Cambridge Climate Change Vulnerability Assessment

Presentation to DCAMM

December 10, 2015

KLEINFELDER

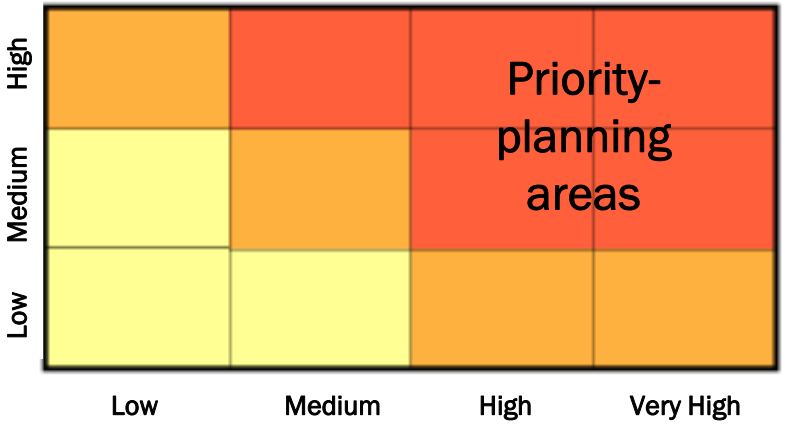
The Challenge

- Design criteria based on past events.
- Past is no longer a reliable indicator of present or future conditions.

How do you translate climate risk into planning and design?

Project's Framework

Phase I: Vulnerability Assessment



Step 1

Climate Scenarios

Step 2

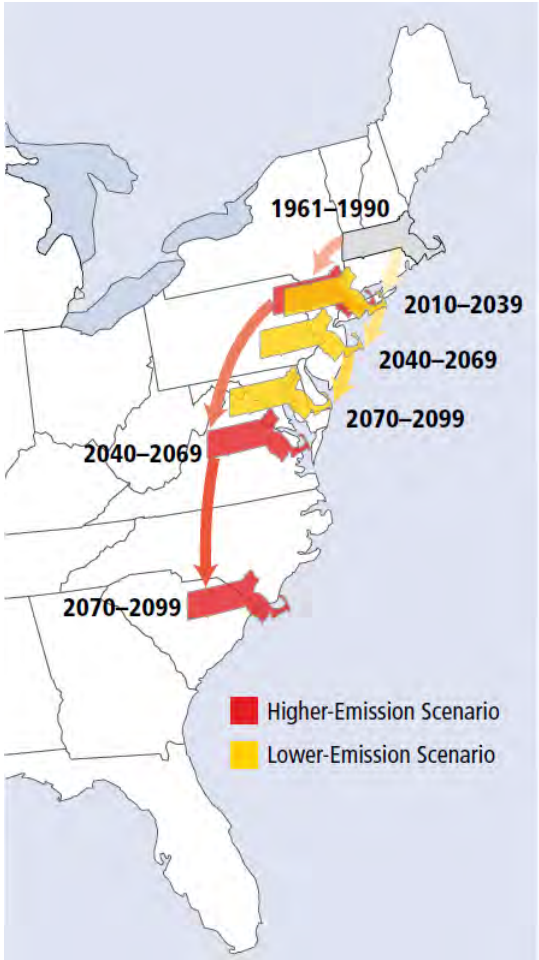
Vulnerability & Risk Assessment

Step 3

Preparedness Plan

Climate Change Effects of Concern

Temperature



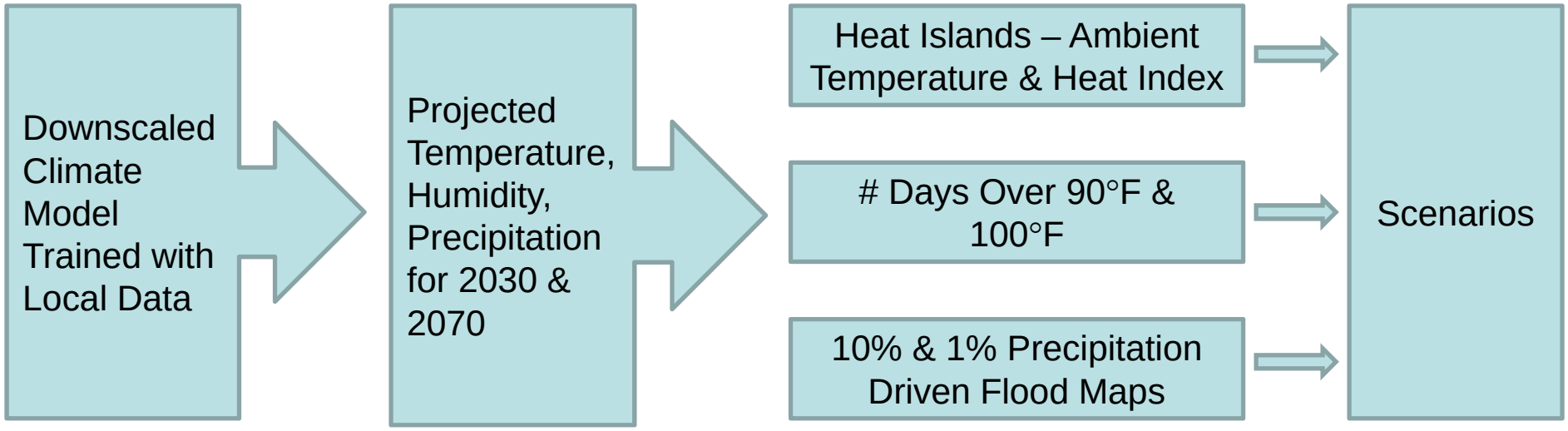
Precipitation

More extreme events

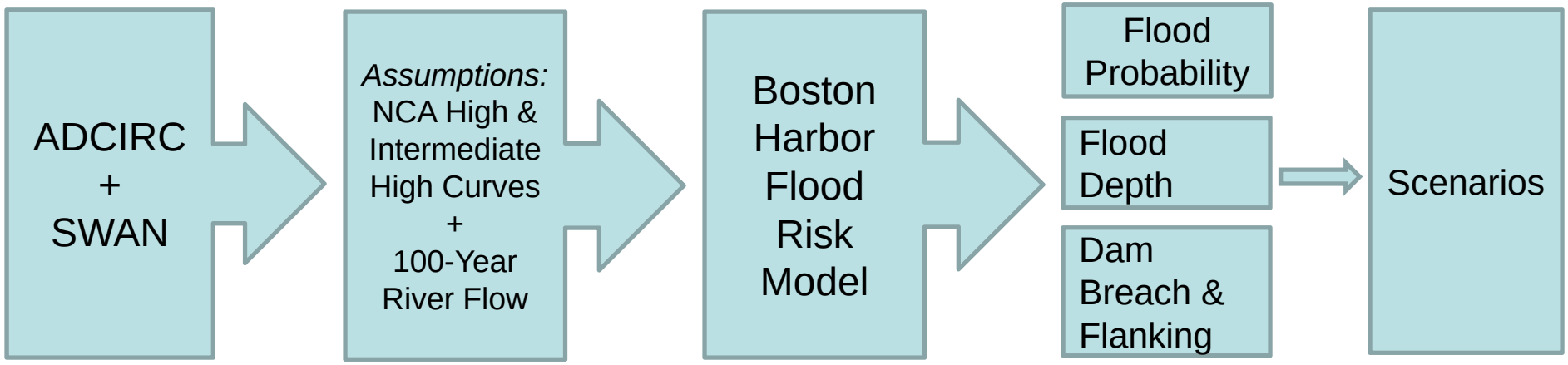
Sea level rise

CCVA Projections

Heat & Precipitation

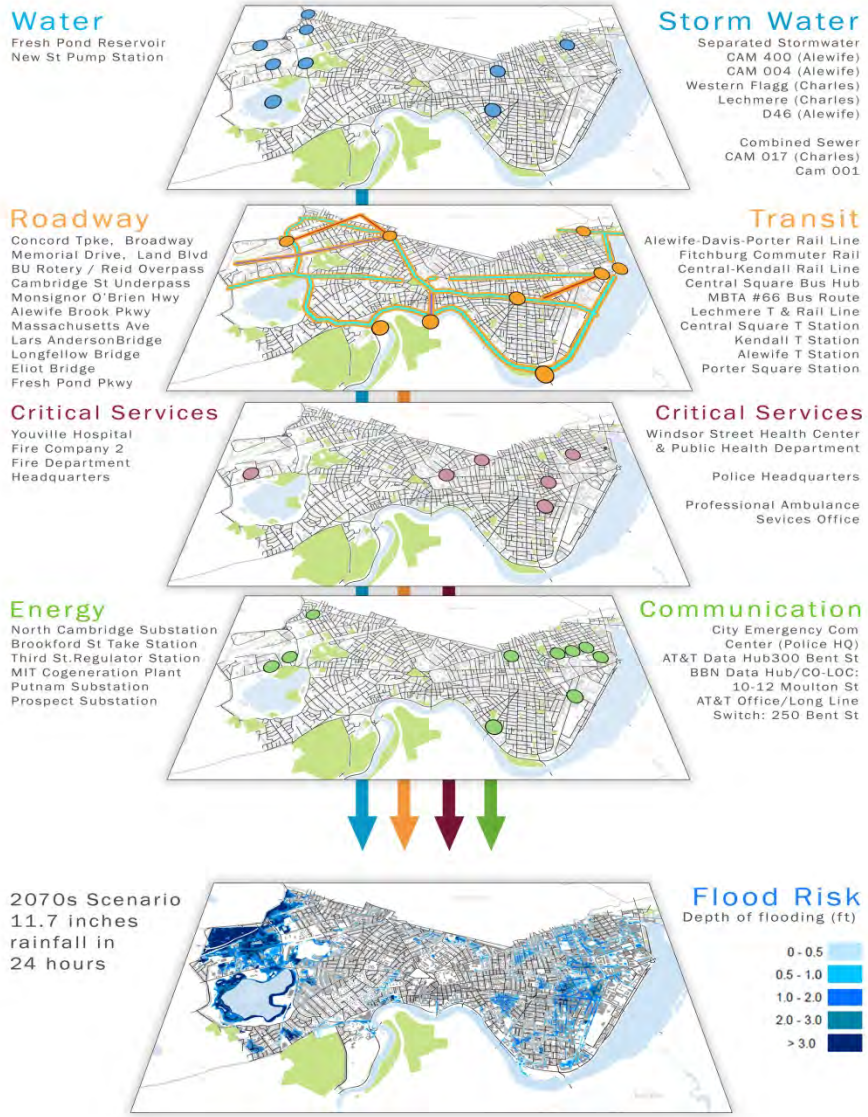


Sea Level Rise & Storm Surge

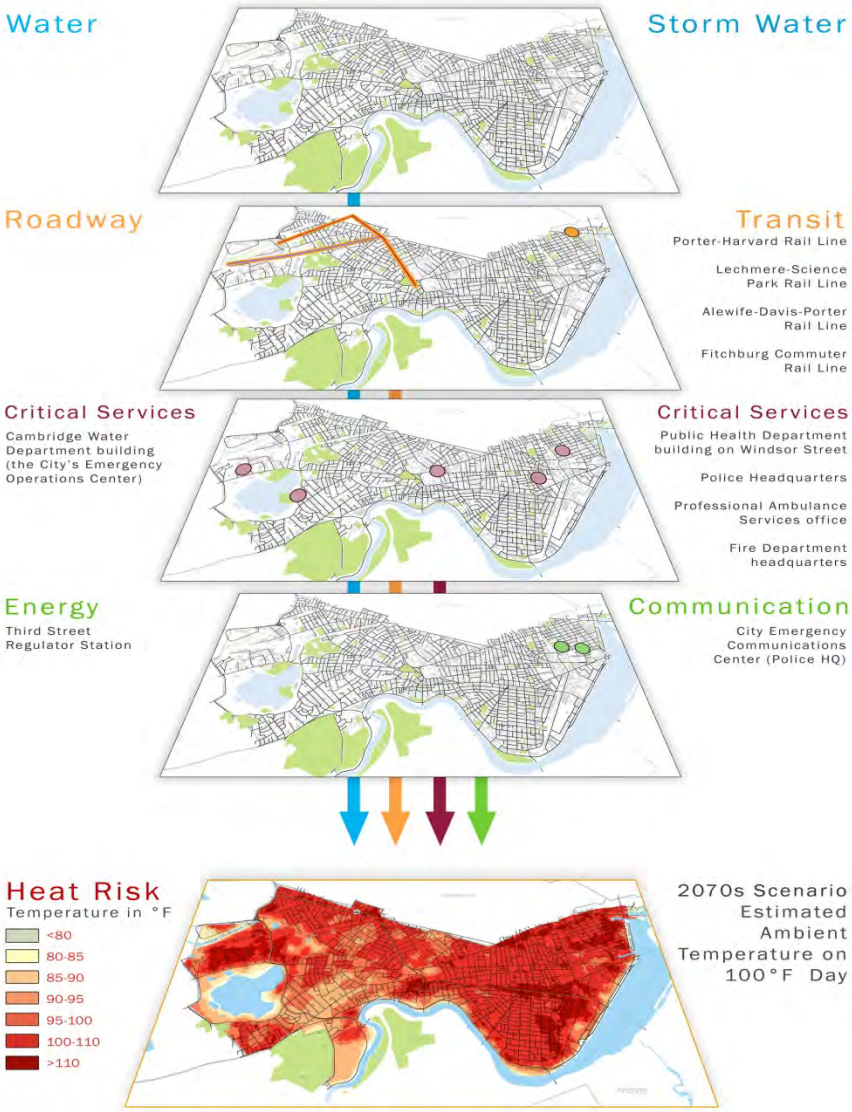


Cambridge Climate Stress Test

Flooding stress test



Heat stress test



Climate Change Vulnerability Assessment

November 2015

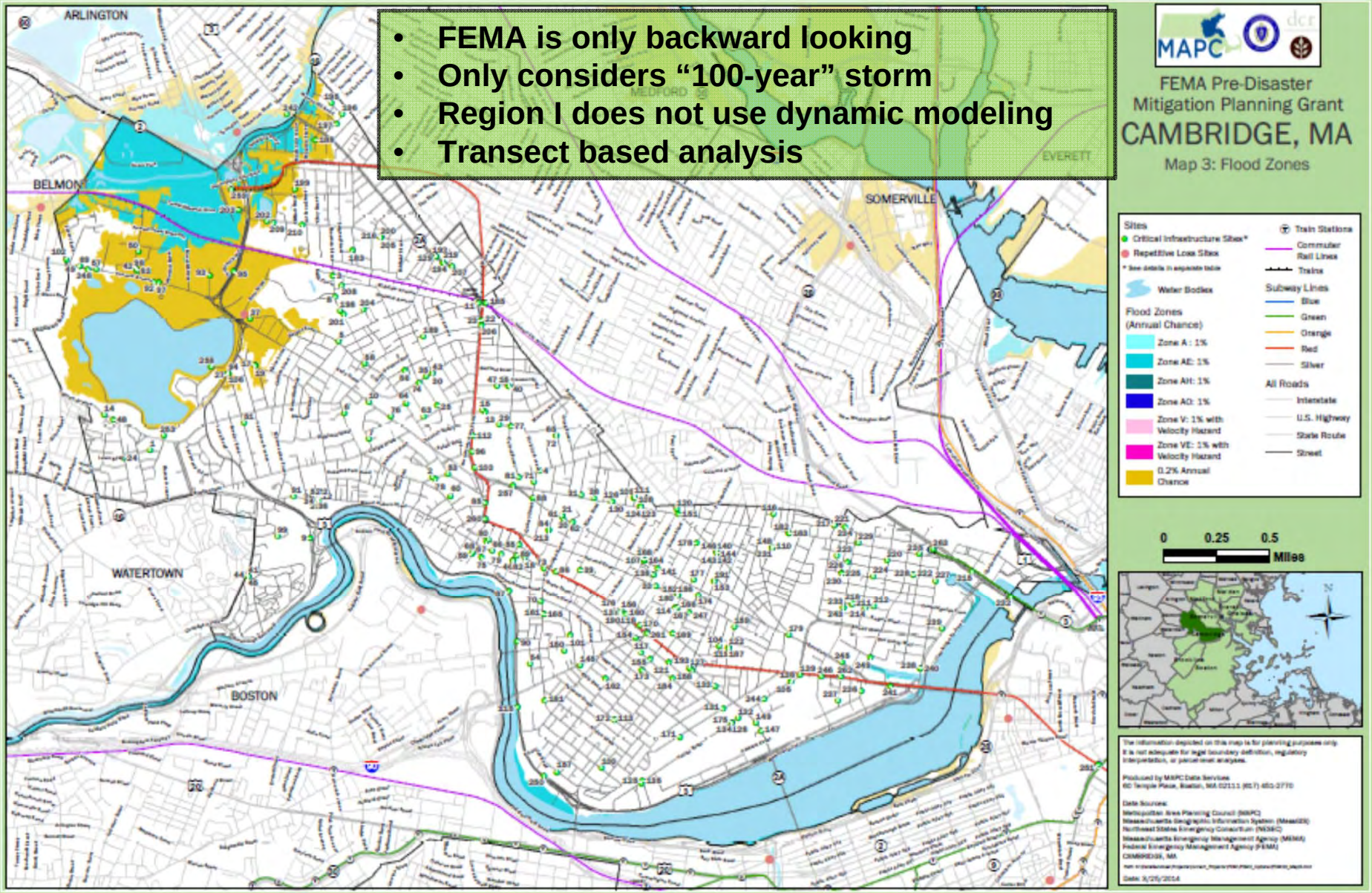
City of Cambridge, Massachusetts

1 Part

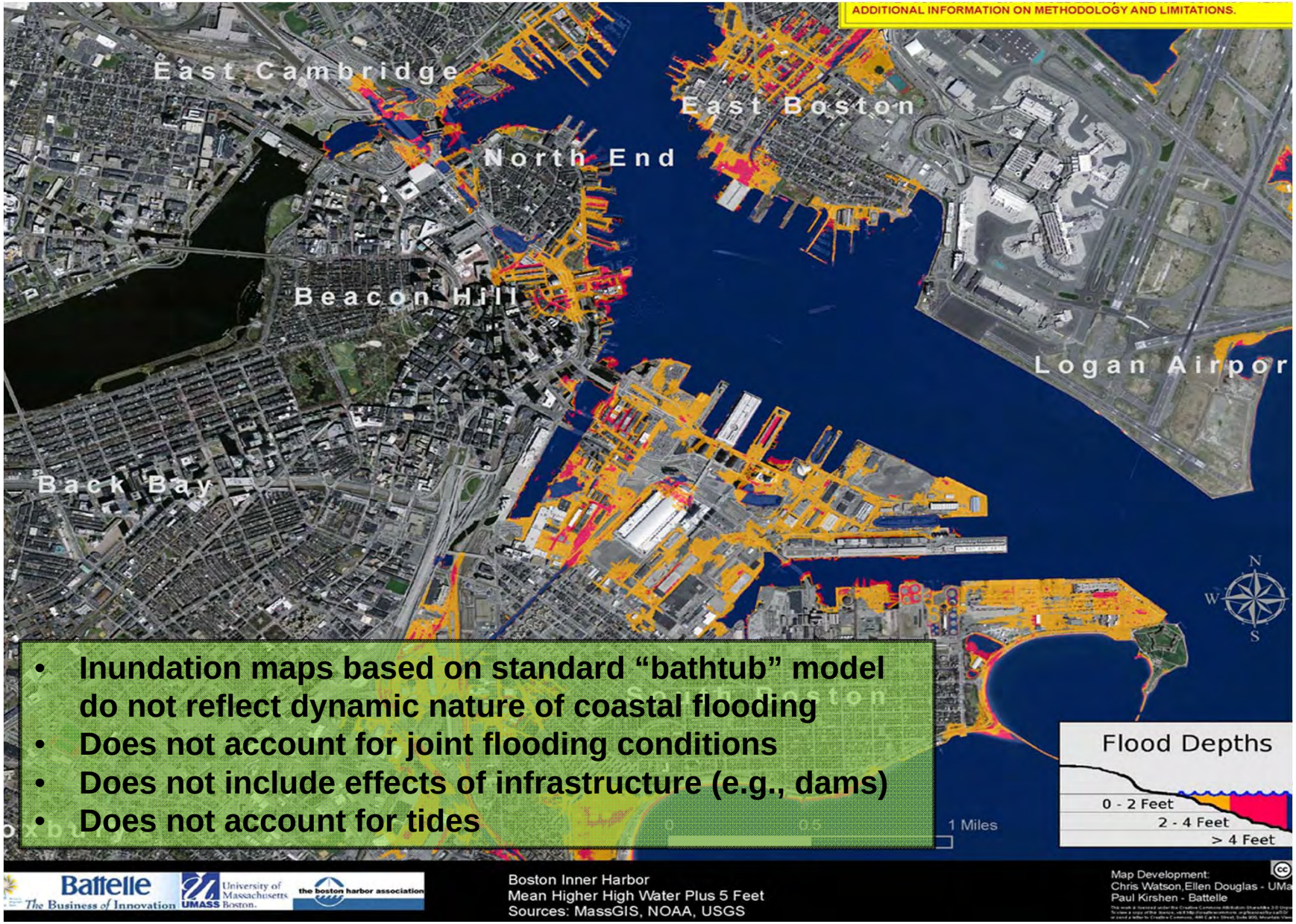
The Report and Technical Appendices online at *www.cambridgema.gov/climateprep*

Flood Map Options - FEMA

- FEMA is only backward looking
- Only considers “100-year” storm
- Region I does not use dynamic modeling
- Transect based analysis

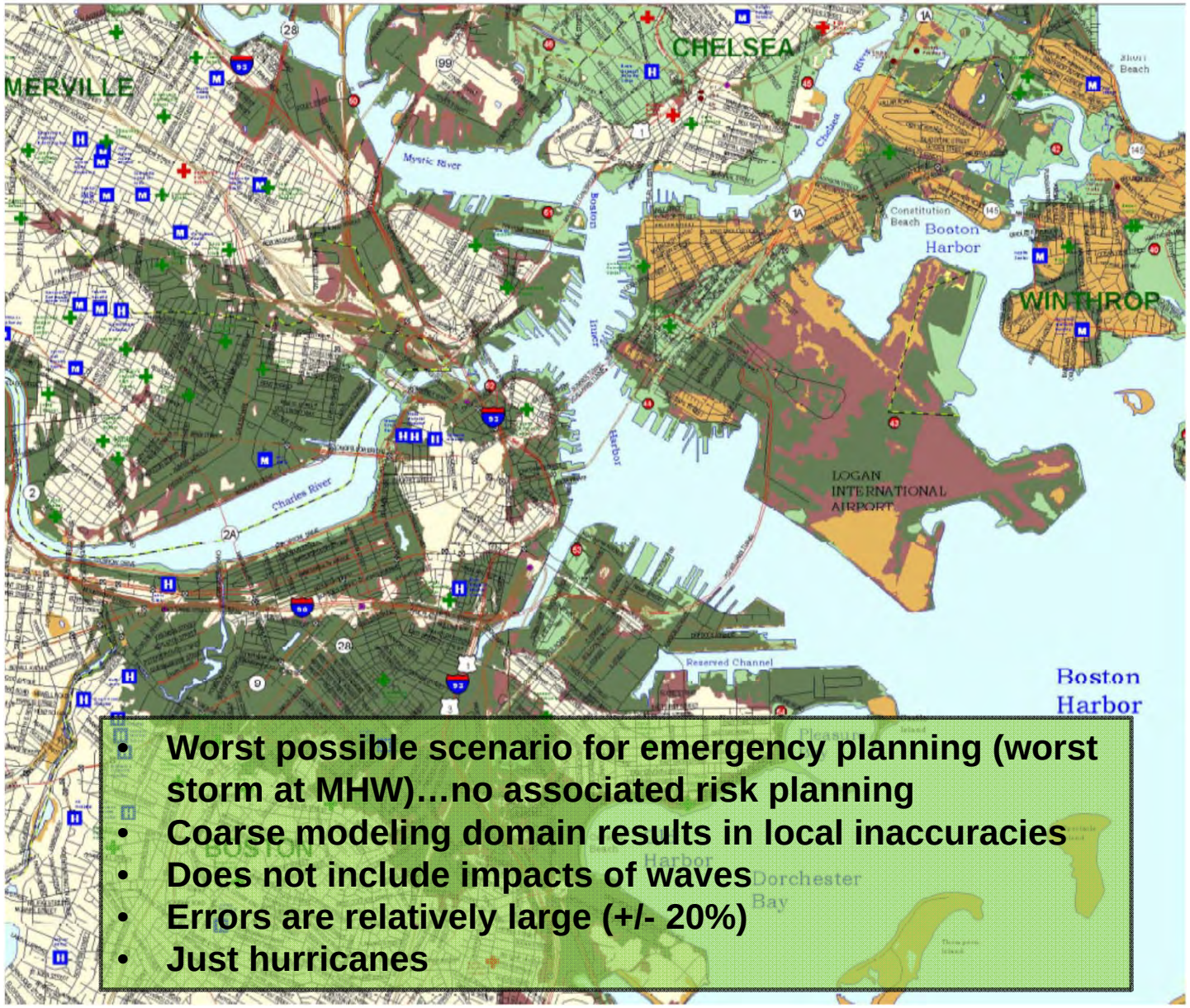


Flood Map Options - Bathtub



- Inundation maps based on standard "bathtub" model do not reflect dynamic nature of coastal flooding
- Does not account for joint flooding conditions
- Does not include effects of infrastructure (e.g., dams)
- Does not account for tides

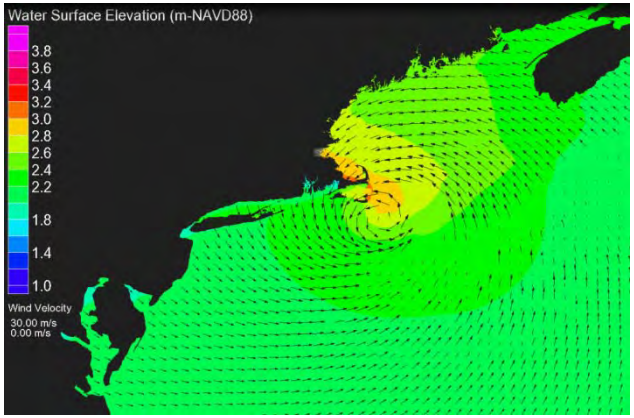
Flood Map Options – Hurricane Evacuation



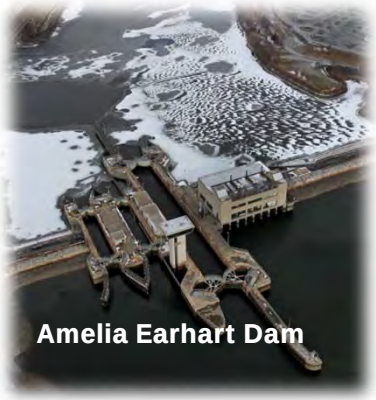
- Worst possible scenario for emergency planning (worst storm at MHW)…no associated risk planning
- Coarse modeling domain results in local inaccuracies
- Does not include impacts of waves
- Errors are relatively large (+/- 20%)
- Just hurricanes

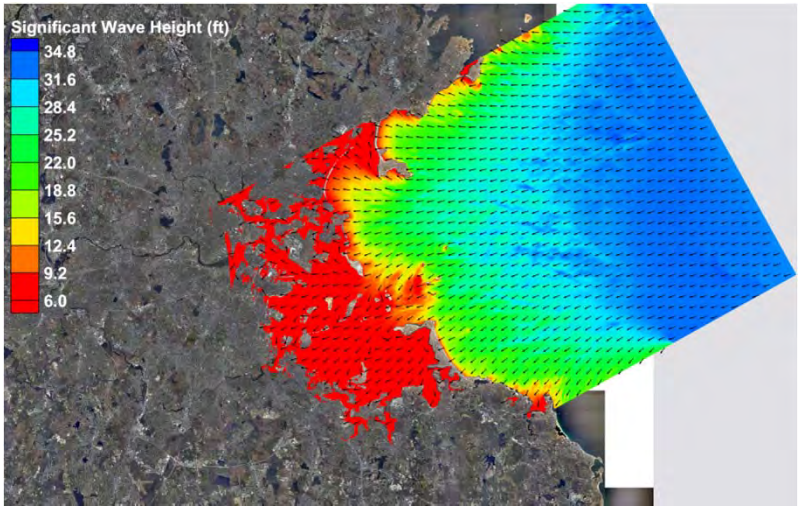
High Resolution Hydrodynamic Modeling

- Includes relevant physical processes (tides, storm surge, wind, waves, wave setup, river discharge, sea level rise, future climate scenarios)



- Currents
- Storm Surge
- Tides
- Water Levels
- Winds
- SLR
- Discharge
- Infrastructure



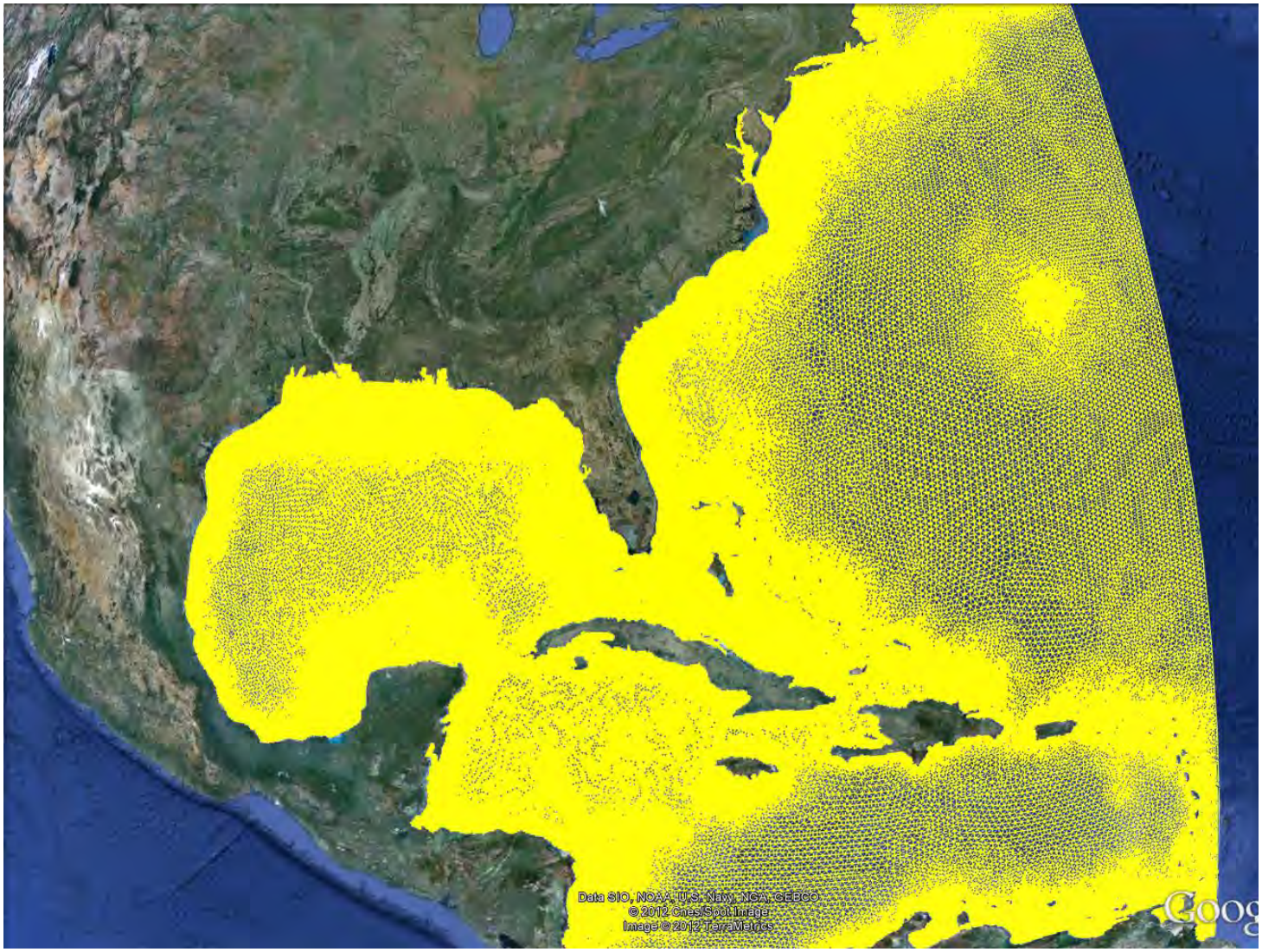


- Waves
- Wave Setup

Tightly Coupled

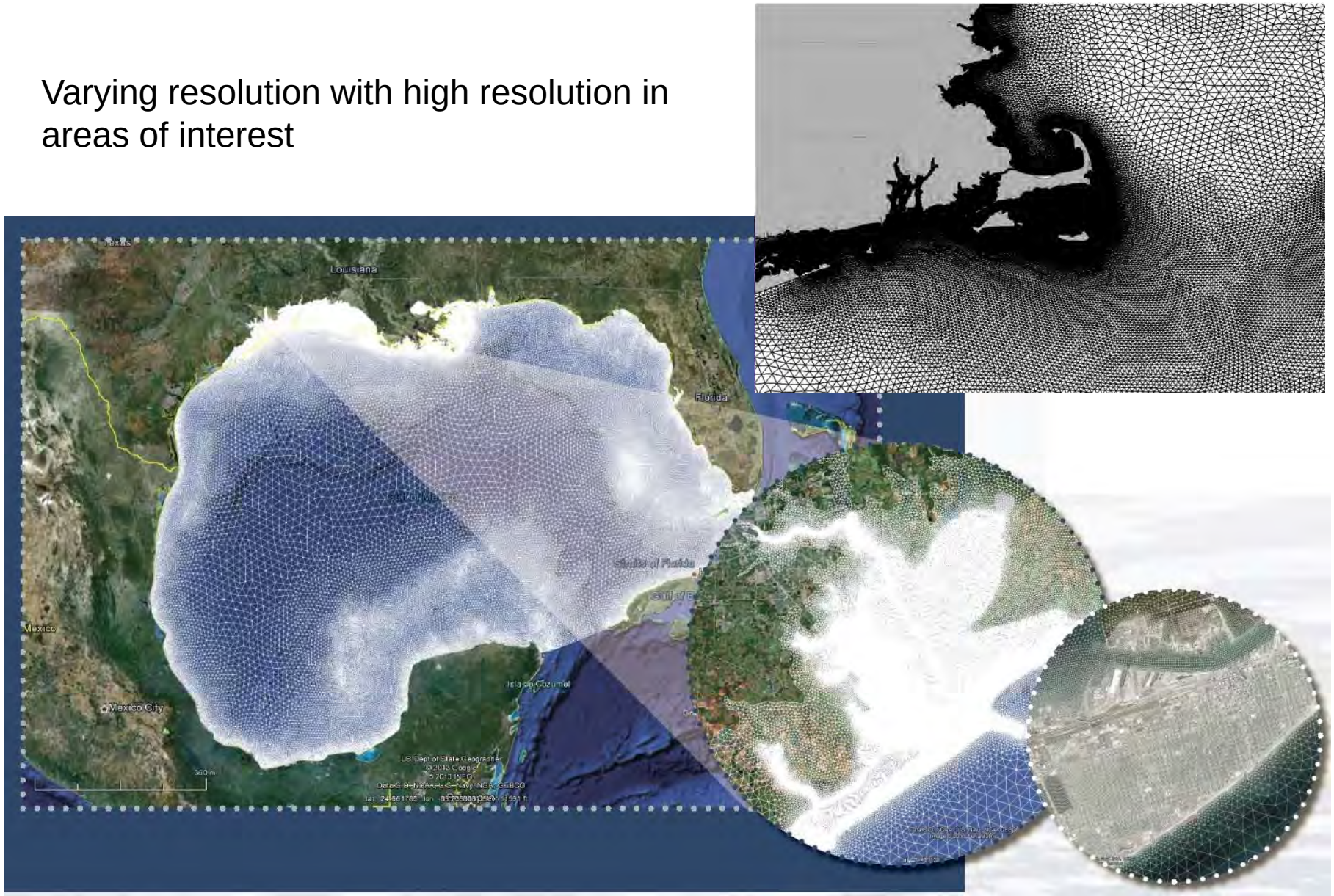
Regional Grid Requirements

Grid covers a large regional area (North Atlantic) to capture large-scale storm (hurricane, nor'easter) dynamics.



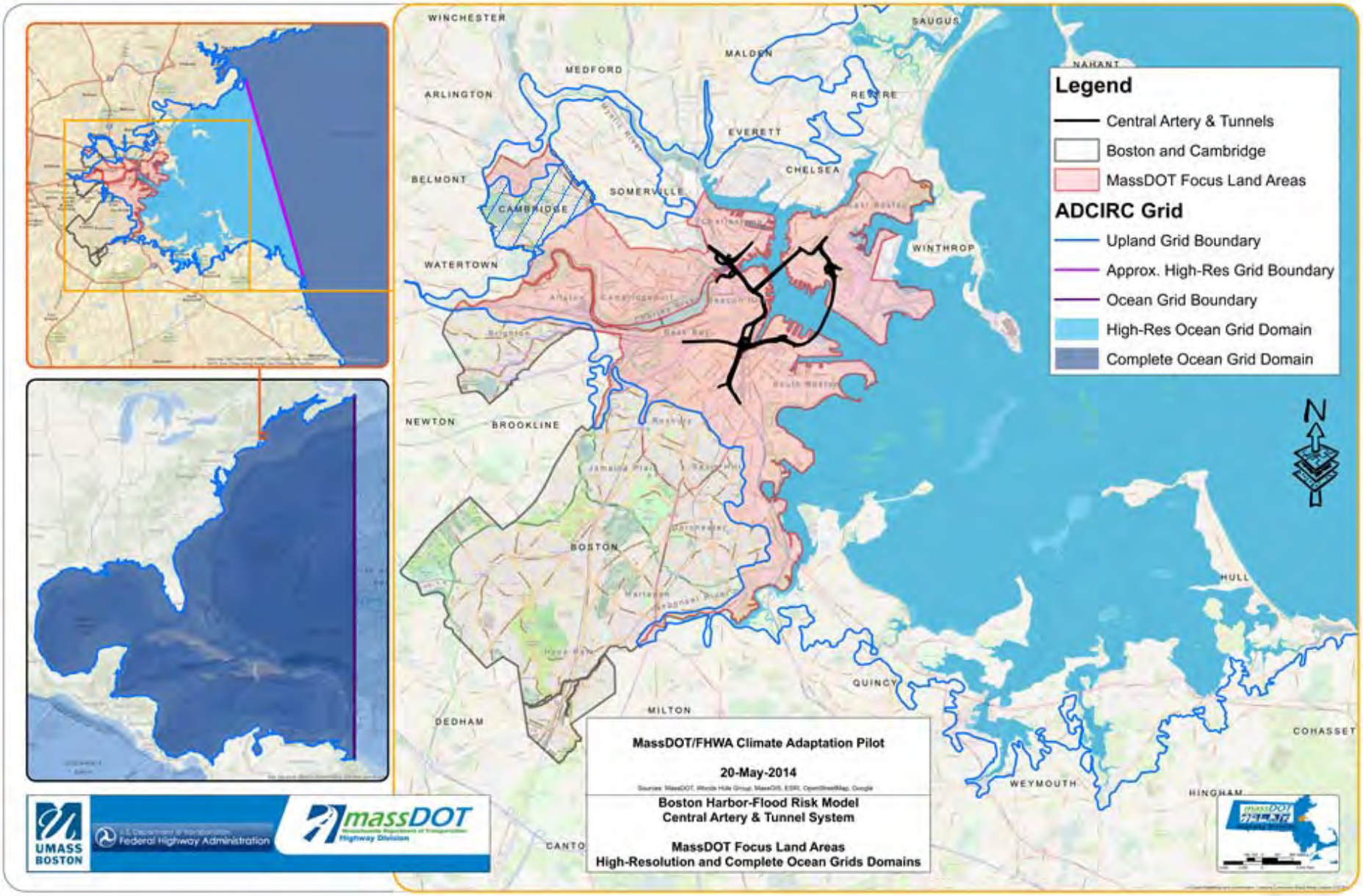
Unstructured Grid

Varying resolution with high resolution in areas of interest



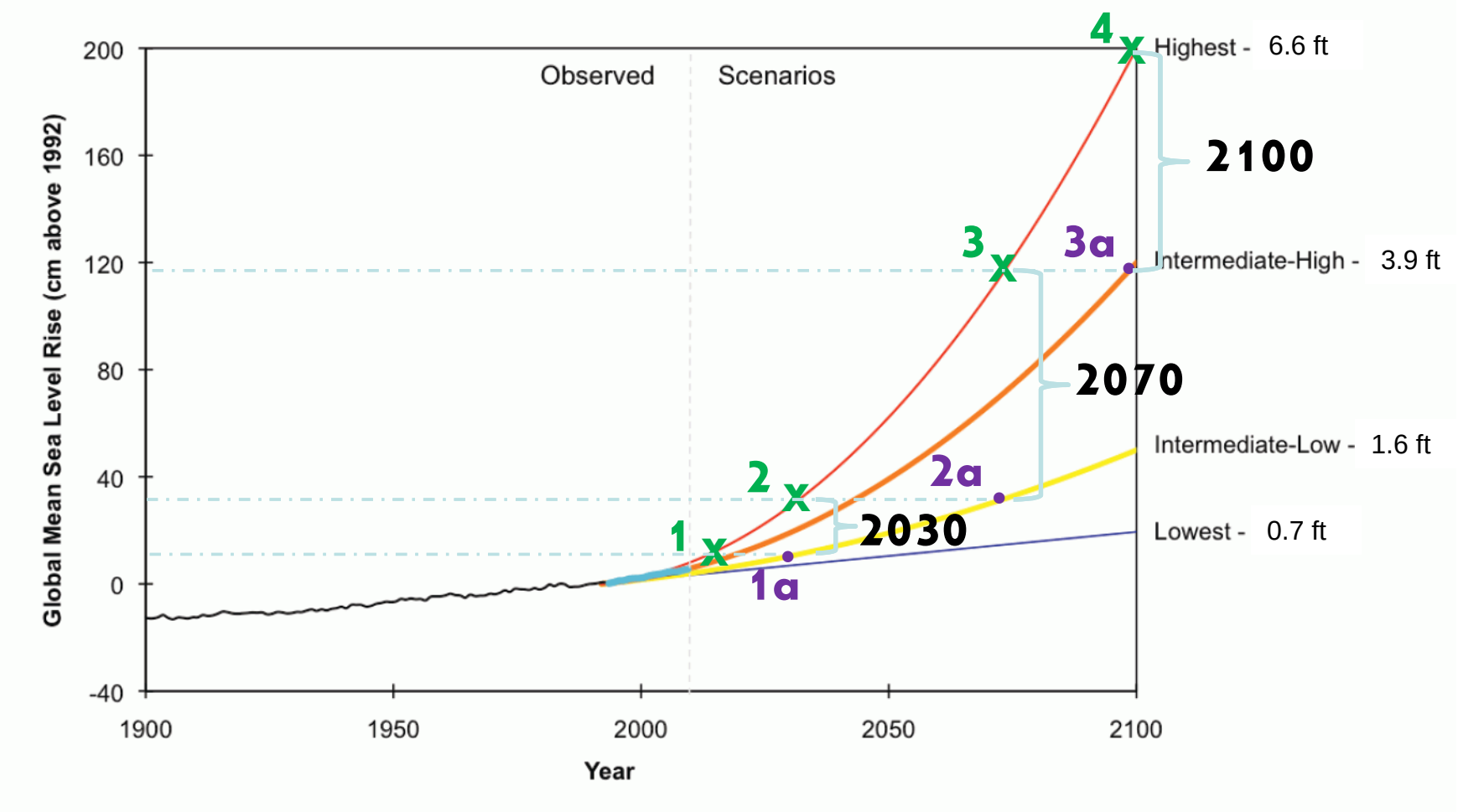
Downtown Boston Grid

Boston Harbor Flood Risk Model



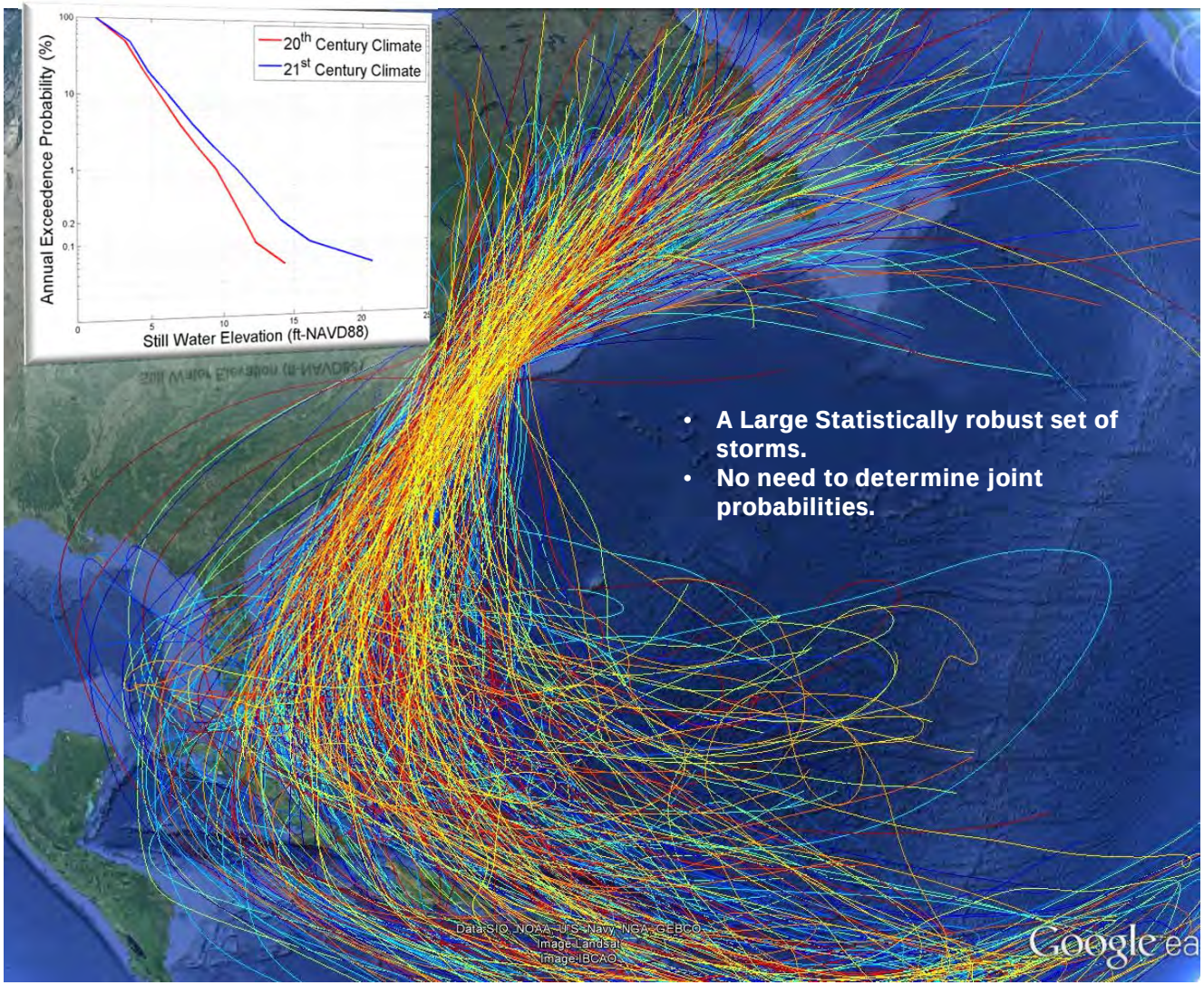
Sea Level Rise Projections

Scenarios	2020	2030	2040	2050	2060	2070	2080	2090	2100
"Highest" Global SLR (from 2013-2020) (feet)	0.21	0.61	1.10	1.70	2.40	3.21	4.11	5.12	6.23
Land subsidence (feet) @ 0.003 ft/yr	0.02	0.06	0.09	0.12	0.15	0.19	0.22	0.25	0.29
"Highest" Relative SLR (from 2013-2020) - (feet)	**0.24**	**0.66**	**1.19**	**1.82**	**2.56**	**3.39**	**4.33**	**5.37**	**6.52**



NOAA (2012). Global Sea Level Rise Scenarios for the United States National Climate Assessment

Storm Climatology



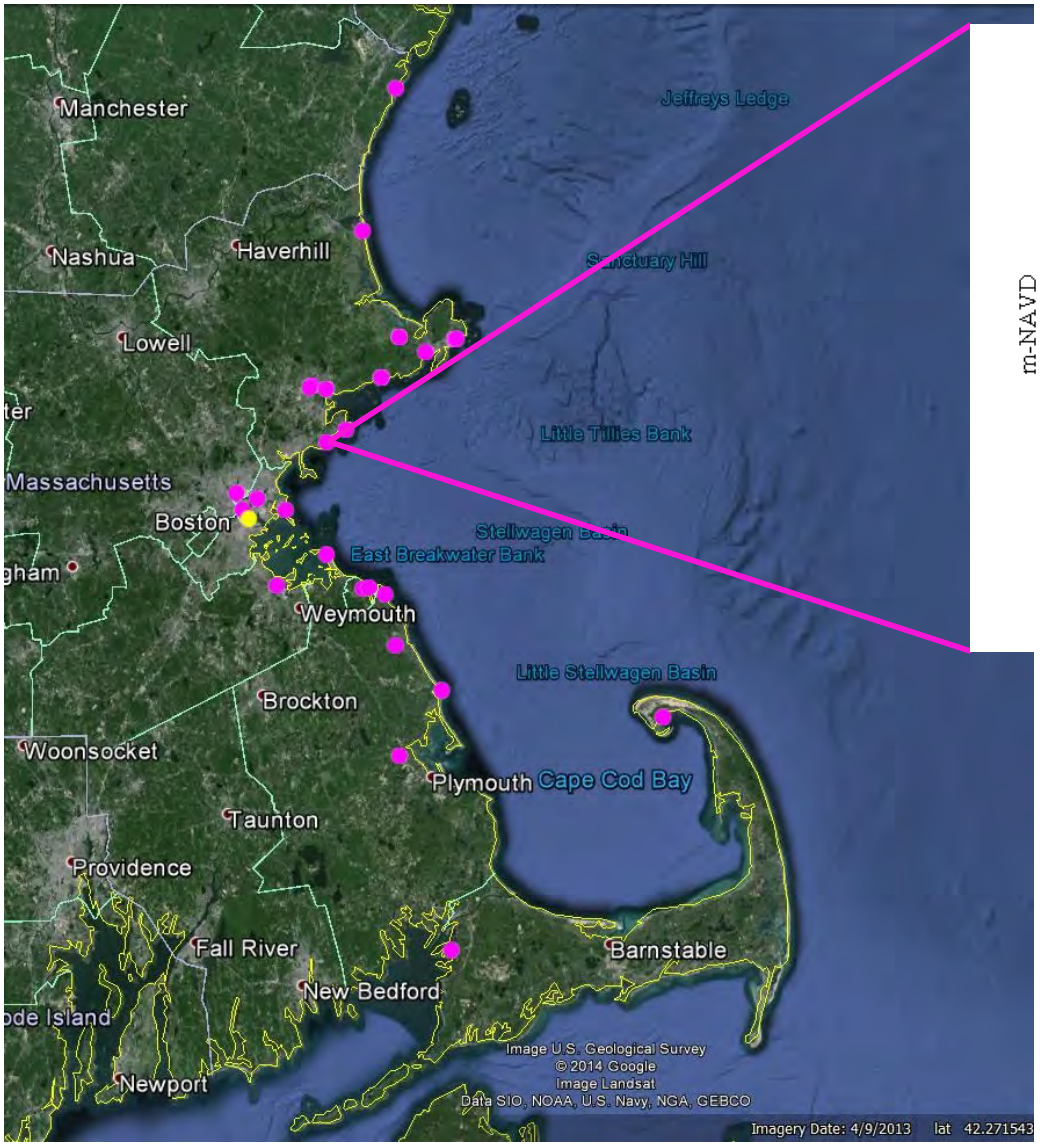
Monte Carlo simulations

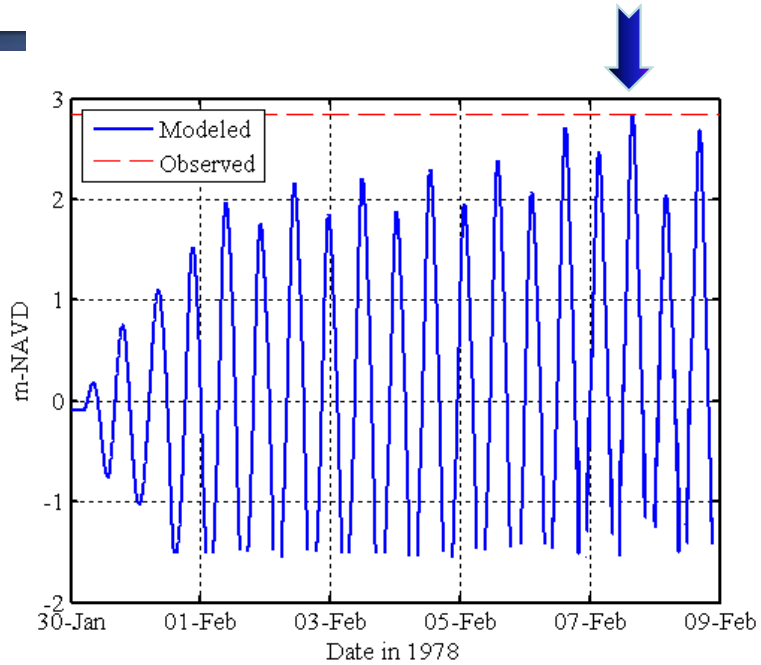
Present and future climate change scenarios

Tropical and Extra-Tropical Storms

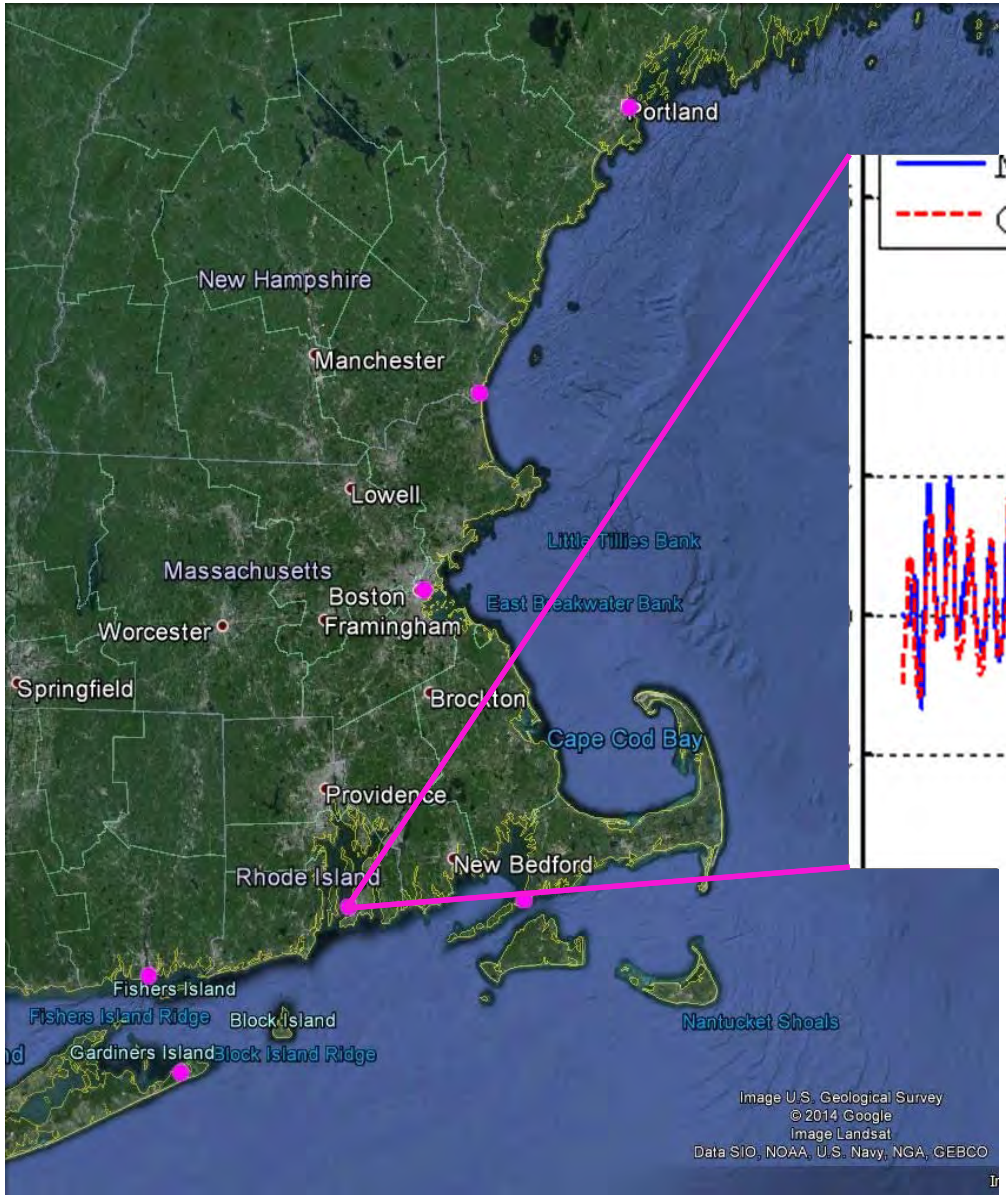
Simulates storms combined with SLR and river discharge

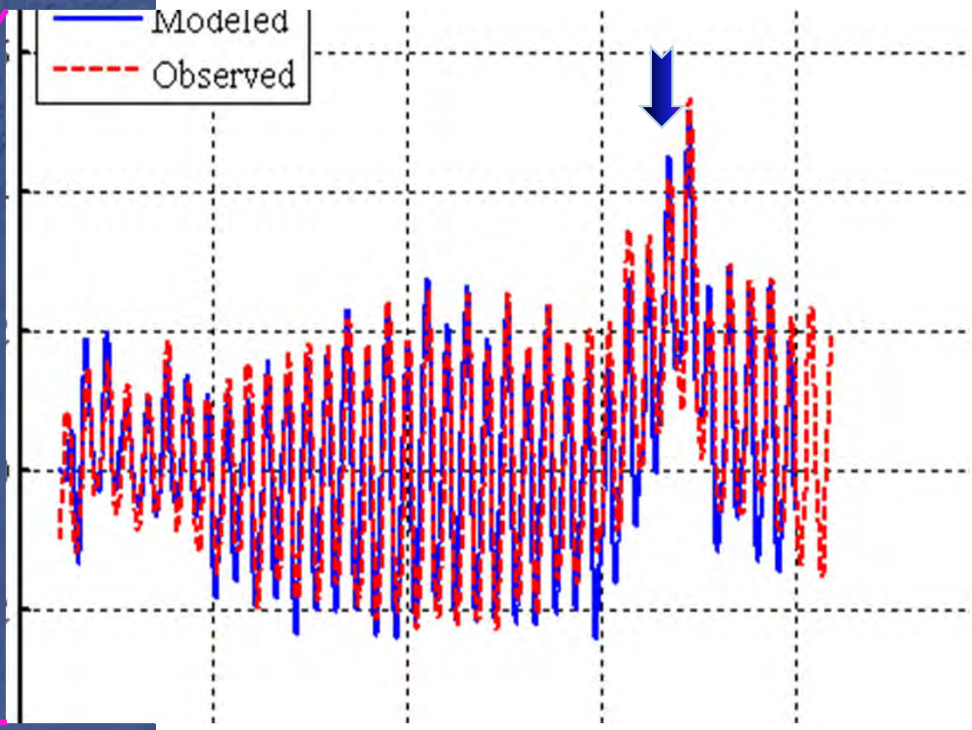
Blizzard of 1978



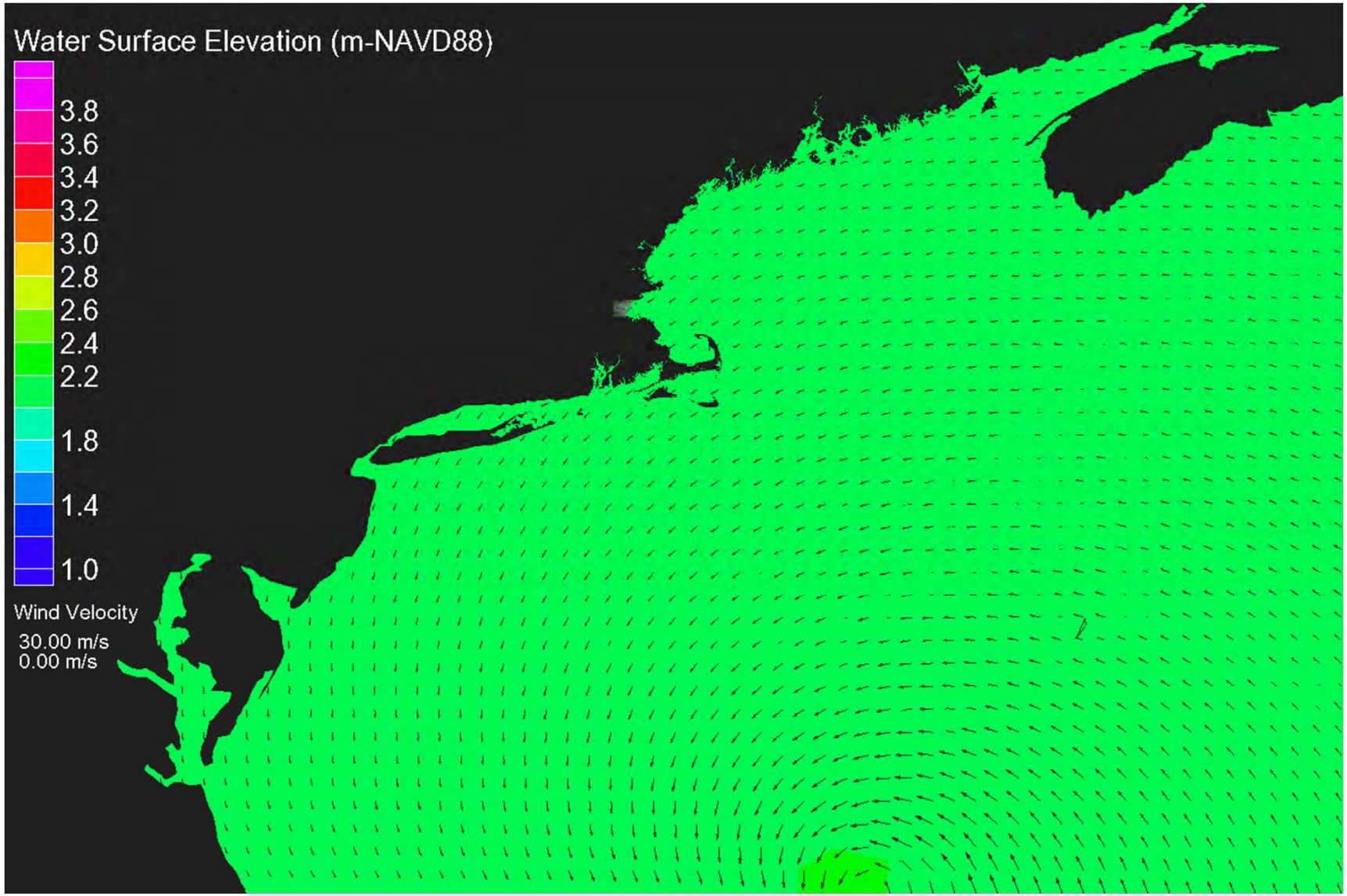


The Perfect Storm





Example Results



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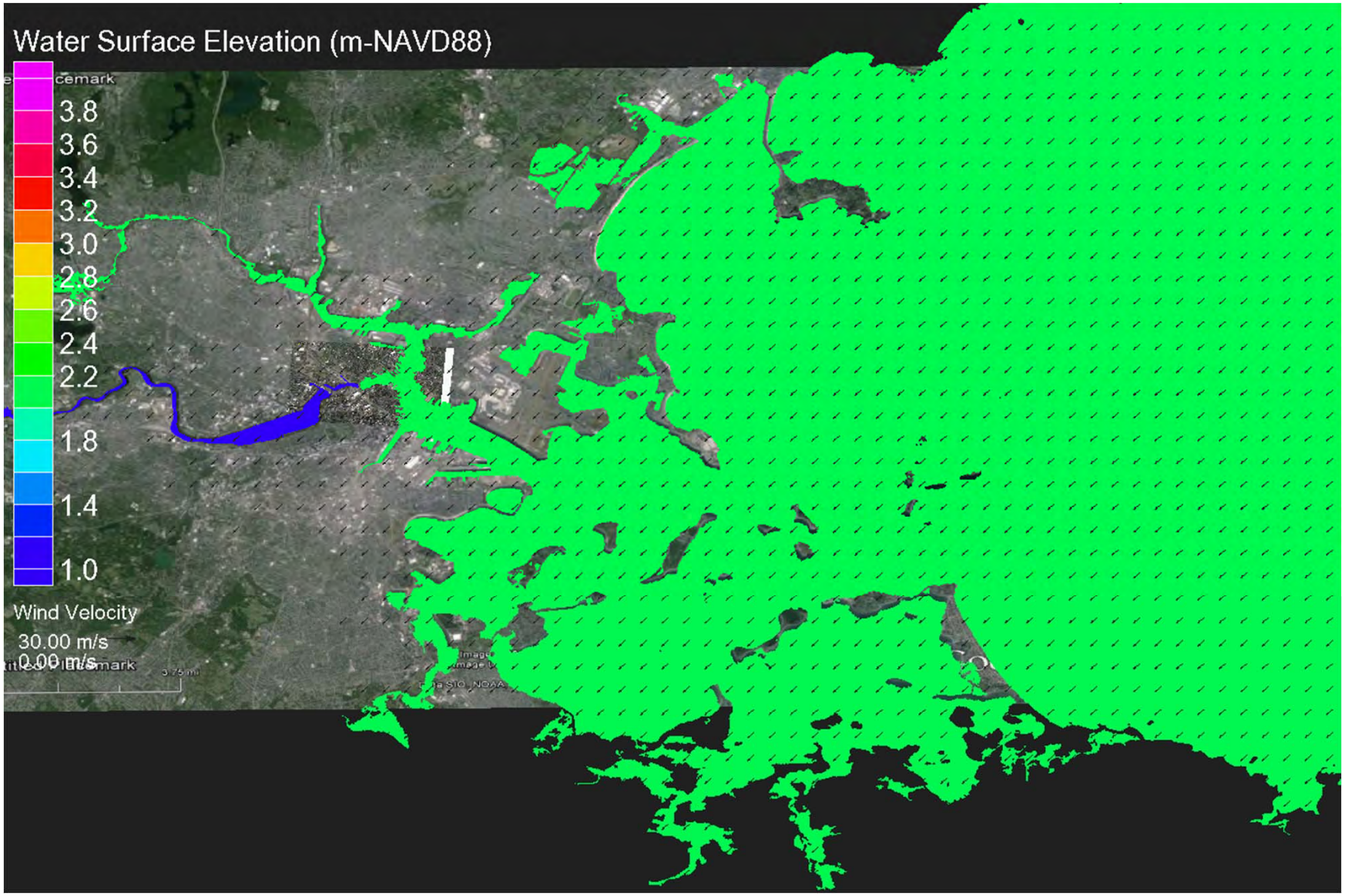
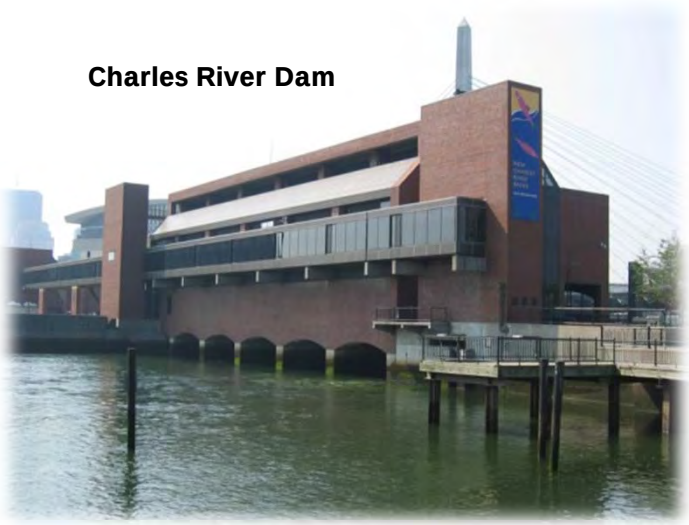


Flooding Impacts at the Dams

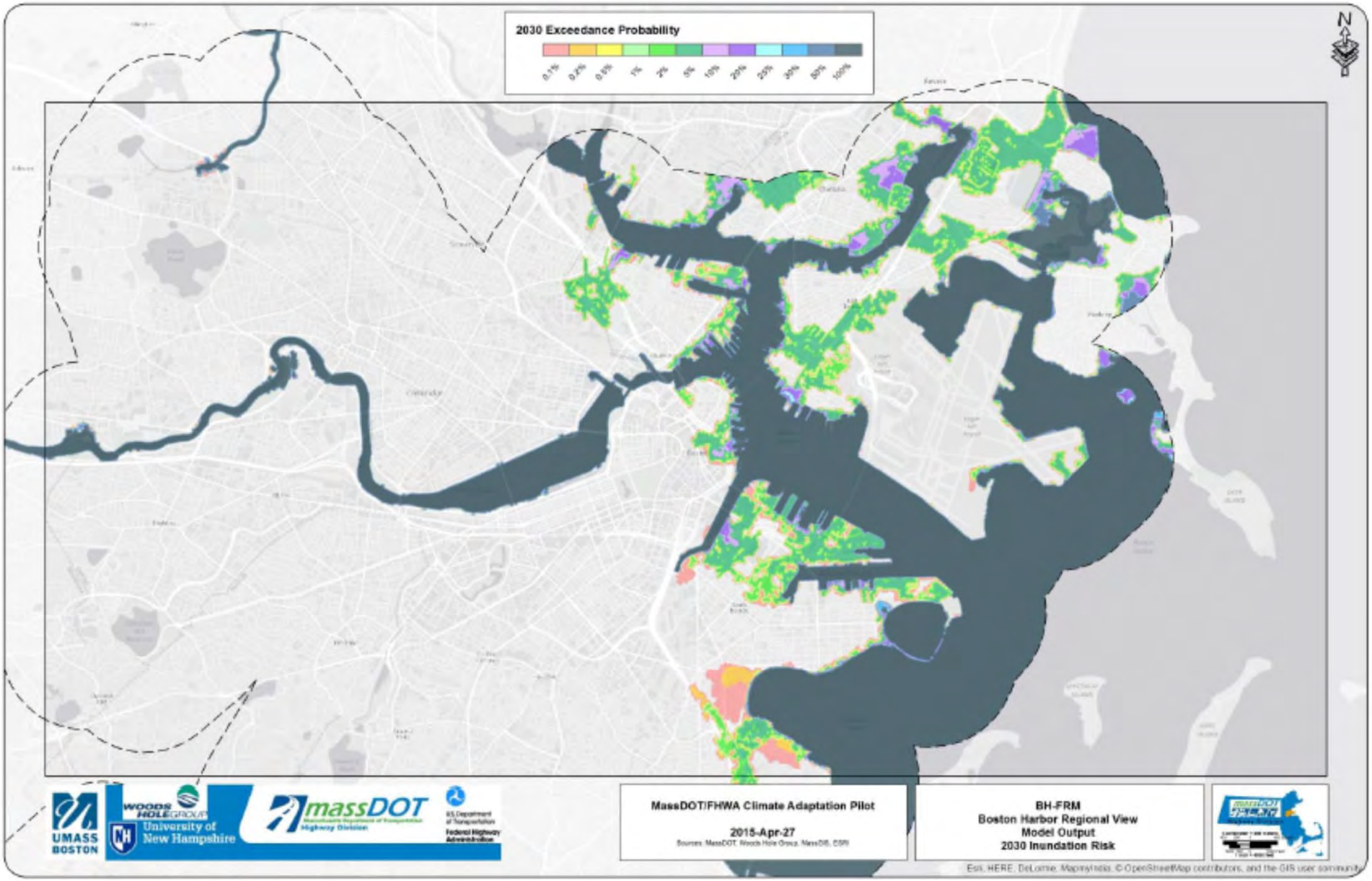
(Assuming high rate of SLR)

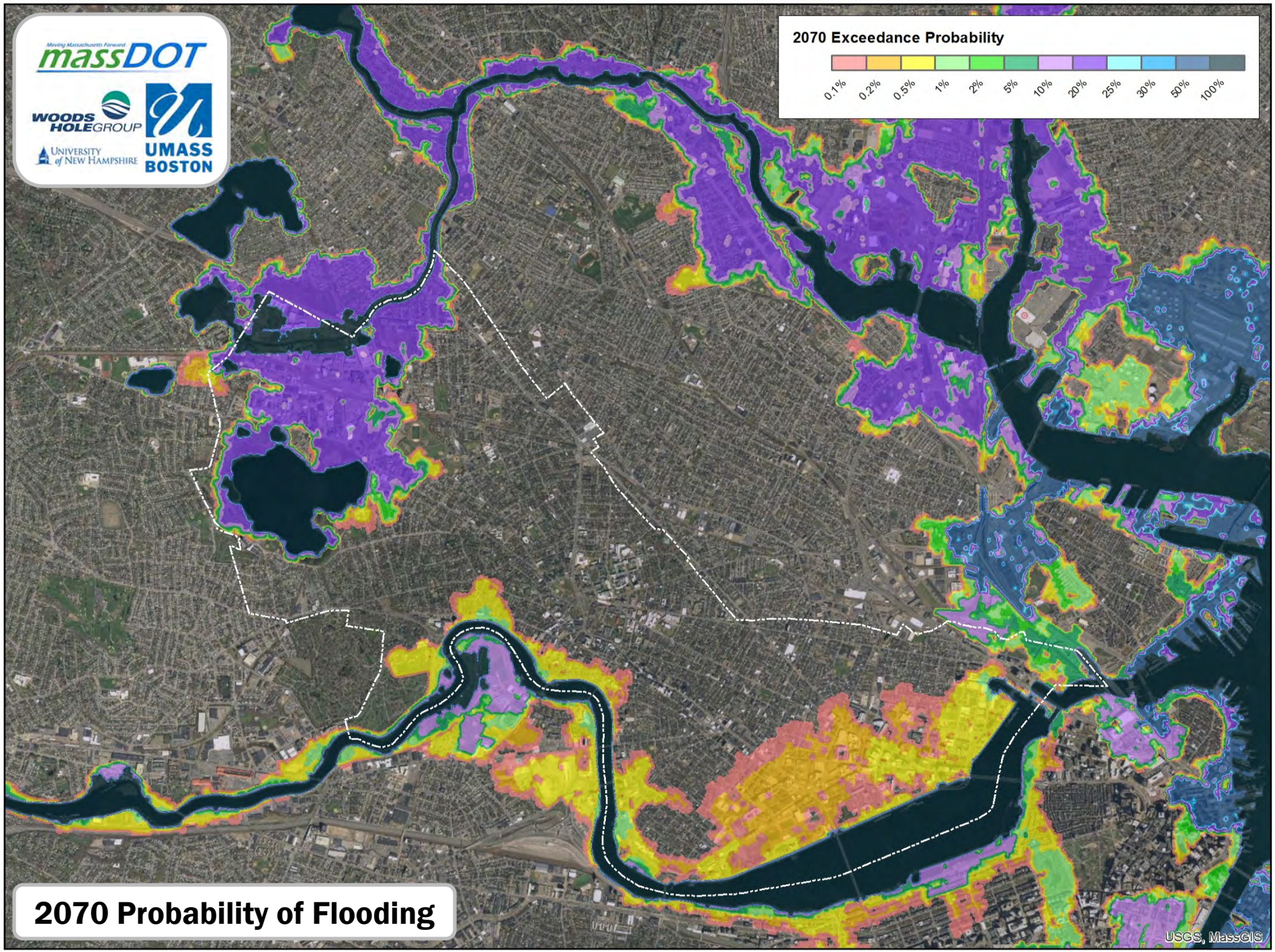


- At 1% (100-yr):
  - Flanked in 2055-2060
  - Overtopped in 2065
- At 0.2% (500-yr):
  - Flanked in 2045
  - Overtopped in 2050

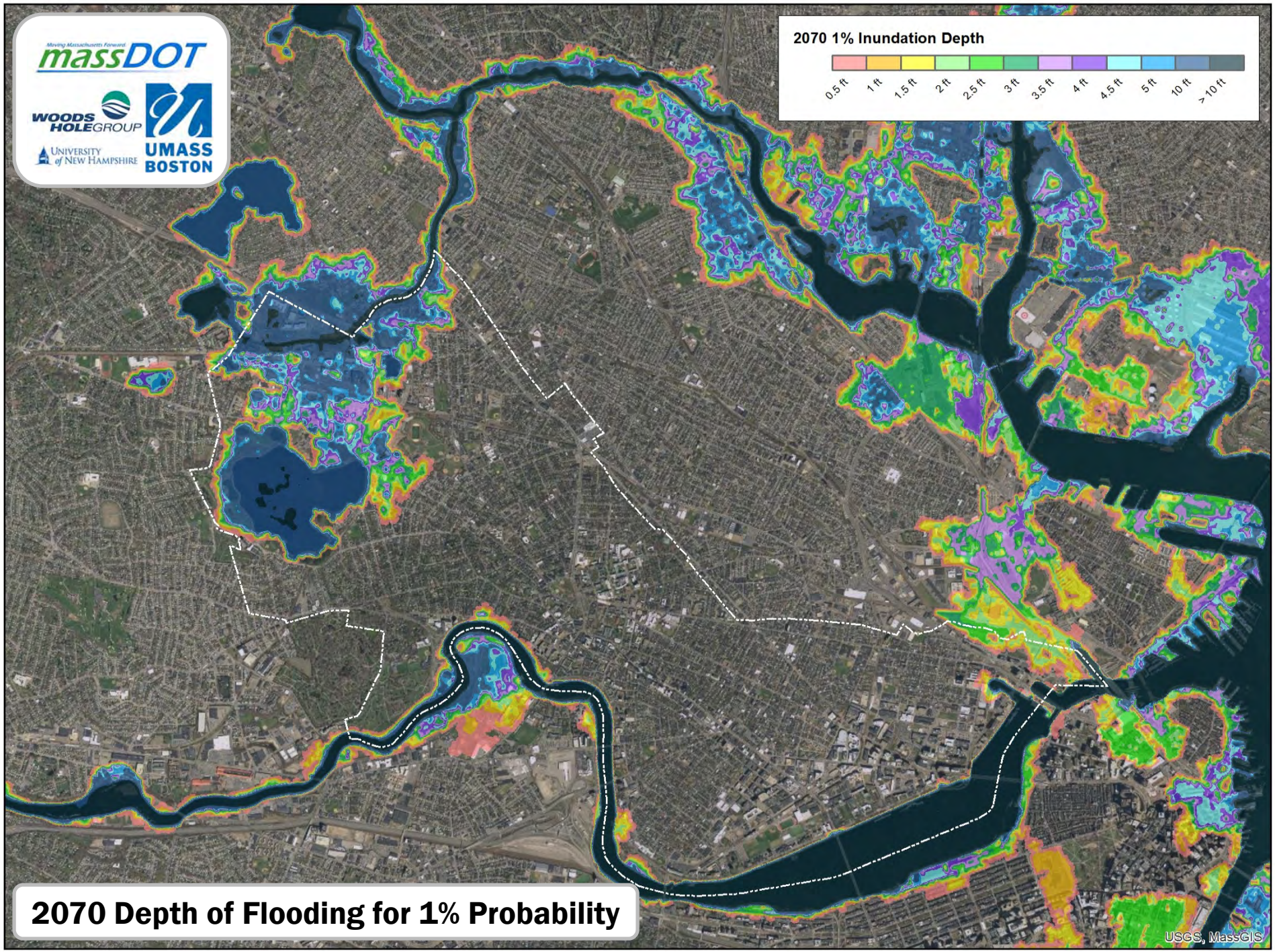
- At 1% (100-yr):
  - Flanked in 2045-2050
  - Overtopped in 2055-2060
- At 0.2% (500-yr):
  - Flanked in 2030-2035
  - Overtopped in 2040

2030 Probability of Flooding



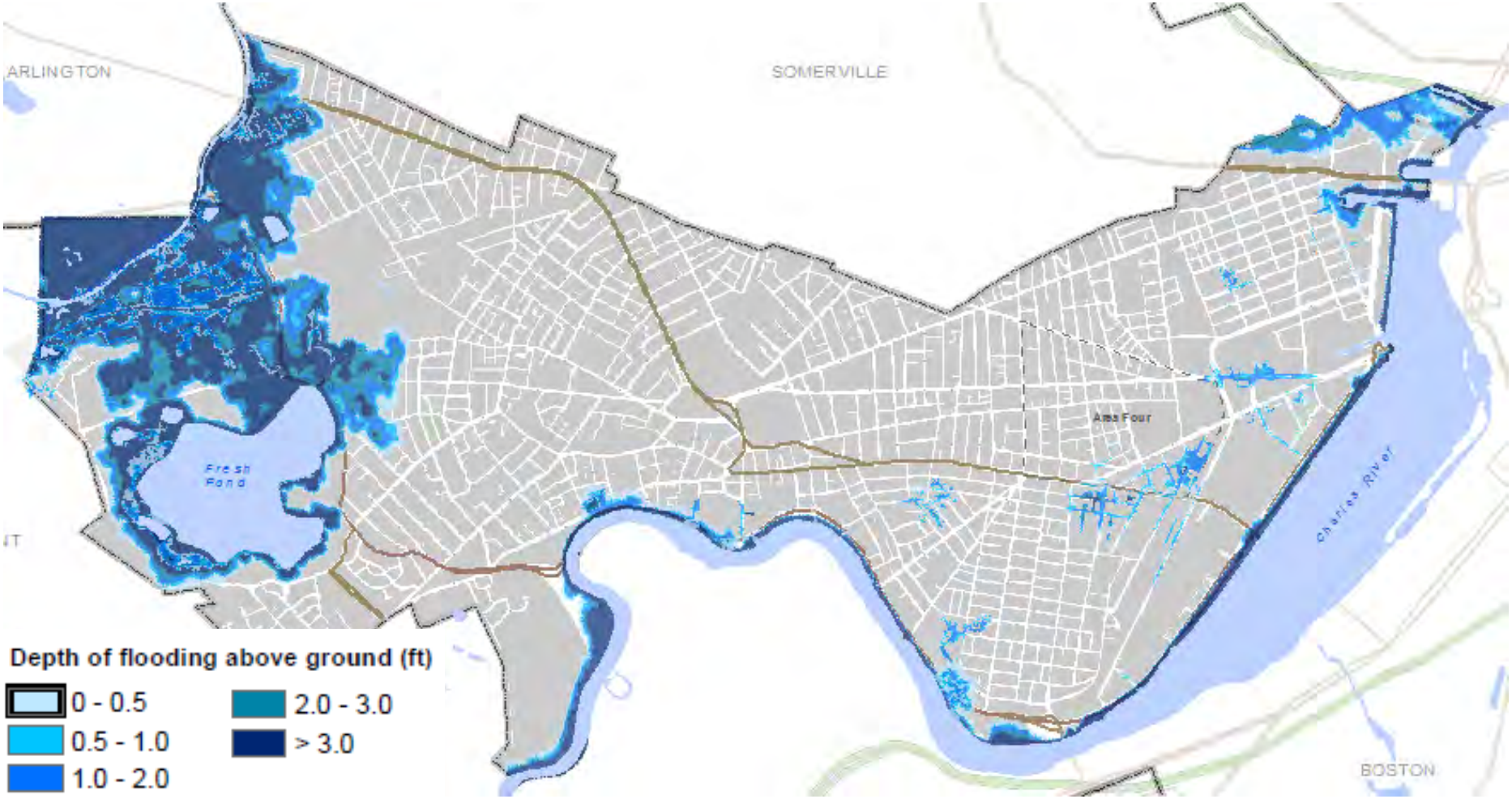


2070 Probability of Flooding



2070 Depth of Flooding for 1% Probability

2070 Depth of Flooding for 1% Probability

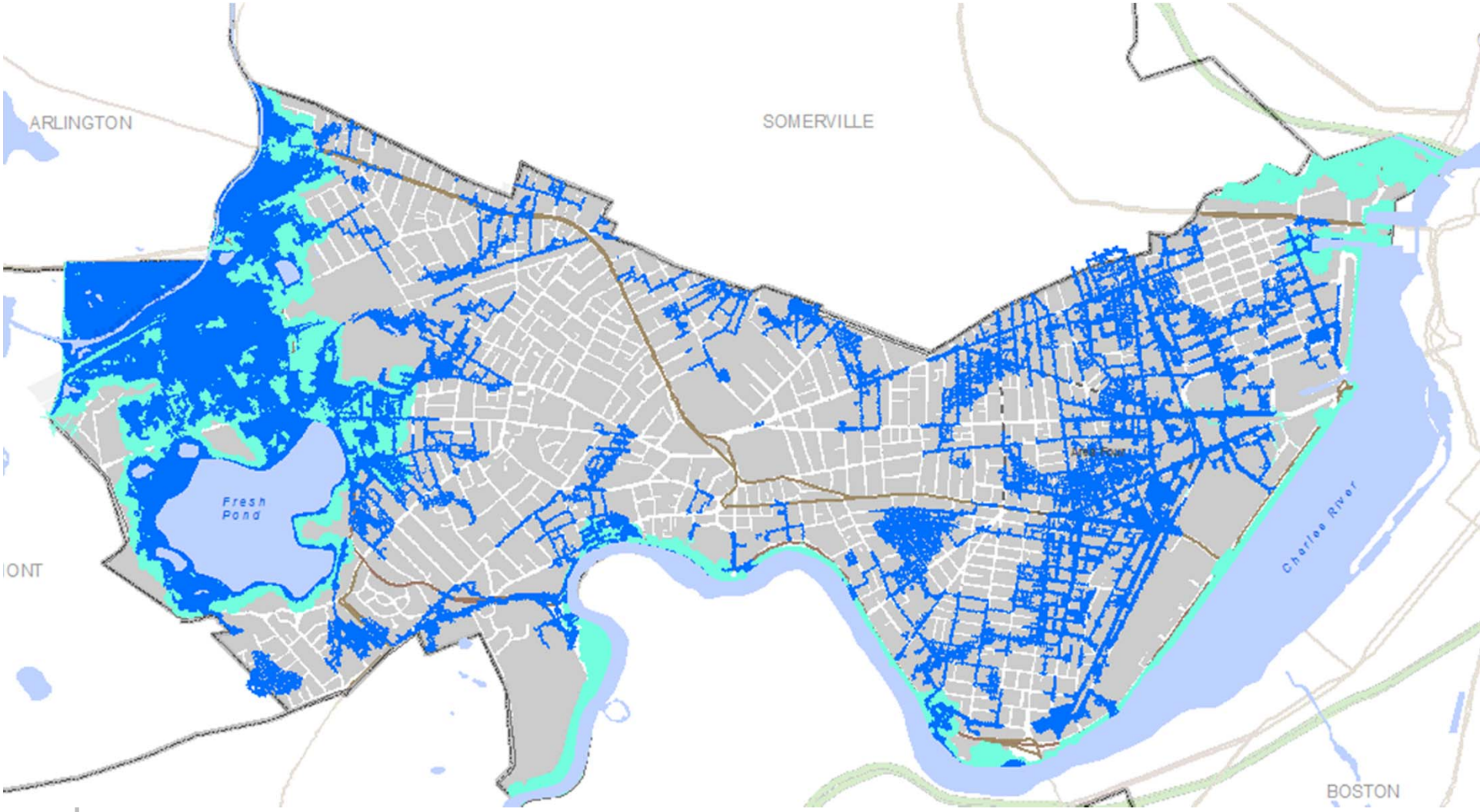


Scenario for Vulnerability and Risk Assessment

SLR/ Storm Surge + propagation through piped infrastructure

Source: Kleinfelder based on WHG & MWH analyses, October 2015

Comparison of Storm Surge and Precipitation Flooding



Extent of flooding from 1% flood by 2070 with SLR and storm surge and propagation through piped infrastructure (no rain)

Extent of flooding from 100-yr 24 hr rain storm by 2070

What We Learned About SLR/ Storm Surge

- Dams effectively protect Cambridge until at least 2030
- Storm surge could impact regional systems outside the City
- Both dams would be flanked before they are overtopped, both overtopped by 2070 at 1% (100-yr flood) probability level
- Ability of the dams to pump after an event will affect the duration of flooding in the City – flooding will be short duration if pumps work
- Flood waters will be contaminated
- Storm surge flooding would be a new experience for Cambridge

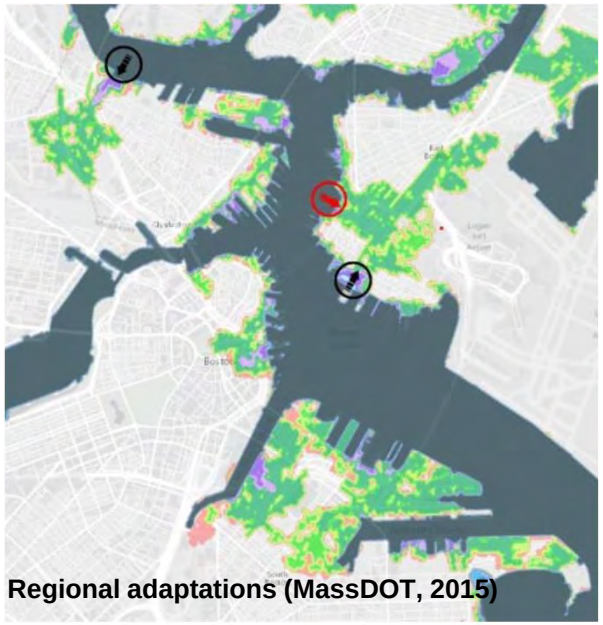
What We Learned About SLR/ Storm Surge

- Storm surge risks more significant in
  - Alewife/Fresh Pond area by 2050
  - North Point area by 2070

- Alewife area – more impacted by storm surge flooding
  Eastern Cambridge – more impacted by precipitation driven flooding

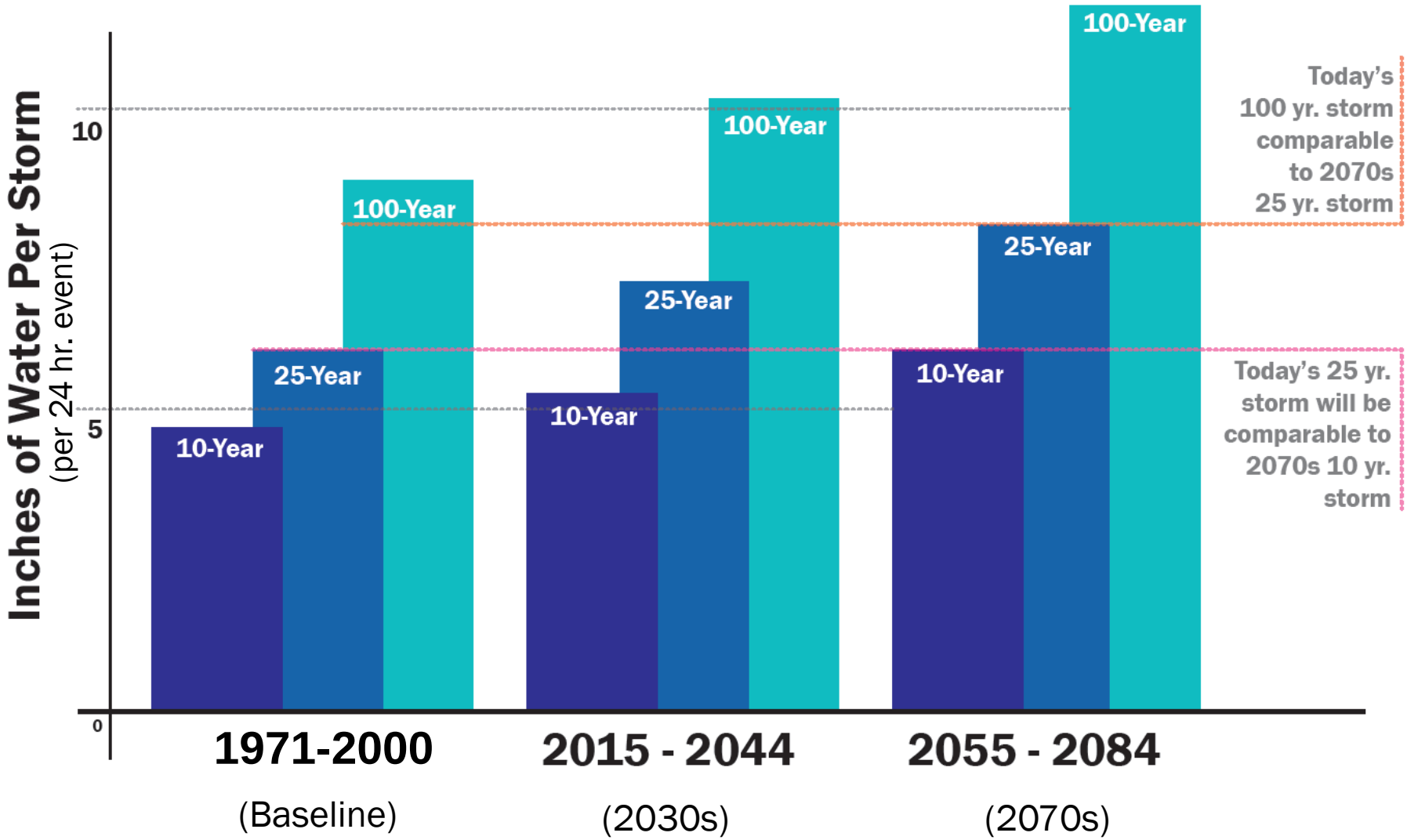
- One potential significant pathway for storm surge is through Charlestown and Somerville; there may be a temporary fix

- Storm surge flooding is a regional challenge

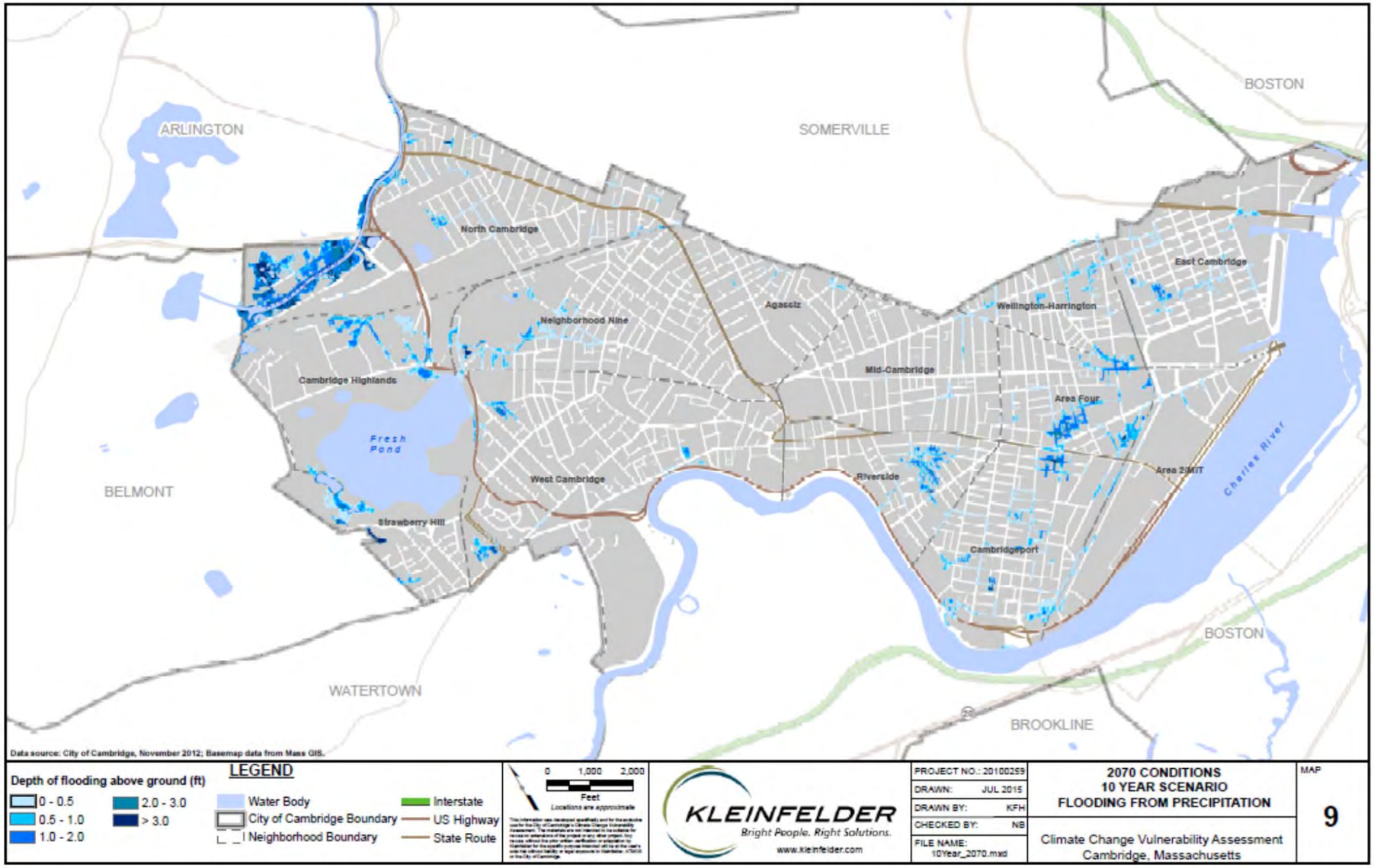


Regional adaptations (MassDOT, 2015)

Precipitation Projections

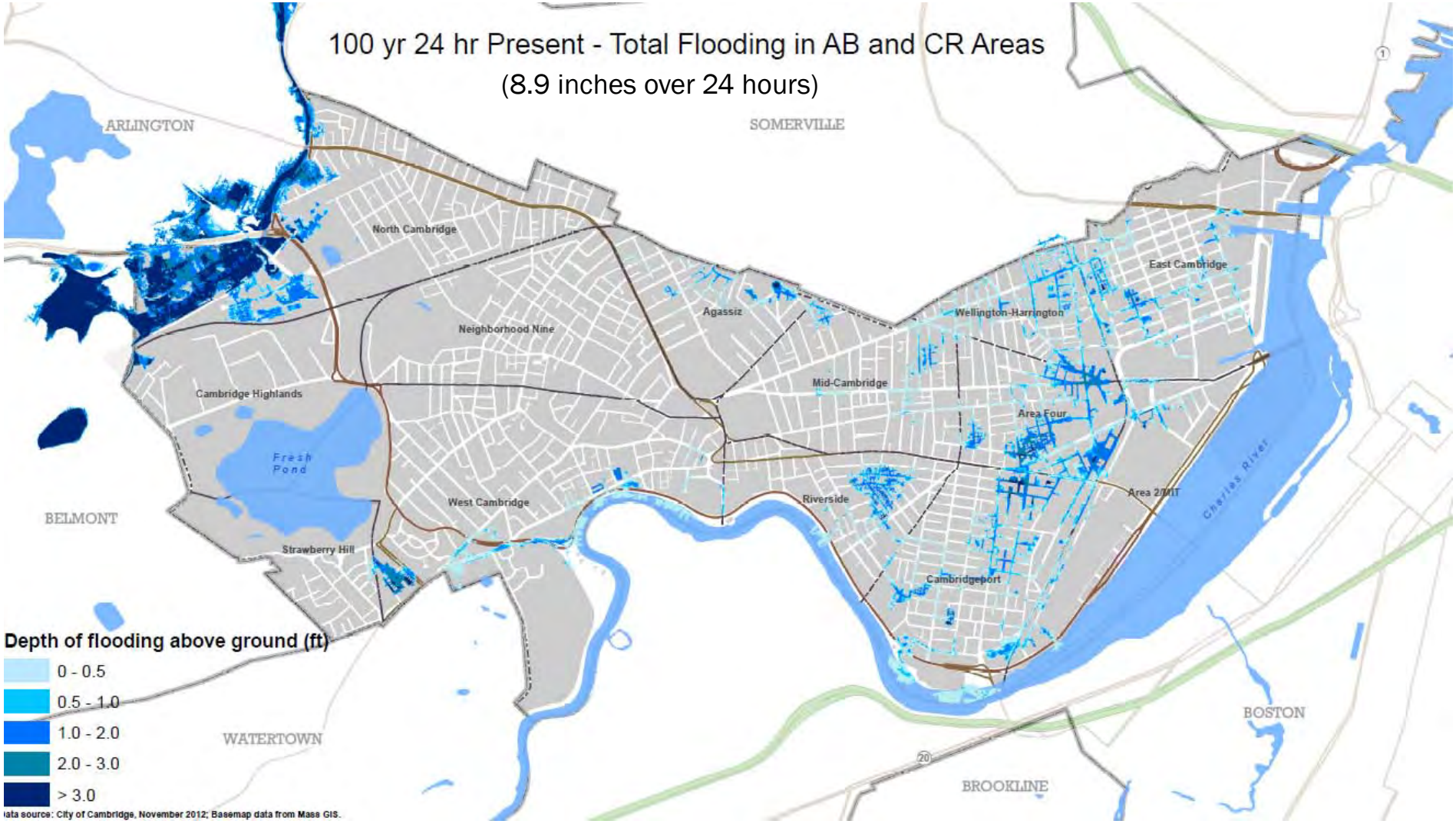


10-Year flood is less extensive and deep, but more frequent



Inland Flooding – Present

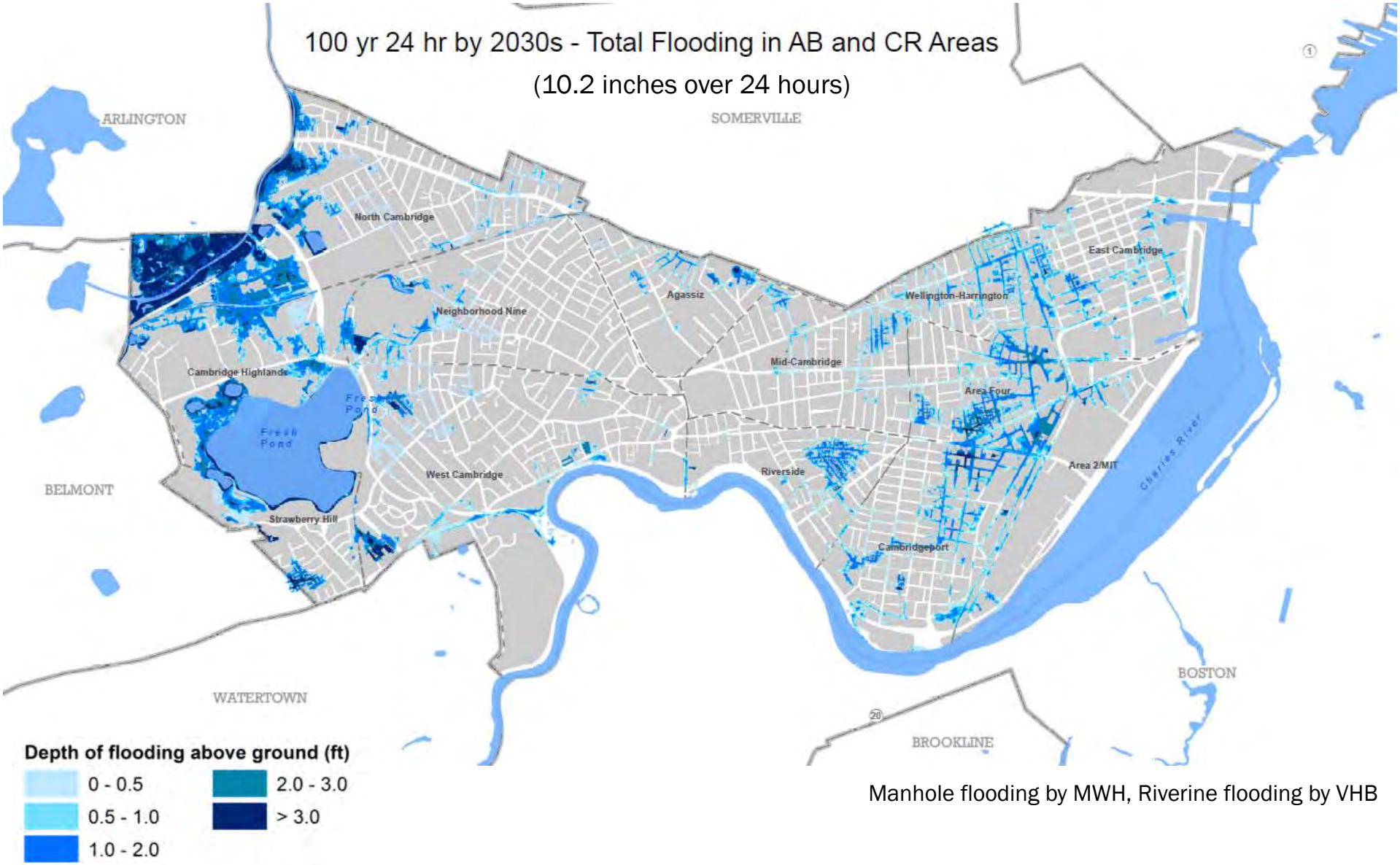
High Scenario



Manhole flooding by MWH, Riverine flooding by VHB

Inland Flooding – 2030s

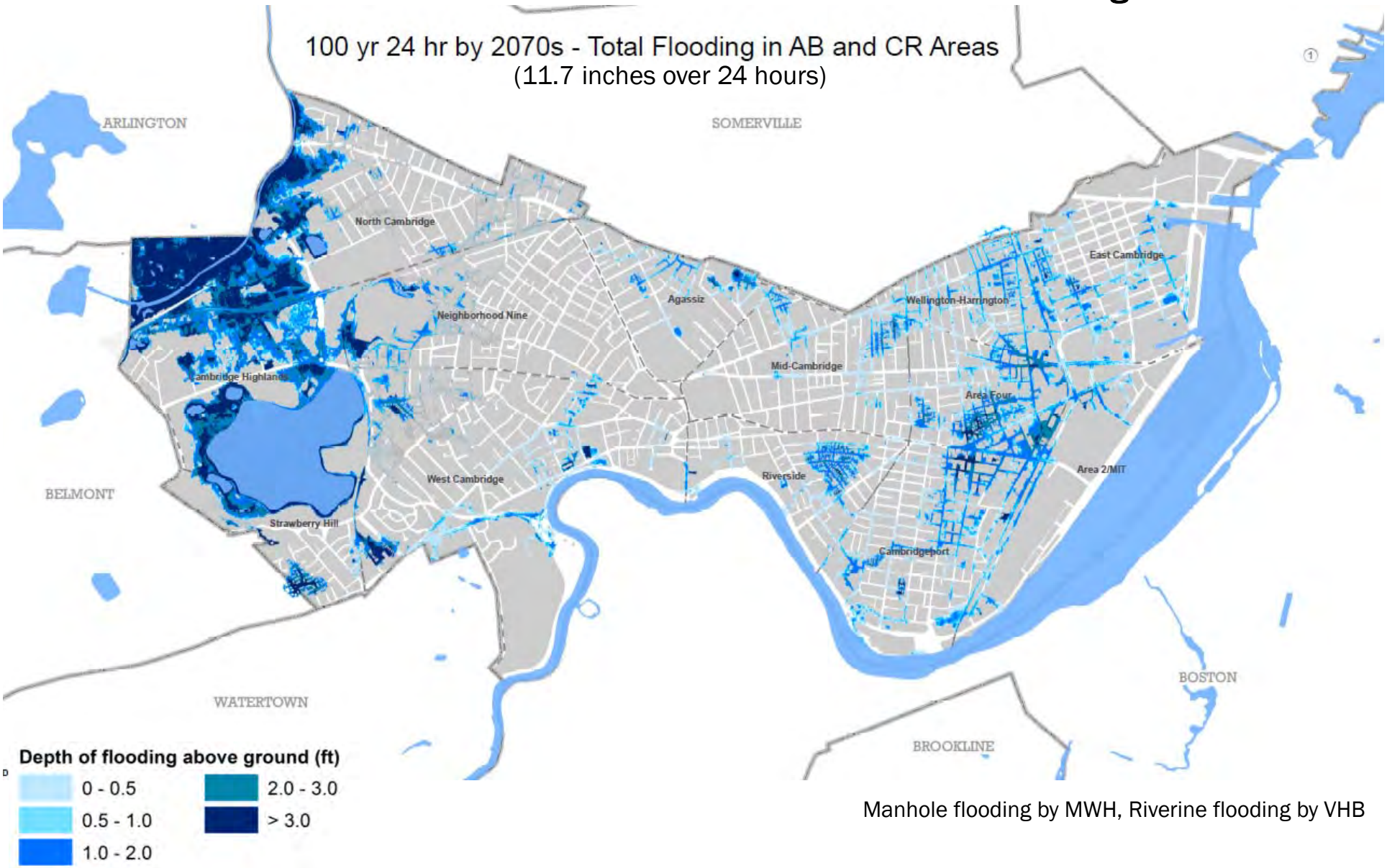
High Scenario



Manhole flooding by MWH, Riverine flooding by VHB

Inland Flooding – 2070s

High Scenario

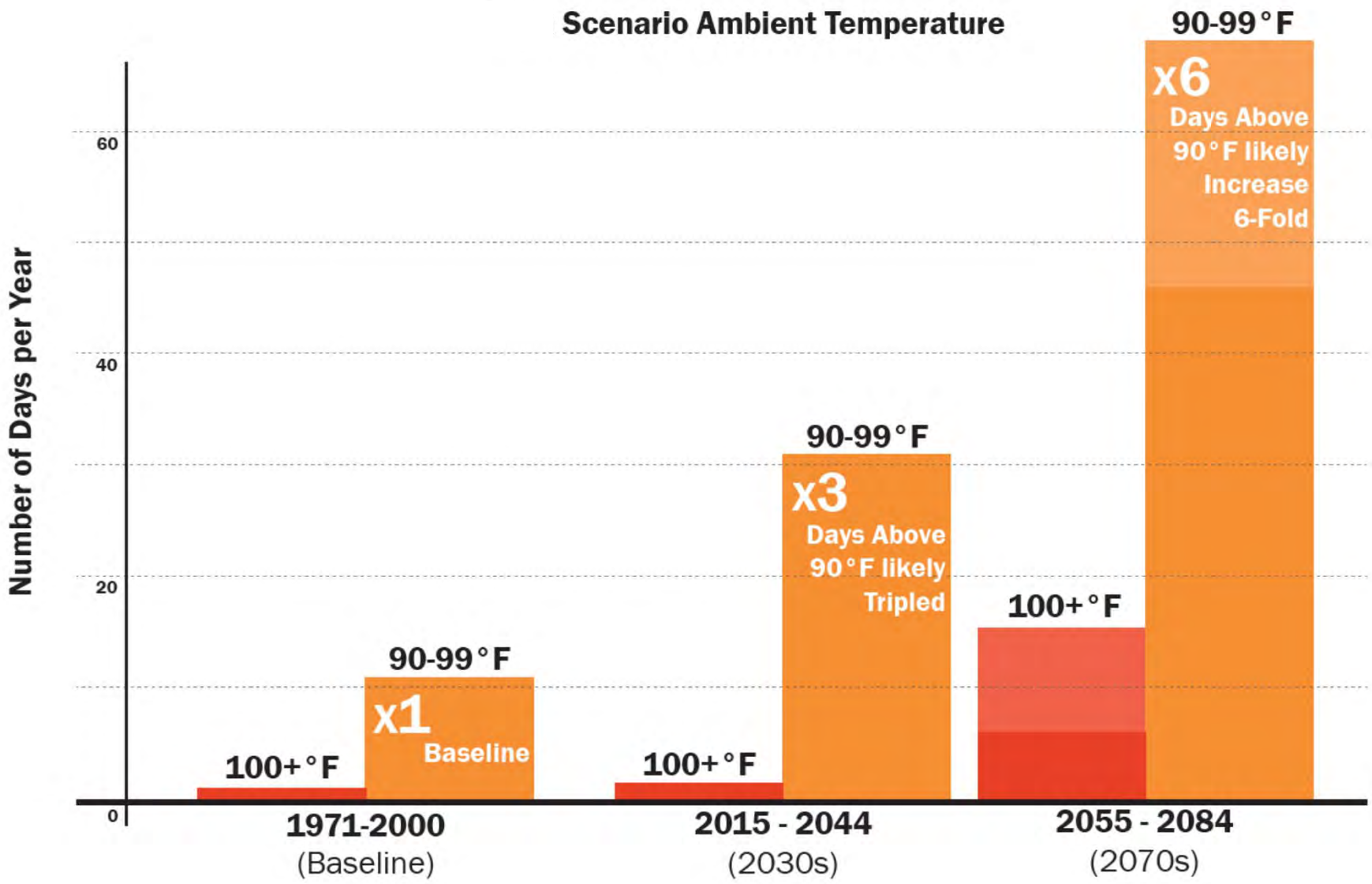


Manhole flooding by MWH, Riverine flooding by VHB

Summer Temperature Projections

Temperature Changes	Baseline	2030s (2015-2044)		2070s (2055-2084)	
	1971-2000	Lower	Higher	Lower	Higher
Annual Temperature (^{0}F)	50	53.3	53.5	55.8	58.7
Summer Temperature (^{0}F)	70.6	74.5	74.8	77.4	80.6
Winter Temperature (^{0}F)	29.8	32.2	33	34.6	38
Days > 90^{0}F (days/year)	11	29	31	47	68
Days > 100^{0}F (days/year)	<1	2	2	6	16
Heat Index (^{0}F)	85	94.75	96	101	115.5

Temperature Projections



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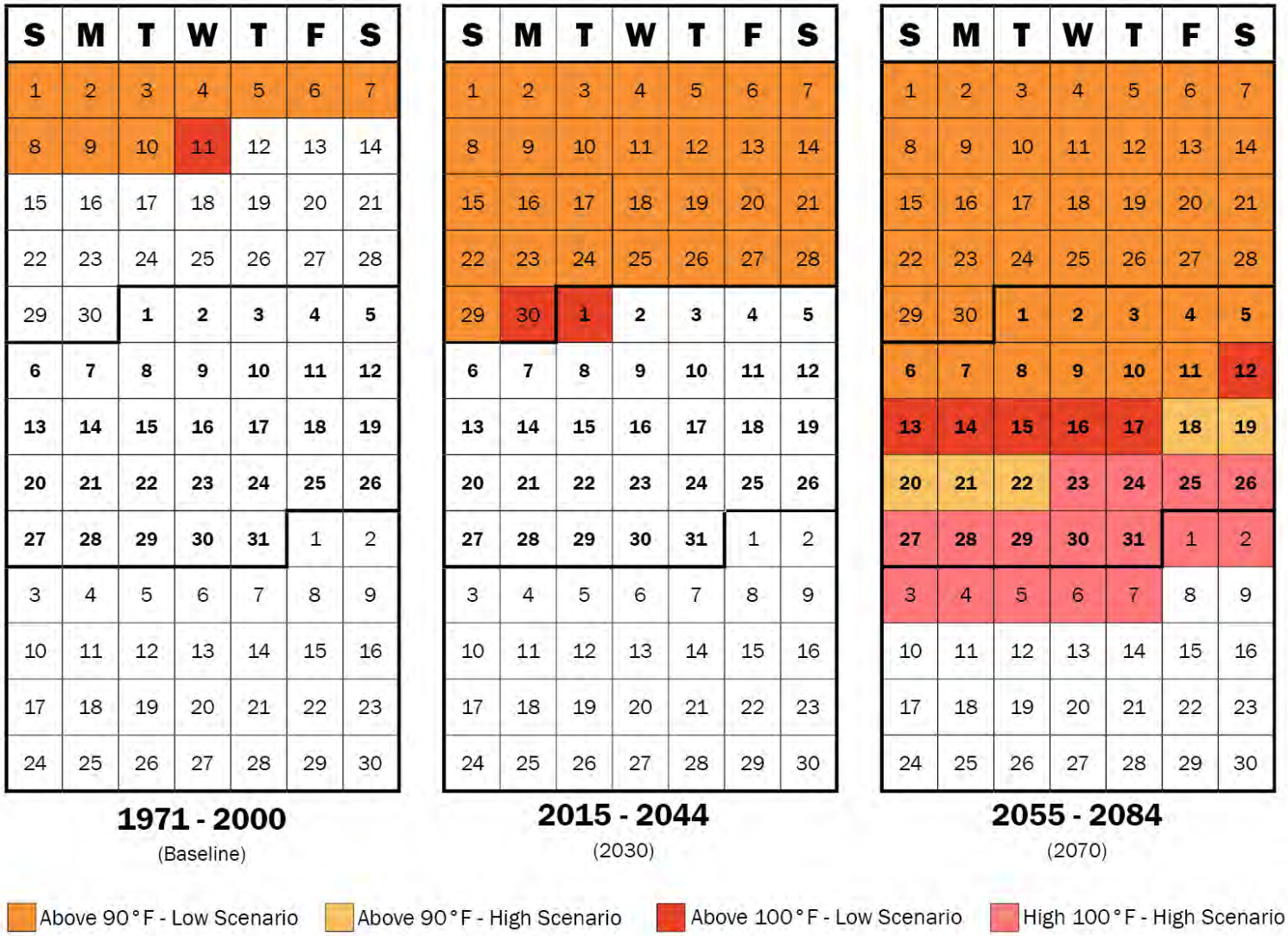
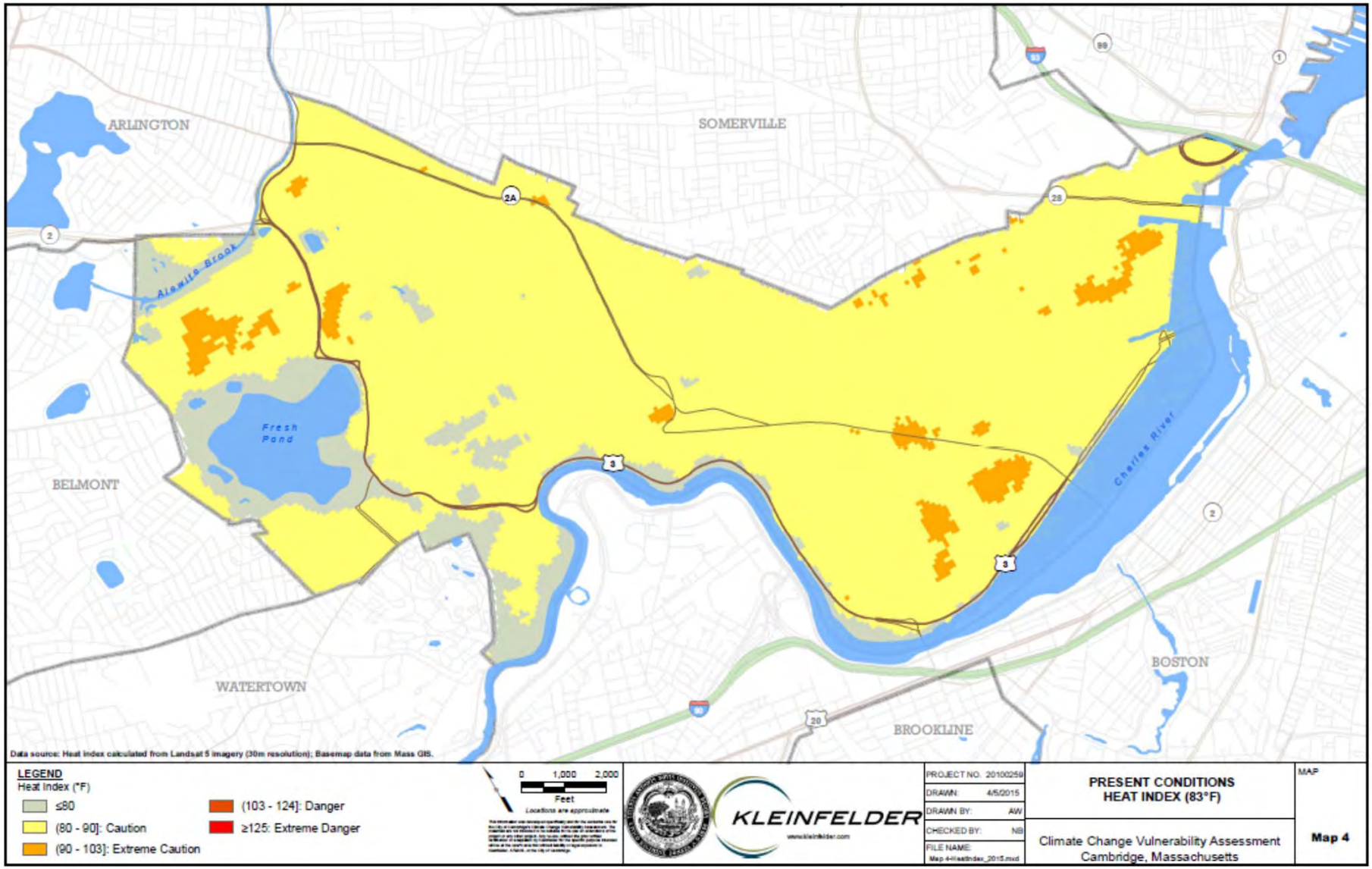


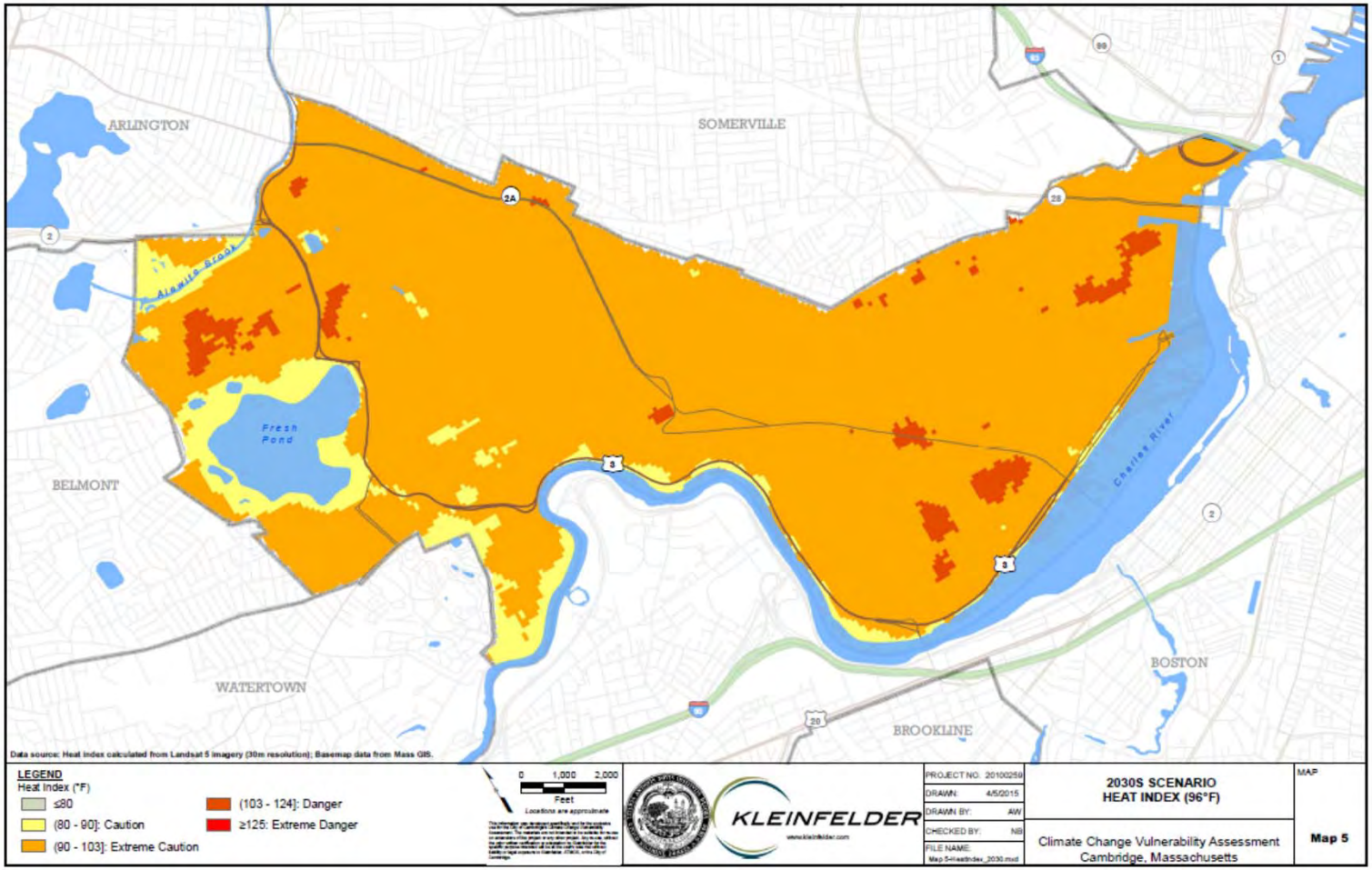
*Summer is considered to be the 91 days of June through August

Heat Index - Present Conditions



Heat Index - 2030s Scenario

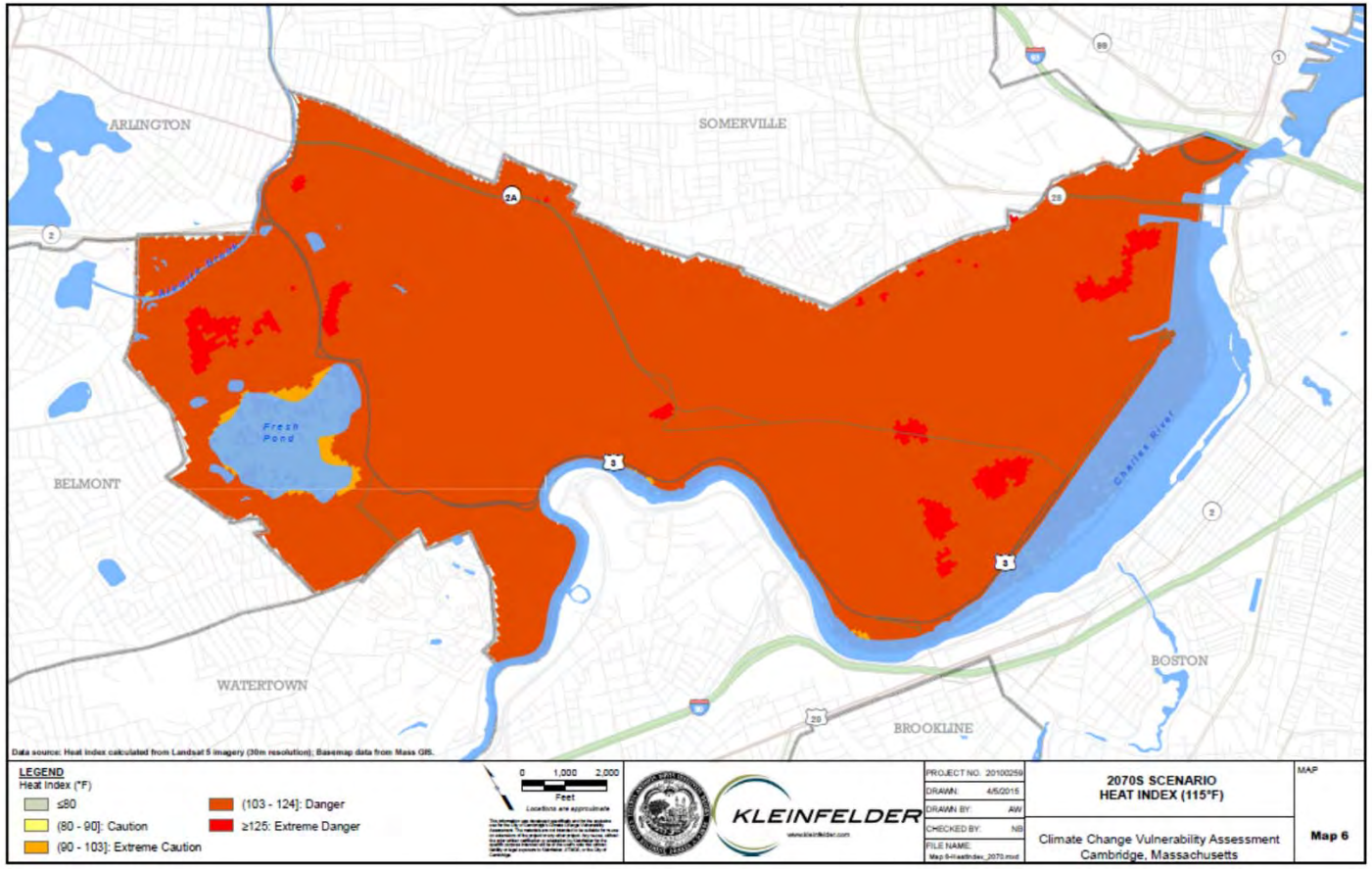
for Social Environment



"Feels-like" temperature variability on a day when heat index is 96°F
(90°F with relative humidity 50 – 55%)

Heat Index - 2070s Scenario

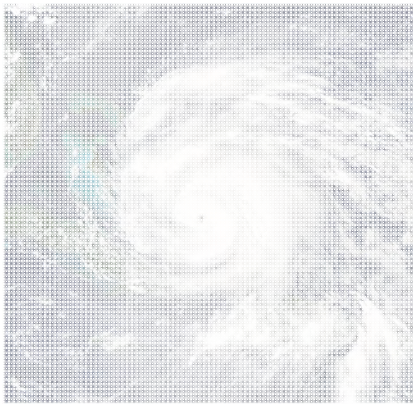
for Social Environment

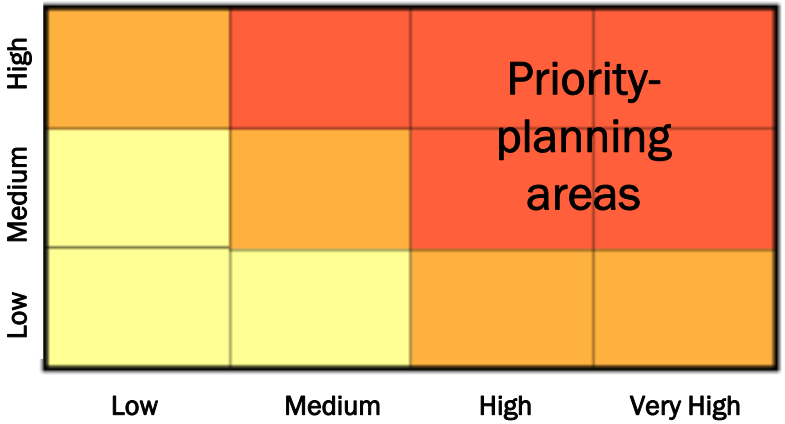


"Feels-like" temperature variability on a day when heat index is 115°F

110°F ~ (90°F with 60-65% RH) 115°F ~ (100°F with 45-50% RH)

Project's Framework





Step 1

Climate Scenarios

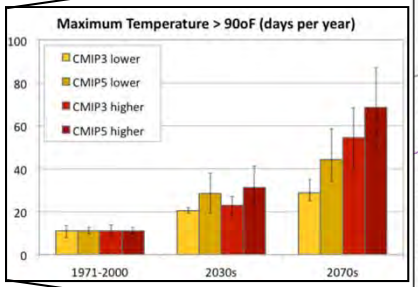
Step 2

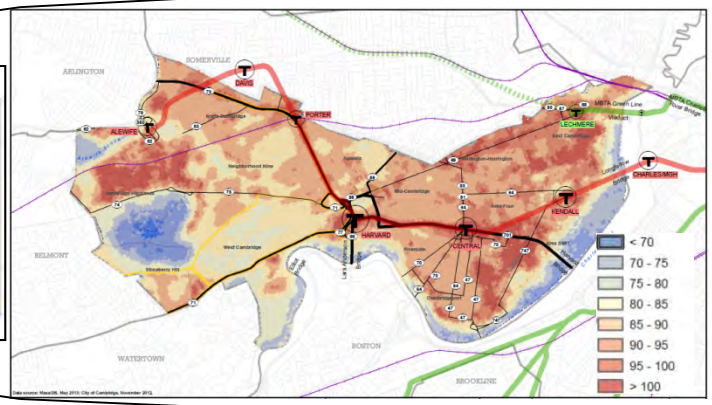
Vulnerability & Risk Assessment

Step 3

Preparedness Plan

How to assess vulnerability & risk for assets?





Lechmere Station MBTA Green Line	
Exposure	>100°F
Sensitivity	High (S4)
Adaptive Capacity	High (AC2)
Vulnerability	Low (V2)

Climate Projections

Modeling & Mapping Exposure

Assessing Vulnerability & Risk

Identifying critical assets & resources

The Built Environment

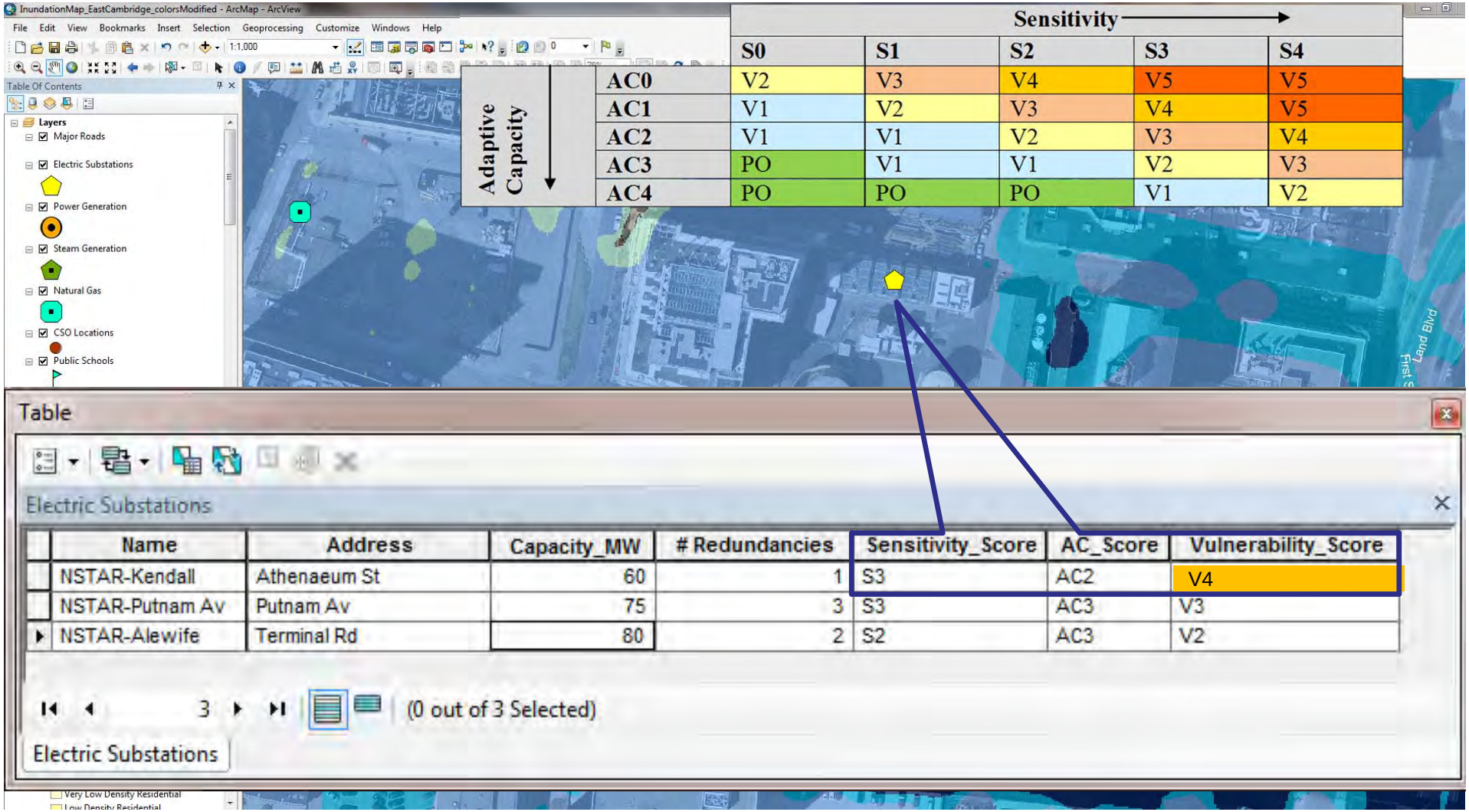
- Energy
- Transportation
- Water
- Telecommunication
- Critical Services
- The Urban Forest

The Social Environment

- Public Health
- Community Resources
- Vulnerable Population
- Economic Impact

How to assess vulnerability & risk for assets?

- **Exposure:** Direct contact with hazard (flood/heat)
- **Vulnerability:** function of asset *Sensitivity* and *Adaptive Capacity* in relation to *Exposure*
- **Risk:** function of *Probability of Occurrence* and *Consequence of Failure*



Adaptive Capacity ↓ / Sensitivity →	S0	S1	S2	S3	S4
AC0	V2	V3	V4	V5	V5
AC1	V1	V2	V3	V4	V5
AC2	V1	V1	V2	V3	V4
AC3	PO	V1	V1	V2	V3
AC4	PO	PO	PO	V1	V2

Name	Address	Capacity_MW	# Redundancies	Sensitivity_Score	AC_Score	Vulnerability_Score
NSTAR-Kendall	Athenaeum St	60	1	S3	AC2	V4
NSTAR-Putnam Av	Putnam Av	75	3	S3	AC3	V3
NSTAR-Alewife	Terminal Rd	80	2	S2	AC3	V2

Risk = function of Probability and Consequence

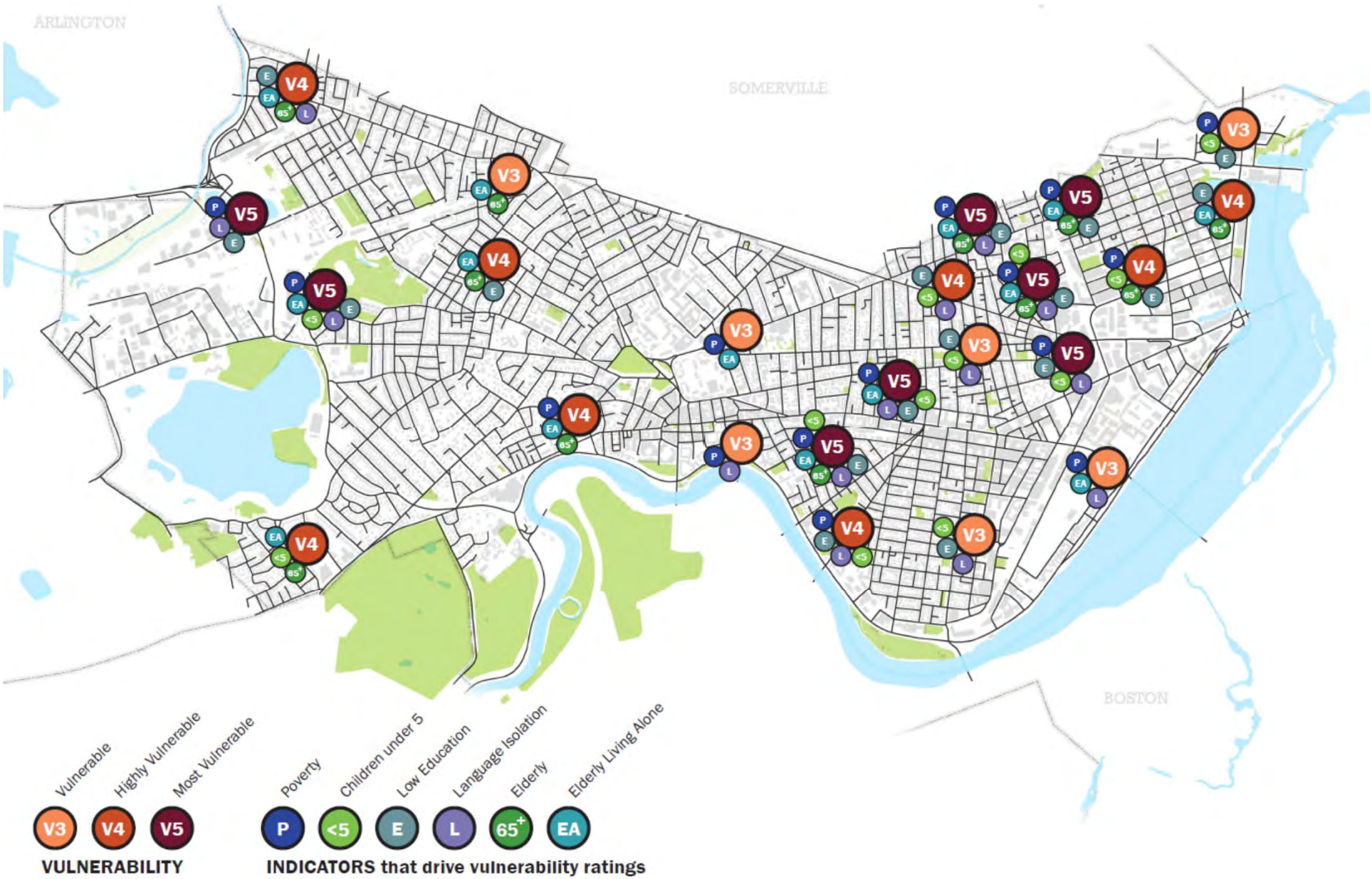
		Probability	
		Low	High
Consequence	High	R3	R4
	Medium	R2	R3
	Low	R1	R2

High Priority Areas

High Priority Areas are Highly Vulnerable assets with R3 and R4 scores

R1- R4: Risk scoring from less severe to most severe

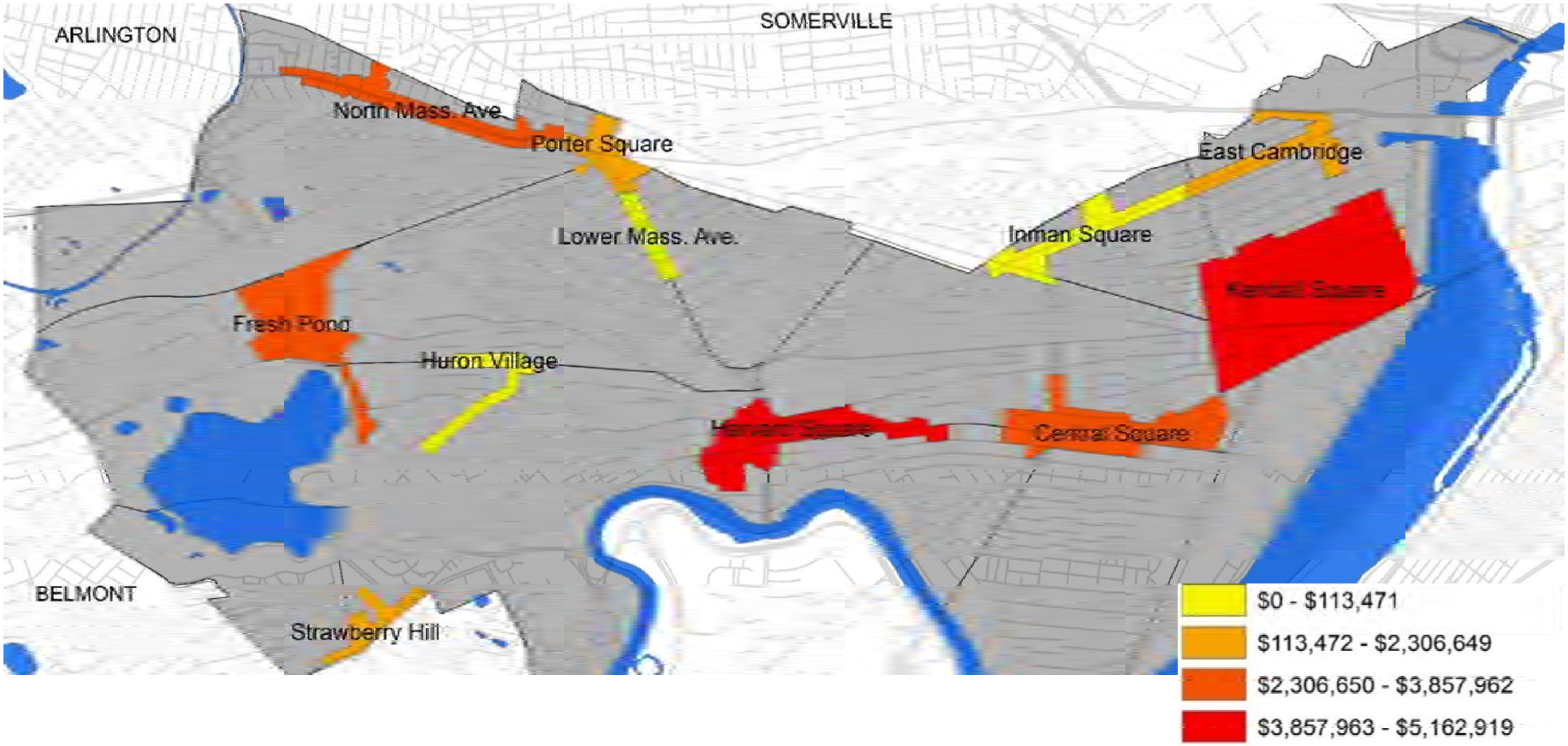
Vulnerable Populations



Economic Analysis: precipitation/flooding impacts

- 2030 – more residential damage - $61 million total damage
- 2070 – more non-residential damage - $232 million total damage

Still, overall structural building damage is small – impacting less than 1%



Estimated structural damages to buildings by commercial districts: 24 hour 100 yr. rainfall event 2070s

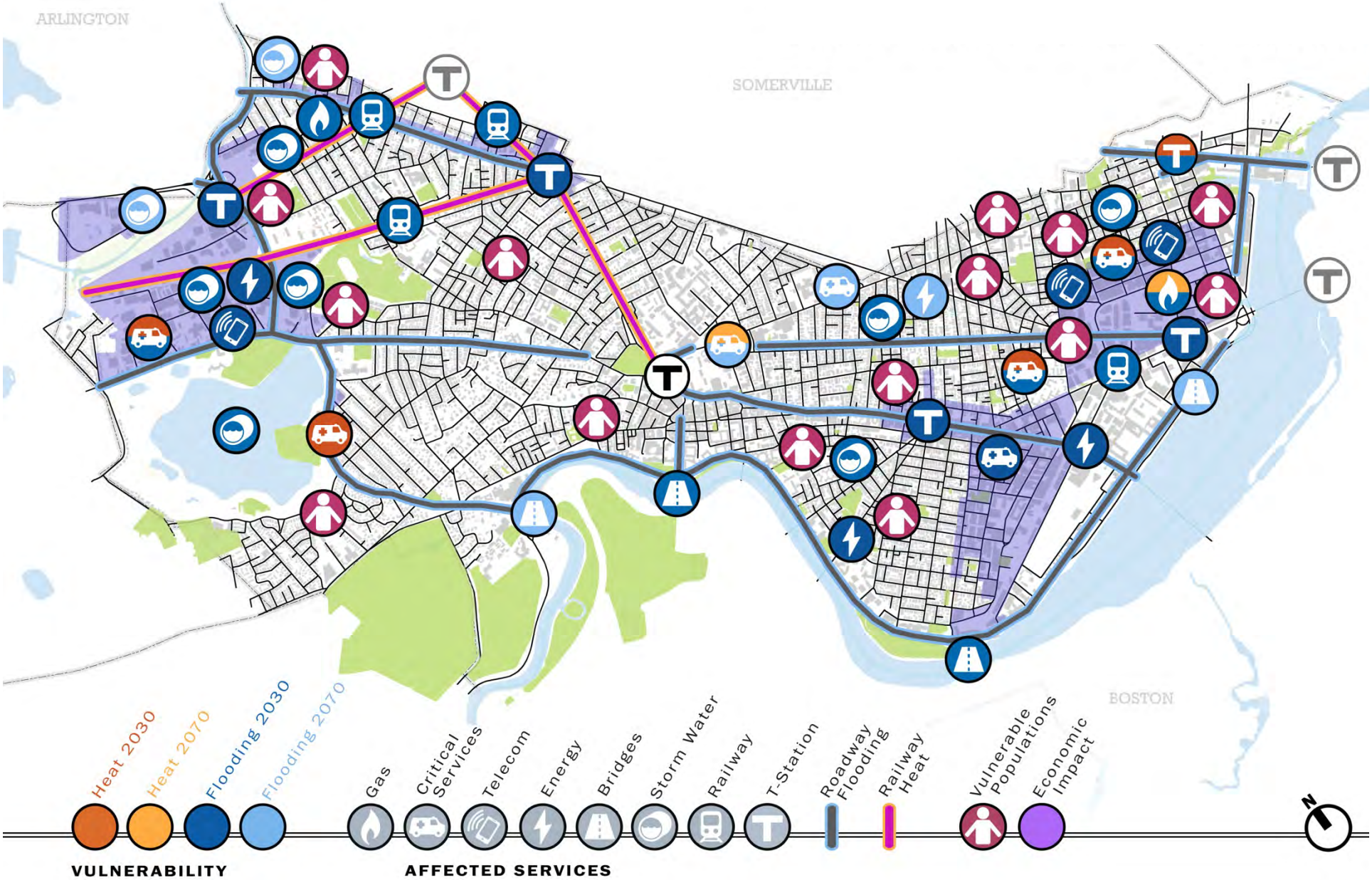
Economic Activity

The daily impact for a city-wide disaster could:

- Impact nearly all of the City's 128,000 jobs
- Result in a loss of **nearly $43 million a day**

The effects would likely spread well beyond Cambridge.

Climate Change Priority Planning Areas



Key Findings for Cambridge

- Cambridge is unlikely to be impacted by **sea level rise or storm surges** by 2030, due to flood protection from both the Charles River and Amelia Earhart dams.

- Storm surge flooding risks become more significant after about 2050. Alewife/Fresh Pond area and North Point see major risks.

- **Heat vulnerability** and **inland flooding** are more imminent.

- **Social vulnerability** is not evenly distributed among the neighborhoods.

- **Key infrastructure assets** are vulnerable in the near-term.

- **Economic losses** from a flood event or an area-wide power loss would be significant.

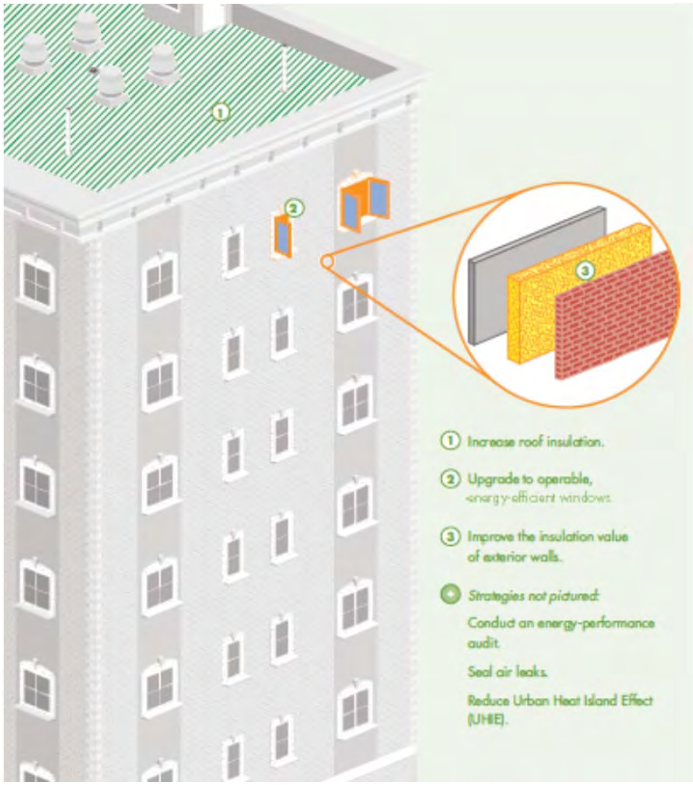
  - Disruption of **economic** activity could be greater than property damage.

- **Adaptation** will require coordination with other entities

Approaches to Resiliency Planning

- Gather “best practices” looking at examples in the region and internationally
- Develop strategies at four scales: Building, Neighborhood, City, Region
- Develop appropriate risk-based standards to inform building and structural design

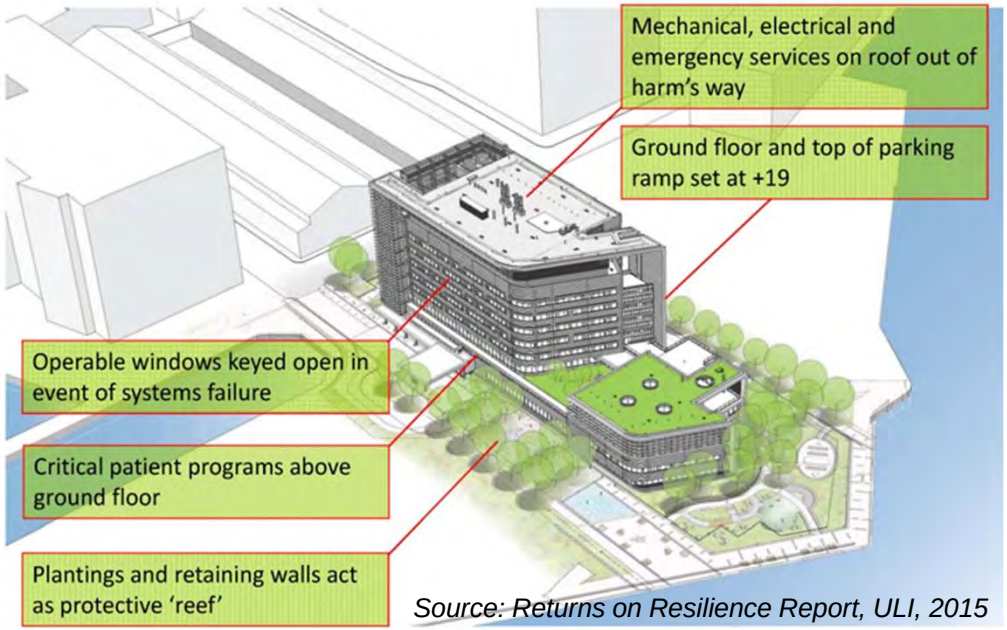
Resiliency at the Building Scale



Source: Strategies for Multifamily Building Resilience, Enterprise green communities, 2015

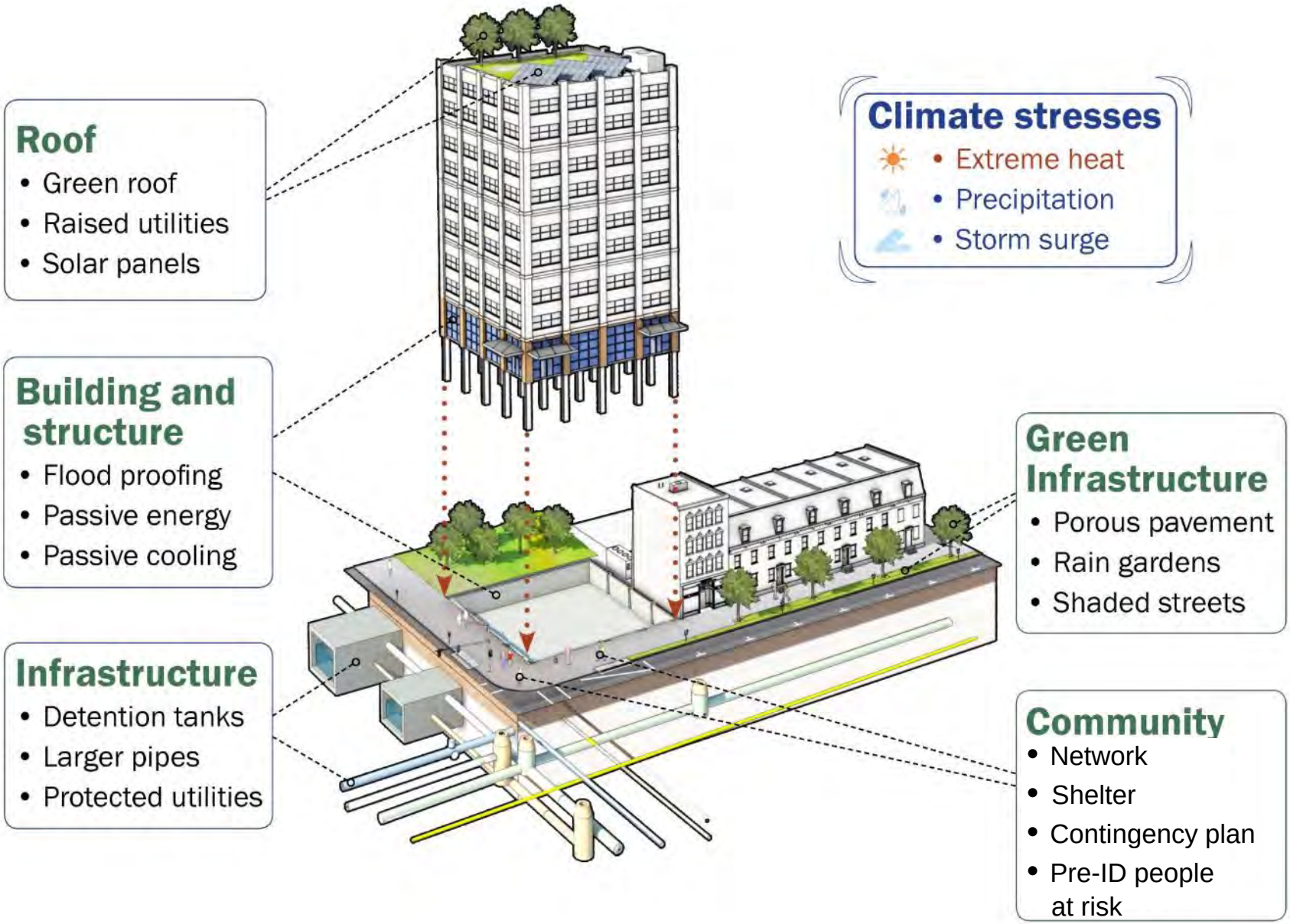
Heat Resiliency for Multifamily Housing

Flood Resiliency for Institutional Building



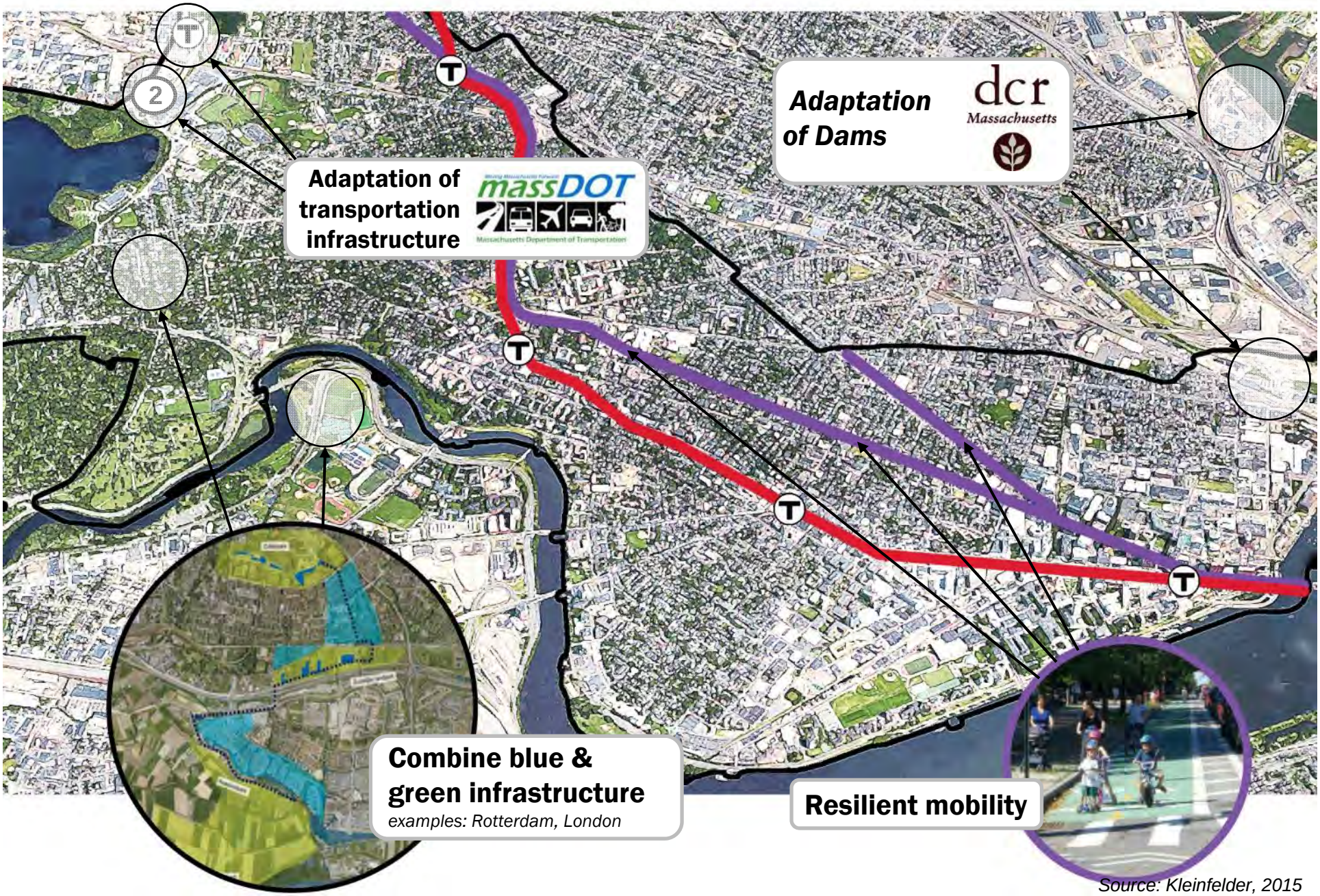
Source: Returns on Resilience Report, ULI, 2015

Resiliency at the Neighborhood Scale



Source: Kleinfelder, 2015

Resiliency at City & Regional Scale



Source: Kleinfelder, 2015

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