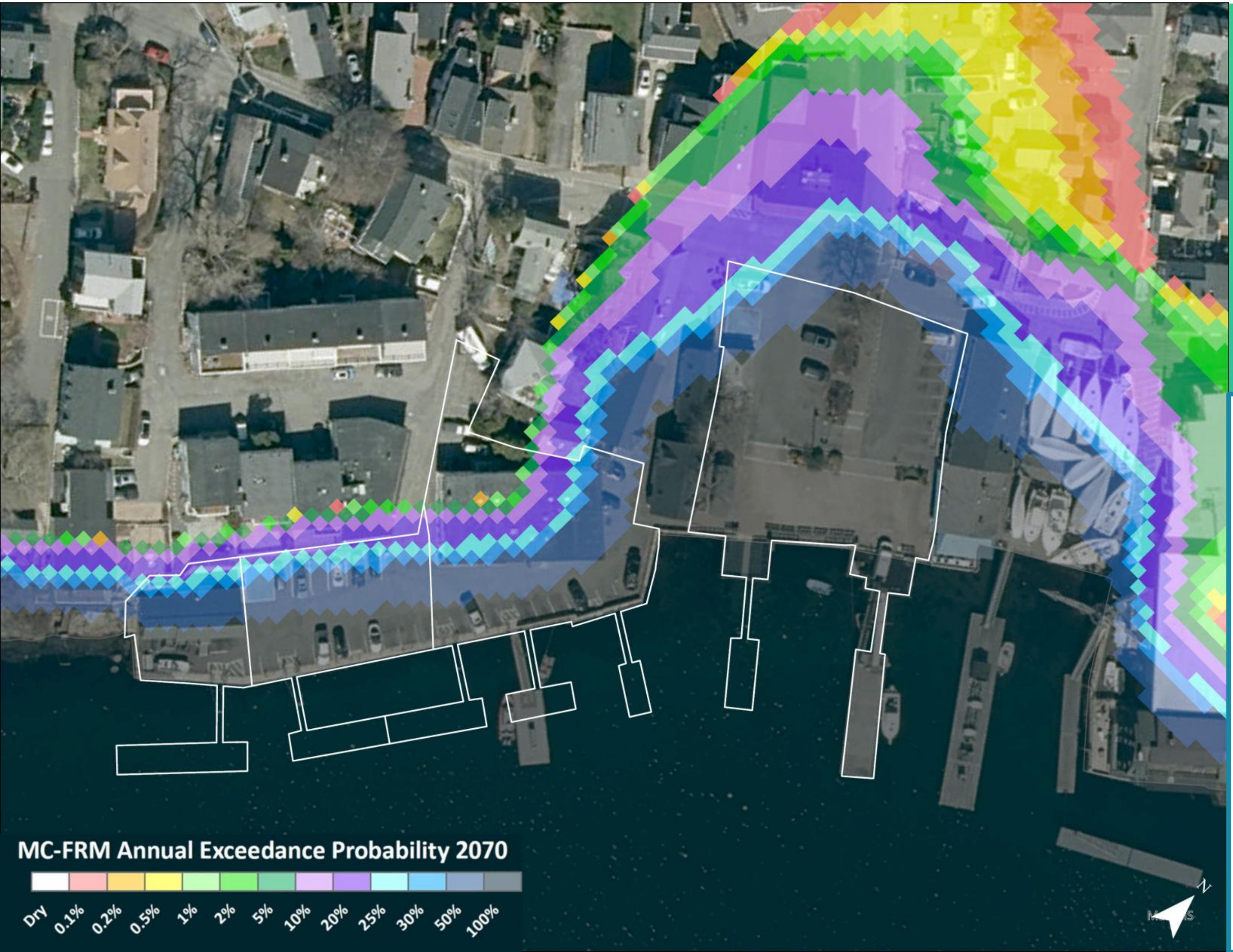
2070 MC-FRM Annual Exceedance Probability (AEP)
4.3' Sea Level Rise (SLR) from 2008 baseline



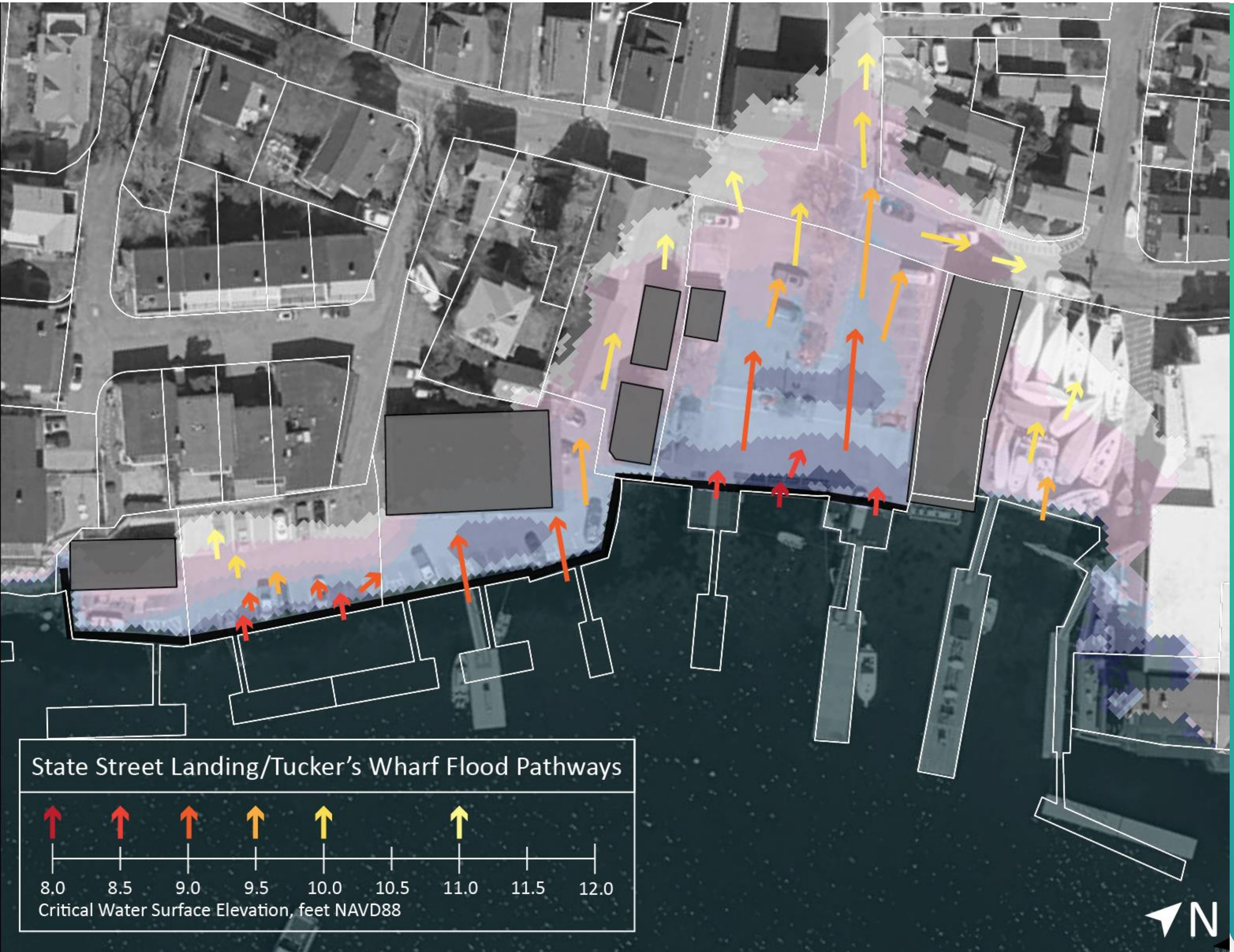
- "as soon as 2070"
- Varying annual probability from 100% - 20% across the site
- Does not include wave overtopping or precipitation

MC-FRM – *Massachusetts Coast Flood Risk Model* - a hydrodynamic probabilistic model that describes coastal flood risk in Massachusetts in terms of annual chance of flooding under conditions predicted for 2030, 2050, and 2070 by a high sea level rise scenario.

AEP – *Annual (Coastal Flood) Exceedance Probability* – the probability that at least one storm event will flood an area or building in one year.

SLR – *Sea Level Rise* – a global phenomenon of rising average sea level due to climate change driven expansion of sea water and introduction of meltwater from glaciers and ice sheets. Sea level rise in this presentation references Boston Harbor, and has been locally adjusted to reflect land subsidence.

Flood Pathways



- Water enters State Street Landing before Tucker's Wharf
- Flood pathway is limited to Front Street/State Street Intersection
- Waves are not accounted for

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Mean High Water (MHW) Vulnerability

- Mean High Water condition occurs approximately twice every day
- Everyday use disrupted as soon as 2070

MHW – *Mean High Water* – the average elevation of all high tides in a specific place over a 19-year tidal epoch.

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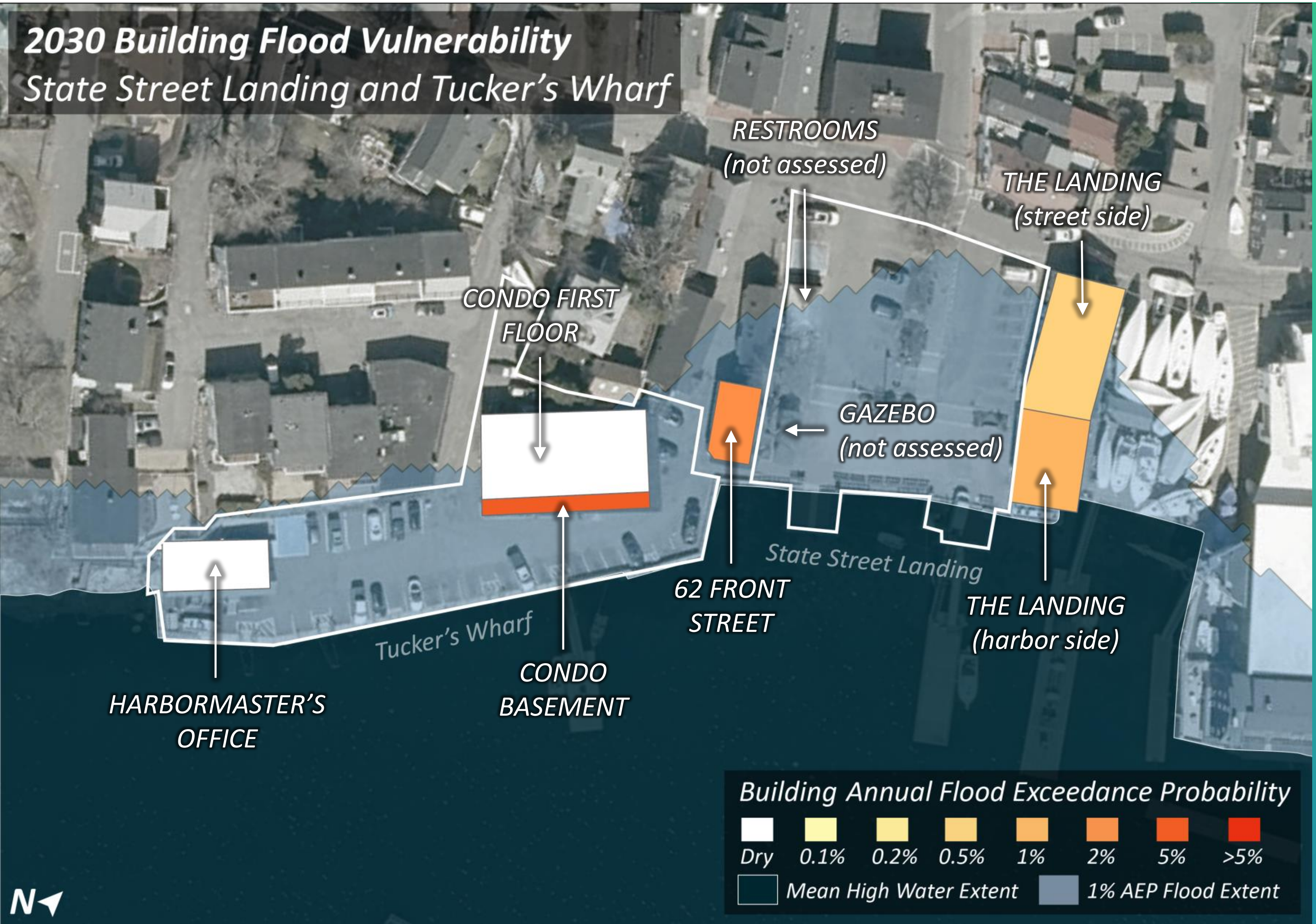
Vulnerability Assessment Results



- Negligible flood probability for Harbormaster and Condo first floor
- 5% AEP for Condo basement

AEP – *Annual (Coastal Flood) Exceedance Probability* – the probability that at least one storm event will flood an area or building in one year.

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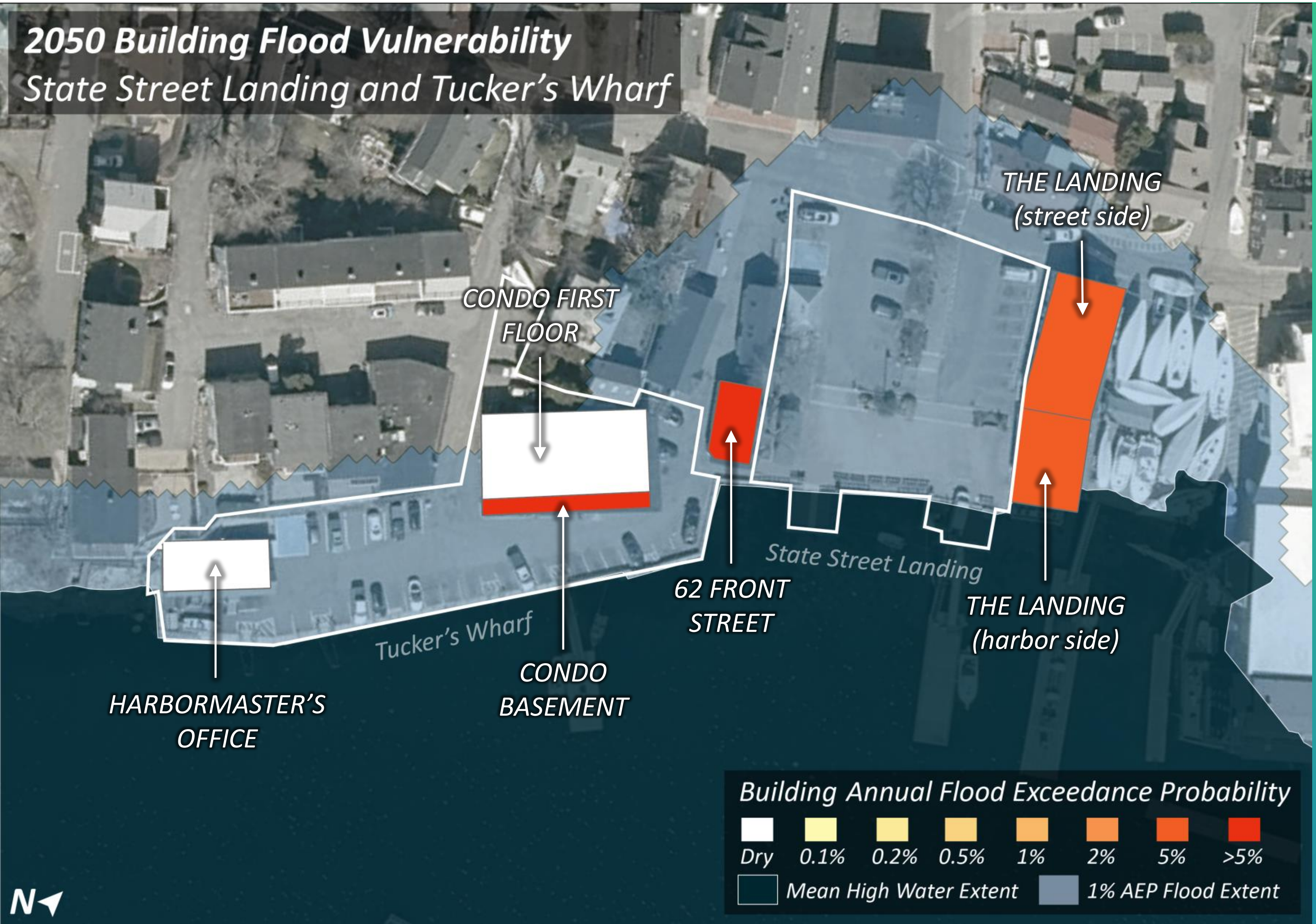
Vulnerability Assessment Results



- Negligible flood probability for Harbormaster and Condo first floor
- >5% AEP for Condo basement

AEP – *Annual (Coastal Flood) Exceedance Probability* – the probability that at least one storm event will flood an area or building in one year.

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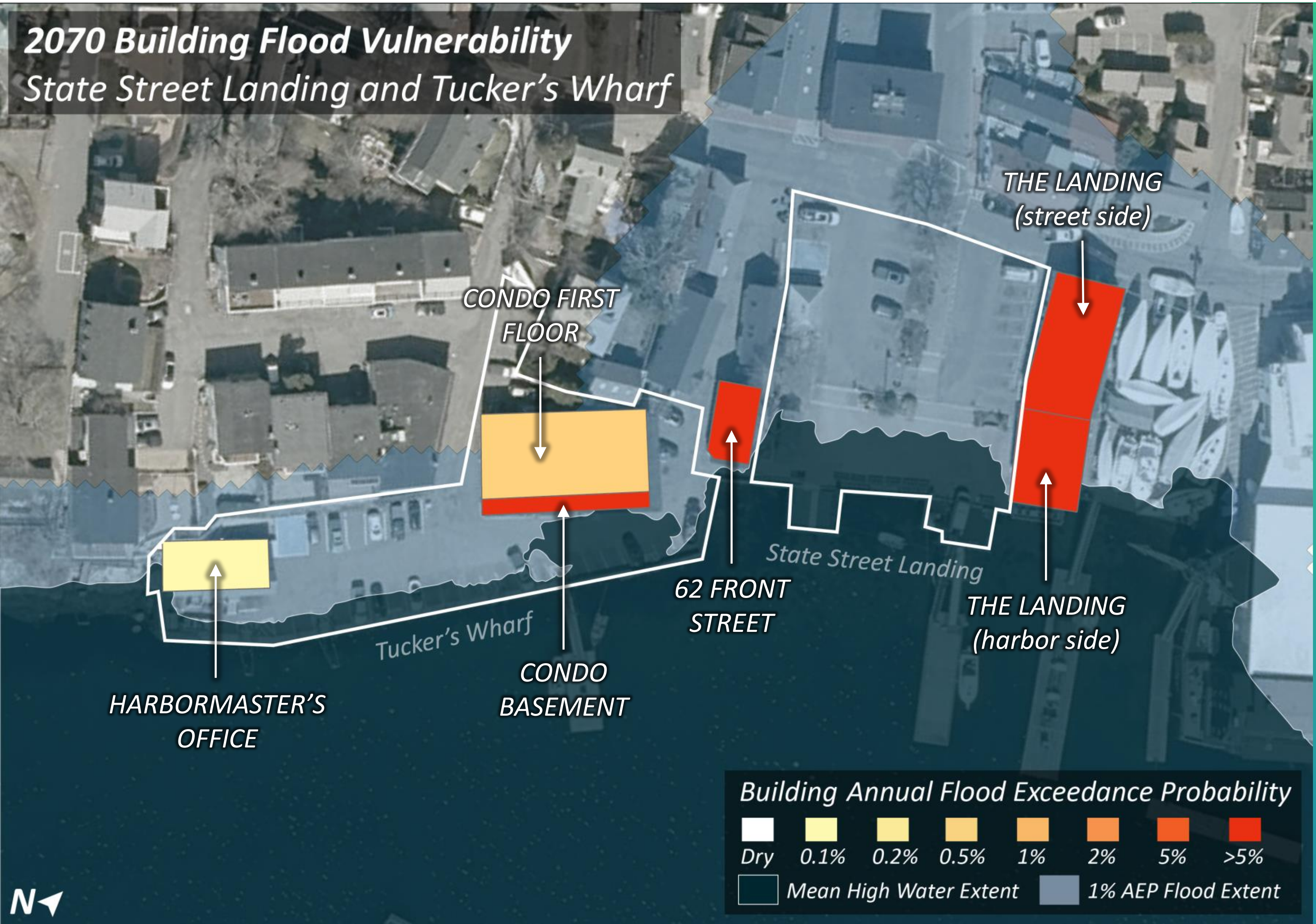
Vulnerability Assessment Results



- 0.1% annual flood probability for Harbormaster
- 0.5% annual flood probability for Condo first floor
- MHW vulnerability for Condo basement

AEP – *Annual (Coastal Flood) Exceedance Probability* – the probability that at least one storm event will flood an area or building in one year.

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Vulnerability Assessment Results

Asset	*Critical Elevation (ft NAVD88)*	*2030 AEP*	*2050 AEP*	*2070 AEP*
HARBORMASTER'S OFFICE – FIRST FLOOR	***14.4***	**0%**	**0%**	**0.1%**
HARBORMASTER'S OFFICE – AC UNIT	***15.3***	**0%**	**0%**	**0%**
HARBORMASTER'S OFFICE – ELECTRICAL PANEL	***16.9***	**0%**	**0%**	**0%**
CONDO BUILDING – FIRST FLOOR	***13.3***	**0%**	**0%**	**0.5%**
CONDO BUILDING - BASEMENT	***8.7***	**5%**	**>5%**	**MHW**
67 FRONT STREET	*9.5*	2%	>5%	>5%
THE LANDING – STREET SIDE FFE	*10.3*	0.5%	5%	>5%
THE LANDING – HARBOR SIDE FFE	*9.8*	1%	5%	>5%

Critical Elevation – the elevation where damage to an asset will begin if flood water reaches it.
NAVD88 – *North American Vertical Datum of 1988*– a control datum or "zero point" for elevations in North America. All elevations in this study reference NAVD88.
AEP – *Annual (Coastal Flood) Exceedance Probability* – the probability that at least one storm event will flood an area or building in one year.

Key Takeaways: Flood Vulnerability

- The project area is highly vulnerable to coastal flooding.
  - Parking lots are expected to flood at least once per year in the near term and at least once per day as soon as 2070 if no changes are made.

- Buildings within the project area have varying levels of vulnerability to coastal flooding.
  - The Condo basement is highly vulnerable to flooding in the near term (> 5% annual chance as soon as 2030), with increasing vulnerability as time goes on
    - It could be inundated chronically as soon as 2070
  - The Harbormaster's Office and Condo first floor have little to no flood vulnerability until the 2070 time horizon.

- Waves splash over the wall and contribute to the volume of flood water behind the wall in small storms.
  - In larger storms, water flows freely over the wall, and the contribution of waves splashing over is not important

- Waves currently damage the wall, and could cause more damage in the future.

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Conceptual Alternatives - Seawall

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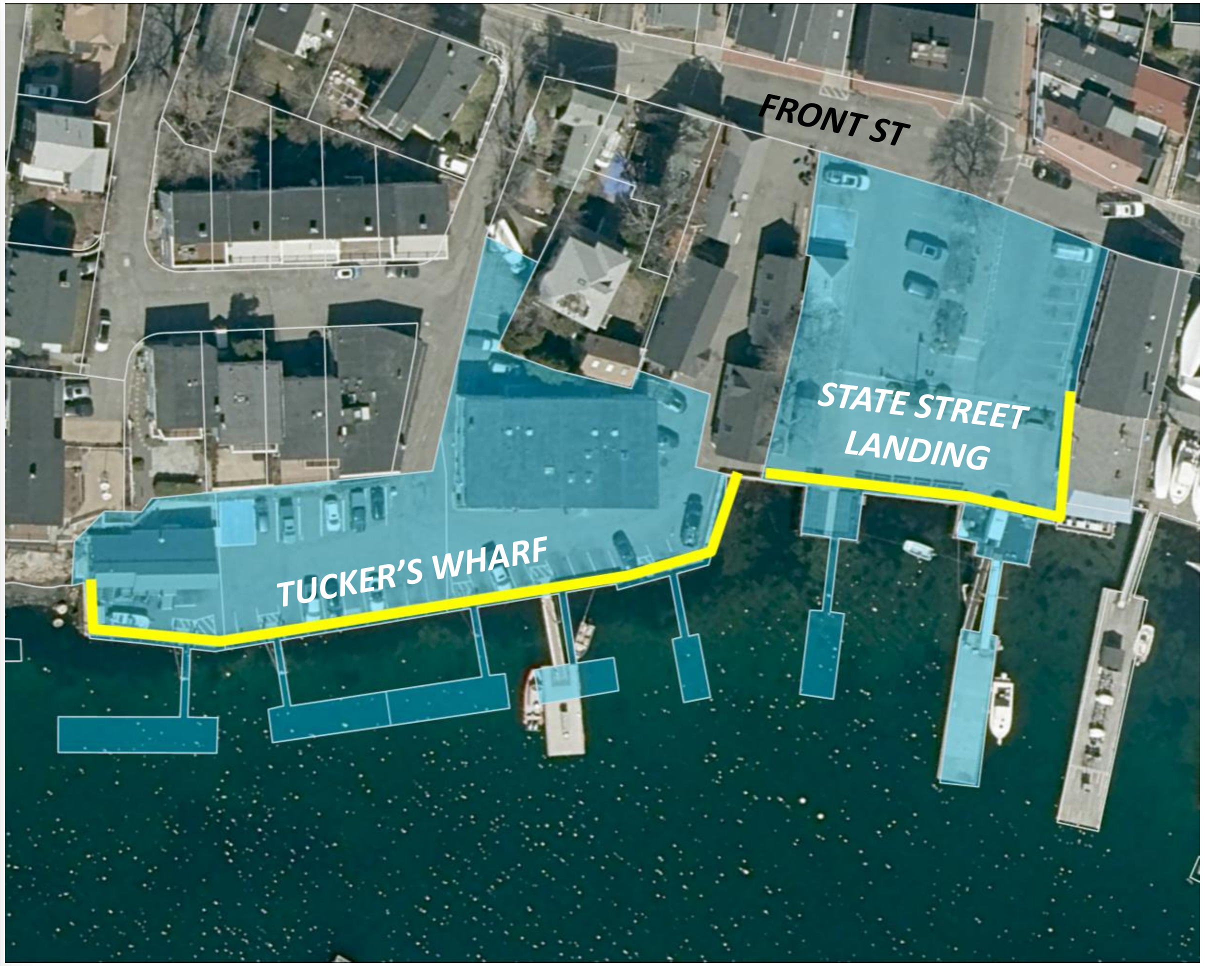

Design Flood Elevations – Results

Asset Name	Critical Elevation (ft NAVD88)	RMAT Year + AEP	RMAT DFE (ft NAVD88)		MC-FRM Stillwater Water Surface Elevation (ft NAVD88)				MC-FRM DFE (ft NAVD88)				Massachusetts Building Code DFE (ft NAVD88)
			2050	*2070*	*2050 2%*	*2050 1%*	*2070 2%*	*2070 1%*	*2050 2%*	*2050 1%*	*2070 2%*	*2070 1%*	
Harbormaster's Office	14.4	2070 1%	12.2	14.4	11.1	11.5	12.9	13.3	11.3	11.9	13.4	14	19
Condo First Floor	13.3	2070 2%	11.7	13.9	11.1	11.5	12.9	13.3	11.3	11.7	13.1	13.7	14
Condo Basement	8.7	2070 2%	11.7	13.9	11.1	11.5	12.9	13.3	11.3	11.7	13.1	13.7	14
Seawall	**~8.0**	**2070**	**-**	**-**	**11.1**	**11.5**	**12.9**	**13.3**	**12.6**	**13**	**14.9**	**15.5**	**-**

Building Code supersedes all other building DFEs, seawall DFEs were chosen by balancing site conditions and target risk level.

Critical Elevation – the elevation where damage to an asset will begin if flood water reaches it.
NAVD88 – *North American Vertical Datum of 1988*– a control datum or "zero point" for elevations in North America. All elevations in this study reference NAVD88.
RMAT – *Resilient Massachusetts Action Tool* – the official tool for determining target risk levels and elevations for state-funded projects in Massachusetts.
AEP – *Annual (Coastal Flood) Exceedance Probability* – the probability that at least one storm event will flood an area or building in one year.
DFE – *Design Flood Elevation* – an elevation recommended for a certain built feature in order to achieve a specific level of flood risk. DFEs can be calculated differently by a variety of sources, and then chosen for features such as a building or seawall based on risk tolerance and regulatory requirements.
MC-FRM – *Massachusetts Coast Flood Risk Model* - a hydrodynamic probabilistic model that describes coastal flood risk in Massachusetts in terms of annual chance of flooding under conditions predicted for 2030, 2050, and 2070 by a high sea level rise scenario.

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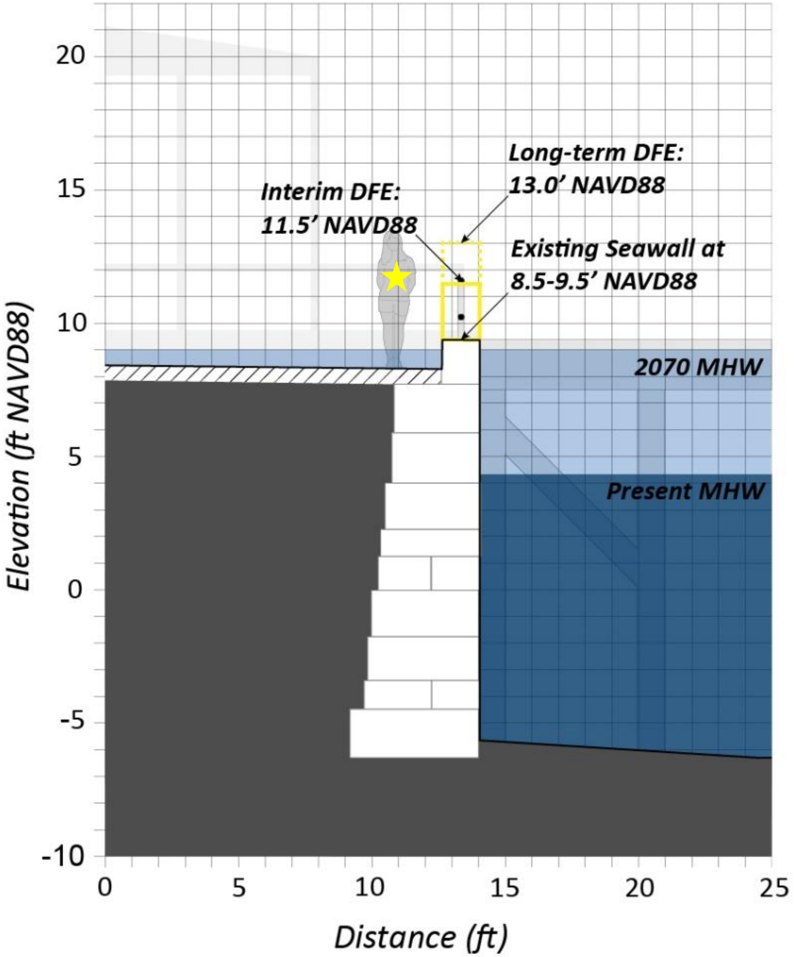
Existing Conditions

Site elevations: yellow areas are higher than interim DFE, red areas are higher than long term DFE.



DFE – *Design Flood Elevation* – an elevation recommended for a certain built feature in order to achieve a specific level of flood risk. DFEs can be calculated differently by a variety of sources, and then chosen for features such as a building or seawall based on risk tolerance and regulatory requirements.

Seawall cap is 8.5-9.5' NAVD88
Interim DFE: 11.5' NAVD88
Long Term DFE: 13.0' NAVD88

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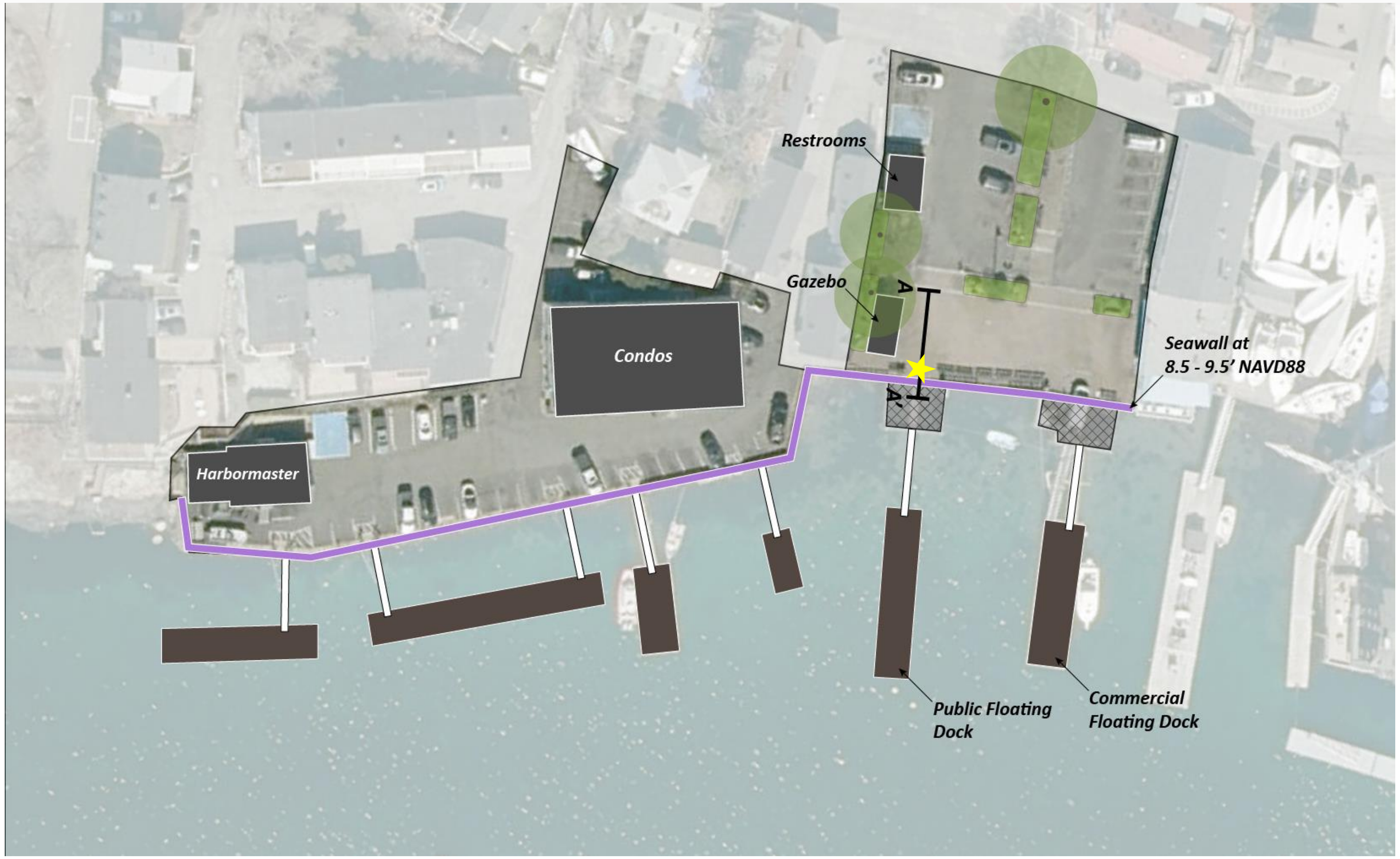
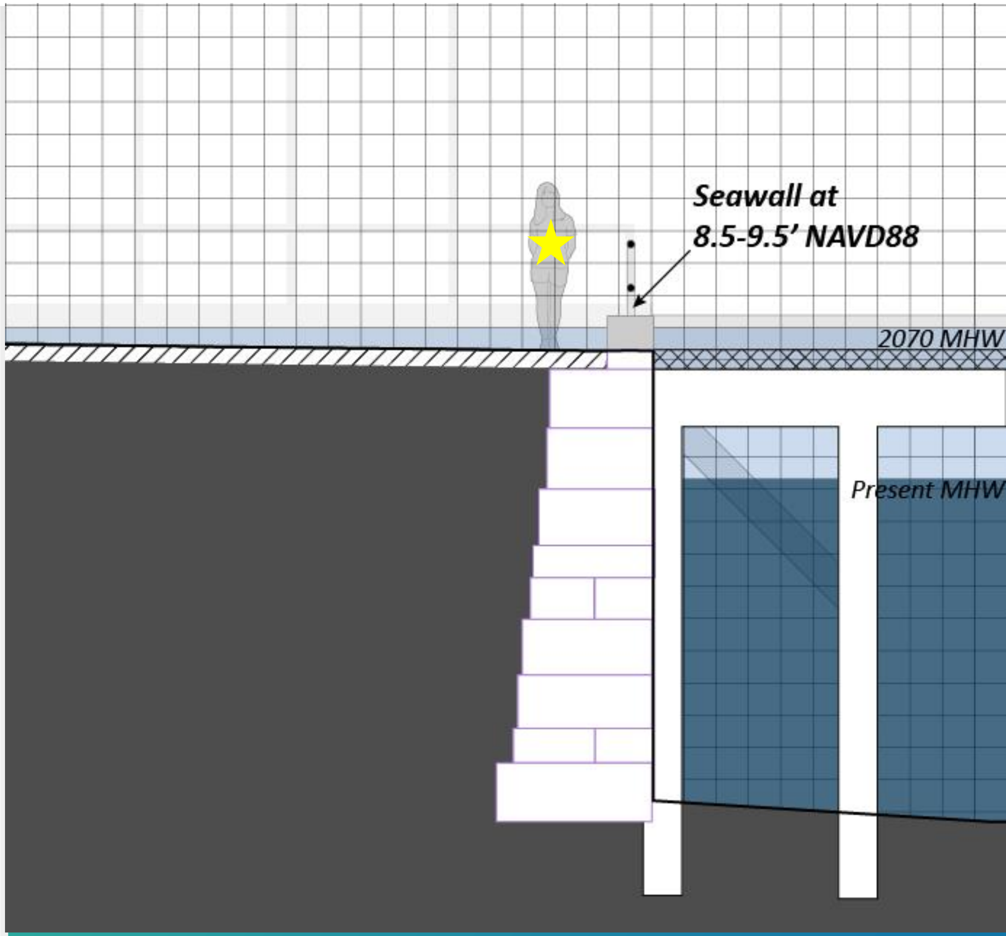
Existing Conditions



Seawall Elevation (ft NAVD88)	MHW vulnerability	Approx Stillwater AEP as soon as 2050	Approx Sig. Wave AEP as soon as 2050
8.5	*As soon as 2070*	*>5%*	*>5%*



Seawall cap: 8.5-9.5' NAVD88
Land behind seawall: ~8.0' NAVD88

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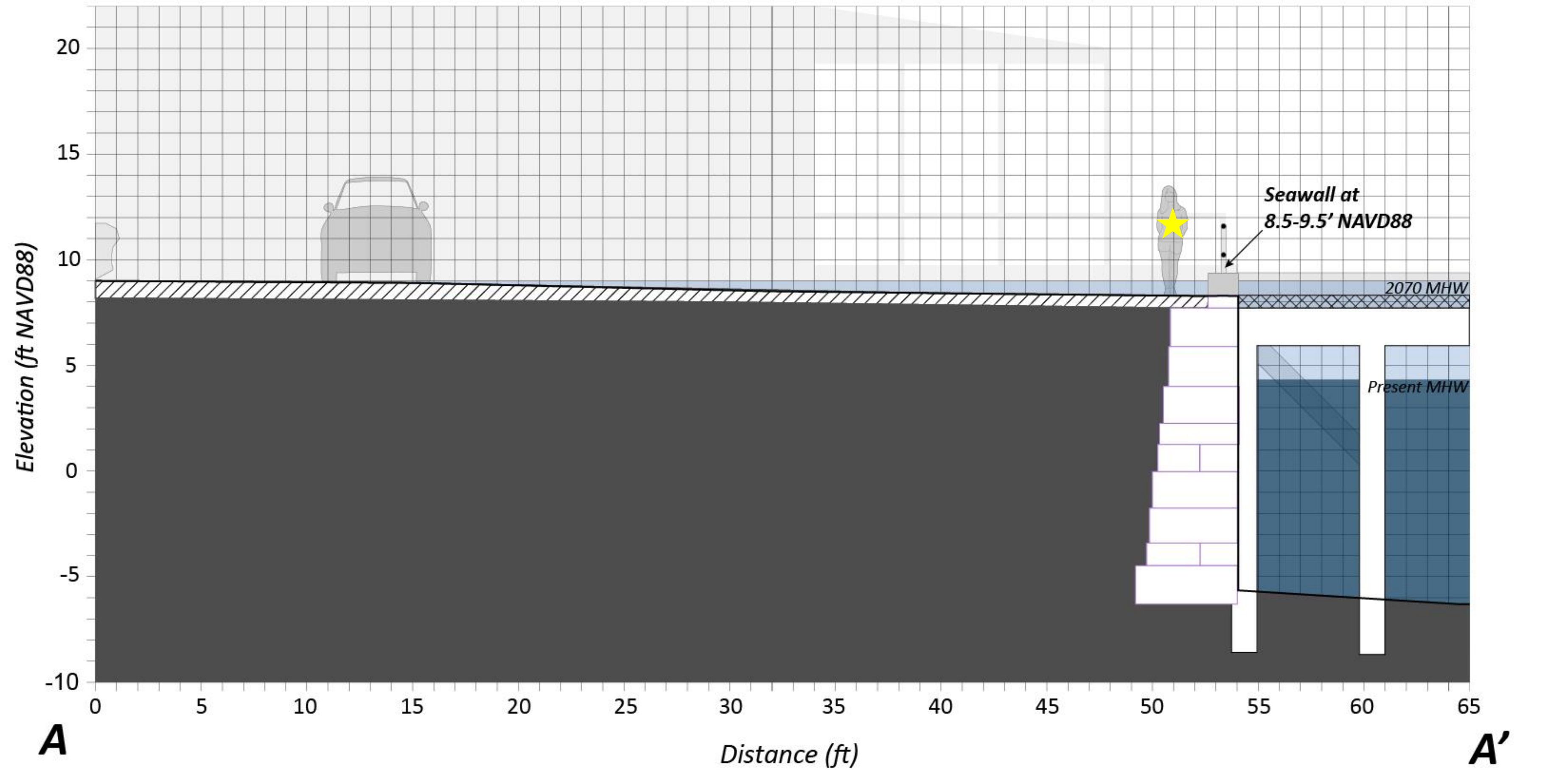
Existing Conditions

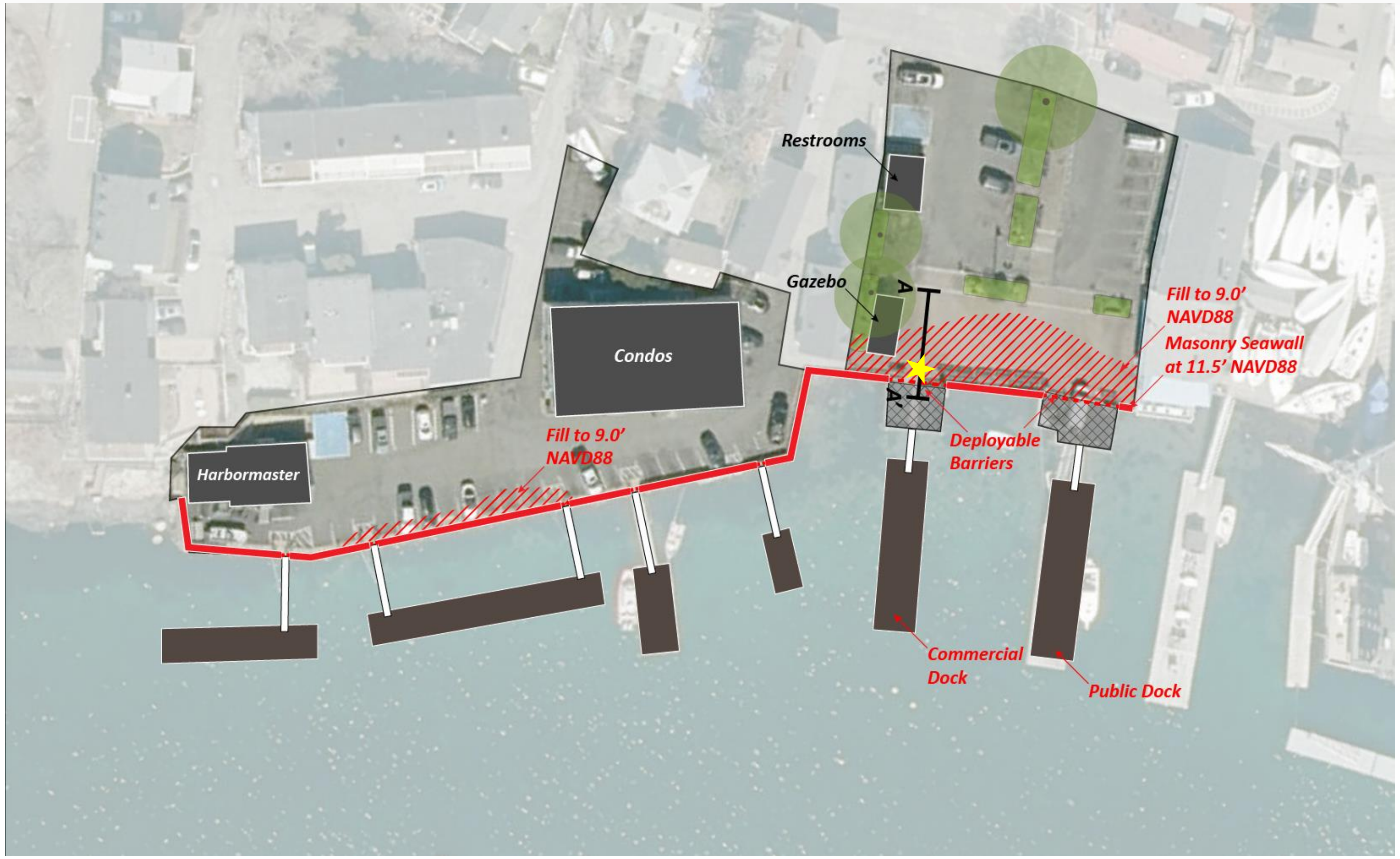


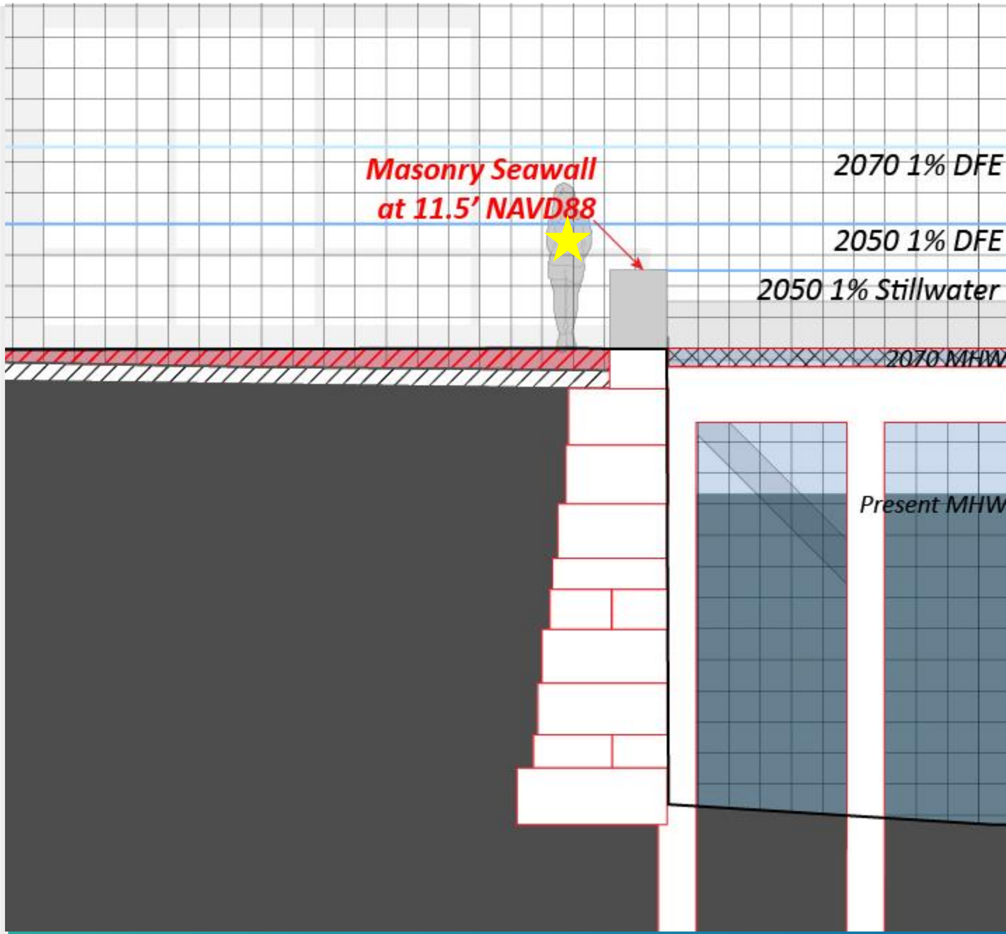
Seawall Elevation (ft NAVD88)	MHW vulnerability	Approx Stillwater AEP as soon as 2050	Approx Sig. Wave AEP as soon as 2050
8.5	*As soon as 2070*	***>5%***	***>5%***

- Mean High Water inundation as soon as 2070
- Small seawall cap, dock access through gaps

Seawall cap: 8.5-9.5' NAVD88
Land behind seawall: ~8.0' NAVD88

Alternative 1: Reconstruct Seawall at 11.5’ NAVD88





Seawall Elevation (ft NAVD88)	MHW vulnerability	Approx Stillwater AEP as soon as 2050	Approx Sig. Wave AEP as soon as 2050
11.5	*After 2070*	***1%***	***2%***

Seawall cap: 11.5’ NAVD88
(could be designed to be extended in the future)
Land behind seawall: 9.0’ NAVD88

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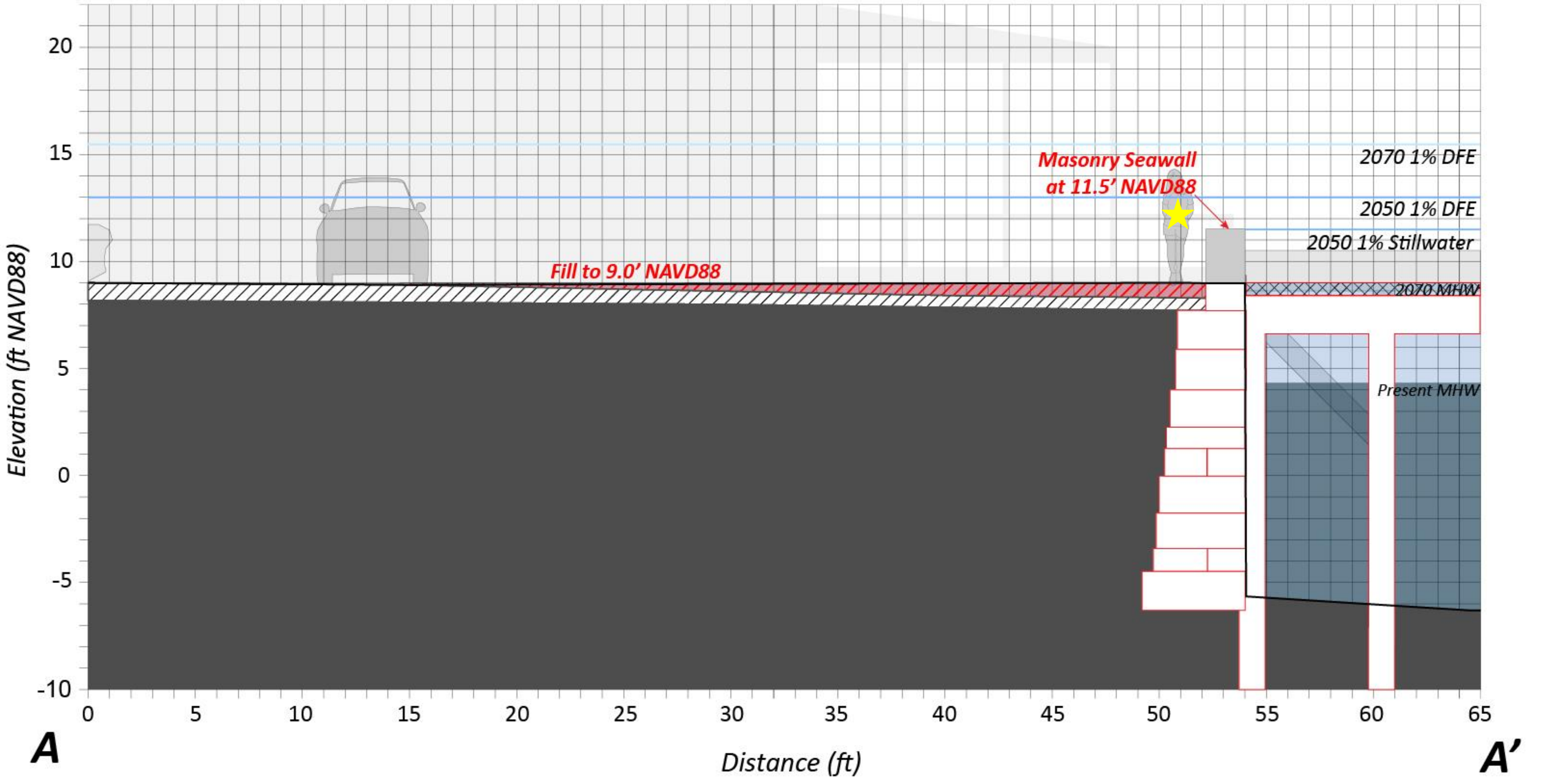
Alternative 1: Reconstruct Seawall at 11.5’ NAVD88



Seawall Elevation (ft NAVD88)	MHW vulnerability	Approx Stillwater AEP as soon as 2050	Approx Sig. Wave AEP as soon as 2050
11.5	*After 2070*	***1%***	***2%***

- Reconstruct seawall at 11.5’ NAVD88 – masonry shown
- Fill land behind to 9.0’ NAVD88
- Switch commercial and public docks
- *Deployable barriers at gaps in seawall – applies to all alternatives*

Seawall cap: 11.5’ NAVD88
Land behind seawall: 9.0’ NAVD88

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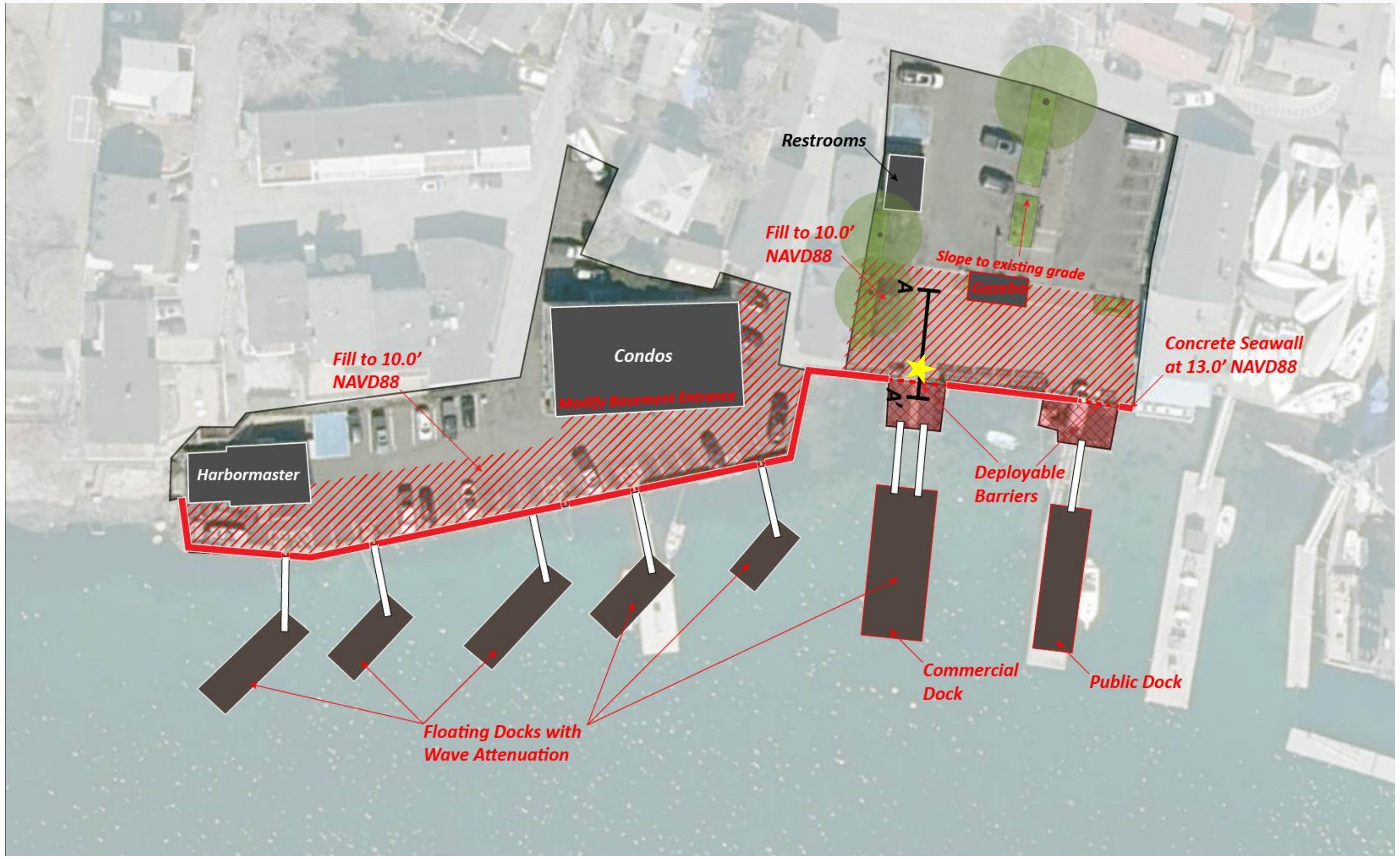
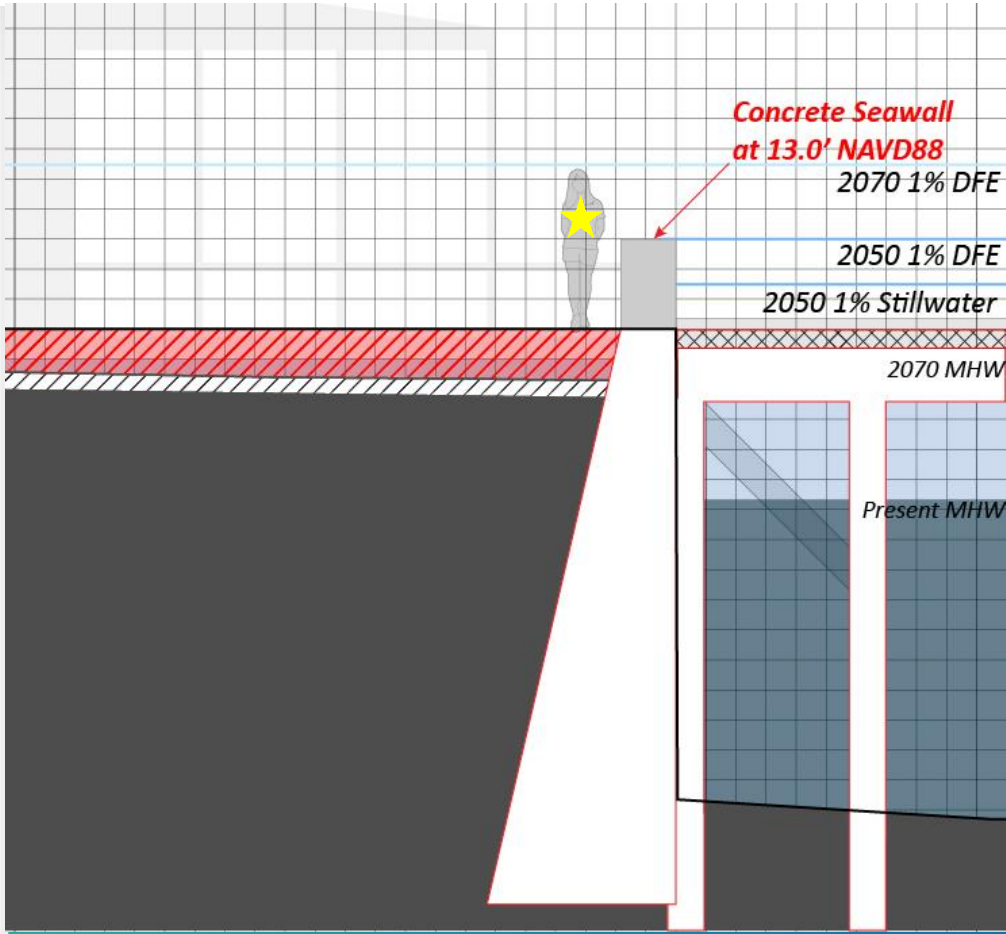
Alternative 2: Reconstruct Seawall at 13.0’ NAVD88





Seawall Elevation (ft NAVD88)	MHW vulnerability	Approx Stillwater AEP as soon as 2050	Approx Sig. Wave AEP as soon as 2050
13.0	*As soon as 2070*	***<0.1%***	***0.5%***

Seawall cap: 13.0’ NAVD88
Land behind seawall: 10.0’ NAVD88

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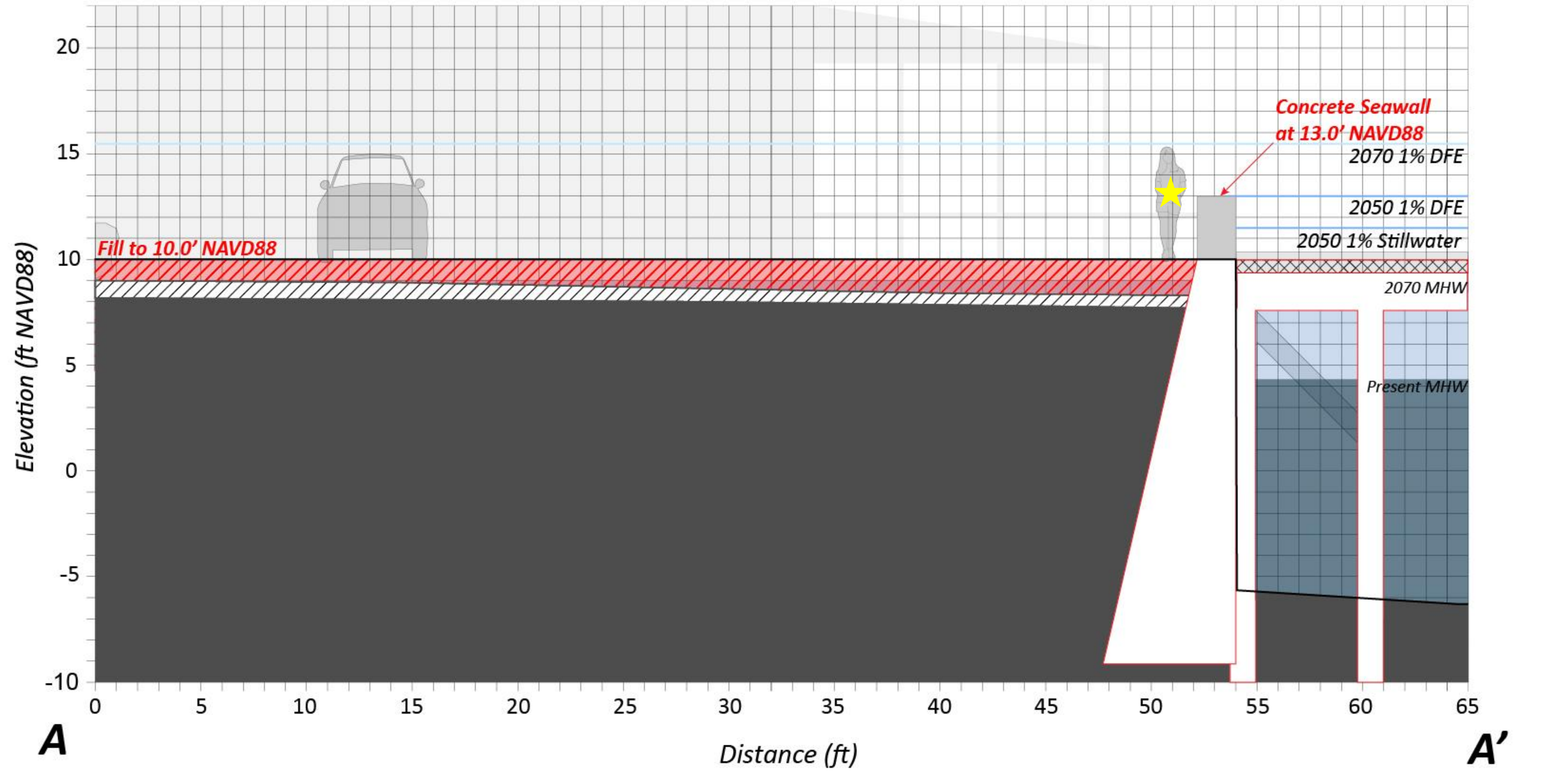
Alternative 2: Reconstruct Seawall at 13.0’ NAVD88



- Reconstruct seawall at 13.0’ NAVD88 – concrete shown
- Fill land behind seawall to 10.0’ NAVD88
- Raise piers at State Street Landing, switch locations of commercial and public docks
- Reconfigure dock layout and switch to wave attenuating docks
- Move gazebo at State Street Landing
- Floodproof Condo basement

Seawall Elevation (ft NAVD88)	MHW vulnerability	Approx Stillwater AEP as soon as 2050	Approx Sig. Wave AEP as soon as 2050
13.0	*As soon as 2070*	***<0.1%***	***0.5%***

Seawall cap: 13.0’ NAVD88
Land behind seawall: 10.0’ NAVD88

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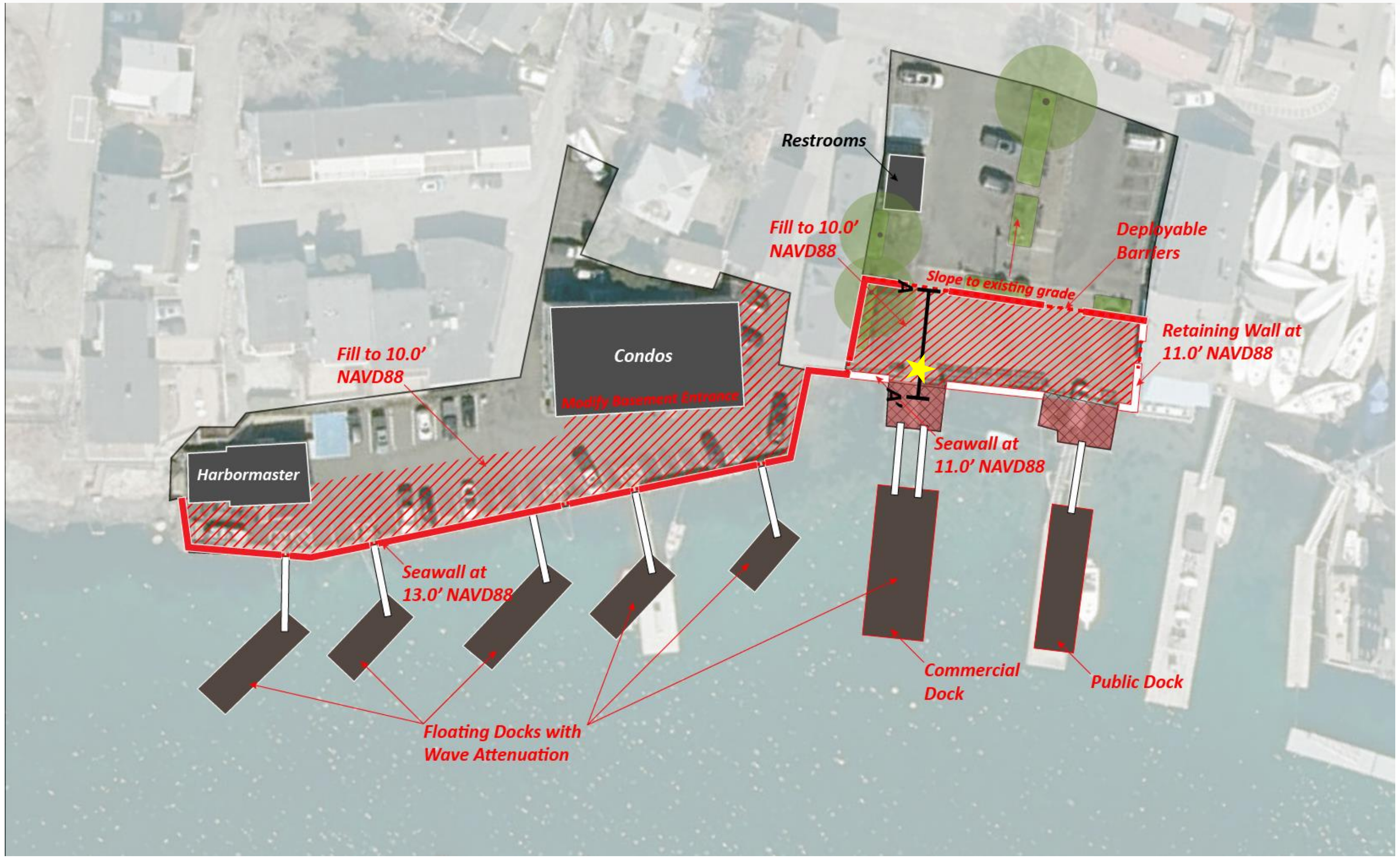
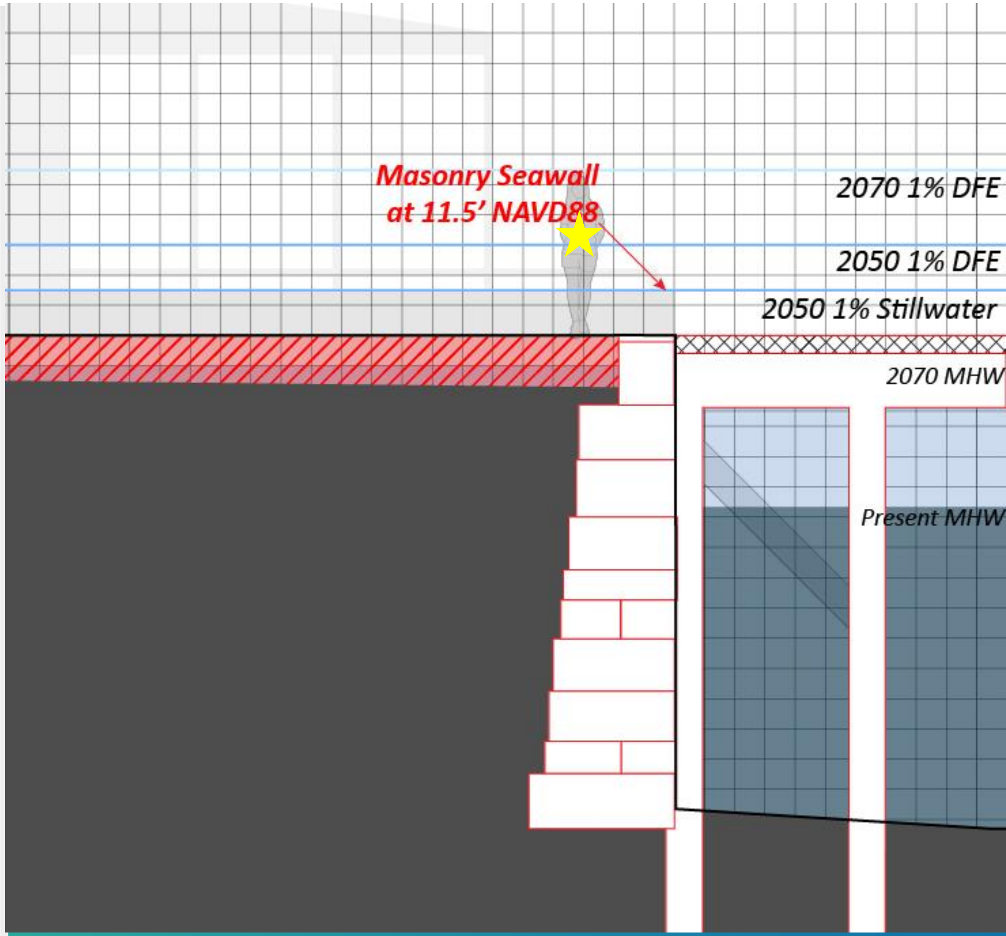
Alternative 3: Reconstruct Seawall at 13.0’ NAVD88 + fill



Seawall Elevation (ft NAVD88)	MHW vulnerability	Approx Stillwater AEP as soon as 2050	Approx Sig. Wave AEP as soon as 2050
13.0	*After 2070*	***<0.1%***	***0.5%***



Seawall cap: 13.0’ NAVD88
Land behind seawall: 10.0’ NAVD88

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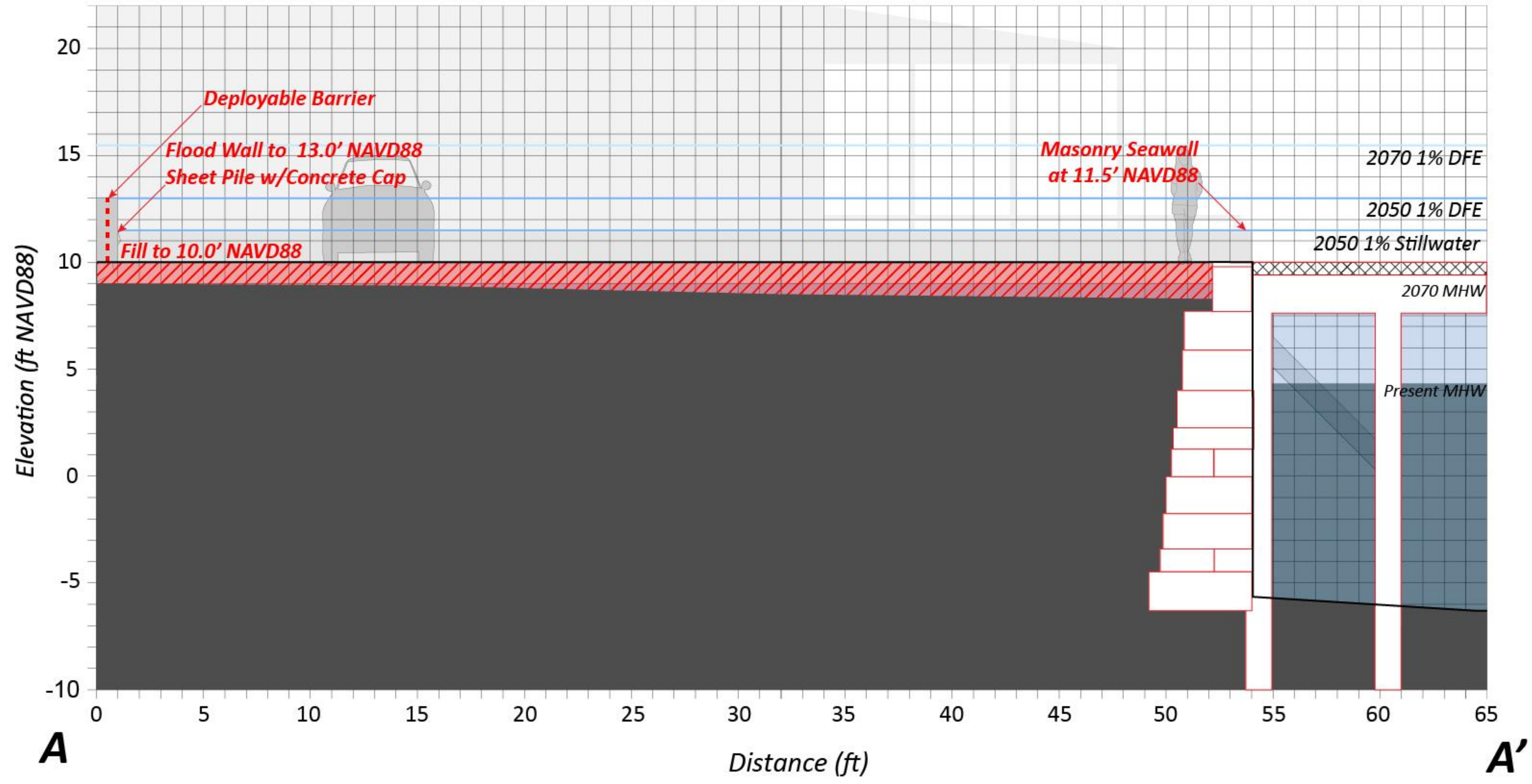
Alternative 3: Reconstruct Seawall at 13.0’ NAVD88 + fill



- Reconstruct seawall at 13.0’ NAVD88 – sheet pile shown
- Fill land behind seawall to 10.0’ NAVD88
- Raise piers at State Street Landing, switch locations of commercial and public docks
- Reconfigure dock layout and switch to wave attenuating docks
- Reconstruct State Street Landing Seawall in kind at 11.5’ NAVD88 and construct a flood wall to 13.0’ NAVD88 in the parking lot
- Floodproof Condo Basement

Seawall Elevation (ft NAVD88)	MHW vulnerability	Approx Stillwater AEP as soon as 2050	Approx Sig. Wave AEP as soon as 2050
13.0	*After 2070*	***<0.1%***	***0.5%***

Seawall cap: 13.0’ NAVD88
Land behind seawall: 10.0’ NAVD88

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STATE STREET LANDING and TUCKER'S WHARF

Summary of alternatives

	Description	Seawall Elevation *(NAVD88)*	MC-FRM Stillwater AEP			Daily High Tide Flooding	Vulnerability to Overtopping	Ease of Permitting	Relative Cost
			2030	*2050*	*2070*				
0	Existing conditions.	8.0 feet	>5%	>5%	MHW	2070	High	N/A	N/A
1	Reconstruct seawall at 11.5' NAVD88, fill land behind to 9.0' NAVD88. Switch locations of commercial and public docks. Add deployable barriers at gaps in seawall.	11.5 feet	0%	1%	>5%	N/A	Moderate	TBD	TBD
2	Reconstruct seawall at 13.0' NAVD88, fill land behind to 10.0' NAVD88. Raise piers at State Street Landing and switch commercial and public docks. Reconfigure dock layout and switch to wave attenuating docks. Move gazebo. Floodproof Condo basement. Add deployable barriers at gaps in seawall.	13.0 feet	0%	0%	1%	N/A	Low	TBD	TBD
3	Reconstruct seawall at 13.0' NAVD88, fill land behind to 10.0' NAVD88. Keep seawall at public dock at 11.5' NAVD88 and construct flood wall to 13.0' NAVD88 in parking lot. Raise piers at State Street Landing and switch locations of commercial and public docks. Reconfigure dock layout and switch to wave attenuating docks. Floodproof Condo basement. Add deployable barriers at gaps in seawall.	13.0 feet	0%	0%	1%	N/A	Low	TBD	TBD

†Based on a conservative sea level rise scenario where mean high water is 9.0' NAVD88 in the 2070 time horizon.

Questions and Feedback

What features stood out to you as desirable or undesirable?

What is most important to keep the same about the site?

What changes do you want to see at the site?

How frequently can the site flood and still be usable for you?

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Information on future engagement events can be found at **marbleheadma.gov** or **salemsound.org**

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Acronym Definitions

- **MC-FRM** – Massachusetts Coast Flood Risk Model – a hydrodynamic probabilistic model that describes coastal flood risk in Massachusetts in terms of annual chance of flooding under 2030, 2050, and 2070 conditions.
- **AEP** – Annual (Coastal Flood) Exceedance Probability – the probability that at least one storm event will flood an area or building in one year.
- **MHW** – Mean High Water - the average elevation of all high tides in a specific place.
- **SLR** – Sea Level Rise – a global phenomenon of rising average sea level due to climate change driven expansion of sea water and introduction of meltwater from glaciers and ice sheets. Sea level rise in this presentation references the increase in sea level from a 2008 baseline in Boston Harbor, and has been locally adjusted to reflect land subsidence.
- **NAVD88** – North American Vertical Datum of 1988 – a control datum or "zero point" for elevations in North America. All elevations in this study reference NAVD88.
- **LiDAR** – Light Detection and Ranging – a remote sensing method that uses light in the form of a pulsed laser to measure ground elevation from above.
- **FFE** – First Floor Elevation – the elevation of the lowest finished floor in a building, excluding basements and crawl spaces. This is usually the floor with the primary entrance.
- **VA** – (Flood) Vulnerability Assessment – An analysis that compares the elevations of specific buildings and/or infrastructure to the flood water surfaces corresponding to different AEPs to determine the annual chance of flooding for the buildings and/or infrastructure.