Risk and Resilience: Assessing Vulnerability for Coastal Communities

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Delaware Sea Grant

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About Delaware Sea Grant

Putting Science to Work for Delaware Communities

- Extension
- Research
- Education

Overview of Today's Presentation

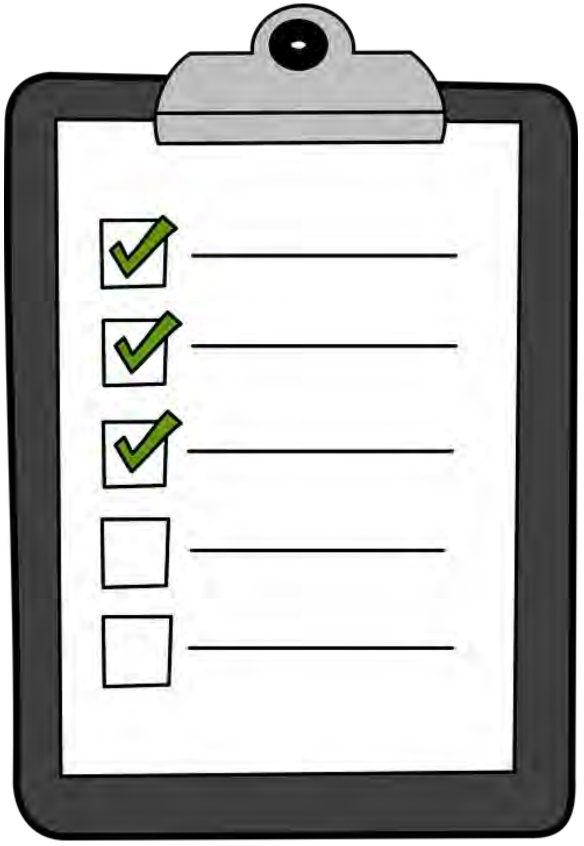
Part I: Risk and Hazard Concepts

Part 2: Future Climate Projections and Implications for Water Systems

Part 3: Building Resilience Through Assessment and Planning

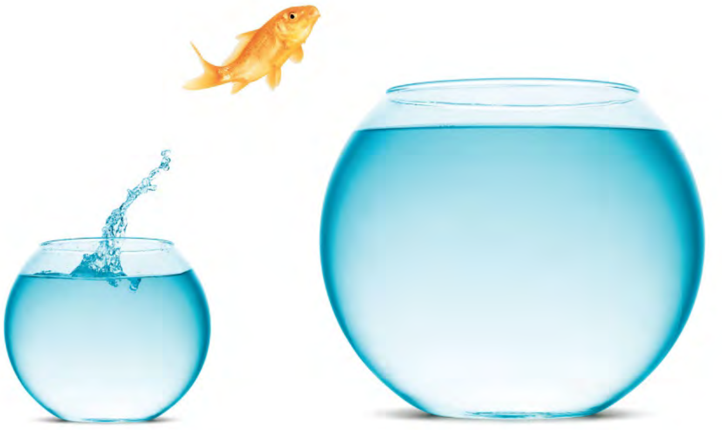
Part 4: Resilience Planning Examples

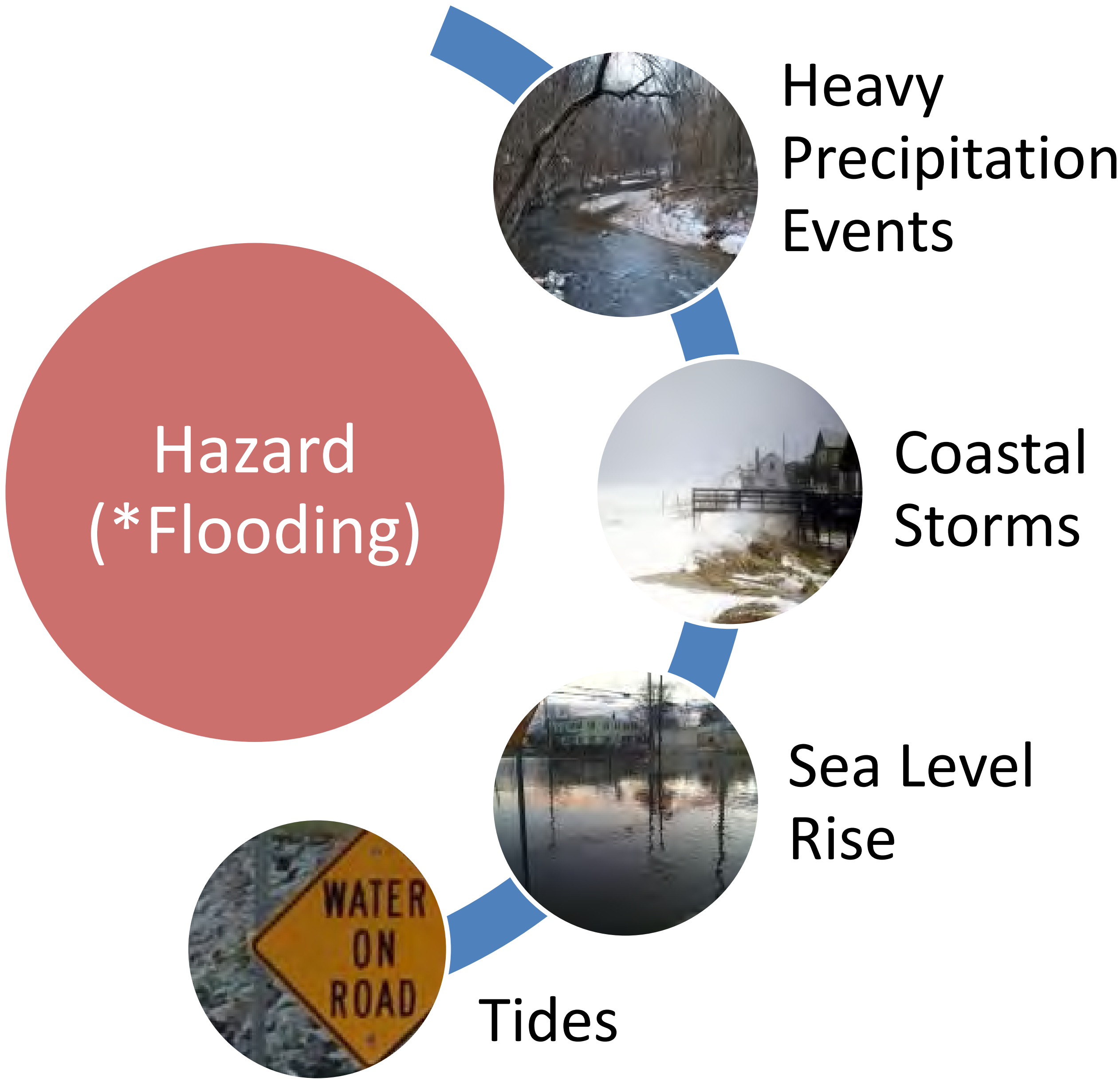
Part 5: Additional Resources



Part 1

Risk and Hazard Concepts

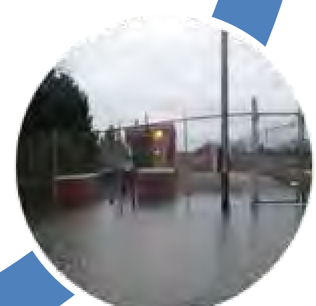



Hazard
(*Flooding)
Heavy
Precipitation
Events
Coastal
Storms
Sea Level
Rise
Tides
WATER
ON
ROAD

Exposure

People

Property



Systems

Adapted from FEMA, IS-393.A
Introduction to Hazard Mitigation

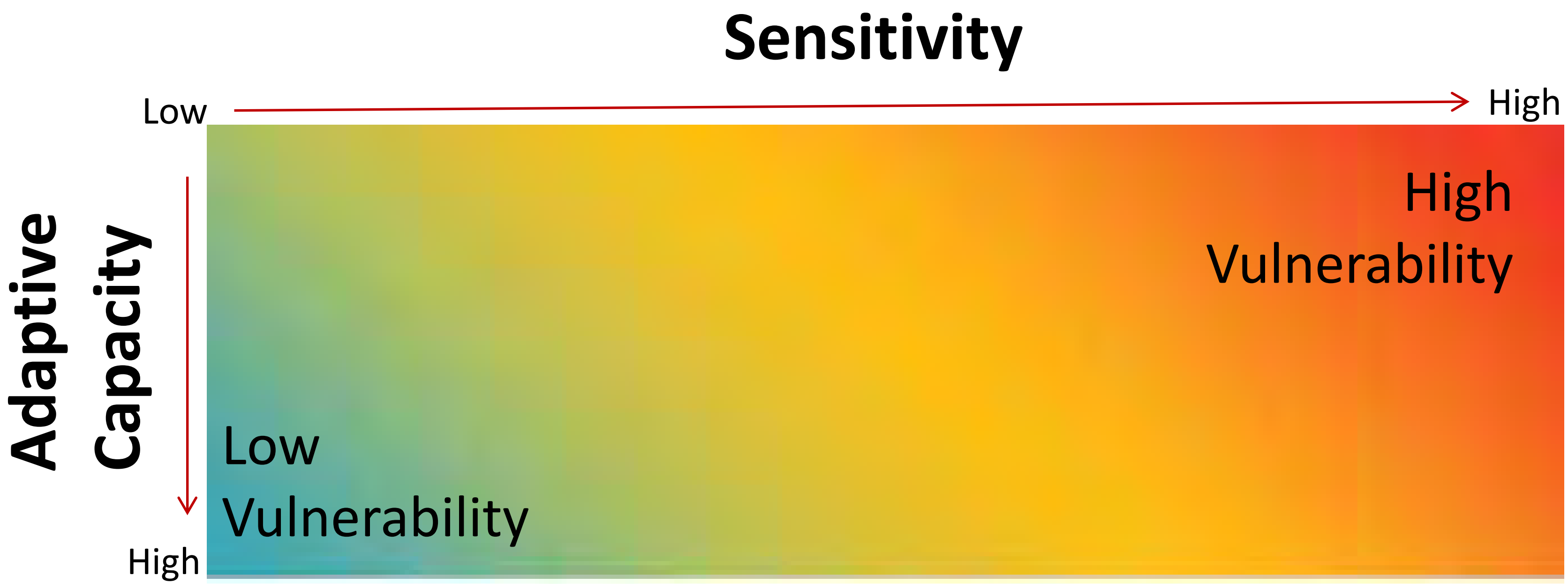
Vulnerability

Land uses and building standards

At-risk populations

Nature-based systems

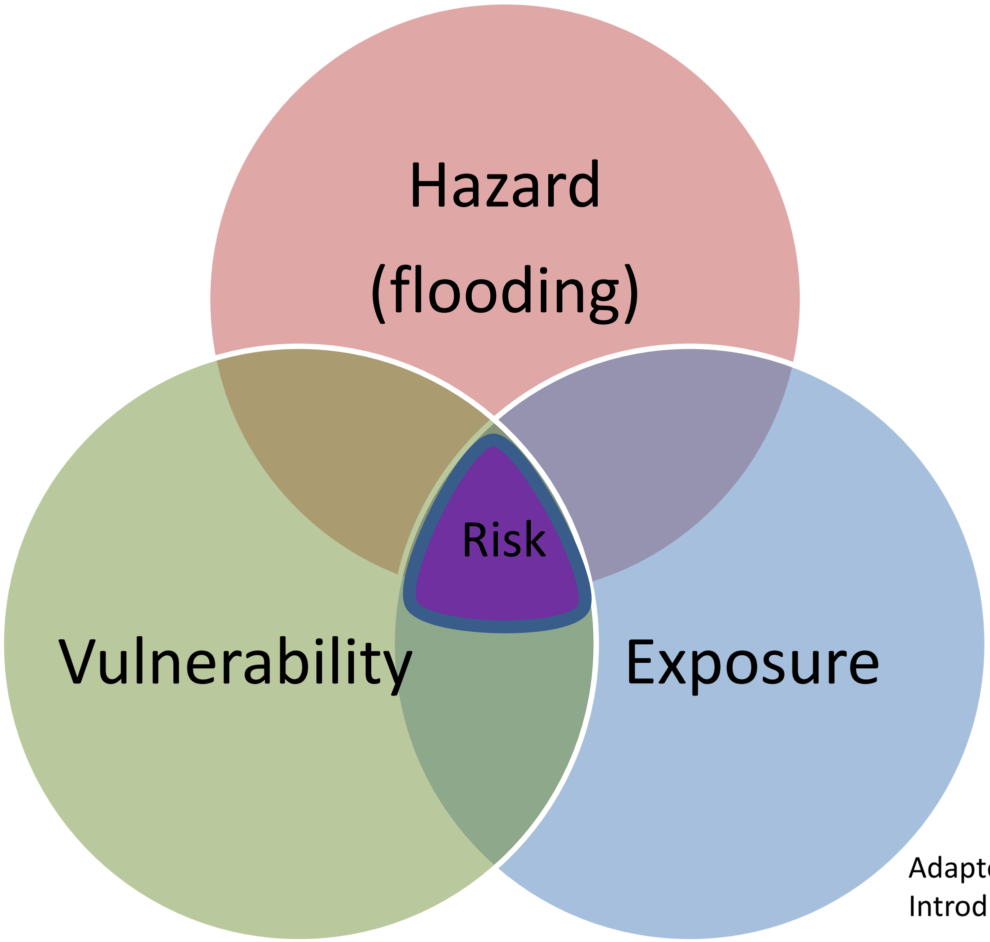
Adapted from FEMA, IS-393.A Introduction to Hazard Mitigation



Graphic courtesy of Daniella Hirschfeld, The Resiliency Place

Sensitivity and Adaptive Capacity are important considerations for Vulnerability

Risk = Hazard + Exposure + Vulnerability



Adapted from FEMA, IS-393.A
Introduction to Hazard Mitigation

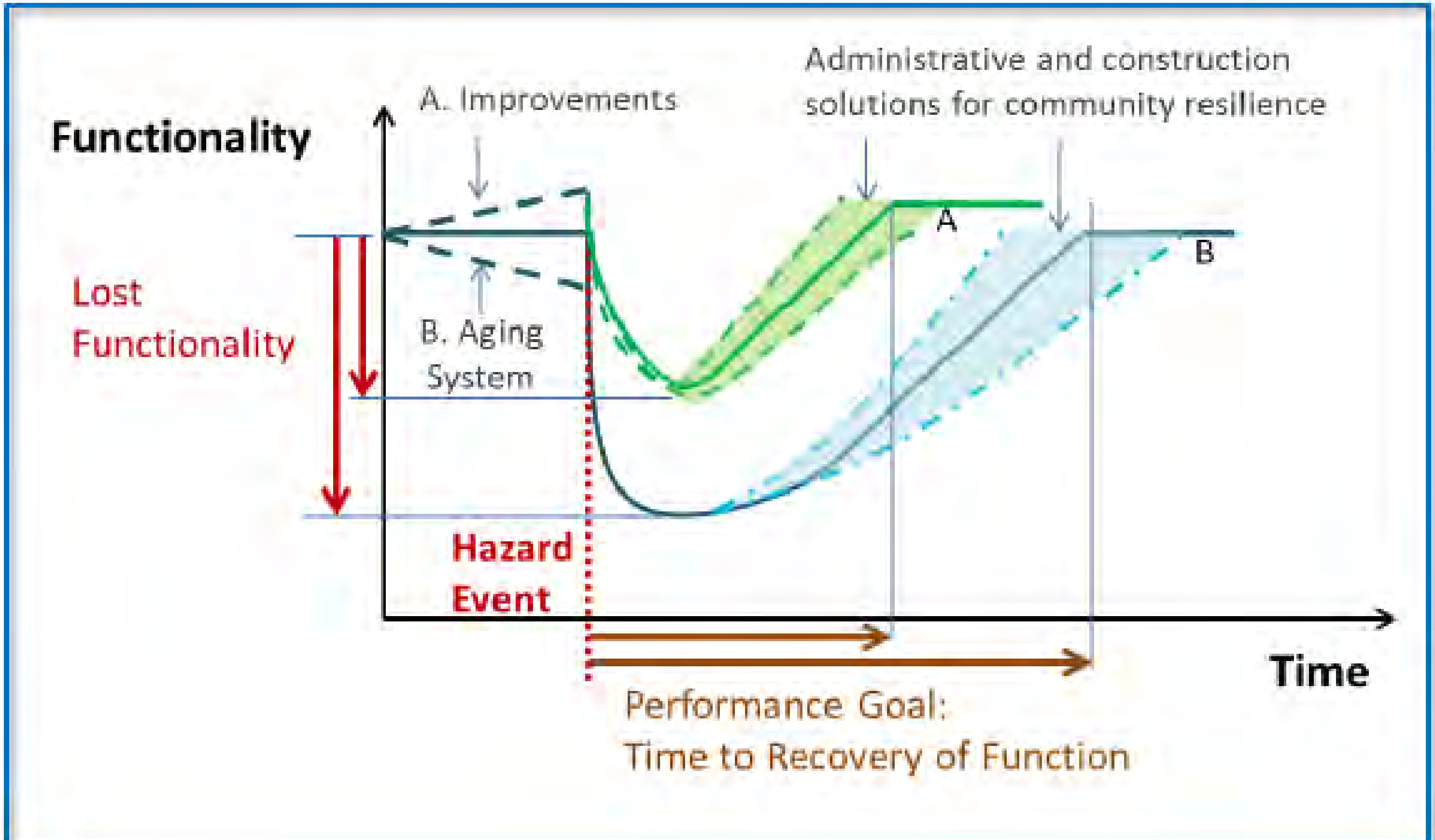
Resilience:

The capacity to *bounce back* quickly from hazardous events or other disruptions

Resilience Planning is anticipatory and proactive

For every $1 spent on flood mitigation, we save $6 in future avoided losses. Source: FEMA

Resilience and the Built Environment



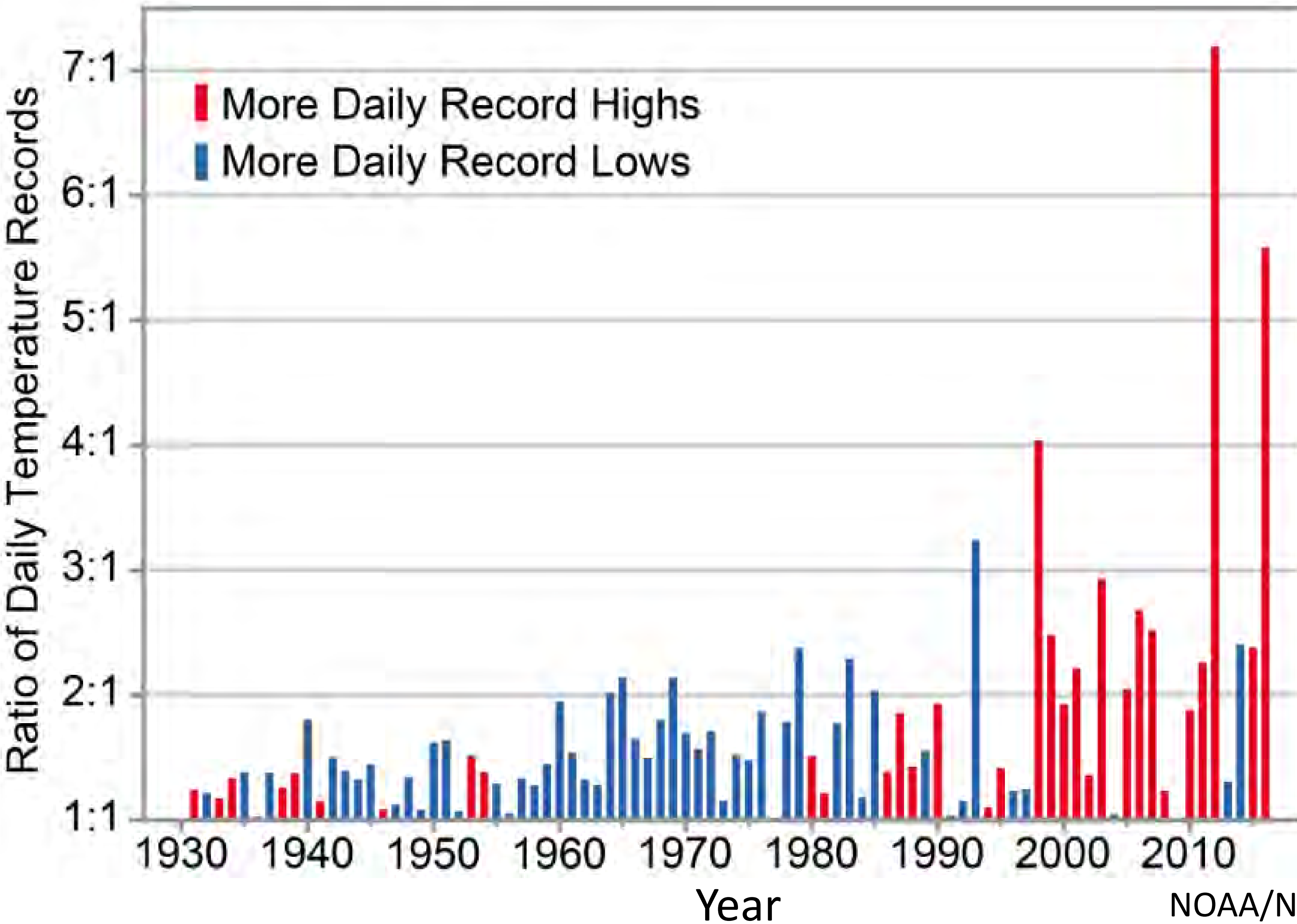
Condition A Experiences modest loss of functionality after the event	Condition B Increased vulnerability to the hazard relative to Condition 'A'
• Well maintained • Benefitted from good design and mitigation projects • Improved level of functionality before hazard event • Modest loss of functionality after event	• Degradation of functionality • Deterioration in the physical system • Lack of adequate maintenance

Source: NIST

Part 2

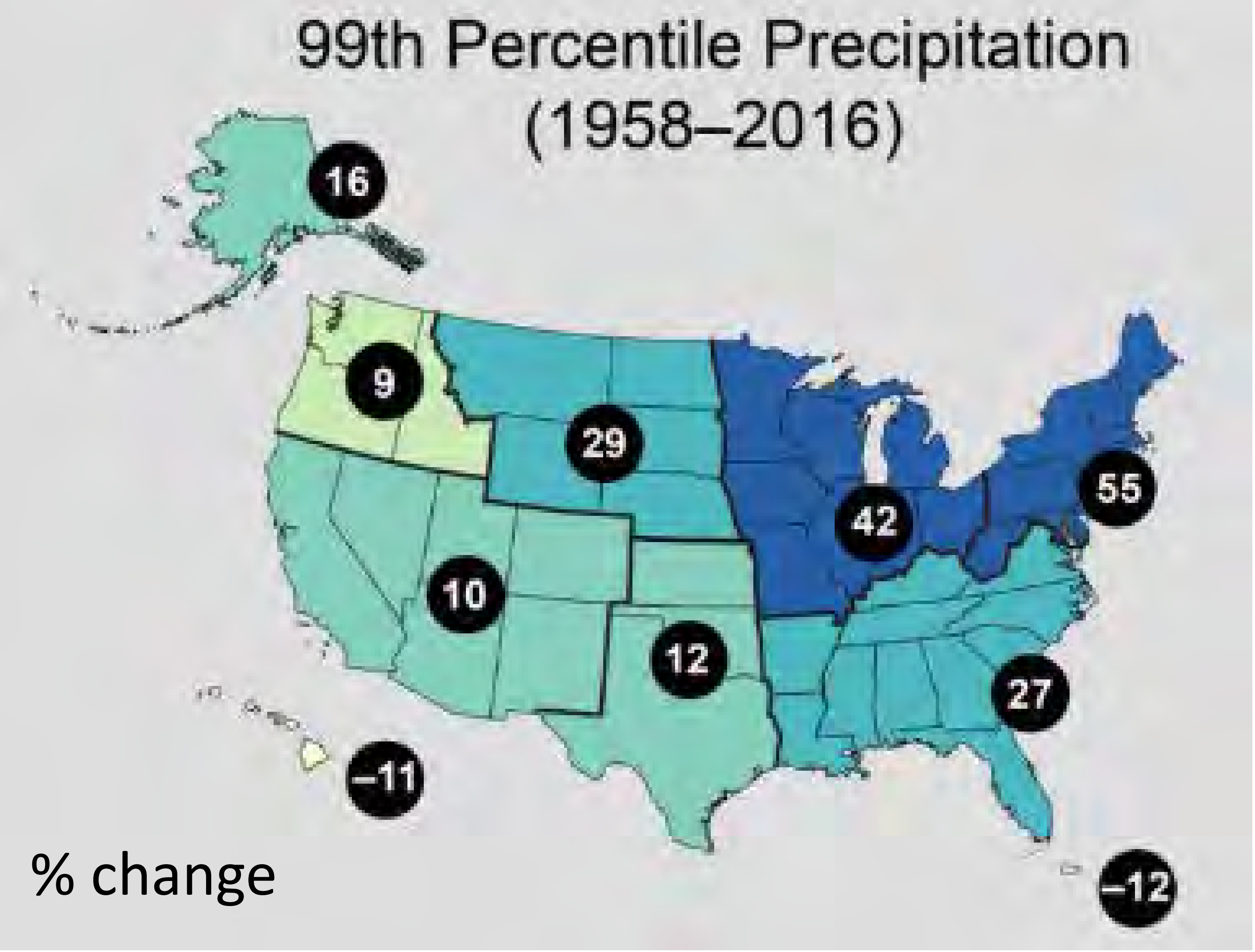
Future Climate Projections

Extreme Temperatures



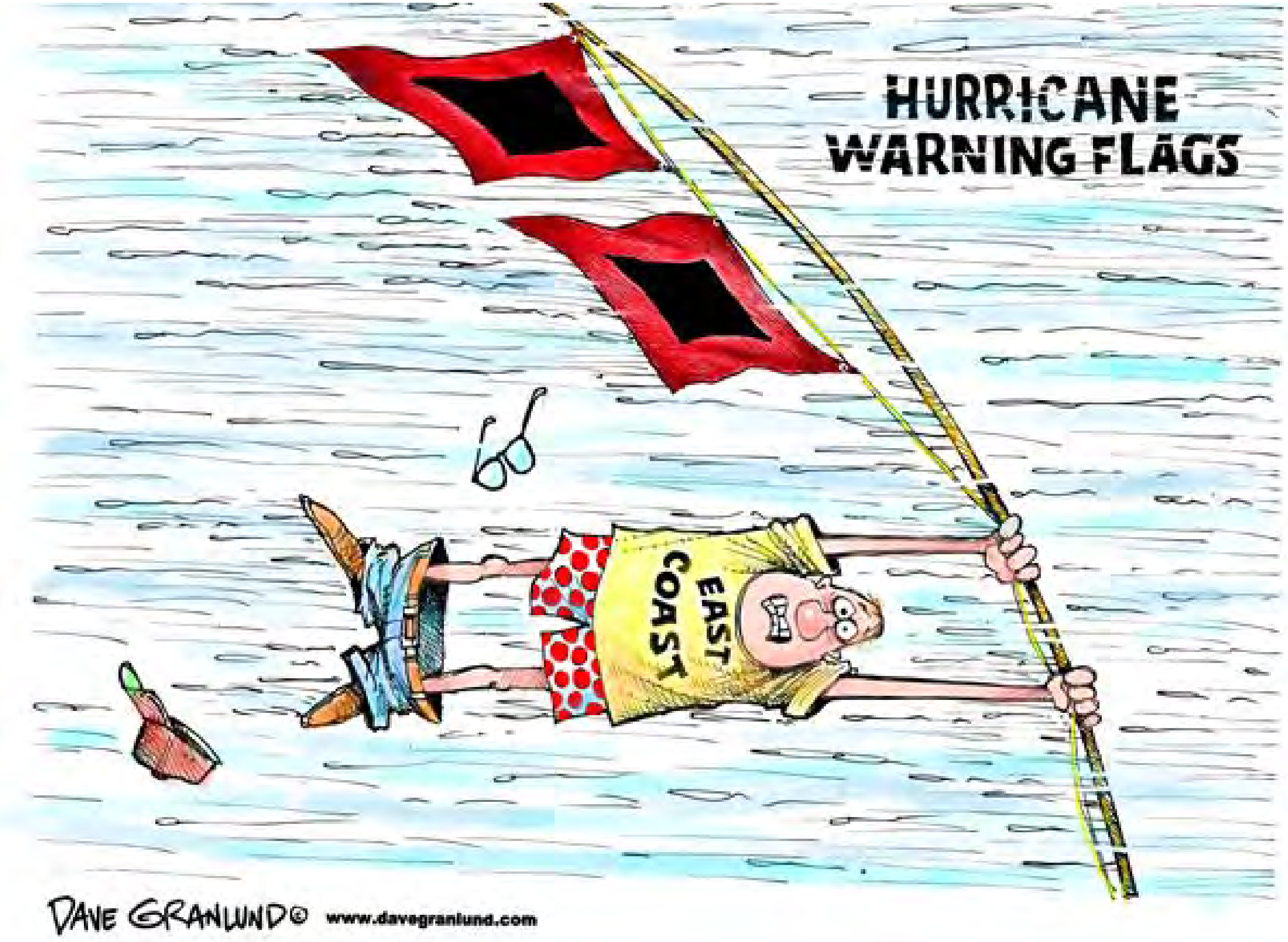
NOAA/NCEI

Precipitation Intensity



USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I*

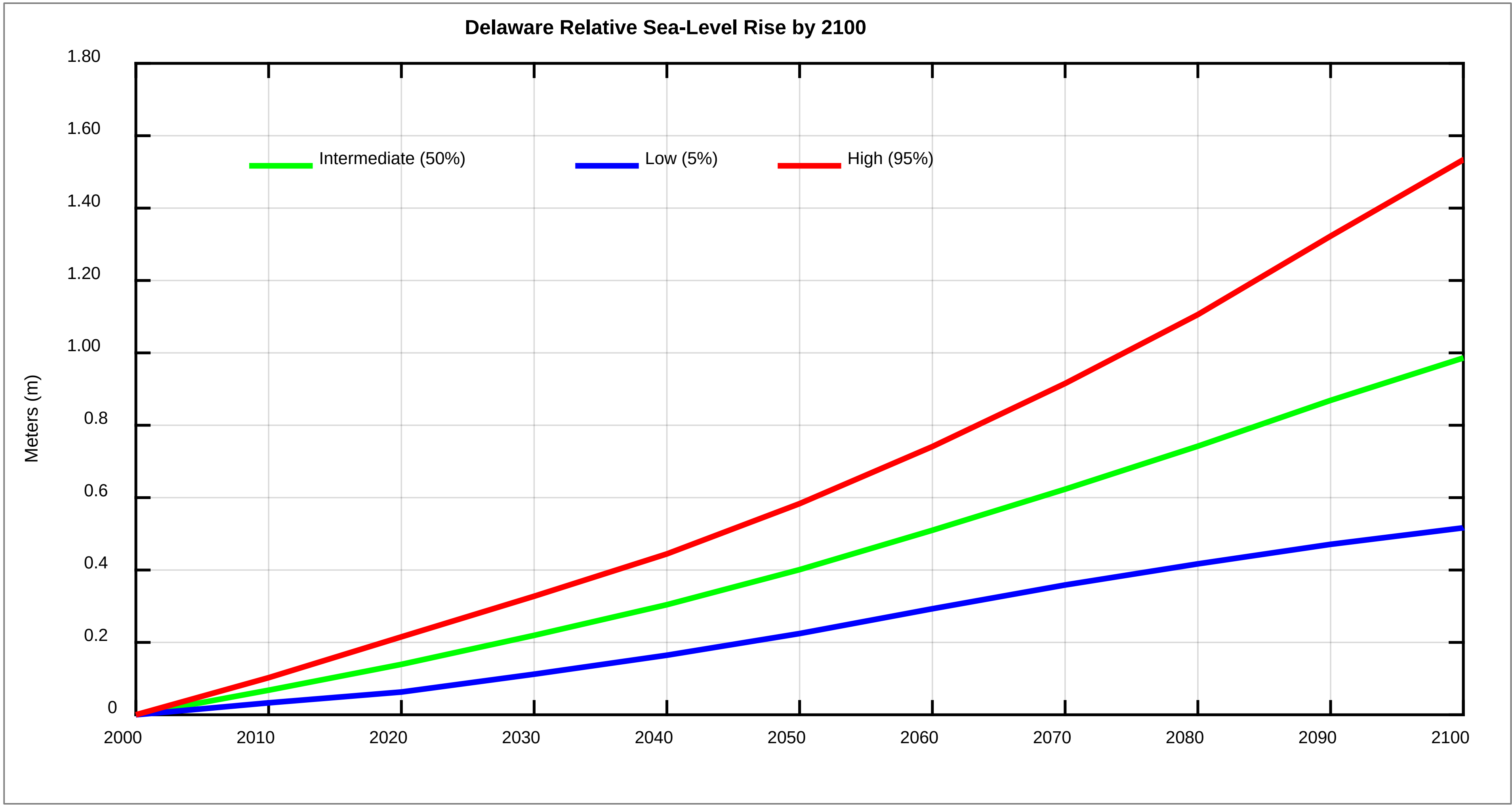
Hurricane Intensity



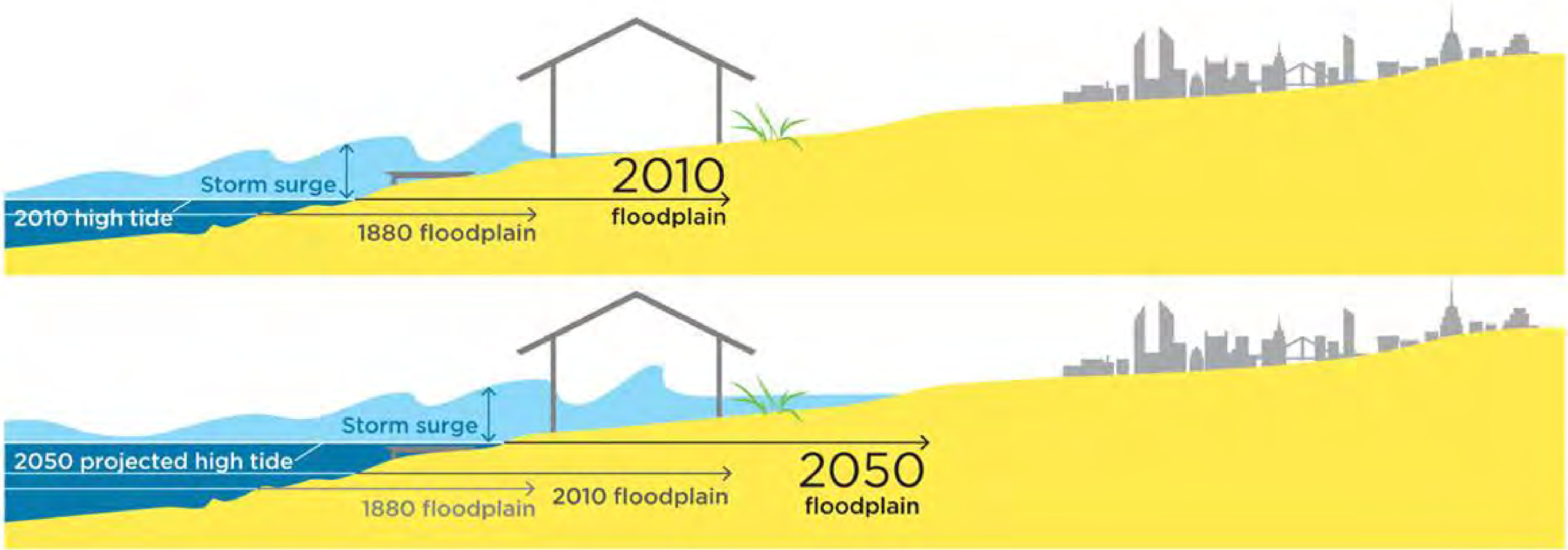
Sea Level Rise

- Appears as an increase in average tide height over time
- 0.5–1.2 feet of global sea level rise projected by 2050
- In Delaware, local sea level rise is twice the global average

Delaware Sea Level Rise Projections

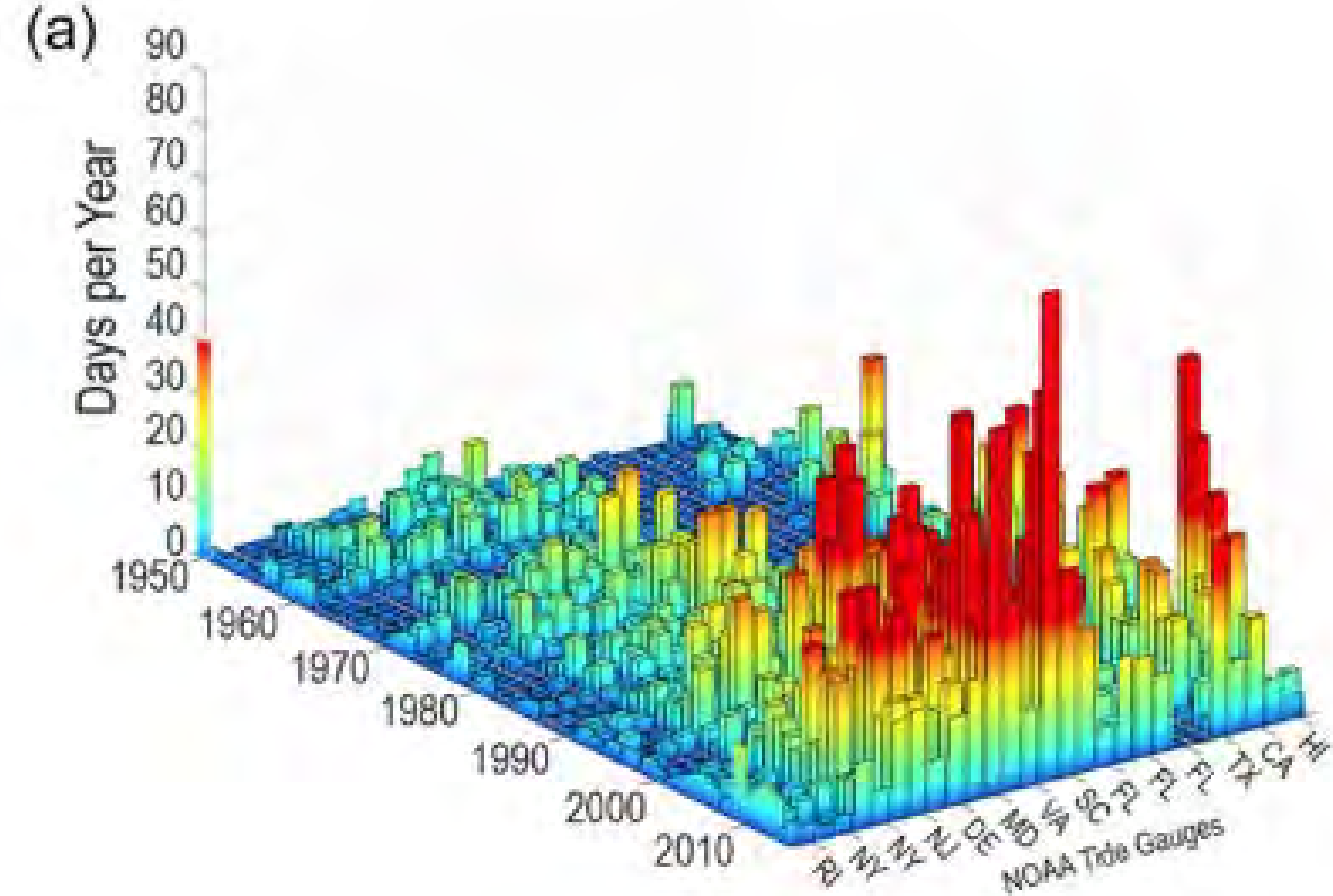


What Does Sea Level Rise Mean for Our Communities?



- The floodplain is changing
- Worsening impacts from storms
- Less viable land to build on
- Damage to infrastructure

Tidal floods



Water Supply

Table 62 - Number of Public Wells Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	1,312	25	75	129	2%	6%	10%
New Castle	264	1	3	7	< 1%	1%	3%
Kent	341	6	15	17	2%	4%	5%
Sussex	707	18	57	105	3%	8%	15%

Source: DNREC, Division of Water. Wells Database, 2010.

Table 61 - Number of Irrigation Wells Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	3,501	25	48	66	1%	1%	2%
New Castle	145	2	3	4	1%	2%	3%
Kent	1,006	11	17	23	1%	2%	2%
Sussex	2,350	12	28	39	1%	1%	2%

Source: DNREC, Division of Water. Wells Database, 2010.

Projections based on 2009 Delaware Sea Level Rise Scenarios

Wastewater Treatment

Table 56 - Number of Public Pumping Stations Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	648	44	111	136	7%	17%	21%
New Castle	156	3	8	10	2%	5%	6%
Kent	176	1	5	9	1%	3%	5%
Sussex	316	40	98	117	13%	31%	37%

Source: New Castle County Special Services, NCC Sewers Geodatabase, 9-01-2010; Kent County Public Works, Kent Sewer Geodatabase, 10-05-2009; Sussex County GIS, Sussex Sewer Pump Stations Points, 6 -12-2009.

Table 58 - Number of Public Treatment/Collection Facilities Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	30	0	2	4	0%	7%	13%
New Castle	9	0	1	2	0%	11%	22%
Kent	6	0	0	0	0%	0%	0%
Sussex	15	0	1	2	0%	7%	13%

Sources: DNREC – financial Assistance Branch (TetraTech), POWWTP, 1-11-2010; New Castle County Special Services, NCC Sewers Geodatabase, 9-01-2010; Kent County Public Works, Kent Sewer Geodatabase, 10-05-2009; Sussex County GIS, Sussex Sewer Pump Stations Points, 6 -12-2009.


"America, we have a problem,"
— Houston
Stiglich
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Part 3

Building Resilience Through Assessment and Planning

Resilience Planning in a Nutshell:

1. Inventory infrastructure and assets
2. Characterize existing and future hazards
3. Identify and prioritize vulnerabilities
4. Outline mitigation and adaptation options
5. Determine implementation steps and resource needs

COLLABORATE & COMMUNICATE

1. Inventory infrastructure and assets

- What infrastructure, assets, and their functions are critical to the continuity of Town operations and/or quality of life?

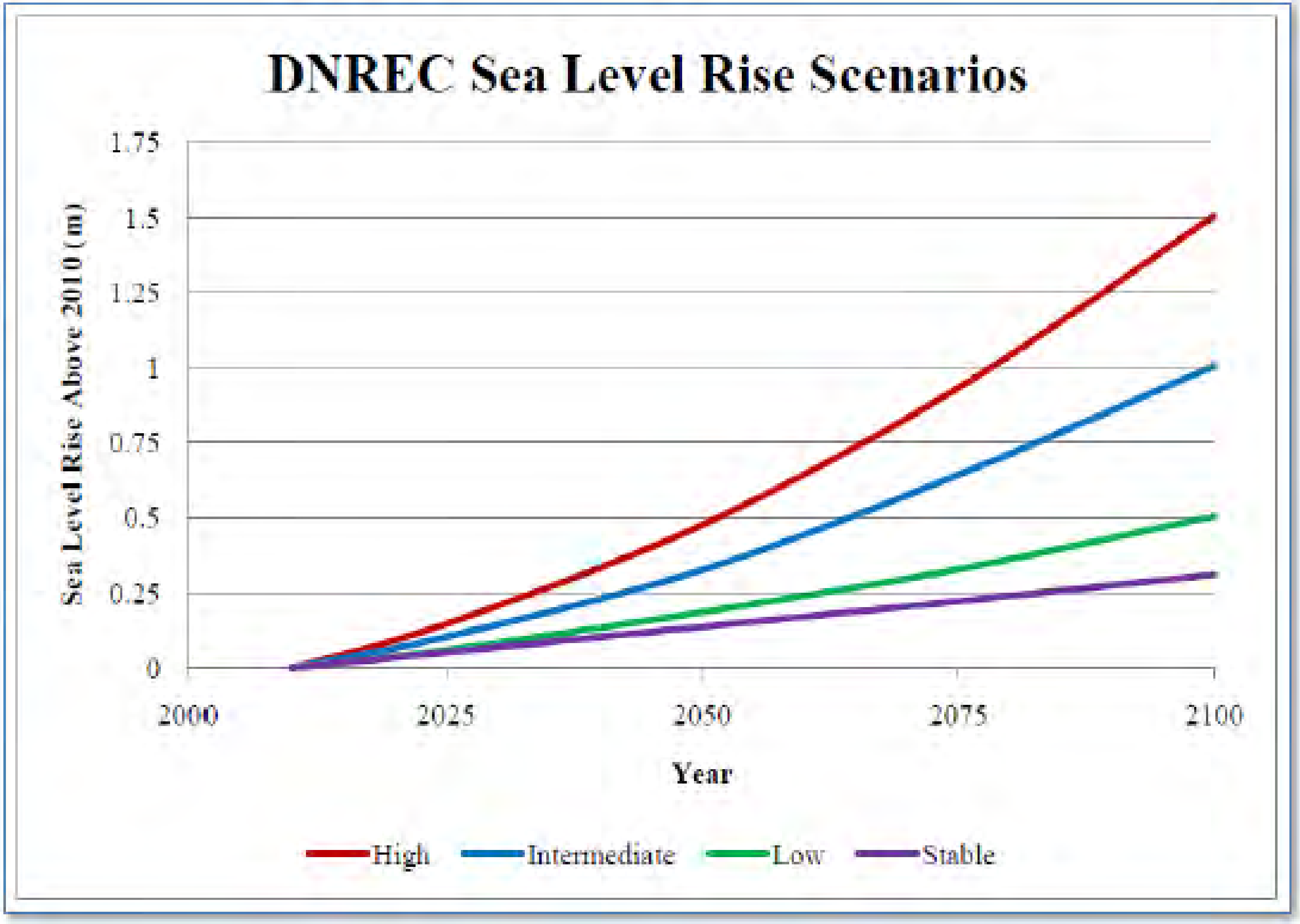
- Identify location and elevation of infrastructure like wells, pump stations, tanks, generators
  - Assess age and current condition
  - Assess dependencies between systems

- Determine desired planning timeframes and performance goals for key infrastructure
  - How far into the future to design to?
  - What is the desired recovery time for functionality?

2. Characterize existing and future hazards

- Past history: FEMA Floodplain maps, tide data, facility's flood history
- Future: Climate projections, inundation mapping tools
- Produce visualizations to communicate risks

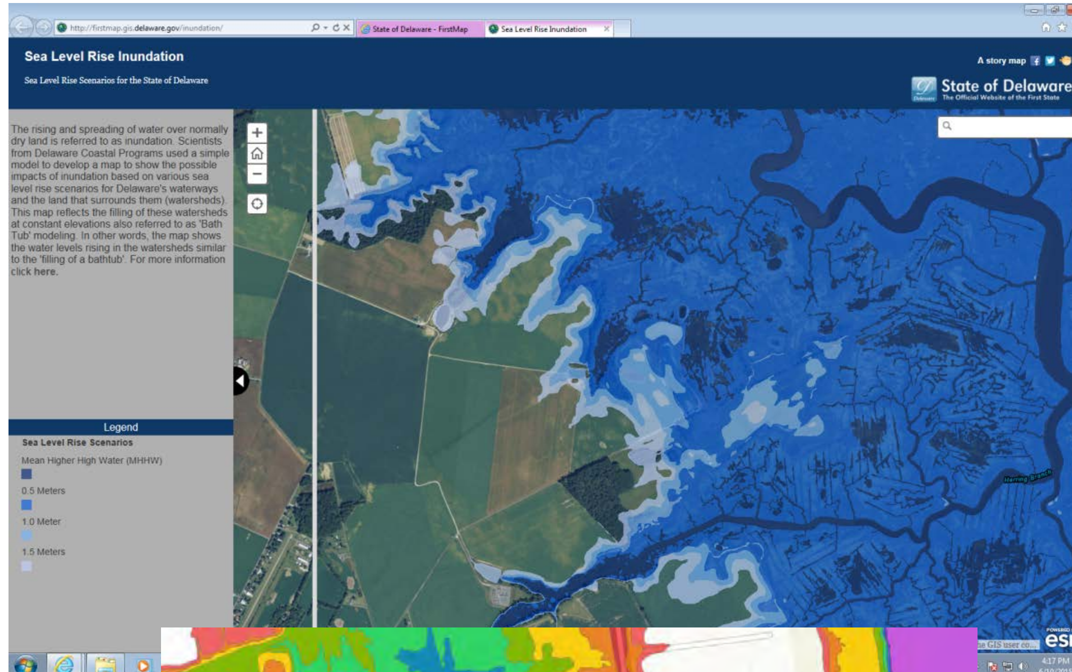
FEMA Map Service Center
https://msc.fema.gov/portal/home

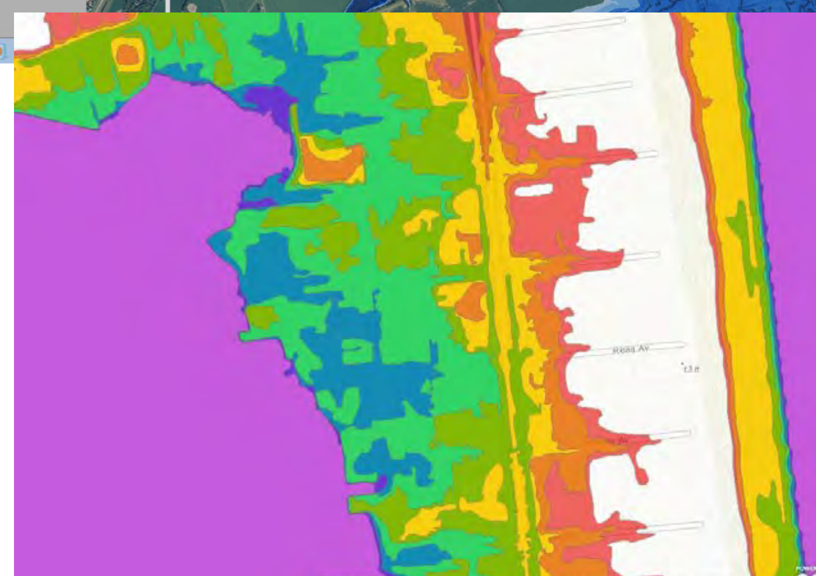


Know your planning timeframe and what level of risk you are willing to plan to

Delaware Sea Level Rise Maps

- Future-looking
- Depicts area that could be inundated at high tide under varying degrees of sea level rise
- Use for planning and assessment





NOAA Sea Level Rise Viewer:
https://coast.noaa.gov/slr/#

3. Identify and Prioritize Vulnerabilities

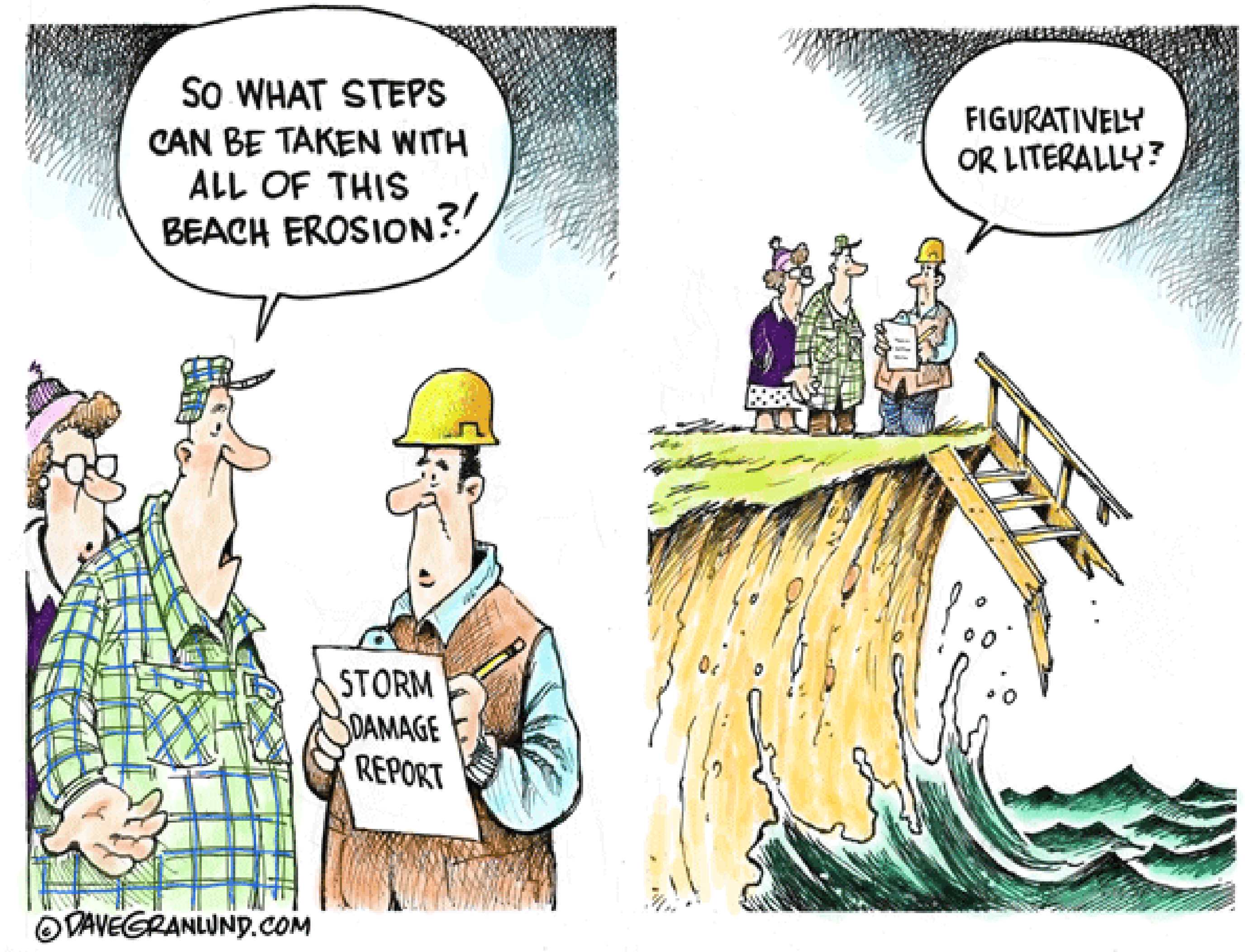
- Document potential impacts
- Select criteria to prioritize the greatest vulnerabilities and needs

Evacuation Route & Critical Infrastructure Vulnerability Study
City of Lewes
Lewes, Delaware
NOAA Grant NA14 NOS 419 0123

<u>Areas of Study/Criteria Matrix</u>

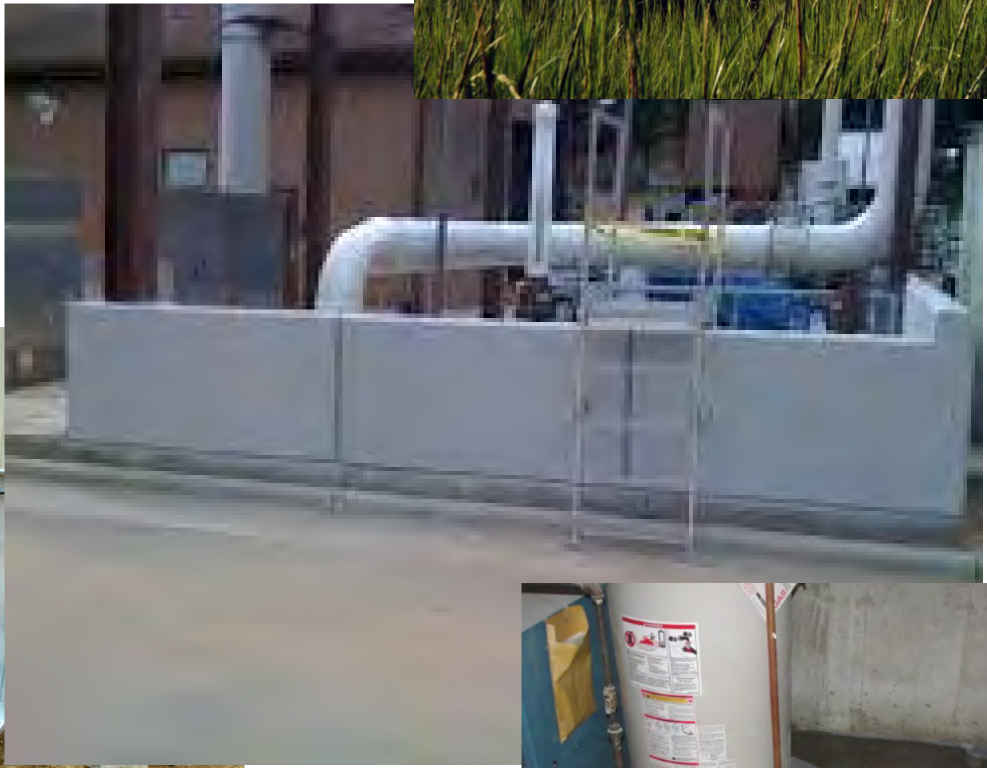
	Areas of Study	Average Rank
1	Savannah Road - Electrical Sub-Station near Wellfield	2.2
2	New Road at Canary Creek Bridge	2.8
3	Savannah Road - North side of Canal Bridge to Massachusetts Avenue	3.6
4	Cape Henlopen Drive at Freeman Highway and Cape Shores Development	4.8
5	Cedar Avenue - West End	5.8
6	Harborview Road - South End	8.6
7	Pilottown Road near Canary Creek Bridge	9
8	Canary Creek Pump Station	9.2
9	American Legion Road	9.2
10	Hoornkill Road - South End	9.6
11	Southside of Reserve at Pilottown & Pilottown Village - Phase 2 Developments	10

4. Outline adaptation and mitigation options



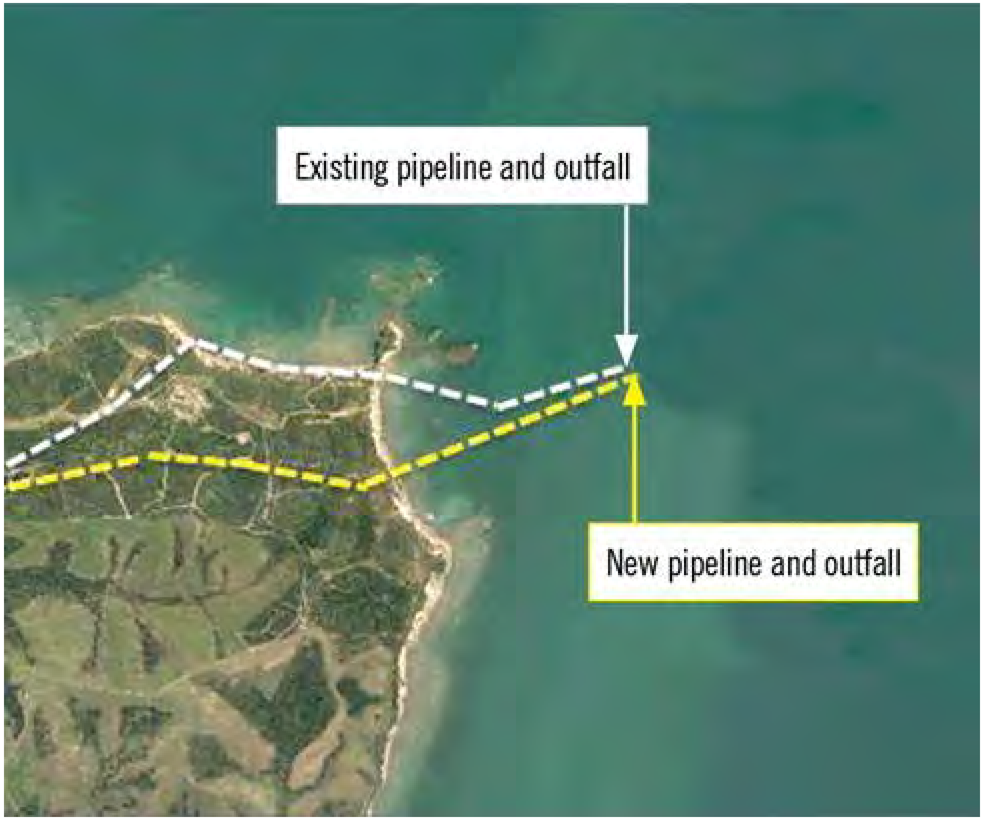
Accommodate

Protect



Avoid

Retreat



Part 4

Resilience Planning Examples

City of Seaford, DE

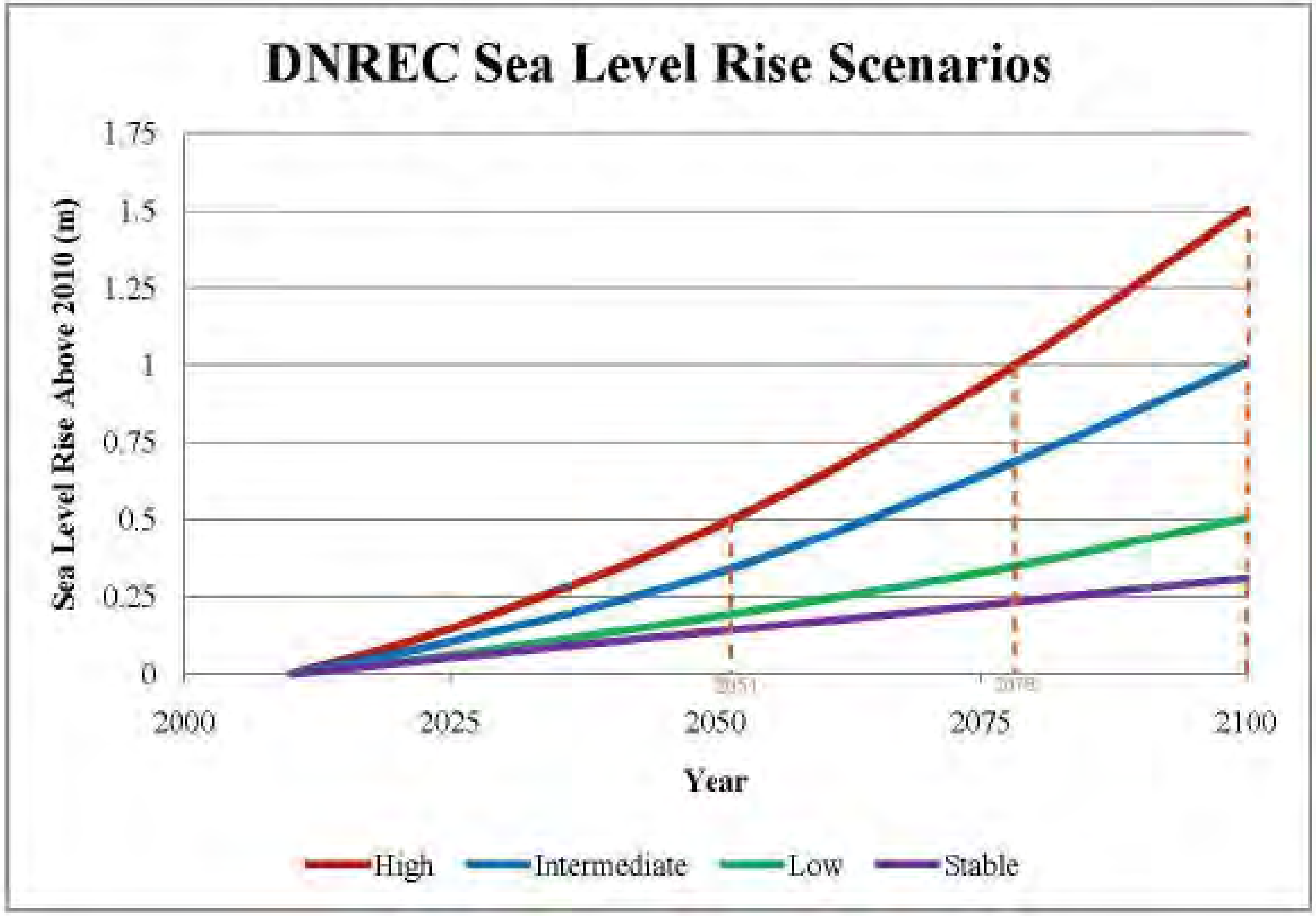
<u>Project: Vulnerability Assessment of Wastewater Treatment Facility (WWTF)</u>

Step 1

- Inventoried all WWTF structures and obtained age, precise elevations

- Determined which WWTF assets could not lose functionality during an event

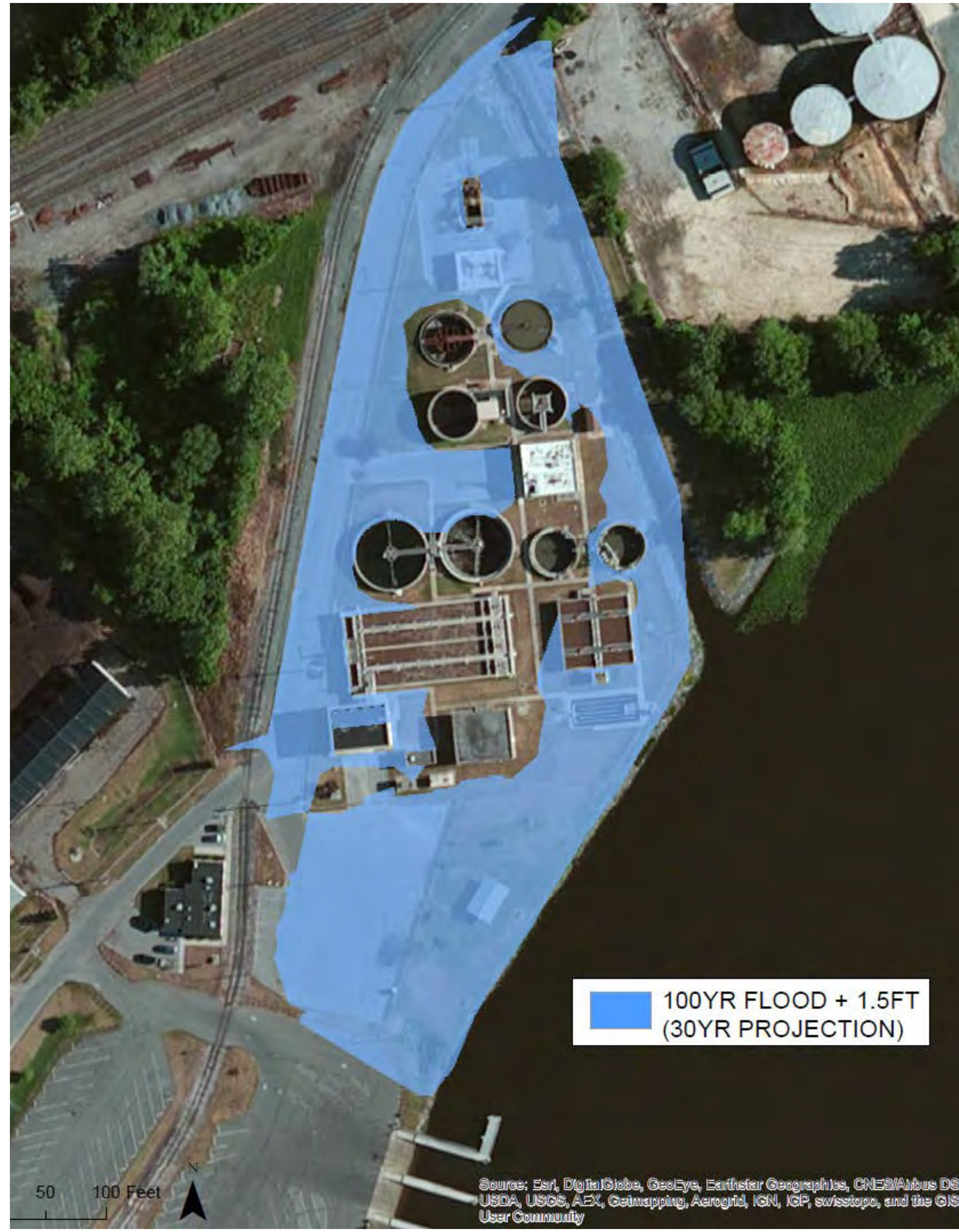
- Agreed upon a planning timeframe of 30 years



Step 2

- Reviewed FEMA Floodplain maps and recorded base flood elevation based on 100 year flood

- Reviewed DE sea level rise projections
- Conducted sea level rise mapping to characterize future risk
- Recorded risk for each asset



Analysis prepared by GMB, LLC

Step 3

Identified and prioritized vulnerabilities based on degree of risk and criticality

Seaford WWTF Vulnerability Study — **Figure 3**

Inventory of Key Assets

	WWTF Asset	Survey Reference	Elevation	Sea Level Rise Inundation (measured in feet)			100-YR Flood Inundation (measured in feet)				Priority Rating
				0.5 m (35 Year)	1.0 m (60 Year)	1.5 m (85 Year)	Flood (2015)	Flood + 1.0' (20 Year)	Flood + 1.5' (30 Year)	Flood + 2.0' (40 Year)	
1	Nanticoke Ave - Plant Access Road	Grade	4 to 9+		0.45	2.09	2.00	3.00	3.50	4.00	3
2	Grit Chamber Bypass Vault	TOW	6.98					0.02	0.52	1.02	2
3	Headworks- Grit Chamber	TOW	8.37								
4	Headworks Bar Screen	TOW	8.37								
5	Primary Pumping Station-Ground Floor	FF	6.62					0.38	0.88	1.38	1
6	Primary Clarifier - East	TOW	12.47								
7	Primary Clarifier - West	TOW	12.47								
8	Flow EQ Tank - No. 3	TOW	17.11								
9	Sludge Building - Ground Floor	FF	9.99								

Rank of 1 to 5, with 1 having greatest importance

TOW = Top of Wall Elevation
FF = Finished Floor Elevation
BFE=Base Flood Elevation-100 Year

Step 4

- Documentation of potential mitigation options

Example

Primary Pumping Station –

- The ground floor is at Elev. 6.62, or 10 ½ inches below the planning level BFE
- Mitigation options include the installation of flood proof doors (3 locations), construction of a surrounding wall, placement of interior curbs to block water entry into the lower levels and/or replacement of the dry-pit pumps with submersible types.

Step 5

- Identify implementation steps

City of New Castle

Comprehensive Vulnerability Assessment

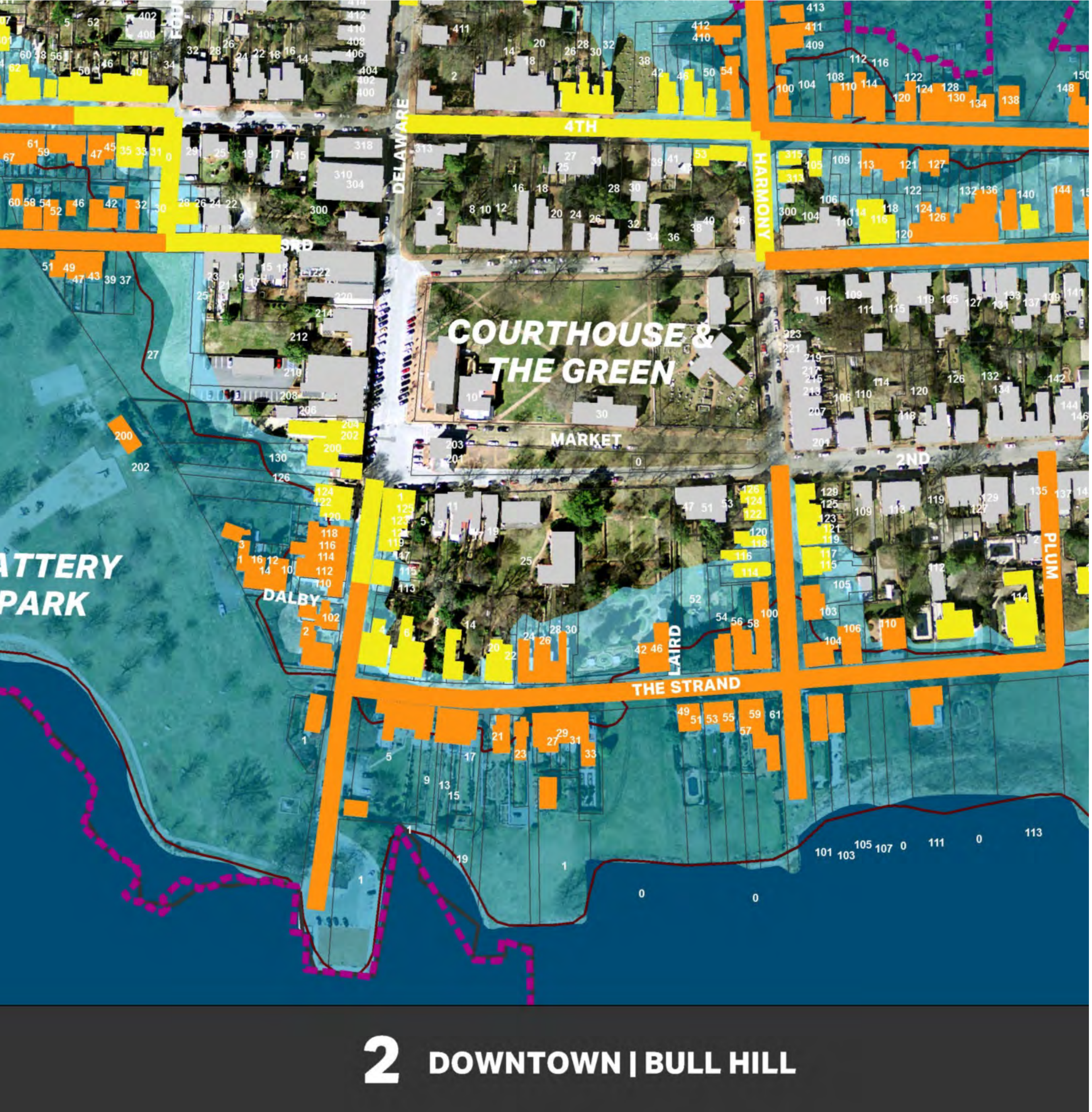
- Approximately 5400 residents
- Designated part of First State National Monument
- Four earthen dikes in/near City are believed to be oldest in the country

City of New Castle Dike System

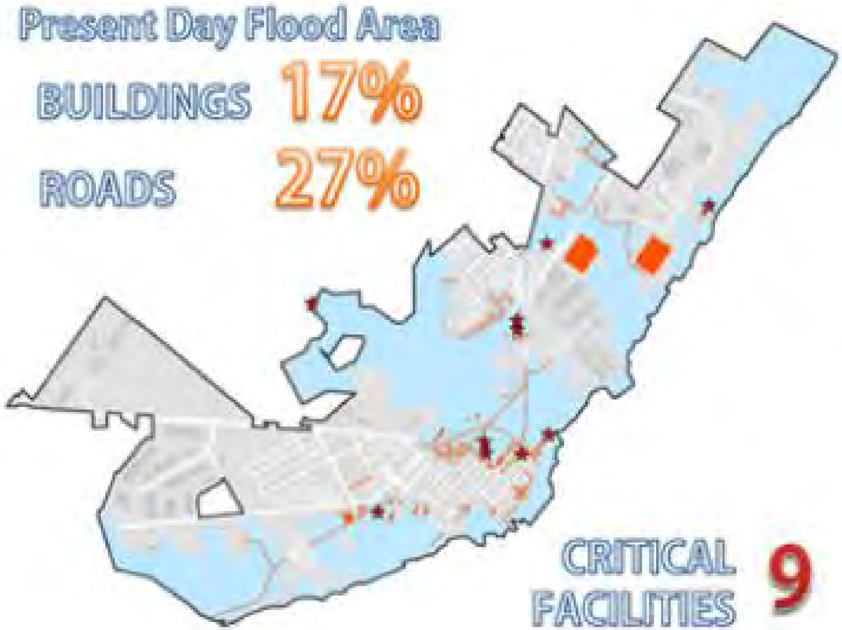

Flood Risks
• Storms, including storm surge
• Extreme high tides
• Heavy precipitation events
• Sea level rise

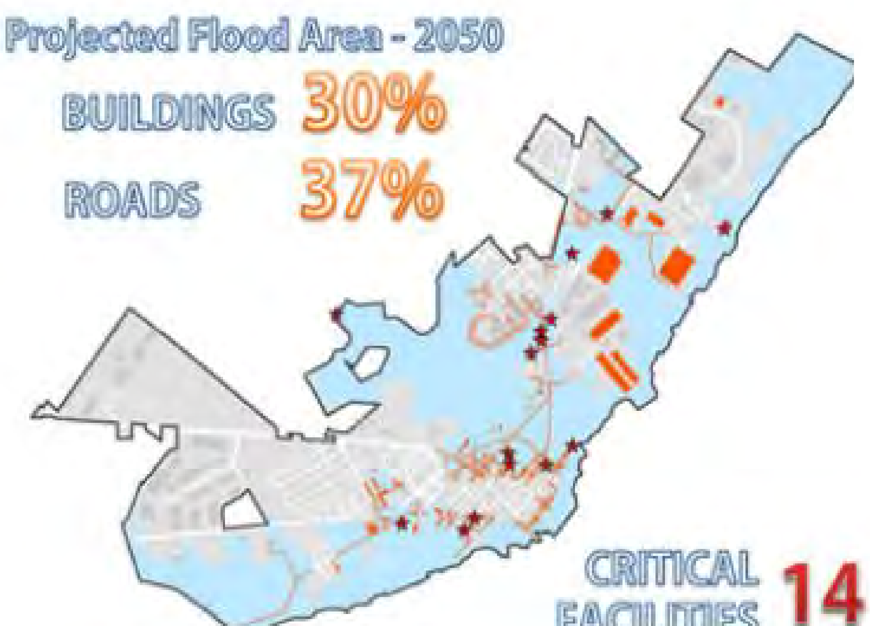
Step 1 - Inventory Critical Assets

Structure ID	Critical Facility Type	Critical Facility Name
99	Schools	New Castle Elementary School
117	Schools	St. Peter Catholic School
183	Schools	Reach Academy for Girls
1698	Historic Register	Glebe House and Cemetery
2220	Library	New Castle Public Library
139	Public Works	MSC Main Office
148	Public Works	MSC Utility Building and Garage
151	Public Works	Public Works Yard
152	Public Safety	Police Department
136	Public Safety	Goodwill Fire Fire Station
134	Community	Senior Center
119	Community	St. Peters Catholic Church
1268	Public Utility	NCC Pump Station
1291	Public Utility	NCC Pump Station
2050	Public Utility	NCC Pump Station
2333	Public Utility	NCC Pump Station
1131	Public Utility	Delmarva Primary Electrical Substation
1669	Public Utility	Wilmington Road Substation Electrical Substation
738	Public Utility	MSC - Gray Street Water Tank Building



Step 2 - Identify existing & future hazards


Present Day Flood Area
BUILDINGS 17%
ROADS 27%
CRITICAL FACILITIES 9


Projected Flood Area - 2050
BUILDINGS 30%
ROADS 37%
CRITICAL FACILITIES 14

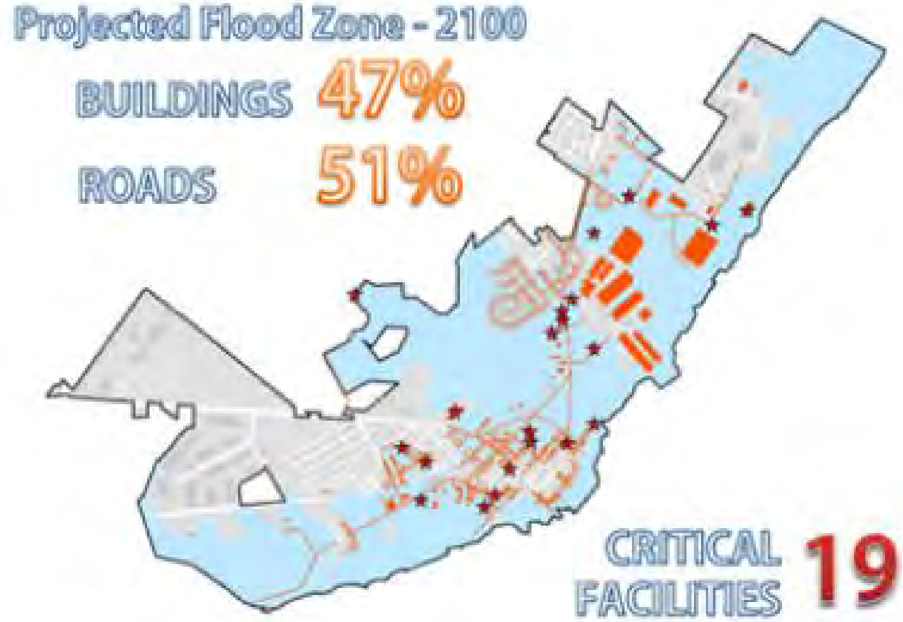

Projected Flood Zone - 2100
BUILDINGS 47%
ROADS 51%
CRITICAL FACILITIES 19

Table 4: Vulnerabilities – Critical facilities

Structure ID	Critical Facility Type	Critical Facility Name	Current 100 Year Flood	2 FT SLR Year 2050	5 FT SLR Year 2100
99	Schools	New Castle Elementary School			1
117	Schools	St. Peter Catholic School	1	1	1
183	Schools	Reach Academy for Girls	1	1	1
1698	Historic Register	Glebe House and Cemetery			1
2220	Library	New Castle Public Library			1
139	Public Works	MSC Main Office	1	1	1
148	Public Works	MSC Utility Building and Garage		1	1
151	Public Works	Public Works Yard	1	1	1
152	Public Safety	Police Department	1	1	1
136	Public Safety	Goodwill Fire Fire Station		1	1
134	Community	Senior Center		1	1
119	Community	St. Peters Catholic Church	1	1	1
1268	Public Utility	NCC Pump Station		1	1
1291	Public Utility	NCC Pump Station			1
2050	Public Utility	NCC Pump Station	1	1	1
2333	Public Utility	NCC Pump Station	1	1	1
1131	Public Utility	Delmarva Primary Electrical Substation	1	1	1
1669	Public Utility	Wilmington Road Substation Electrical Substation		1	1
738	Public Utility	MSC - Gray Street Water Tank Building			1
			9	14	19

Step 3 -Identify & prioritize vulnerabilities

Name	Sensitivity			Adaptive Capacity			Criticalness		Total
	Inundation Depth	Susceptibility to Waves	Subtotal	Material	Can be Floodproofed	Subtotal	Public Safety	Subtotal	
Weight	4	2		3	3		5		
MSC Well House	Low	Low	6	High	N/A	3	Medium	10	19
New Castle Elementary School	Low	Low	6	Medium	N/A	6	Low	5	17
Town Hall	Low	Low	6	Low	N/A	9	High	15	30
Senior Center	Low	Low	6	Medium	Low	15	Low	5	26
Goodwill Fire Station	Low	Low	6	Medium	Low	15	High	15	36
MSC office	Medium	Medium	12	Low	Low	18	High	15	45
MSC Building / Garage	Medium	Low	10	Medium	Low	15	High	15	40
Public Works Yard	Medium	Medium	12	Medium	Low	15	High	15	42
Police Department	Medium	Medium	12	Low	Low	18	High	15	45
MSC Water Tower	Low	Low	6	High	N/A	3	Medium	10	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 5: New Castle Resilient Community Partnership example critical structures vulnerability matrix

Structure_ID	Type	Name	Sensitivity			Adaptive Capacity			Criticalness		Total
			Inundation Depth	Susceptibility to Waves	Subtotal	Material	Can be Floodproofed	Subtotal	Public Safety	Subtotal	
		Weight	4	2		3	3		5		
25	Well House	MSC Well House	Low	Low	6	High	N/A	3	Medium	10	19
99	School	New Castle Elementary School	Low	Low	6	Medium	N/A	6	Low	5	17
129	Town Hall	Town Hall	Low	Low	6	Low	N/A	9	High	15	30
134	Senior Center	Senior Center	Low	Low	6	Medium	Low	15	Low	5	26
136	Fire Station	Goodwill Fire Station	Low	Low	6	Medium	Low	15	High	15	36
139	MSC office	MSC office	Medium	Medium	12	Low	Low	18	High	15	45
148	MSC Building / Garage	MSC Building / Garage	Medium	Low	10	Medium	Low	15	High	15	40
151	Public Works Yard	Public Works Yard	Medium	Medium	12	Medium	Low	15	High	15	42
152	Police Department	Police Department	Medium	Medium	12	Low	Low	18	High	15	45
738	Water Tower	MSC Water Tower	Low	Low	6	High	N/A	3	Medium	10	19
1131	Electric Substation	Delmarva Electrical Substation	Low	Medium	8	Low	Low	18	Medium	10	36
1132	Electric Substation	Delmarva Electrical Substation	Low	Medium	8	Low	Low	18	Medium	10	36
1268	Pump Station	NCC Pump Station	Medium	Low	10	High	Low	12	Medium	10	32
1291	Pump Station	NCC Pump Station	Low	Low	6	High	N/A	3	Medium	10	19
1668	Electric Substation	MSC Electric Substation	High	Medium	16	High	Low	12	Medium	10	38
1669	Electric Substation	MSC Electric Substation	Low	Low	6	High	Low	12	Medium	10	28
1671	Electric Substation	MSC Electric Substation	Low	Low	6	High	Low	12	Medium	10	28
1673	Water Tower	MSC Water Tower	Low	Low	6	High	N/A	3	Medium	10	19
1683	School	Carrie Downie School	Low	Low	6	Medium	N/A	6	Low	5	17
2050	Pump Station	NCC Pump Station	High	Medium	16	High	Low	12	Medium	10	38
2253	Historic Register	Old Courthouse	Low	Low	6	Medium	N/A	6	Low	5	17
2254	Historic Register	Old Courthouse	Low	Low	6	Medium	N/A	6	Low	5	17
2278	City Hall	City Hall	Low	Low	6	Low	N/A	9	High	15	30
2333	Pump Station	NCC Pump Station	Low	Medium	8	High	Low	12	Medium	10	30
2335	Well House	MSC Well House	Low	Medium	8	High	Low	12	Medium	10	30

Public Workshops Used to Inform and Seek Input


EXIT

Step 4 - Identify Adaptation and Mitigation Options

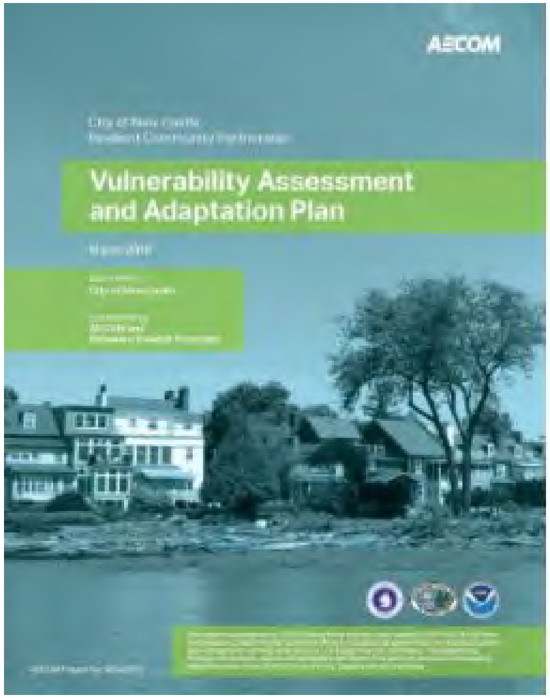
Step 5 - Recommended Implementation Steps

- Elevate dikes near Battery and Strand

- Implement wetland restoration program

- Perform additional surveys of tops and inverts of drainage systems

- Perform dynamic modeling of drainage system to identify capacity issues



Part 5

Resources

- **USGCRP**, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume 1*: https://science2017.globalchange.gov/
- **US Climate Resilience Toolkit: https://toolkit.climate.gov/**
  - **Climate Explorer: https://toolkit.climate.gov/tool/climate-explorer-0**
  - **NOAA Sea Level Rise Viewer: https://coast.noaa.gov/slr/#**
  - **NOAA State Climate Summaries: https://statesummaries.ncics.org/**
- **NIST** Community Resilience Planning Guide for Buildings and Infrastructure Systems: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1190v1.pdf
- **EPA** Flood Resilience: A Basic Guide for Water and Wastewater Utilities: https://www.epa.gov/sites/production/files/2015-08/documents/flood_resilience_guide.pdf
- **Delaware Sea Grant** Natural Hazard and Climate Change Adaptation Toolkit: https://www.deseagrant.org/coastal-hazards

"Floods are an act of God, but flood losses are largely an act of man."

-Gilbert F. White

Thank you

Danielle Swallow
Coastal Hazards
Specialist
DE Sea Grant

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