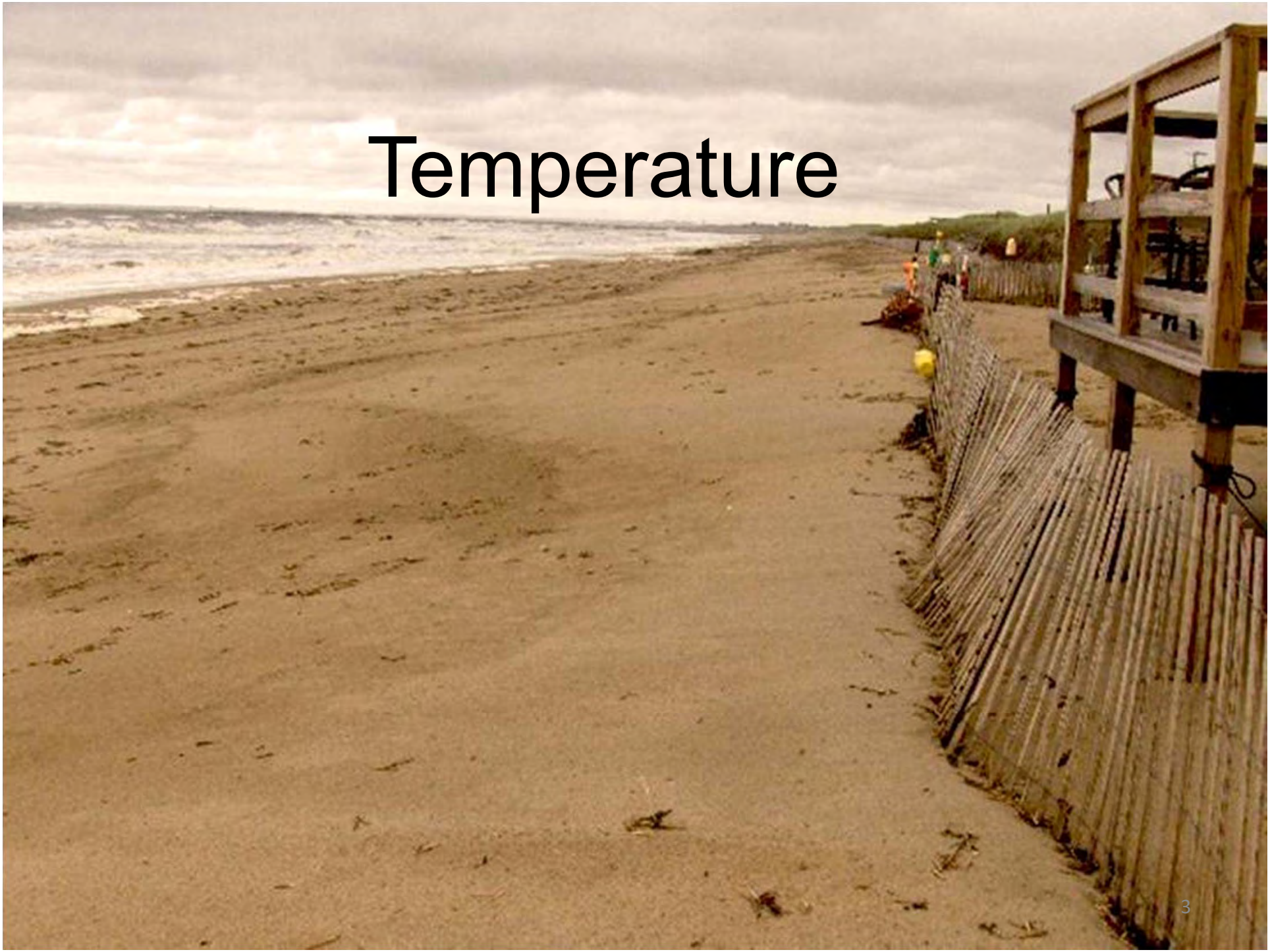
Steven Roy, LEED AP
Climate Adaptation and Green Infrastructure
Weston & Sampson

Julie Eaton
Lead Resiliency Engineer
Weston & Sampson

Weston & Sampson

Existing and Predicted Climate Change in Massachusetts

Temperature

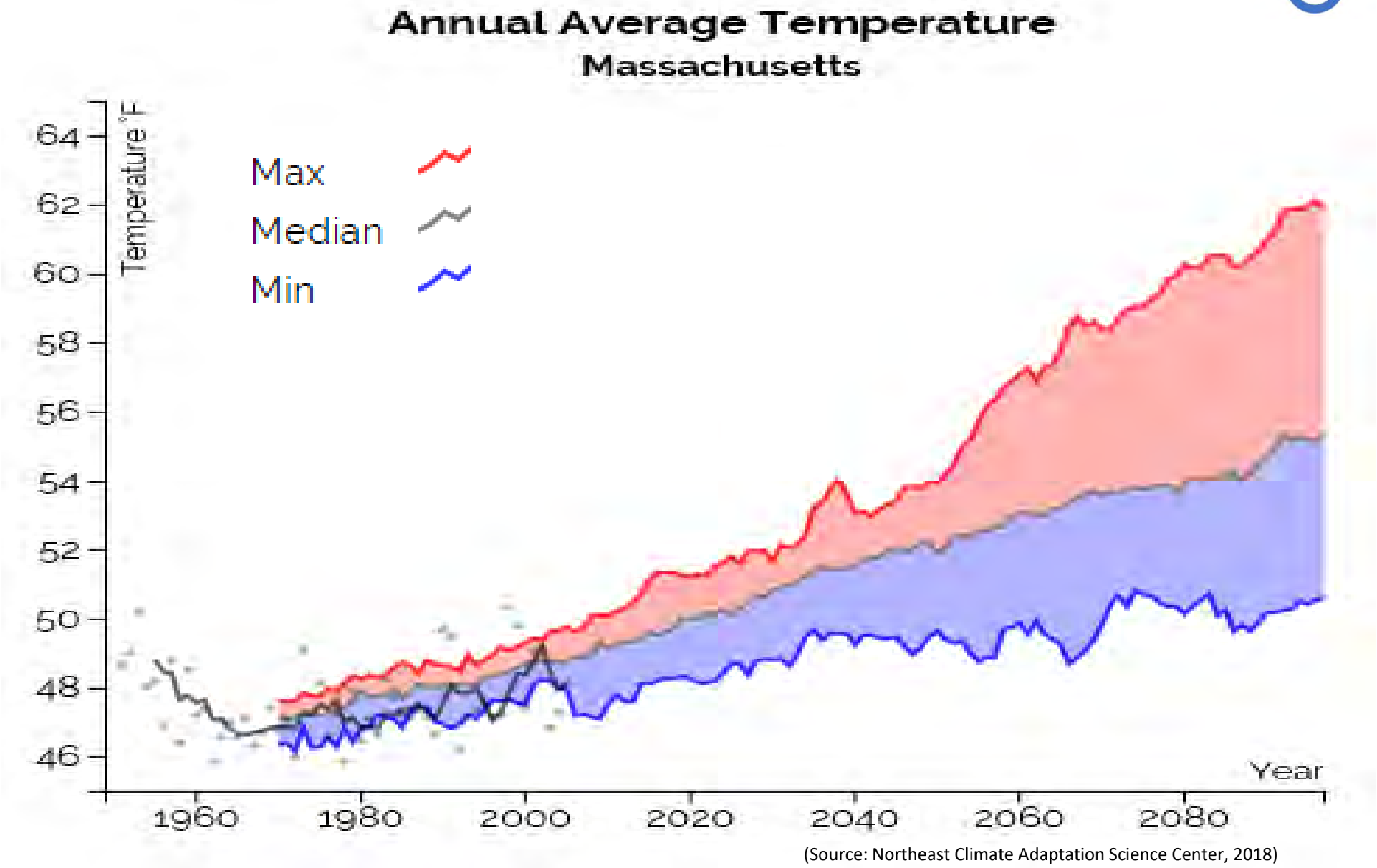


Projected Temperature Increases

	Observed Baseline	Projected Change 2050's	Projected Change End of Century
MA Average Temp (°F)	47.6	+2.8 to +6.2	+3.8 to +10.8
Days with Temperatures Above 90°F	8	+7 to +26	+10 to +62
Days with Temperatures Above 100°F	<1	<1 to +3	<1 to +13
Days with Temperatures Below 32°F	121	-18 to -44	-23 to -66

(Source: Northeast Climate Adaptation Science Center, 2018)

Projected: Annual Average Temperature in Massachusetts



(Source: Northeast Climate Adaptation Science Center, 2018)

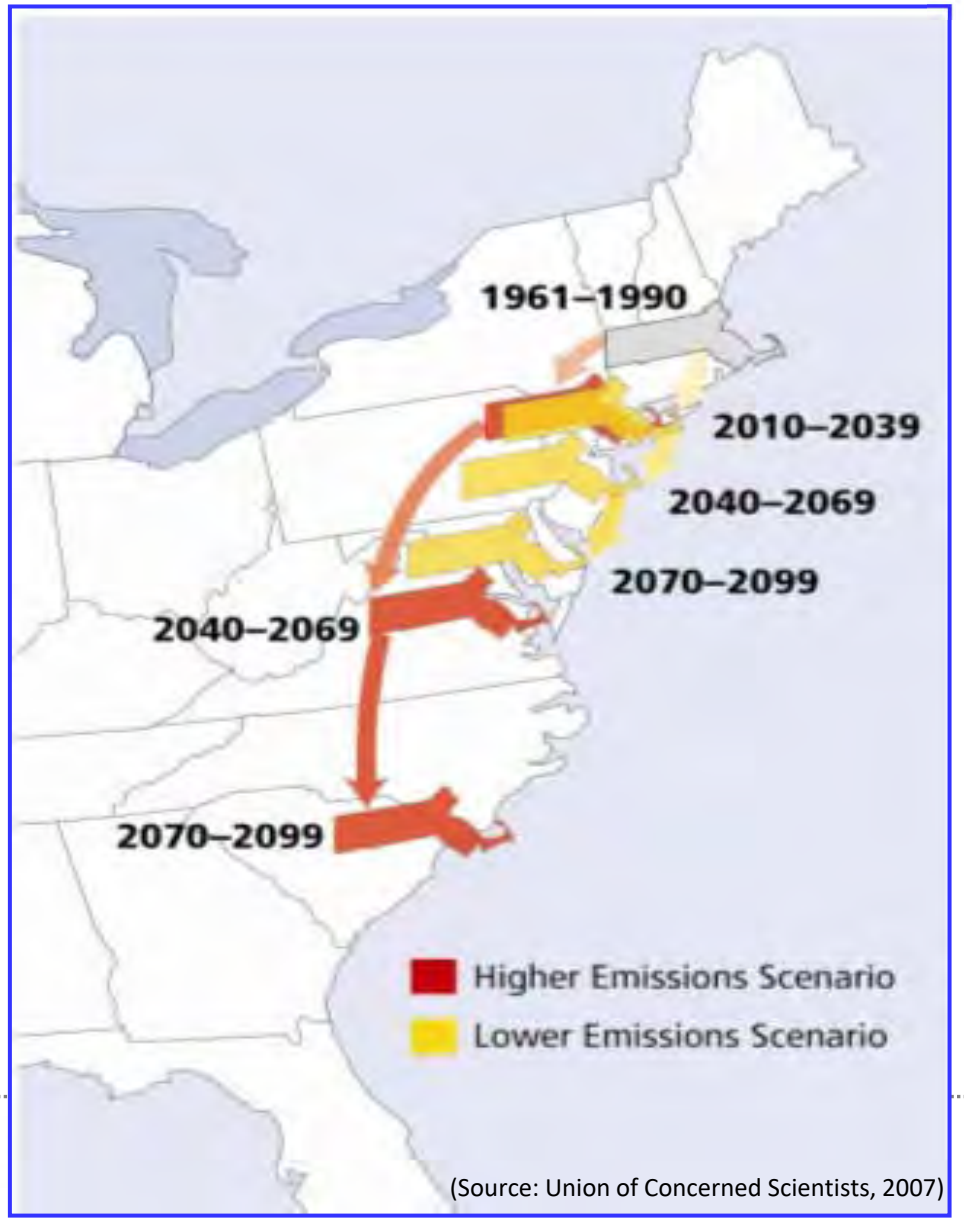
Projected Extreme Heat in Massachusetts

Temperatures Predicted to Increase

Winter: 15 to 40% ↑

Summer: 6 to 18% ↑

(Source: Northeast Climate Adaptation Science Center, 2018)

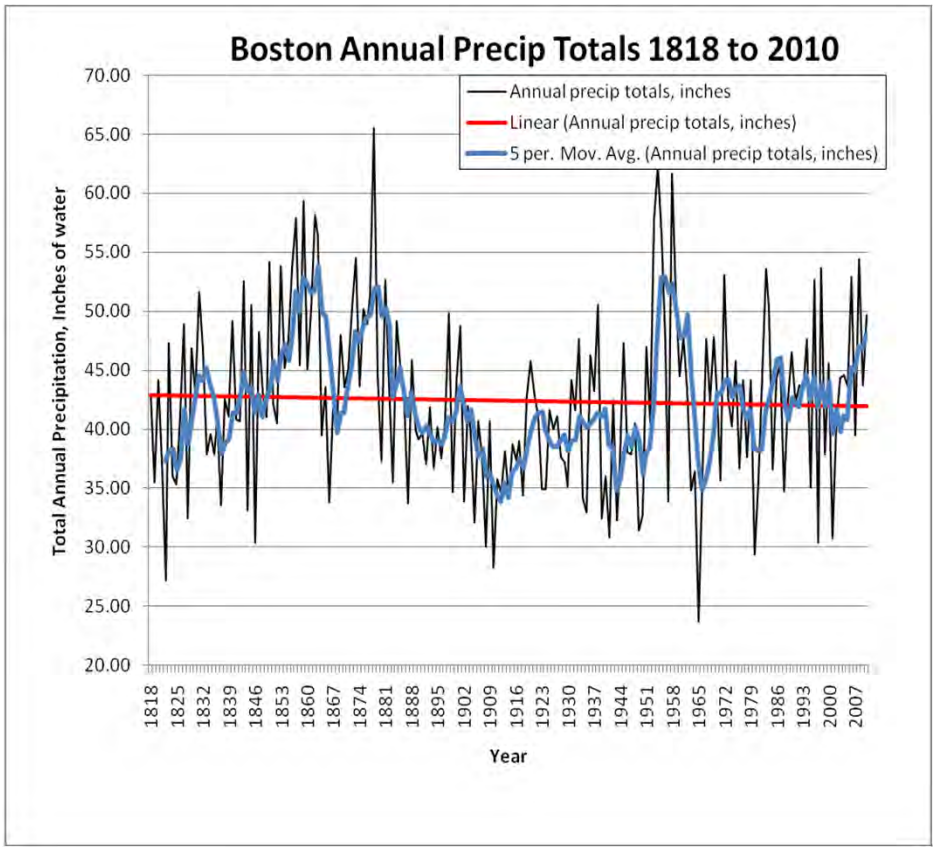


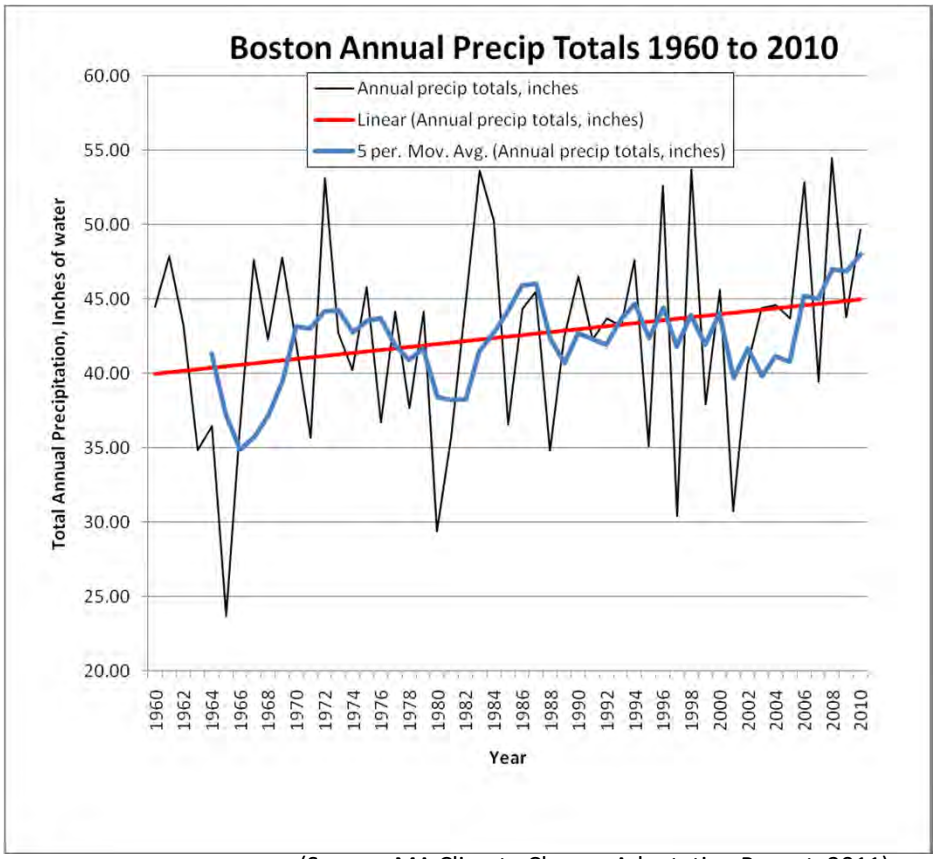
(Source: Union of Concerned Scientists, 2007)


Precipitation:
More Droughts, More Floods

Historical Annual Precipitation in Boston

January 1818 to December 2010





(Source: MA Climate Change Adaptation Report, 2011)

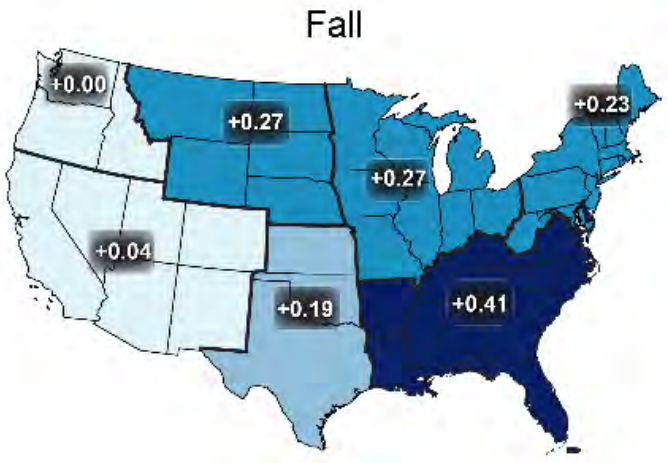
The blue line represents a five-year moving average and the red line a least squares regression.

Change in Precipitation in Massachusetts and US

24-hour, 100-year event in MA

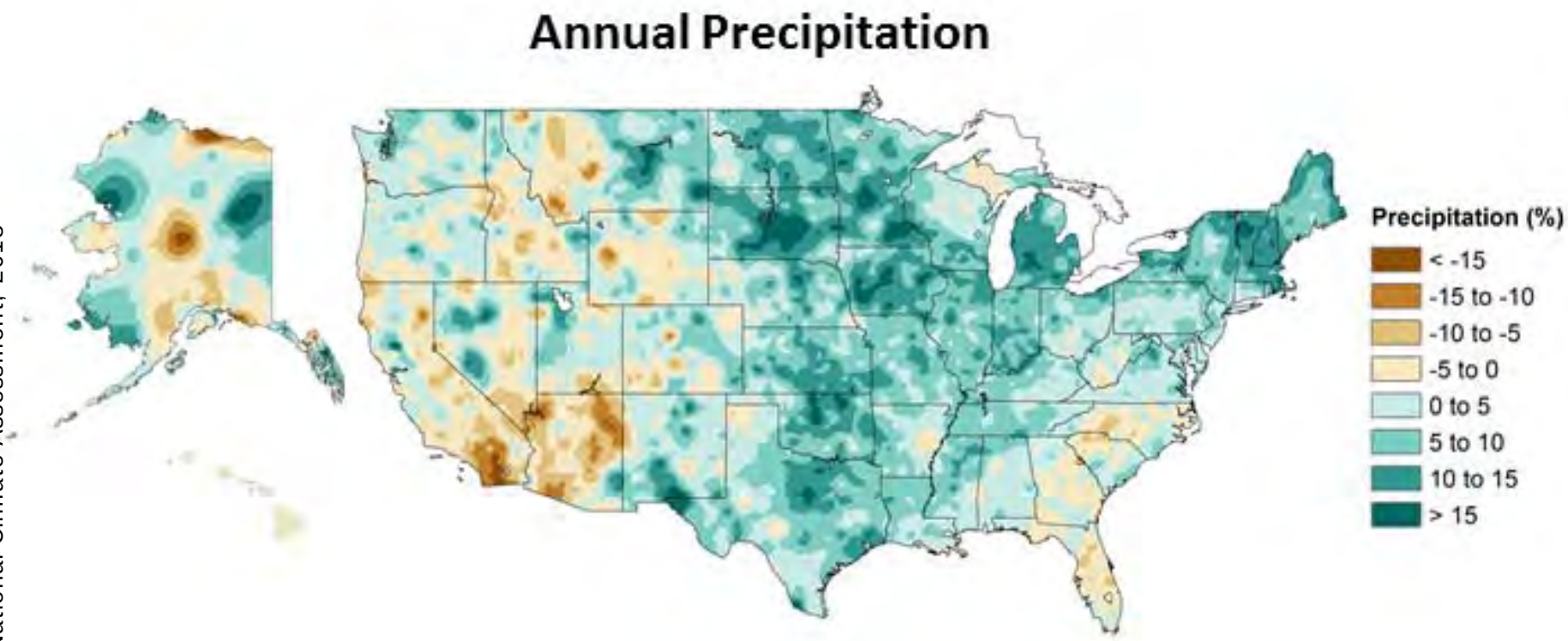
- 1961: Technical Paper 40 = 6.5 inches
- 2015: Atlas 14, Volume 10 = 8.4 inches

24-hour, 20-year event in Fall in US (change in inches)



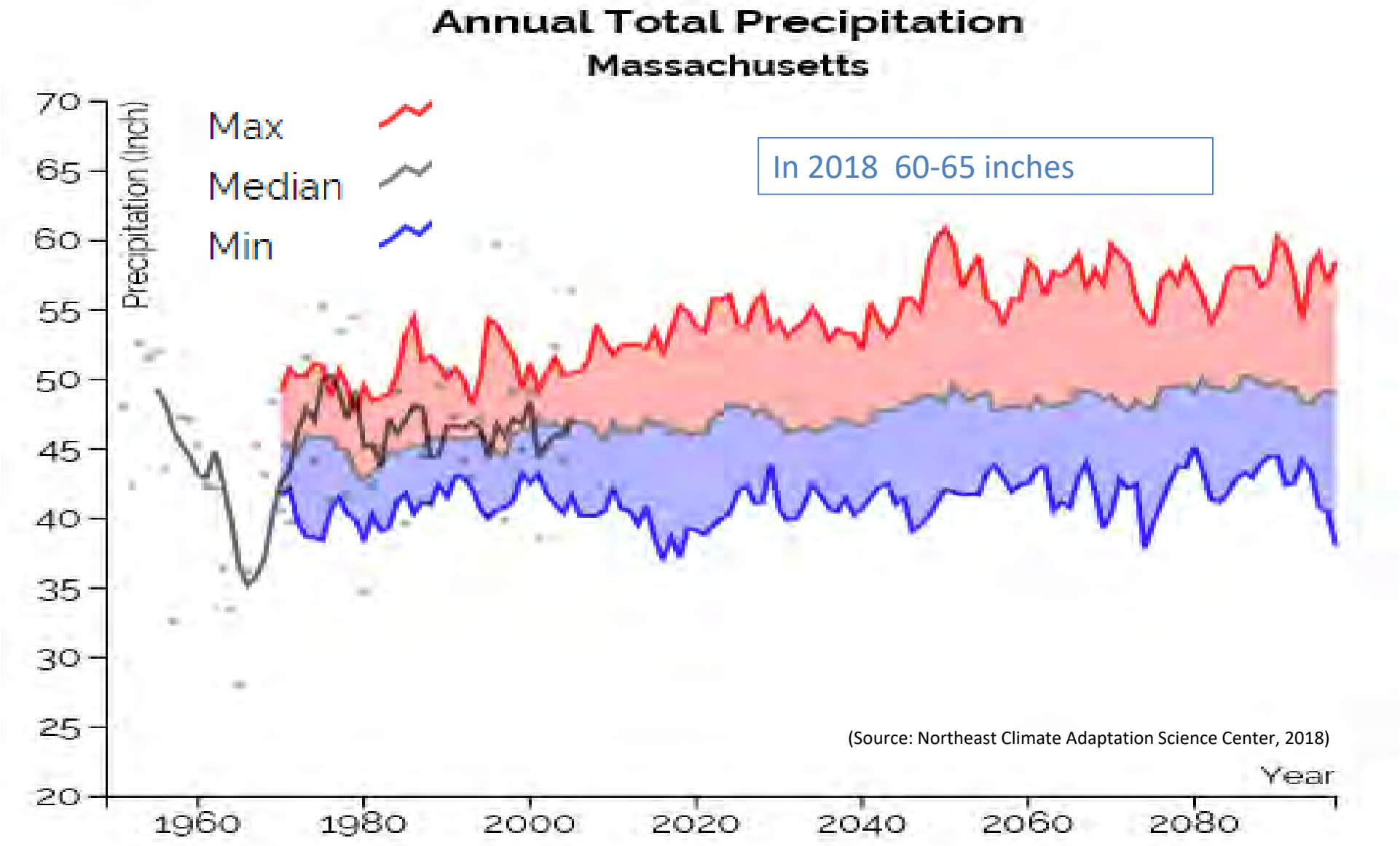
Source: The Fourth National Climate Assessment, 2018

Increases in Extreme Precipitation Events



Source: The Fourth National Climate Assessment, 2018

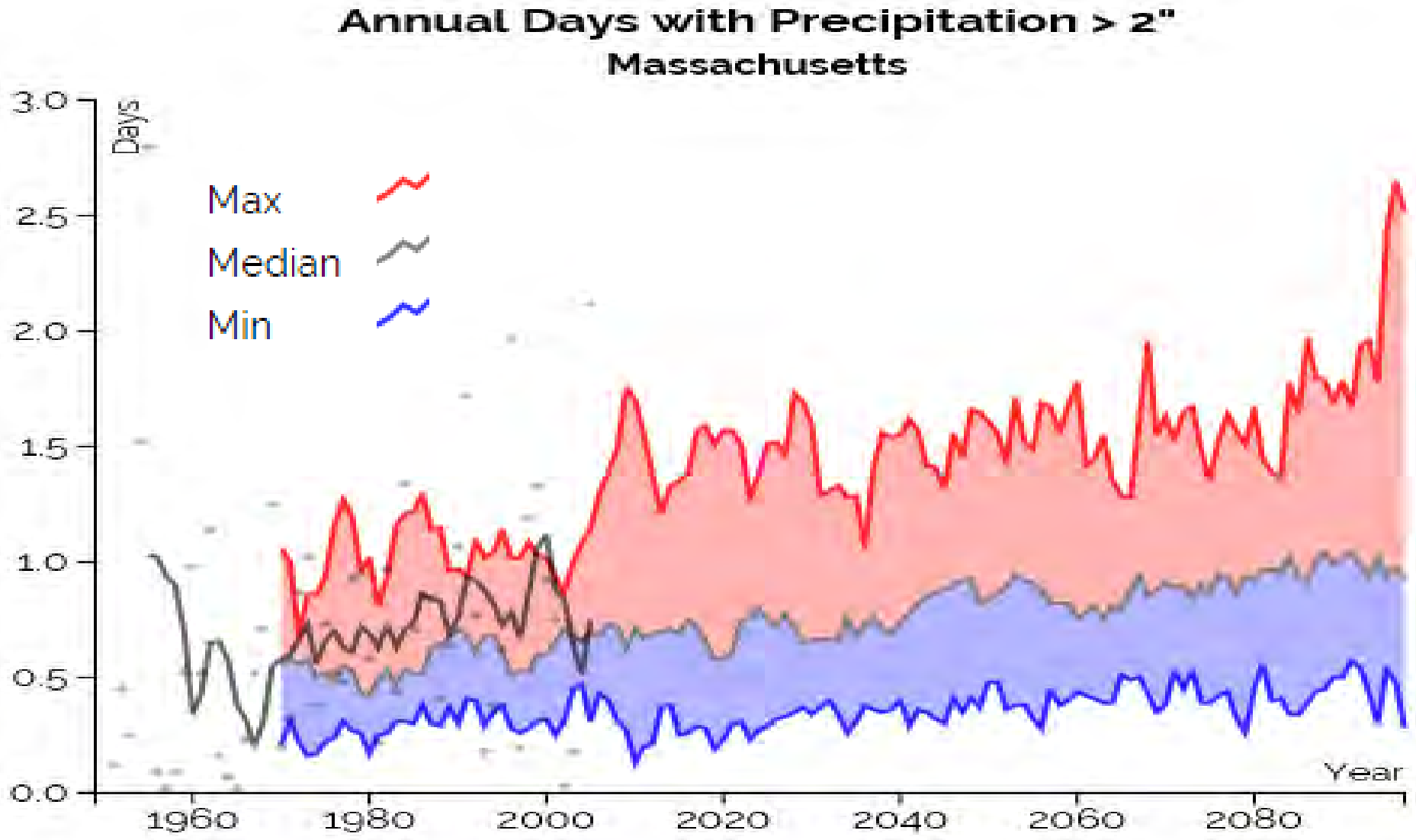
Projected: Annual Total Precipitation in Massachusetts



In 2018 60-65 inches

(Source: Northeast Climate Adaptation Science Center, 2018)

Projected: Annual Days with Precipitation ≥ 2” in Massachusetts



(Source: Northeast Climate Adaptation Science Center, 2018)

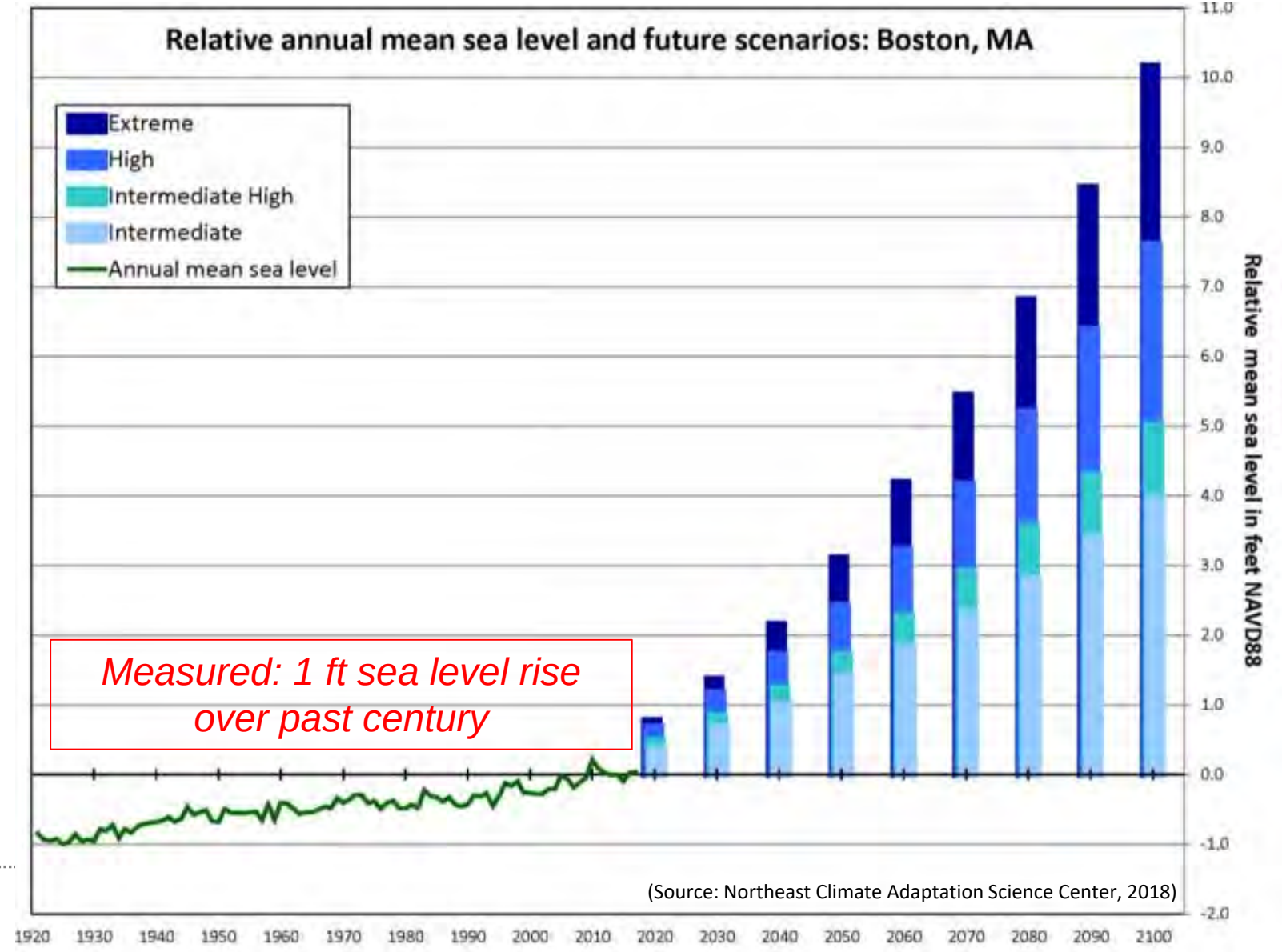
More Extreme Droughts – 2016 as an Example

- Longest duration of drought (48 weeks) since 2000

Worcester Reservoir During 2016 Drought (Source: The Boston Globe, 2016)

Sea Level Rise

Existing and Projected Sea Level Rise in Boston Harbor



(Source: Northeast Climate Adaptation Science Center, 2018)

Boston Sea Level Rise Projections

Threatens barrier buildings, infrastructure, beach and dune systems, and people

Emission Scenario	2030 (ft)	2050 (ft)	2070 (ft)	2100 (ft)
Intermediate	0.7	1.4	2.3	4.0
Intermediate-High	0.8	1.7	2.9	5.0
High	1.2	2.4	4.2	7.6
Extreme	1.4	3.1	5.4	10.2

- Increased coastal flooding
- Permanently inundated low-lying coastal areas
- Increased shoreline erosion

(Source: Northeast Climate Adaption Science Center)


The Impetus

Snowmageddon 2015: Record Breaker

(108.6 inches for 2014-2015 winter)

A man tees off from the top of a snow mound Photo: Zuma Press/PA

Weston & Sampson

Winter 2015: It Wasn't All Snow

Weston & Sampson

(Source: abcnews.go.com)

Winter 2015: It Wasn't All Snow

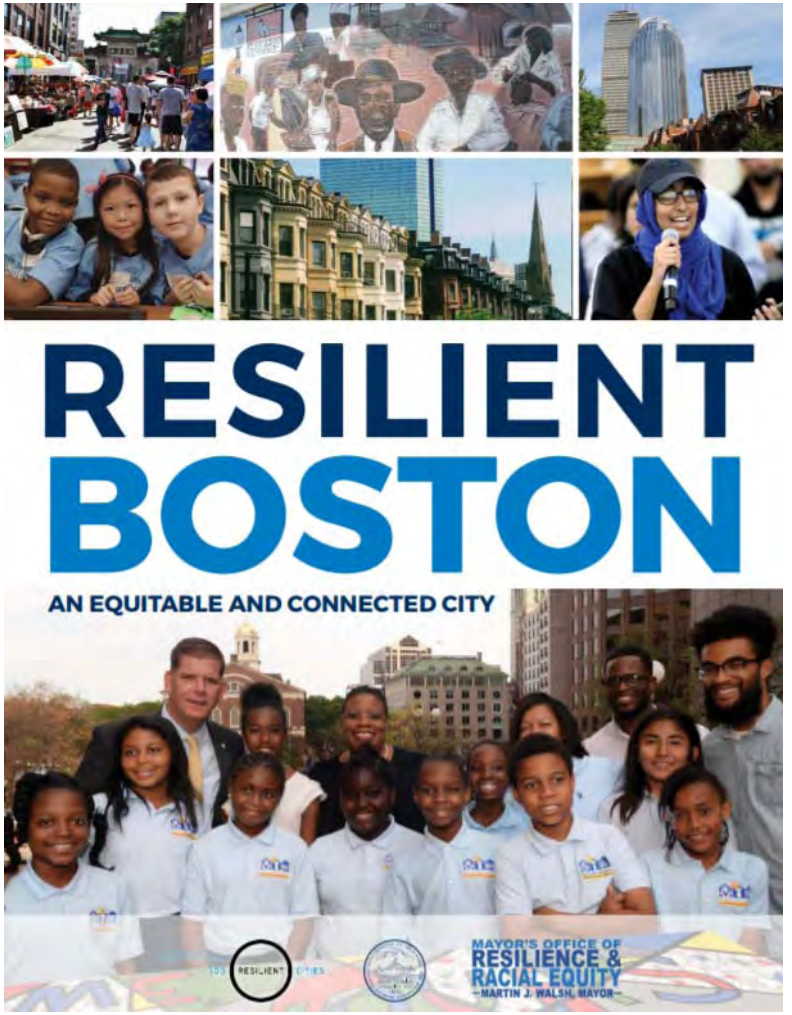
(Source: abcnews.go.com)

More Consequences: Potential Monetary Losses

- Boston 2050: 0.65 m (~2 ft) SLR = $463 billion in losses
- Northeast 2100: $6B to $11B in annual property losses
- Bond Ratings: Moody's, "Credit risks resulting from climate change are embedded in our existing approach to analyzing the key credit factors in our methodologies"

Sources:
WWF/ Allianz: Major Tipping Points in the Earth's Climate System and Consequences for the Insurance Sector, 2009;
Ceres: Insurer Climate Risk Disclosure Survey 2012 Findings and Recommendations, March 2013
Moody's: Evaluating the impact of climate change on US state and local issuers, 2017

RESILIENCE IN BOSTON



Weston & Sampson

RESILIENT HARBOR VISION

Weston & Sampson

CONCEPTS FOR FLOOD PROTECTION

Source:Kleinfelder-Stoss-One-WHG

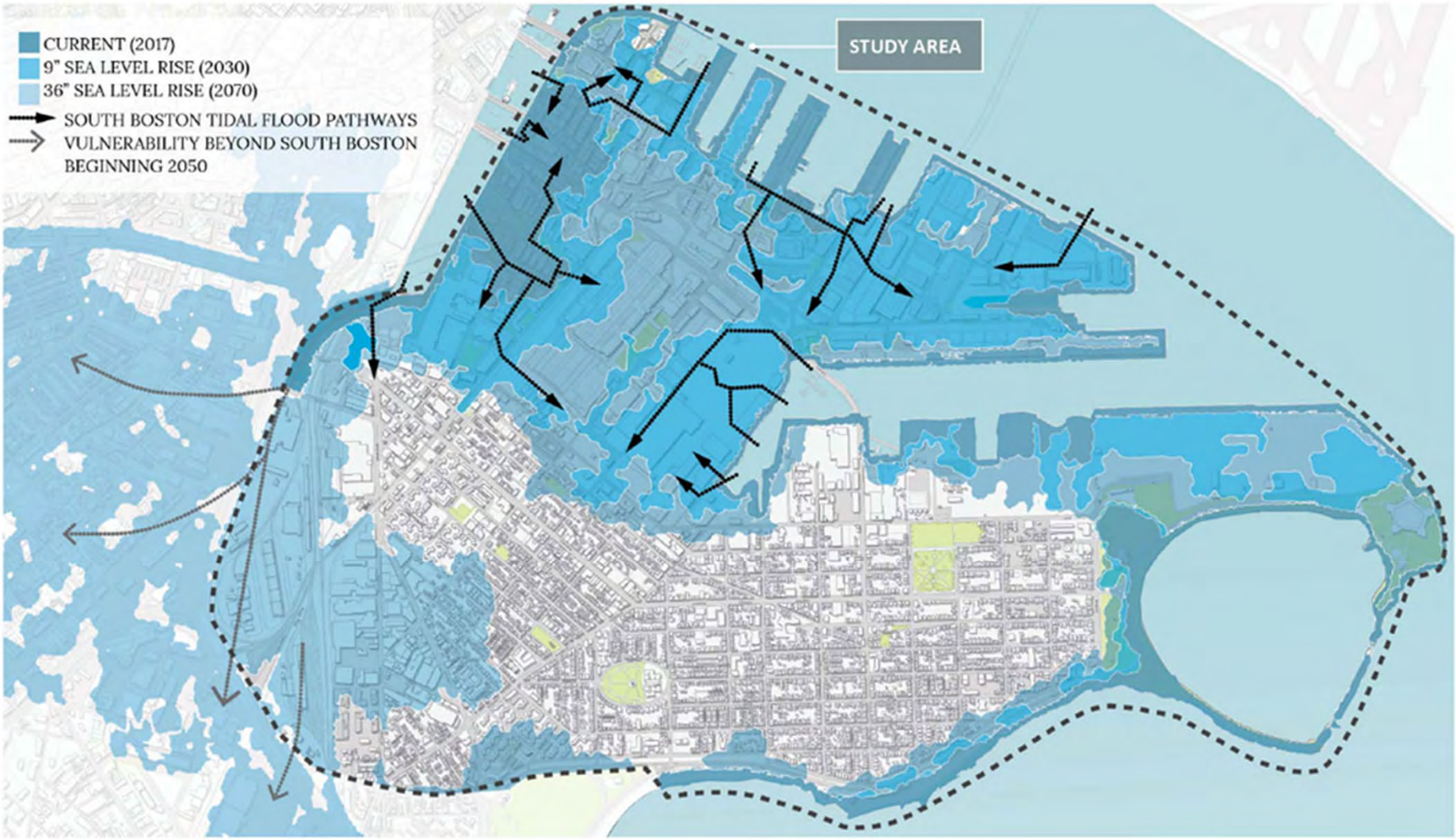
FLOOD VULNERABILITIES – NOW &

DISTRICT SCALE STRATEGIES

City of Boston has completed 3 out of the 5 waterfront Climate Resilience neighborhood plans

Weston & Sampson

MAPPING FLOOD PATHWAYS



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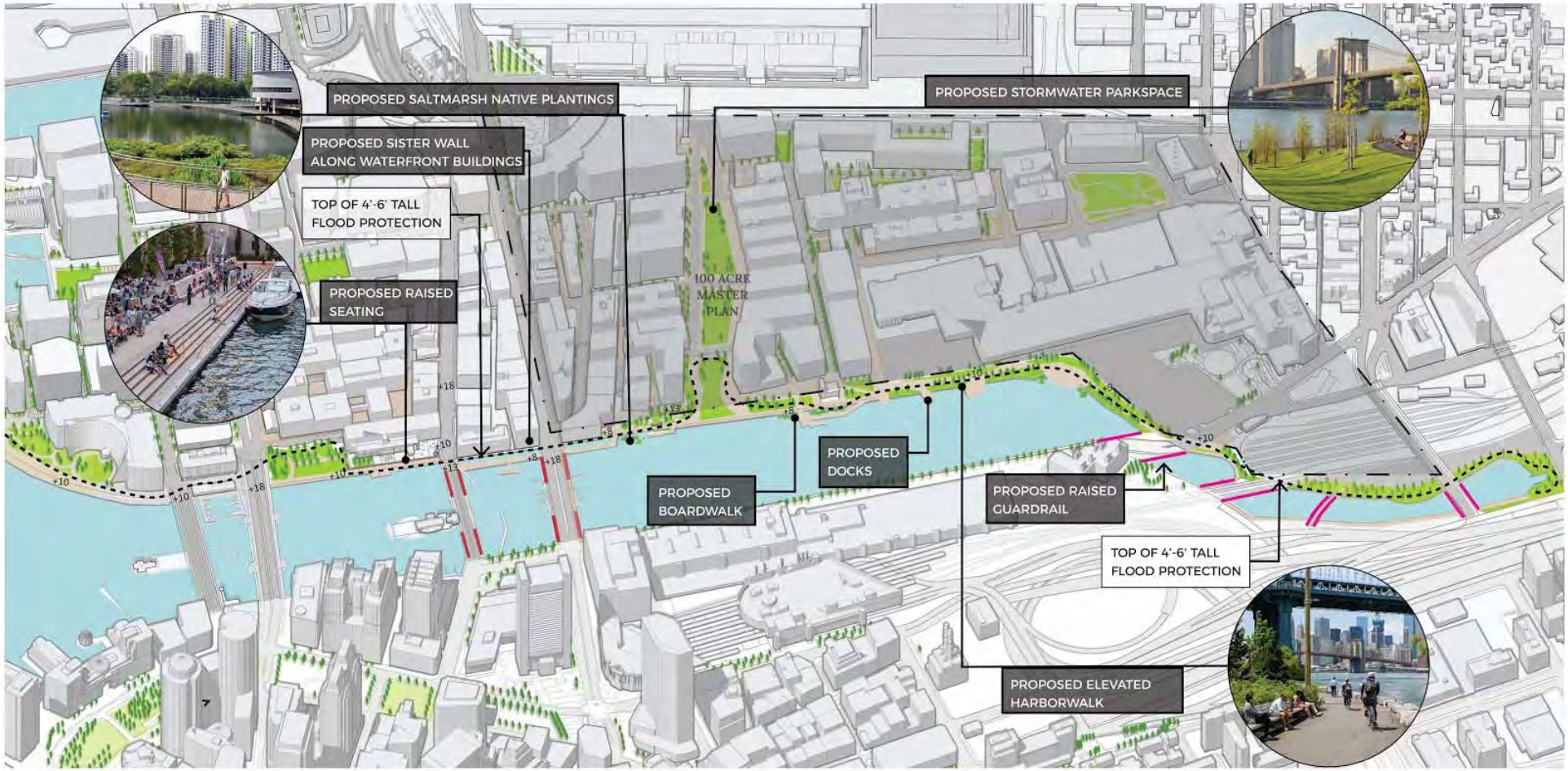
DEVELOPING DESIGN OPTIONS



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EXISTING CONDITIONS

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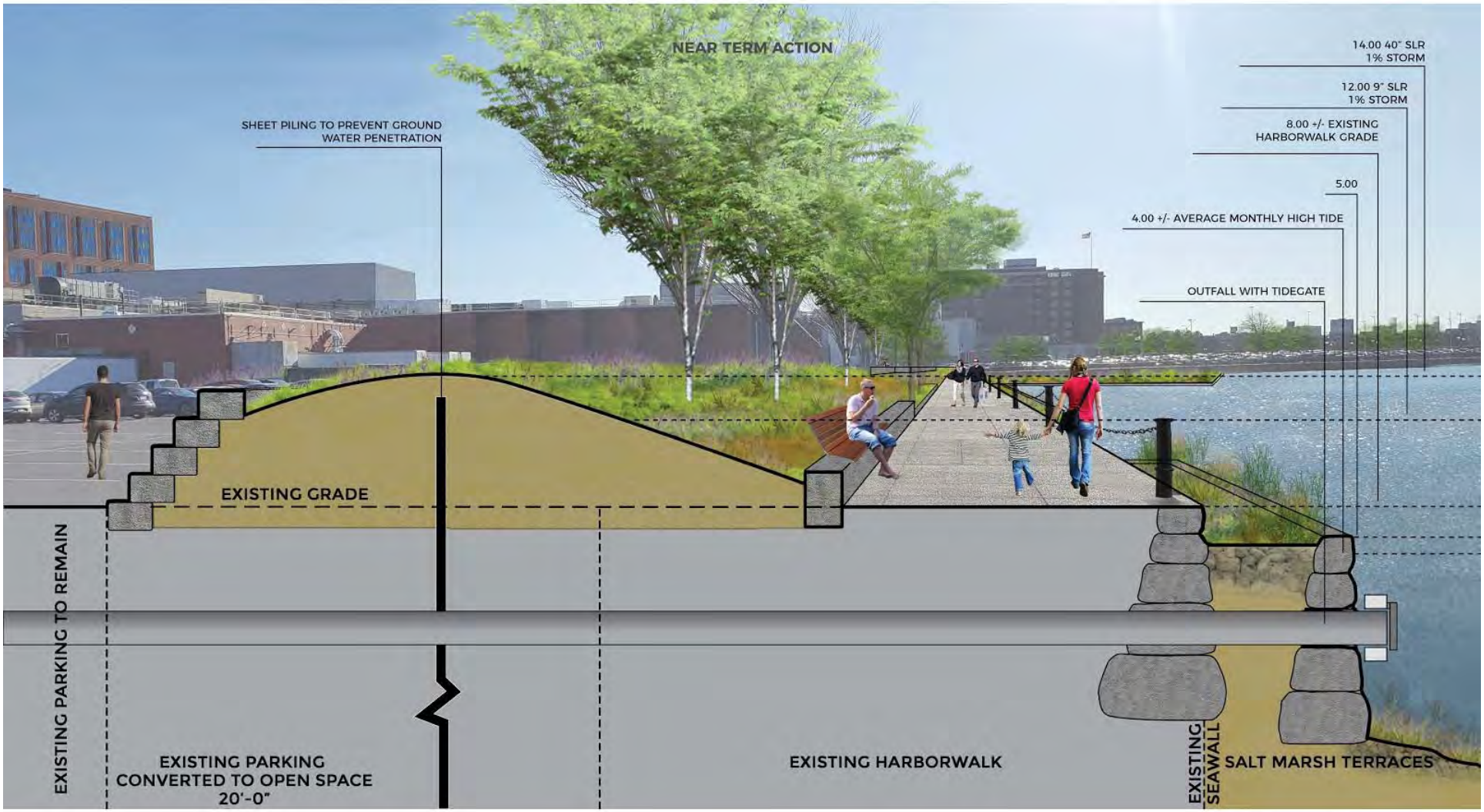
NEAR TERM ACTION



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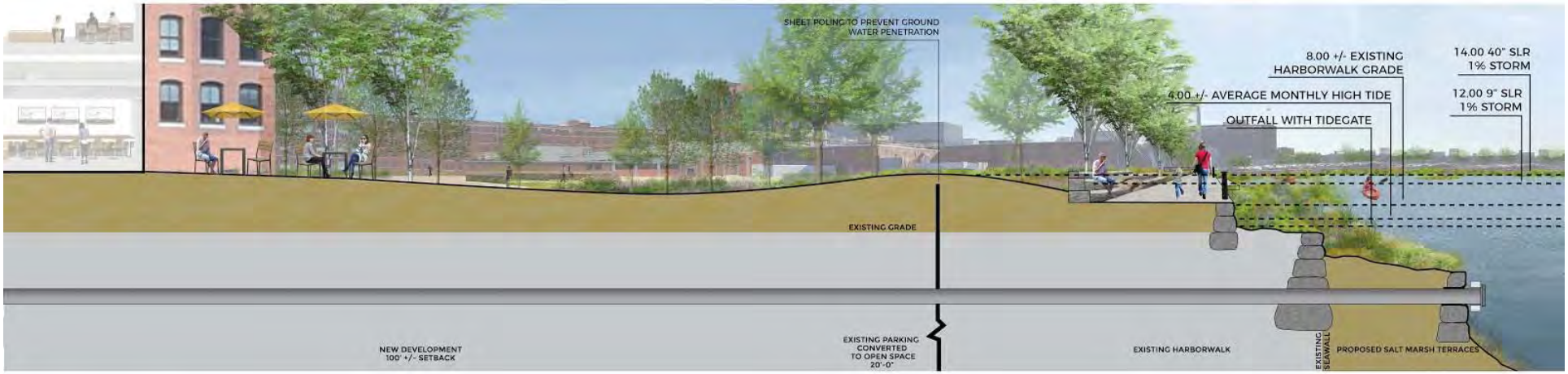
LONG TERM ACTION



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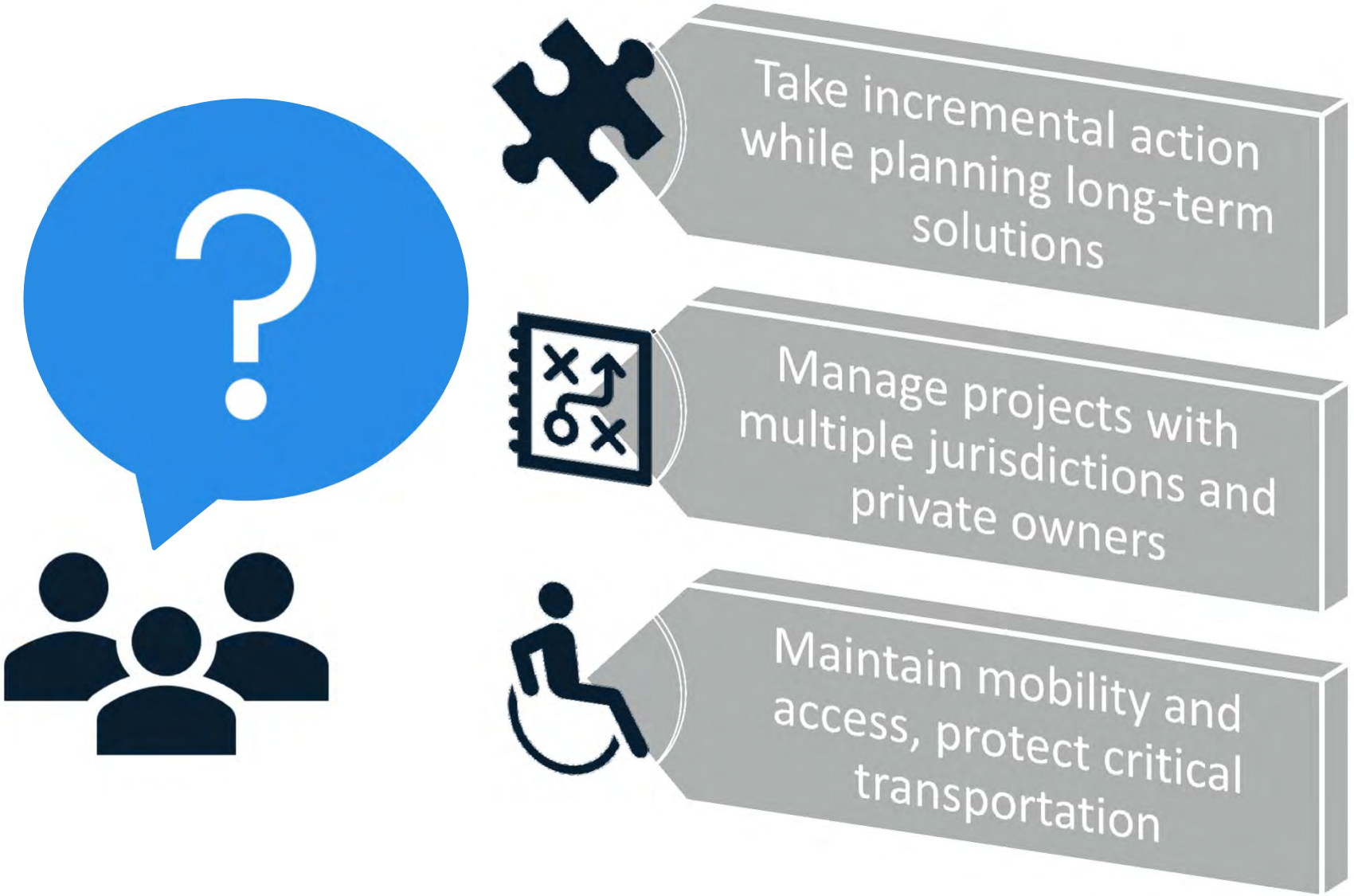
NEED FOR GUIDANCE



GUIDELINES GOALS

Climate Resilient Design Standards and Guidelines Goals:

Establish **resilience design guidelines** for discrete priority projects and for segmental adaptation projects to achieve **flood protection by 2070**, with the option to add an additional 2 ft. of protection in the future

Translate the Climate Ready Boston concepts into **feasible engineering and operational solutions** that focus on **protecting public right-of-way from flooding** due to tidal and storm surge events

Provide a menu of **sample flood protection options** with engineering **design considerations**, preliminary cost estimates, as well as **operations and maintenance guidance**

SAMPLE FLOOD BARRIERS

VEGETATED BERMS

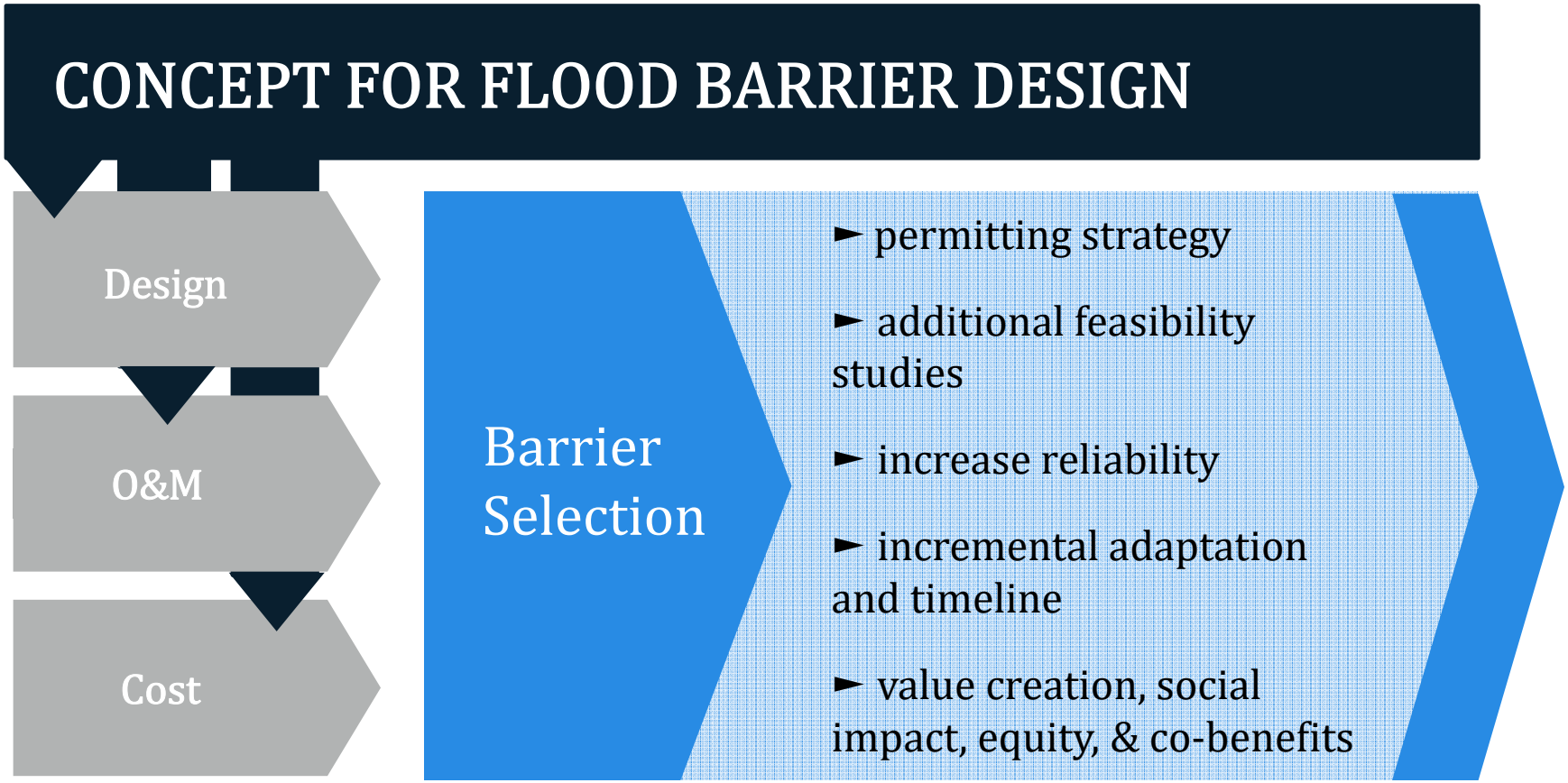
HARBORWALK FLOOD BARRIER

RAISED ROADWAYS

TEMPORARY FLOOD BARRIERS

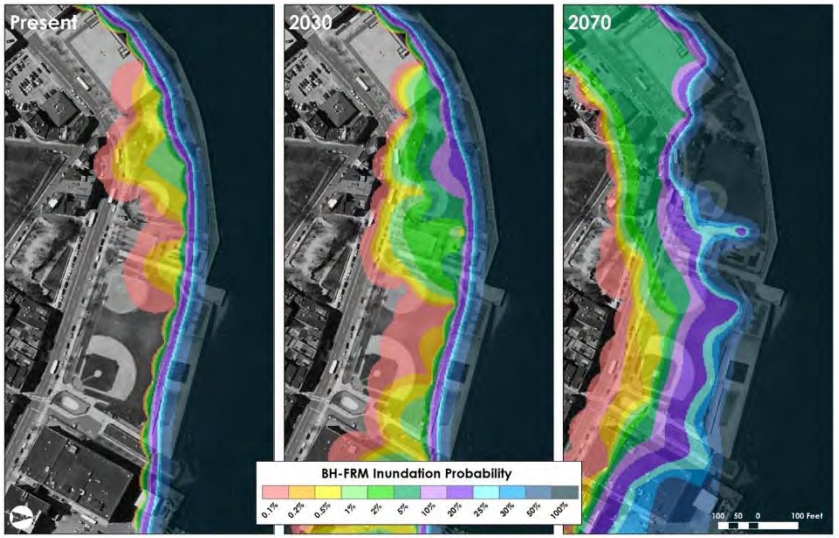
Note: All samples assumed a barrier height of 4 ft. for 2070 flood protection

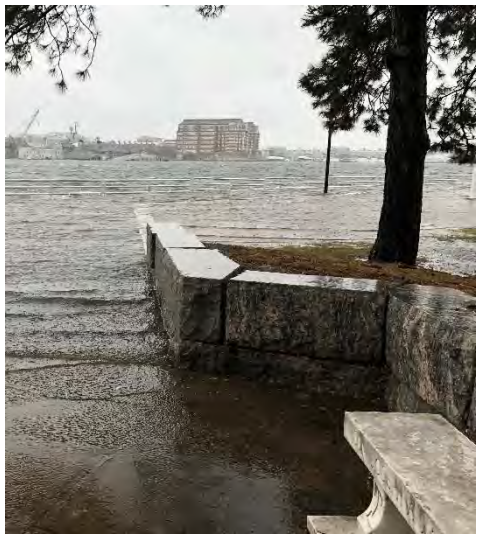
CLIMATE RESILIENT FLOOD BARRIER DESIGN

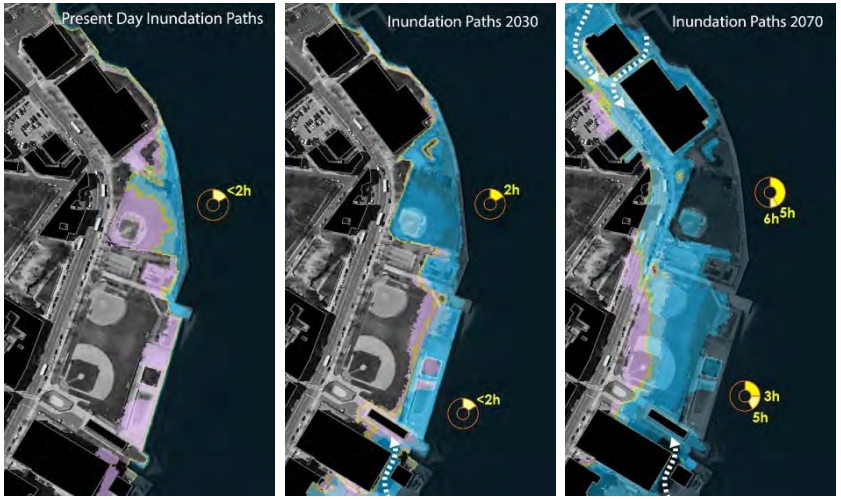


DESIGN CONSIDERATIONS

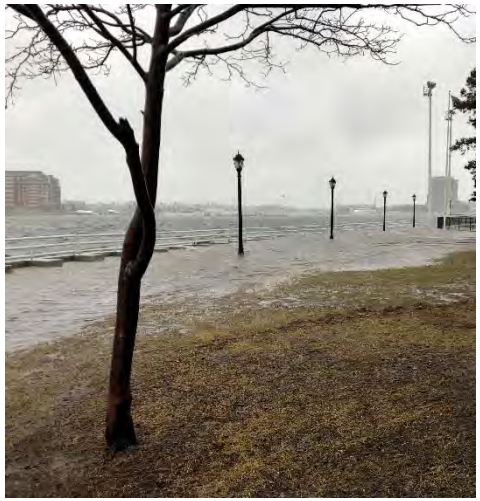
CLIMATE DESIGN ADJUSTMENTS







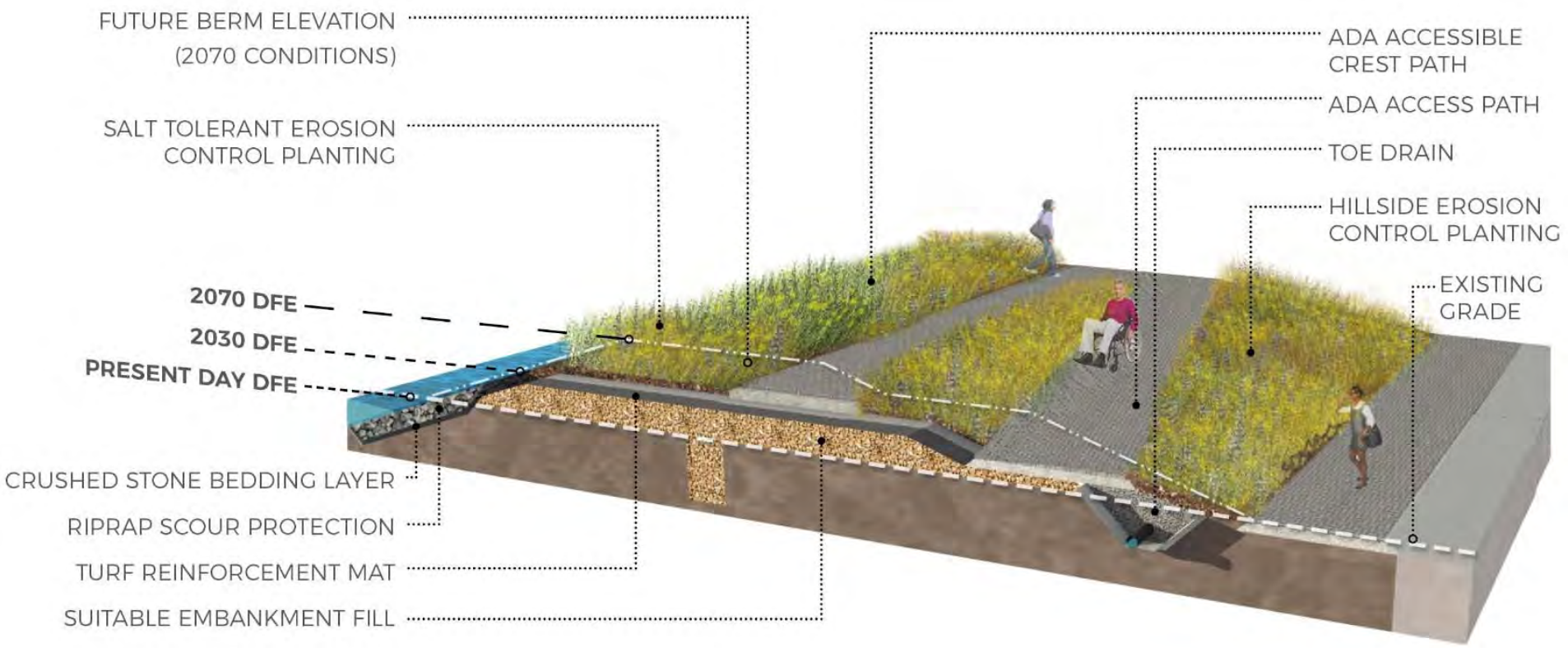
WOODS HOLE GROUP FOR EARTH, FROM SPACE
A CLS COMPANY



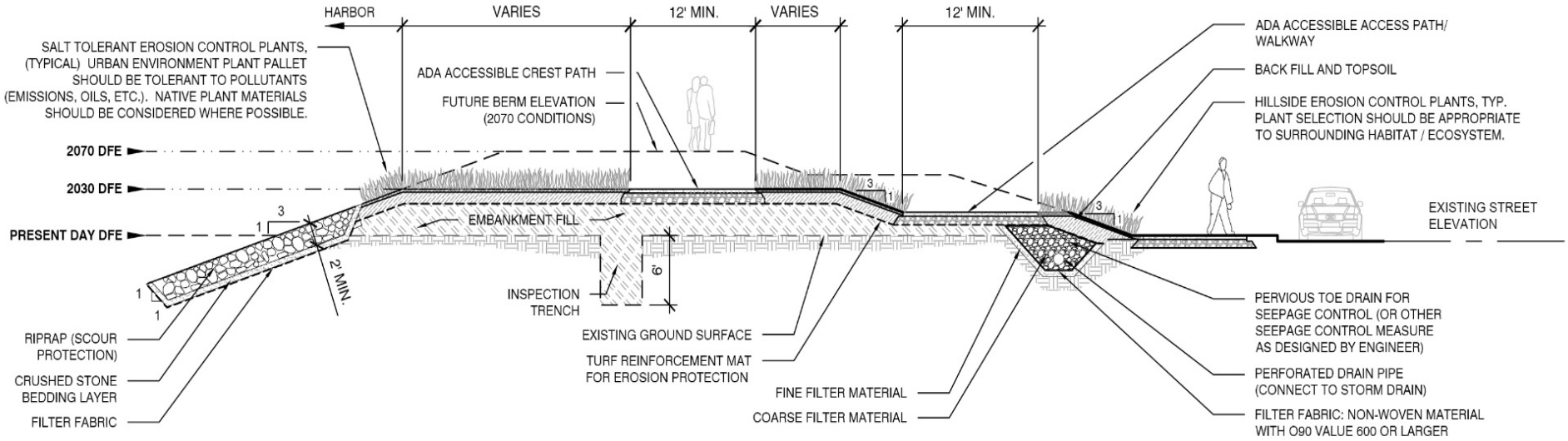
Flooding during the March 2, 2018 Nor'easter at Langone Park & Puopolo Playground

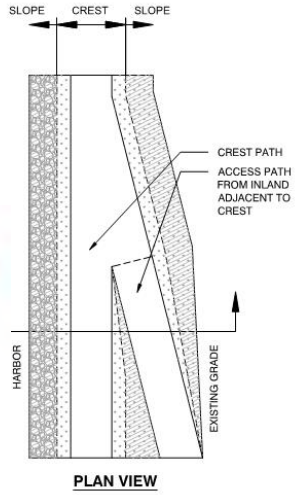
Weston & Sampson

SAMPLE VEGETATED BERM BARRIER



SAMPLE VEGETATED BERM BARRIER





CLIMATE RESILIENT DESIGN STANDARDS AND GUIDELINES FOR PROTECTION OF PUBLIC RIGHTS-OF-WAY

B.1 VEGETATED BERM BARRIER

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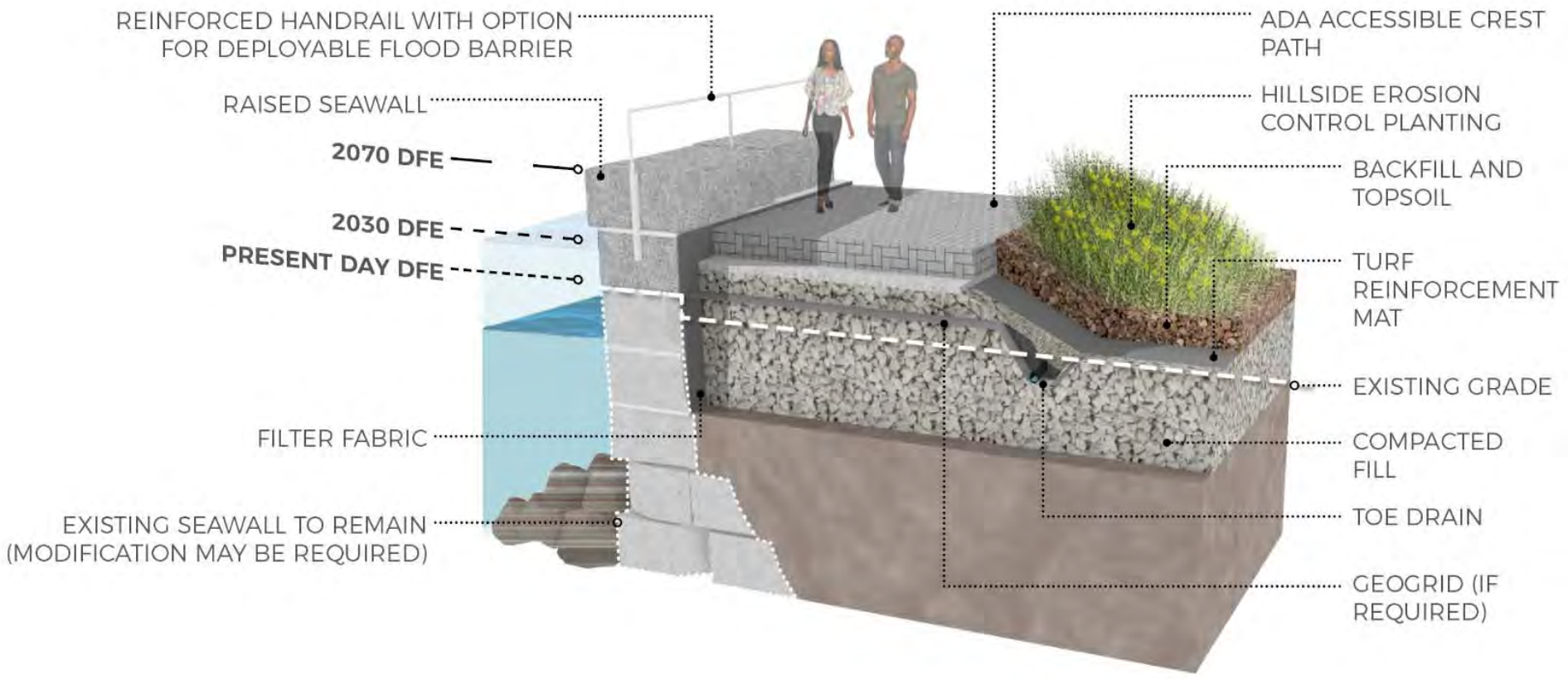
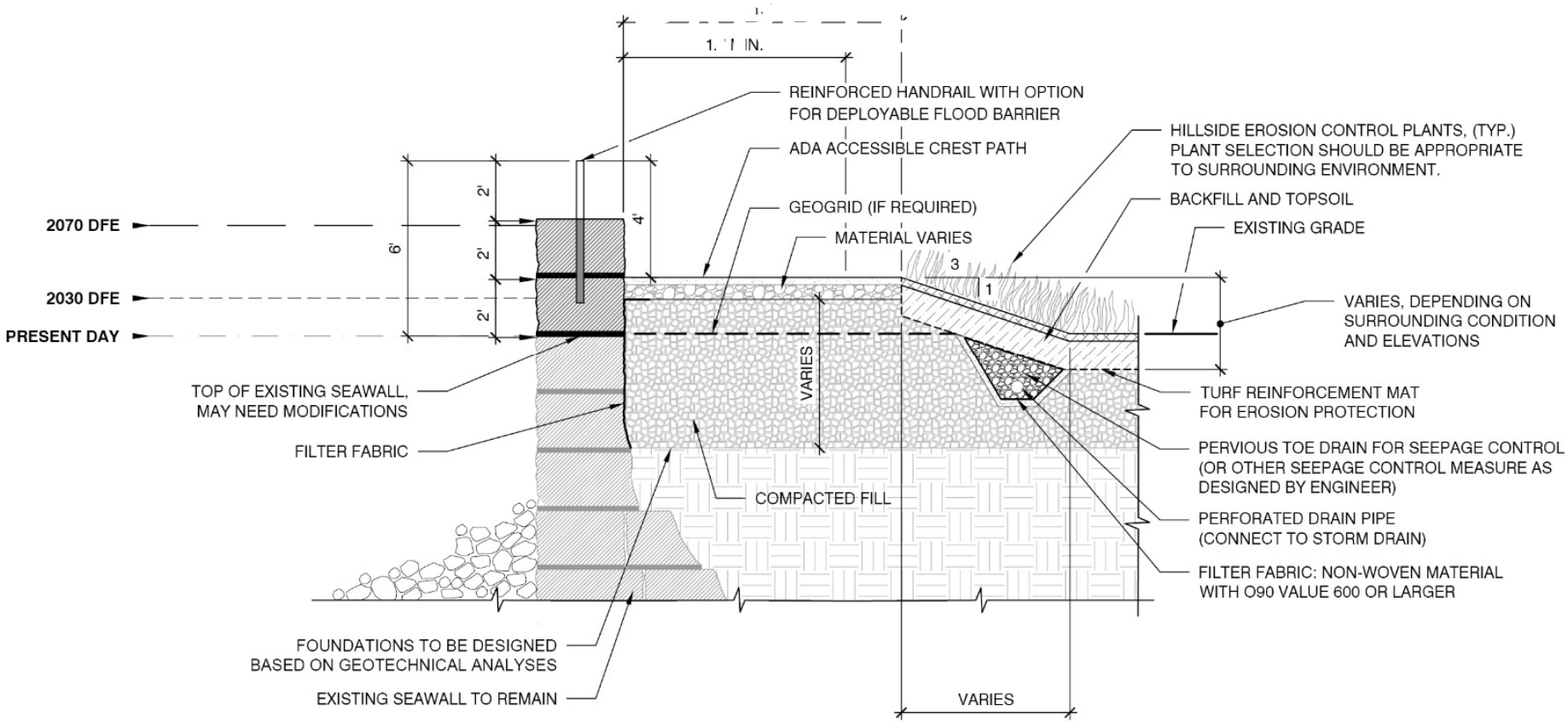
SAMPLE HARBORWALK (SEAWALL)



SAMPLE HARBORWALK (SEAWALL)



CLIMATE RESILIENT DESIGN STANDARDS AND GUIDELINES FOR PROTECTION OF PUBLIC RIGHTS-OF-WAY

B.2 HARBORWALK AS FLOOD BARRIER (RAISED SEAWALL)

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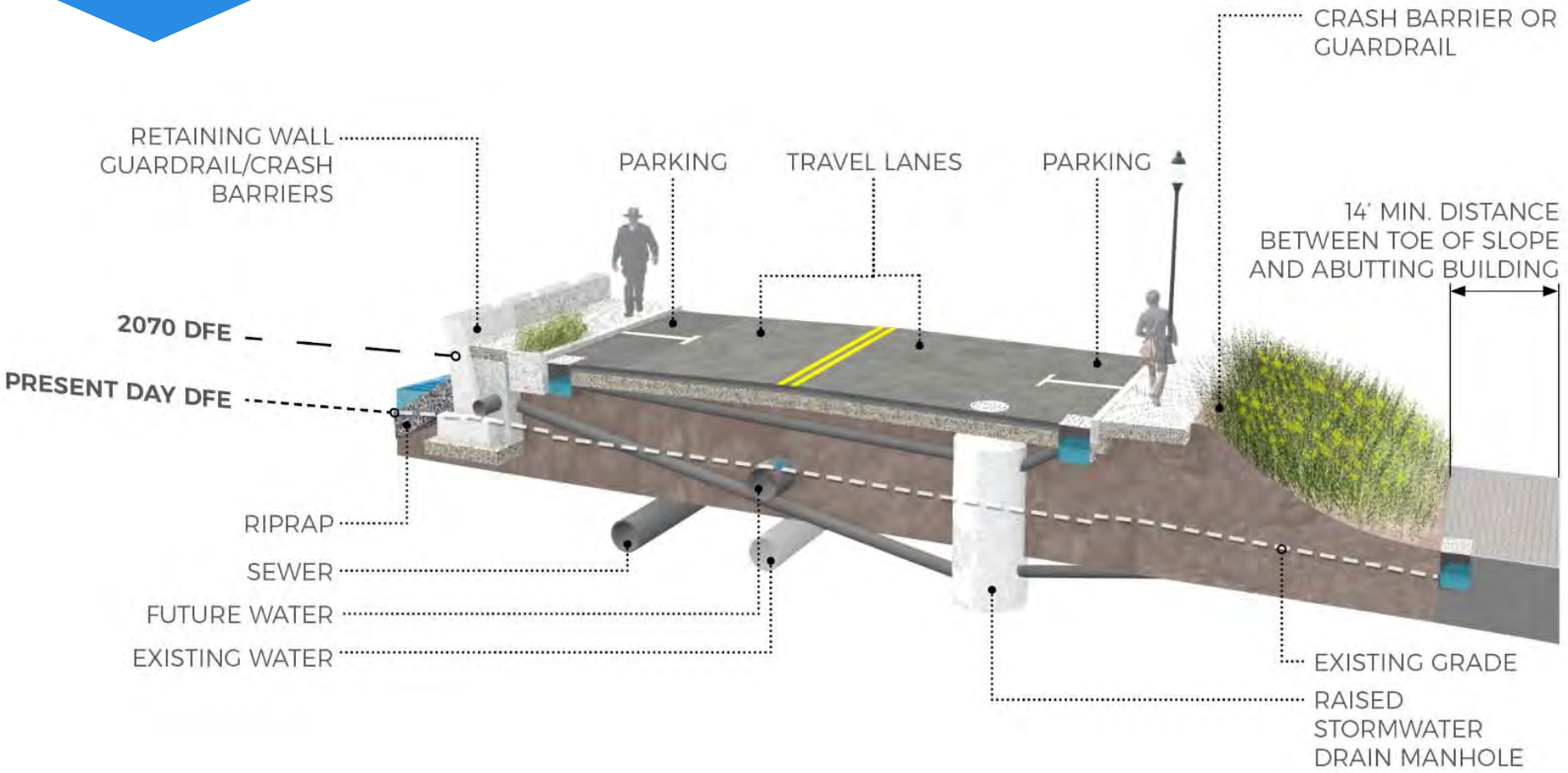
SAMPLE RAISED ROADWAY BARRIER

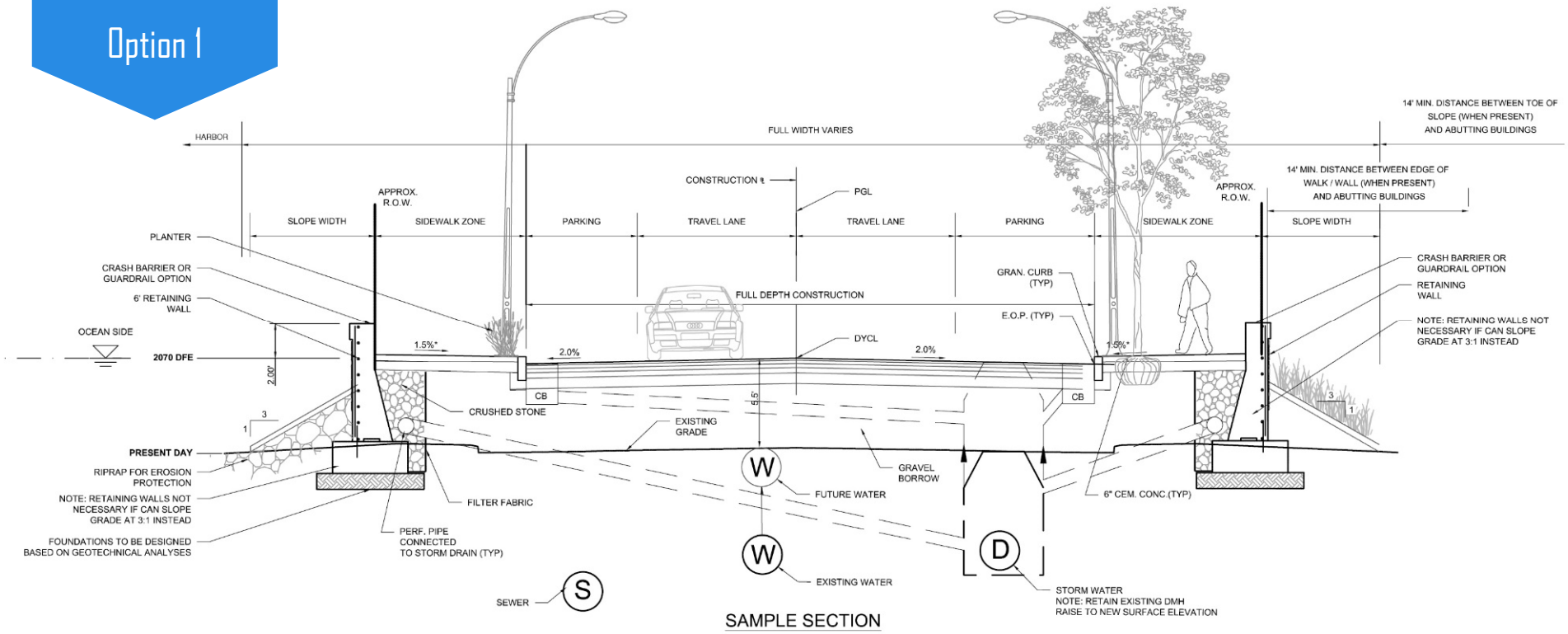
Option 1



Consider options to reduce to one-way traffic and add bike lanes, meet Complete Streets Standards

SAMPLE RAISED ROADWAY BARRIER

Option 1



SAMPLE SECTION

CLIMATE RESILIENT DESIGN STANDARDS AND GUIDELINES FOR PROTECTION OF PUBLIC RIGHTS-OF-WAY

B.3 RAISED ROADWAY - OPTION 1 NO BUILT PROPERTY WITHIN AT LEAST 14 FEET OF EXISTING RIGHT OF WAY

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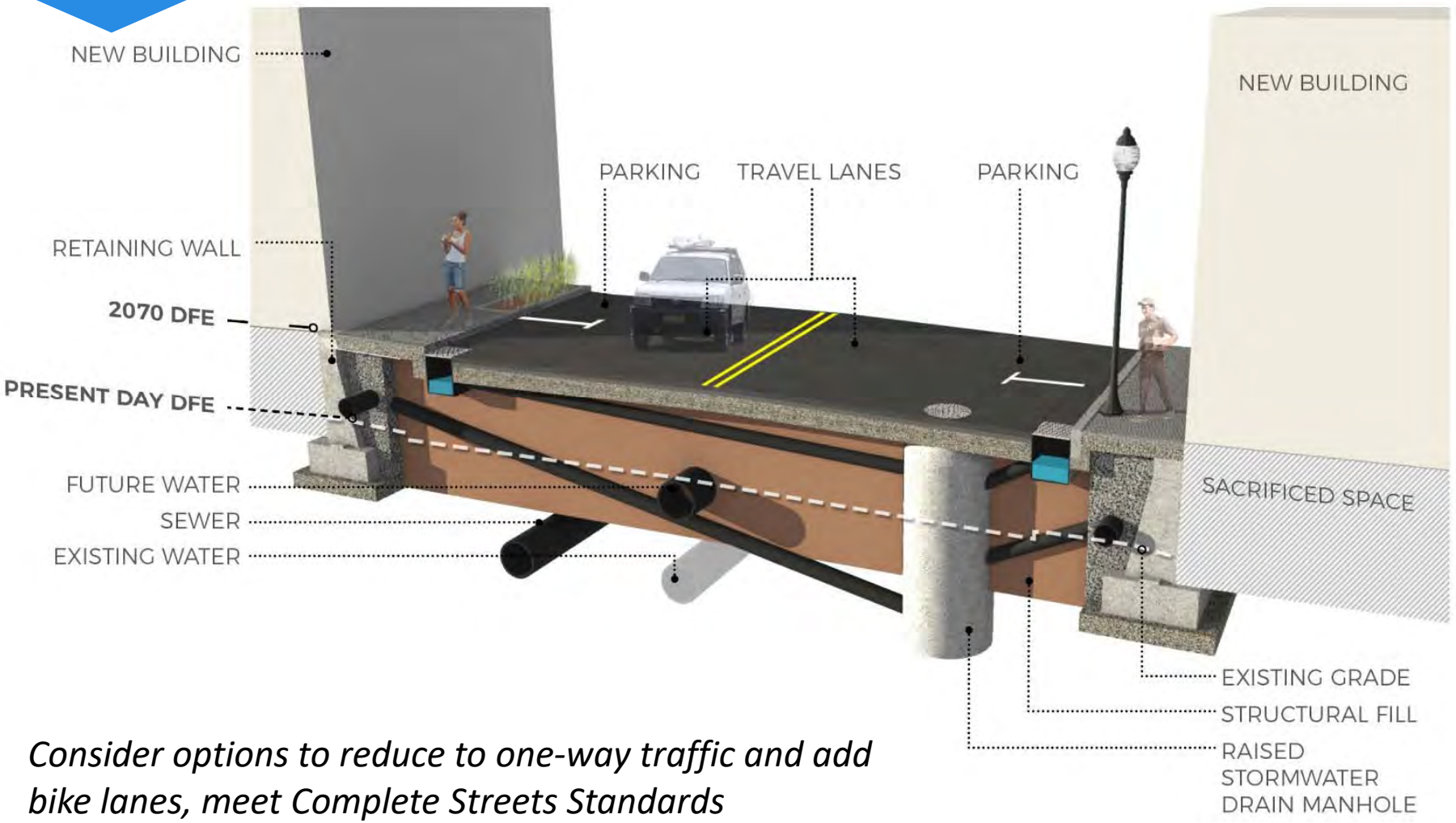
SAMPLE RAISED ROADWAY BARRIER

- Sidewalk gutters (debris, stormwater runoff)
- Snow removal problems
- Poor lighting and personal safety
- Accidents more deadly

- Vehicle emission pipes at head level of pedestrians (poor air quality)
- ADA compliance
- Emergency accessibility
- Business and community health

SAMPLE RAISED ROADWAY BARRIER

Option 2



Consider options to reduce to one-way traffic and add bike lanes, meet Complete Streets Standards

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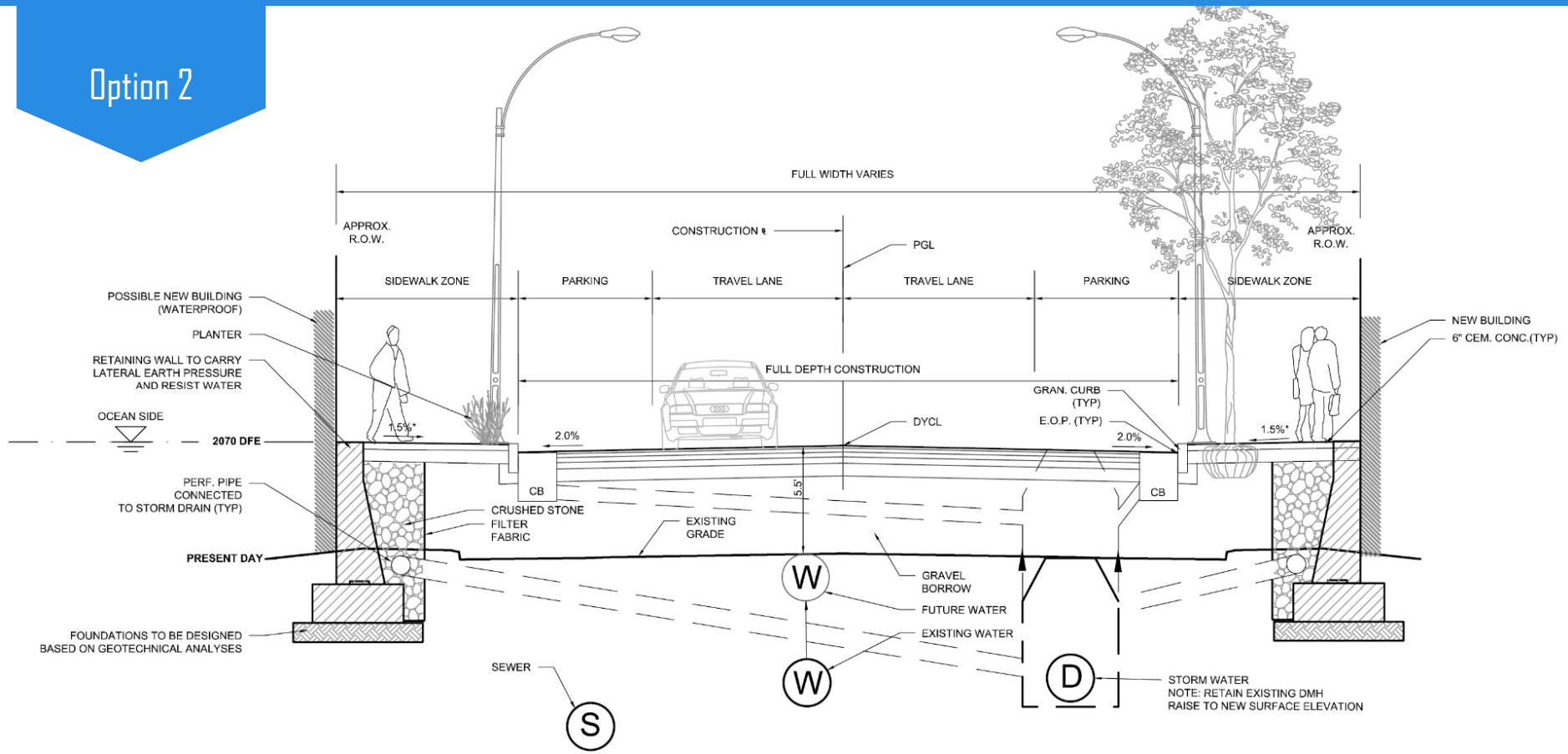
SAMPLE RAISED ROADWAY BARRIER

Option 2



SAMPLE SECTION

CLIMATE RESILIENT DESIGN STANDARDS AND GUIDELINES FOR PROTECTION OF PUBLIC RIGHTS-OF-WAY

B.4 RAISED ROADWAY - OPTION 2 RAISED ROADWAY & SIDEWALKS WITH NEW DEVELOPMENT

DEPLOYABLE FLOOD BARRIER

Design Considerations for the Site

- Barrier extent/connection to site
- Available open space (deployment or storage)
- Accessibility
- Terrain conditions
- Offsite impacts

Design Considerations for the Product

- Physical Characteristics
- Structural Properties
- Operational Requirements
- Industry Warranty, Certification, Testing

OPERATIONAL CAPACITY

PRIVATE PROPERTY PROTECTION & THE PUBLIC RIGHT OF WAY

Weston & Sampson

DEPLOYABLE FLOOD BARRIER

Type	Product	PHYSICAL CHARACTERISTICS									
		Barrier Type	Product Dimensions		Adjustable/Height Can Increase During Service?	Mobility	Material Information		Pre-Installation Site Modification	Average Design Life	Cost
		Description	Height Range	Width Range	Yes/No	Wheels/Cart	Material Type	Resistant to Environmental and Chemical Exposure	(Slight/Moderate/Extensive) *Not including retrofitting existing structures	Number of Years/Uses	Up Front Cost
ENTER TYPE	*ENTER PRODUCT FOR COMPARISON*	*Barrier type and description*	*As provided by product manufacturer*	*As provided by product manufacturere*	*Applicable if additional barrier modifications are available for increased protection height*	*Applicable if product is designed with wheels, or cart-compatible*	*As provided by product manufacturer*	*As provided by product manufacturer*	*As provided by product manufacturer*	*As provided by product manufacturer*	*Custom pricing may be available, as well as unit-based costs*
Modular Barriers											
Rigid/Panel	Aquafence	Modular Barrier: Rigid panels that are placed together to form one cohesive barrier.	4 ft. to 9 ft.	Limitless (current longest stretch is 5100 lf.)	Potentially (Product available)	Yes	Marine grade laminate, stainless steel, aluminum, reinforced PVC canvas	Yes	Slight - Anchor installation for best performace (Varies by site)	50+ years	$315/lf. - 4 ft. Height $415/lf. - 5 ft. Height $575/lf. - 6 ft. Height $650/lf. - 7 ft. Height $750/lf. - 8 ft. Height (Additional $10/lf. for anchors)
Rigid/Panel	FB33 Adjustable Lift-Out Barrier	Modular Barrier: Rigid adjustable panels that can be used as single units or in multiples	6 in. increments from 1.5 ft. to 4 ft.	Dependent on barrier height	No	Yes	Carbon steel (stainless steel option available), neoprene, carbon steel mechanical tubing, closed-cell foam, mastic epoxy painted finishes	Yes	Slight - Optional removable mullions for multi-panel installation (Varies by site)	25+ years	Custom pricing based on required width and height
Rigid/Stop Log	CISIL Stop Logs	Modular Barrier: Stop log style barrier with customizable width and height	2:1 factor of safety based on material yield strength. Can increase height in 6 in. and 8 in. increments		Yes	Yes	6063-T5 aluminum panels, aluminum, low carbon stteel, neoprene seals (Viton and other materials available)	Yes	Moderate - sill/conversion frame installation will require site work (Varies by site)	25+ years	Custom pricing based on required height, width, and jamb type
Rigid/Stop Log	FastLogs Stop Logs	Modular Barrier: Stop log style barrier with customizable width and height	2:1 factor of safety based on material yield strength. Can increase height in 6 in. increments		Yes	Yes	Mill-finish alumnium, steel (primed with one coat rust inhibitive, lead free, red primer), high-density closed cell neoprene sponge	Yes	Moderate - frame/jamb installation will require site work (Varies by site)	25+ years	Custom pricing based on required height, width, and jamb type
Rigid/Hinged	PS Flood Barriers Hinged Flood Barrier (Single)	Modular Barrier: Hinged door barrier with customizable width and height	2:1 factor of safety based on material yield strength		No	Yes	Steel, stainless steel, 6063 aluminum, 6061 aluminum, EPDM rubber	Yes	Moderate - frame/jamb/sill installation will require site work (Varies by site)	25+ years	Custom pricing based on required width and height
Rigid/Sliding	PS Flood Barriers Sliding Flood Barrier	Modular Barrier: Sliding door barrier with customizable width and height	2:1 factor of safety based on material yield strength		No	Yes	Steel, stainless steel, 6063 aluminum, EPDM rubber	Yes	Moderate - frame/jamb/sill installation will require site work (Varies by site)	25+ years	Custom pricing based on required width and height
Membrane Barriers											
Flexible	ILC Dover Vertically Deployed Flex Wall	Membrane Barrier: Flexible wall with rapid vertical deployment for building and equipment protection	Ideal height for constructability and deployment time is a DFE of 4 ft. above grade or less. Higher heights are possible with the addition of braces to the posts	With itermittent deployable posts, no real limit to span (10 ft. to 12 ft. between posts or connection points)	No	N/A	Kevlar webbings, PVC coated polyester, metal (stainless steel, etc.), H2O covers	Yes	Extensive - excavation efforts (1.5 ft. trench) are necessary for barrier installation (Varies by site)	20 years	Custom pricing based on required width and height; estimated cost range of $350-550/sf.
Flexible	ILC Dover Side Deployed Flex Wall	Membrane Barrier: Flexible wall with rapid horizontal deployment for building and equipment protection	DFE heights of 1 ft. to 10 ft. above grade (typically, but can go higher)	6 ft. to 60 ft. with deployable or permanent posts	No	N/A	Kevlar webbings, PVC coated polyester, metal (stainless steel, etc.), H2O covers	Yes	Moderate - structural supports may be needed for barrier installation (Varies by site)	19 years	Custom pricing based on required width and height; estimated cost range of $350-550/sf.
Passive Barriers											
Automatic	Self Closing Flood Barrier (SCFB)	Membrane Barrier: Self-rising floodgate. Rises automatically as floodwaters approach	Up to 12 ft. Design should be verified by structural calculations.	Limitless but requires vertical supports	No	N/A	PUR foam core, fiberglass, gaskets, galvanized steel	Yes	Extensive - excavation efforts are necessary for barrier installation (Varies by site)	25+ years	Custom pricing based on required width, height, loadings needed, and FEMA zones
Automatic	FloodBreak Gate	Membrane Barrier: Self-rising floodgate. Rises automatically as floodwaters approach	No practical limit. Design validated by structural engineer to 39 ft. height (multiple 12 ft. tall gates installed)	Limitless with no stanchions or vertical stops. (100 ft. length gates are installed without stanchions across highways)	No	N/A	Marine grade aluminum, stainless steel fittings, and EPDM rubber gaskets	Yes	Extensive - excavation efforts are necessary for barrier installation (Varies by site)	Decades of service life with minimal maintenance. Recommend to change gaskets every 10 years	Custom pricing based on required width and height

Notes:

1. The types and products provided are not endorsed by the City of Boston and do not indicate a preference for one barrier type over another. The list is not comprehensive and does not reflect all possible products on the market. As products are identified for possible use, they should be entered into this table to compare and contrast with other products. The products should comply with City of Boston policies, zoning, and regulations.
2. Product manufacturers should be contacted to provide content in this table and be able to provide back-up documentation for submittals.
3. The following framework is based on the methodology developed for "Temporary and Demountable Flood Protection Guide," (Ogunyoye, Fola, Richard Stevens, and Scott Underwood, 2011).

O&M AND COST CONSIDERATIONS

NOT JUST BARRIER OPERATIONS AND MAINTENANCE CONSIDERATIONS!

Elevated roads and pump station

Case Study: Stormwater management for raised roadways in Sunset Harbor, Miami Beach, FL

- ► energy costs for pump stations and system redundancy
- ► reassigned or new staff (or contractors) to maintain the new pump stations, generators, treatment systems, and utilities associated with stormwater management
- ► new O&M equipment needed for stormwater management
- ► operations management support
- ► staff training

O&M AND COST CONSIDERATIONS

NOT JUST WATER! SNOW & ICE!

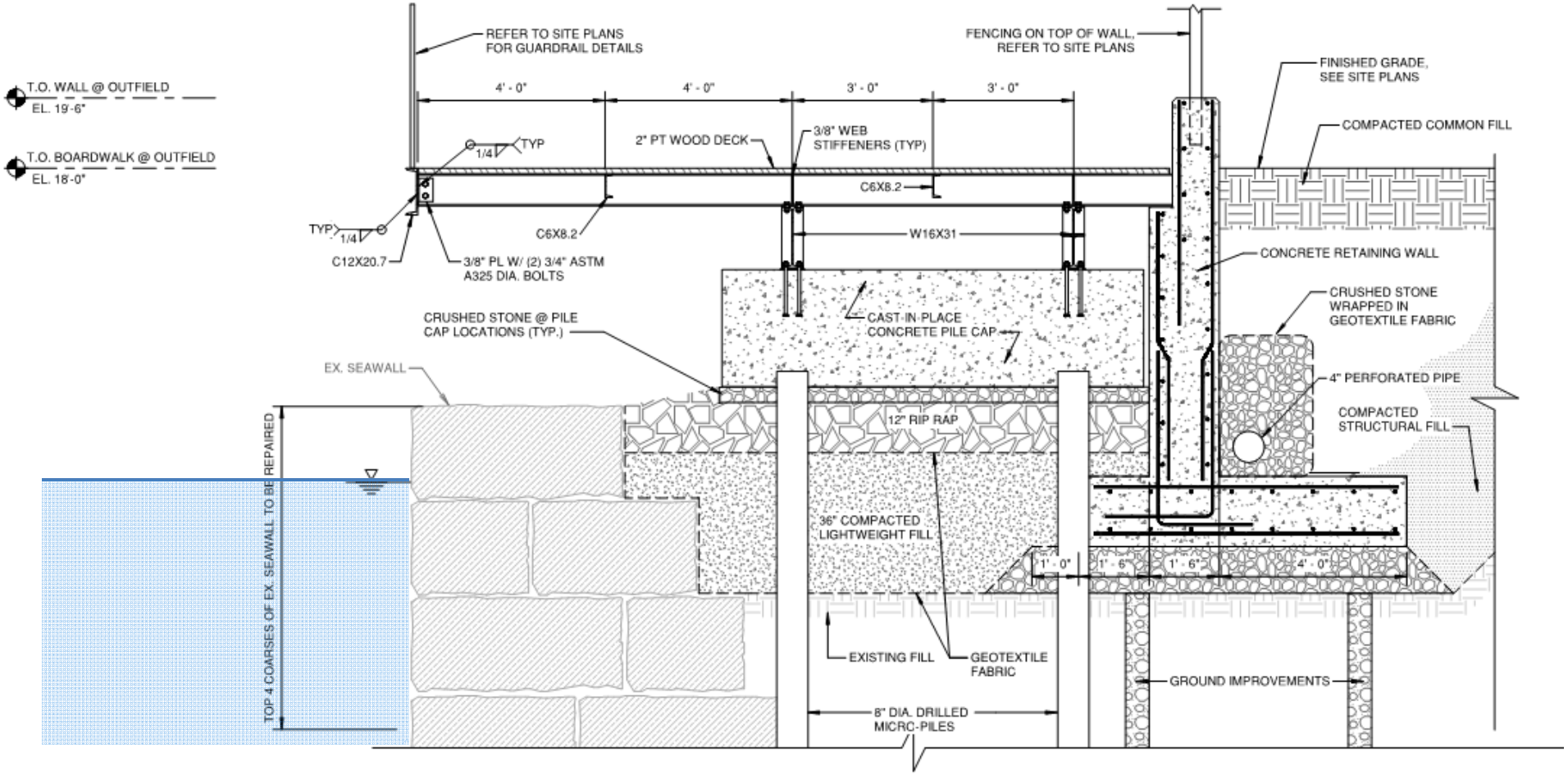
Source: Boston_January 2015_Shutterstock_Svitlana Pimenov

LANGONE & PUOPOLO PARK

Weston & Sampson

LANGONE & PUOPOLO PARK

Flood protection cross-section – elevated boardwalk



1 SECTION @ OUTFIELD

Weston & Sampson

CLIMATE RESILIENT FLOOD BARRIER

Please visit the Boston Public Works Department Website for more information, including:

► general engineering and design considerations

► sample design drawings and specifications

► opinion of probable costs for sample barriers (construction and annual)

► operations and maintenance guidance.

https://www.boston.gov/departments/public-works/climate-resilient-design-standards-and-guidelines

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