Demystifying Resiliency

Uncertainty & Decision Making

Lynette Cardoch, PhD, LEED AP
Director of Resilience & Adaptation

lcardoch@moffattnichol.com

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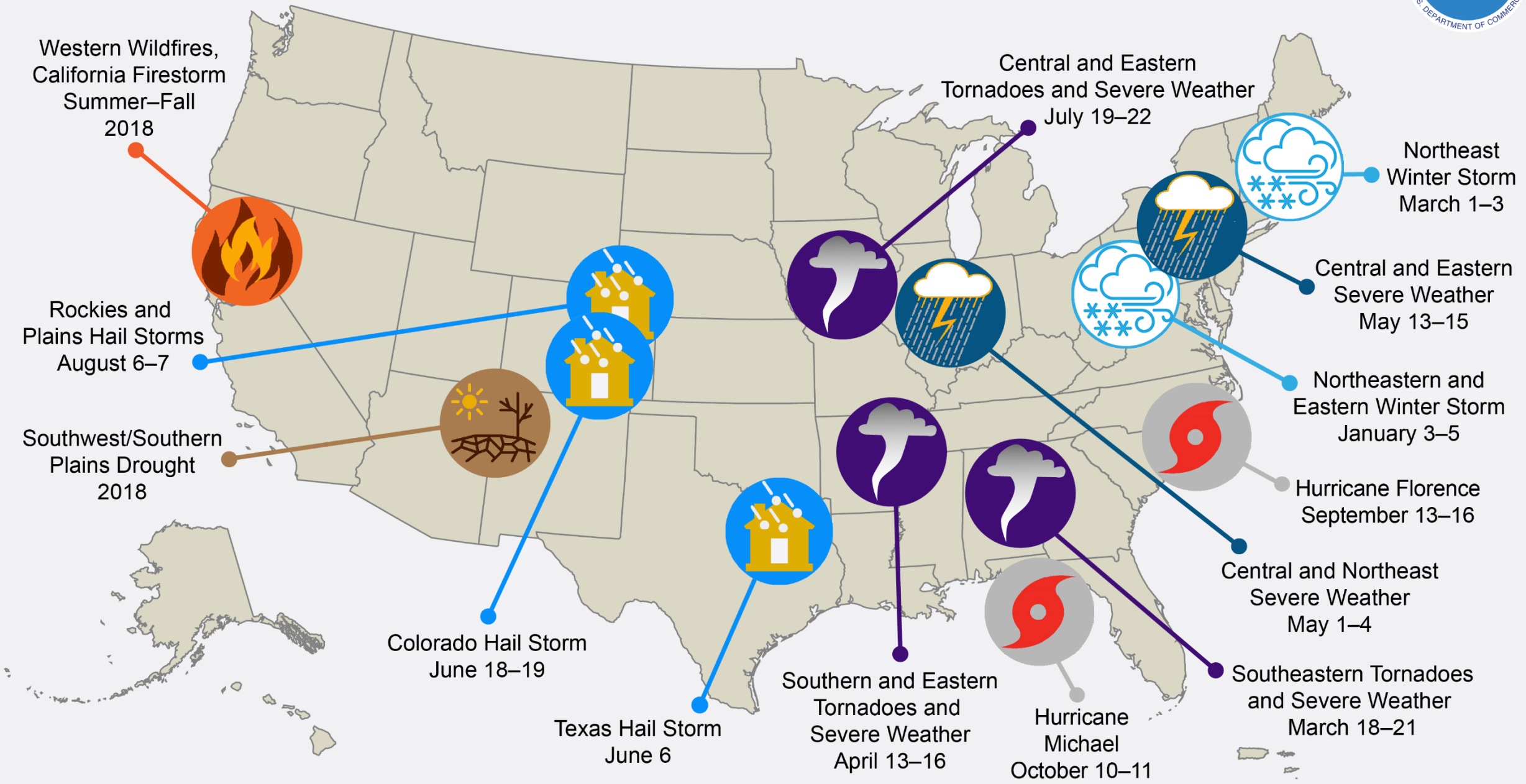
U.S. 2018 Billion-Dollar Weather and Climate Disasters



Rank	Date	Event	Insured loss
1	Aug. 25, 2005	Hurricane Katrina, storm surge, damage to oil rigs	82.4
2	Mar. 3, 2011	Fukushima earthquake (Mw 9.0) triggers tsunami	38.1
3	Sep. 19, 2017	Hurricane Maria	32.0
4	Oct. 24, 2012	Hurricane Sandy, storm surge	30.8
5	Sep. 6, 2017	Hurricane Irma	30.0
6	Aug. 25, 2017	Hurricane Harvey	30.0
7	Aug. 23, 1992	Hurricane Andrew, storm surge	27.9
8	Sep. 11, 2001	Terror attacks on WTC, Pentagon and other buildings	25.9
9	Jan. 1, 1994	Northridge earthquake (Mw 6.7)	25.3
10	Sep. 6, 2008	Hurricane Ike, floods, damage to oil rigs	23.1

Top 10 Costliest World Insurance Losses, 1970-2017 (2017 $; SwissRe)

Business Continuity

Capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience.

(100 Resilient Cities, Rockefeller Foundation)

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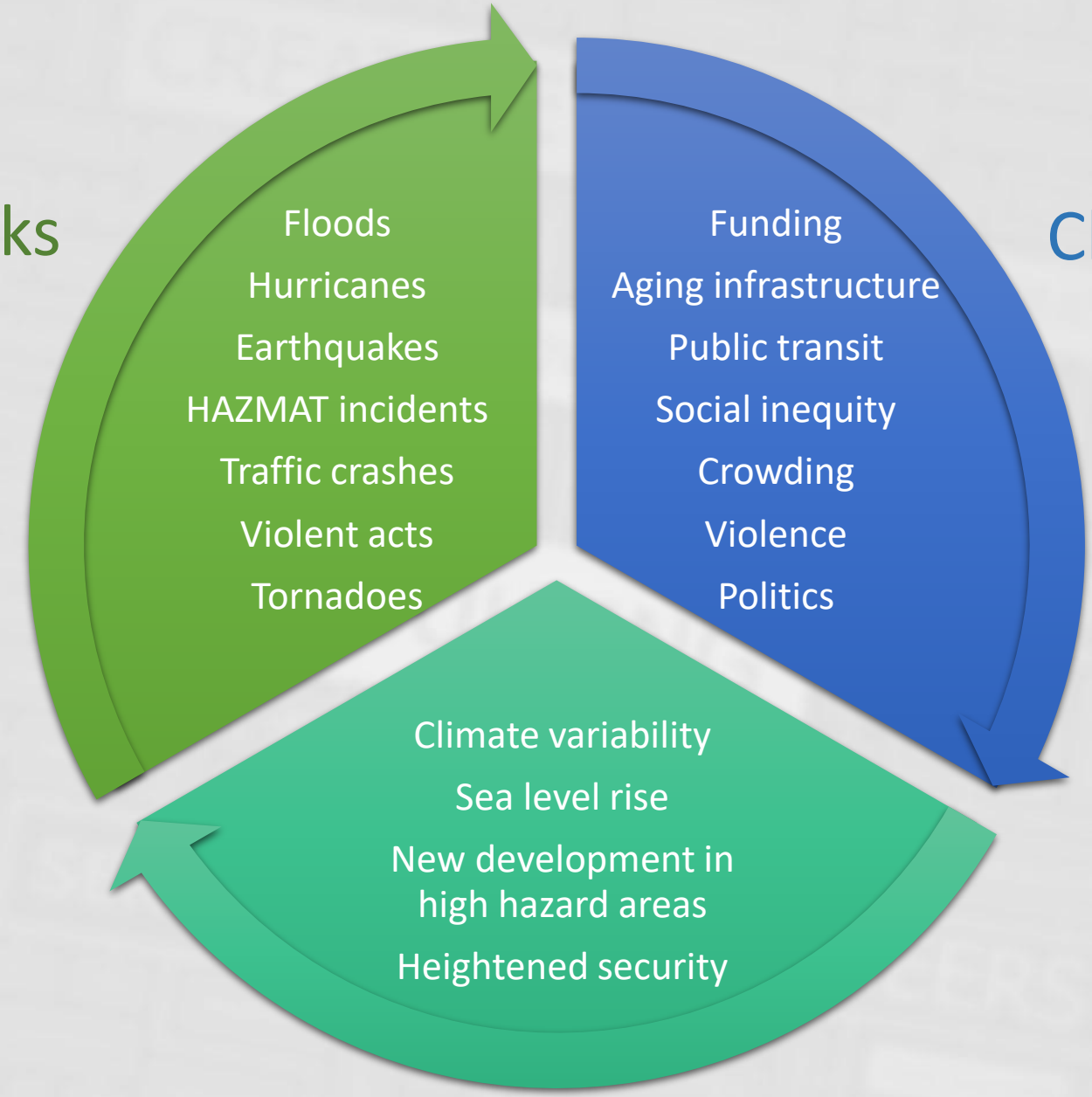
Acute Shocks



Chronic Stressors

Potential Accelerators

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The Resiliency Lens: Fundamental Concepts

- Interconnectivity of systems
- Asset versus system resilience
- Acute shocks & chronic stressors

Interconnectivity of Systems

Interconnectivity of Systems

Climate Variability and Notable Vulnerabilities of Transportation Assets

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Intermodal Implications: Port of Long Beach

- Temperatures > 90º F = Potential buckling and derailments
- Rail speeds slowed
- Increased inundation from SLR, prevent cargo from leaving piers

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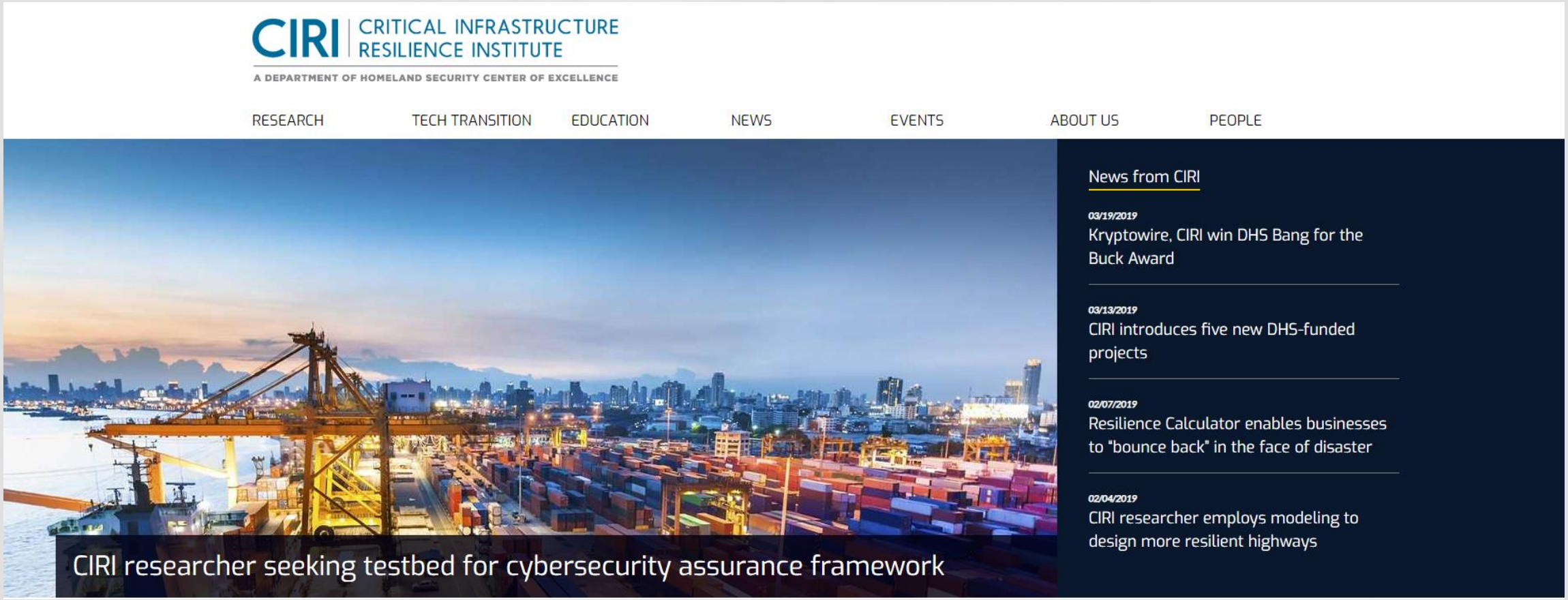
#1 Florida Petroleum Storage Port

- Since 1930s
- ±420 million gallons
- FLL and MIA pipelines
- Former Crude Pipeline
- Serve 12 Counties
- Consume tanker/day (±14 million gallons).

PORT EVERGLADES
BROWARD COUNTY, FLORIDA
Florida's Powerhouse Port™



Interconnected Systems

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Asset Resilience vs System Resilience

Hurricane Michael
Mexico Beach, FL
(October 2018)

Decision Making in Light of Uncertainty

Scenario Planning

Probabilistic Approaches

Dynamic Adaptive Policy Pathways

- First Floor Elevation
- Site Grading
- Nuisance Flooding
- Greening Measures
- Extreme Rainfall
- Deployable Protection
- Future Storm Surge Elevations
- Storm Surge Probability
- Sea Level Rise Probability
- Economic Consequences
- Trade-off Analyses

Resiliency | Right amount of flood-proofing improvements?

Resilient Site

- Raise the site
- Walls and pumps
- Greening and terracing
- Building hardening
- Deployable measures

Resiliency | Sea Level Rise

NOAA Technical Report NOS CO-OPS 083

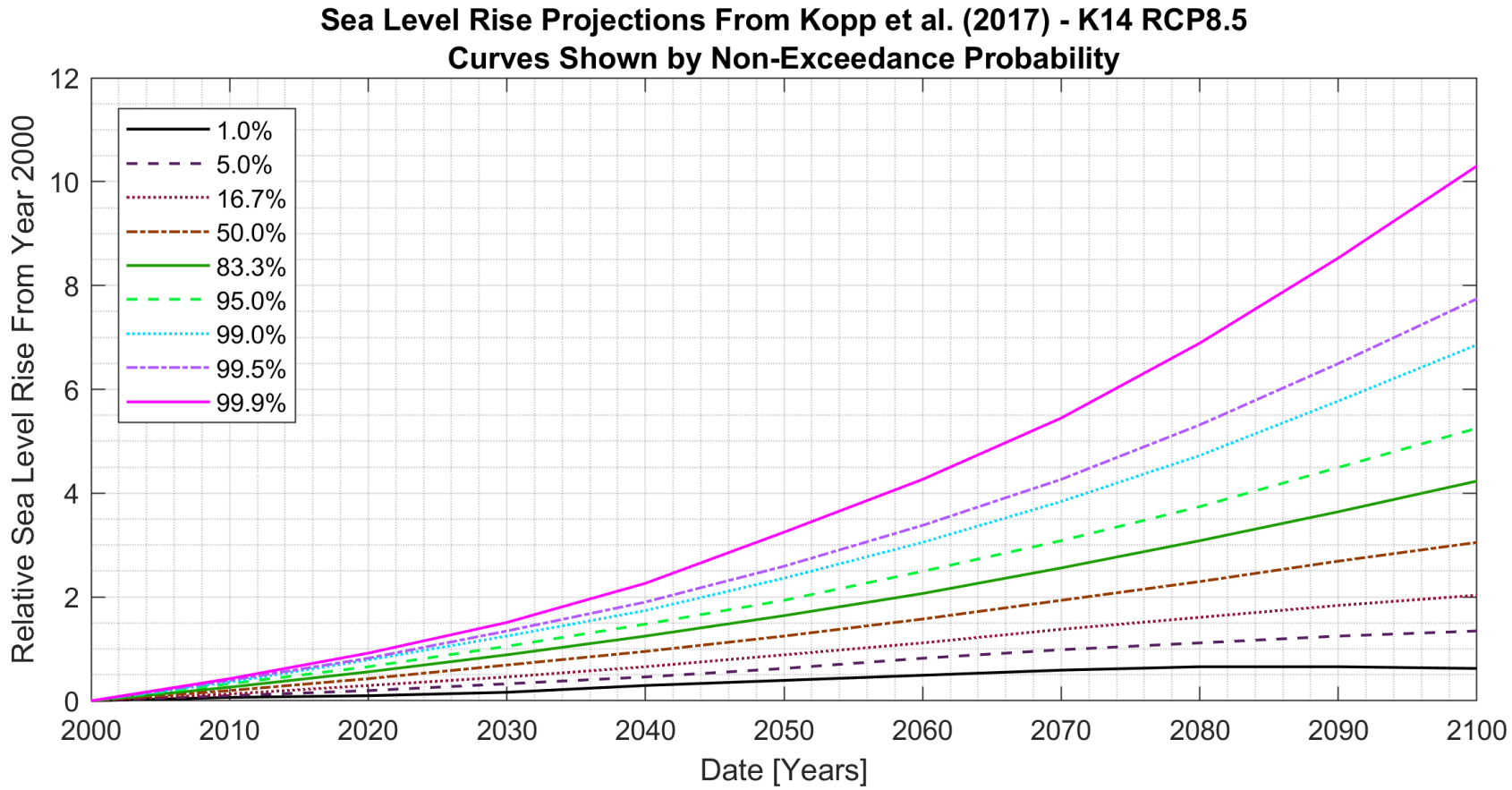
GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES

Photo: Ocean City, Maryland

Silver Spring, Maryland
January 2017

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

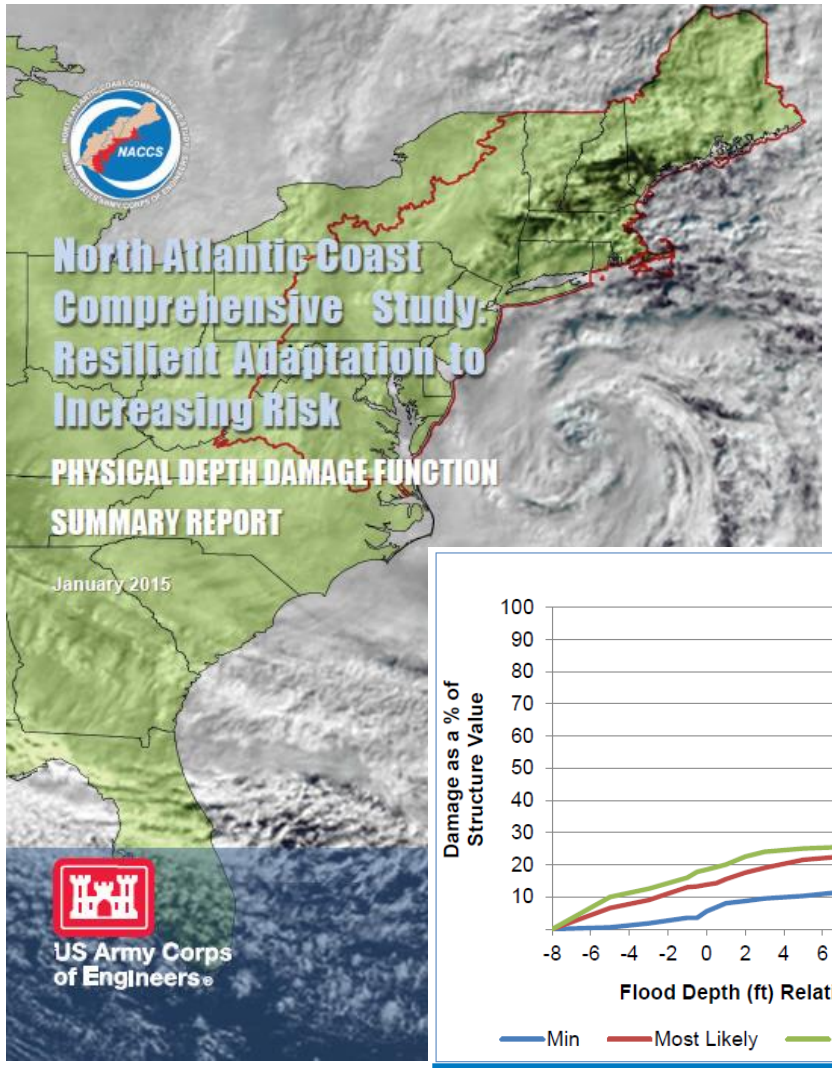


Sea Level Rise Probability Projections for
Charleston, South Carolina

Resiliency | Risk Tolerance

Elevation [ft NAVD88]	Likelihood of Annual Maximum Storm Surge Elevation During Project Life (2020-2100)							
	10 Years (2030)	20 Years (2040)	30 Years (2050)	40 Years (2060)	50 Years (2070)	60 Years (2080)	70 Years (2090)	80 Years (2100)
10.0	11.8%	23.1%	33.8%	44.1%	53.9%	63.4%	72.4%	80.2%
11.0	8.6%	17.0%	25.5%	34.0%	42.3%	50.6%	58.8%	66.8%
12.0	5.9%	11.9%	18.3%	24.9%	31.7%	38.9%	46.2%	53.6%
13.0	4.1%	8.3%	12.9%	17.8%	23.0%	28.7%	34.8%	41.2%
14.0	2.8%	5.8%	9.0%	12.6%	16.4%	20.7%	25.4%	30.6%
15.0	1.9%	4.0%	6.2%	8.7%	11.5%	14.6%	18.2%	22.2%
FFE: 16.0	1.3%	2.7%	4.3%	6.0%	7.9%	10.2%	12.7%	15.6%
17.0	0.9%	1.9%	2.9%	4.2%	5.5%	7.1%	8.9%	10.9%
18.0	0.6%	1.3%	2.0%	2.9%	3.8%	4.9%	6.1%	7.6%
19.0	0.4%	0.9%	1.4%	2.0%	2.6%	3.4%	4.2%	5.3%
20.0	0.3%	0.6%	0.9%	1.3%	1.8%	2.3%	2.9%	3.6%

Resiliency | Benefit Cost Ratio = Value



$$\frac{BENEFIT\ OF\ PROTECTION}{COST\ OF\ PROTECTION} = BENEFIT\ COST\ RATIO$$

Figure 68. Prototype 4A: Urban High Rise, Inundation Damage – Structure

Table 46. Prototype 4A: Urban High Rise, Inundation Damage – Structure

Flood Depth	Min	Most Likely	Max
-8	0	0	0
-5	0.5	6.5	10
-3	1.75	9	12.5
-1	3.5	13	16
-0.5	3.5	13.25	17.75
0	5.5	13.75	18.5
0.5	6.75	14.25	19.25
1	8	15.5	20
2	8.75	17.5	22.5
3	9.5	19	24
5	10.25	21.5	25
7	11.5	22.5	25.5
10	12.5	23.5	26.5

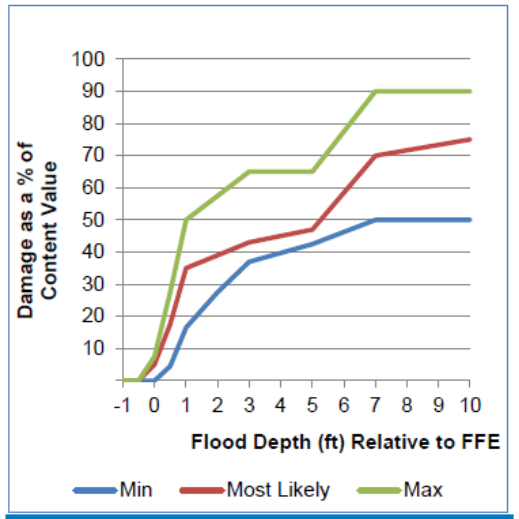
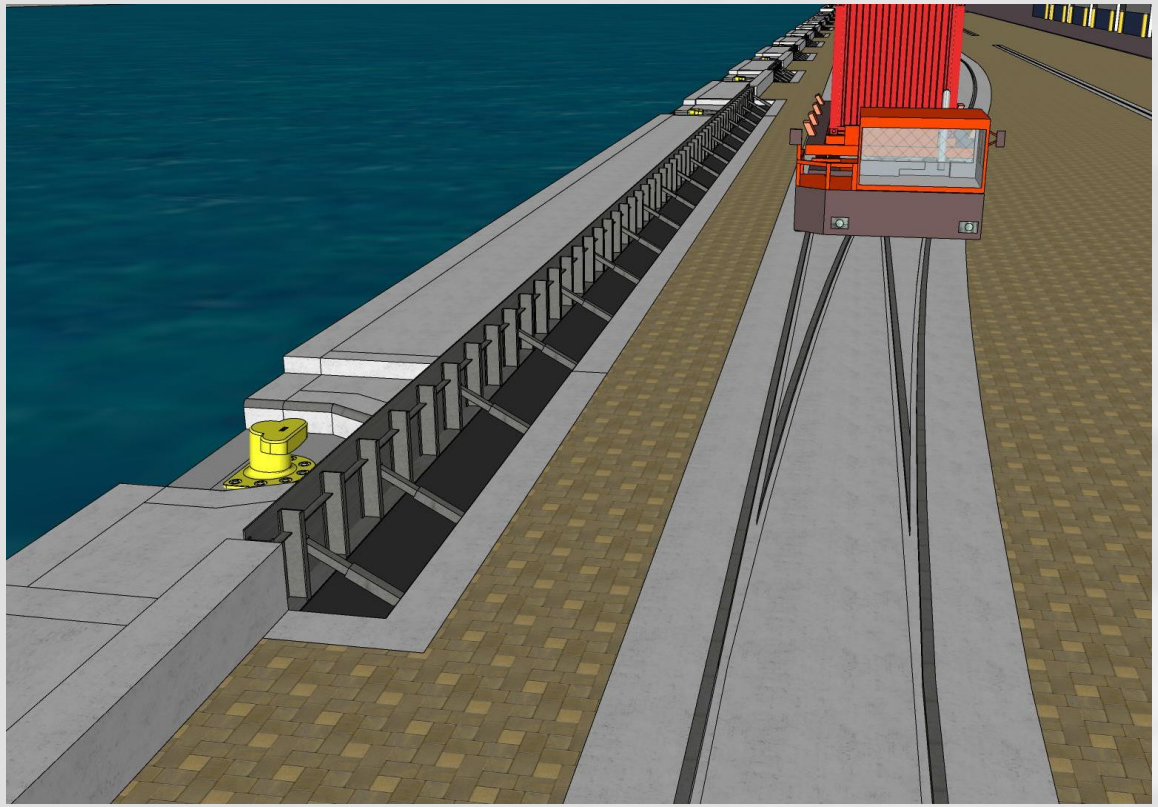
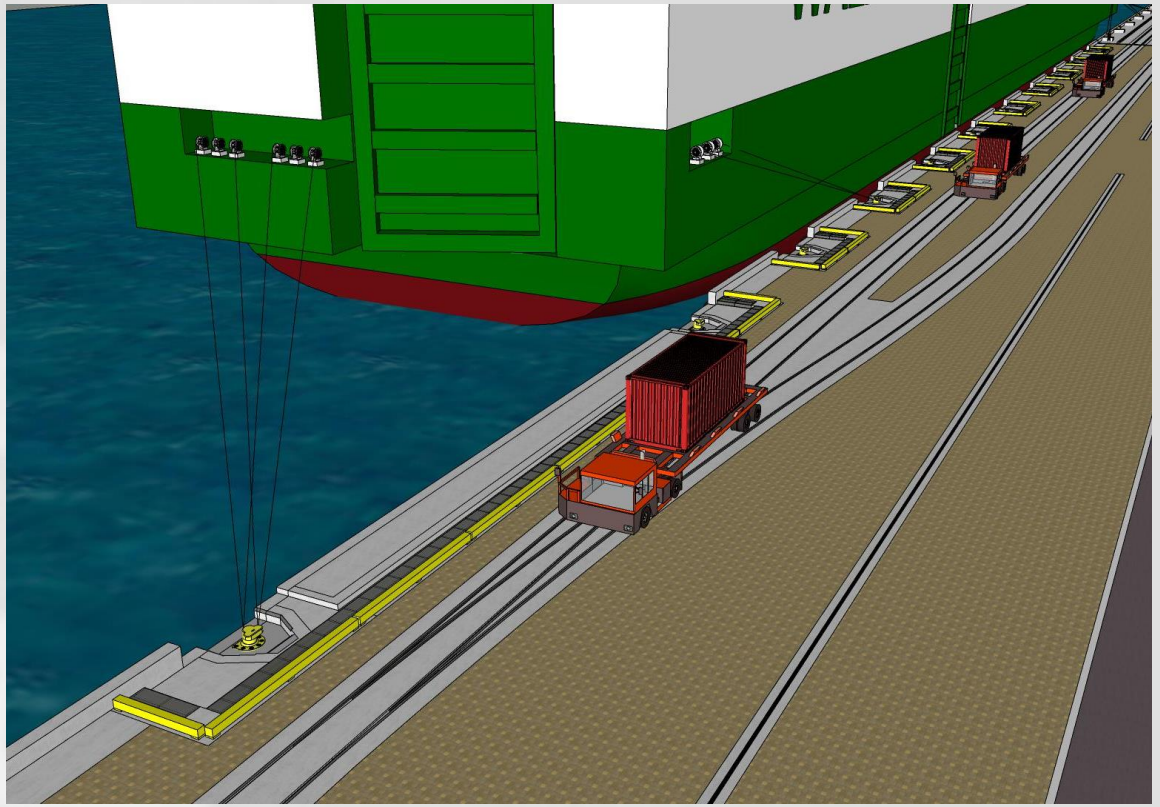


Figure 50. Prototype 2: Commercial Engineered, Inundation Damage – Perishable Content

Table 26. Prototype 2: Commercial Engineered, Inundation Damage – Perishable Content

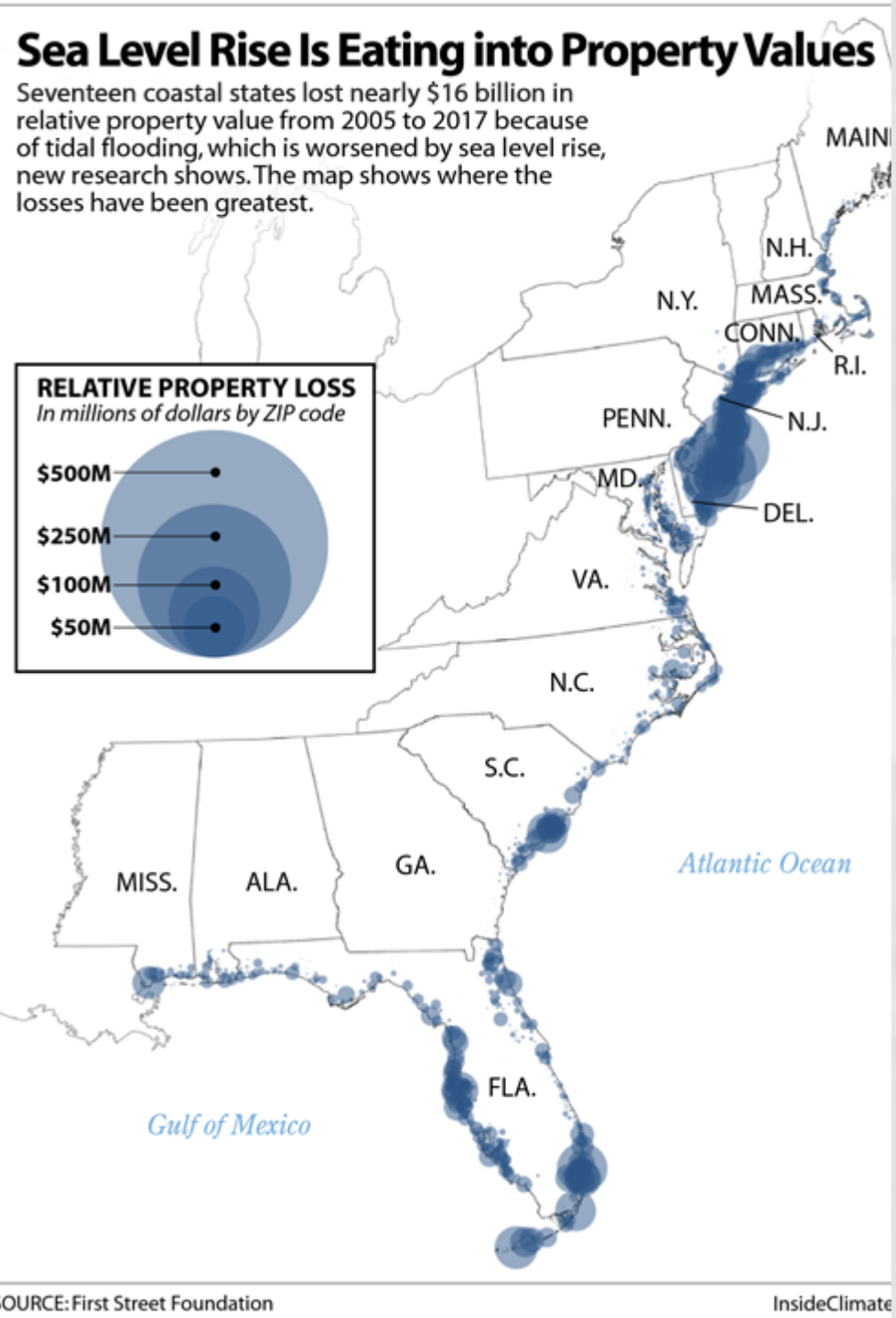
Flood Depth	Min	Most Likely	Max
-1.0	0	0	0
-0.5	0	0	0
0.0	0	5	8
0.5	5	18	28
1.0	17	35	50
2.0	28	39	58
3.0	37	43	65
5.0	43	47	65
7.0	50	70	90
10.0	50	75	90





Reduce Operational Interruptions

Acute versus Chronic Stressors



Chronic Stressor: Fiscal Resiliency

- Revenue Streams
- Tax Base
- Concentration of assets

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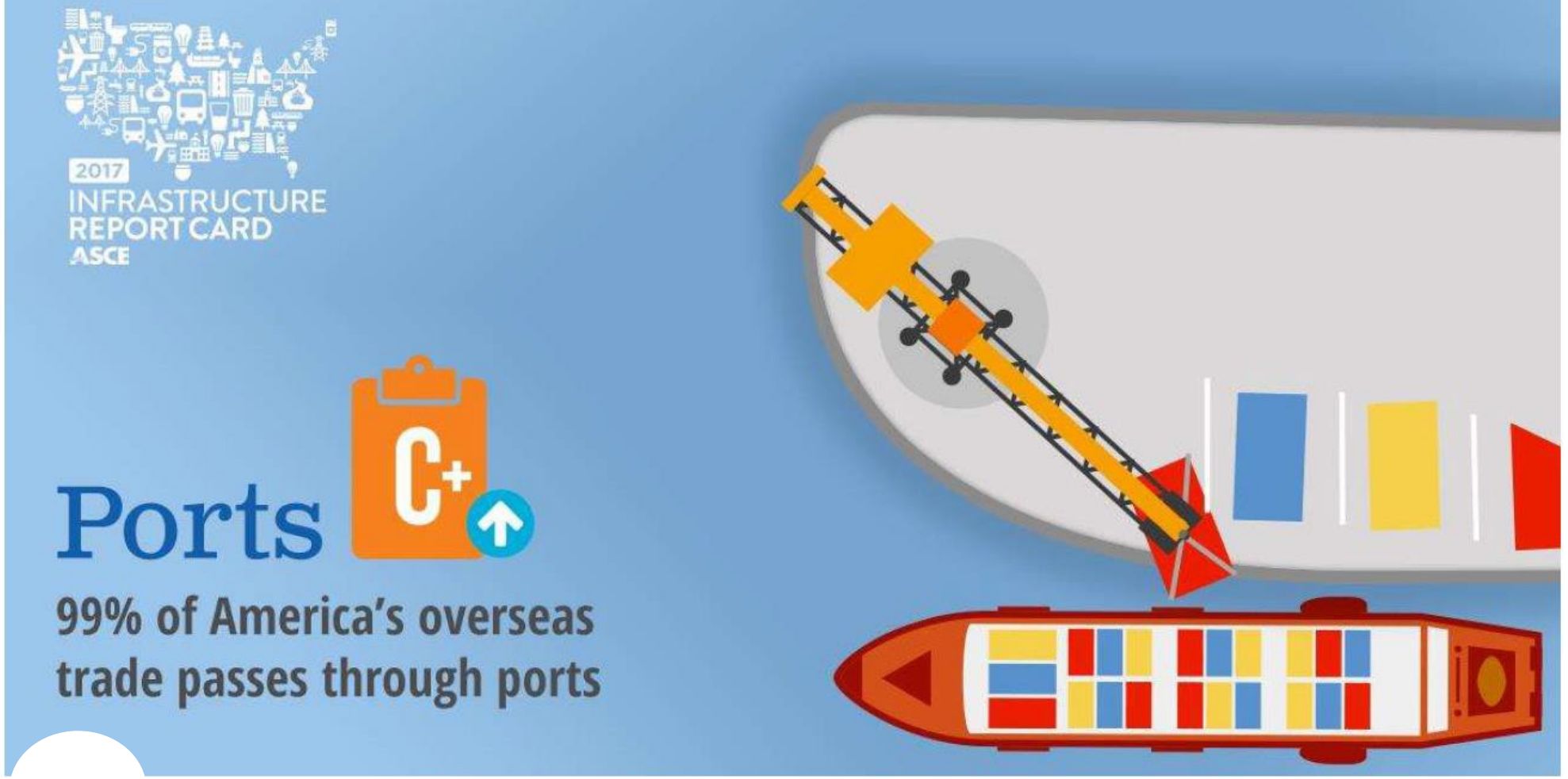

Chronic Stressors

- Capacity and Condition
- Funding and Future Need
- Public Safety and Resilience

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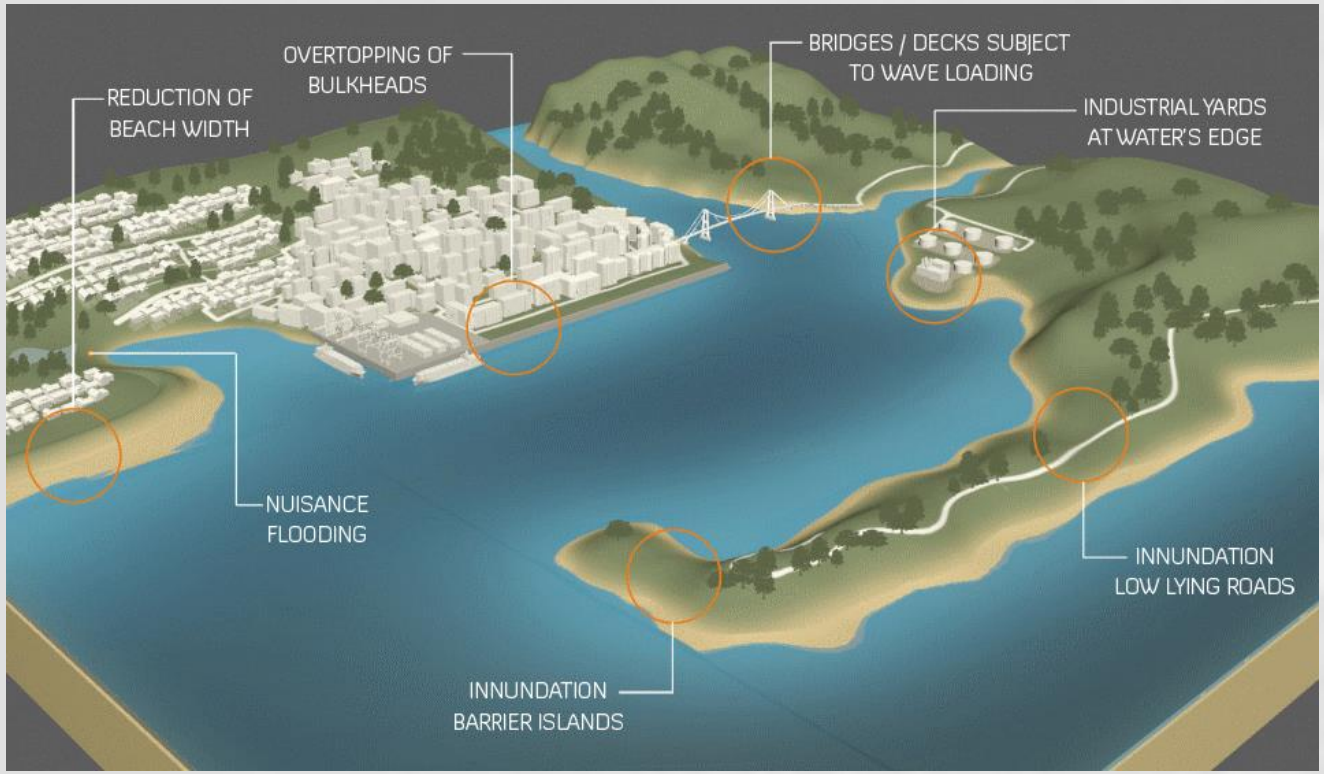

Future Storm Surge Consequence

Chronic Stressor: Sea Level Rise

- Threats
  - Sea level rise
  - Wind and wave driven storm surge
  - Riverine flooding
  - Extreme rainfall
- Consequences
  - Water damage
  - Loss of buildings and infrastructure
  - Operational disruptions
  - Occupancy reductions (future business)
  - No longer insurable

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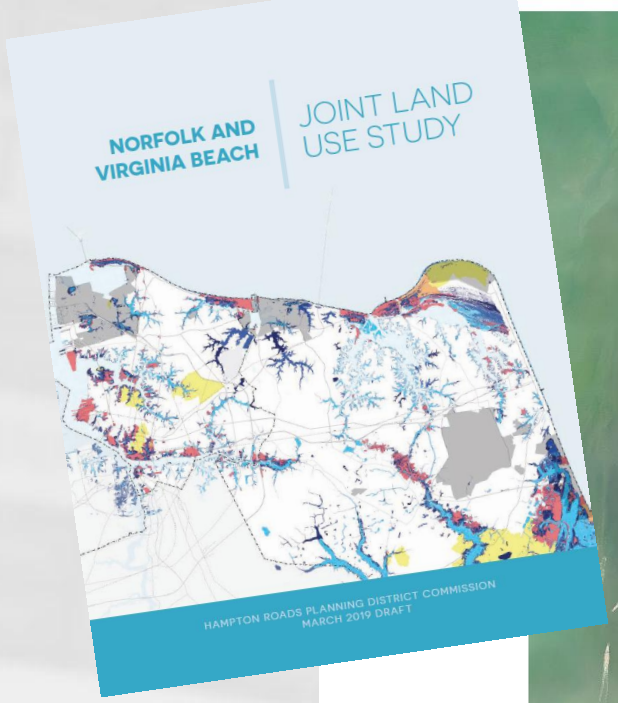
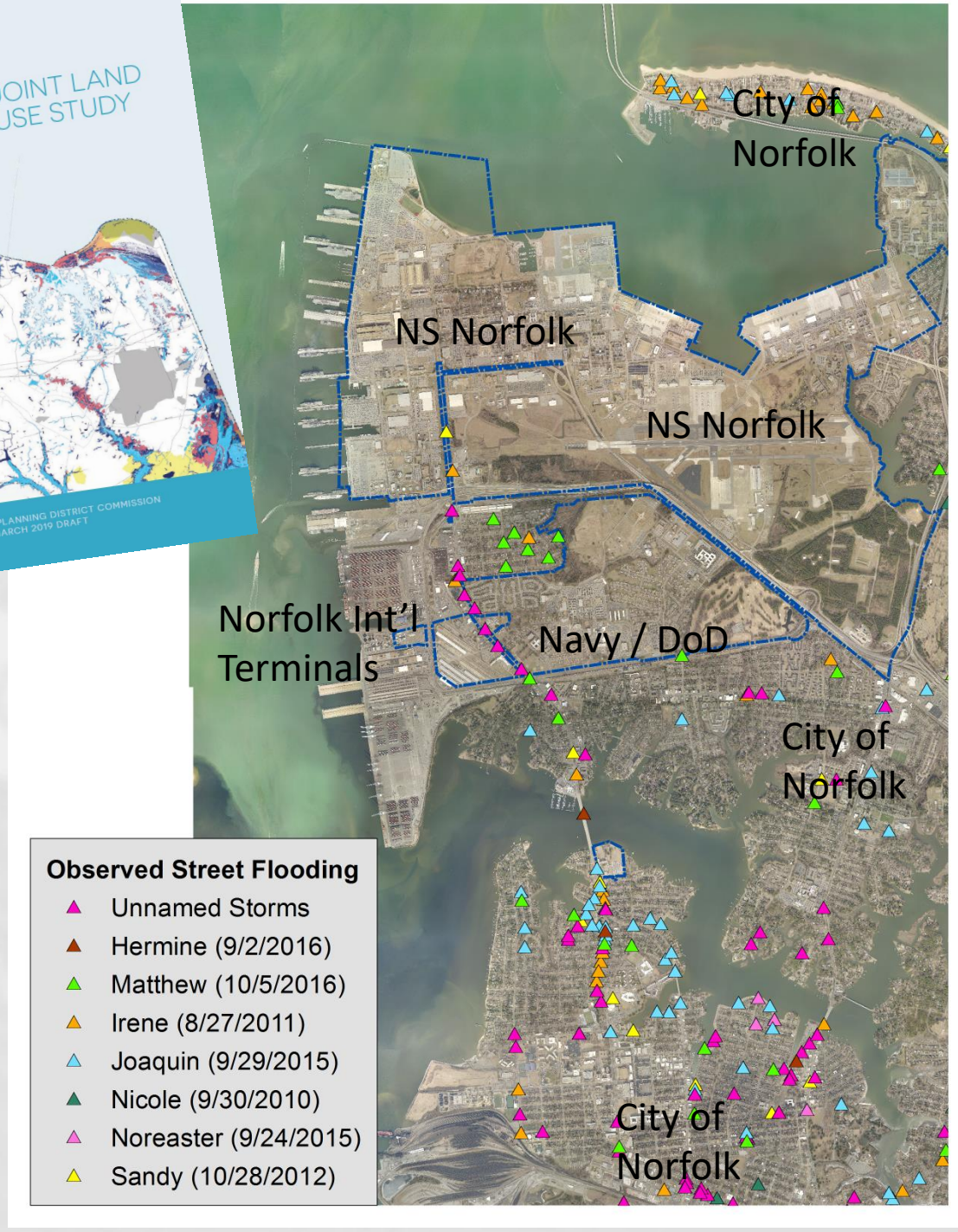
Chronic: Flooding Vulnerability Affecting Operations

- Regional economic engine: 36% employment
- DOD and Port of Virginia
- Critical infrastructure impacts: flooding arterial streets
- Collaboration: Cities, Port, Navy staff, DoD, others





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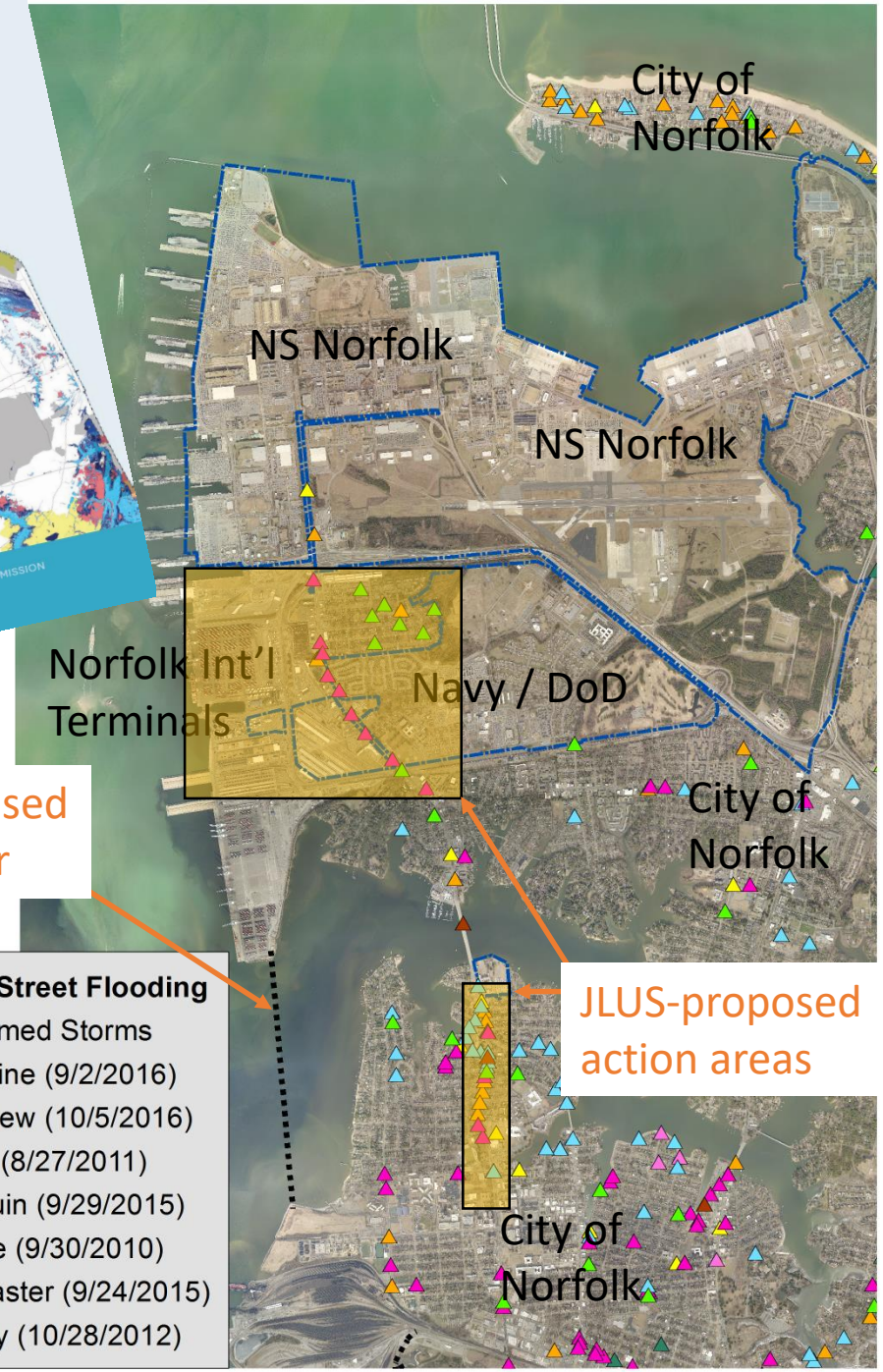

- JLUS: infrastructure & policy to mitigate chronic roadway and adjacent area flooding
- Norfolk's USACE Coastal Storm Risk Management (CSRM): mitigate acute hurricane and nor'easter flooding
- Projects from both eligible for Federal partnership & funding; would be complementary

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Decision Making with the Resiliency Lens

- Uncertain future vs confidence in actions
- Regional resiliency assessments
- Multi-jurisdictional cooperation
- Robust asset management
- No regrets

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THANK YOU!

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