2-23-2018

Spatial Interactions Between Public Health and Water Infrastructure in Coastal Communities

Tom Allen

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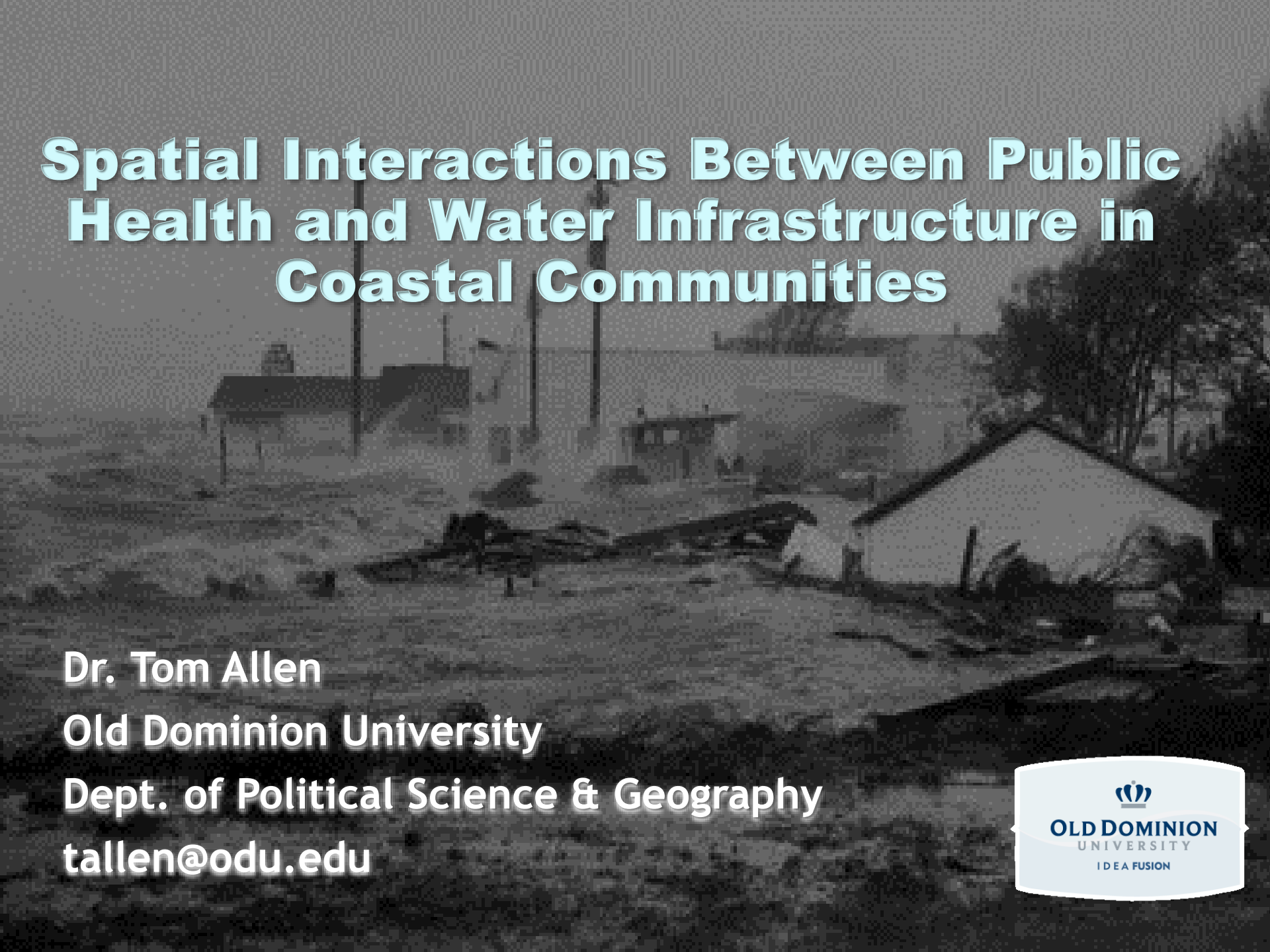

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OLD DOMINION UNIVERSITY
IDEA FUSION

Acknowledgements

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Purpose

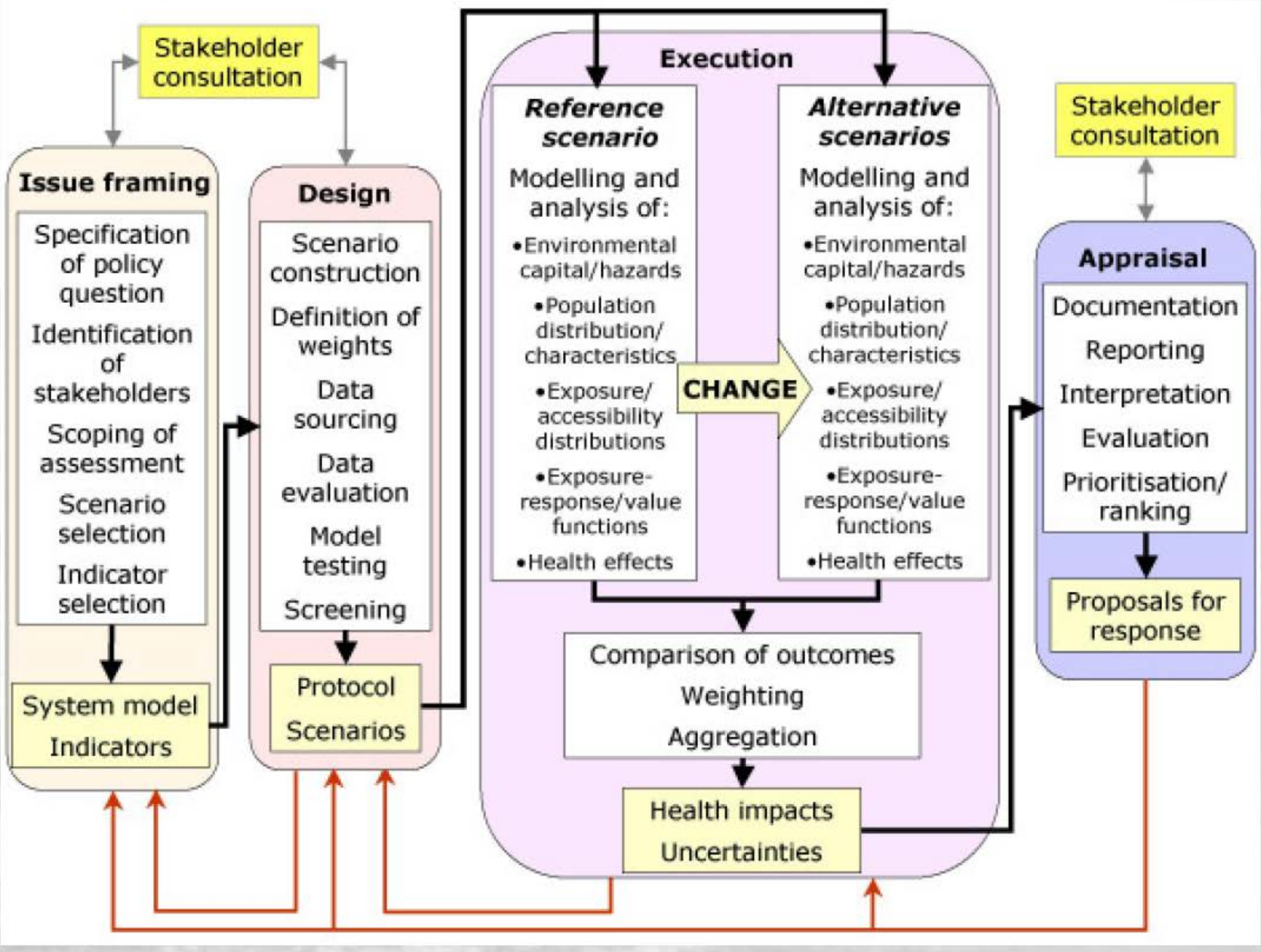
- Better inform and empower communities to address sea level rise in a changing climate
- Support decision-makers to integrate public health, emergency mgt. and coastal planning
- Test new information and tools to boost resiliency
- Explore interacting threats
  - Sea level rise
  - Storm surges
  - Tidal flooding
  - Extreme rainfall
  - Groundwater

Steps to Resilience

US Climate Resilience Toolkit https://toolkit.climate.gov/

1. Explore Hazards
2. Assess Vulnerability & Risks
3. Investigate Options
4. Prioritize & Plan
5. Take Action

FRAMEWORK: Briggs (2008) *Integrated Environmental Health Impact Assessment*



Reveal Health Impacts & Reduce Uncertainties

Population Exposure

- Census, cadastral and dasymetric mapping
- Medically fragile and socially vulnerable
- Limited health registry
- Seasonal and transhumant population
- Tourists and migrants

Environmental Health and Sanitation

- Onsite wastewater treatment
- Centralized wastewater
- Groundwater
- Infrastructure elevations
- Effluent spills
- System infiltration
- Cascading failures

Health Care Access and Continuity

- Hospitals and acute primary care
- Outpatient tertiary care
- Dialysis, Oxygen and medical technology

Indirect and Lagged Effects

- Mosquito vectors and disease
- Waterborne pathogens and contaminants
- Shellfish, waterway, and beach closures

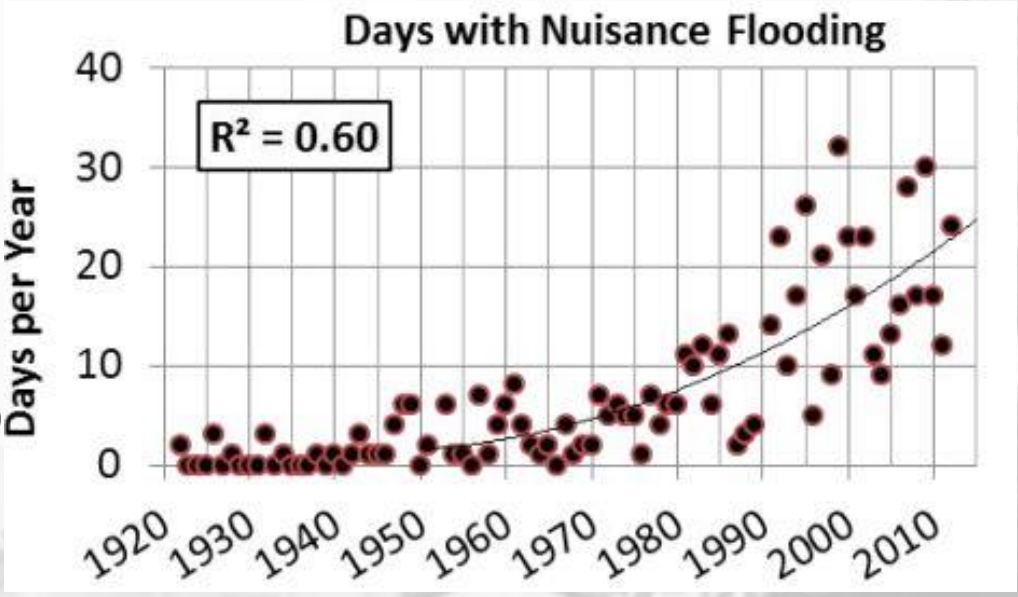
Two Cities with Recurrent Coastal Flooding

Morehead City, NC

Charleston, SC

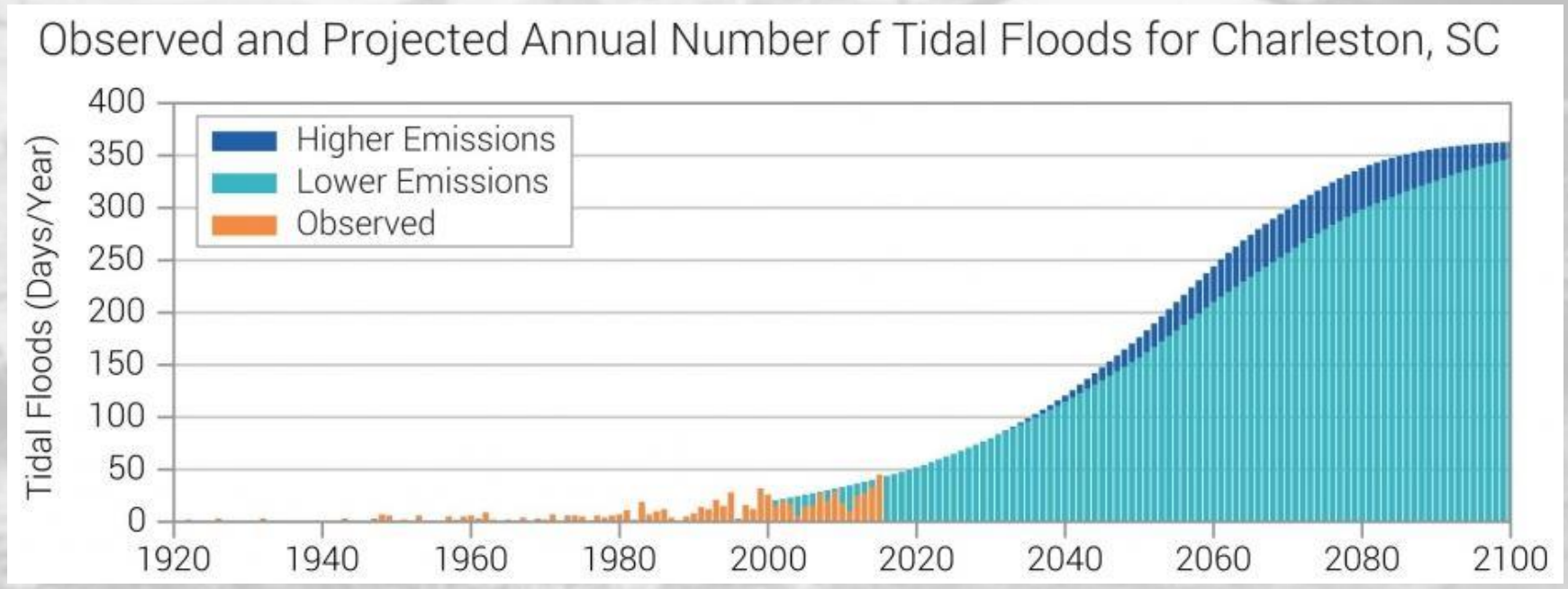
“Nuisance Flooding”

Localized, street-level impacts above mean high water

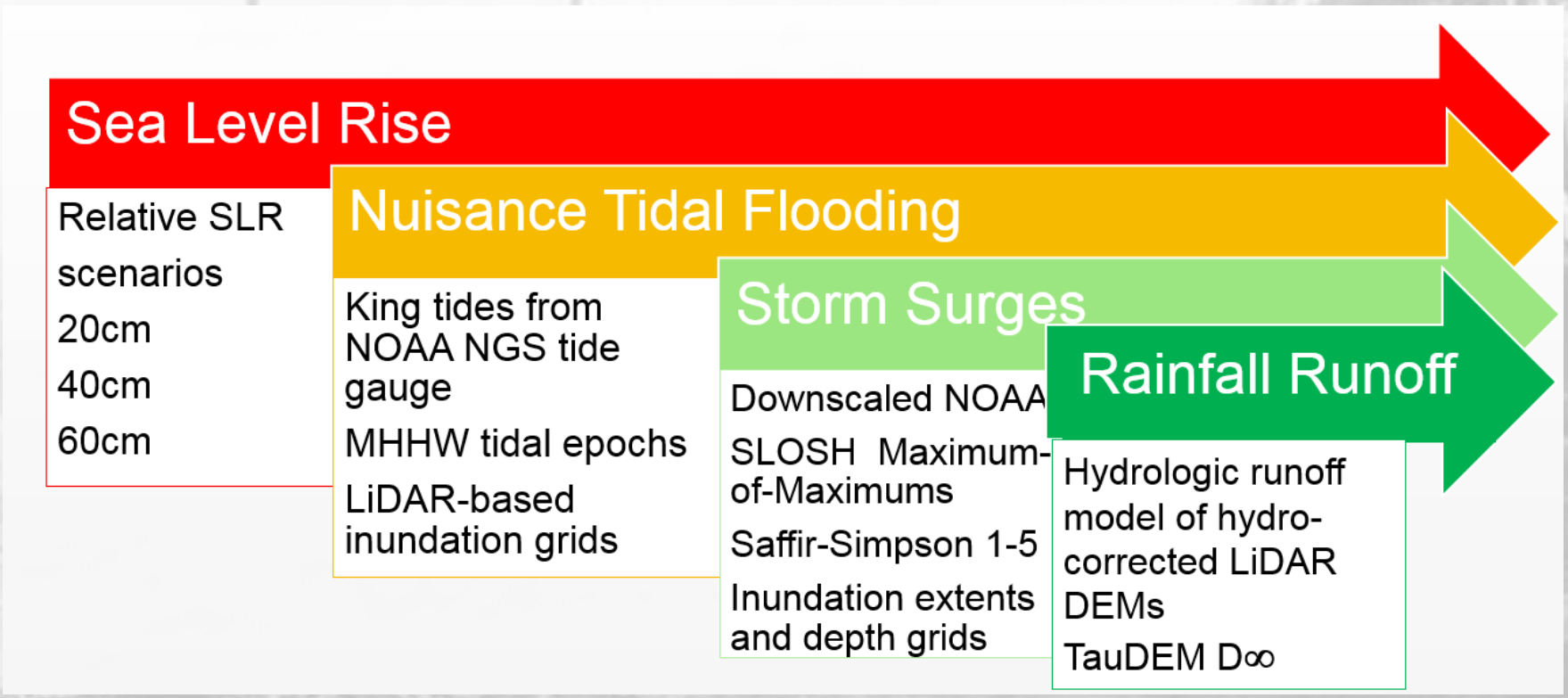


Sweet et al. (2014)

Charleston Sea Level Rise Plan (2016)



Multi-hazard flooding is modeled using NOAA SLOSH, LiDAR DEMs, tide gauges, and rainfall runoff for baseline flood events and SLR scenarios.



Surge Model Downscaling and Inundation

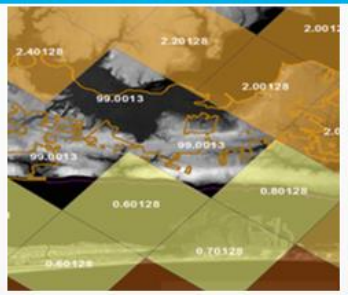
Acquire SLOSH MOMs

SLOSH basins

ehatv2

hchsv2

Downscale SLOSH MOMs to LiDAR



Downscale SLOSH MOMs to LiDAR DEM

10m cells

Inundation DEM

Inundate DEMs enforcing

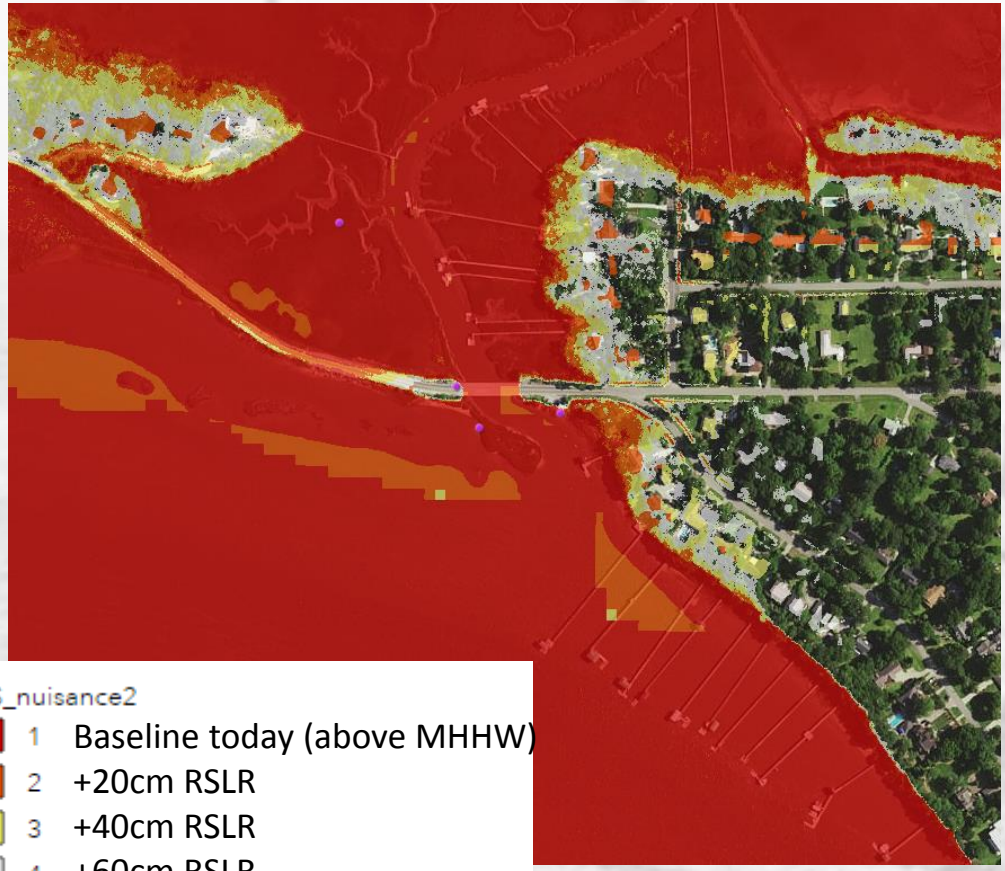
hydro-connectivity

Potential Impacts

Overlay and spatial analysis of infrastructure and other impacts

Hydrologic Controls

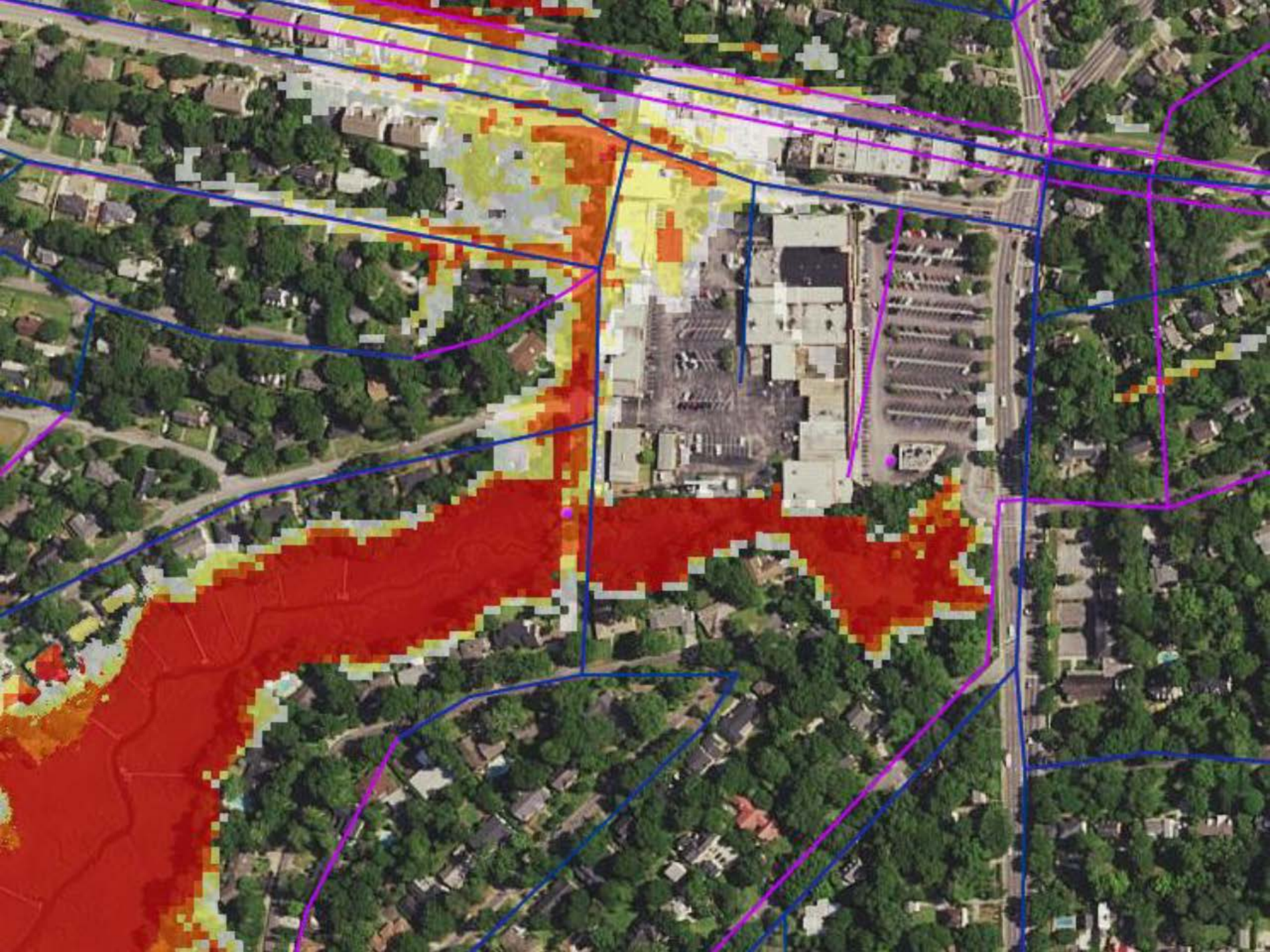
Charleston Field Recon July 2016



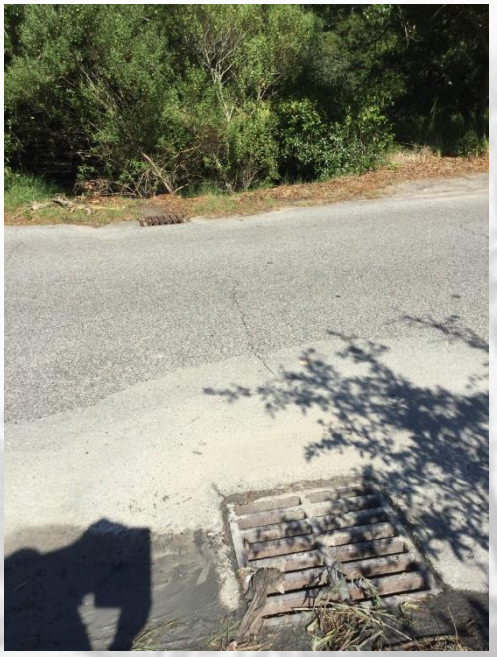
Causeway at Edgewater

Pump infrastructure…and elevation

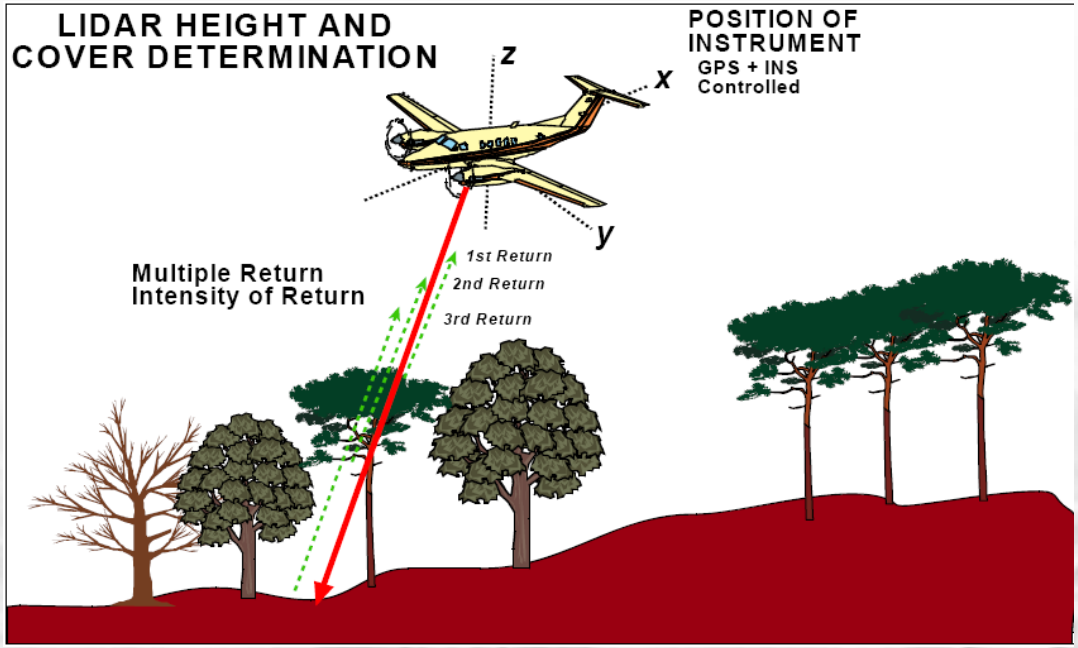
Hydro-Correction and Hydro-Conditioning



Culverts and Ditches

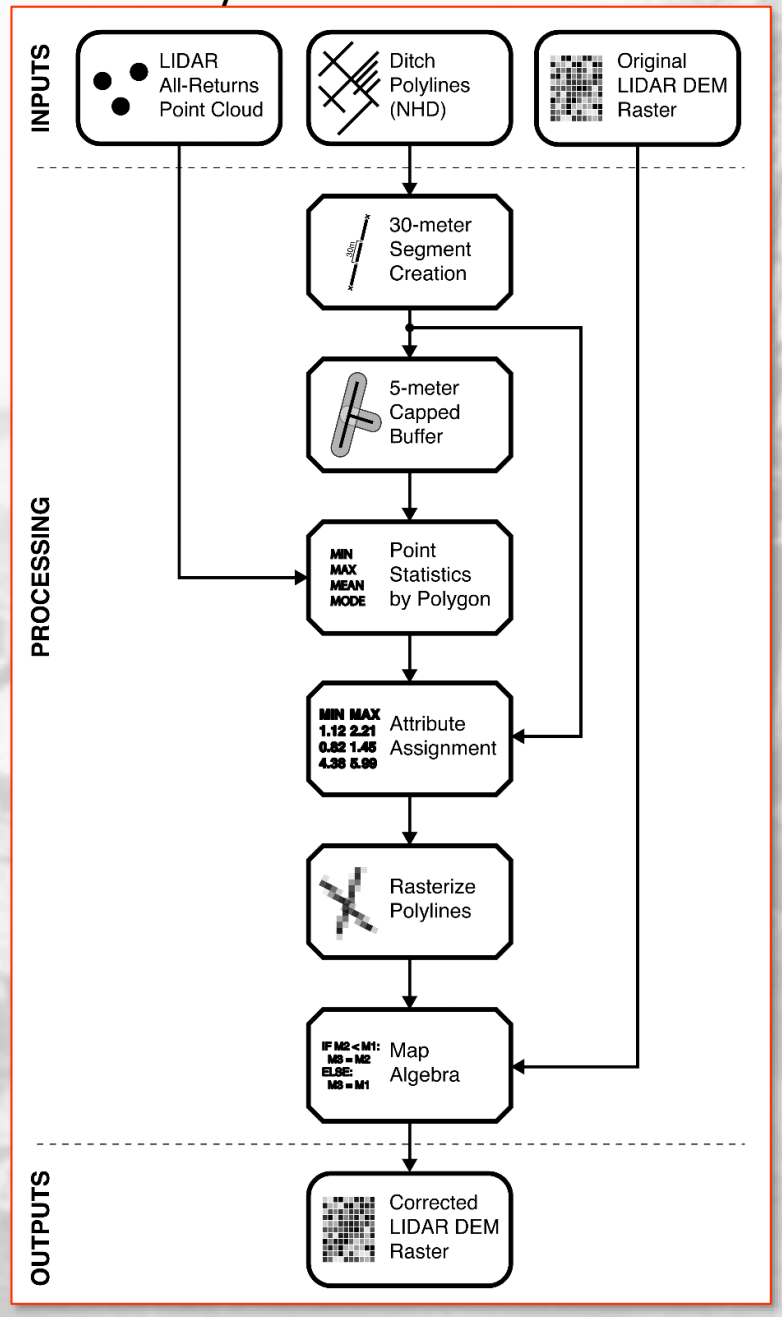


Hydro-correction of LiDAR Digital Elevation Models



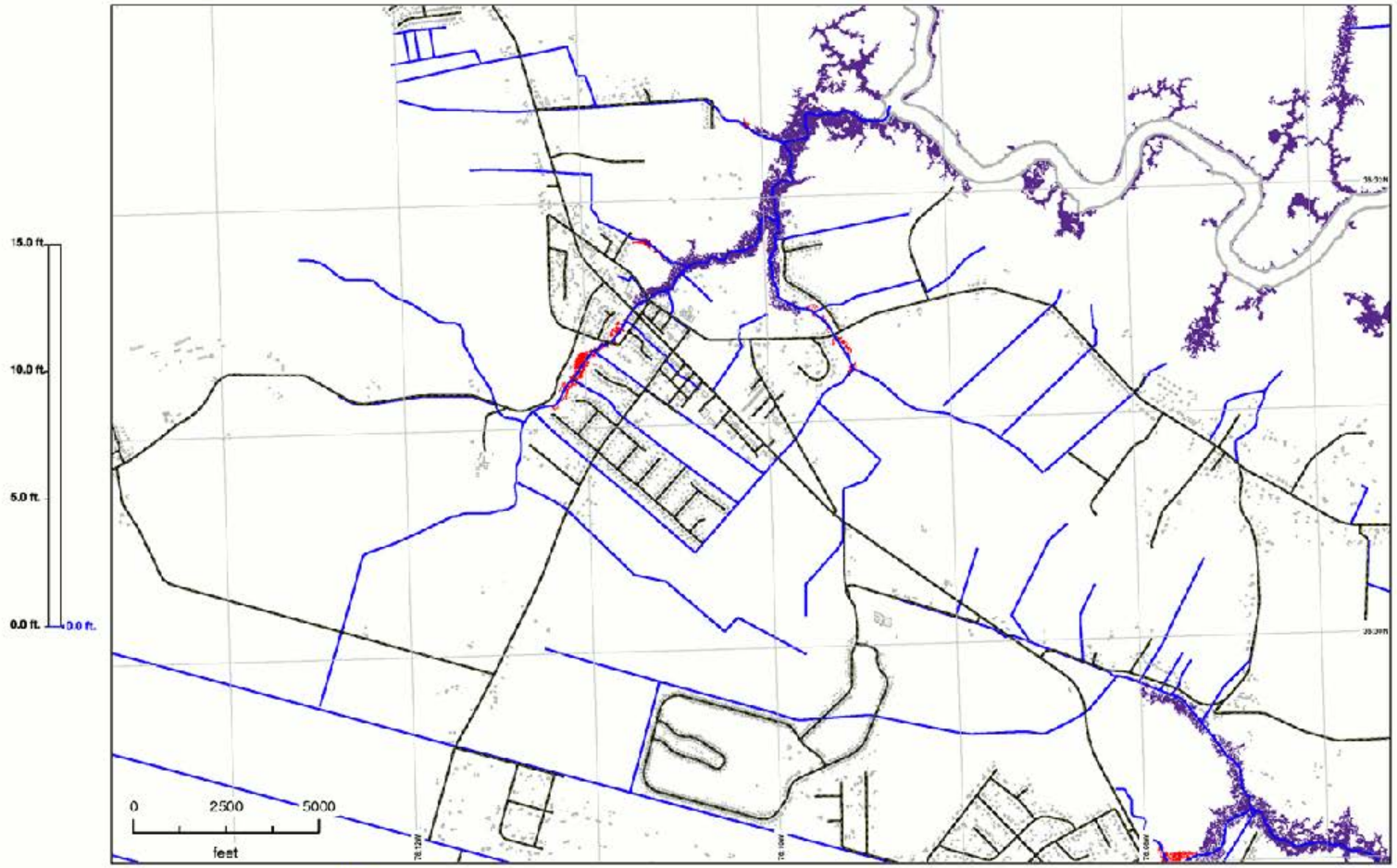
Filtered LiDAR point clouds for "bare earth" DEMs, then post-process to correct them for flood mapping

Hydro-correction Process



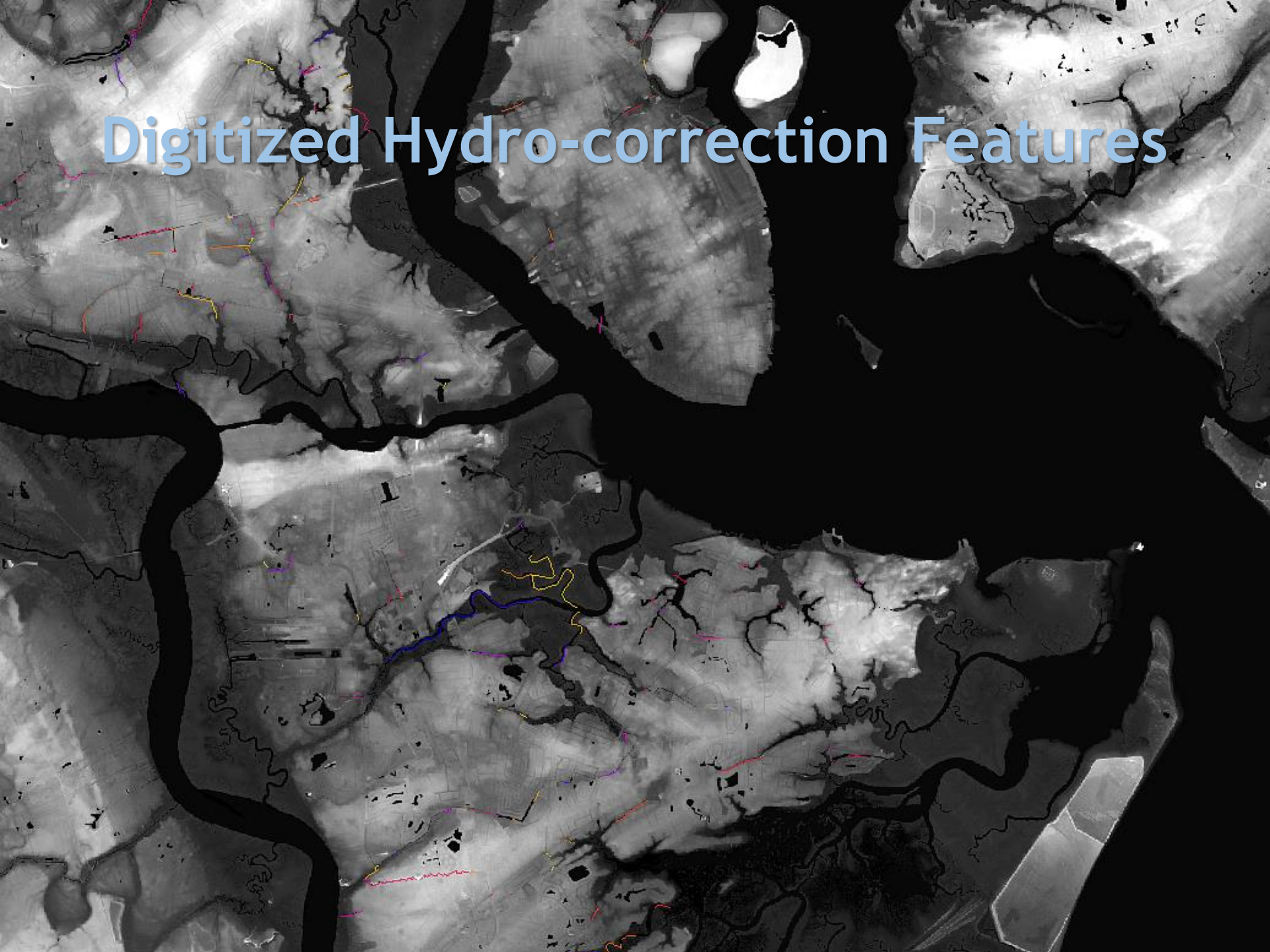
Reducing Flood Omission Error

GRASS r.flood simulation using 10m LiDAR DEM with ditch "***stream* burning**" hydro-correction

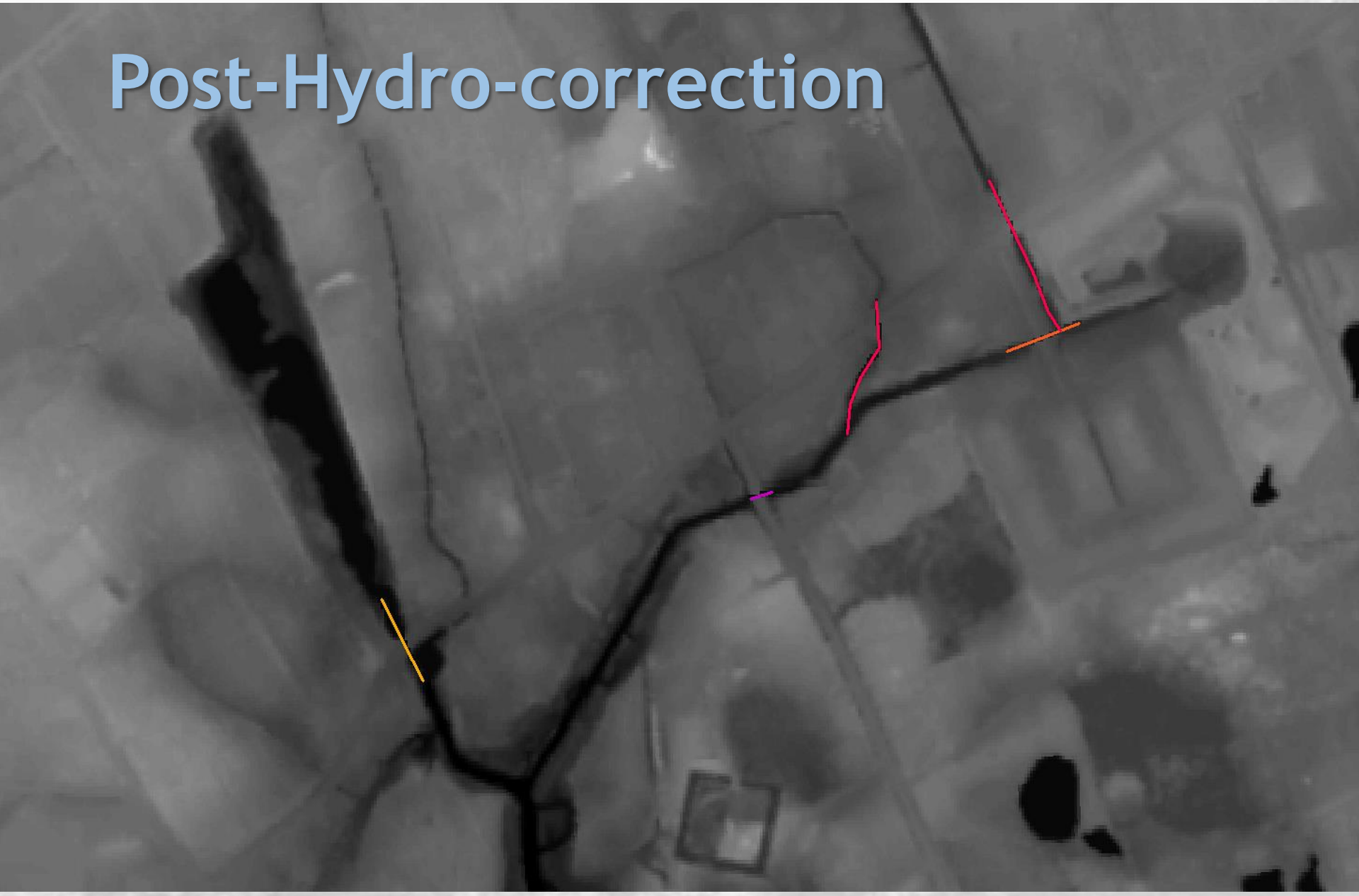


#	Category Information description	% cover	square kilometers	hectares
2	Inundated only in modified (burned) DEM. . . .	0.19	0.143146	14.31456
3	Inundated in both original and modified DEMs .	2.37	1.758240	175.87980
*	no data.	97.44	72.287216	7228.72155
TOTAL		100.00	74.188651	7418.86511

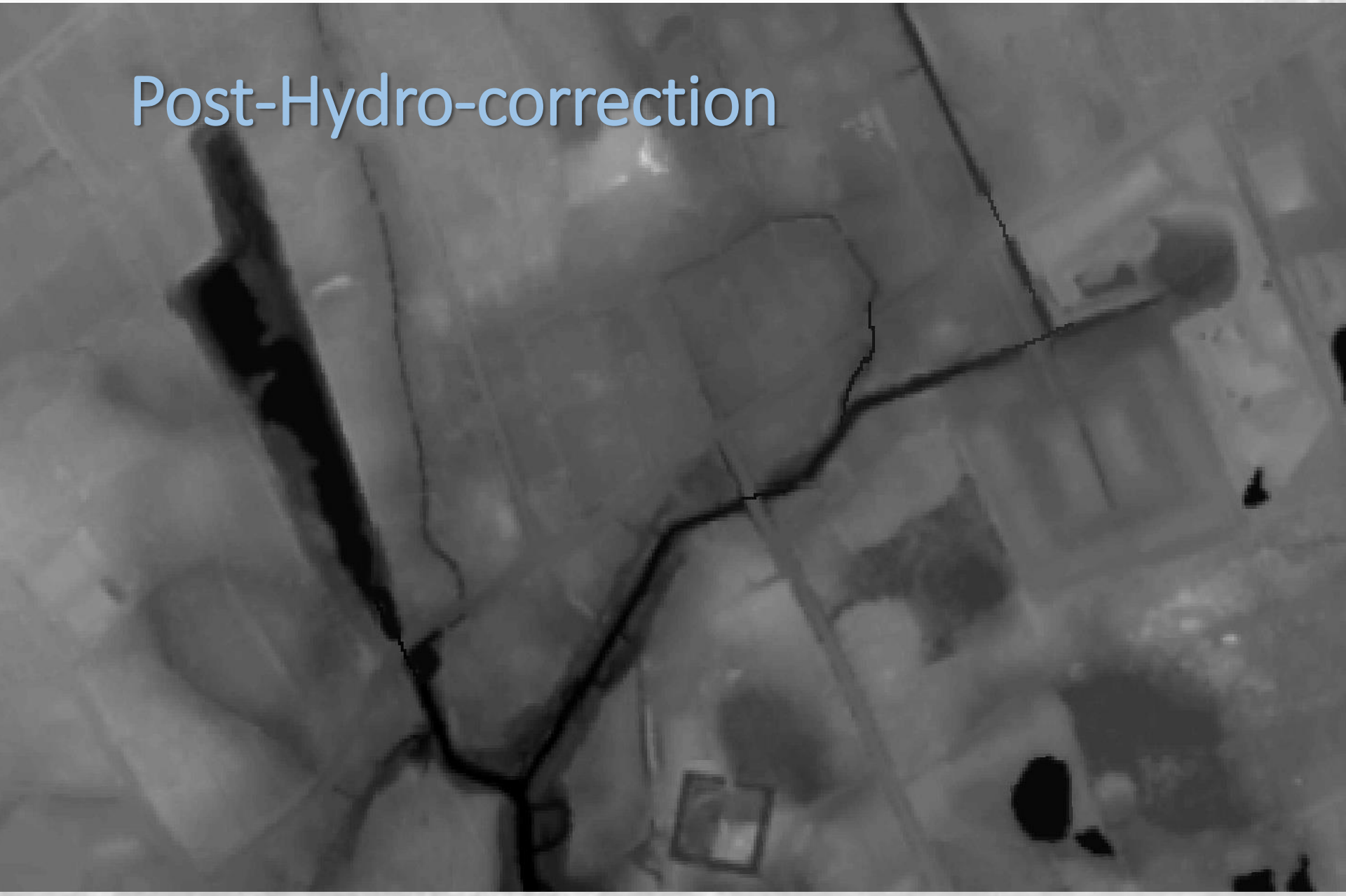
Digitized Hydro-correction Features



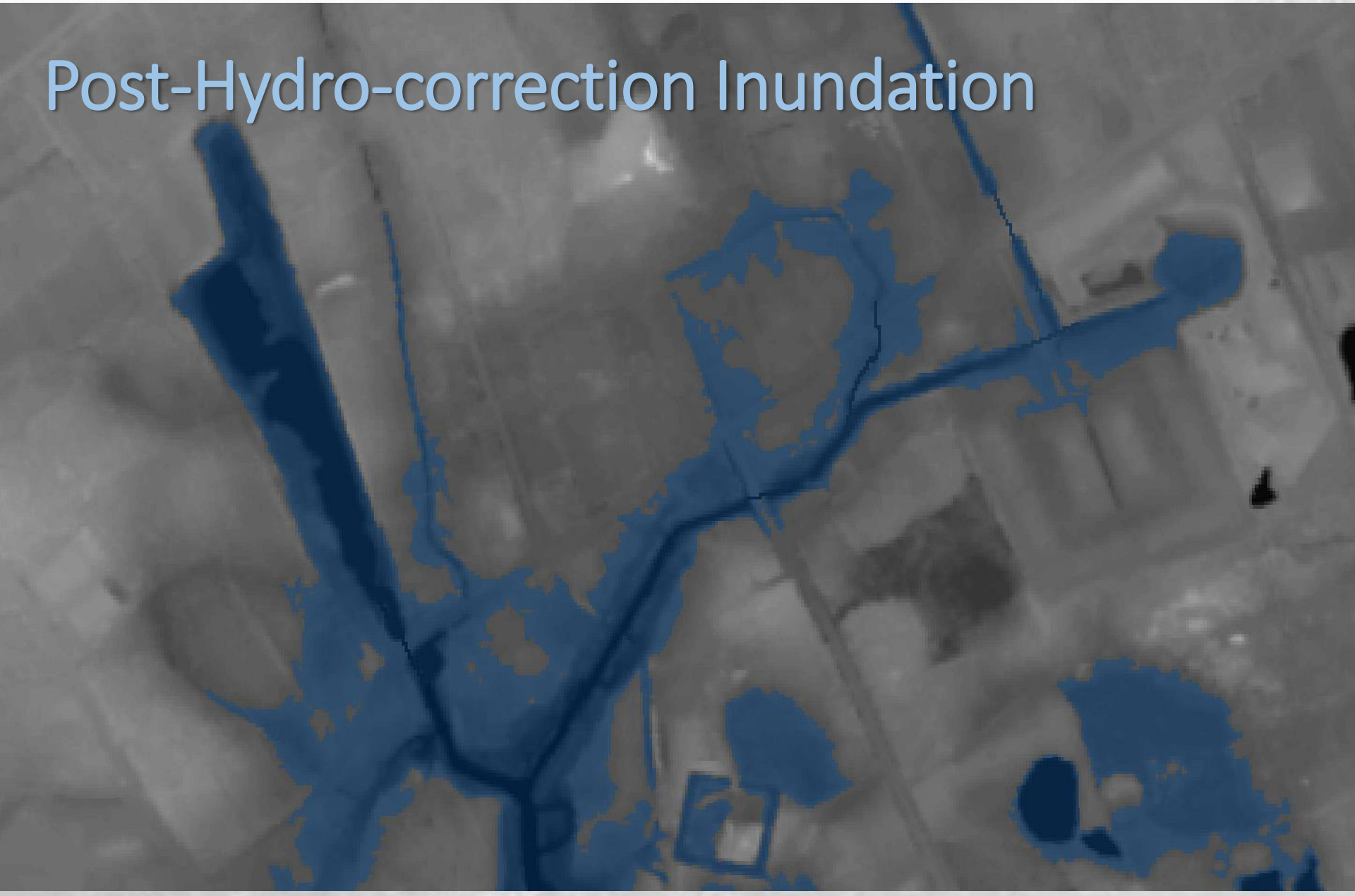
Post-Hydro-correction



Post-Hydro-correction



Post-Hydro-correction Inundation



Hydro-correction for Tidal Flooding and Rainfall Runoff

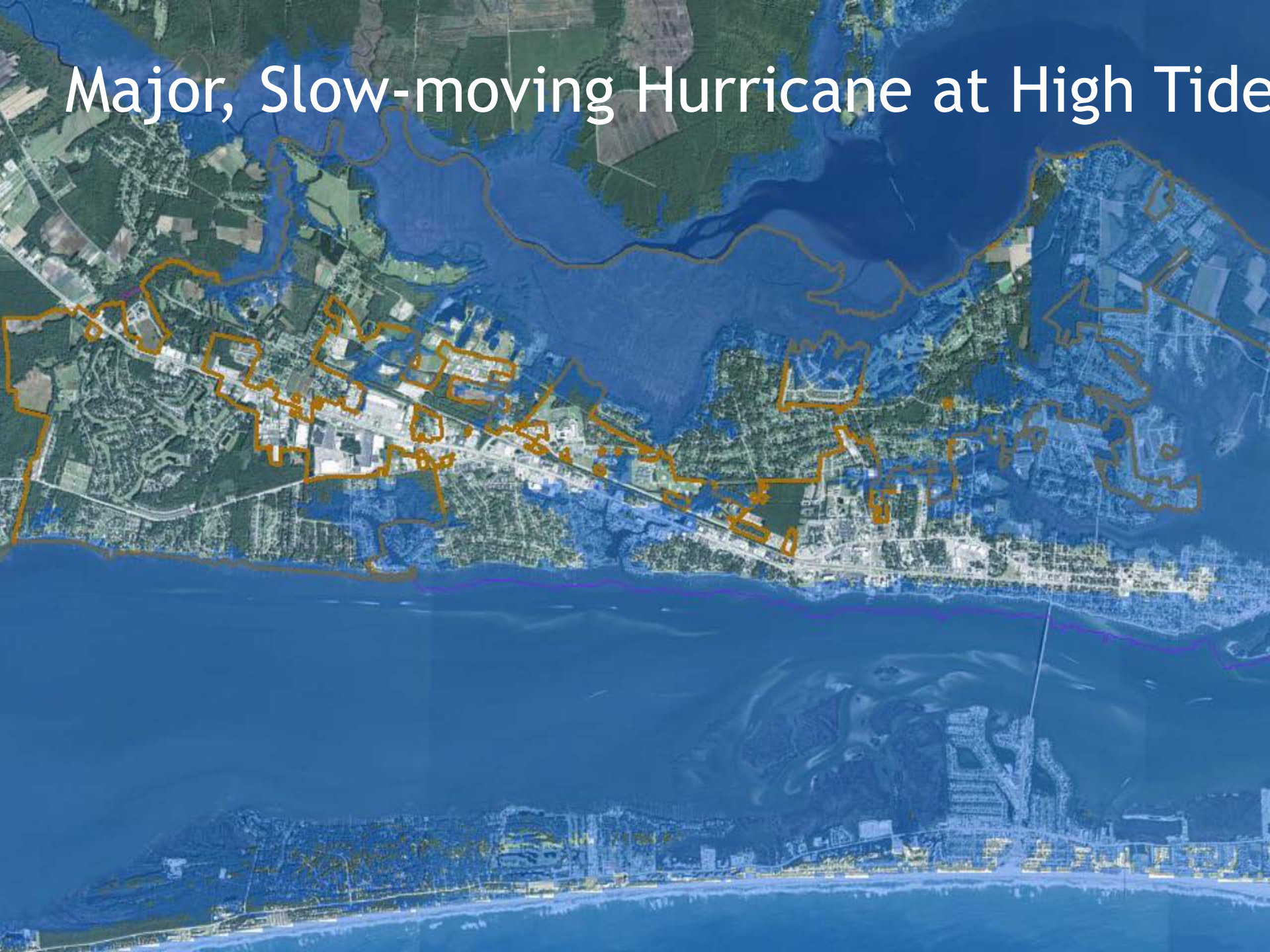
Morehead City June 2016

Runoff Ponding and Groundwater

Street Runoff Flooding in a Mobile Home Park

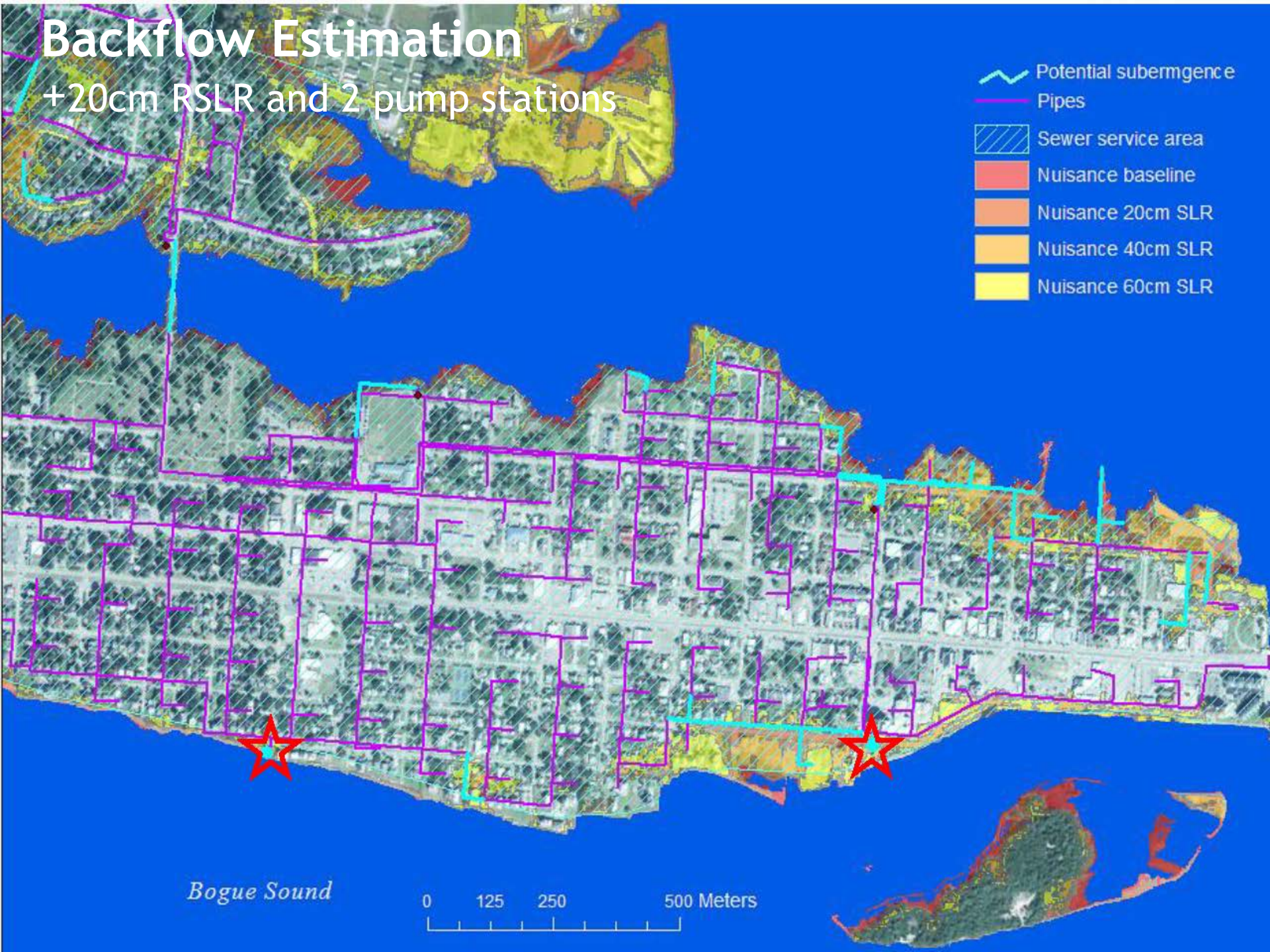
Tidal Flooding and Runoff near a Sewer Pump Station

Major, Slow-moving Hurricane at High Tide



Backflow Estimation

+20cm RSLR and 2 pump stations



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

- Diminished volume of aerobic soil in vadose zone
- Lower O2 solubility and decrease in the vadose/freeboard zone
- Overall pathogen removal functions of OWTS decline
- "..*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)

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)

MHC+ETJ Onsite Wastewater Treatment Groundwater Risk

Today

+20cm RSLR

+40cm RSLR

+60cm RSLR

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

Dasymetric Mapping – Putting People in Pixels

Census blocks with an example block in yellow containing 259 people. Much of this block polygon contains tidal creek and marsh area.

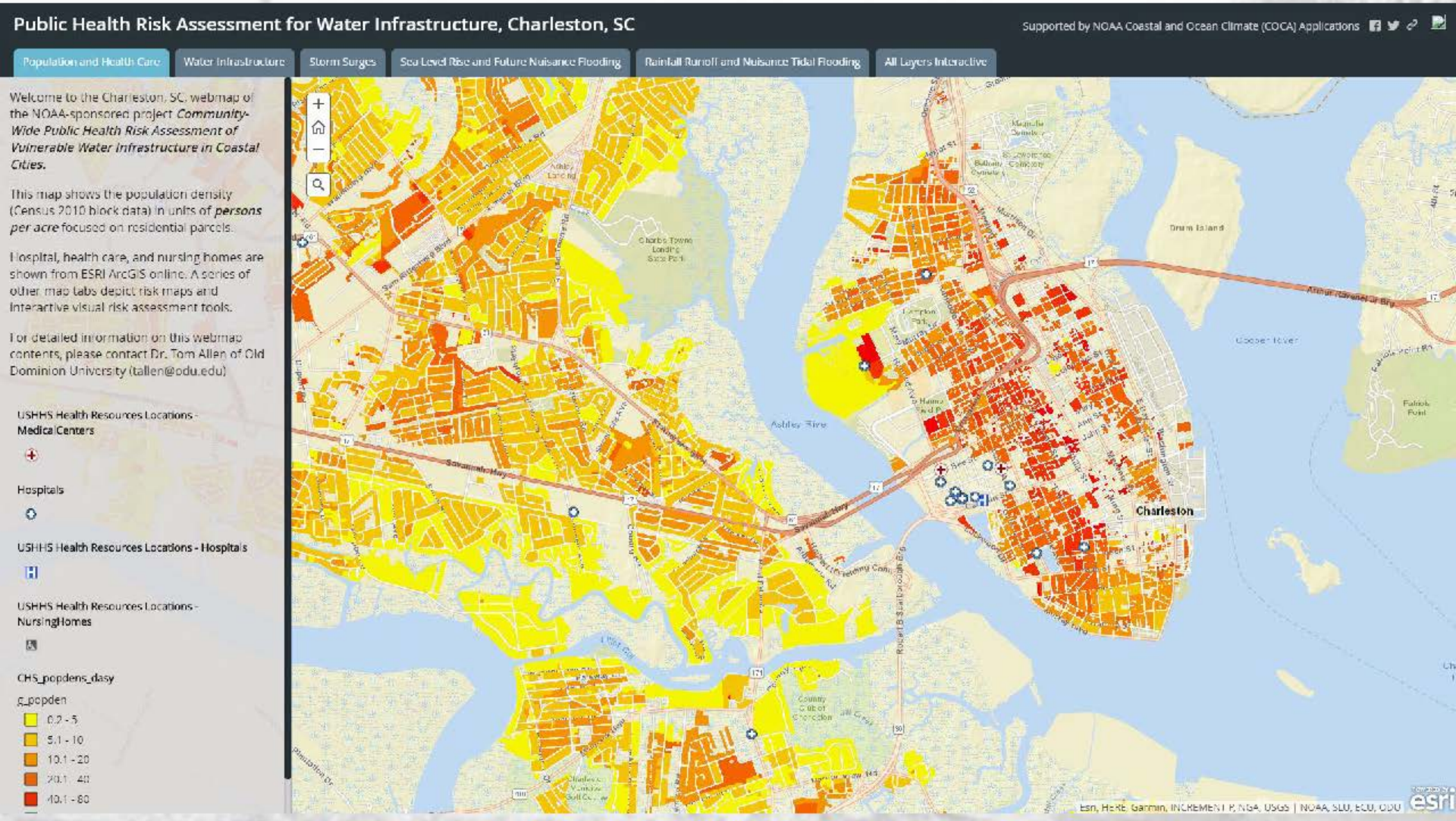
James Island with Charleston Harbor to the north.

Dasymetric Mapping – Putting People in Pixels

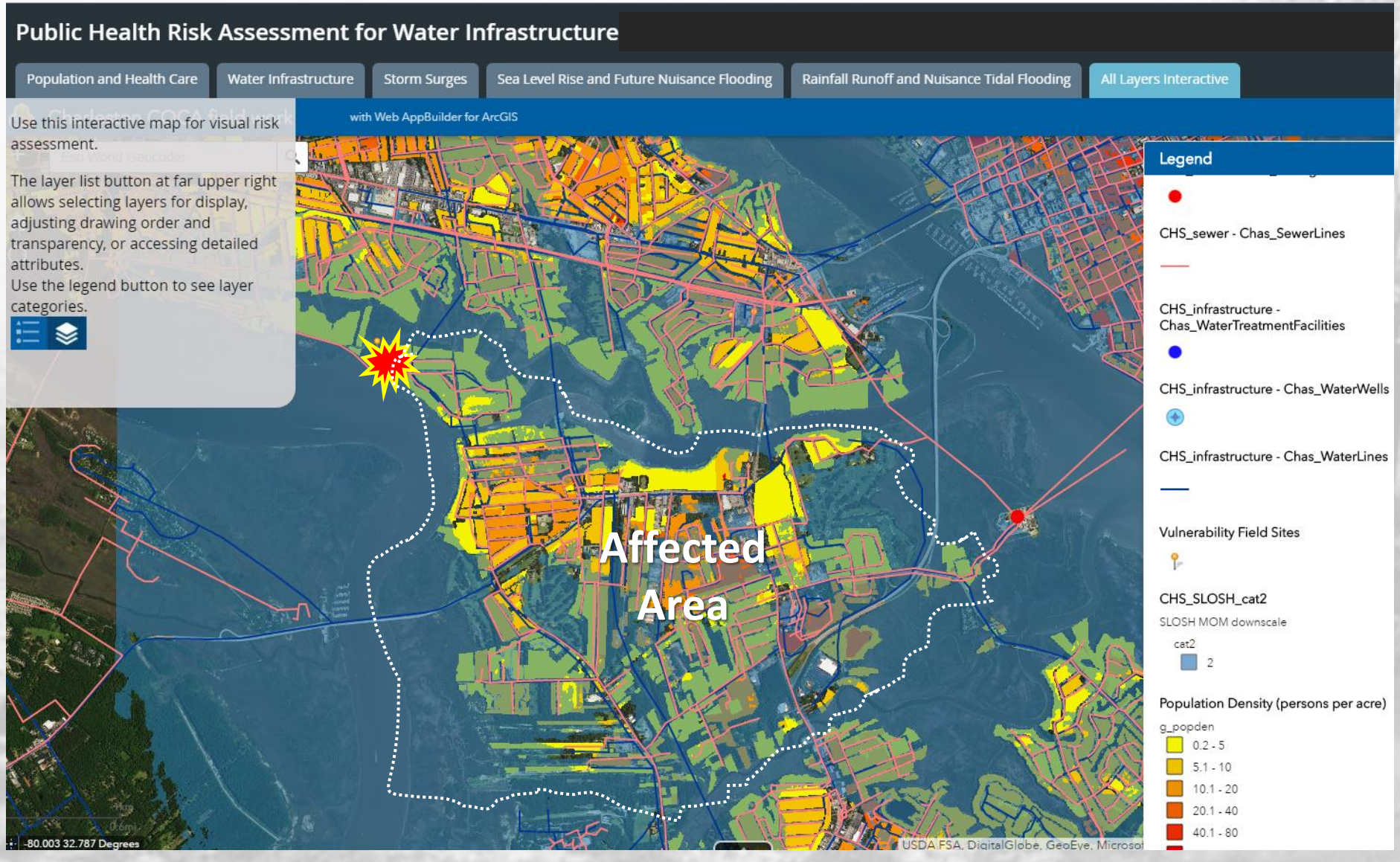
Final population density at 20 ft pixel resolution.

Note: Highest legend values not present in this area but are present in Charleston urban core on the peninsula.

Public Health Workshop WebApp



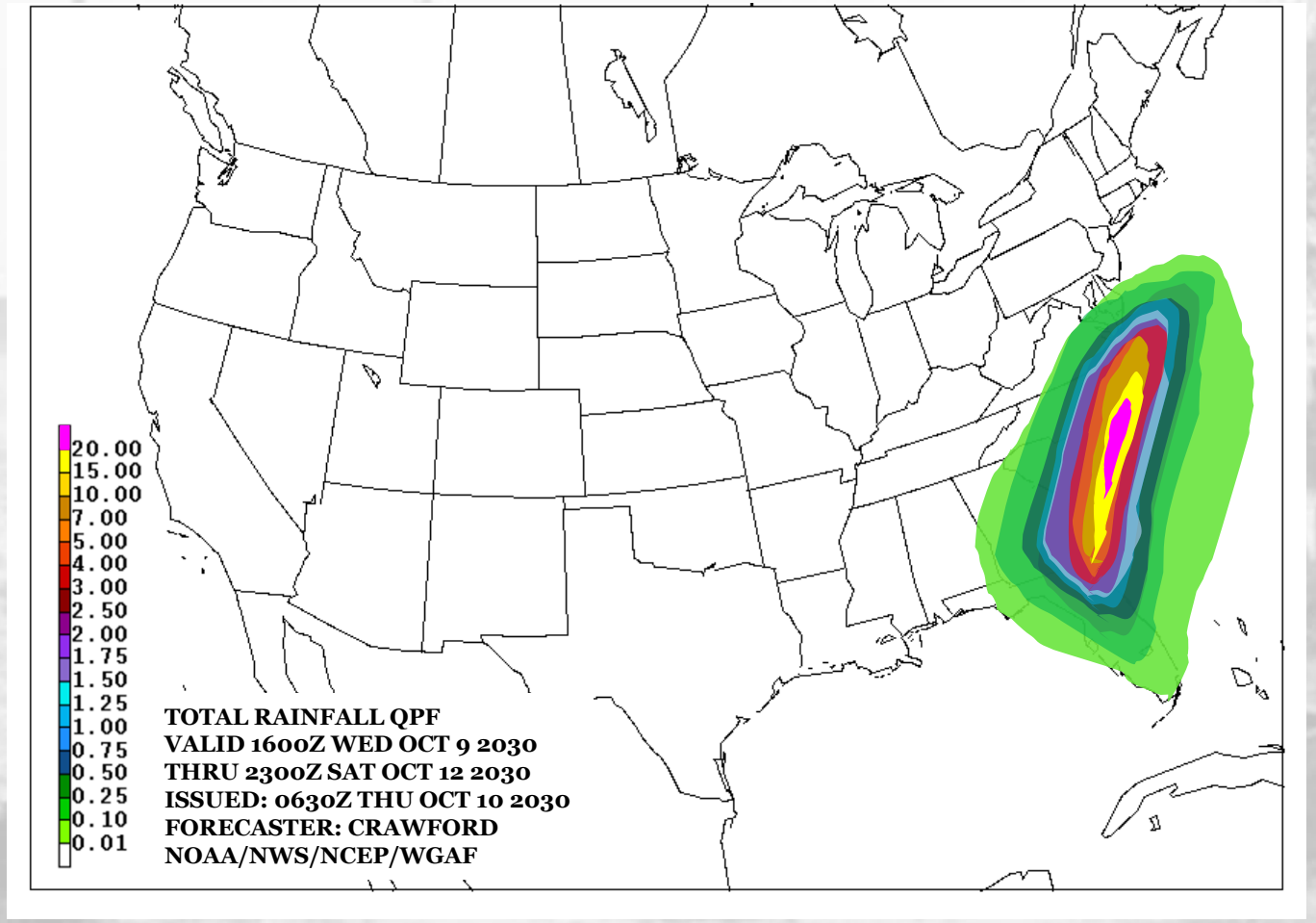
Hurricane landfall, surge and loss of power, gas, and water



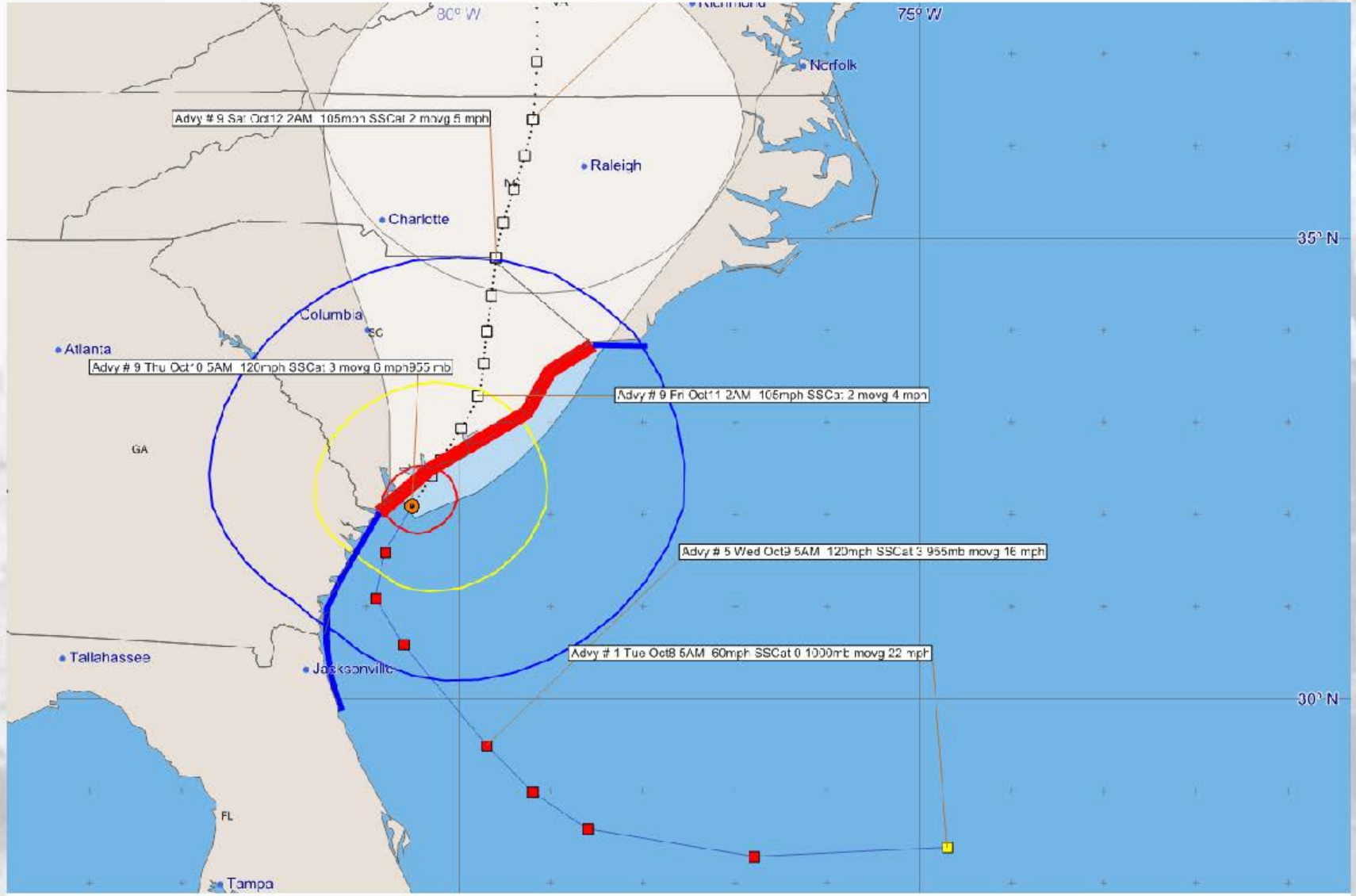
Tabletop Exercise

- Two workshops for Charleston and Morehead City, September 2017 and March 2018
- Functional scenario exercise
- Map analysis
- 2x2 matrix risk assessment
- 4x4 resilience assessment

Precursor Rainfall Event and Cumulative Rainfall

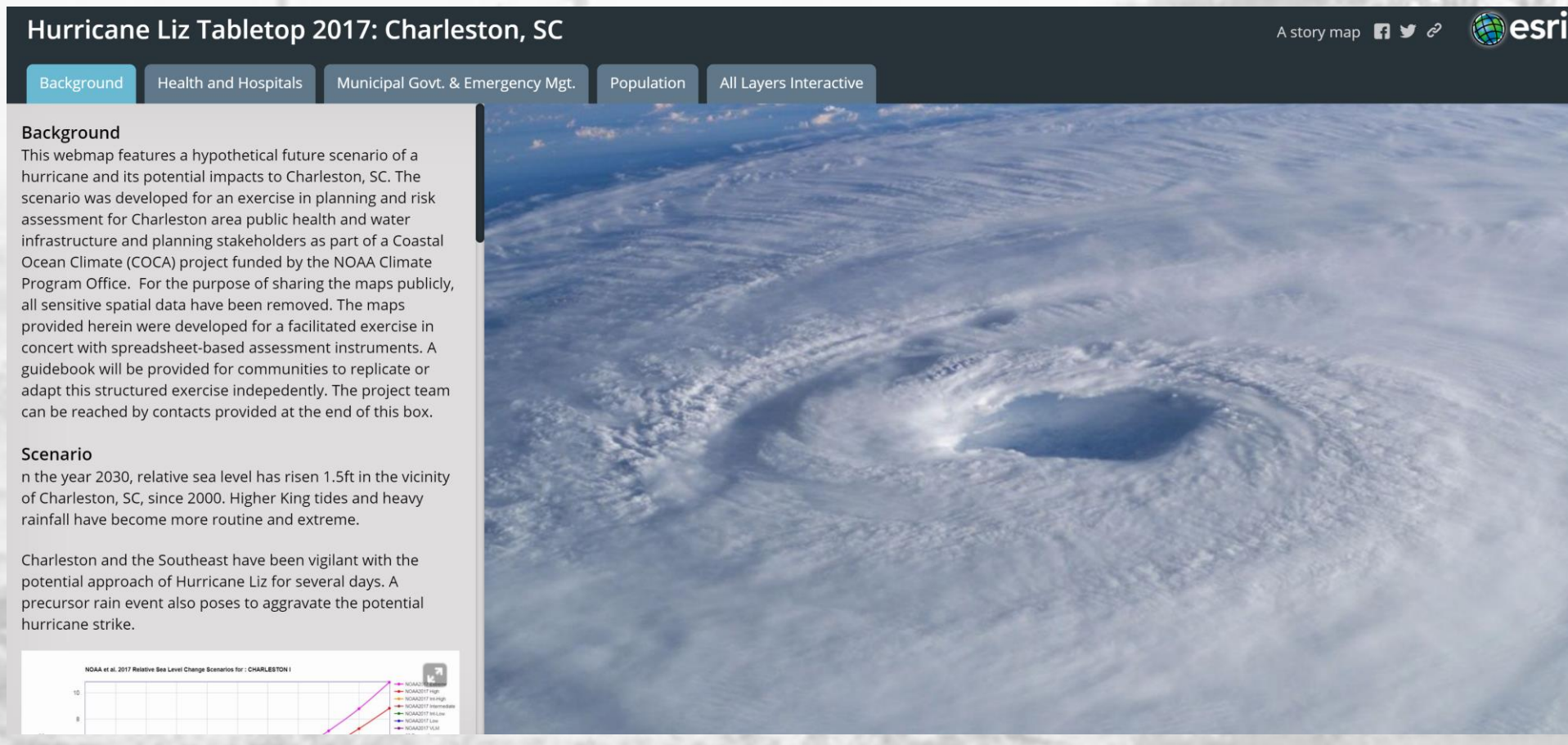


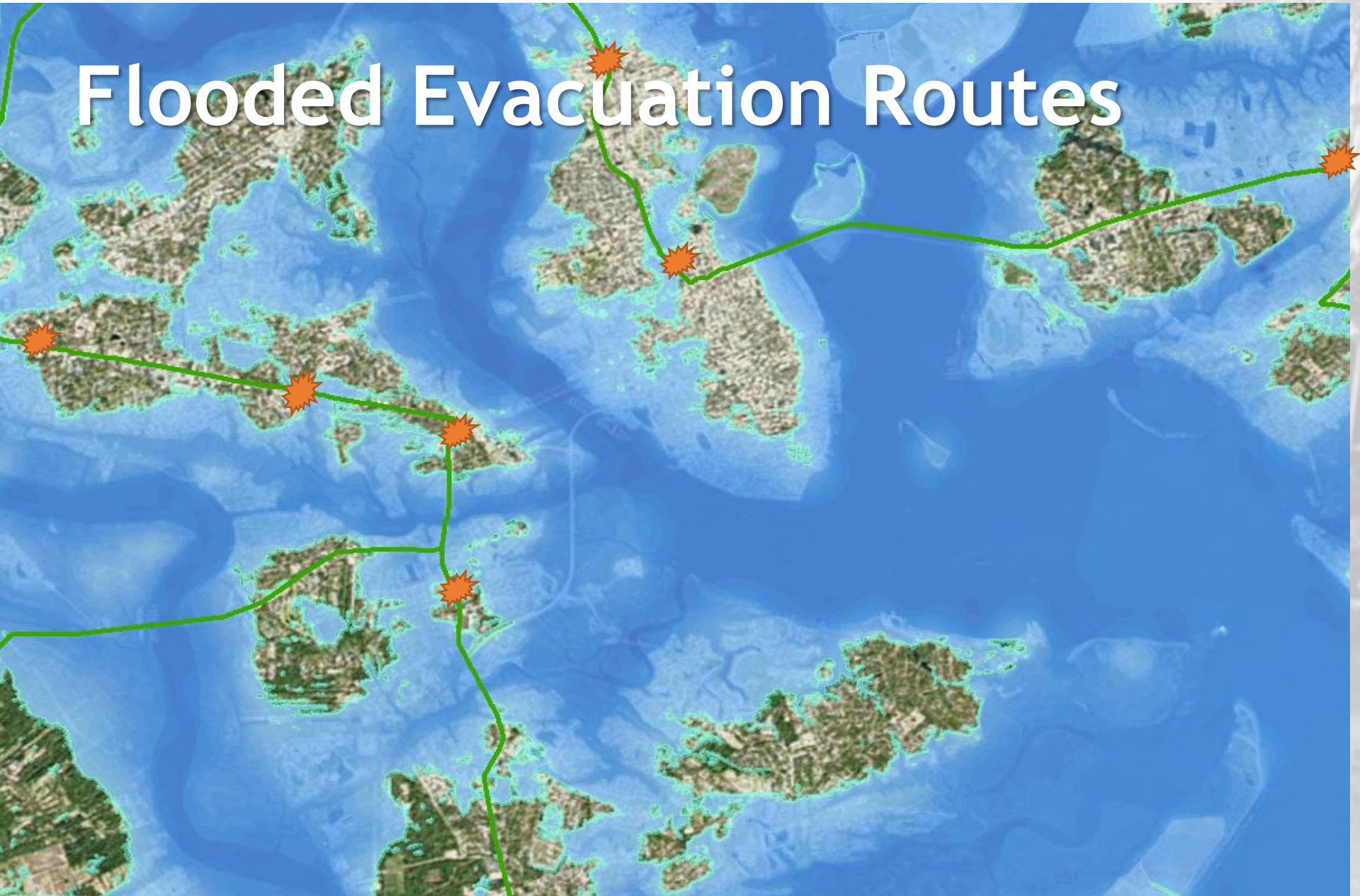
Hurricane Track and Evacuation Simulation

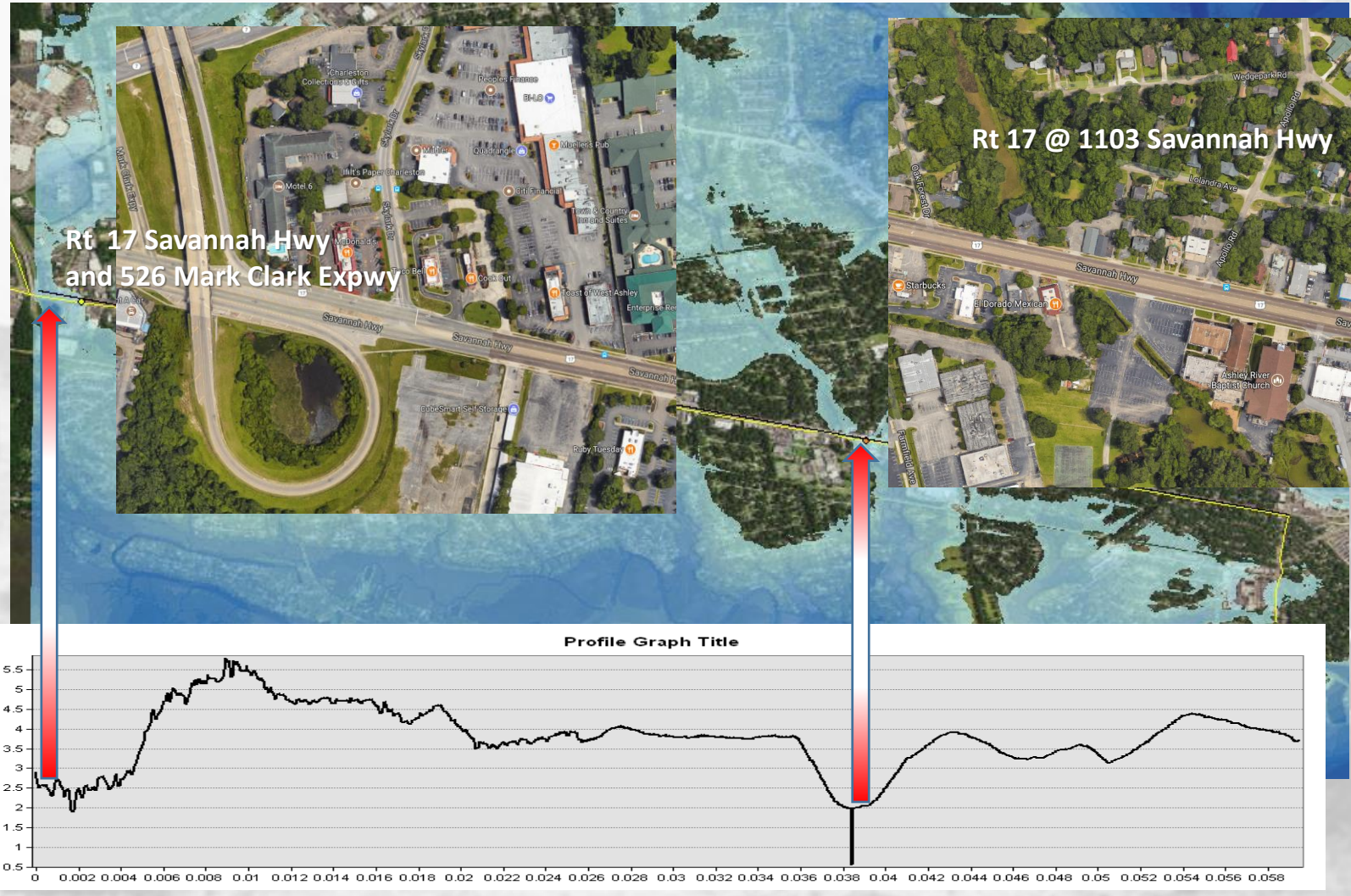


Charleston Hurricane Liz 2030 Tabletop

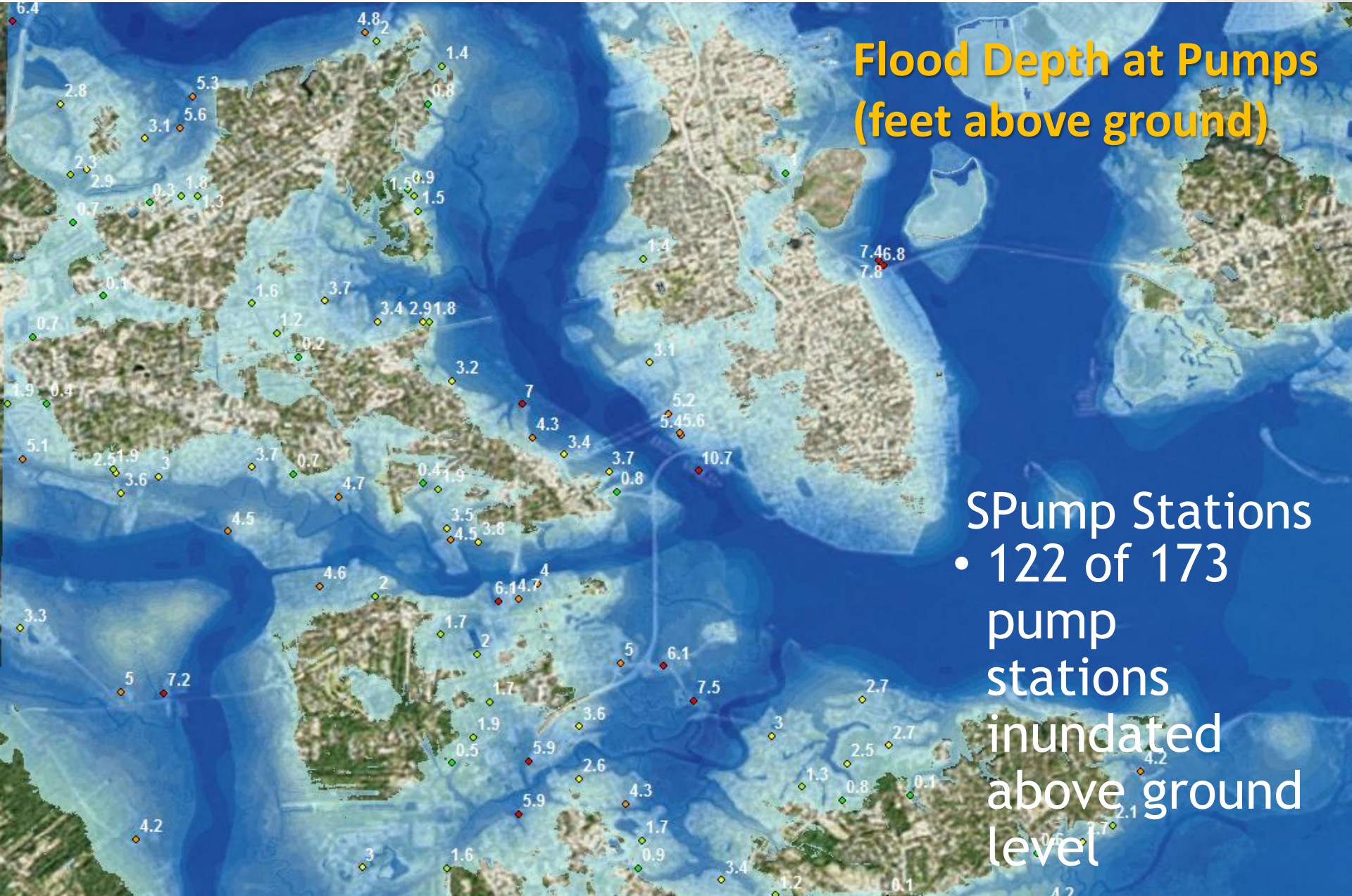
- https://arcg.is/qrCG5

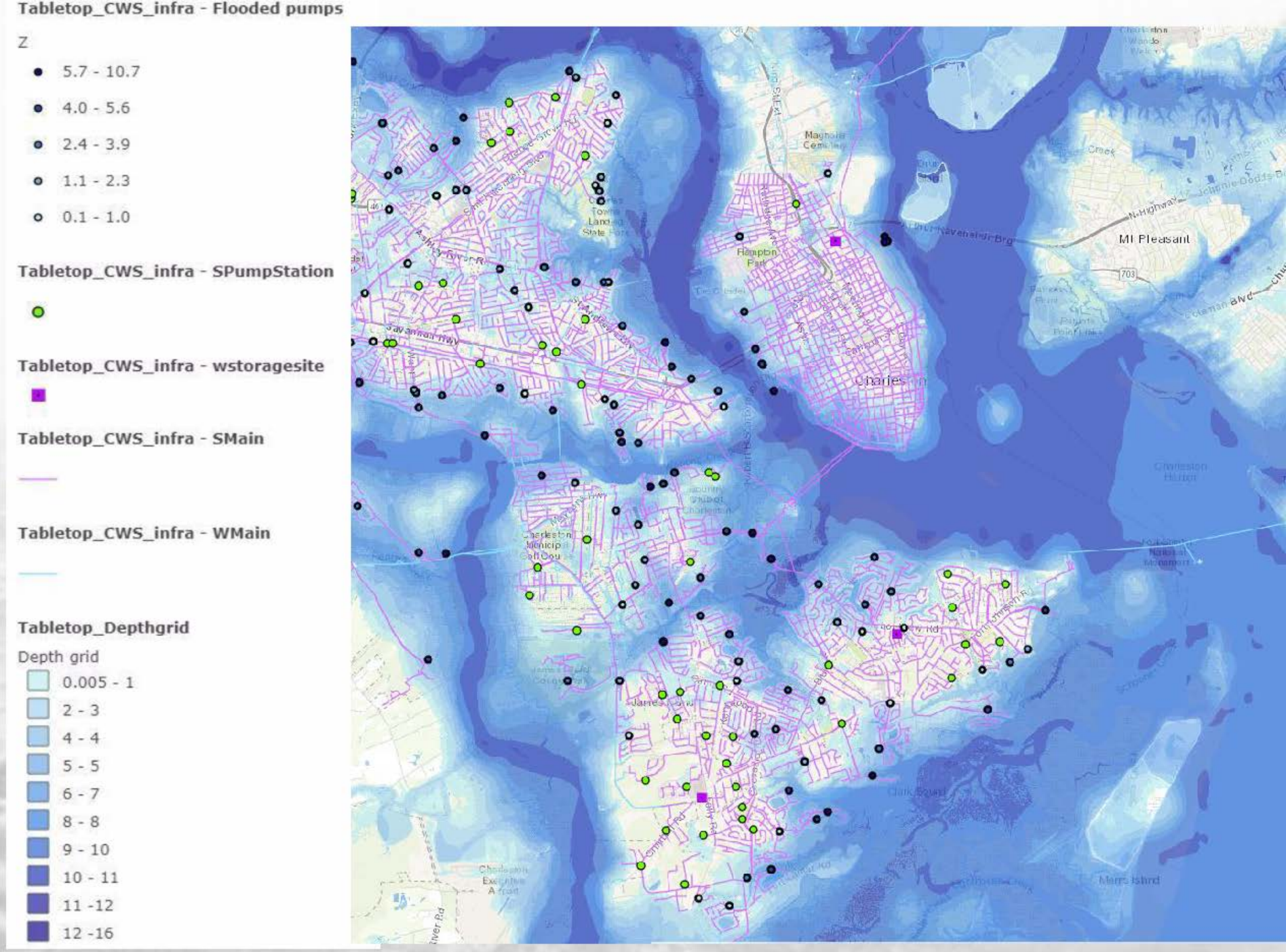



Flooded Evacuation Routes


Rt 17 Savannah Hwy
and 526 Mark Clark Expwy
Rt 17 @ 1103 Savannah Hwy
Profile Graph Title
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0 0.002 0.004 0.006 0.008 0.01 0.012 0.014 0.016 0.018 0.02 0.022 0.024 0.026 0.028 0.03 0.032 0.034 0.036 0.038 0.04 0.042 0.044 0.046 0.048 0.05 0.052 0.054 0.056 0.058

Water Infrastructure




Tabletop_CWS_infra - Flooded pumps
Z
5.7 - 10.7
4.0 - 5.6
2.4 - 3.9
1.1 - 2.3
0.1 - 1.0
Tabletop_CWS_infra - SPumpStation
Tabletop_CWS_infra - wstoragesite
Tabletop_CWS_infra - SMain
Tabletop_CWS_infra - WMain
Tabletop_Depthgrid
Depth grid
0.005 - 1
2 - 3
4 - 4
5 - 5
6 - 7
8 - 8
9 - 10
10 - 11
11 -12
12 -16
Mt Pleasant
Charles
Magnolia Cemetery
Hampton Park
Marrs Island

Map layers in this pane highlight public safety and emergency management, including evacuation routes and historical road closures during prior extreme coastal flooding.

Tabletop_Govt_EMgt - Police_Stations

Tabletop_Govt_EMgt - Fire_Stations

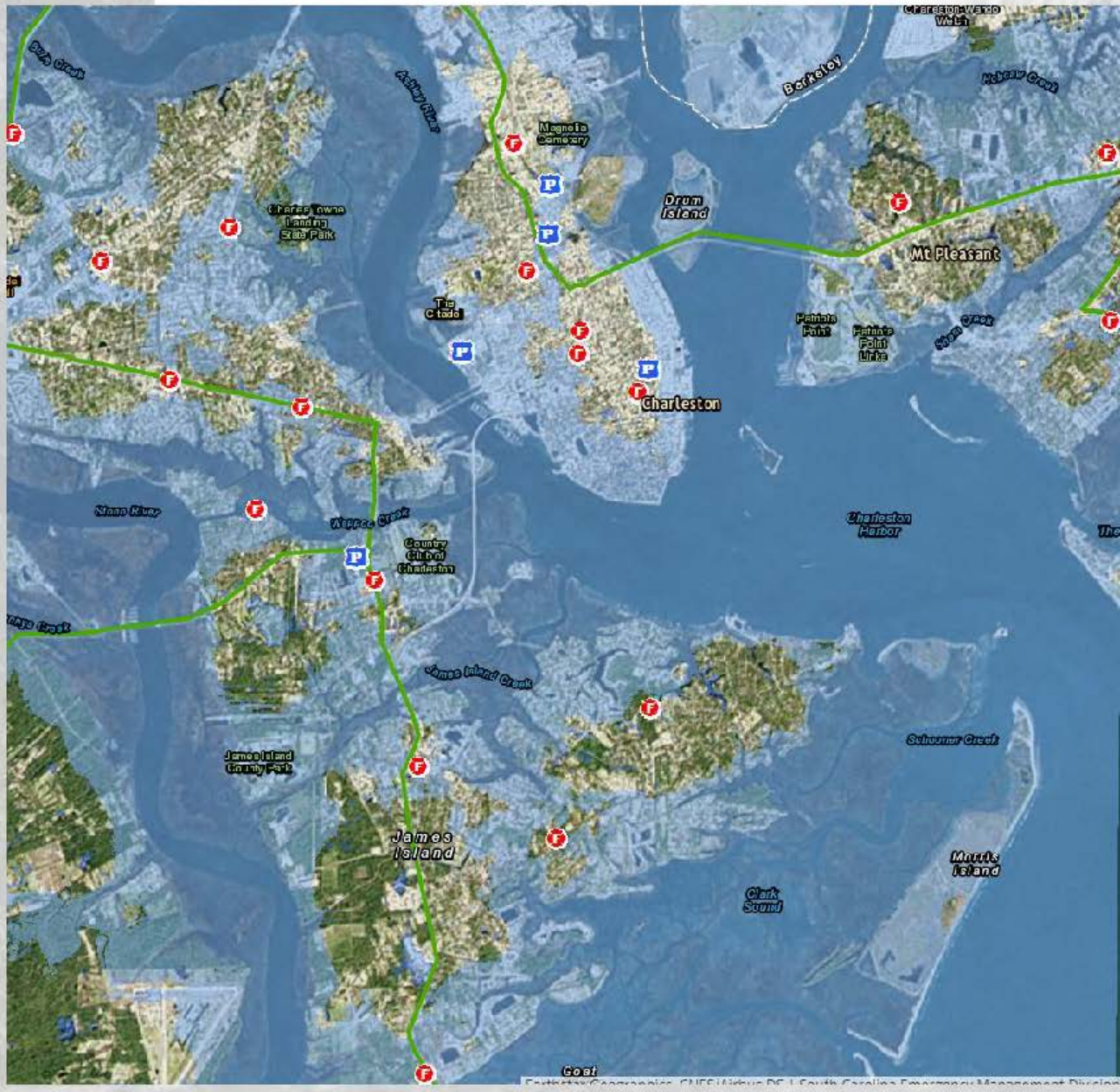
Tabletop_Govt_EMgt - Charleston_SC_Road_Closures

- FLOOD 1/15/2016
- FLOOD 10/1/2015 - 10/6/2105
- FLOOD 10/27/2015 - 10/28/2105
- FLOOD 10/9/2015
- FLOOD 11/3/2015
- FLOOD 11/9/2015
- FLOOD 8/81/2015
- TS COLIN / KING TIDE
- TS JULIA

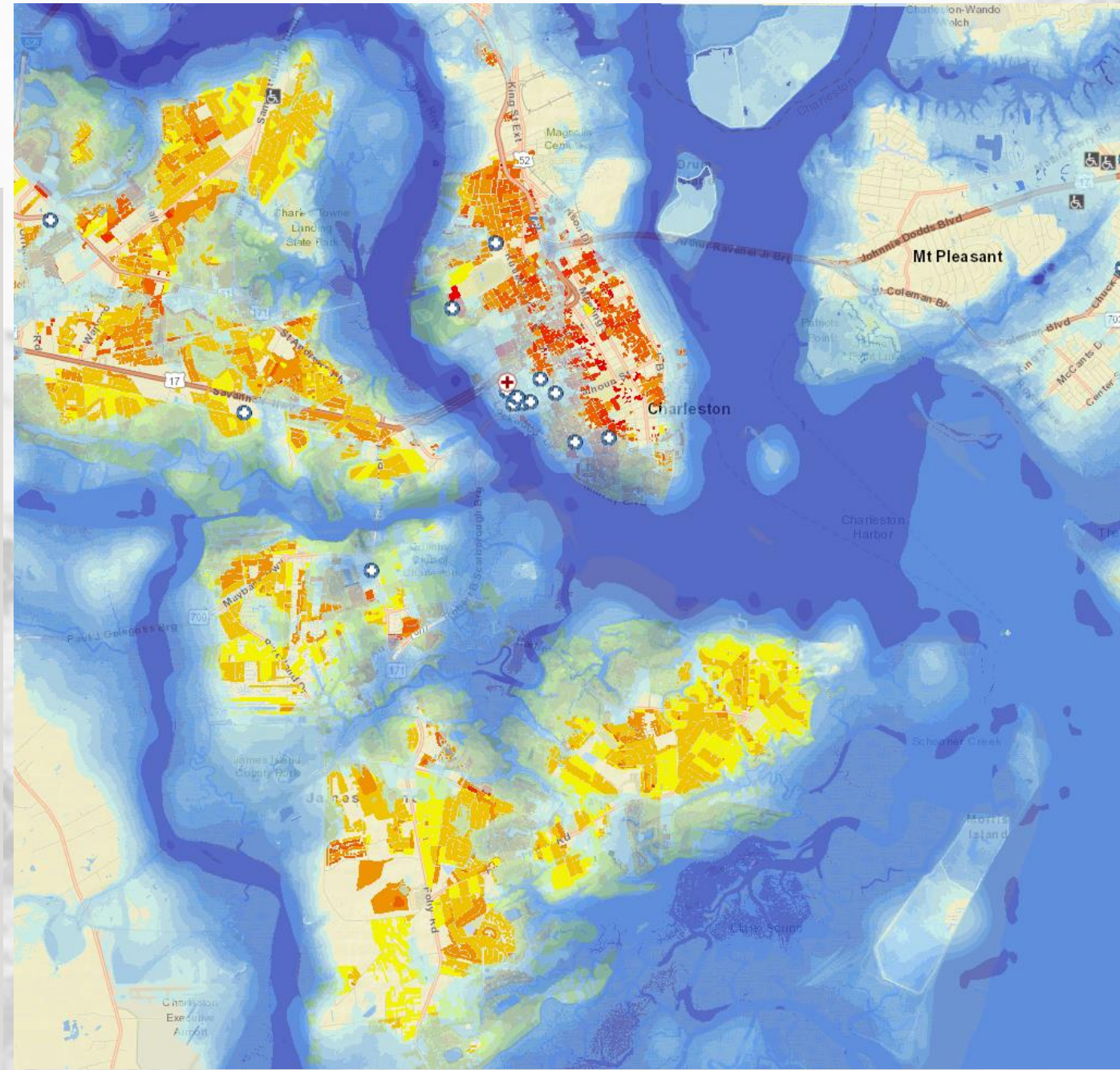
Tabletop_Govt_EMgt - Evacuation route

Tabletop_Govt_EMgt - Hurricane_Shelters_2013

Tabletop_flooded_poly



Population Exposure to Flooding



Hospital and Health Care

- Dialysis
- Pharmacies
- Nursing homes, elderly assisted living, group homes
- OB-GYN
- Mental health
  - Private counseling
  - Outpatient
  - Addiction therapy

Health Services

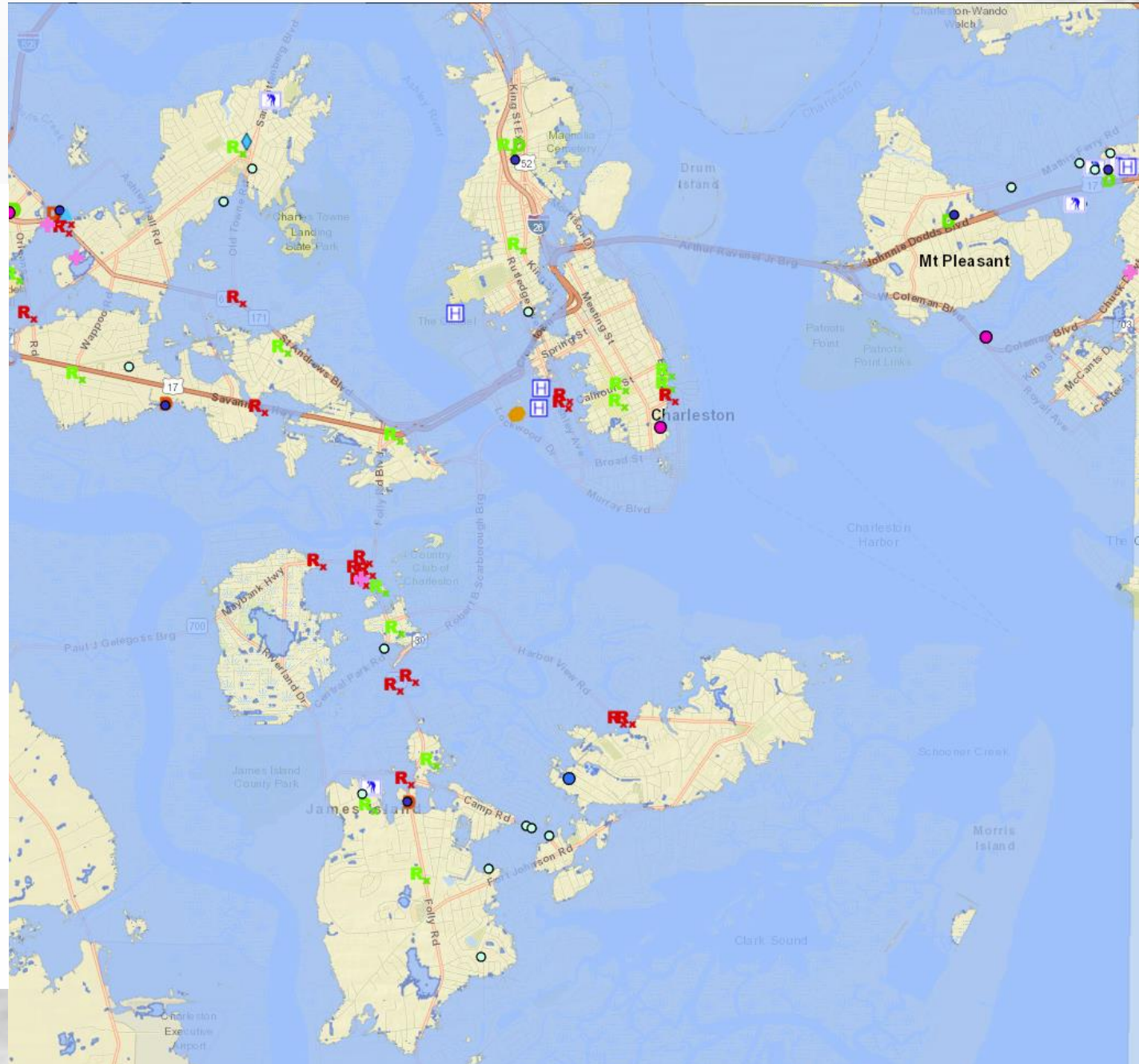
- HL- Adult Day Care
- HL- Ambulatory Surgery
- HL- Community Residential Care Facility
- HL- Habilitation R15
- HL- Hospice Program
- HL- Hospital or Institutional General Infirmary
- HL- Inhome Care Provider
- HL- Nursing Home
- HL- PSAD Inpatient
- HL- PSAD Outpatient
- HL- Renal Dialysis

Dialysis

- D Not flooded
- D Flooded

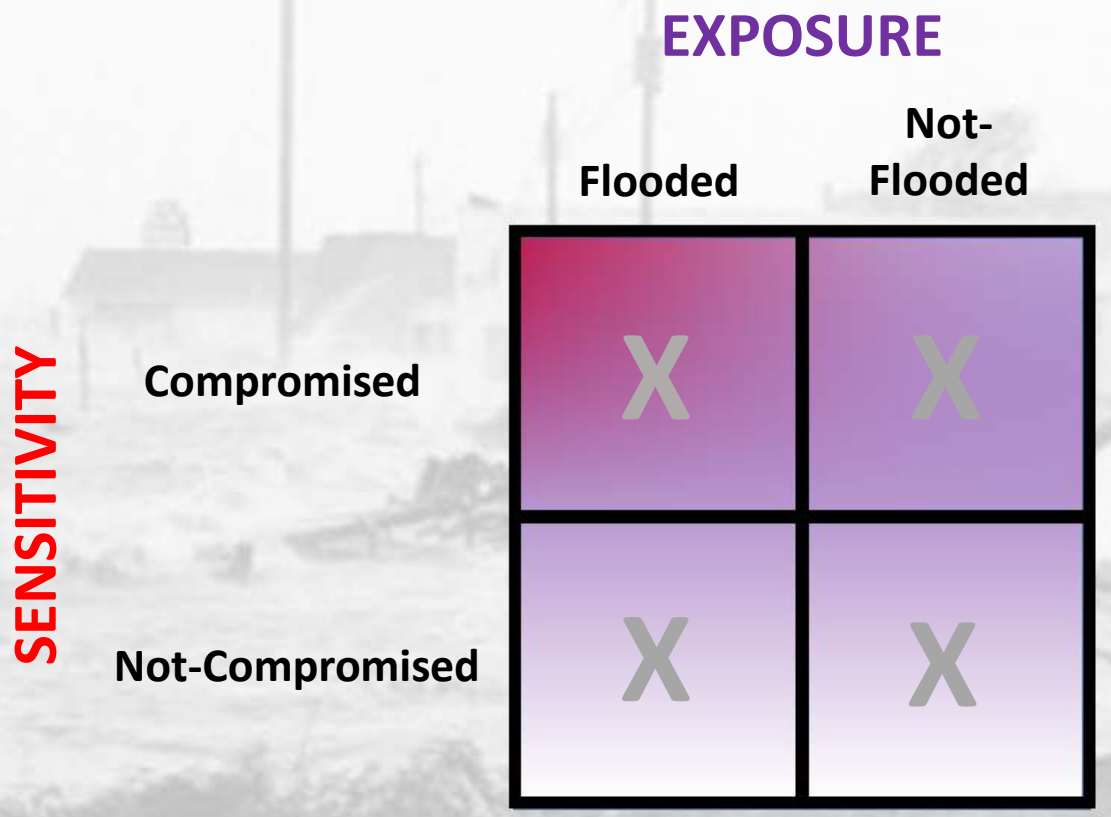
Pharmacy

- Rx Not flooded
- Rx Flooded



2X2 Matrix Model

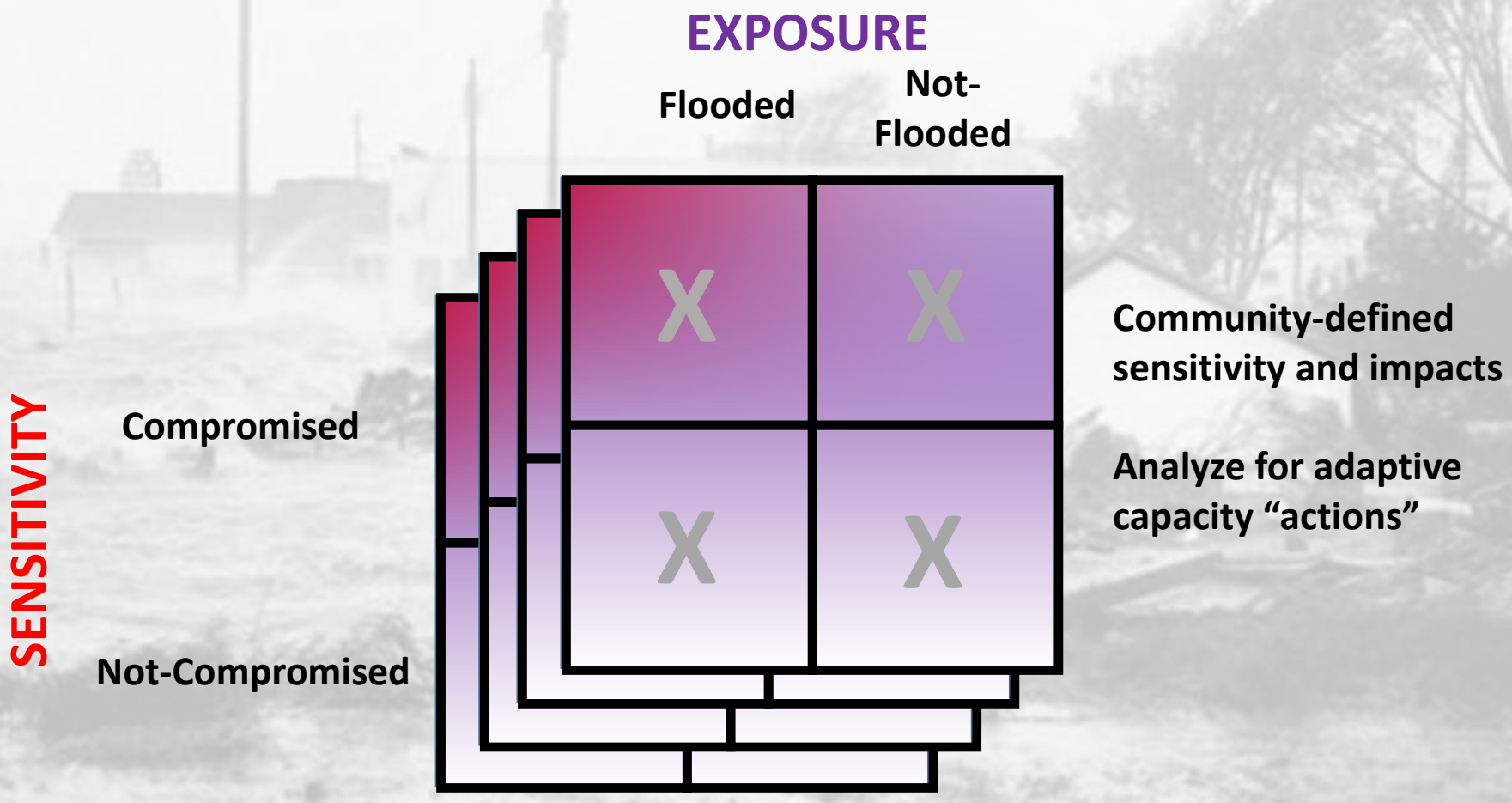
Exposure vs. Sensitivity



Community-defined sensitivity and impacts

Analyze for adaptive capacity “actions”

2X2 Matrix Model of Exposure vs. Sensitivity



Sector:
- ☐ Water Infrastructure
- ☐ Healthcare System
- ☐ Municipal Government
- ☐ Population

Layer
- ☐ Sewage Treatment Facilities
- ☐ Sewer Lines
- ☐ Water Treatment Facilities
- ☐ Wells
- ☐ Water Lines

- ☐ Hospitals
- ☐ Home Health Services
- ☐ Medical Centers
- ☐ Nursing Homes
- ☐ Population Density

Area
- ☐ Peninsul
- ☐ West Ashley
- ☐ James Island

Scenario
- ☐ Nuisance Floodin
- ☐ Runoff
- ☐ Cat 1
- ☐ Cat 2
- ☐ Cat 3

	Inundated	Not Inundated
Compromised	Coverage/Score: Notes: (i.e. expo etc.)	Coverage/Score:
Not Compromised	Coverage/Score Notes:	

Impact Scoring:

1. **No impact, full, normal function**
2. **Sporadic or partial disruption of service, local outage, miniminal damages**
3. **Partial service disruption, localized functions offline**
4. **Widespread and prolonged service disruption, multiple core segments offline or damaged**
5. **Complete service disruption, emergency declared, long-term impact/recovery**

Impact Scoring:

1: No impact, full function
2: Sporadic or partial disruption of service, local outage, nominal damages
3: Partial service disruption, localized functions offline
4: Widespread service disruption, multiple core segments offline or damaged
5: Complete service disruption, emergency declared, long-term impact

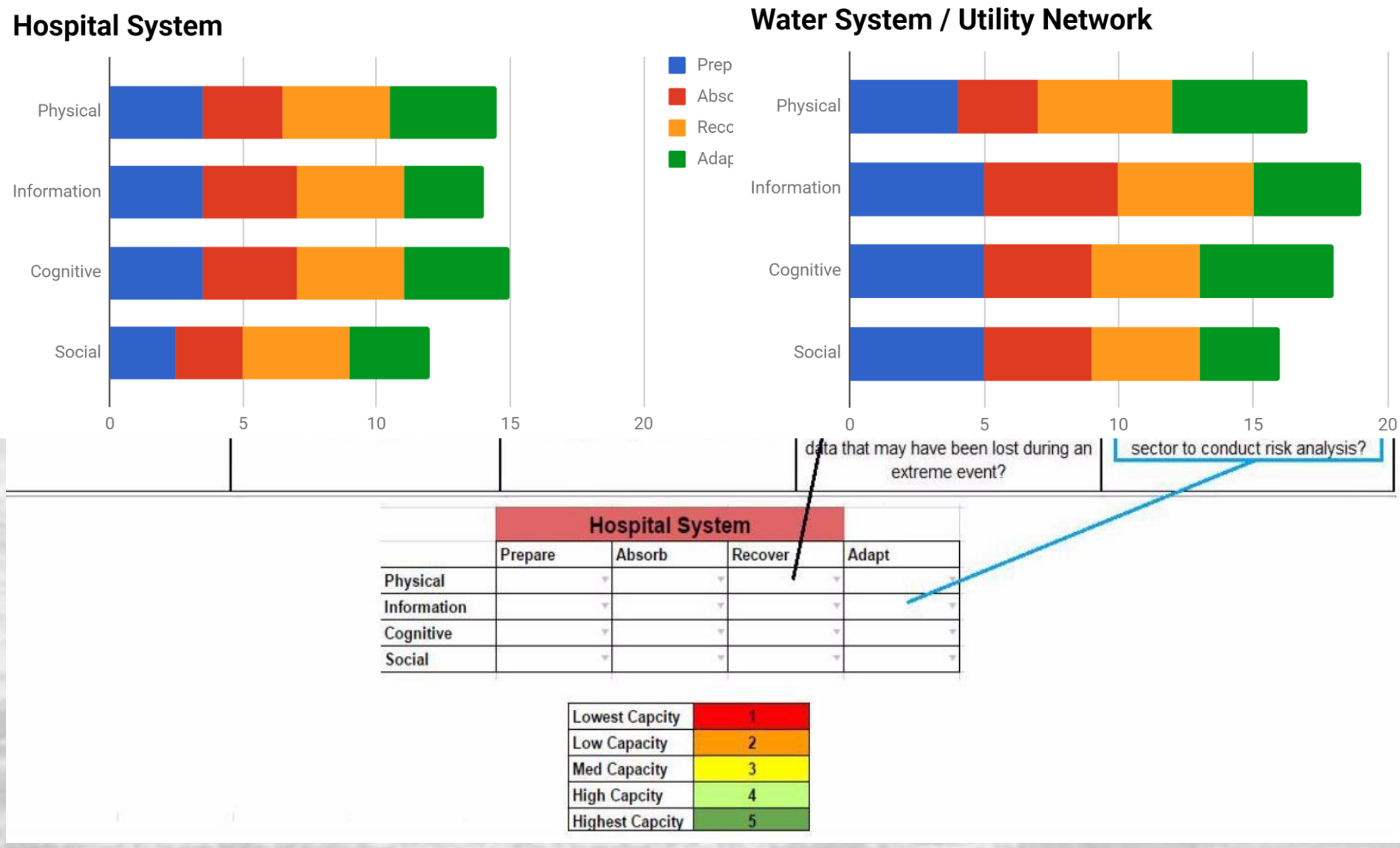
2x2 Lessons

Water: Opened our eyes – 3 utilities here and some things we thought about, but some we took for granted (like bigger tires on vehicles). For us at CWS about to do hotwash for Irma on Friday – want to open this Google Doc and share with them because these are some things we should be thinking of.

Municipal: useful because knew County preparedness was good but adaptability not so much and it's a political fight. 4X4 shows that, need to get this in our annual exercises.

Health: Liked idea about the duck boat idea around Hospital district for amphibious use during event

4x4 Resiliency Matrix



https://docs.google.com/document/d/1Gnzn90WfQZZjcfurcoVa1dvq4RTREIwz6-j40yQHhfg/edit

4x4 Lessons

Above the first floor – where are the pumps located? Where is the airvent located, so it doesn't take water through the pipe. Pumps can be inundated by water. More than generator! Need to be grounded and protected from wind. (-80 fridges), lightening strike could take out generator → might be forced to evacuate

Freezers and fridges and kitchens often on first floor! Almost every hospital!

Not all of the generators have external hookup

Try to conserve water, not eliminate need

Highest use in hospital is the HVAC system (500,000 gallons a day) – sterilizations, dialysis, ICUs, should be doing a business impact analysis before an event so they can divert flow of water, should have shut off values and external hookups for water sources

Would like to see them do it, but do not have wells

Need to treat it as well, filter it for the HVAC system

Flush water after certain period of time to conserve water

Consider more water resistant vehicles (duck tours for example)

If hospital is not working then you can't have people being allowed back
Speed the recovery process

Utility wise – more data for us, projected power outages, winds?? Shut down grids as a precautionary measure,

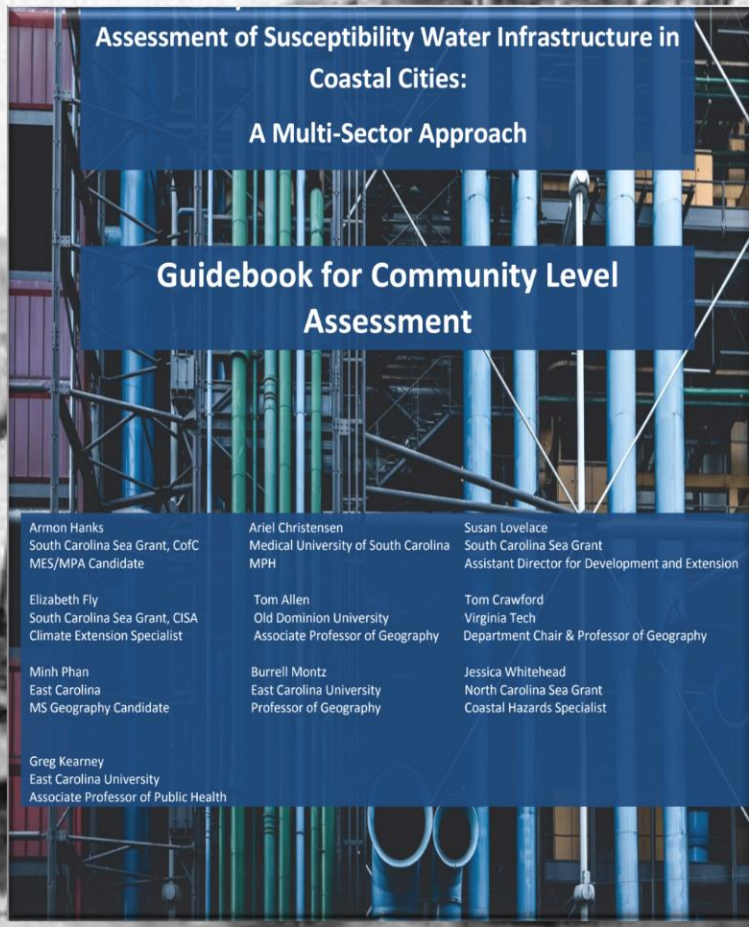
Transferrable to training, it can be used more than an exercise, can be used for preparedness

Planning tool – utility sector

Water is the Achilles heel of every hospital in the country

Conclusions

- Value in exploring future scenarios
  - Exercises + planning + training
  - Multiple hazards
  - Critical review of data and models
- Decision-maker responses
  - Value in sessions across sectors
  - Differential vulnerability
  - Awareness of cumulative, cascading impacts
  - Prototype tools
    - Webapp
    - Tabletop exercise
    - 2x2 and 4x4 matrices
- Guidebook in preparation



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References

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