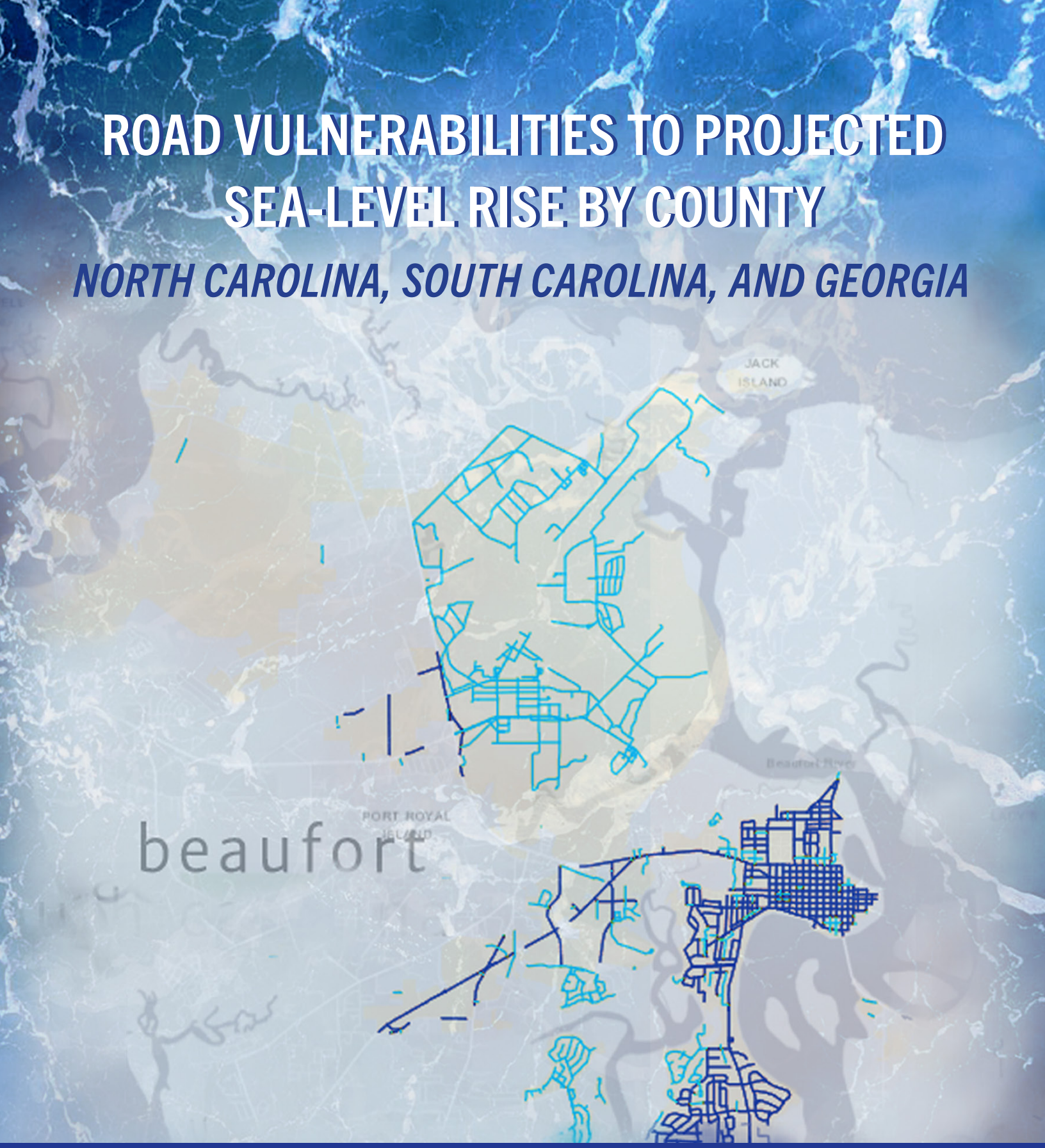
ROAD VULNERABILITIES TO PROJECTED SEA-LEVEL RISE BY COUNTY

NORTH CAROLINA, SOUTH CAROLINA, AND GEORGIA



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ABOUT THE AUTHORS

ELEANOR DAVIS, graduate assistant in the Department of Geography at the University of South Carolina, and Professor **KIRSTIN DOW**, Carolina Trustees Professor in the Department of Geography at the University of South Carolina, provided the assessment of miles of road maintained by state, local (city/county), or private entities that will be affected by different levels of projected sea level rise.

PROJECT BACKGROUND

This white paper is one outcome of a four-state regional project funded by the National Oceanic Atmospheric Administration Office of Coastal Management, Florida Sea Grant, Georgia Sea Grant, South Carolina Sea Grant, and North Carolina Sea Grant (Project No.: FY2014-2018: NA14OAR4170084). Coastal communities are increasingly becoming aware of the risks to their ecosystems, homes, and economies because of increased flooding, more extreme storm surges, and sea level rise. Reducing risk on the coast will be achieved by means of a variety of approaches, including policy and regulatory changes, natural resource protection, structural and non-structural intervention and investment, and retreat. A project team involving researchers, legal and policy experts, and law students have assisted coastal communities in four states – Florida, Georgia, South Carolina, and North Carolina – to prepare for present vulnerabilities and projected future conditions based on likely sea-level rise scenarios. This paper is part of the project's objective to analyze legal and policy factors affecting adaptation responses, focusing on the state and local levels. Additional white papers associated with this project may be found at http://gacoast.uga.edu/.

INTRODUCTION

Sea level rise and sinking land surface means that the coastal areas in the South Atlantic are very likely to experience a relative sea level rise of one to four feet in the coming century.[1] Many communities are already experiencing impacts of recurrent, sometimes called nuisance flooding, associated with "king tides" and meteorological events. For the state and county and local governments, sea level rise and increased flooding pose a significant, costly, and persistent threat to roads and highways. These natural disasters and chronic flood damages will inevitably encourage decision-makers to reconsider the status quo of road maintenance and repair. Under projected sea level rise, repetitive or severe damages will lead to tough decisions about whether to abandon existing roads, decrease routine maintenance, or transfer control of the roads to different government authorities.

To begin to understand the potential scope of the problem, this white paper presents an analysis of roadways in coastal cities and counties in North Carolina, South Carolina, and Georgia vulnerable to sea level rise under one-, two-, and three-foot scenarios, using sea level rise data from NOAA's Office for Coastal Management Sea Level Rise Viewer Data Download.[2] The analysis raises the following overall points for consideration:

- **Adaptation planning must be highly localized.** While a birds-eye view of road ownership statewide is helpful, cities and counties will not be affected in the same way by sea level rise as the state as a whole nor will their responsibility for roads in their jurisdictions necessarily reflect statewide trends. For example, in South Carolina, although the state is responsible for most of the road miles inundated, that is not the case for all jurisdictions. More locally maintained roads in Colleton, Horry, and Jasper counties are projected to be inundated by sea level rise than state-maintained roads.

- **Long-term and comprehensive planning involving multiple jurisdictions is more likely to create outcomes that result in community-wide resilience.** Proportional responsibility for road miles inundated by projected sea level in some instances changes depending on the scenario. In Beaufort County, South Carolina, for example, the state maintains the majority of roads inundated by a projected sea level rise of one foot. Projections of two or three feet, however, result in more locally maintained roads becoming inundated. Given that projections are uncertain, jurisdictions should work together to jointly plan for several scenarios, understanding that their burdens may change depending upon the scenario that occurs.

1. Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville, 2014: Ch. 2: Our Changing Climate. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT.

2. coast.noaa.gov/digitalcoast/tools/slr.html

- **Using data to identify future road vulnerabilities to sea level rise has great potential, with opportunities to include additional detail and make refinements.** For example, the databases used for this analysis break down road types further into paved and unpaved, and also include other information. Additionally, this analysis assumed that the roads are at the same elevation as the surrounding land. Using LiDAR datasets[3] would result in a more comprehensive outlook of future impacts.

METHODS

The methodology for NOAA's Sea Level Rise Inundation Mapping is considered a modified bath-tub model that "attempts to account for local and regional tidal variability and hydrological connectivity" not including wind tides. It maps sea level rise on top of mean higher high water but does not "incorporate future changes in coastal geomorphology" and does not include a detailed hydrological network analysis. It is meant for high-level management decisions, and further research and surveys are necessary for "navigation, permitting, or other legal purposes." These data came in one-foot intervals in geodatabases that were separated geographically by state and then by coastal region in the state (Table 1). As seen in Table 1, Pitt, Hyde, and Beaufort counties in North Carolina are in multiple geodatabases, likely due to their geographic extent across regions.

The county shapefiles were selected from the Census Boundary Shapefiles at a 1:500,000 scale. Each state has its own road database, which presents some difficulties when comparing states. The North Carolina road data can be found on the North Carolina Department of Transportation (NCDOT) GIS Data Layers website. It includes state-maintained and non-state-maintained roads, and delineates between county-, city-, and township-maintained roads. The South Carolina road data are located on the South Carolina Department of Transportation (SCDOT) GIS Mapping website. These data came in two files, "statewide highways" and "statewide other roads." SCDOT defines highways as being maintained by SCDOT, while the other roads are maintained by local or private entities. Finally, Georgia does not have an accessible state road database, so the analysis relies on the US Census Bureau's 2017 Tiger/Line Road Shapefiles.[9]

3. LiDAR stands for light detection and ranging. It is a "remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth." See oceanservice.noaa.gov/facts/lidar.html.

4. coast.noaa.gov/data/digitalcoast/pdf/slr-inundation-methods.pdf

5. coast.noaa.gov/slr/

6. www.census.gov/geo/maps-data/data/cbf/cbf_counties.html

7. connect.ncdot.gov/resources/gis/pages/gis-data-layers.aspx

8. info2.scdot.org/sites/GIS/SitePages/GISFiles.aspx?MapType=Shape

9. www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2017&layergroup=Roads

Table 1: Sea Level Rise Viewer Data Download Geodatabases by State

GEODATABASES	NC COUNTIES	SC COUNTIES	GA COUNTIES
Region 1	Bladen, Brunswick, Columbus, New Hanover, Pender	Florence, Georgetown, Marion, Williamsburg	Brantley, Bryan, Camden, Charlton, Chatham, Glynn, Liberty, Long, McIntosh, Wayne
Region 2	Camden, Chowan, Currituck, Gates, Pasquotank, Perquimans	Beaufort, Berkeley, Charleston, Colleton, Dorchester, Hampton, Jasper	
Region 3	Beaufort, Bertie, Hertford, Hyde, Martin, Pitt, Tyrrell, Washington	Horry	
Region 4	Dare, Hyde		
Region 5	Beaufort, Carteret, Craven, Jones, Onslow, Pamlico, Pitt		

To select and calculate roads affected by sea level rise, two primary steps were required: data preprocessing and processing. ArcMap and Python were used to conduct the majority of the methodology. To begin the preprocessing, 12 identified counties were exported as a separate shapefile. If necessary, the multiple regional geodatabases were merged to encompass the entire coastline as well as potentially impacted inland counties. This process resulted in three sea level rise shapefiles per state at one-, two-, and three-feet of sea level rise. Each state's road shapefiles were clipped by the county shapefiles, resulting in individual county-level road networks.

After the data preprocessing took place, the extraction of impacted road data commenced. Each county's road layers were clipped by the sea level rise layers. The length of each road segment included within the final clipped road shapefiles was calculated using ArcMap. They were then aggregated, depending on the state's road shapefile metadata, into three categories: state maintained, locally maintained, and privately maintained. Only in North Carolina could a federally maintained category be added and the locally maintained category be broken into two further categories: county maintained, and town, city, or municipally maintained. In North Carolina, state roads were aggregated by route class, and county, local, and private roads were aggregated by owner type (Table 2). In South Carolina, the roads were aggregated by route type. Roads that fell under the "highway" designation were all maintained by the state and were simply aggregated without respect to route type. The "other roads" were separated into locally or privately main-

tained and then totaled (Table 3). This analysis was conducted for each potential foot of sea level rise up to three feet. Additionally, the City of Beaufort, South Carolina, was separately calculated using a similar methodology. In Georgia, the MAF/TIGER Feature Class Code (MTFCC) was used to determine the road aggregation (Table 4). Some counties that were identified by the NOAA Sea Level Rise Inundation Mapping as at risk for sea level rise did not have roads impacted at the one-, two-, or three-foot levels; however, they are still included to present a complete picture of the impacts in each state.

Table 2: North Carolina Road Maintenance Designations[10]

AGGREGATED CATEGORY	ROUTE CLASS	OWNER TYPE
Federally Maintained		60, 63
State Maintained	2, 3, 4, 6, 7	21
County Maintained		2
Town, City, Municipally Maintained		3, 4
Privately Maintained		98, 99
Other *(unknown owner type, planned road project)*	5	0

Table 2: South Carolina Road Maintenance Designations[11]

AGGREGATED CATEGORY	HIGHWAY SHAPEFILE	OTHER ROADS SHAPEFILE
State Maintained (highway file)	I-, US, SC, S-, D-, R-, RS	
State Maintained		L-, D-
Privately Maintained		PR

10. xfer.services.ncdot.gov/gisdot/DistDOTData/NCDOTRouteArcsFieldDescriptions.pdf

11. In downloadable road zip file titled "Data Dictionary"

Table 3: Georgia Road Maintenance Designations[12]

AGGREGATED CATEGORY	MTFCC CODE
State Maintained	S1100, S1200
Locally Maintained	S1400 *(may include some private rural roads)*
Privately Maintained	S1740
Other (ramps, vehicular trail, internal US Census Bureau use)	S1500, S1630, S1750

Note that these calculations are just the tip of the iceberg in terms of using these data to identify future road vulnerabilities to sea level rise. The databases breakdown road types further into paved and unpaved as well as including other information. Further work to distinguish between county- and city-maintained roads would also seem prudent in South Carolina and Georgia. Additionally, this analysis was done assuming that the roads are at the same elevation as the surrounding land; however, with the addition of LiDAR, a more comprehensive outlook of future impacts could be conducted.

12. *www.census.gov/geo/reference/mtfcc.html*

NORTH CAROLINA:

MILES OF ROAD MAINTAINED BY STATE, LOCAL (CITY/COUNTY), OR PRIVATE ENTITIES THAT WILL BE IMPACTED BY ONE, TWO, OR THREE FEET OF SEA LEVEL RISE

	1 foot of SLR	2 feet of SLR	3 feet of SLR
Beaufort			
Federal	0.0	0.0	0.0
State	5.1	13.3	35.5
County	0.0	0.0	0.0
Town/City/Muni	0.1	2.7	11.3
Private	0.2	7.2	26.1
Other	0.1	1.4	3.6
Bertie			
Federal	0.0	0.0	0.0
State	3.0	3.3	3.5
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.0	0.0	0.0
Other	0.2	0.3	0.4
Bladen			
Federal	0.0	0.0	0.0
State	0.1	0.1	0.1
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.0	0.0	0.0
Other	0.0	0.0	0.0
Brunswick			
Federal	0.0	0.0	0.0
State	2.4	3.0	4.4
County	0.0	0.0	0.0
Town/City/Muni	0.3	3.6	17.2
Private	1.1	2.2	5.4
Other	3.1	3.5	5.1
Camden			
Federal	0.0	0.0	0.0
State	1.2	8.3	18.5
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	1.5	7.3	11.4
Other	1.7	7.2	10.0

NORTH CAROLINA: MILES OF ROAD MAINTAINED BY STATE, LOCAL (CITY/COUNTY), OR PRIVATE ENTITIES THAT WILL BE IMPACTED BY ONE, TWO, OR THREE FEET OF SEA LEVEL RISE

	1 foot of SLR	2 feet of SLR	3 feet of SLR
Carteret			
Federal	0.05	0.05	0.1
State	4.3	8.0	29.6
County	0.0	0.0	0.0
Town/City/Muni	0.6	2.4	12.6
Private	0.7	6.0	23.0
Other	1.4	2.9	8.0
Chowan			
Federal	0.0	0.0	0.0
State	3.9	5.6	6.3
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.1	0.3
Private	0.1	0.2	0.5
Other	0.0	0.1	0.1
Columbus[13]			
Federal	0.0	0.0	0.0
State	0.0	0.0	0.0
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.0	0.0	0.0
Other	0.0	0.0	0.0
Craven			
Federal	0.0	0.0	0.0
State	5.0	5.7	6.3
County	0.0	0.0	0.0
Town/City/Muni	0.5	0.6	1.2
Private	0.0	0.0	0.7
Other	1.9	2.8	3.9
Currituck			
Federal	0.0	0.0	0.0
State	3.2	6.5	19.5
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.3	3.2	15.0
Other	0.0	0.5	1.8

13. Columbus is included in the NOAA SLR Viewer; however, no roads are touched at one, two, or three feet of rise.

NORTH CAROLINA:
MILES OF ROAD MAINTAINED BY STATE, LOCAL (CITY/COUNTY), OR PRIVATE ENTITIES THAT WILL BE IMPACTED BY ONE, TWO, OR THREE FEET OF SEA LEVEL RISE

	1 foot of SLR	2 feet of SLR	3 feet of SLR
Dare			
Federal	0.4	36.4	113.8
State	21.5	44.6	105.2
County	0.0	0.1	0.5
Town/City/Muni	0.0	0.5	5.6
Private	0.3	3.0	18.9
Other	0.2	1.0	3.2
Gates			
Federal	0.0	0.0	0.0
State	0.2	2.7	6.6
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.0	0.0	0.2
Other	0.0	0.0	0.6
Hertford			
Federal	0.0	0.0	0.0
State	0.3	0.9	1.5
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.0	0.3	0.4
Other	0.0	0.1	0.1
Hyde			
Federal	0.0	0.7	2.9
State	3.4	53.2	128.9
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.1	54.8	103.9
Other	0.0	1.4	3.4
Jones			
Federal	0.0	0.0	0.0
State	0.1	0.1	0.1
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.0	0.0	0.0
Other	0.1	0.1	0.2

NORTH CAROLINA:
MILES OF ROAD MAINTAINED BY STATE, LOCAL (CITY/COUNTY), OR PRIVATE ENTITIES THAT WILL BE IMPACTED BY ONE, TWO, OR THREE FEET OF SEA LEVEL RISE

	1 foot of SLR	2 feet of SLR	3 feet of SLR
Martin			
Federal	0.0	0.0	0.0
State	0.1	0.1	0.1
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.0	0.0	0.0
Other	0.0	0.0	0.0
New Hanover			
Federal	0.0	0.0	0.0
State	6.8	9.0	12.8
County	0.0	0.0	0.0
Town/City/Muni	0.3	3.1	7.3
Private	0.4	1.7	4.8
Other	2.5	3.3	4.3
Onslow			
Federal	0.0	0.0	0.0
State	2.5	3.4	6.8
County	0.0	0.0	0.0
Town/City/Muni	1.6	3.6	6.7
Private	1.6	3.7	5.8
Other	1.3	2.1	2.9
Pamlico			
Federal	0.0	0.0	0.0
State	0.7	7.6	26.2
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.5	1.8
Private	0.0	1.9	5.8
Other	0.0	0.0	0.4
Pasquotank			
Federal	0.0	0.0	0.0
State	0.6	3.8	17.7
County	0.0	0.0	0.0
Town/City/Muni	0.1	0.7	2.8
Private	0.7	1.7	3.4
Other	0.1	1.2	3.2

NORTH CAROLINA:
MILES OF ROAD MAINTAINED BY STATE, LOCAL (CITY/COUNTY), OR PRIVATE ENTITIES THAT WILL BE IMPACTED BY ONE, TWO, OR THREE FEET OF SEA LEVEL RISE

	1 foot of SLR	2 feet of SLR	3 feet of SLR
Pender			
Federal	0.0	0.0	0.0
State	1.0	3.6	6.6
County	0.0	0.0	0.0
Town/City/Muni	0.2	1.4	3.6
Private	15.3	16.1	17.9
Other	16.5	16.7	17.5
Perquimans			
Federal	0.0	0.0	0.0
State	1.4	2.3	4.1
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.1	0.1
Private	0.0	0.2	0.5
Other	0.0	0.2	0.3
Pitt			
Federal	0.0	0.0	0.0
State	0.8	1.0	1.1
County	0.0	0.0	0.0
Town/City/Muni	0.0	0.0	0.0
Private	0.0	0.0	0.1
Other	0.0	0.1	0.1
Tyrrell			
Federal	0.0	0.0	0.0
State	3.0	28.8	82.5
County	0.0	0.0	0.0
Town/City/Muni	0.0	1.4	3.3
Private	0.0	1.0	5.2
Other	0.1	1.1	2.2
Washington			
Federal	0.0	0.0	0.0
State	2.0	2.6	6.0
County	0.0	0.0	0.0
Town/City/Muni	0.1	0.1	0.8
Private	0.1	0.3	1.2
Other	0.0	0.0	0.2

SOUTH CAROLINA:
MILES OF ROAD MAINTAINED BY STATE, LOCAL (CITY/COUNTY), OR PRIVATE ENTITIES THAT WILL BE IMPACTED BY ONE, TWO, OR THREE FEET OF SEA LEVEL RISE

	1 foot of SLR	2 feet of SLR	3 feet of SLR
Beaufort			
State	13.5	19.5	34.7
Local	8.5	23.6	70.7
Private	0.9	3.5	23.7
City of Beaufort			
State	0.1	0.3	1.2
Local	0.16	0.6	1.9
Private	0.0	0.0	0.0
Berkeley			
State	3.9	5.7	8.7
Local	2.9	6.2	13.5
Private	0.0	0.0	0.2
Charleston			
State	24.9	44.0	93.7
Local	11.0	34.6	99.4
Private	1.1	3.6	35.9
Colleton			
State	6.9	12.8	24.9
Local	10.9	18.6	28.3
Private	0.6	0.9	1.1
Dorchester			
State	0.06	0.07	0.07
Local	0.1	0.2	0.4
Private	0.0	0.0	0.0
Georgetown			
State	5.0	9.5	15.2
Local	3.8	9.7	24.6
Private	2.0	2.2	2.9
Horry			
State	1.6	2.9	4.9
Local	5.2	7.6	18.7
Private	0.0	0.0	0.0
Jasper			
State	1.5	2.3	4.7
Local	3.5	4.9	7.0
Private	0.0	0.0	0.0

GEORGIA:
MILES OF ROAD MAINTAINED BY STATE, LOCAL (CITY/COUNTY), OR PRIVATE ENTITIES THAT WILL BE IMPACTED BY ONE, TWO, OR THREE FEET OF SEA LEVEL RISE

	1 foot of SLR	2 feet of SLR	3 feet of SLR
Brantley			
State	0.0	0.0	0.0
Local	0.0	0.0	0.0
Private	0.0	0.0	0.0
Other	0.0	0.0	0.0
Bryan			
State	0.8	0.9	1.5
Local	4.8	7.2	12.3
Private	0	0.1	0.3
Other	0.0	0.0	0.0
Camden			
State	4.4	5.1	5.7
Local	23.2	38.9	58.1
Private	1.0	1.3	1.6
Other	0.0	0.1	0.4
Charlton			
State	0.1	0.2	0.2
Local	0.6	1.8	2.7
Private	0.0	0.0	0.2
Other	0.0	0.0	0.0
Chatham			
State	16.6	22.4	30.4
Local	7.1	20.5	61.4
Private	0.2	0.4	0.9
Other	1.2	2.1	2.8
Glynn			
State	15.0	16.2	19.5
Local	12.0	25.1	68.8
Private	0.7	1.2	2.2
Other	0.0	0.0	0.1
Liberty			
State	2.2	2.6	3.0
Local	9.0	13.3	19.5
Private	4.2	8.5	12.7
Other	1.2	2.6	3.3

GEORGIA:
MILES OF ROAD MAINTAINED BY STATE, LOCAL (CITY/COUNTY), OR PRIVATE ENTITIES THAT WILL BE IMPACTED BY ONE, TWO, OR THREE FEET OF SEA LEVEL RISE

	1 foot of SLR	2 feet of SLR	3 feet of SLR
Long			
State	0.0	0.0	0.0
Local	0.0	0.0	0.0
Private	0.0	0.0	0.0
Other	0.0	0.0	0.0
McIntosh			
State	8.2	9.6	10.5
Local	20.1	36.2	56.0
Private	1.1	1.5	1.9
Other	0.1	0.3	0.6
Wayne			
State	0.0	0.0	0.0
Local	0.0	0.0	0.0
Private	0.0	0.0	0.0
Other	0.0	0.0	0.0