

# Geospatial Risk Assessment for Community Water and Wastewater Infrastructure

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**Phan and Dieu**

# Two Cities with Recurrent Coastal Flooding

**Morehead City**



**Charleston**



Low-lying coasts  
Estuarine  
Storm surges  
Ports  
Extreme rainfall  
Subsidence  
Socio-economic  
diversity



*Morehead City Waterfront Looking West, Morehead City, N. C.*



# NC Seafood Festival 2015

Don't have to go to sea to the fish...the fish come to you...





Front Street, Beaufort, NC

# Connecting Flooding and Community Health

## Health Impacts

- Physical injuries (including drowning)
- Allergies (mold)
- Food and water-borne illnesses
- Food security
- Displacement
- Vectorborne disease
- Mental health issues
- Interruption of emergency services

## Impacts on Water Quality

- Disruption of and damage to water supply/sewage systems
- Overflow of toxic waste sites
- Waterborne pathogens
- Contamination of recreational areas

# Impact of Flooding on Water Quality

- Disruption of underground piping and damage to water supply systems
  - Sewage disposal system damage leading to drinking/clean water contamination
  - Insufficient supplies of drinking and cleaning water
- Overflow of toxic waste sites, release of chemicals
- Waterborne infections (E. coli, Shigella, hepatitis A, leptospirosis, giardiasis, campylobacteriosis)
- Standing water leading to expanded range of vector habitats and vector borne diseases
- Contamination of recreational areas, such as fishing zones, shellfishing zones and areas for swimming

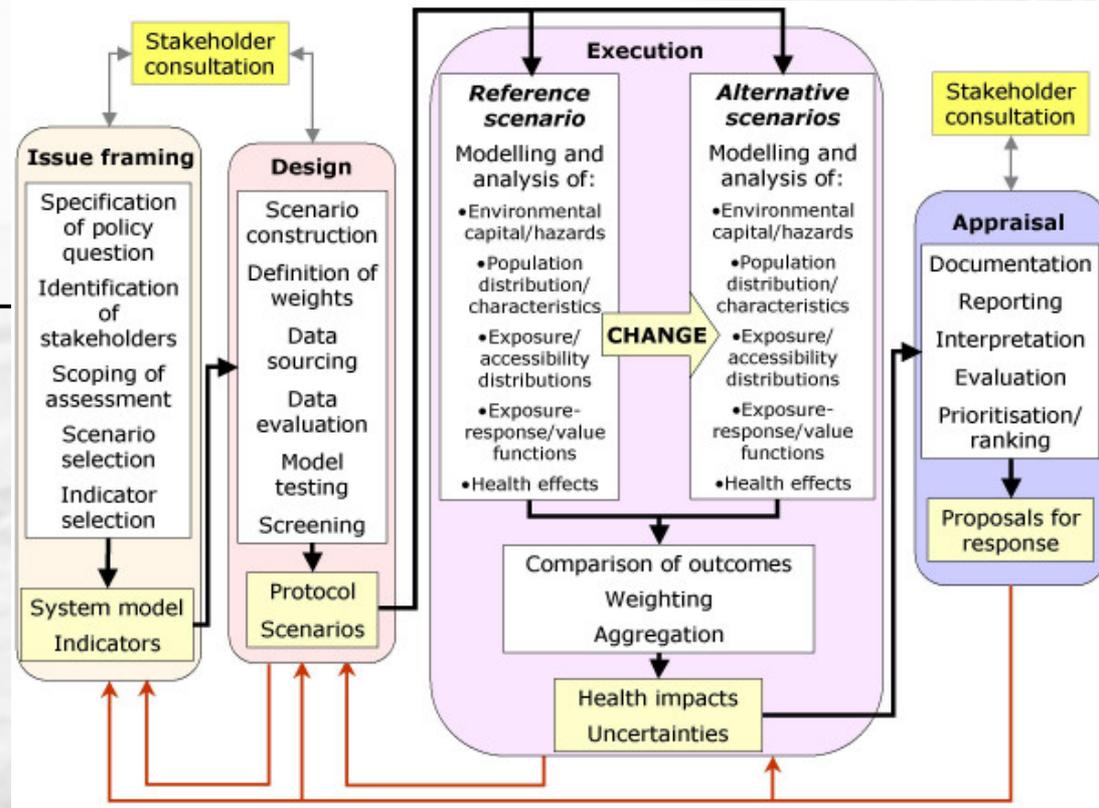
# Vulnerable Populations: Health Interventions Using Targeted, Explicit Susceptibility Indices

- Less educated
- Older (65 years and over with/without a disability)
- Economically disadvantaged: Households at 200% poverty level or on food stamps
- Renter-occupied homes or homeless
- Racial and ethnic minorities
- Uninsured
- Mental illness
- Activity-based susceptibility



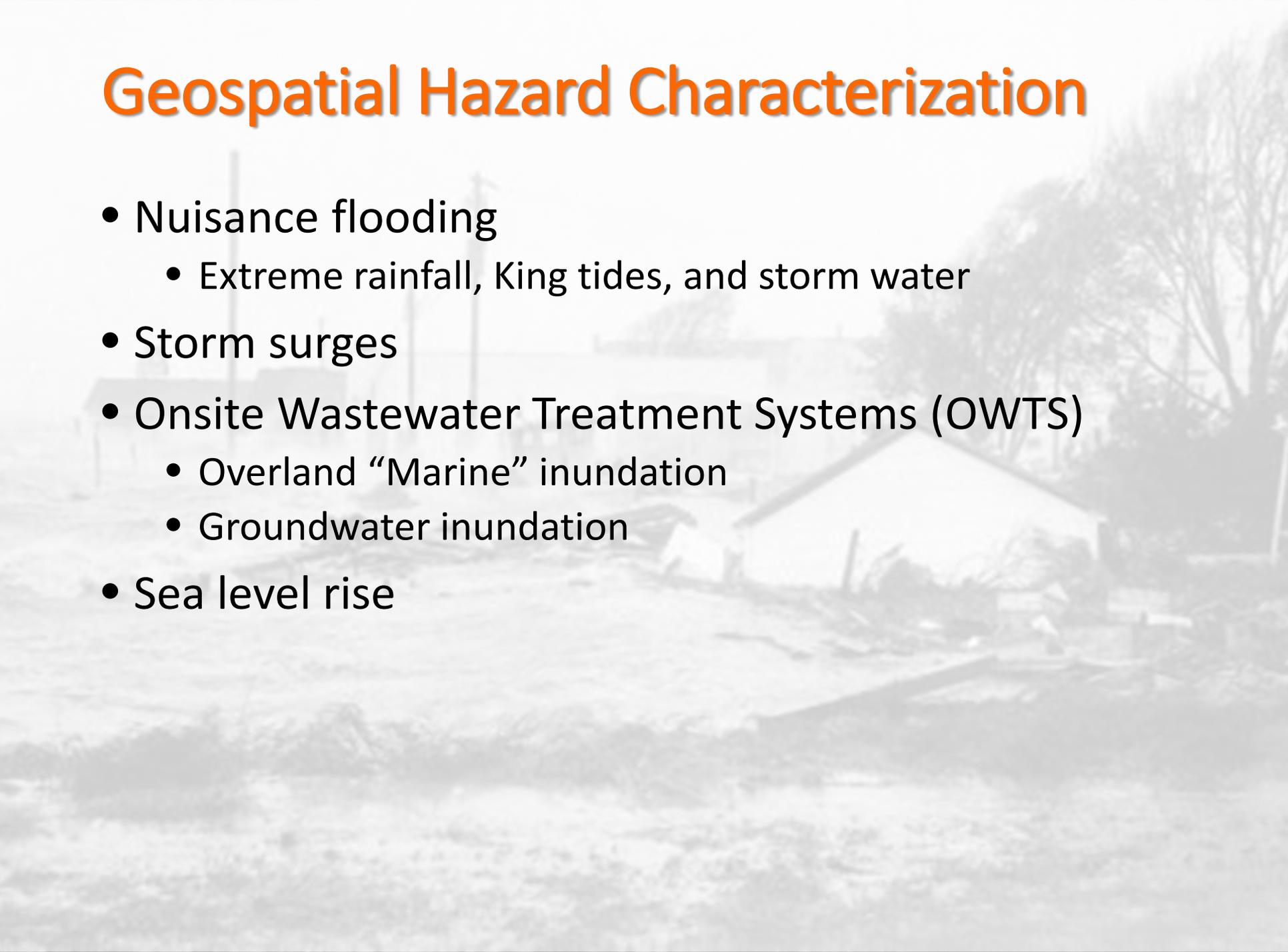
- Shaped by stakeholders
- Including
  - Vulnerable populations
  - Vulnerable activities
  - Vulnerable infrastructure
- Activity and Exposure
  - Boating, kayaking, paddleboarding
  - Fishing
  - Tourism facilities
  - Medical facilities
  - Transportation
  - Basic hygiene
- Utility
  - Public health
  - Emergency management
  - Planning
  - Public utilities

# Susceptibility



Briggs, 2008 Integrated Environmental Health Impact Assessment

# Geospatial Hazard Characterization



- Nuisance flooding
  - Extreme rainfall, King tides, and storm water
- Storm surges
- Onsite Wastewater Treatment Systems (OWTS)
  - Overland “Marine” inundation
  - Groundwater inundation
- Sea level rise

# Focus on Coastal Water Infrastructure

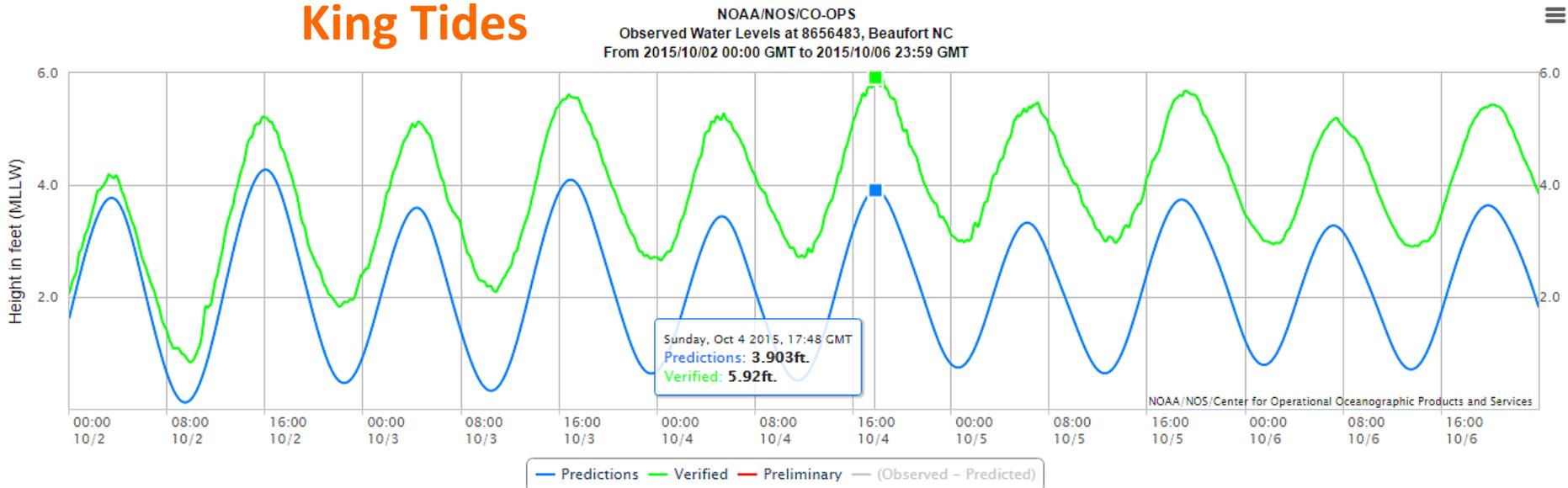
- Water supply
  - Wells, salinization, pumping and aquifer depression
- Wastewater
  - Sewage overflows, onsite wastewater treatment systems
- Storm water
  - Contaminated runoff, nuisance flooding
- Green infrastructure
  - Ecosystem goods and services affecting health or flooding impacts

# Nuisance Flooding

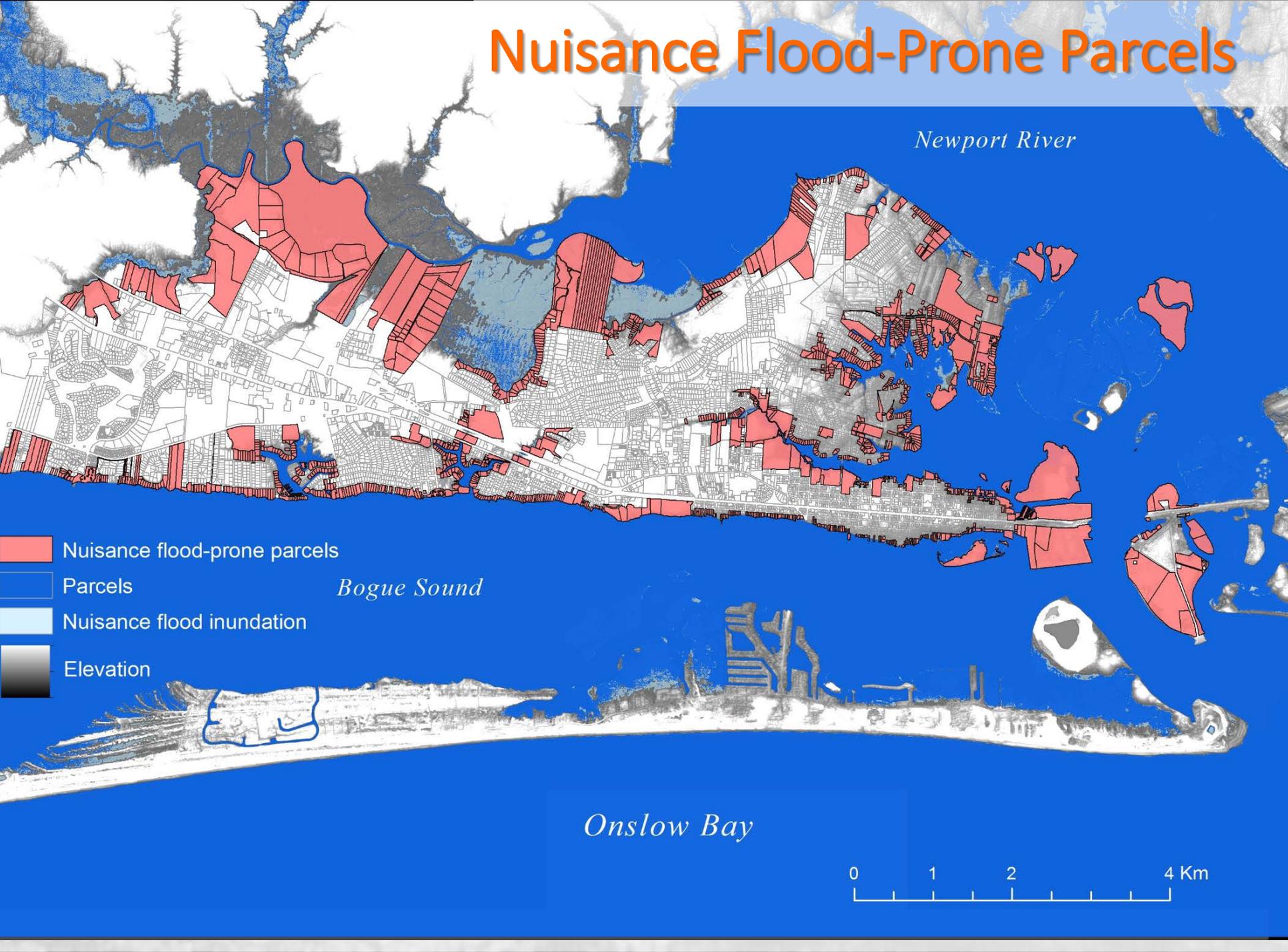


“There has been a significant increase of nuisance flooding occurrences...largely in response to high regional RSLR rates (~3-5mm/yr) from vertical land subsidence....” (Sweet *et al.* 2014) and multi-decadal cycles of the North Atlantic and anomalies in the Gulf Stream (Ezer 2014)

## King Tides



# Nuisance Flood-Prone Parcels



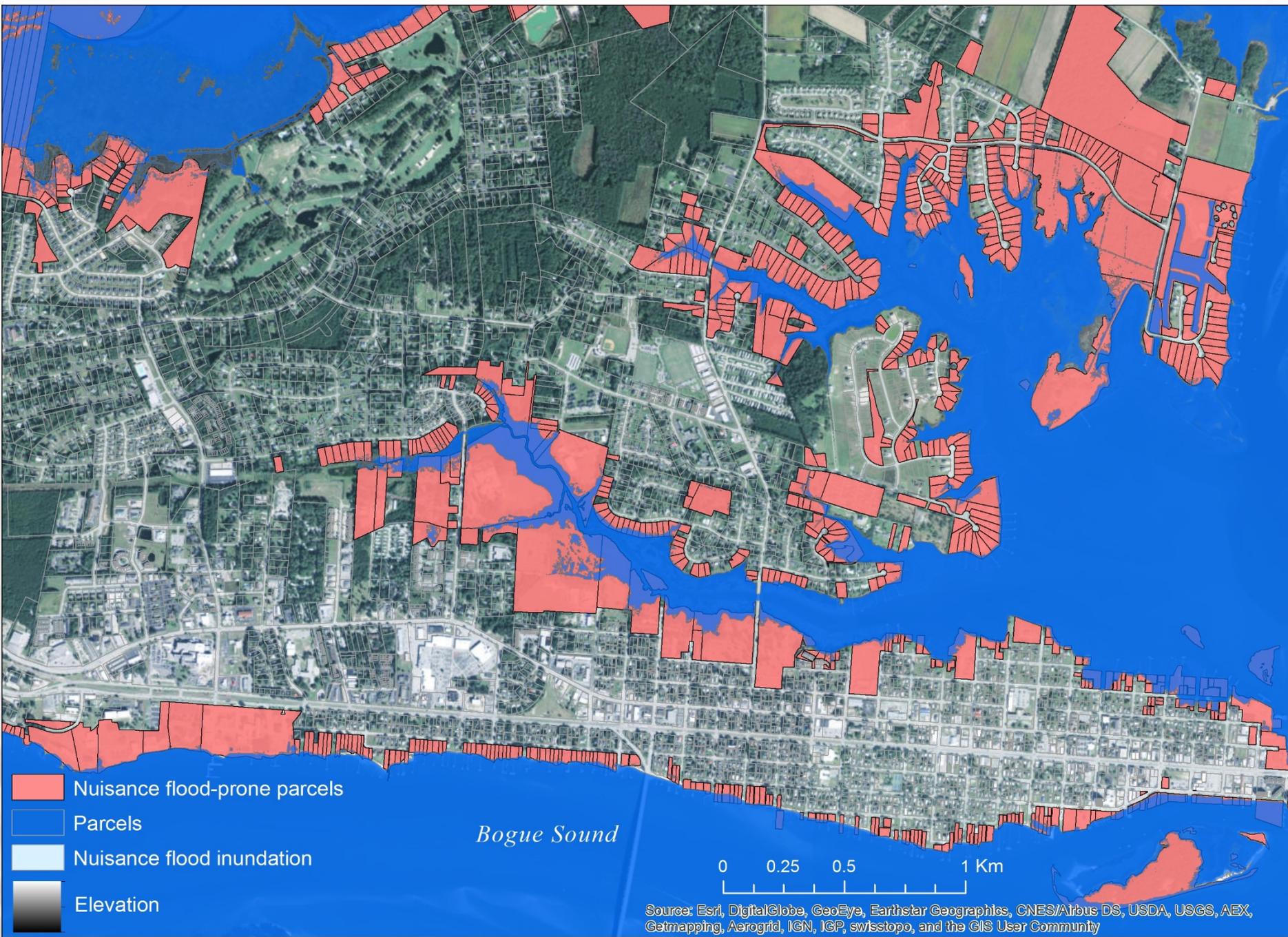
*Newport River*

*Bogue Sound*

*Onslow Bay*

- Nuisance flood-prone parcels
- Parcels
- Nuisance flood inundation
- Elevation





# Nuisance Flooding

- 0.29m above MHHW
- Directly affects ~1,600 parcels of ~10,00 parcels within city limits and ETJ
- \$812M total parcel value

Parcel Type	Parcel Count	% of Parcels	% of Area
Residential	5416	54.7	30.3
Condo	1088	11.0	0.4
Commercial	647	6.5	9.4
Townhouse	299	3.0	0.2
Mobile Home	155	1.6	2.6
Church	71	0.7	0.9
Apartment	26	0.3	0.4
School	27	0.3	1.3
Other	2169	21.9	54.5

## Morehead City Parcels

- 6,141 parcels and 14.7 sq km
- 62% of total parcels and 36% of total area\*

Parcel Type	Parcel Count	% of Parcels	% of Area
Residential	2870	46.7	22.7
Condo	911	14.8	0.8
Commercial	558	9.1	17.9
Townhouse	237	3.9	0.2
Mobile Home	20	0.3	1.6
Church	53	0.9	1.3
Apartment	26	0.4	1.1
School	27	0.4	3.5
Other	1439	23.5	50.9

\* Percents of combined total MHC and ETJ parcel counts and area.

## Extra-Territorial Jurisdiction (ETJ) Parcels

- 3,757 parcels and 26.4 sq km
- 38% of total parcels and 64% of total area\*

Parcel Type	Parcel Count	% of Parcels	% of Area
Residential	2546	67.8	34.5
Condo	210	5.6	0.2
Commercial	89	2.4	4.6
Townhouse	62	1.6	0.1
Mobile Home	136	3.6	3.2
Church	18	0.5	0.6
Apartment	0	0.0	0.0
School	0	0.0	0.0
Other	696	18.5	56.8

\* Percents of combined total MHC and ETJ parcel counts and area.

# Sewer Pipes and Nuisance Flooding

4,020ft

Newport River

Bogue Sound

-  Potential submergence
-  Pipes
-  Sewer service area
-  Nuisance baseline
-  Nuisance 20cm SLR
-  Nuisance 40cm SLR
-  Nuisance 60cm SLR



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

# Sewer Pipes and Nuisance Flooding

+20cm SLR  
5,960ft

Newport River

Bogue Sound

-  Potential submergence
-  Pipes
-  Sewer service area
-  Nuisance baseline
-  Nuisance 20cm SLR
-  Nuisance 40cm SLR
-  Nuisance 60cm SLR



# Sewer Pipes and Nuisance Flooding

+40cm SLR  
9,250ft

*Newport River*

*Bogue Sound*

-  Potential submergence
-  Pipes
-  Sewer service area
-  Nuisance baseline
-  Nuisance 20cm SLR
-  Nuisance 40cm SLR
-  Nuisance 60cm SLR



# Sewer Pipes and Nuisance Flooding

+60cm SLR  
12,950ft

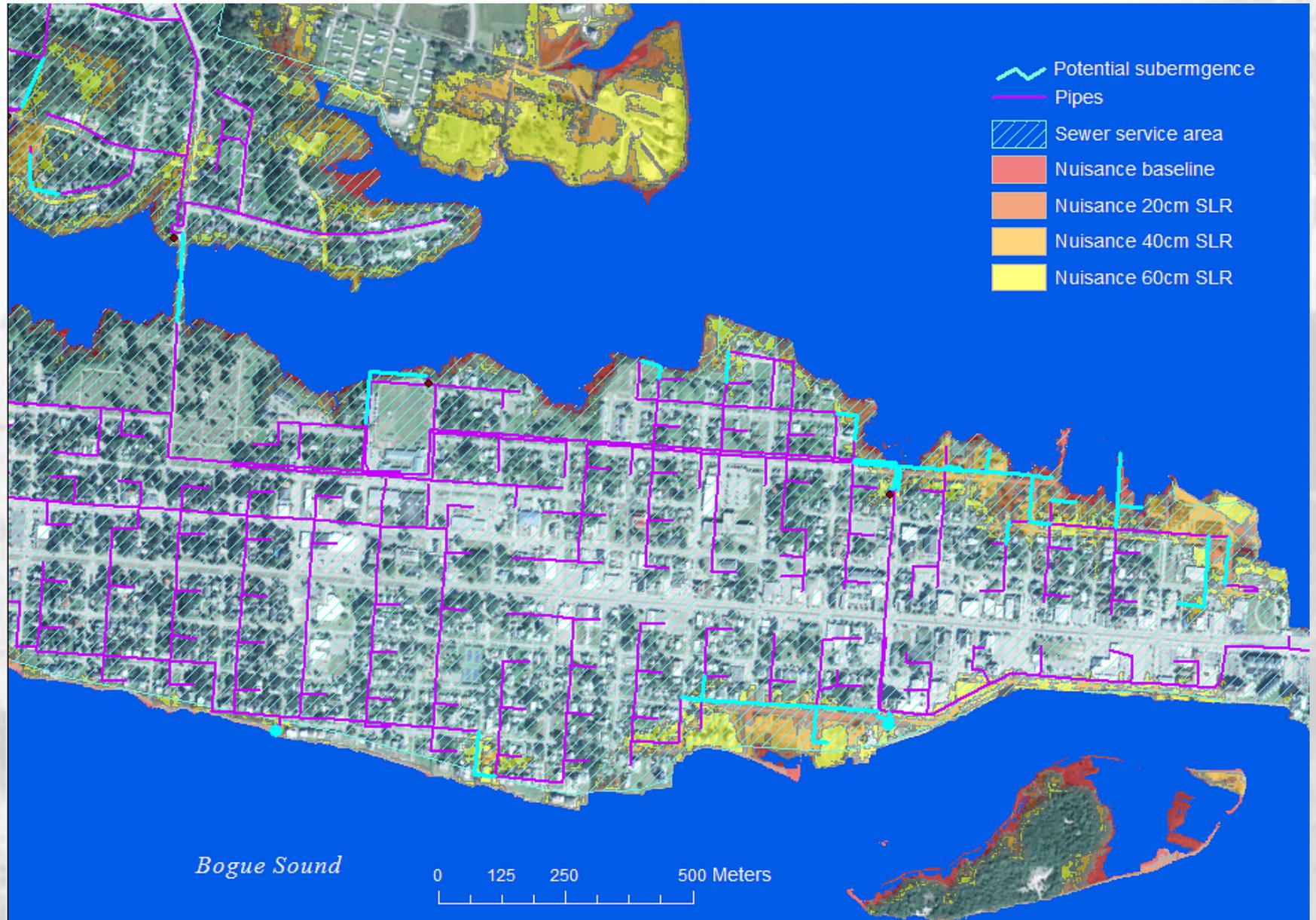
*Newport River*

*Bogue Sound*

-  Potential submergence
-  Pipes
-  Sewer service area
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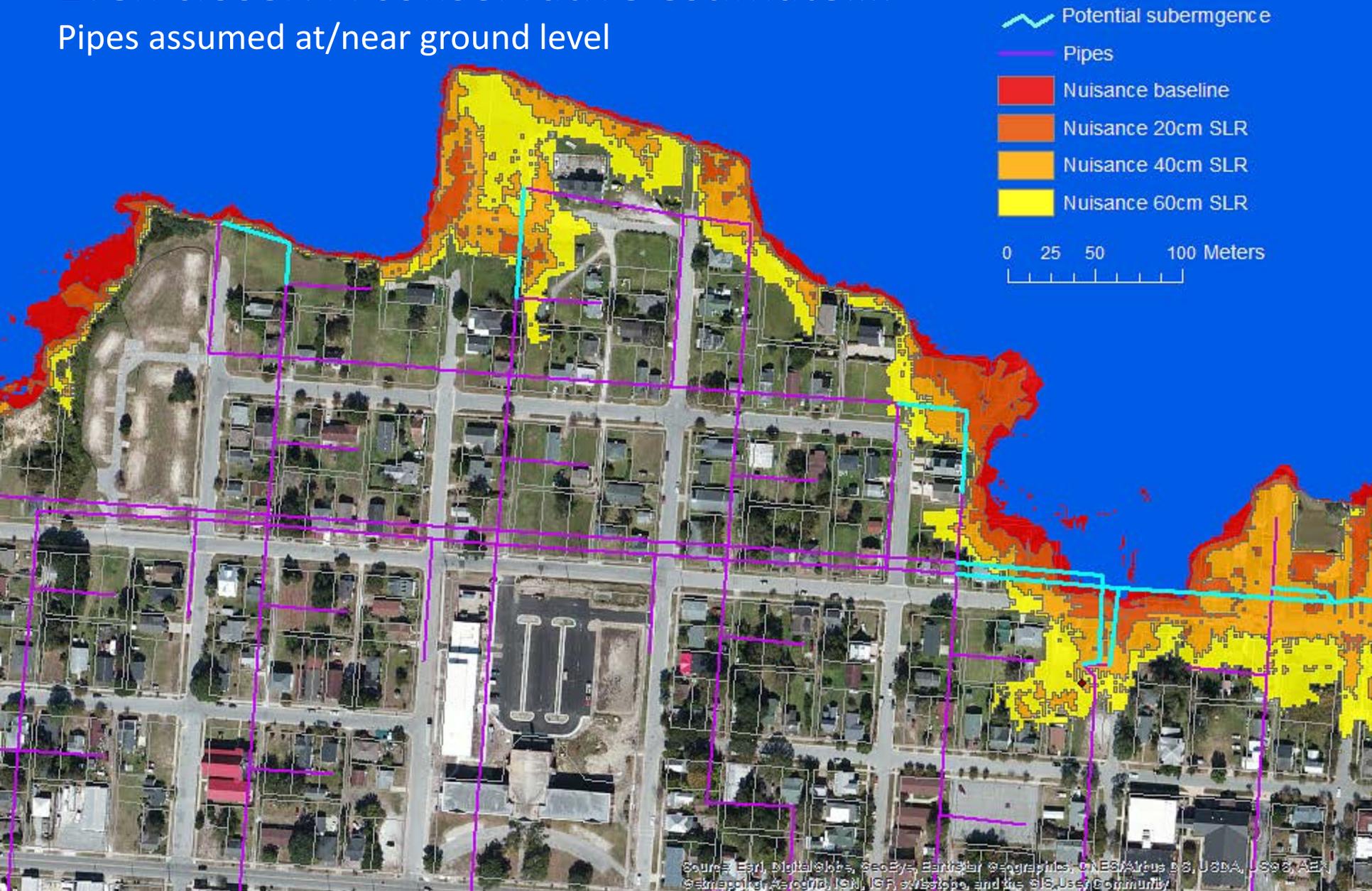


# Zoom view- 20cm and 2 pump stations

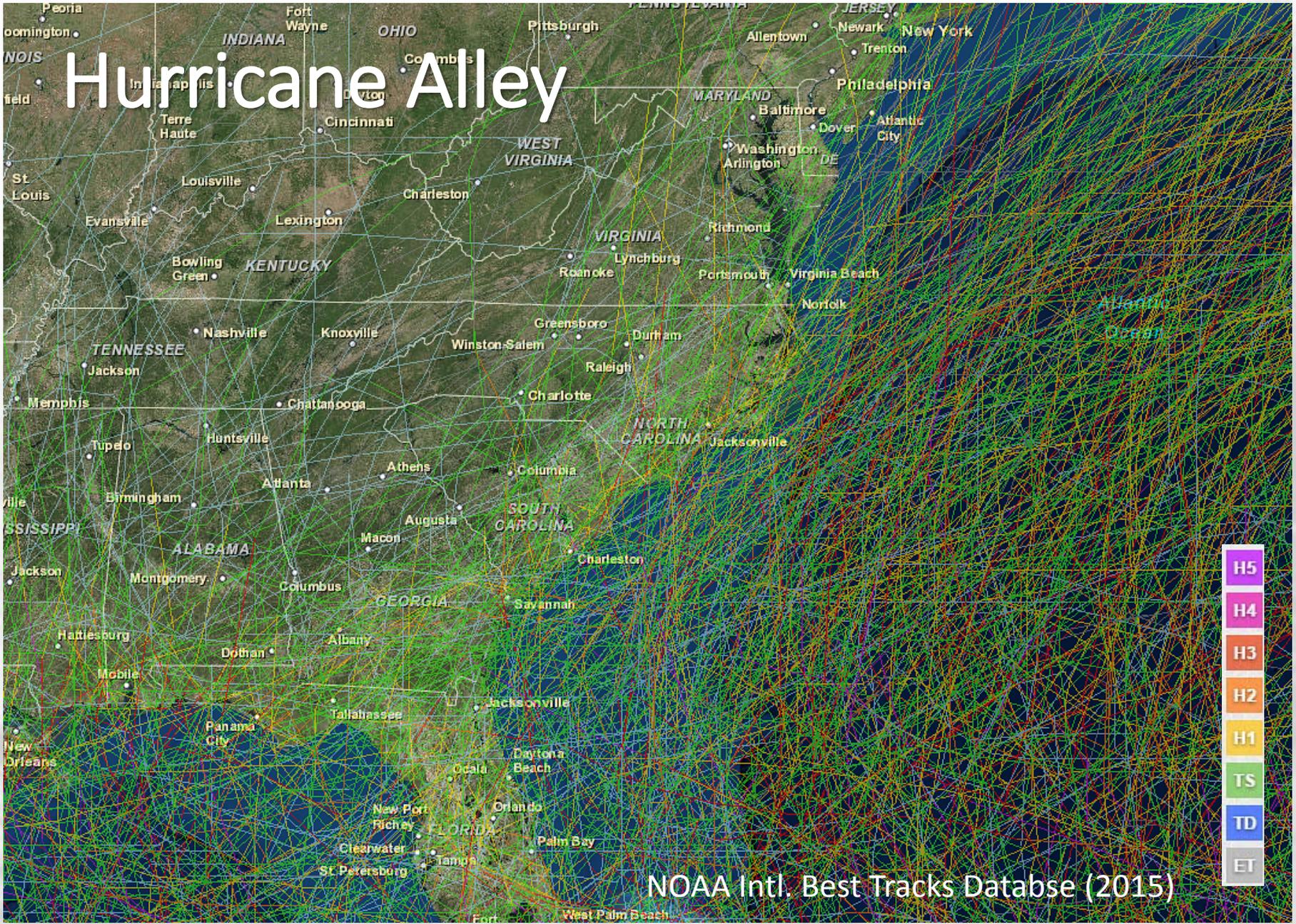


# Even closer: A conservative estimate....

Pipes assumed at/near ground level

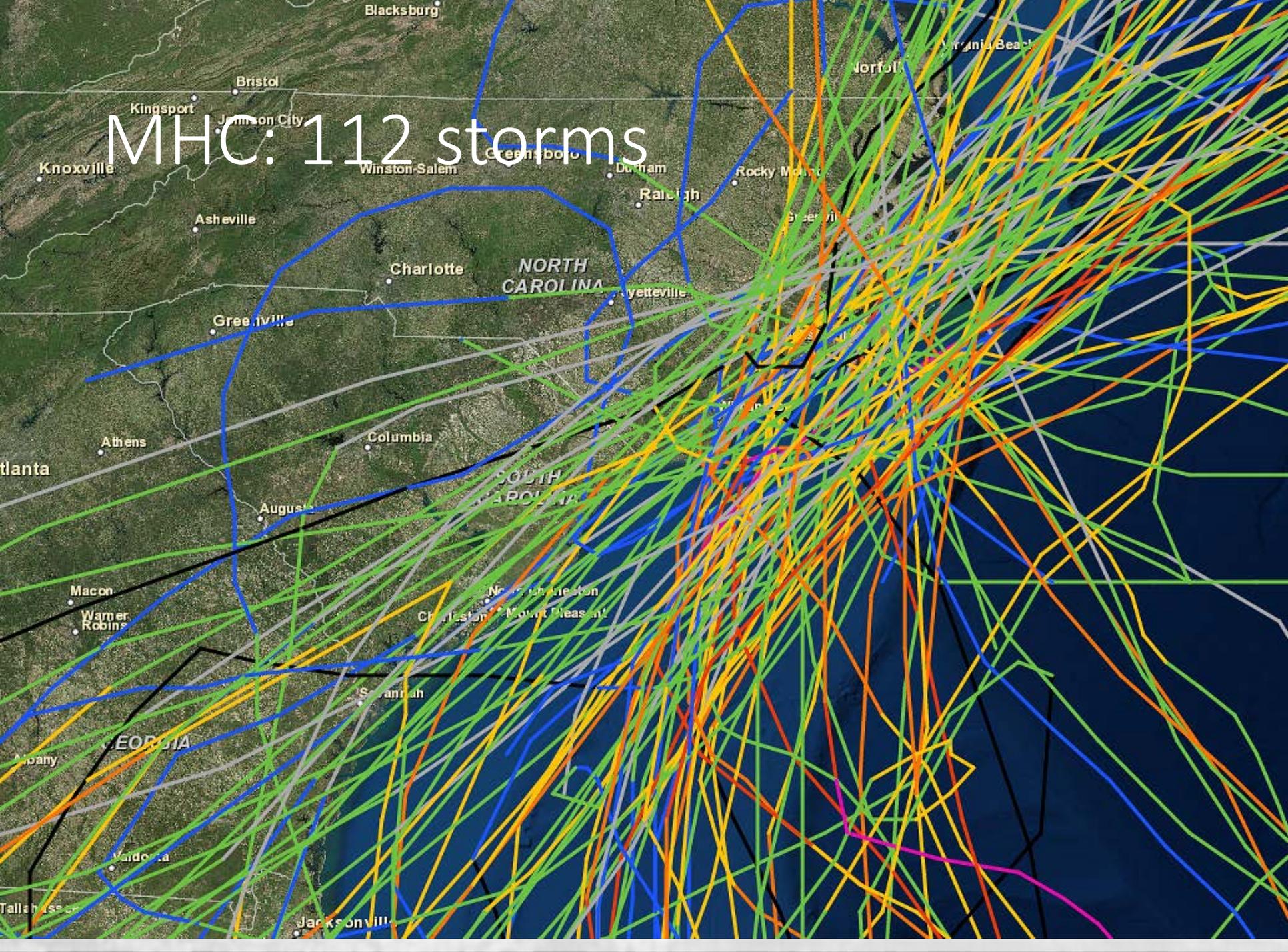


# Hurricane Alley

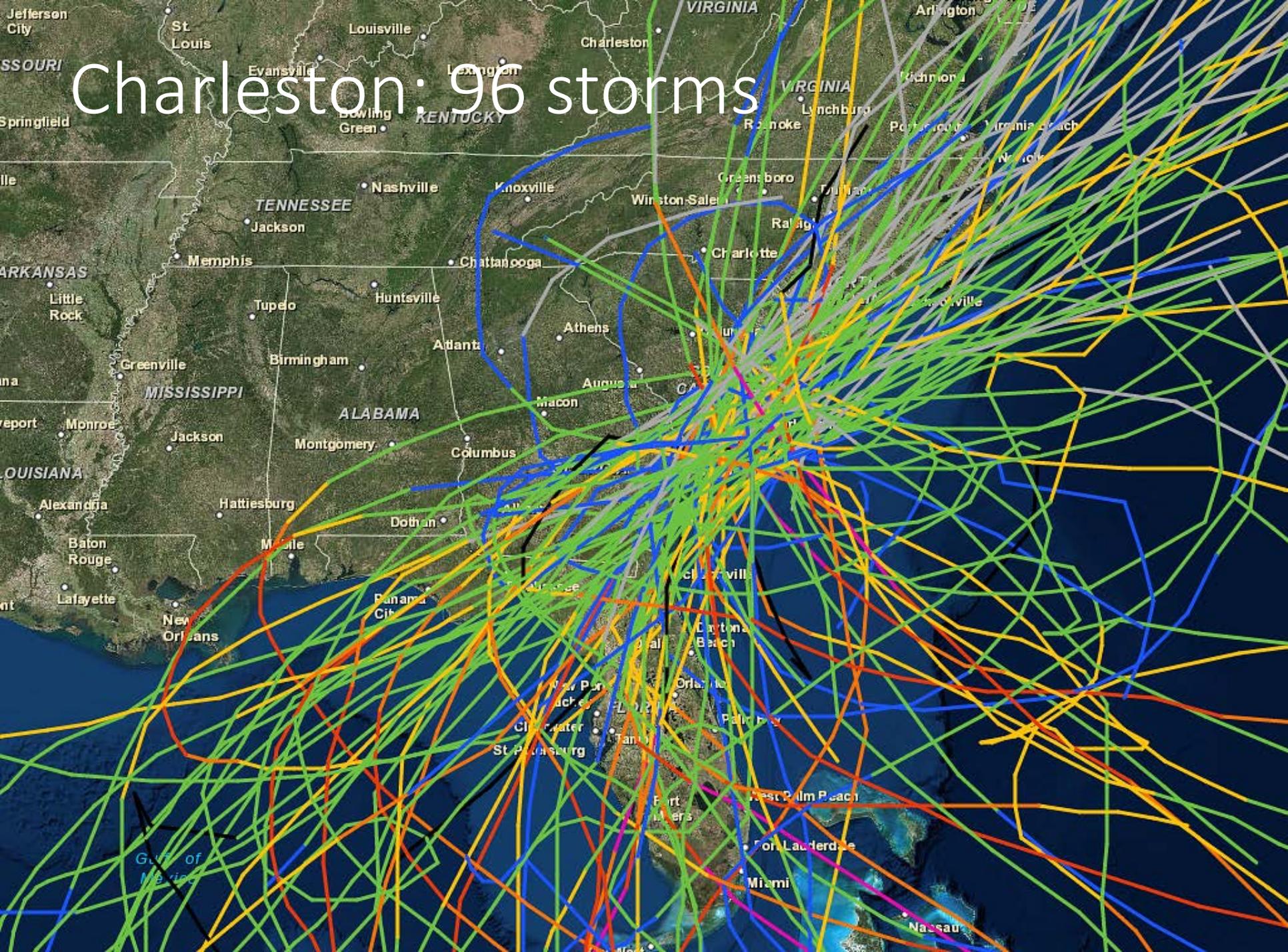


NOAA Intl. Best Tracks Database (2015)

# MHC: 112 storms

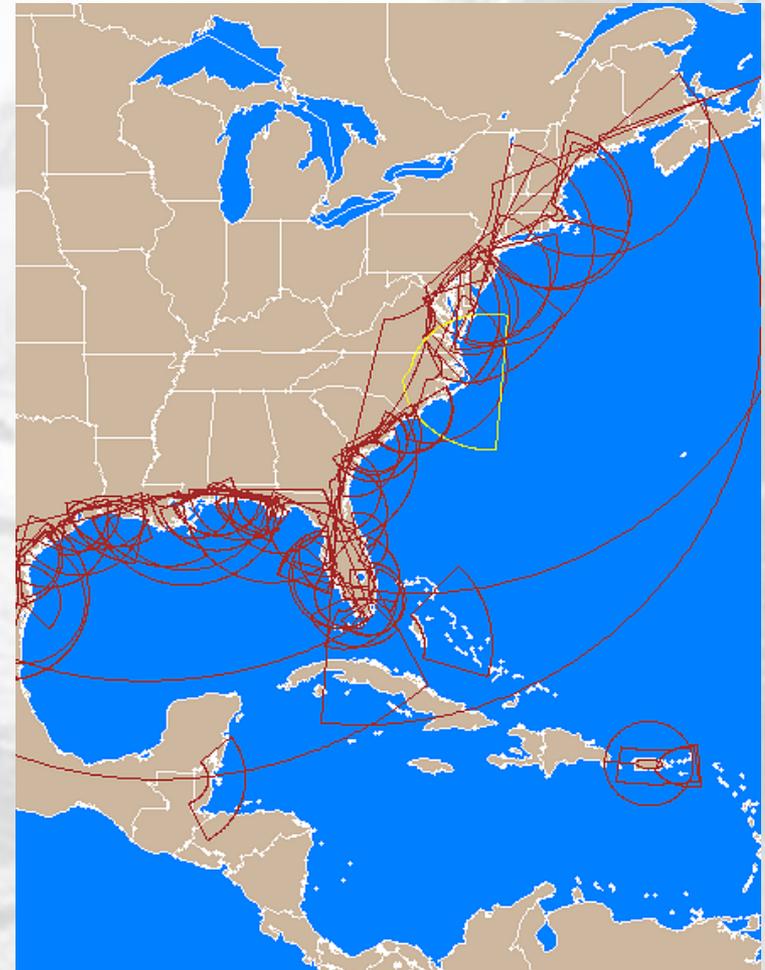
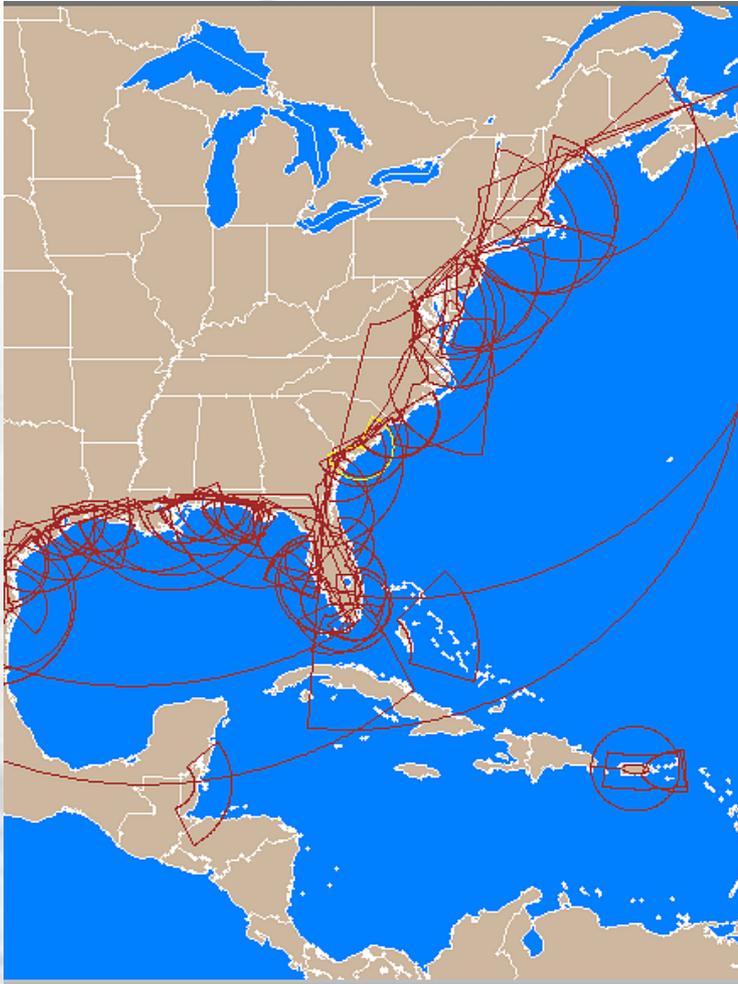


# Charleston: 96 storms

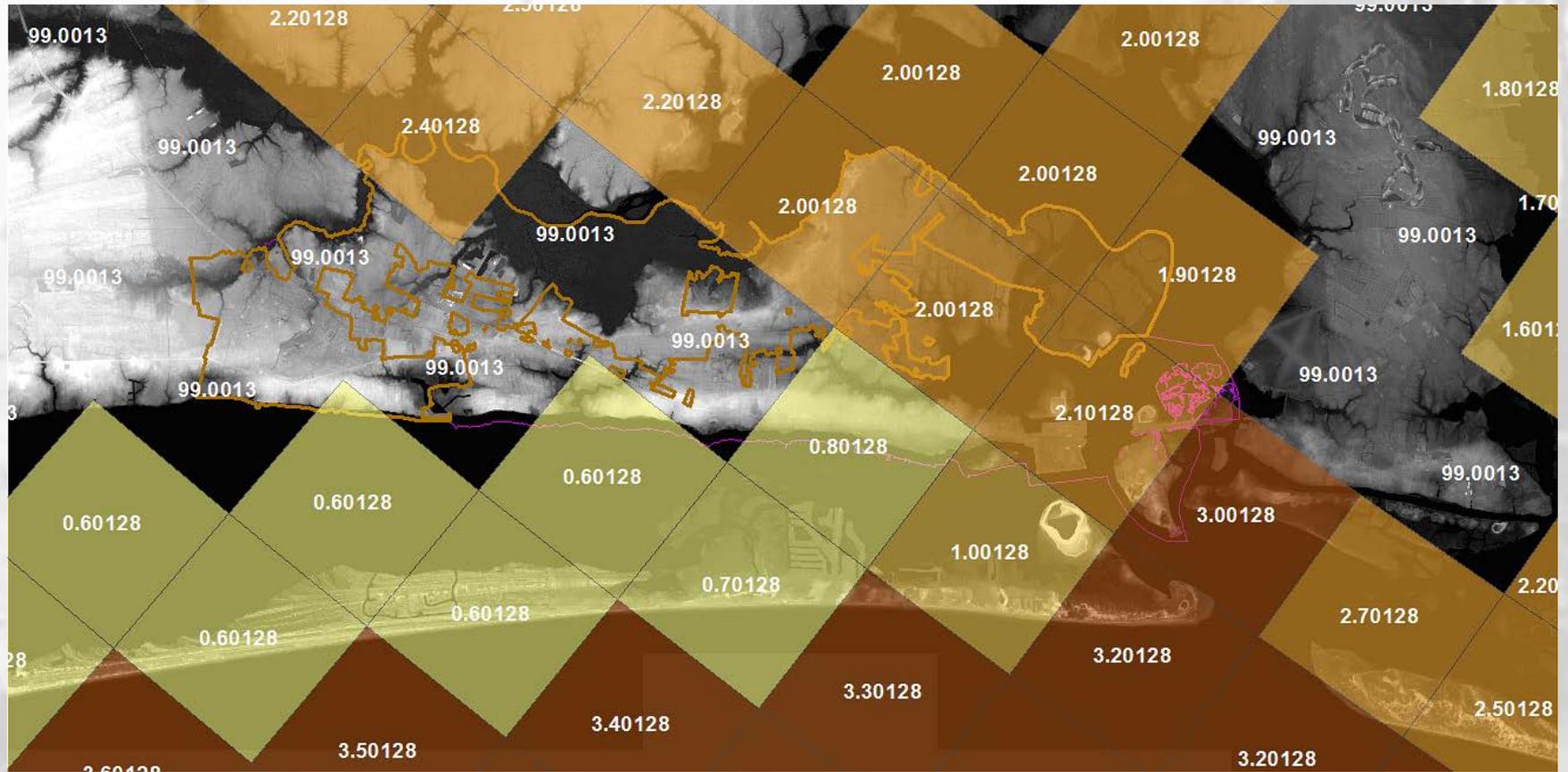


# SLOSH Basins

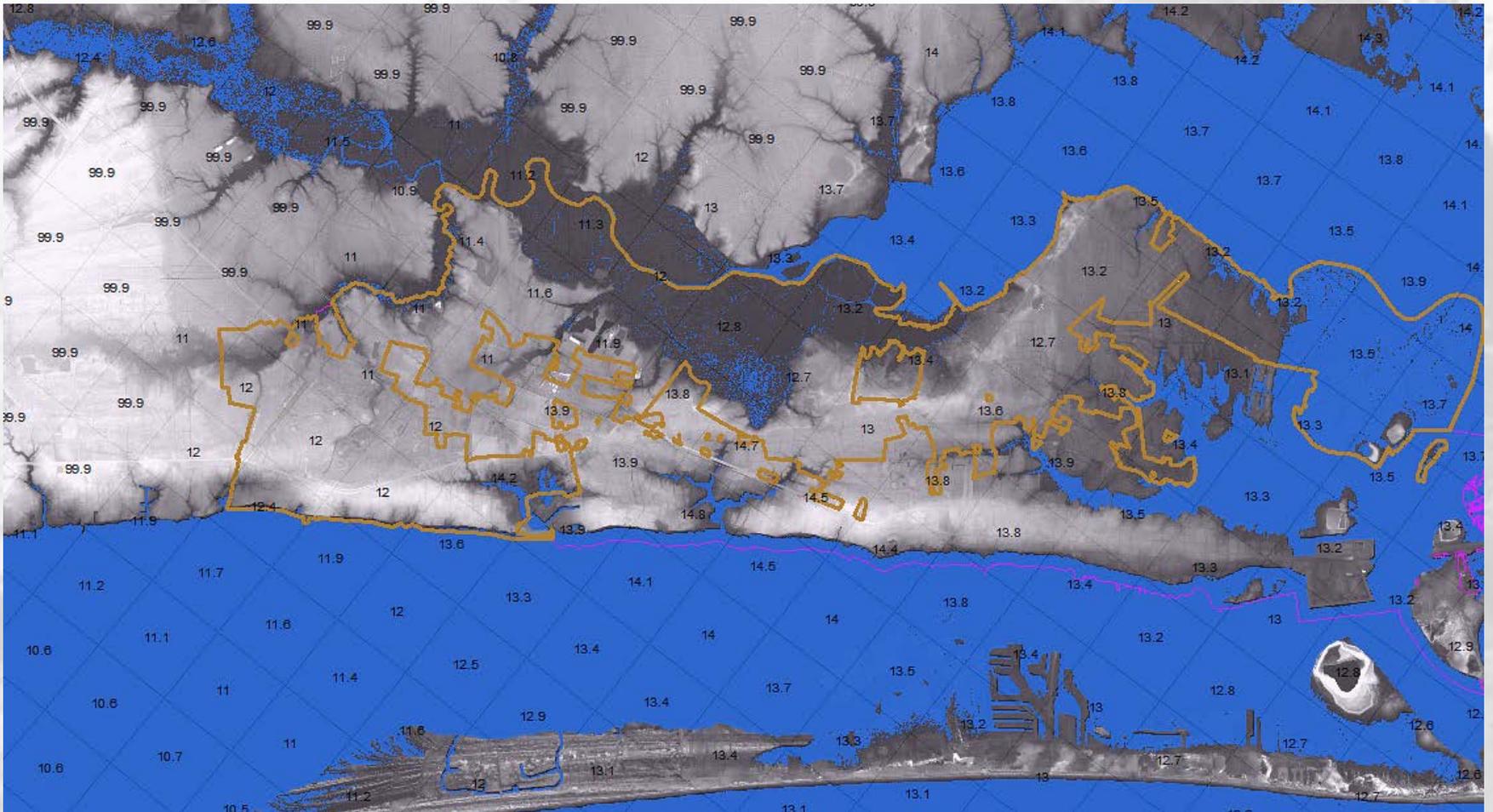
Pamlico Sound (*ehatv2*) and Charleston Harbor (*hchs v2*)



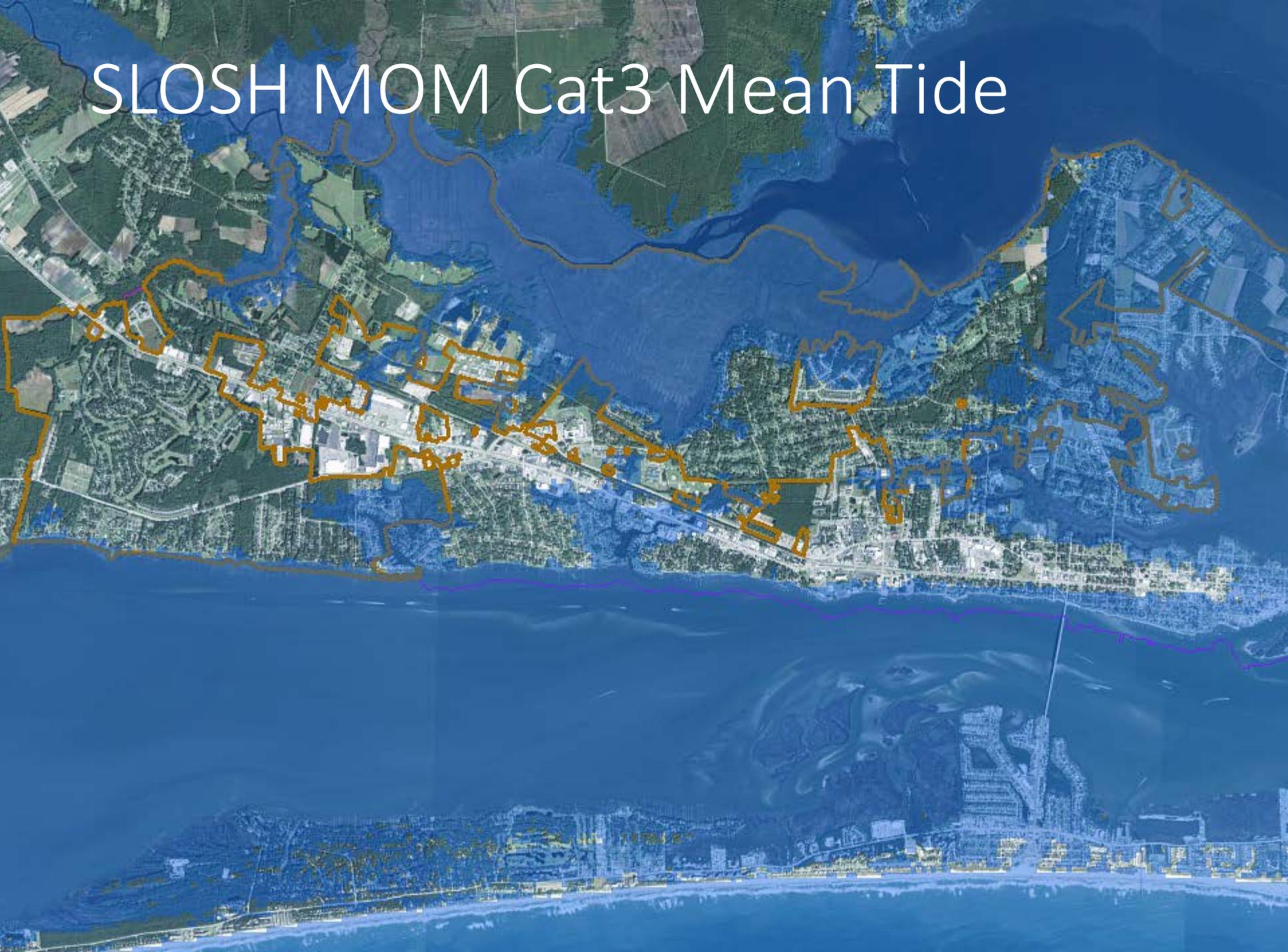
# SLOSH MOM Cat1 Storm Tide



# SLOSH MOM Cat3 Mean tide



# SLOSH MOM Cat3 Mean Tide



# Onsite Wastewater Treatment Systems (OWTS), Climate Change, and Sea Level Rise

- “..the effects of climate change in humid regions receiving more precipitation and warmer temperatures are expected to result in complete loss of the infiltrative and water quality functions of OWTS.”

Amador *et al.* (2014)

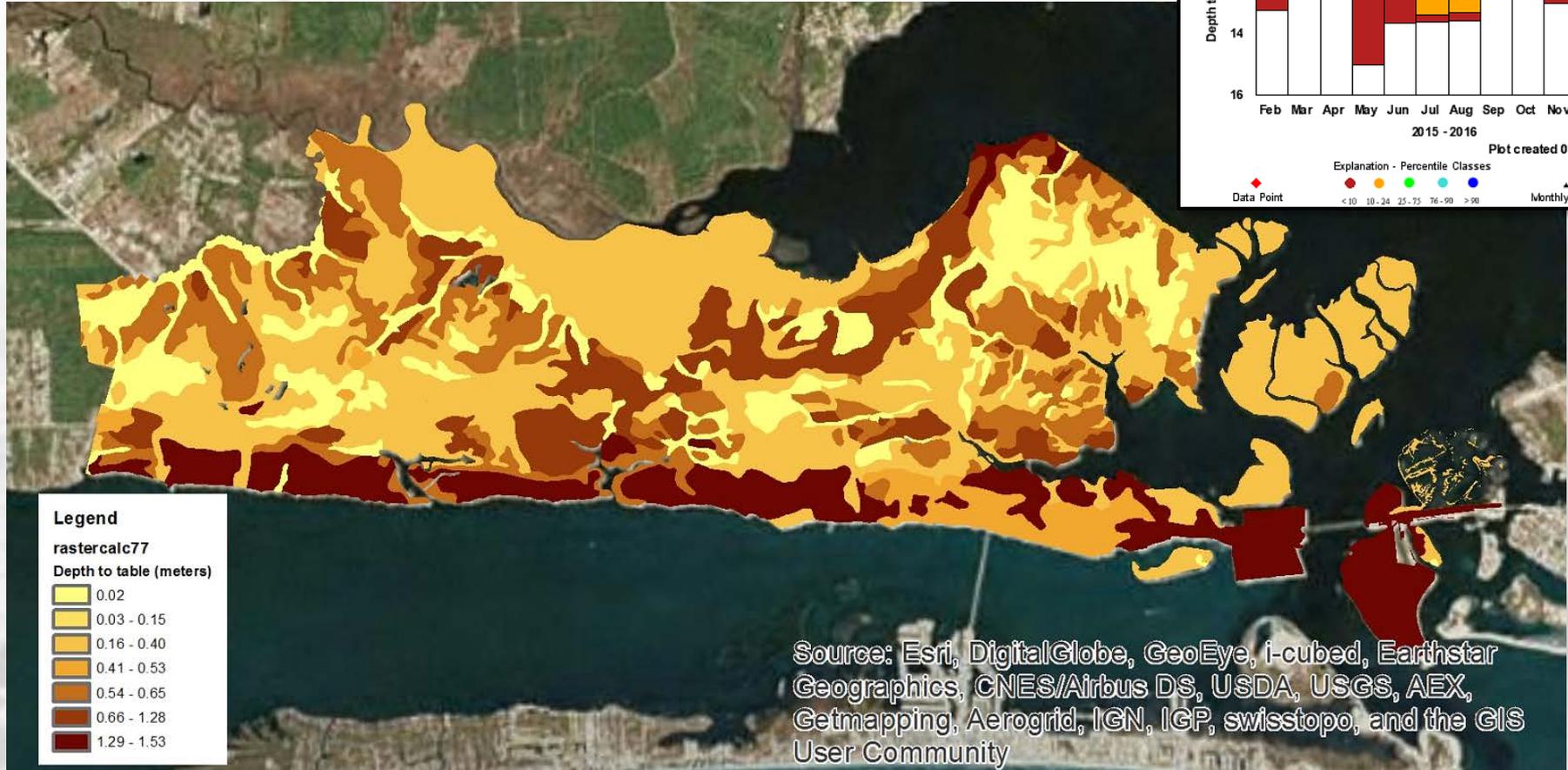
- Decreased volume of aerobic soil in vadose zone
- Lower O<sub>2</sub> solubility and reduced vadose/freeboard zone
- Overall pathogen removal functions of OWTS decline



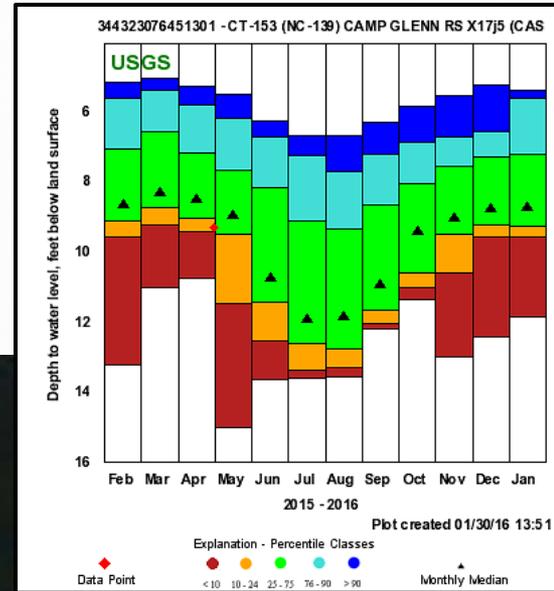
Amador, J., Loomis, G., Kalen, K. 2014. Soil-Based Onsite Wastewater Treatment and the Challenges of Climate Change. *Proceedings, Innovation in Soil-Based Onsite Wastewater Treatment*, Albuquerque, NM, April 7-8, 2014.

(<https://www.soils.org/files/meetings/specialized/full-conference-proceedings.pdf>)

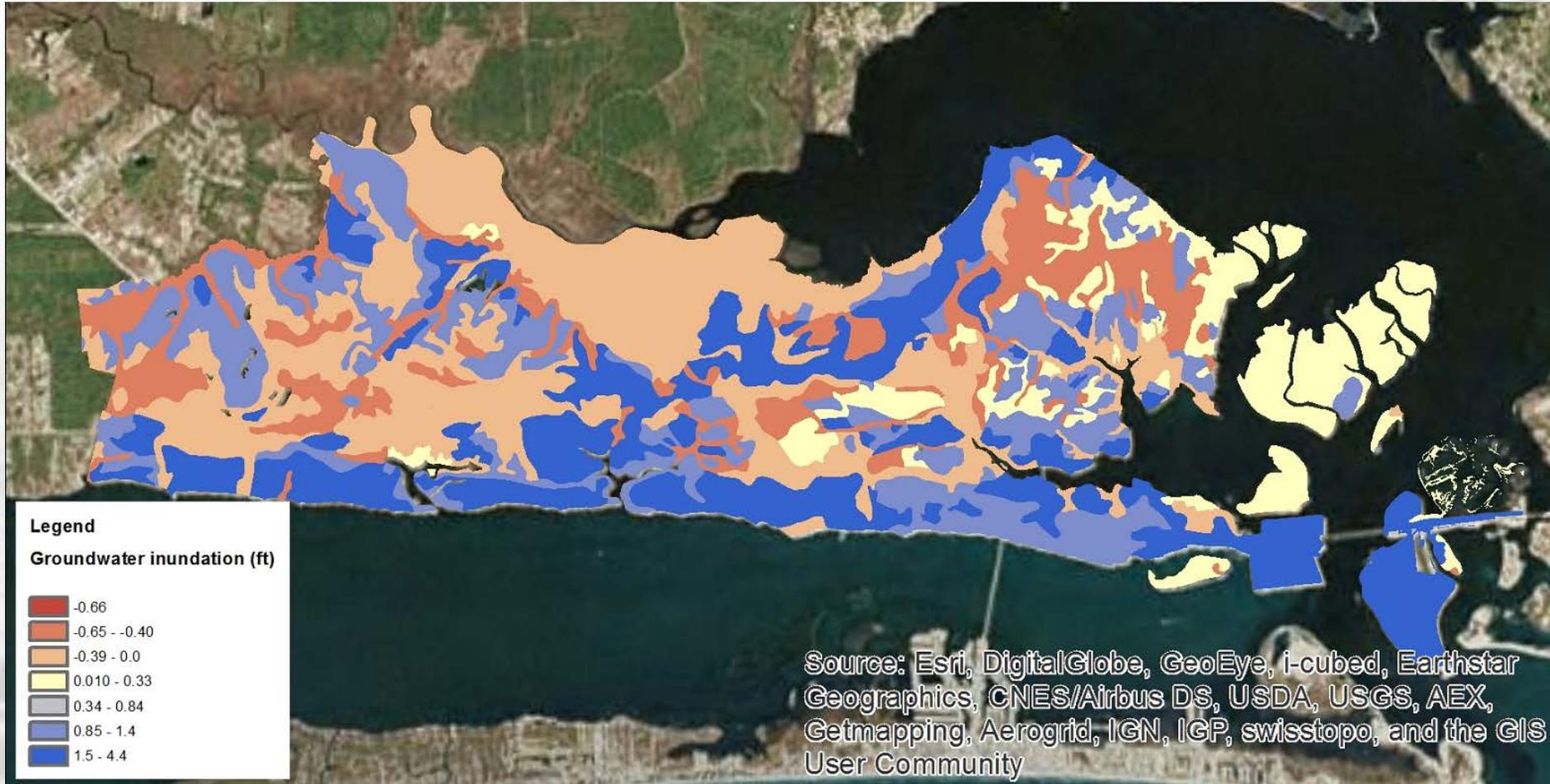
# Soil Depth to Water Table



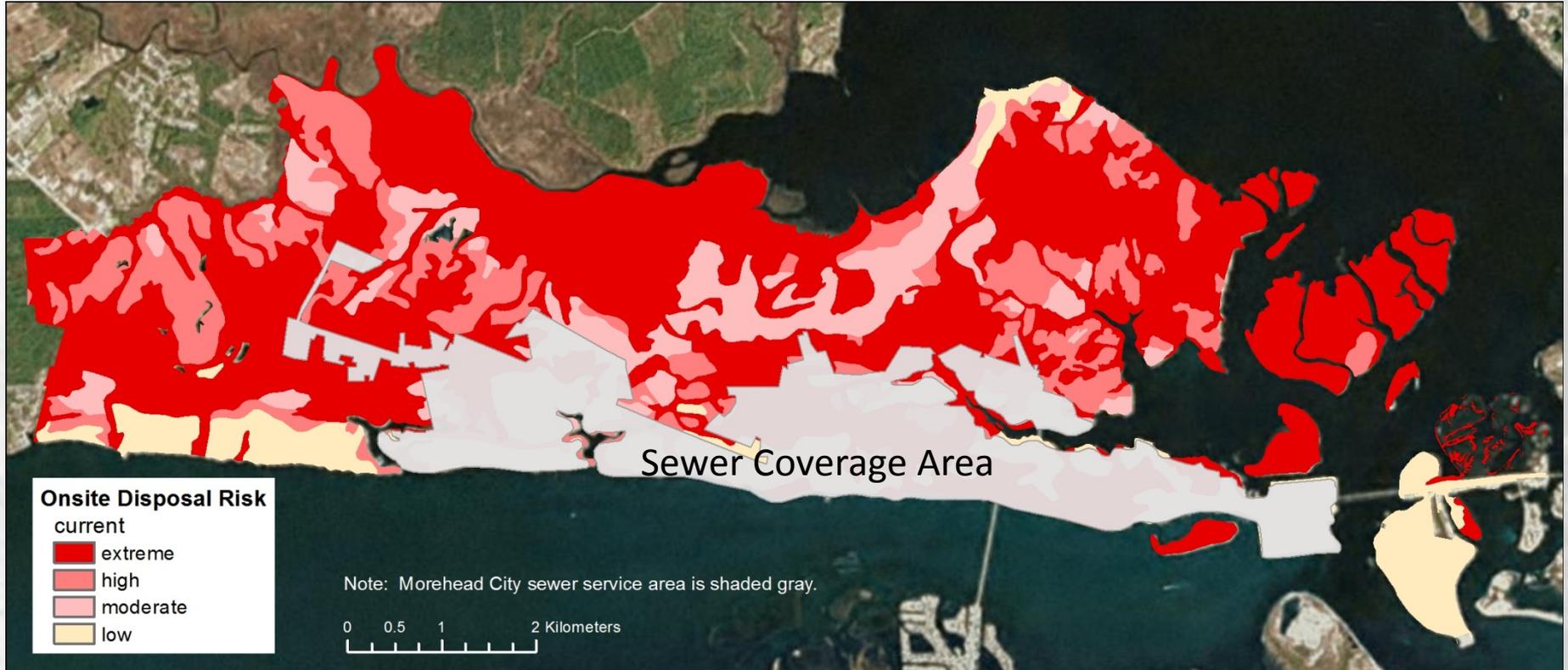
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



# Groundwater Inundation of OWTS

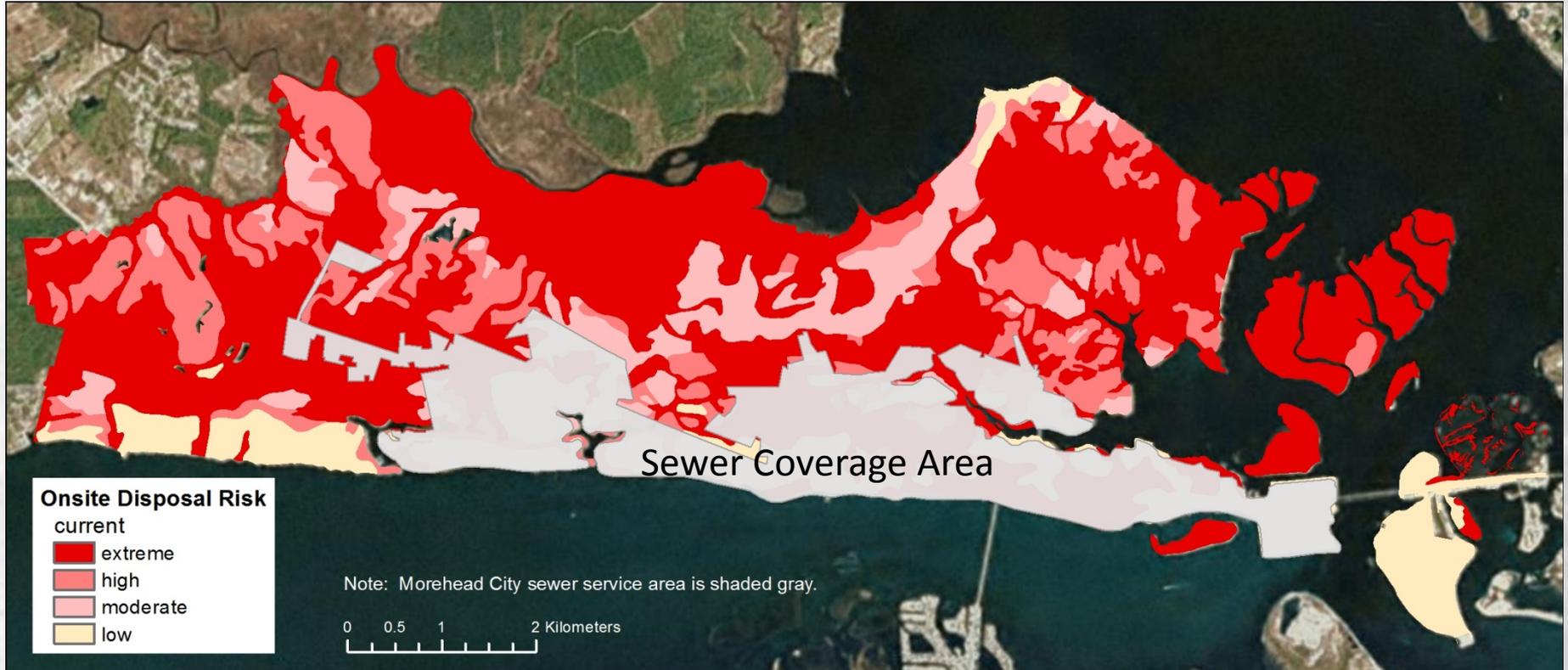


# ETJ Onsite Wastewater Treatment Risk, current



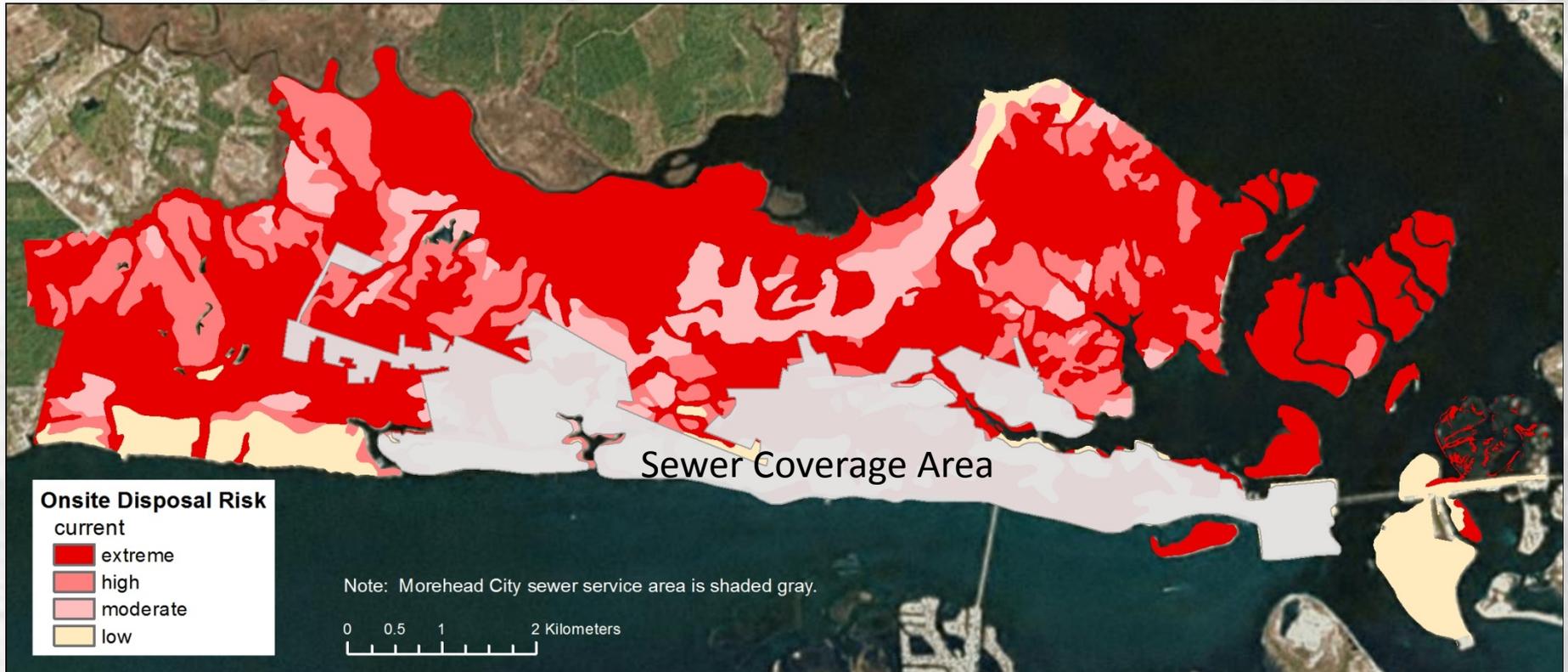
Note: Gray area is in Morehead City sewer coverage area..

# ETJ Onsite Wastewater Treatment Risk, 20cm SLR



Note: Gray area is in Morehead City sewer coverage area..

# ETJ Onsite Wastewater Treatment Risk, 40cm SLR



Note: Gray area is in Morehead City sewer coverage area..

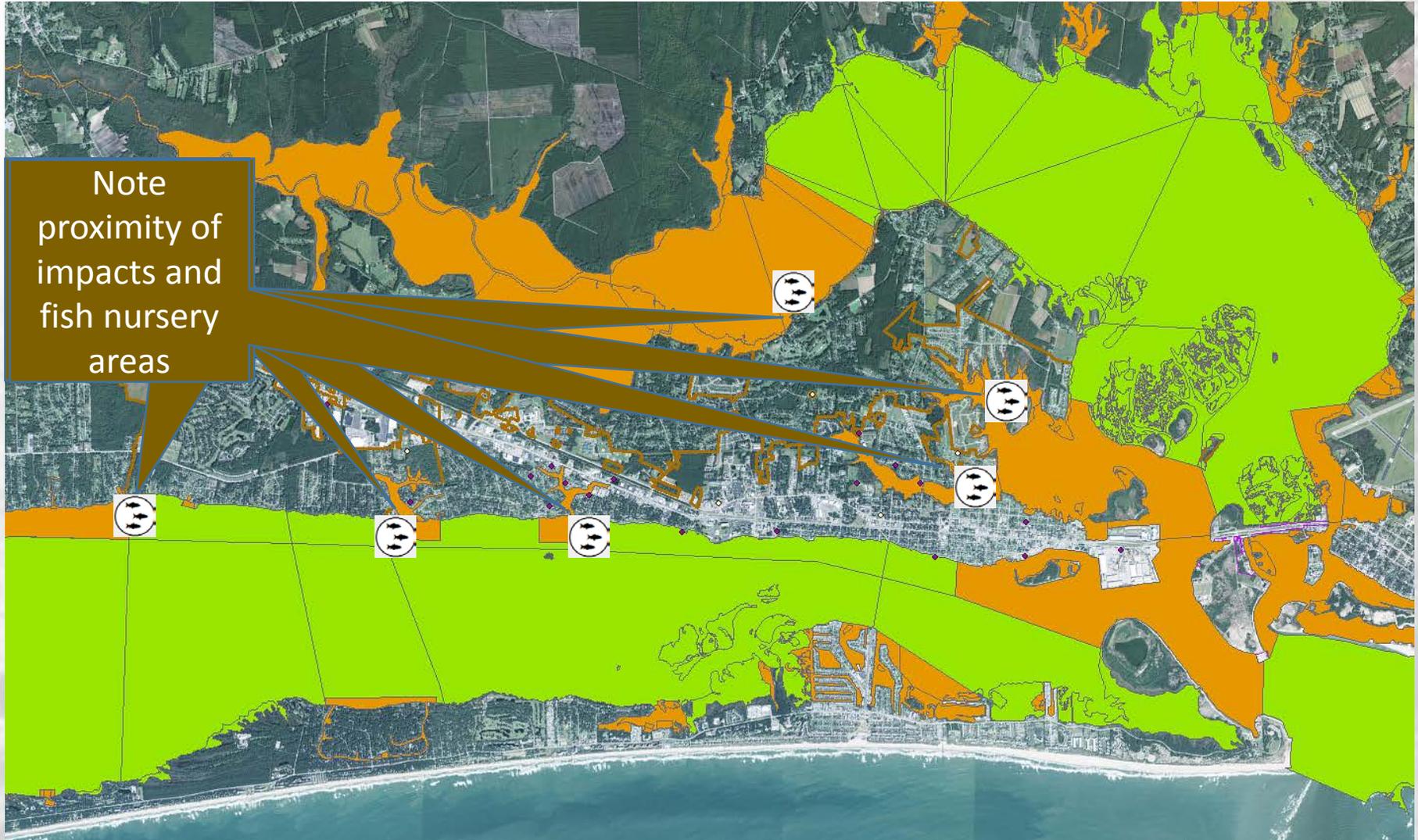
# ETJ Onsite Wastewater Treatment Risk, 60cm SLR



Note: Gray area is in Morehead City sewer coverage area..

# Shellfish Harvesting: Open vs. Closed

Surrounding estuaries are extremely productive and popular activity spaces for crabbing, fishing and cast netting for shrimp and bait fish



Source: NC DEQ Shellfish Sanitation & Recreational Water Quality

# NOAA ESI Socio-Economic Inventory of Human-Use Resources for Oil Spill Response

NOAA NOS ORR, OCM and Strategic Environmental Assessments Division (2000)

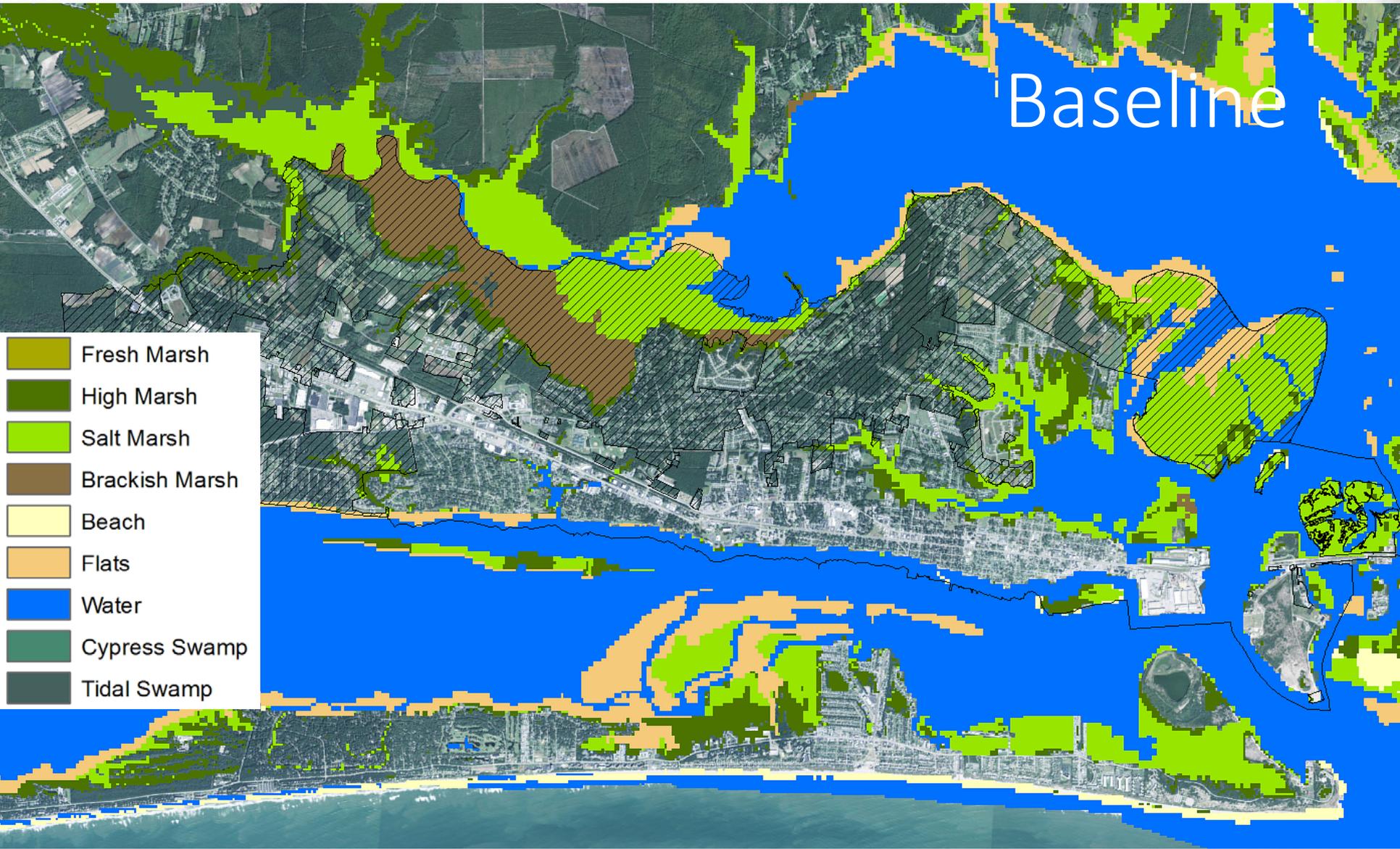


16 marinas  
1 recreational beach\*  
1 public boat ramp\*  
6 tidal creek nurseries

# Sea Level Rise and Wetlands

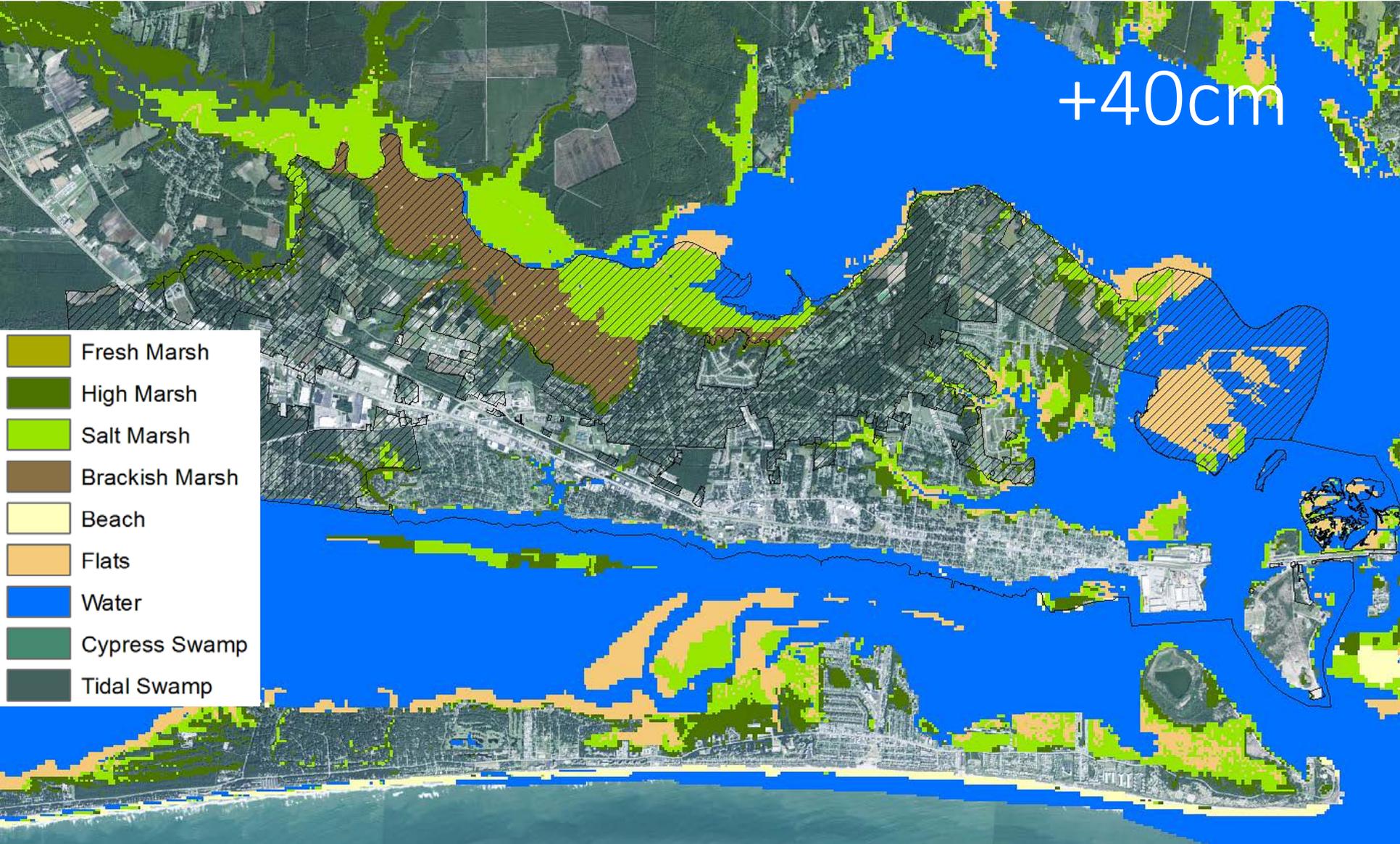
- SLR also threatens area salt and brackish marshes
- Potential degradation of ecosystem goods and services:
  - Storm surge and wave attenuation
  - Nutrient uptake
  - Sediment and carbon storage
  - Habitat function
- Relatively lower subsidence in the Cape Lookout region indicates moderate wetland transgression, yet *net losses* can be anticipated
- Local awareness and SLR policy

Baseline



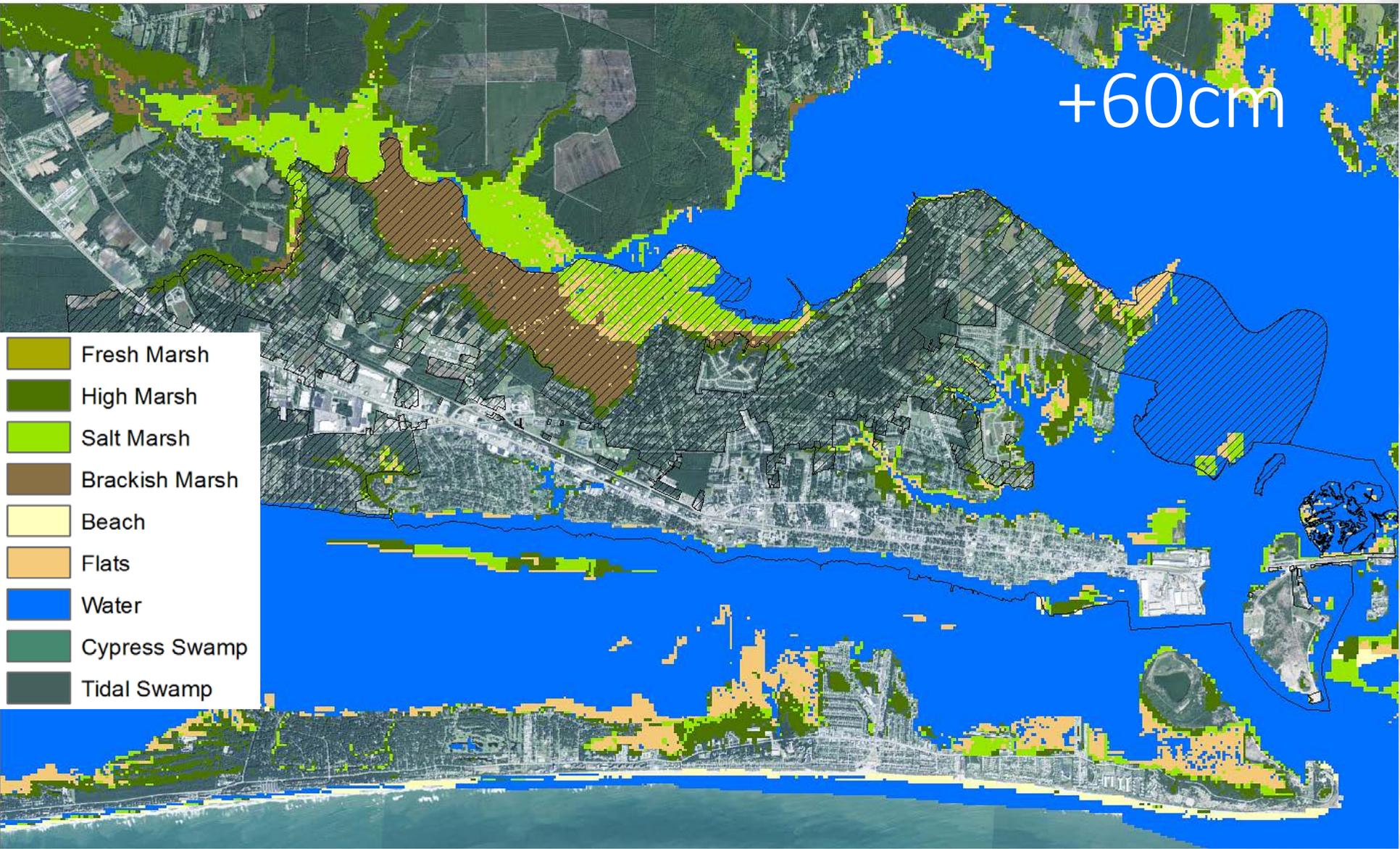
+40cm

- Fresh Marsh
- High Marsh
- Salt Marsh
- Brackish Marsh
- Beach
- Flats
- Water
- Cypress Swamp
- Tidal Swamp



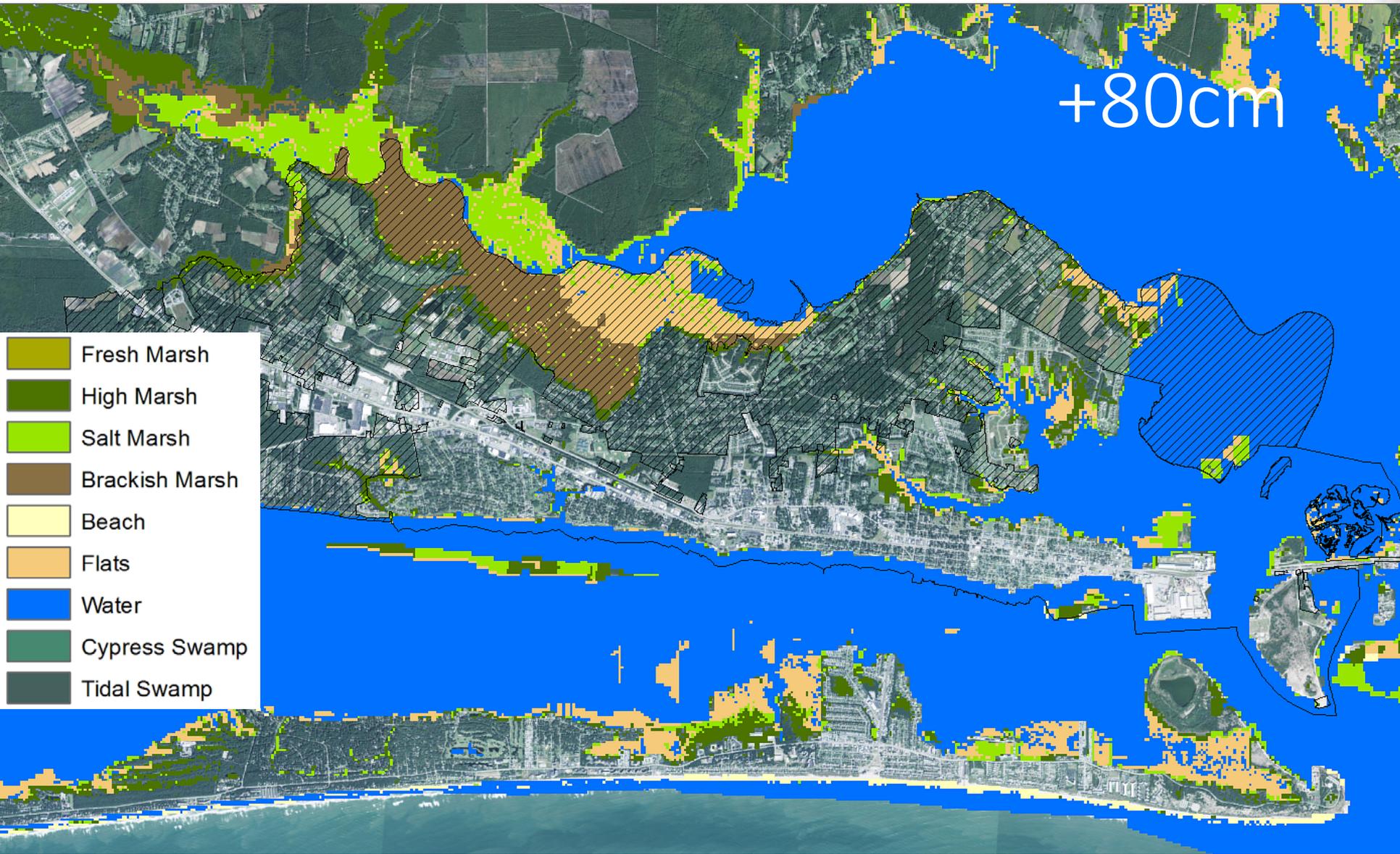
+60cm

- Fresh Marsh
- High Marsh
- Salt Marsh
- Brackish Marsh
- Beach
- Flats
- Water
- Cypress Swamp
- Tidal Swamp



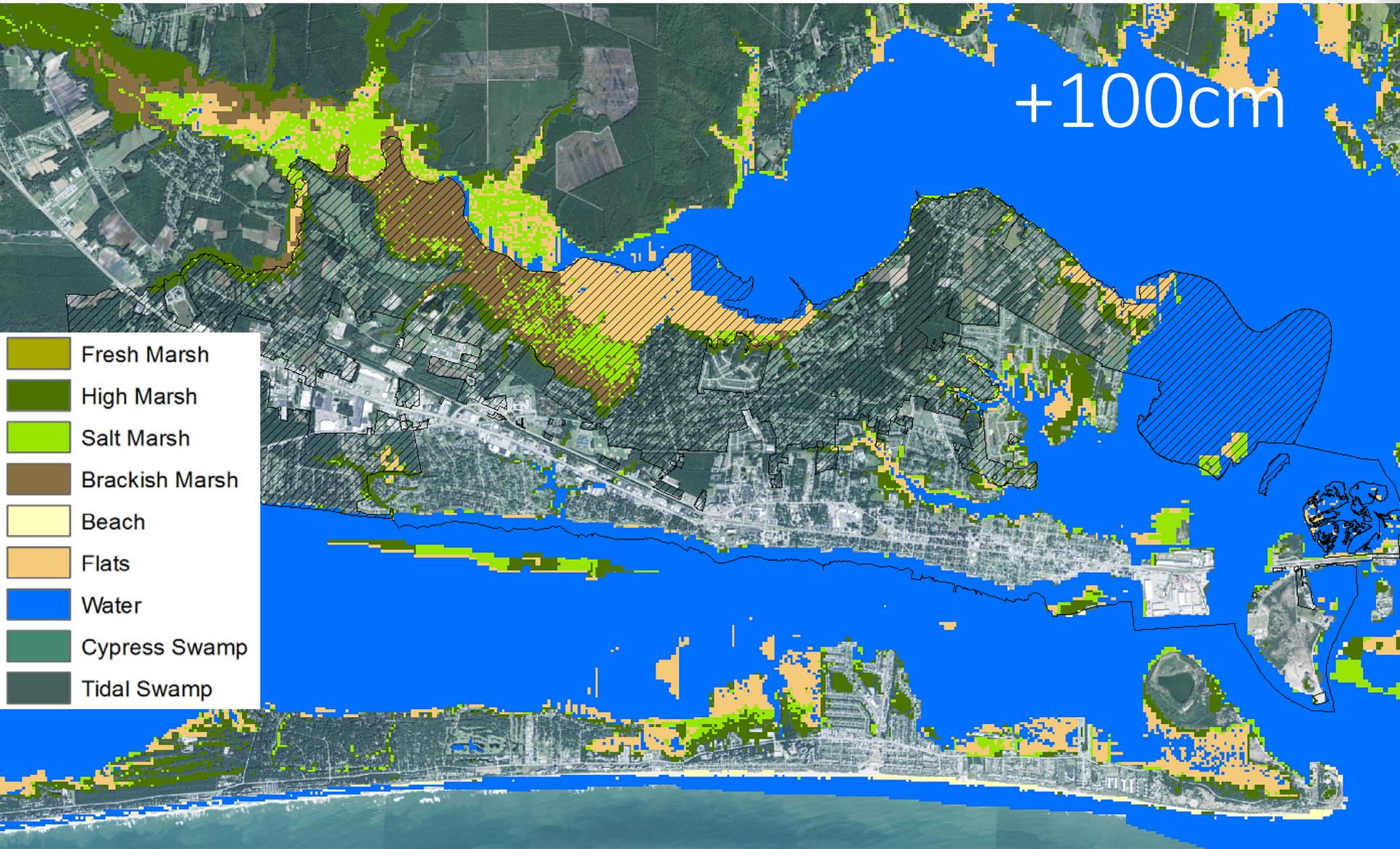
+80cm

- Fresh Marsh
- High Marsh
- Salt Marsh
- Brackish Marsh
- Beach
- Flats
- Water
- Cypress Swamp
- Tidal Swamp



+100cm

- Fresh Marsh
- High Marsh
- Salt Marsh
- Brackish Marsh
- Beach
- Flats
- Water
- Cypress Swamp
- Tidal Swamp



# Next Steps: Towards Adaptation and Intervention

- Scoping and providing useful information to officials and the public
  - Nuisance flood maps
  - Susceptibility index
  - Developing community tabletop exercise
  - Cross-cutting public health, planning, emergency mgt., and utilities
- Community and infrastructure planning
  - Retention ponds and wetlands increase water storage
  - Pervious surfaces and rain gardens increase infiltration, reducing run-off
  - Increasing capacity of stormwater system
  - Targeting surveillance and mosquito abatement
  - Model ordinance and codes

# Conclusions

- Localized multi-hazard risk mapping
- Tangible, explicit and spatial susceptibility
- Progress toward place-based community adaptation and resilience
- Replicability and portability

