



MULTI-HAZARD VULNERABILITY
OF COASTAL WATER
INFRASTRUCTURE TO SEA LEVEL,
STORM SURGES, AND RIVERINE
FLOODING

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Burrell Montz, Tom Allen, and Zach Oyer

Dept. of Geography, Planning & Environment
East Carolina University

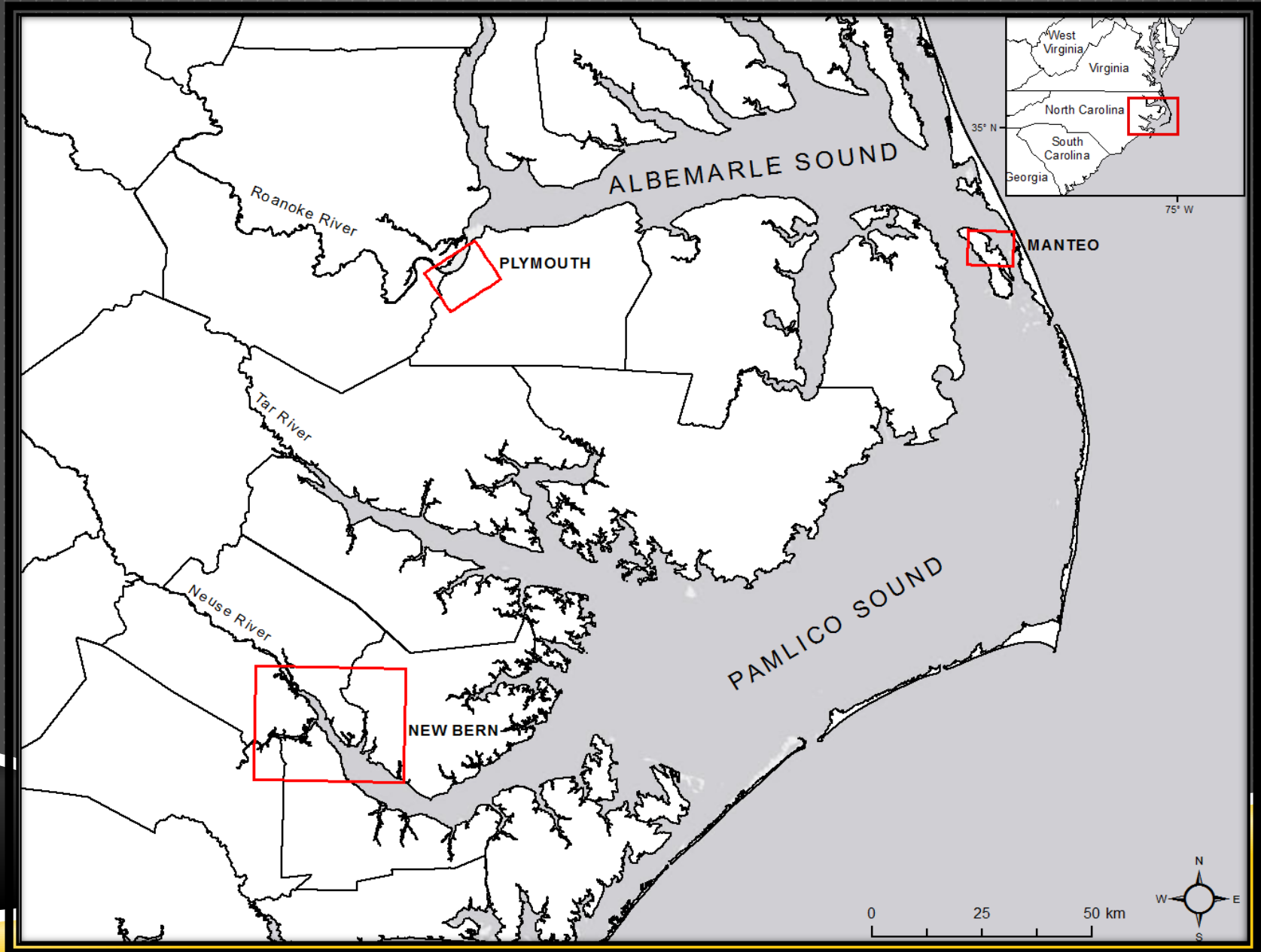
RESEARCH GOAL

- ▶ Understanding and measuring individual and multihazard infrastructure vulnerability
 - ▶ Riverine Flooding
 - ▶ Storm Surge
 - ▶ Sea level Rise
- ▶ In three different coastal and near coastal locations

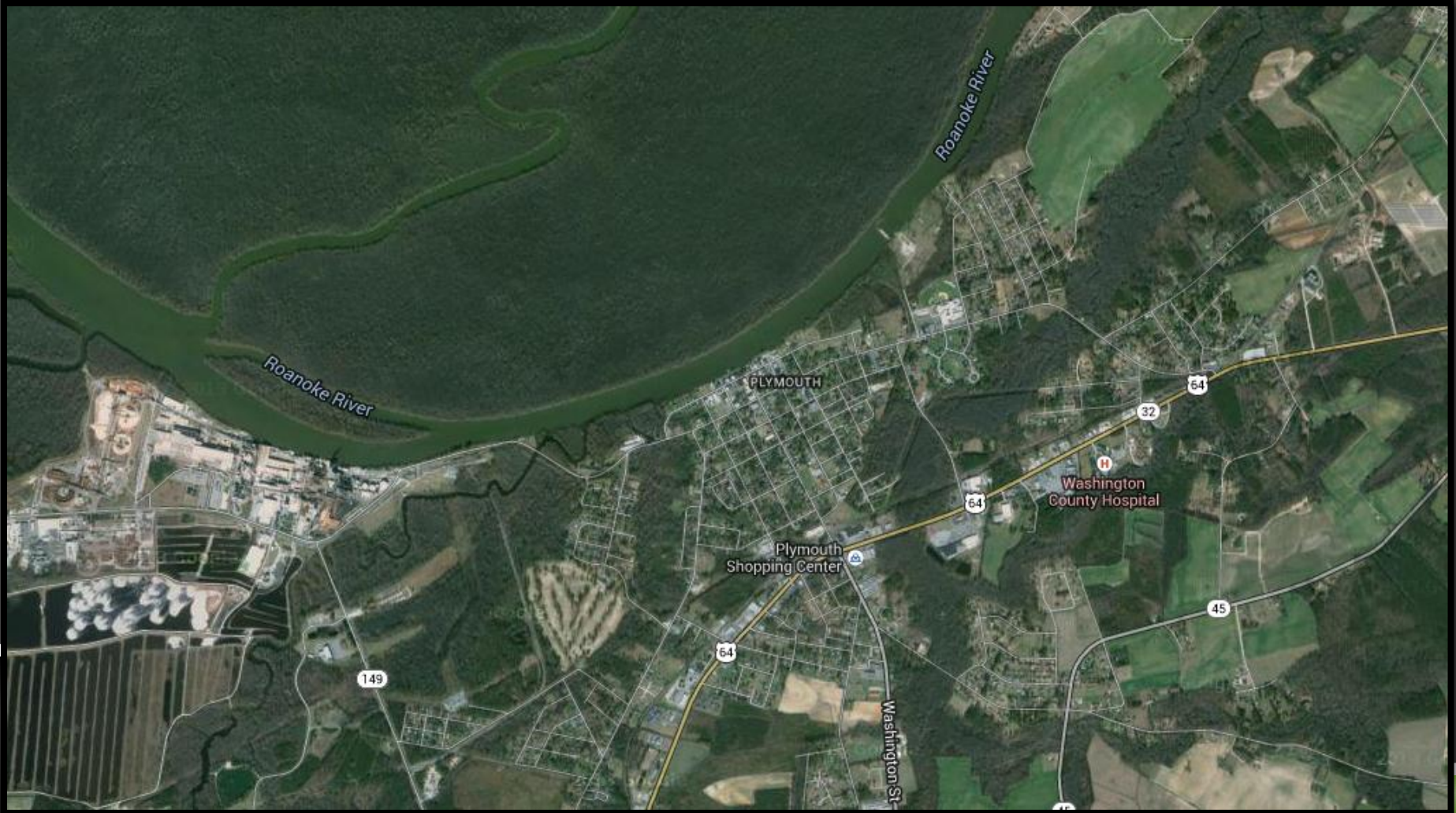
RESEARCH QUESTIONS

- ▶ How vulnerable is the water infrastructure?
- ▶ Which coastal hazard poses the greatest threat for each community?

STUDY AREAS



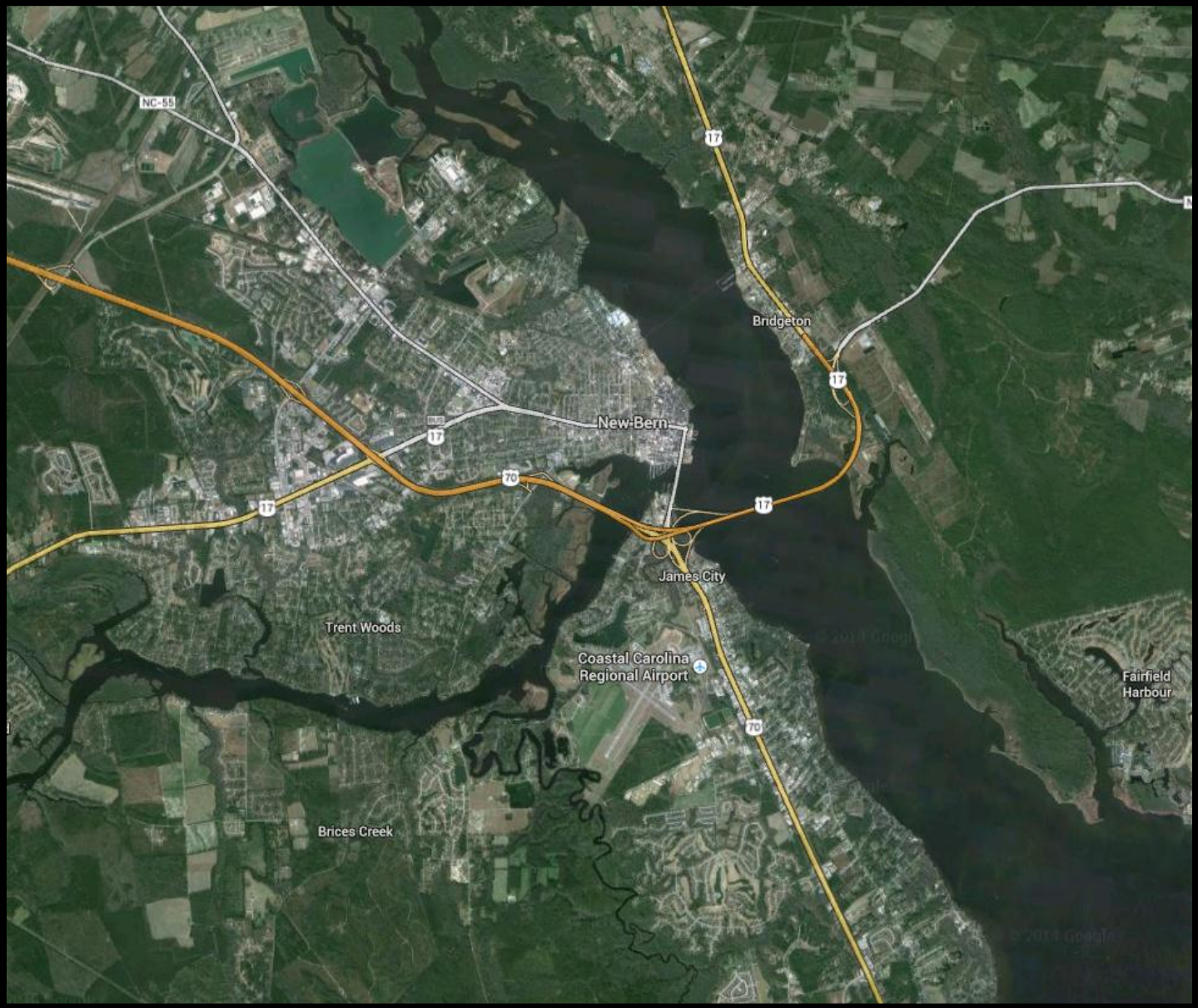
PLYMOUTH



MANTEO



NEW BERN



INFRASTRUCTURE

- ▶ Sanitary sewers

- ▶ pumps, treatment plants, discharge outfalls, land application areas, pipelines, and service areas

- ▶ Water distribution

- ▶ intakes, meters, pumps, tanks, distribution treatment plants, pipes, distribution wells, and distribution service areas

- ▶ Service areas

WORSENING PROBLEMS

▶ Rising Sea Level

- ▶ Estimates of RSLR vary from 3.6 mm/yr to 4.5 mm/yr (Kemp *et al.*, 2009, Kemp *et al.*, 2009)

▶ Population Increase at the Coast

- ▶ 40% of population on 10% of total land cover (U.S. Census Bureau, 2011)
- ▶ 446 people/ mi² on coast to 105 people/ mi² for contiguous US
- ▶ Dare County fastest growing in NC between 1970 and 1995 (Overton *et al.*, 1999)

▶ Storm Intensity Increase

- ▶ Expected increase in storm intensities (IPCC, 2007)
- ▶ Model expectations for intensity to increase 2 to 11%, and increase in frequency of major storms (Knutson *et al.*, 2010)

OTHER CONSIDERATIONS

High Vulnerability of Wastewater Infrastructure

- ▶ Treatment plants are often built in low elevations
- ▶ Some structures underground
- ▶ Health implications from flooding of
- ▶ Expensive facilities and equipment



DATA SOURCES

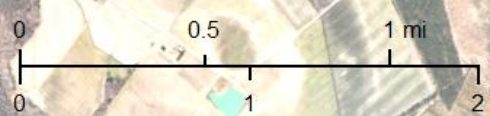
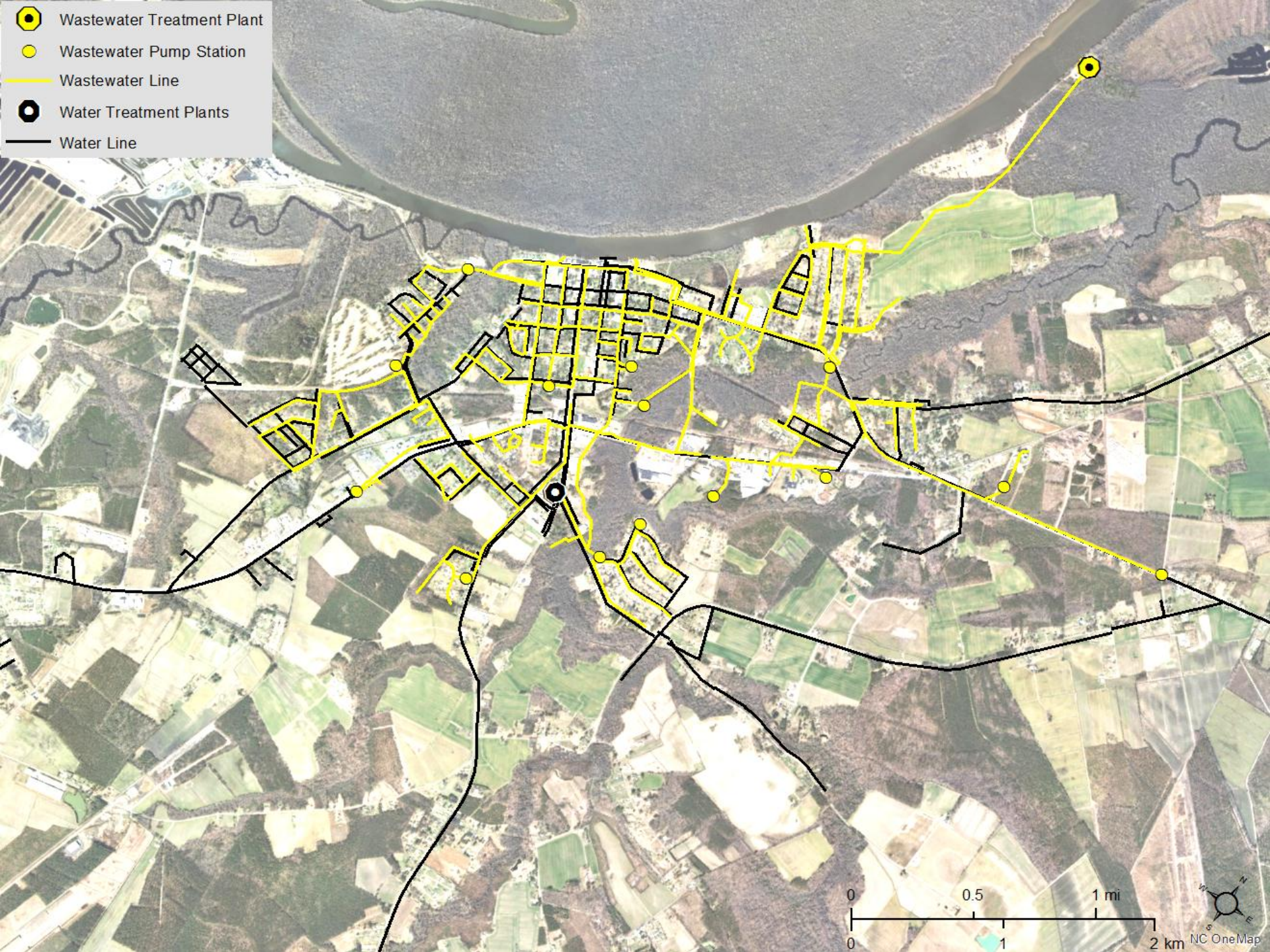
- ▶ NC One Map
- ▶ USGS
- ▶ NOAA and US Census
- ▶ NCFMP

Layer Name	Type of Data/ Resolution	Source	Pub. Date
Wastewater Service Areas	Polygons	NC One Map	3/6/2007
Treatment Plants	Points	NC One Map	3/21/2000
Pump Stations (Manteo, Plymouth)	Points	NC One Map	3/20/2000
Wastewater Pipelines (Manteo, Plymouth)	Lines	NC One Map	3/20/2000
Water Pipelines (Manteo, Plymouth)	Lines	NC One Map	3/28/2000
Pump Stations and Pipelines (New Bern)	Points and Lines	ESRI Map Publisher	1/3/2013
Riverine Floodplains	Polygons	NCFMP	4/16/2013
Dare County and Craven County DEM	20 ft (6.1 m) Raster	NCFMP	9/23/2002
Washington County DEM	20 ft (6.1 m) Raster	NCFMP	9/15/2004
Land Cover	30 m Raster	NOAA	2010
Census Block Groups	Polygons	Census Bureau	2/3/2011
NHD Canal/ditch	Lines	USGS NHD	

WATER INFRASTRUCTURE AND POPULATION

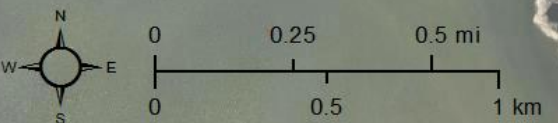
	Manteo	New Bern	Plymouth
Wastewater Treatment Plant	1	4	1
Water Treatment Plant	1	1	1
Wastewater Pump Stations	7	104	14
Water Booster Station	0	3	0
Wastewater Lines (km)	22.38	652.37	55.10
Water Lines (km)	30.33	603.09	72.51
Population serviced by Wastewater	2,547	49,217	3,494

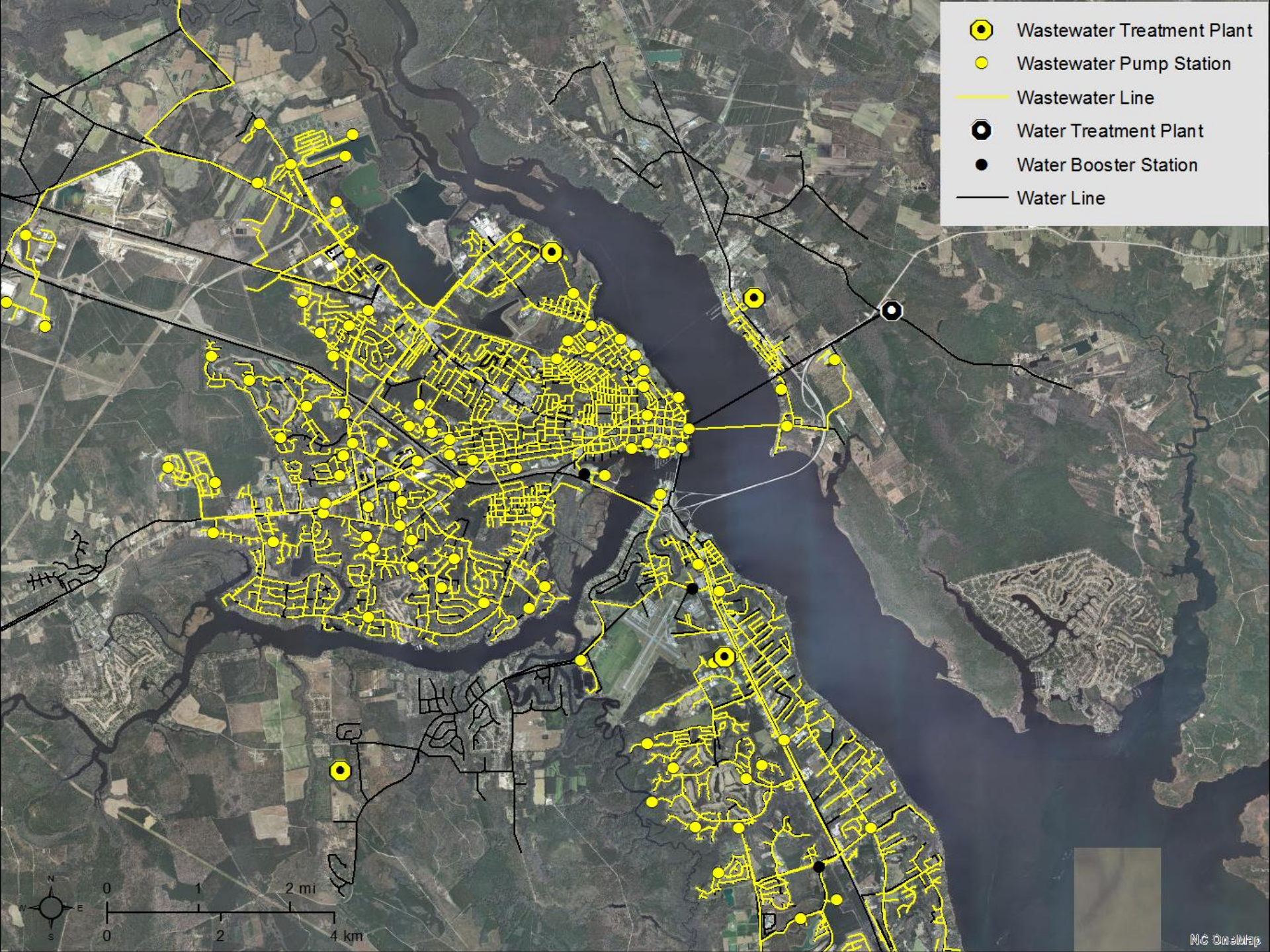
- Wastewater Treatment Plant
- Wastewater Pump Station
- Wastewater Line
- Water Treatment Plants
- Water Line





- Wastewater Treatment Plant
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- Wastewater Treatment Plant
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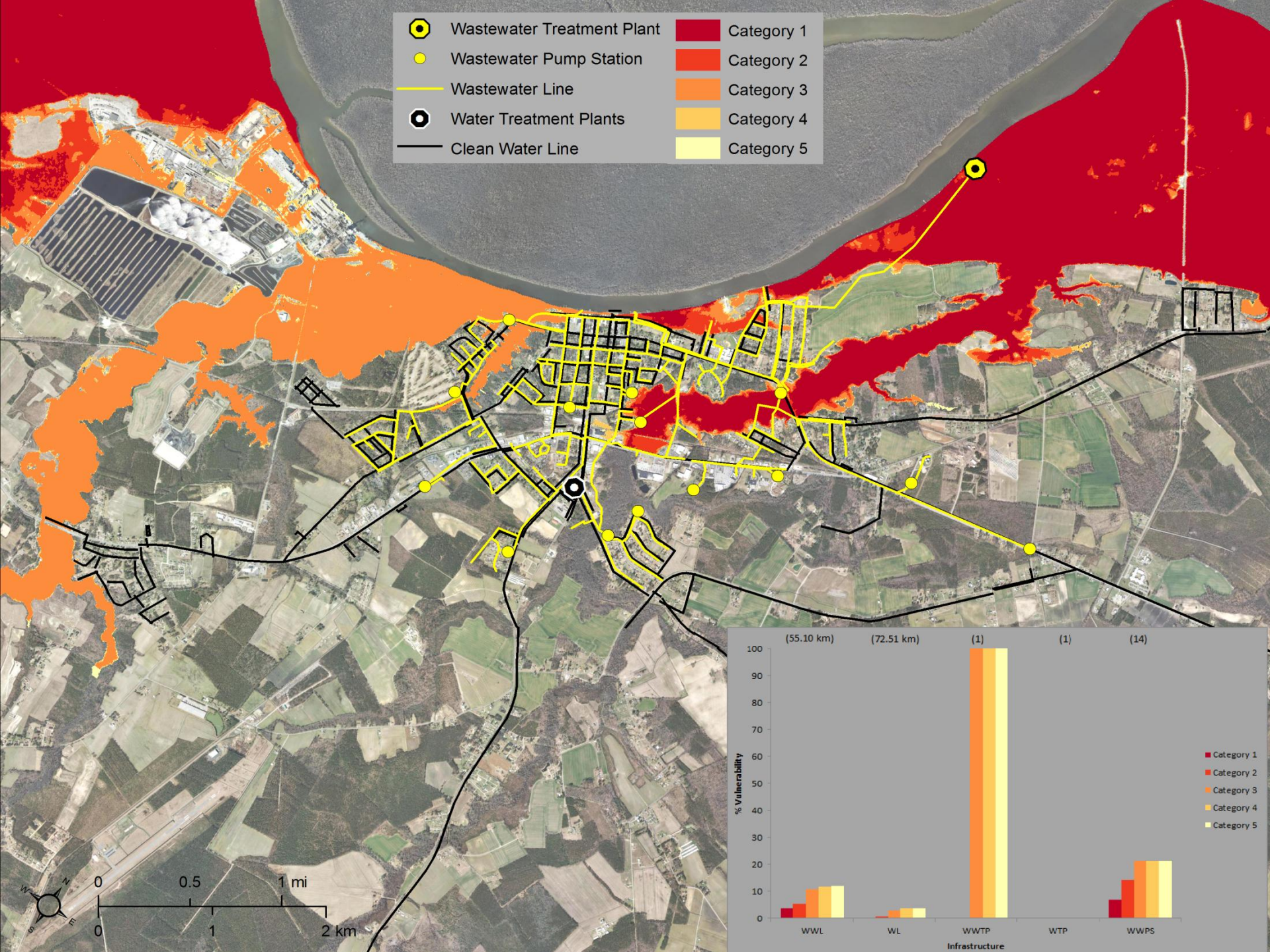


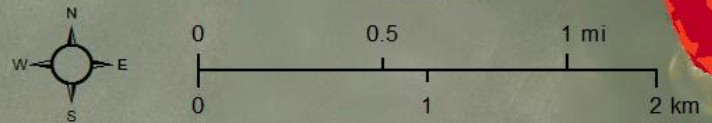
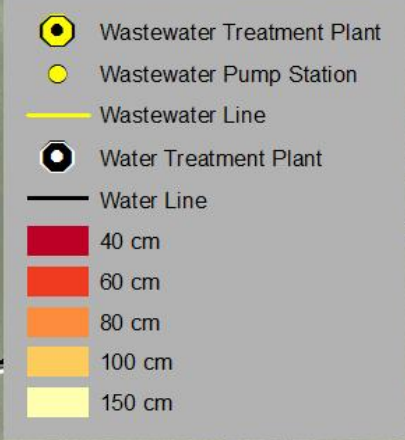
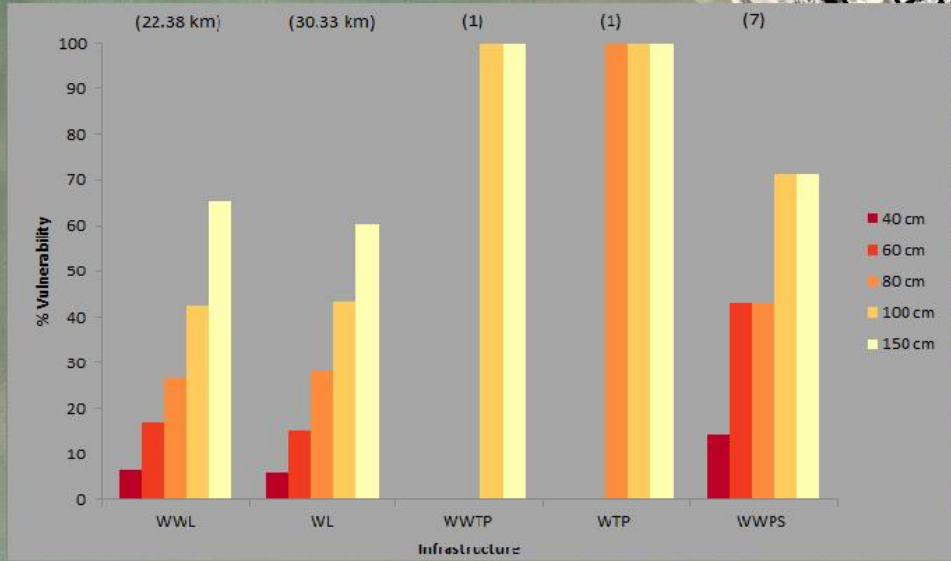
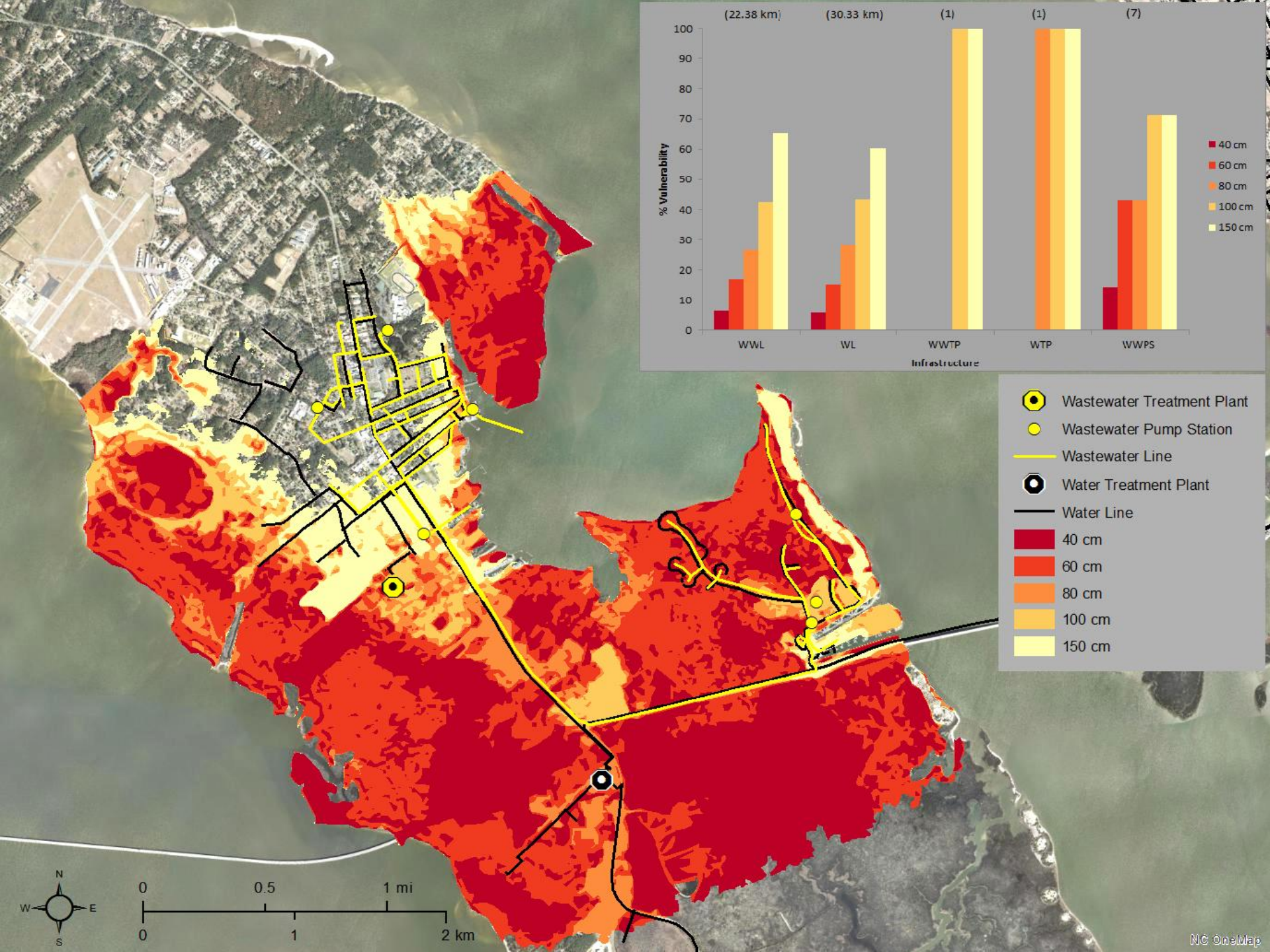
MODELING COASTAL INUNDATION

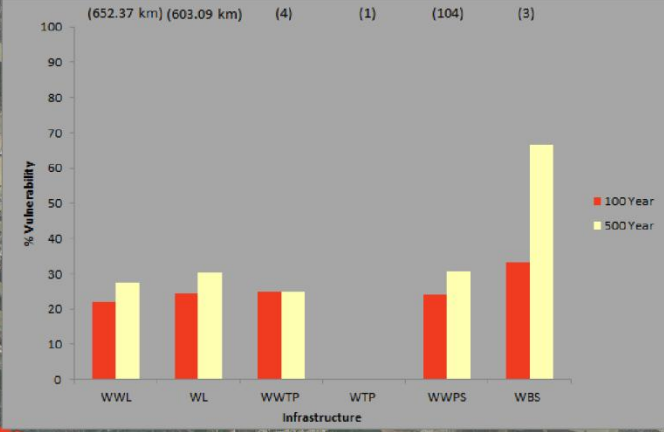
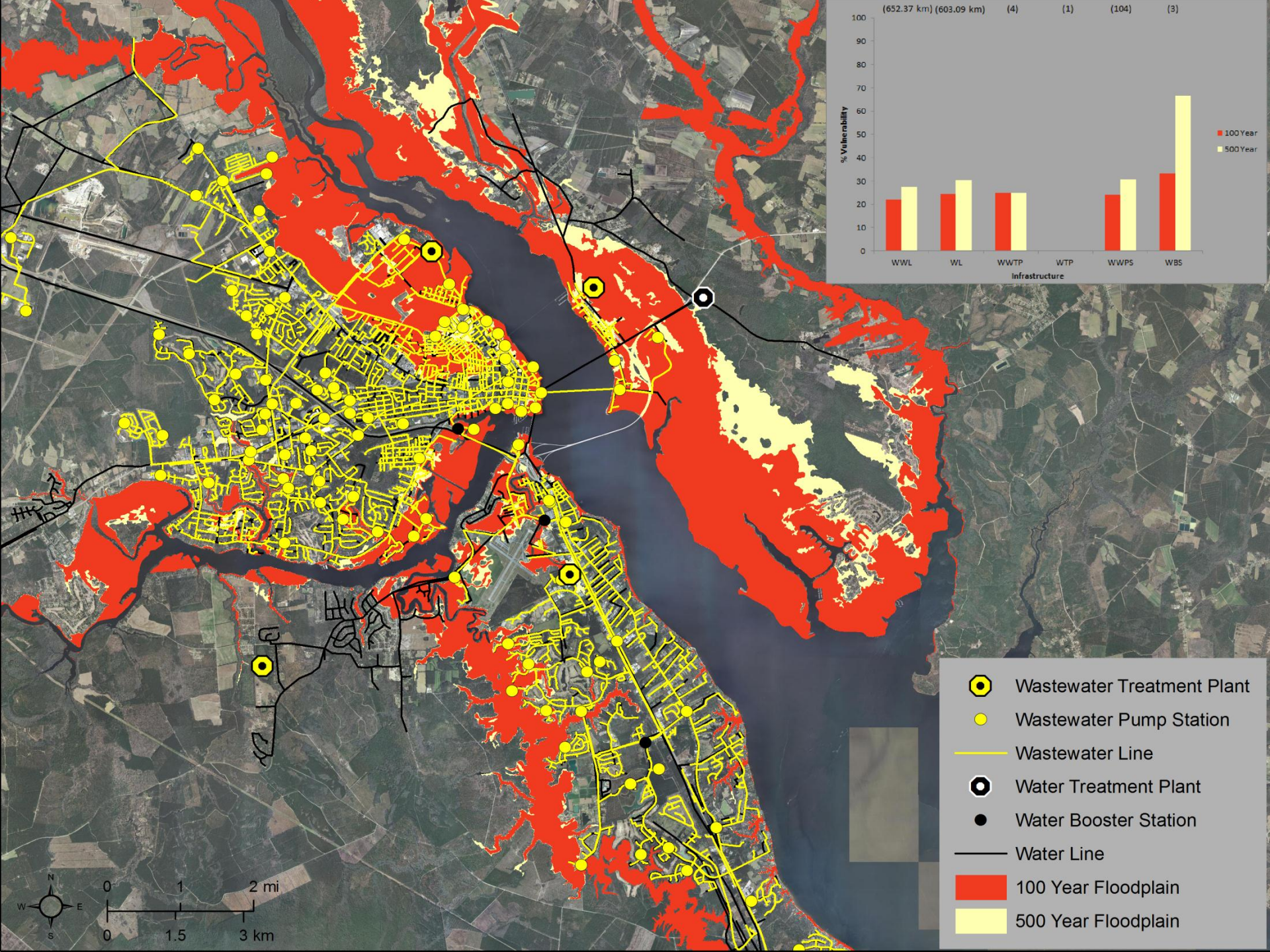
- ▶ Storm Surge
 - ▶ SLOSH MOMs
 - ▶ Downscaled to local 20 ft. DEMs
 - ▶ Categories 1-5
 - ▶ *Category 5 is determined to be a highly unlikely/impossible event for NC, but floodplains are not impossible due to compounding flooding
- ▶ Sea Level Rise
 - ▶ 40 cm, 60 cm, 80 cm, 100 cm, and 150 cm (NC CRC Science Panel 2010)
- ▶ Riverine Floods
 - ▶ DFIRMs from NCFMP (50 ft. resolution)
 - ▶ 100 and 500 year floodplains

VULNERABILITY ASSESSMENT

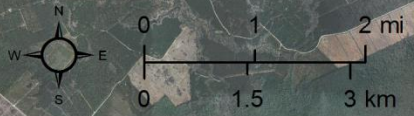
- ▶ Each hazard is assessed in increments
- ▶ Graphs of the change in vulnerability as flooding increases
 - ▶ Number of inundated pieces of each infrastructure/ total number of each infrastructure
- ▶ Hypsometric graphs
 - ▶ Area inundated vs. height of flood level
 - ▶ Shows floodplain progression as hazard becomes more drastic
 - ▶ Illustrates the shape of the coast



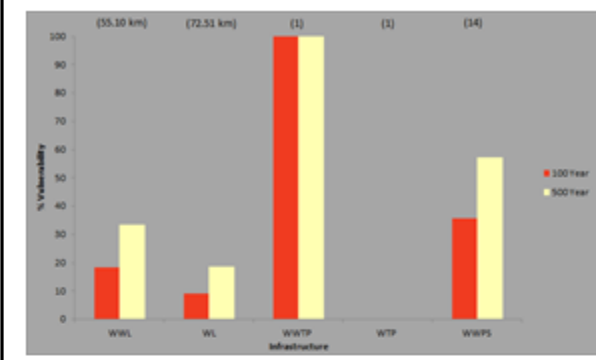
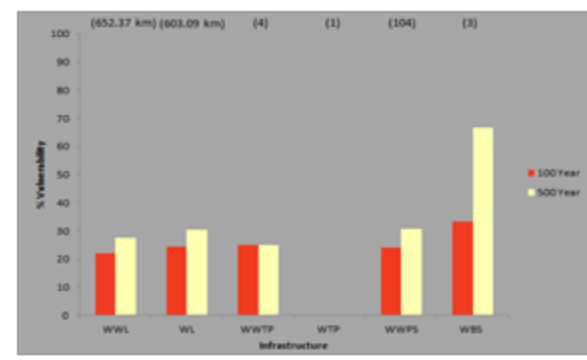
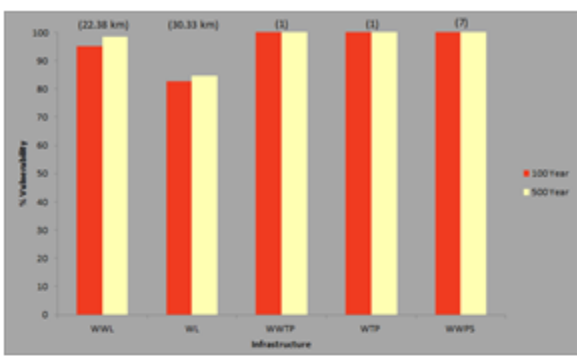




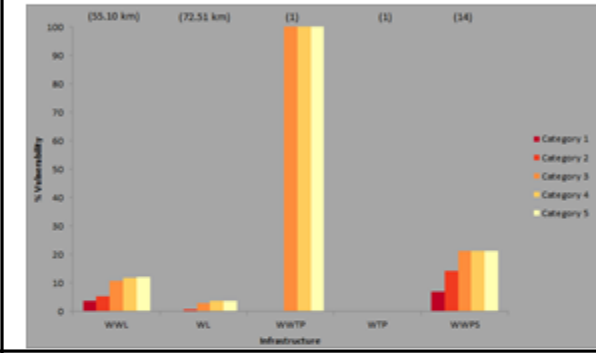
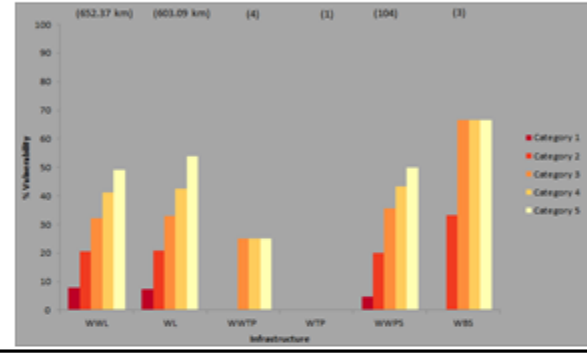
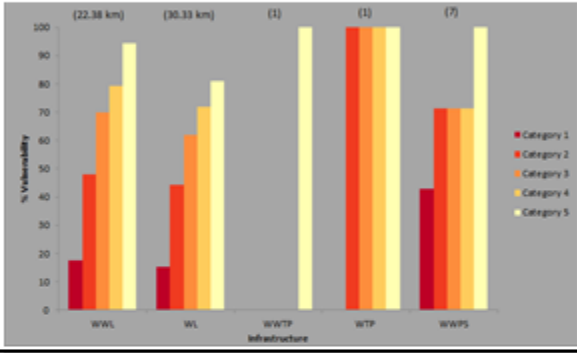
- Wastewater Treatment Plant
- Wastewater Pump Station
- Wastewater Line
- Water Treatment Plant
- Water Booster Station
- Water Line
- 100 Year Floodplain
- 500 Year Floodplain



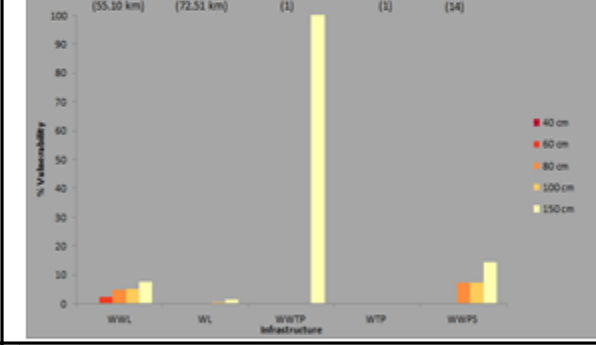
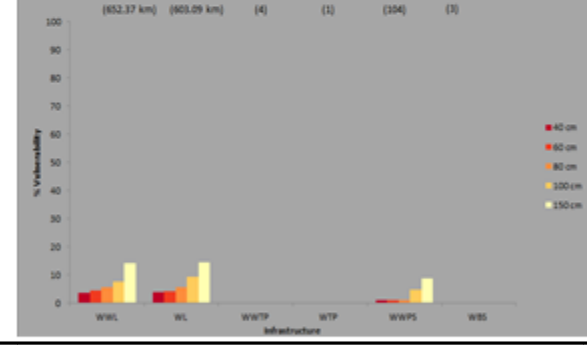
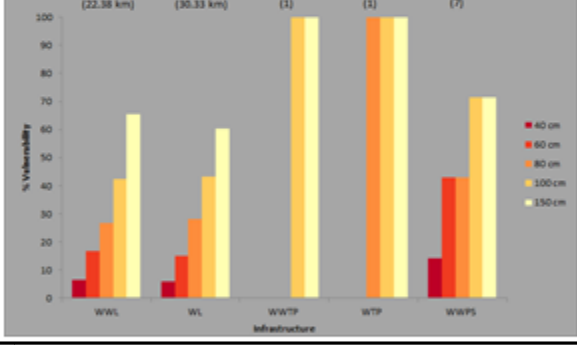
Riverine



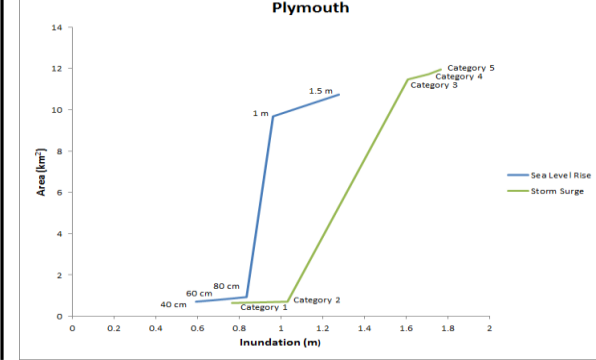
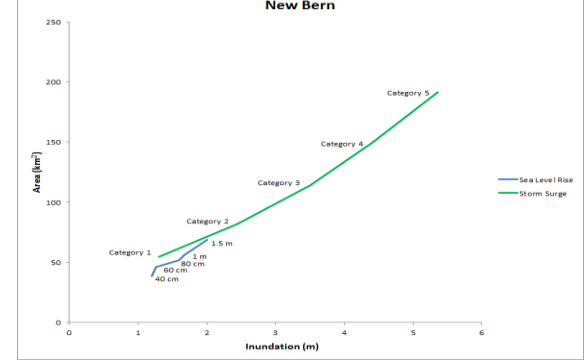
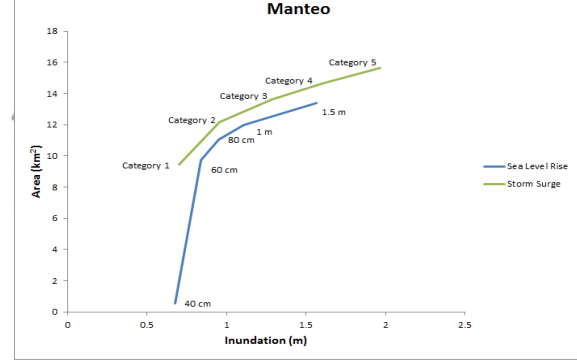
Storm Surge



Sea Level Rise



Hypsographs





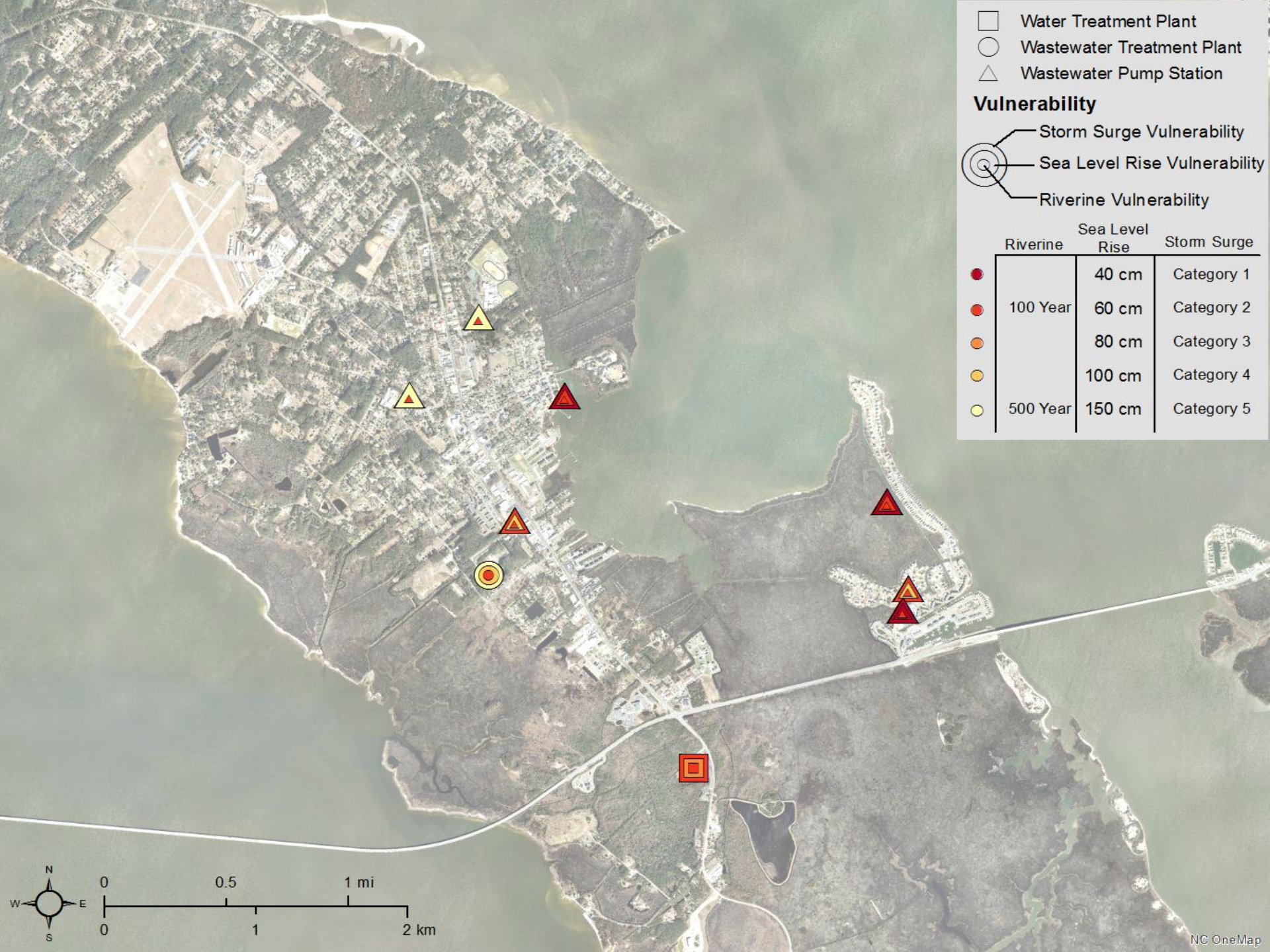
- Wastewater Treatment Plant
- △ Wastewater Pump Station




Vulnerability




- Storm Surge Vulnerability
- Sea Level Rise Vulnerability
- △ Riverine Vulnerability






	Riverine	Sea Level Rise	Storm Surge
●		40 cm	Category 1
●	100 Year	60 cm	Category 2
●		80 cm	Category 3
●		100 cm	Category 4
●	500 Year	150 cm	Category 5

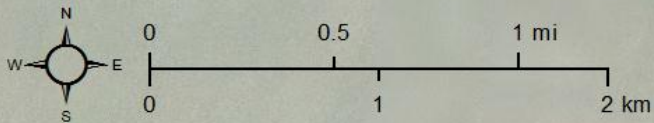


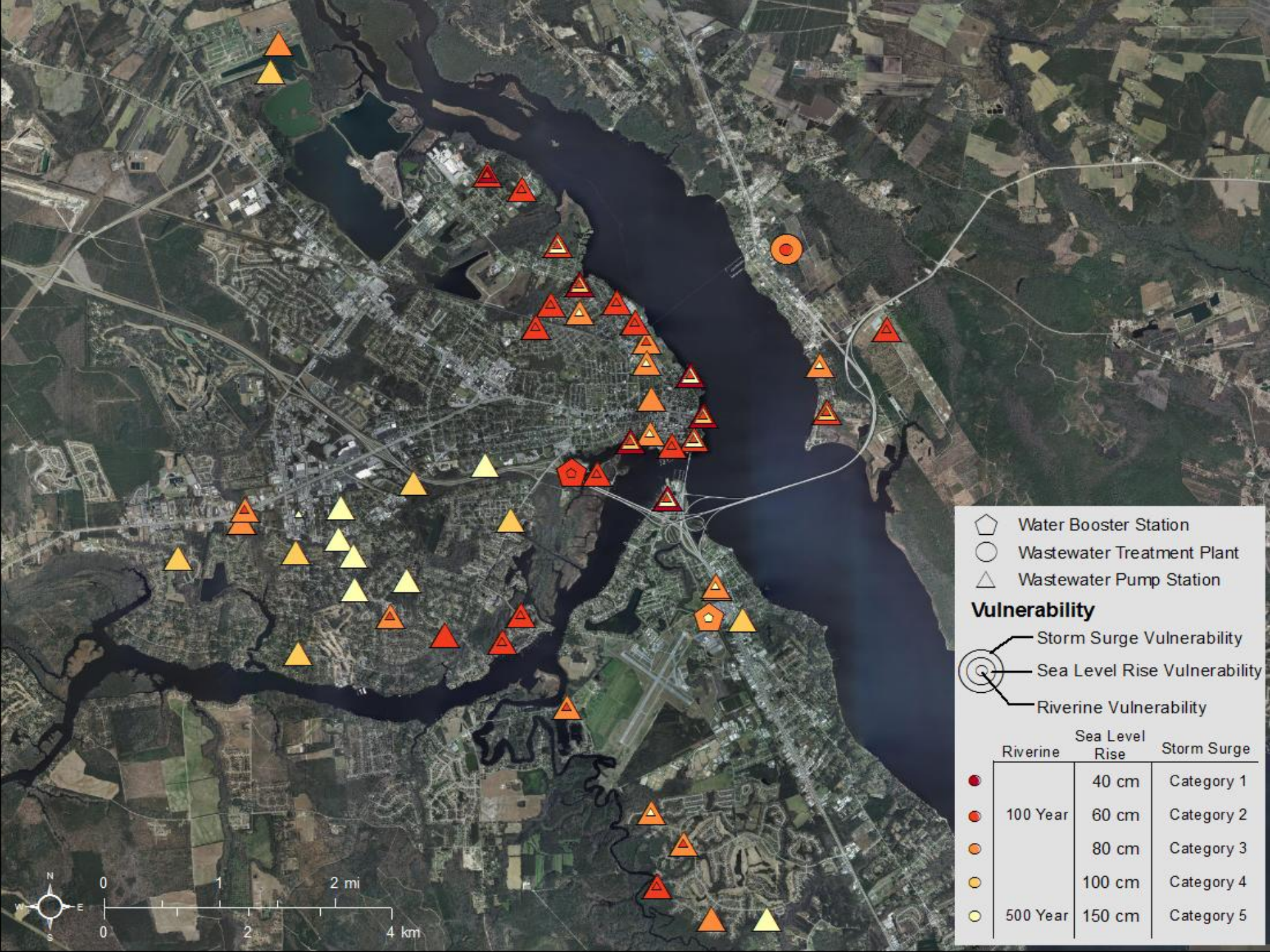





-  Water Treatment Plant
-  Wastewater Treatment Plant
-  Wastewater Pump Station

- Vulnerability**
-  Storm Surge Vulnerability
 -  Sea Level Rise Vulnerability
 -  Riverine Vulnerability




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 Water Booster Station
 Wastewater Treatment Plant
 Wastewater Pump Station

Vulnerability

 Storm Surge Vulnerability
 Sea Level Rise Vulnerability
 Riverine Vulnerability

	Riverine	Sea Level Rise	Storm Surge
		40 cm	Category 1
	100 Year	60 cm	Category 2
		80 cm	Category 3
		100 cm	Category 4
	500 Year	150 cm	Category 5



VULNERABILITY ASSESSMENT

- ▶ Manteo has greatest vulnerability
 - ▶ Only community with vulnerable WWTP and WTP
 - ▶ Low lying and gently sloping topography, and only island of study sites
- ▶ New Bern has second most vulnerability
 - ▶ Only community with WBS, creates cascading vulnerability for clean water distribution
 - ▶ Wide-mouth estuary and gradual sloping topography
- ▶ Plymouth has least vulnerability
 - ▶ Very little to no vulnerability to fresh water system from single event, and least pipeline vulnerability
 - ▶ Orientation to open waters of Albemarle Sound

CONCLUSIONS

- ▶ Importance of Infrastructure
- ▶ Vulnerability of Infrastructure
 - ▶ Cost vs. reward
 - ▶ Long term fix (relocation) vs. short term fix (berms, raised platforms, etc)
- ▶ Multihazard approach
 - ▶ Location matters
 - ▶ Context matters

QUESTIONS?

