Technical Memorandum:

Risk Assessment on SIS Facilities

Prepared for:

Florida Department of Transportation

Systems Implementation Office

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May 2018

Table of Contents

List of Tables

List of Figures

1.0 Executive Summary

Among the goals of the Florida Transportation Plan (FTP) are “Safety & Security for Residents, Visitors, & Businesses” and “Agile, Resilient, and Quality Infrastructure”, which calls for the Florida Department of Transportation (FDOT) to provide transportation infrastructure and services to help prepare for, respond to, and recover from emergencies as well as for the FDOT to reduce and mitigate transportation-related environmental and security risks through steps such as providing diversity and redundancy of the transportation system and developing and implementing comprehensive emergency and recovery plans.

This study was intended to analyze the Strategic Intermodal System (SIS) highway network to identify critical infrastructure, network risks and vulnerabilities due to impacts of flooding and lay the groundwork for pre-disaster mitigation planning as it relates to all SIS facilities, including retrofitting, adapting or diversifying infrastructure to promote resilience; pre-disaster emergency response planning, and emergency response operations immediately following a flood-event; and longer-term restoration of affected infrastructure.

The outcome of this effort includes a series of maps identifying SIS facilities potentially vulnerable to coastal and inland flooding and tropical storm/hurricane effects. Traffic volumes for facility segments were used to help rank or prioritize segments for future actions. These maps are based on recent historical traffic data and modeled water-related information and are shown in Section 4.0, Results. **Figure 1** provides information about facilities affected by potential inundation equivalent to Category 1, Category 3, and Category 5 hurricanes. Other recommendations for additional actions, including further studies and steps to incorporate the provided information into project planning, design, construction, and operations and maintenance are provided in Section 5.0, Recommendations.

Hurricane Irma emergency and evacuation planning was recognized as a significant case study that highlighted planning issues as they related to the SIS network’s function for disaster mitigation planning and response. Several policy and system management questions have come up regarding the resilience and SIS network performance in evacuation during hurricanes Irma and lessons learnt from the response. Traffic data for interstates associated with population evacuation and return are provided in Section 4.0.

Section 2.0 provides the national and state frameworks for performing vulnerability assessments and enhancing emergency preparedness, response and recovery. This section also provides notable state of the practice information as reference for additional efforts.

Section 3.0 describes the methodology used to perform the SIS vulnerability assessments. As part of the process, other information, such as the location and access to evacuation shelters, was reviewed and analyzed and this section includes discussion.

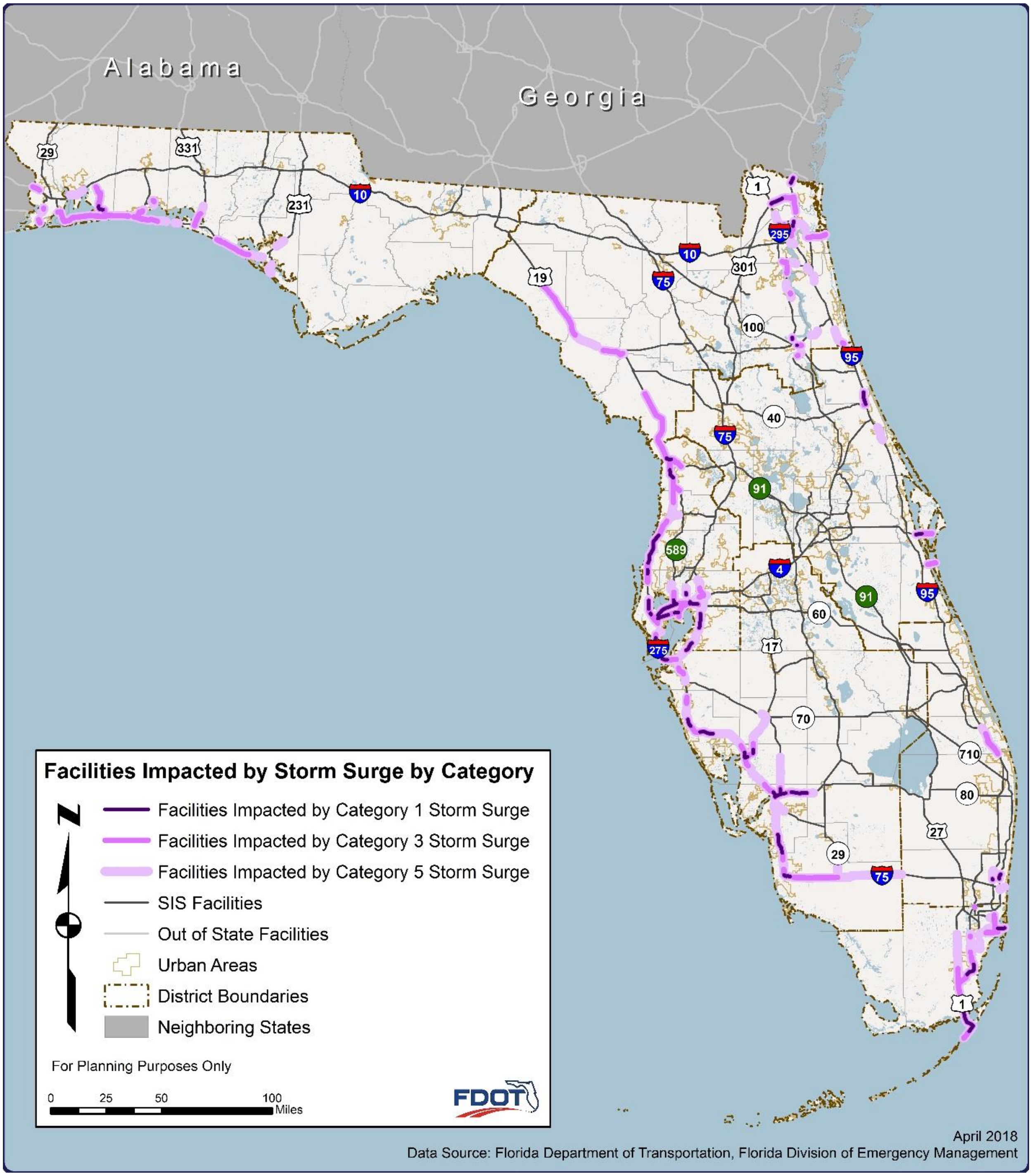

Figure 1: Facilities Impacted by Storm Surge by Hurricane Storm Category

2.0 Background and Best Practices

2.1 Federal and State Guidance

Federal guidance on climate resilience has been shaped by laws and executive action[1] over the years that catalyzed adaptation planning at the Federal level. Much of the overarching Federal work in the field of climate trends adaption has been undertaken by the U.S. Global Change Research Program (USGCRP), which was established by Presidential initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990, which comprises of 13 Federal agencies – including the USDOT, to conduct research to examine potential climate impacts on transportation. One product of the USGCRP is the National Climate Assessment (NCA), which "integrates scientific information from multiple sources and sectors to highlight key findings and significant gaps in our knowledge; establishes consistent methods for evaluating climate impacts in the US."

USDOT's policy statement on climate adaptation states that "DOT shall integrate consideration of climate impacts and adaptation into the planning, operations, policies, and programs of DOT in order to ensure that taxpayer resources are invested wisely and that transportation infrastructure, services and operations remain effective in current and future climate conditions." The Fixing America's Surface Transportation (FAST) Act, signed into law in December 2015, included a number of provisions addressing the resilience of the nation's transportation system. It requires agencies to take resiliency into consideration during transportation planning processes. The Fast Act is administered by the Federal Highway Administration (FHWA) and expanded[2] the scope of the planning process for state Departments of Transportation, Metropolitan Planning Organizations, and Federal Transit Administration (FTA) to include the following:

Adaptation makes changes to prepare for and negate the *effects of climate trends*, thereby reducing the vulnerability of communities and systems. By adapting to cope with the effects, communities, enterprises and institutions for **resilience.**

- Consideration for implementation of a new planning factor for states and metropolitan planning organizations (MPOs): improving the resiliency and reliability of the transportation system (23 CFR 450.206(a)(9) and 23 CFR 450.306(b)(9)).
- During the course of development of a metropolitan transportation plan and the transportation improvement program, consult with agencies and officials responsible for natural disaster risk reduction (23 CFR 450.316(b)).

[1] Executive Order 13653, (which replaced EO 13514) has led to agency action on adaptation planning across the Federal level. It has been rescinded by the current administration. FHWA's Order 5520 is based on EO 13653. Among other executive action which stands revoked/rescinded is the EO 13690, related to the flood risk management standard.

[2] Resilience and Transportation Planning, FHWA Office of Planning, Environment and Realty (HEP) (FHWA-HEP-17-028)

https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/ratp/index.cfm

(Footnote continued on next page...)

- Assess capital investment and other strategies as part of the transportation planning process to reduce the vulnerability of the existing transportation infrastructure to natural disasters (23 CFR 450.324(g)(7)).

FHWA provides guidance on eligibility of activities[3] to adapt to climate change and extreme weather events under the Federal-Aid and Federal Lands Highway programs. As part of this guidance, it notified that activities that "plan, design, and construct highways to adapt to current and future climate change and extreme weather events are eligible for reimbursement under the Federal-aid program." Among the eligible activities include vulnerability and risk assessments of highways that are eligible for Federal aid, among other activities. Among the funding programs listed for conducting vulnerability or risk assessments are Statewide Planning (SPR) and Surface Transportation Program (STP).

The US Army Corps of Engineers' (USACE) sea level change (SLC) scenarios[4], which have been used to conduct screening level assessments of vulnerability of USACE projects to coastal flooding has been adopted by various agencies across the US and in Florida in projecting sea level change, while considering local effects like subsidence.

At the State level, Florida passed the Community Planning Act (CPA) in the year 2011, which designated Adaptation Action Areas to address coastal hazards and potential impacts to sea level rise and eventually prioritizing funding for infrastructure improvements and adaptation planning. In 2015, Florida Senate Bill 1094, "An Act relating to the peril of flood," also became a law, which required planning considerations for potential coastal future flood risk due to sea level rise and storm surge, as part of local area comprehensive plans. It also mandated several changes as they relate to flood insurance and promoting strategies that mitigate risk.

As part of the Florida Transportation Plan (FTP), FDOT long-range goal envisions an "agile, resilient, and quality infrastructure," with continued preparation for "extreme weather events such as more frequent or severe tropical storms; flood risks in coastal areas resulting from high-tide events, storm surge, flash floods, stormwater runoff, and related impacts; changes in precipitation patterns and temperatures; and other environmental conditions that could impact transportation infrastructure."[5] The plan also calls for preparing and ensuring that the State's transportation system be resilient to extreme weather and other risks and identifies the role of research, collaboration, and development of creative solutions to support that effort. Two key relevant objectives[6] that are identified under this planning goal are:

- Adapt transportation infrastructure and technologies to meet changing customer needs; and,

[3] Eligibility of Activities To Adapt To Climate Change and Extreme Weather Events Under the Federal-Aid and Federal Lands Highway Program

https://www.fhwa.dot.gov/federalaid/120924.cfm

[4] Comprehensive Evaluation of Projects with Respect to Sea-Level Change,

http://www.corpsclimate.us/ccaceslcurves.cfm

[5] Florida Transportation Plan, Policy Element, Agile, Resilient, and Quality Infrastructure (pp.10) http://floridatransportationplan.com/pdf/FDOT_FTP-SIS_PolicyElement.pdf

[6] Ibid., pp.11

- Increase the resiliency of infrastructure to risks, including extreme weather and other environmental conditions.

Several regions in Florida also are working collaboratively to address resilience in their communities. Two of the larger, most frequently cited efforts are the Southeast Florida Regional Climate Compact consisting of Monroe, Miami-Dade, Broward, and Palm Beach Counties and several municipalities; and the ONE BAY Resilient Community Working Group for the Tampa Bay region coordinated by the Tampa Bay Regional Planning Council. A collaboration of Miami-Dade County and the Cities of Miami and Miami Beach are also receiving support from the Rockefeller Foundation’s 100 Resilient Cities program.

Mandates and guidance provided by Federal and State agencies, and regional groups, are valuable for shaping response to extreme weather and climate variability.

2.2 Best Practice Review

Transportation agencies and practitioners have researched and refined approaches to assessing impacts of climate variability on transportation infrastructure both at the national and state levels through federal and state funded or sponsored projects. Most noteworthy and prominent of these efforts are the two rounds of FHWA Vulnerability Assessment Pilot Case Studies, which have tested and refined the FHWA’s Climate Change and Extreme Weather Vulnerability Assessment Framework. This framework has been geared towards state DOT’s and MPOs across the country to design and implement climate vulnerability assessment of a given region’s transportation infrastructure. Many state DOT’s and MPOs successfully piloted this framework over two rounds of vulnerability and risk assessment pilot projects that FHWA has sponsored over the years.

A visual repwresentation of the FHWA Adaptation Framework is shown in **Figure 2**. Major components of this framework include:

- Defining objectives and scope;
- Assessing vulnerability; and,
- Integrating vulnerability into decision-making.

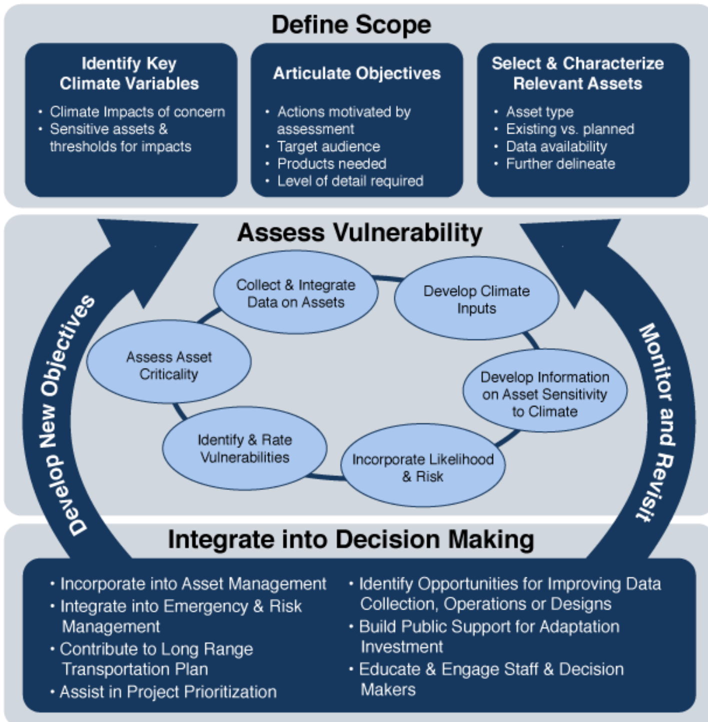

Figure 2: FHWA's Climate Change and Extreme Weather Vulnerability Assessment Framework (Source: FHWA)

It is well recognized that some of these components have been pre-set (for example – the scope and objective and elements of vulnerability assessment), which leaves other specific elements of the framework to be implemented if the framework is chosen for adoption in the current project. Given the variety of application experience (across the nation and in the State of Florida), available tools and resources which would be extremely helpful in implementing the vulnerability assessment, makes this framework a choice for consideration in this current effort with the requisite level of customization for specific requirements.

A scan of prior reviews of literature on climate trend vulnerability and risk assessment and adaptation approaches[7] provides guidance on general methodologies to conduct vulnerability and risk assessments. There have been a range of frameworks, simple and complex, to cater to a range of context applications designed to be implemented for an equally expansive range of studies and projects based on scope, level of effort, and overall project objectives. From earlier frameworks which were less refined compared to the ones followed, allowed for interventions and feedback as the frameworks were tested and refined over the years. The frameworks expanded and evolved despite being built over some of the same building blocks as the three key elements shown in **Figure 3. Figure 3** assessed current vulnerabilities based on historic trends and past climatic events. The following elements estimate future conditions and vulnerabilities to such potential impacts to the system in the future.

[7] Literature Review: Climate Change Vulnerability Assessment, Risk Assessment, and Adaptation Approaches: https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/vulnerability_assessment/index.cfm

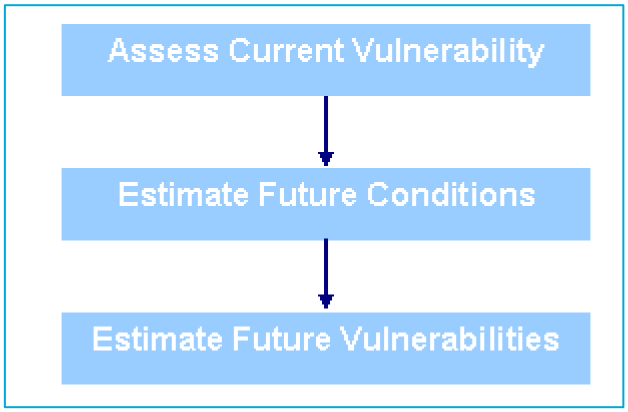

Figure 3: Key Steps of a Vulnerability Assessment (Source: Snorer, A.K., L. Whitely Binder, J. Lopez, E. Willmott , J. Kay, D. Howell and J. Simmonds. 2007. Preparing for Climate Change: A Guidebook for Local, Regional and State Governments.)

One of the earlier stages of this evolution (see **Figure 4**) recognized the need for feedback and interventions and monitoring or course correction (as may be needed during review) of elements of the vulnerability assessment process to interface with the transportation infrastructure life cycle processes including transportation planning, asset management, and transportation operations, which cater to a range of adaptation options to improve resilience of the transportation system.

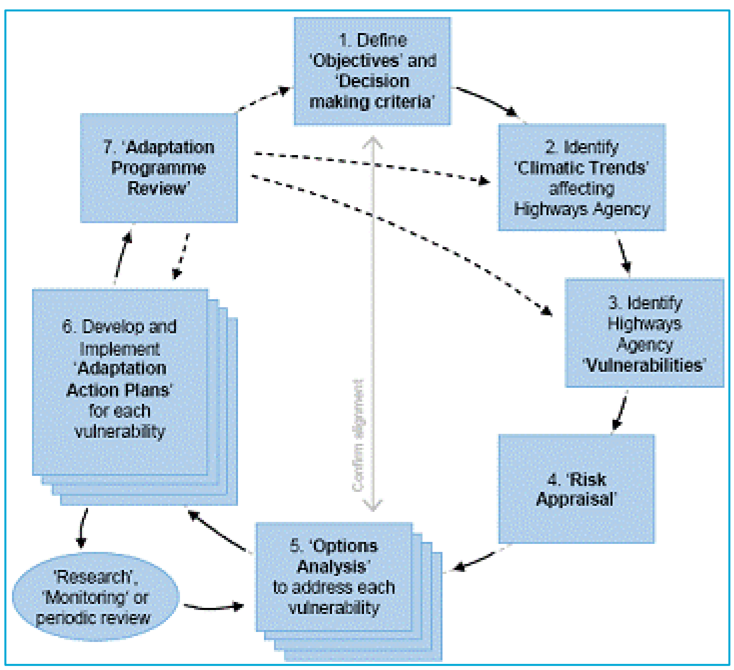

Figure 4: Highways Agency Adaptation Strategy Model (Source: U.K. HACCAS, 2008)

There is also an array of options that the current project approach may consider for implementation on each element of an assessment framework – for example, designation of significance for assets (criticality determination) and types of methodologies that the study team may choose to adopt in such a designation. A methodology can be chosen based on a range of factors including the scope of the current effort and data available in the region.

2.2.1 State Level Best Practices

State and local jurisdictions in Florida have been involved in developing consensus climate projections and methodologies for assessing potential impacts on transportation infrastructure for several years. Some of this work has been funded by FDOT, which resulted in creating tools and processes that help undertake a vulnerability and assess risk. Among the notable efforts is the continued development of sketch planning tools for performing statewide and regional assessments of transportation facilities, initially by Florida Atlantic University (FAU) and thereafter by University of Florida GeoPlan Center.

Two key efforts in this area are the FHWA-sponsored vulnerability and risk assessment pilots:

- Hillsborough County MPO Vulnerability Assessment and Adaptation Pilot
- South Florida Climate Change Vulnerability Assessment and Adaptation Pilot Project

Hillsborough County MPO Vulnerability Assessment and Adaptation Pilot:

The scope of Hillsborough County MPO's assessment was to evaluate and identify the economic impact of sea level rise, storm surge and inland flooding to the multi-modal transportation assets across the County and targeted analysis on critical assets identified during the process. The study was undertaken in three phases:

- Assemble climate and asset data and screen assets for criticality (See Figure D for asset screening process);
- Assess vulnerability of critical assets; and,
- Estimate general economic losses associated with climate impacts.

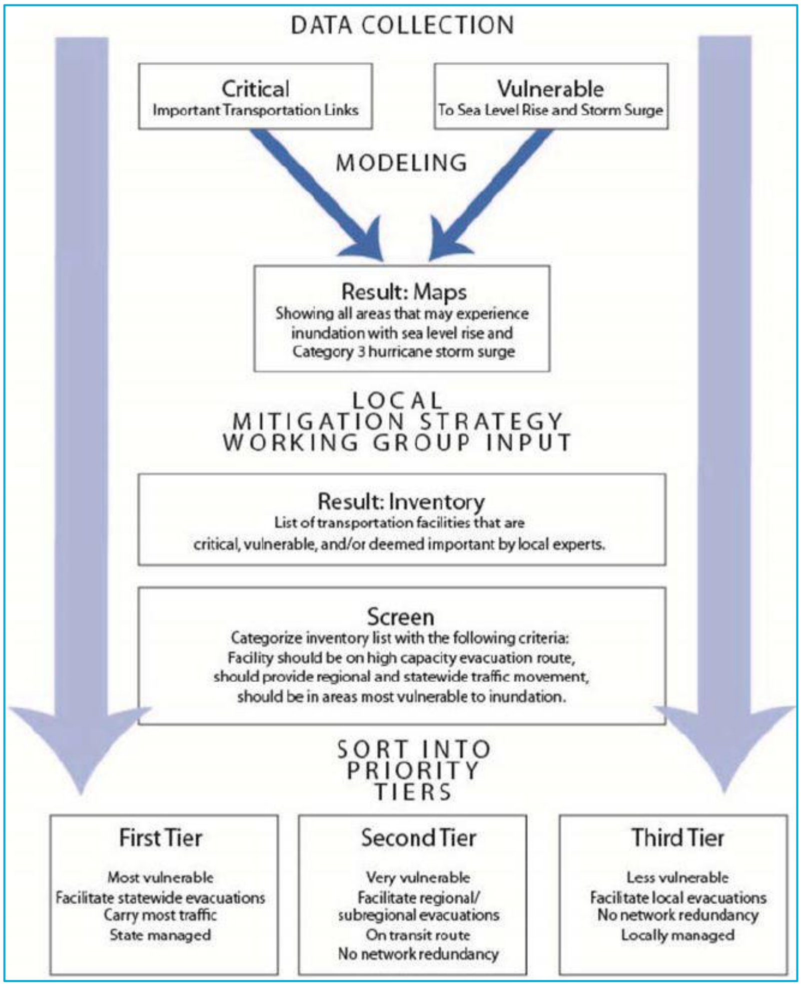

Figure 5: Hillsborough MPO Adaptation Pilot Asset Screening Process

This assessment and resulting findings have been incorporated into the Hillsborough MPO's 2040 LRTP. There are several components of the pilot that can be applied/modified to be scaled-up for a statewide implementation, some of which will be discussed in the following section on synthesis of local/regional efforts.

South Florida Climate Change Vulnerability Assessment and Adaptation Pilot Project:

Partnering agencies in the pilot included Broward Metropolitan Planning Organization (MPO), Miami-Dade MPO, Palm Beach MPO, and the Monroe County Planning and Environmental Resources Department, which conducted the assessment (**Figure 6**) in the four Southeast Counties of the State. Similar to the Hillsborough County MPO pilot, the South Florida pilot also considered the effects of sea level rise, storm surge, and rain driven inundation as the climate stressors for consideration.

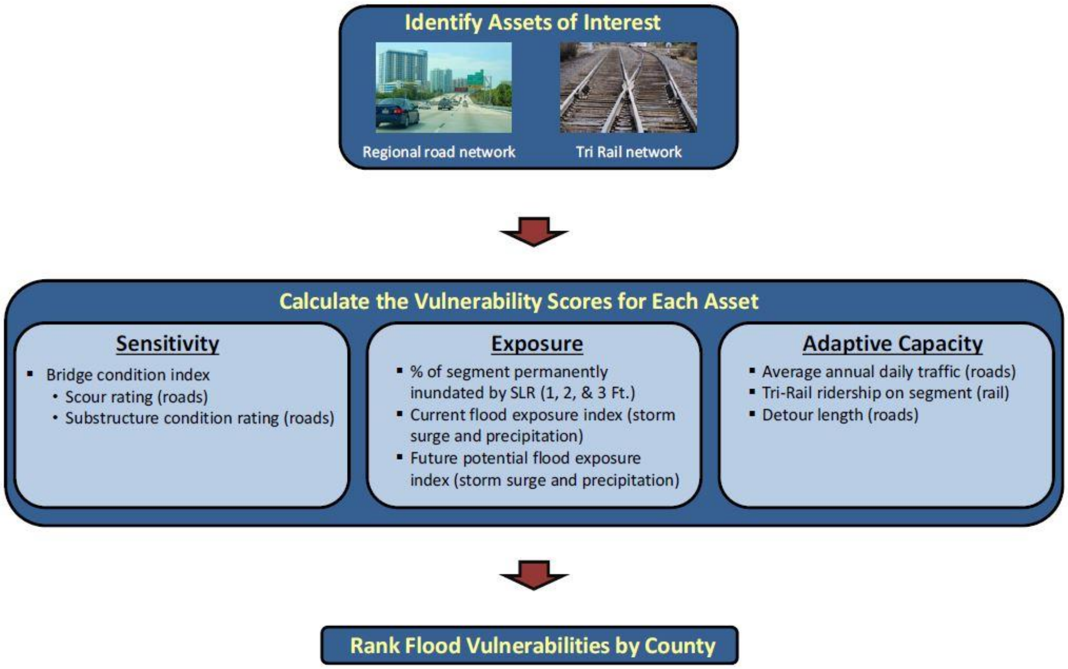

Figure 6: South Florida Climate Adaptation Pilot Vulnerability Assessment Approach

The result of the assessment was a vulnerability score for each regionally significant roadway asset in the study area. Along with identification of vulnerable assets, the study recommended policy directions in the following areas of decision-making:

- Transportation Policy, Planning and Project Prioritization;
- Rehabilitation or Reconstruction of Existing Facilities in High Risk Areas;
- New Facility on New ROW in High Risk Areas;
- Operations; and,
- Maintenance.

This study also provides valuable lessons that are directly relevant in the current project approach construction. Some of the noteworthy areas for consideration include pre-processing of available topographic, climate, and asset data; bringing together data from multiple sources to be combined for a regional (multi-jurisdictional) analysis.

Subsequent studies that built upon the vulnerability assessments were a local-roads vulnerability assessment for Broward County, a South Florida storm surge evaluation to assess the compounding affects of storm surge with sea level change for the modeled 2040 network, and an engineering assessment of potential adaptation strategies for a project in Tampa Bay.

2.3 Synthesis of Regional and Local Efforts

There is a significant body of work that exists from studies and initiatives that have been completed or currently in progress in the State which can inform the development and implementation of this current project. Leveraging methods, data, and results from this previous work may be considered as jump-off points or guidance pathways in undertaking a climate risk assessment of SIS facilities. The project team grouped these efforts based on the following common elements. These elements are integral to performing vulnerability assessments:

- Defining scope and long-term vision for undertaking the risk assessment;
- Data collection, management, and suitability;
- Development and implementation of vulnerability and risk assessment framework based on current conditions and facilities; and,
- Recommendations for additional research and/or integration and mainstreaming resilience into transportation practice.

2.3.1 Defining Scope and Long-Term Vision for Undertaking the Risk Assessment

An expanded review of the scope based on a preliminary approach will identify the means in which the objectives of the effort can be realized as it relates to various stages of transportation practice including planning, programming, asset management, maintenance, and operations. Ultimately, the framework is intended to be a decision-support tool/mechanism that strengthens FDOT's institutional capacity to incorporate climate risks into its decision-making, as it relates to the sustainability of SIS network and the larger issues of enhancing the State's transportation mobility and economic competitiveness.

2.3.2 Data Collection, Management, and Suitability

Climate, topography, and asset data collection and pre-processing it to fit the scope, scale, and other specific requirements of the analysis is key for the success of the risk assessment effort. There are several examples of reliance on data and tools that have been used by multiple previous studies and efforts undertaken in the state. One such example is the Sea Level Scenario (SLS) Sketch Planning Tool, created by the University of Florida GeoPlan Center, an effort, which was funded by FDOT. This tool helps identify vulnerable transport infrastructure to current and future flood risk. It visualizes and provides inundation and exposure data for current flood risks including inland flooding and storm surge as well as future flood risks due to sea level rise. It should be noted that there are some constraints to the data, which required pre-processing and rectification to exposure analysis results. These were documented in both FHWA pilots undertaken in Florida and subsequent enhancements to the tool have been made.

Use of topographic data suited for the purpose is another key consideration for this current project. The project team must decide on selecting best suited Digital Elevation Model (DEM) to cover the state's extent or another model. There are better resolution DEMs for some selected areas that have been recently available that could be considered in creating a mosaic for the extent suited for this project purpose. A mosaic of DEMs, some more recent than others with higher resolution but older, is anticipated to be used for this project.

2.3.3 Development and Implementation of Vulnerability and Risk Assessment Framework

There have been several vulnerability and risk assessment frameworks or assessment methodologies developed by various studies conducted across the US and specifically in Florida. In the transportation sector, FDOT has been involved in funding projects which have developed techniques to identify potentially vulnerable transportation infrastructure. In 2012, FDOT funded research by Florida Atlantic University (FAU)[8] to undertake literature review of sea level rise projections, data gaps, and its potential impacts on transportation infrastructure. This study also developed a methodology to conduct a statewide assessment of state highways and SIS facilities that are at risk of inundation due to sea level rise in the near term.

More recently, the SLS Sketch Planning Tool, developed by the GeoPlan Center, developed an interactive GIS-based planning tool framework to conduct statewide and regional assessments of transportation facilities potentially vulnerable to sea level change. The tool and data have been enhanced and are good starting points to refine the methodology as it relates to data or processing for use in the vulnerability assessment.

It should also be mentioned here that the two FHWA pilot projects implemented the FHWA adaptation framework successfully while adjusting it to their needs and scope of each project. While the Hillsborough pilot employed the area's regional model to estimate impacts to regional mobility associated with disruptions due to inundation risk, the South Florida pilot used a scoring-based approach based on travel activity measures like average annual daily traffic (AADT) of roadway segments to generate vulnerability scores.

2.3.4 Integration and Mainstreaming Climate Resilience into Transportation Practice

The ultimate objective of a vulnerability and risk assessment is to inform the transportation decision-making process. Hence a key outcome of the assessment should be integration and institutionalization of accounting for extreme weather and climate risk into FDOT's transportation policy and implementation. Both FHWA pilots have made specific recommendations to area jurisdictions and project partners on how to mainstream inclusion of risk as a key factor in their decision-making processes.

Recognizing that the FTP's goals and objectives include adaptation and resilience to extreme weather, a key outcome of the current project may be to provide a feedback mechanism to elements of the transportation decision-making process. This can be done by providing relevant summaries of the vulnerability assessment to practitioners at FDOT who may incorporate climate risk throughout the planning, programming, design, maintenance, and operation of Florida's transport infrastructure.

[8] Development of a Methodology for the Assessment of Sea Level Rise Impacts on Florida's Transportation Modes and Infrastructure, Florida Atlantic University, BDK79 977-01

http://www.fdot.gov/research/Completed_Proj/Summary_PL/FDOT_BDK79_977-01_rpt.pdf

3.0 Methodology

3.1 Vulnerability and Risk Adaptation Framework*:*

The project team employed a customized vulnerability and risk assessment framework, loosely based on FHWA's adaptation framework, for use in this project. The advantages of using an assessment methodology compatible with FHWA's framework include adoption of a tested and refined methodology developed over a range of regional and state DOT projects across the US, consistency with Federal guidance, and scope for availability of technical and other resources as may be needed.

The project team used the following SIS Risk Assessment Framework as shown in **Figure 7** to provide decision support for enhancing climate resilience of SIS facilities by identifying and assessing potential risks and vulnerabilities. The framework has the following modules with ample scope for monitoring and evaluation of outcomes:

- Setting Mission Goals and Objectives;
- Data Collection and Processing;
- Conduct Vulnerability and Risk Assessment;
- Develop recommendations for Adaptation Strategies; and,
- Integrate Assessment Outcomes into FDOT's Decision Support Systems.

This scope of work provides recommendations for next steps, such as additional studies or pilot projects.

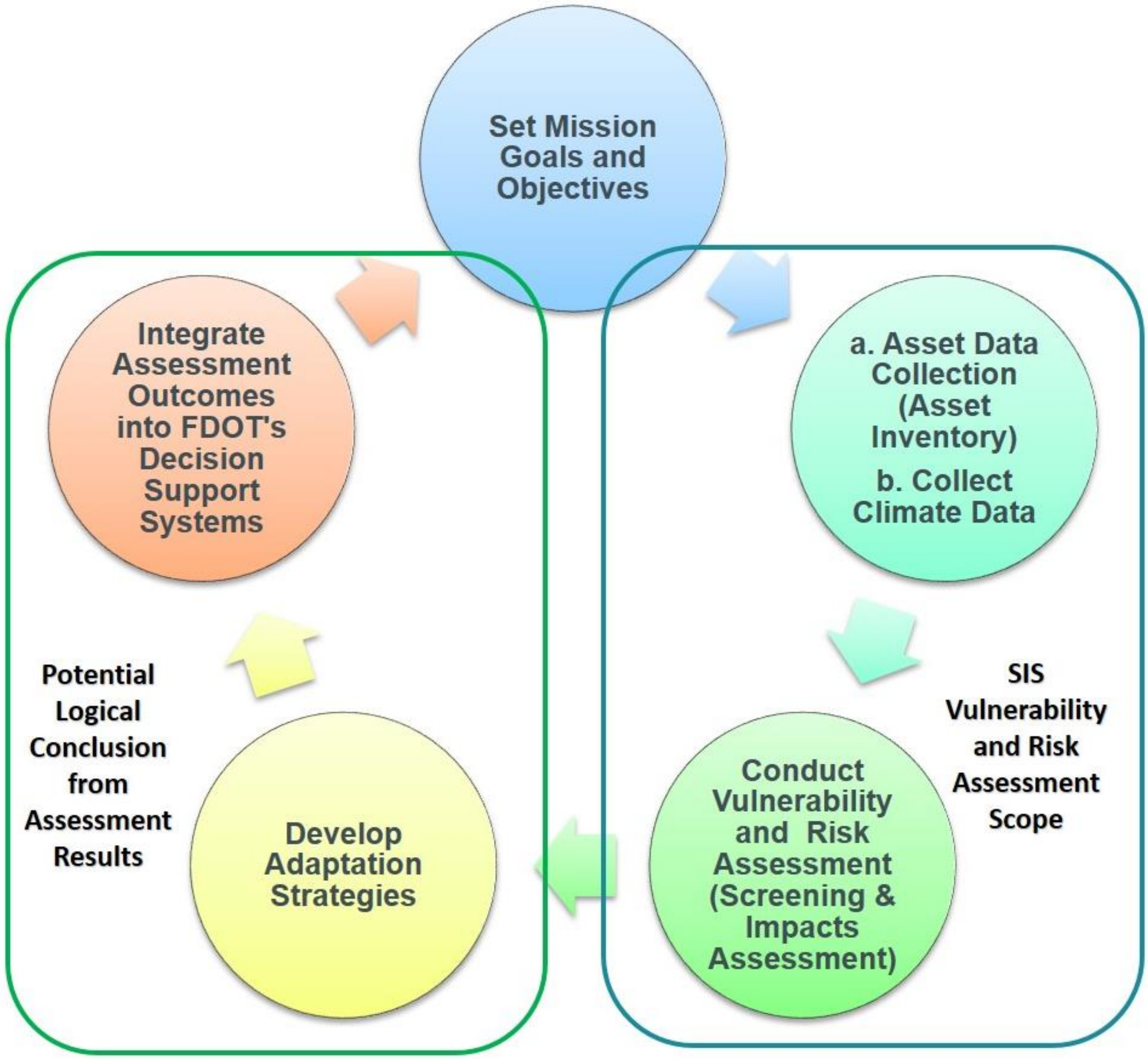

Figure 7: Proposed Framework for SIS Vulnerability and Risk Assessment

3.1.1 Setting Mission Goals and Objectives

This module helps inform how the assessment may be used by FDOT over the transportation infrastructure life-cycle of SIS assets from planning to operations and maintenance. It also serves as an opportunity to articulate and plan how the risk assessment fits into FDOT's larger decision-making process and identify stakeholders within FDOT divisions like planning, engineering, and management as they relate to SIS facilities. FHWA's vulnerability assessment framework provides an informative module[9] on defining the objectives of a vulnerability assessment and how it may be used to define the desired

[9] Virtual Framework for Vulnerability Assessment, Module 1: Articulate Objectives

https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/modules/index.cfm?moduleid=1 outcomes set out by FDOT. For this work effort, the existing (2017) SIS highway network and associated bridges has been evaluated.

3.1.2 Data Collection Plan

Data collection and processing is the critical building block of undertaking a vulnerability risk assessment and the quality and suitability of available data determines the output and even the outcome of the assessment. Data that needs to be collected and processed for this purpose can be broadly classified into the following data categories:

- Climate;
- Topographic;
- Asset;
- Asset Characteristics; and,
- Critical Facilities.

The project team identified sources and configuration of data for application on this project to suit its scope and requirements. The project team leveraged existing data resources, scenarios and sensitivity thresholds from previous studies and projects to suit the scope and scale of application in this project.

Tasks involved with the data collection plan included collection, processing, and management of climate, asset, topographic, and critical facilities data. **Table 1** on the next page presents the data collected for the project and whether additional processing was required of the data to be used for the multiple assessments.

Name of the Dataset	Description	Source	Processing Needed
Climate Data			
Sea Level Rise Projections	USACE 1 and 2-foot projections	University of Florida (UF) GeoPlan Center / Florida Department of Transportation (FDOT)	No
Storm Surge Depth Inundation	Maximum Depth Inundation for Category 1/3/5 Hurricane Storm Events	Florida Division for Emergency Management (FDEM)	No
Flooding	Most recent statewide DFIRM available	Federal Emergency Management Agency (FEMA) / Florida Geographic Data Library (FGDL)	No
Topographic Data			
Digital Elevation Model (DEM)	5-meter Statewide DEM	UF GeoPlan Center / FDOT	Yes
	10-meter National Elevation Dataset	Unites States Geological Survey (USGS)	Yes
	10-meter NOAA Coastal DEMs (2014 Central Florida, 2015 Miami, 2015 Pensacola, 2014 Tampa Bay)	National Oceanic and Atmospheric Administration (NOAA)	Yes
	3-meter Lake County, 3-meter Polk County, 3-meter Orange County, 1.5-meter Eastern Charlotte County, 3-meter Herbert Hoover Dike Project	South Florida Water Management District	Yes
	1-meter Kingsley to Rodman and Satsuma	St. Johns Water Management District	Yes
Asset Data			
Study Highway Corridors	SIS and Emerging SIS Corridors and Military Access Facilities (Centerline)	FDOT	Yes
Study Bridges	Bridge Locations	FDOT	Yes
Asset Characteristics Data			
Traffic Volumes	2016 Annual Average Daily Traffic Volumes (AADT)	FDOT	Yes
Hurricane Irma Volumes	Continuous 24-Hour Traffic Volume Reports for Telemetered Collection Sites Along Interstates	FDOT	Yes
Bridge Characteristics	2018 Quarter 1 Bridge Information Report, National Bridge Inventory (NBI)	FDOT / Federal Highway Administration	Yes
Highway Pavement Conditions	Most Recent Pavement Condition Ratings Statewide	FDOT	No
Critical Facilities Data			
Bulk Fuel Facilities	Major Bulk Fuel Distribution Facilities	US Department of Energy	Yes
Seaports	Seaport Locations / Current and Historical Tonnage and TEU Data	FDOT	Yes
Public Shelters	Public Shelter Locations and Capacities	FDEM	Yes

Table 1: SIS Vulnerability Assessment Project Data Matrix

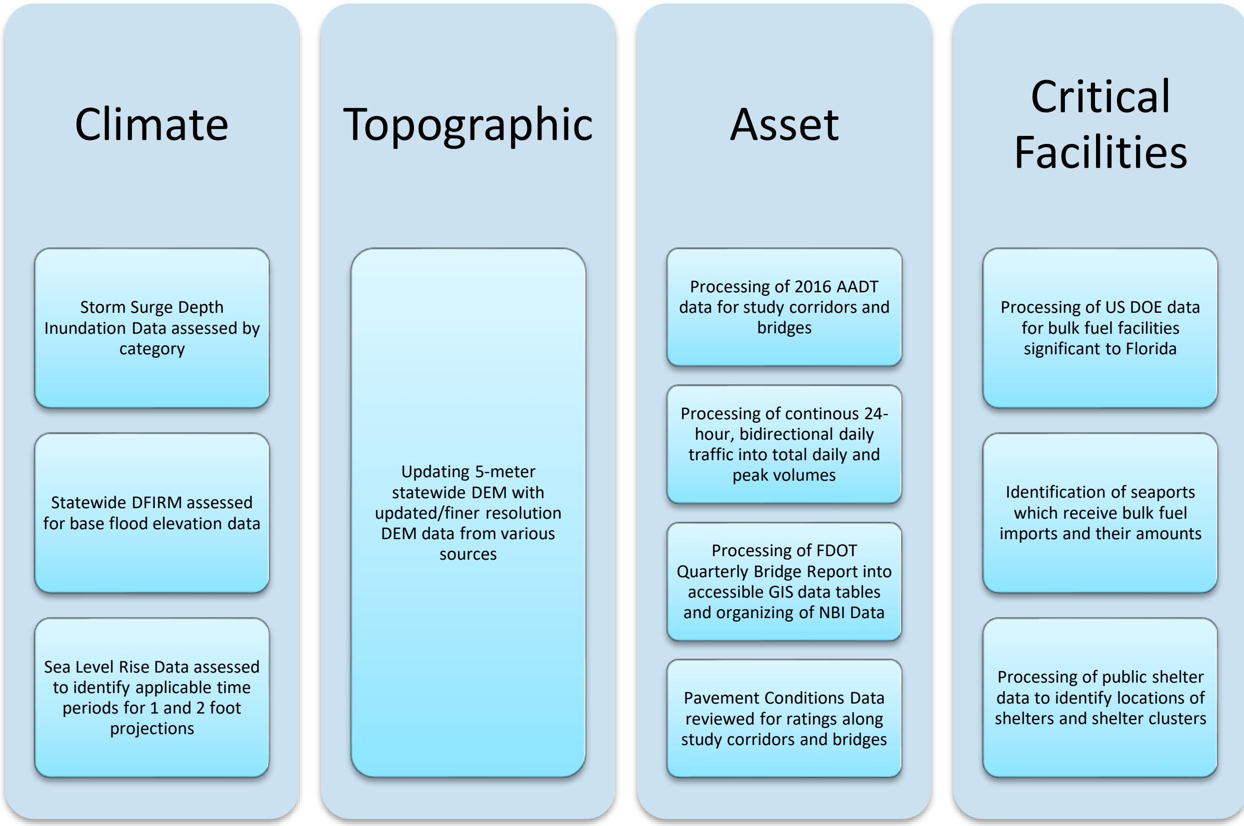

Figure 8: Data collection, processing and source considerations

The data collected for this project required additional processing as described in **Figure 8** except for climate data and pavement condition data associated with asset characteristics. As described in further detail later in this is section, storm surge inundation depth data did not require additional processing due to elevation values from relatively recent, fine resolution DEM and LiDAR sources being used. Sea level rise data was utilized to identify necessary time periods for each county within the state to be impacted by 1 and 2-foot projections. Assessment of Florida's SIS highway corridors was already completed in previous work for FDOT and the results of those assessments were reviewed for this project. Statewide flooding data was collected from FEMA's National Flood Hazard Layer as October 6, 2017. The National Flood Hazard Layer is the agency's database which contains DFIRM information for the entire country. This includes the most recent county level DFIRM data that was present in the National Flood Hazard Layer at the time. Pavement condition data was provided in the format and context required for assessment. **Figure 8** describes the processing needed for the other data collected for this effort of which additional details can be found in the next section.

Criticality Assessment/Determination:

The scope of assets that may be included for vulnerability and risk assessment shall be narrowed during a further selection and characterization of assets during assessment of "criticality."[10] It is important to define

[10] Assessing Criticality in Transportation Adaptation Planning, FHWA https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/modules/criticality_guidance/

how to evaluate criticality, to determine the variables that may be used to constitute what is critical for FDOT from a SIS perspective and data sources that may need to be inputted to make such a determination. This process is typically a collaborative and consultative one that takes the implementing agency and any other stakeholders' interpretation of what constitutes criticality. AADT is most often used as a proxy for determining criticality as it is a good measure of use for any given roadway facility.

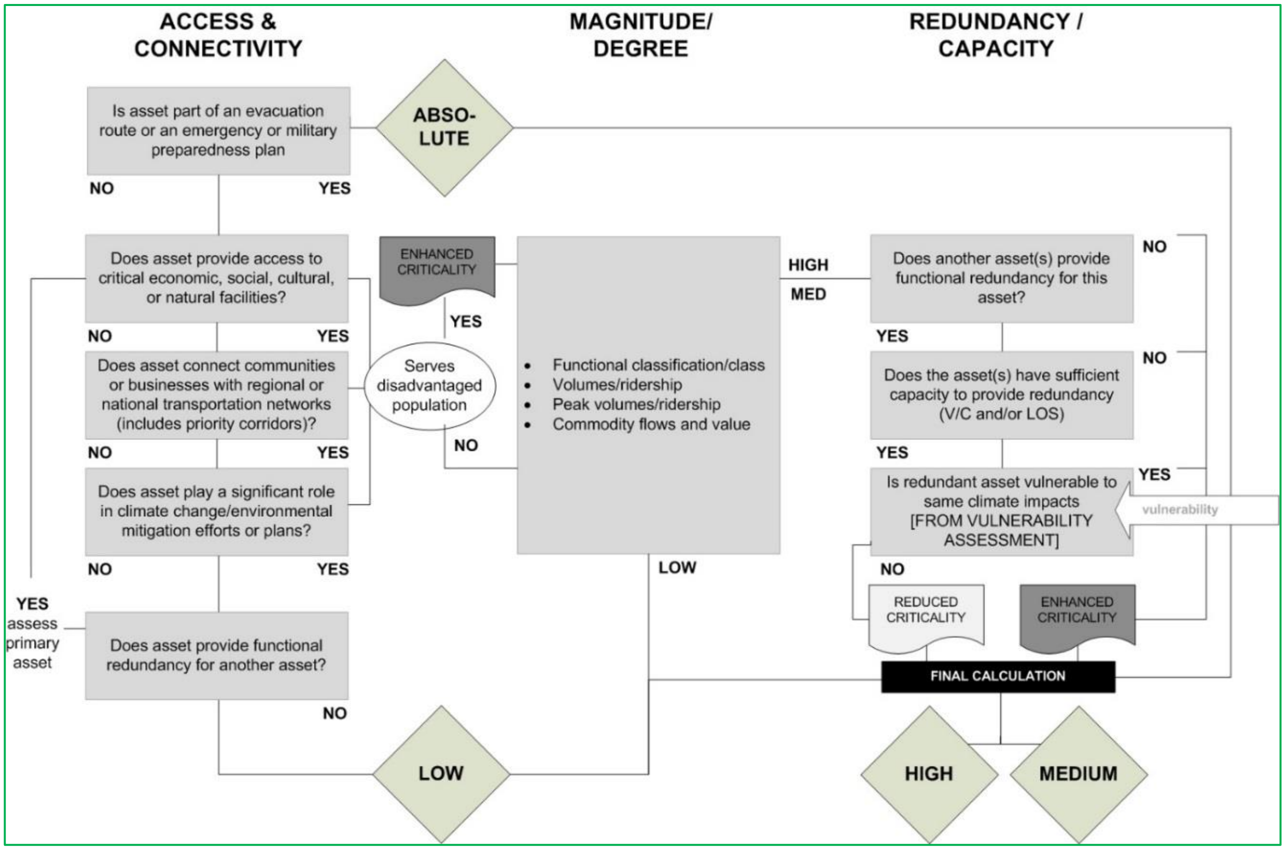

Figure 9: Illustrative Criticality Assessment Development Process (Source: NJTPA Phase-1 Climate Change Vulnerability and Risk Assessment, FHWA Pilot)

3.1.3 Conduct Vulnerability and Risk Assessment

This is the core module of the assessment process and can be subdivided into three sub-modules:

- Refining Asset Selection;
- Vulnerability Screening; and,
- Impact assessment.

Refining Asset Selection

For the purposes of this effort, specific natural hazard stressors – storm surge, flooding, and sea level rise – will be factored into the vulnerability assessment. SIS highways and military access facilities have been chosen as transportation assets for evaluation. The assessment will consider both roadways and bridges.

A GIS analysis of inundation exposure can be used as a further refinement to narrow the pool of assets that may have to be included for further assessment. This process can form the basis for prioritization of resources not only in this project, but also for eventual targeted engineering assessments. The selected assets may also be eventually subject to economic analysis to evaluate adaptation options using cost-benefit analysis.

Vulnerability Screening

The vulnerability of any given asset has been defined as a product of three factors:

- Exposure;
- Sensitivity; and,
- Adaptive Capacity.

While exposure can be determined and verified by GIS-based approaches, sensitivity of an asset is unique to the impact of exposure (prolonged flooding, wave velocity, etc.) determine its vulnerability and the impact on their serviceability. Sensitivity is asset focused, and pavement and bridge conditions will be used. The team assessed adaptive capacity of the SIS roadways by looking at aspects such as AADT and daily vehicle miles traveled (VMT). Exposure for this project refers to potential impacts from storm surge and flooding which are described in greater detail in Sections 3.2.4 and 3.2.5.

Sensitivity:

Sensitivity of roadway assets depend on the type of asset – for example, bridges, decks, approaches, etc. Sensitivity also varies by the type of water that may be the cause of flooding – salt or fresh water, given the corrosive effects. Sensitivity is based on the type of impact – inundation, submergence or impact as a result of high velocity water action (due to waves, surge or flash floods). A high-level sensitivity screening could be applied subsequently to the exposure analysis to identify specific assets that are vulnerable to such specific detailed impacts, as data may permit. Incidence of such assets along a SIS roadway facility can further qualify the asset as being vulnerable based on its sensitivity.

For highway corridors, pavement condition ratings are used. The last update to this data source is November 25, 2017 and is derived from event mapping feature 230 from the FDOT Roadway Characteristics Inventory (RCI). For bridges, two sets of bridge condition data were collected and processed: sufficiency ratings and scour critical. Sufficiency ratings pertain to the overall fitness of the bridge structure including its functional status and condition ratings for each structural component of a bridge. Scour critical pertains to erosive actions from flowing water impacting a bridge's structural support system.

Adaptive Capacity:

Adaptive capacity is the ability of a system or an asset to cope with the impacts and consequences of extreme weather or other climate trends. Adaptive capacity has an inverse relationship with an asset's vulnerability. The higher the adaptive capacity of an asset, the lower its vulnerability and vice versa. Typical indicators that are taken into considerations for adaptive capacity include AADT, detour lengths, change in VMT, delay, designation as an evacuation route, and functional classification of the facility (also typically correlated to AADT). Relative weights can be designated to these indicators as they are brought together to develop an index of adaptive capacity.

It should be noted that adaptive capacity is also a systemic indicator, and some of the impacts (including disruptions) may need to be considered at a holistic (systemic) level. This is typically executed better in a travel model environment, but if the adaptive capacity of individual assets are determined at an individual asset level, the assumptions should be caveated accordingly. For example, availability of redundant facilities that are not part of the SIS network is something that needs to be recognized, though it extends beyond the scope of the project.

3.2 Evaluation Methodology

3.2.1 Overview and Scope

The Strategic Intermodal System (SIS) is the backbone of Florida's transportation system and was created by the Florida Legislature and Governor in 2003 to enhance Florida's transportation mobility and economic competitiveness. The SIS is a statewide network of high-priority transportation facilities which includes interstates and state highways which are critical to the movement of people and freight between Florida's diverse regions, as well as between Florida and other states. In addition, in times of hazardous weather events, these same facilities are used for the evacuation of vulnerable populations to points of safety.

Hazardous weather events such as severe thunderstorms and hurricane storm events, as well as changes in climate, can expose the state to damaging flooding and storm surge. These risks can impact the functionality of the SIS network in times of greatest need. The project team reviewed these risks and assessed the existing SIS network's exposure to these risks. The project team developed a multistep process for assessing exposure to these risks:

- Identified the transportation infrastructure along the SIS network to be assessed;
- Creation of a digital elevation model;
- Separate assessments of storm surge depth inundation data and 100-year base flood elevation data in relation to the identified SIS network;
- Review of roadway results from the University of Florida GeoPlan Center's Sea Level Rise Calculator tool for SIS facilities; and,
- Development of composite assessments of flooding and storm surge risks.

3.2.2 Transportation Infrastructure (Asset)

As described earlier, the roadway centerline and bridge data were sourced from FDOT. The project team assessed SIS corridors and military access facilities (MAFs) that have been designated as of November 2017[11]. The risk assessments were conducted for highway corridors and bridges separately. For the purpose of this analysis, only bridge structures associated with interstates were assessed[12].

[11] Please note that additional facilities associated with US 98 in West Florida and SR 50 in Central Florida were also analyzed as they are planned to be designated as SIS Corridors.

[12] Bridge structures for this analysis include both those that cross over waterways and other transportation structures such as interchanges. Inclusion of ramps associated with interchanges was identified due to their function as access

(Footnote continued on next page...)

Elevation data for the transportation infrastructure was developed from a digital elevation model (DEM) using ESRI ArcGIS. A DEM is a specialized database file that represents the relief of a terrain's surface between points of known elevation using data from ground surveys and photogrammetric data capture methods such as LiDAR. Roadway centerline and bridge data are interpolated onto the DEM which then pulls the elevation values from the DEM for the facilities. After this is completed, riverine waterways identified using the US Fish and Wildlife's National Wetland Inventory were removed. This is to ensure that incorrect elevation data associated with river and lake beds are not used. The elevation point used for each roadway segment is the minimum elevation value identified along the specific segment. The assessments look at a roadway's lowest (weakest) point that could be impacted. For bridges, the lowest point of the approaches were used for the investigation[13].

The storm surge and flooding analyses both use the transportation infrastructure data. However, as described in the storm surge section, the storm surge data already considers elevation data. The elevation data values generated from the DEM were used for the flooding analysis.

3.2.3 Digital Elevation Model (DEM)

For the flooding analysis, a DEM was developed to identify elevation values for highway corridors and bridge approaches associated with the SIS transportation infrastructure under analysis. The most recent data available was used with the highest possible resolution. This ensures the best possible elevation data that can be used at a high-level. Several DEM data sources were assessed including: Unites States Geological Survey National Elevation Dataset (USGS NED), National Oceanic and Atmospheric Administration (NOAA) Coastal Elevation Models, DEMs available through the Florida Water Management Districts (WMD), Florida Land Boundary Information System (LABINs), University of Florida (UF) GeoPlan's DEM for Sea Level Rise Inundation Surface Calculator tool, and more.

UF Geoplan DEM

The UF GeoPlan DEM for the Sea Level Rise Calculator tool was identified for use as the basis for developing a DEM. The UF GeoPlan DEM was completed in 2013. The UF GeoPlan DEM was used for the analysis because:

- The Sea Level Rise Calculator tool was already released, and the data could be easily obtained. The tool has also been used for previous work products for the Florida Department of Transportation (FDOT).
- The DEM covers the entire state with a resolution of 5 meters (or 1/9 arc second). The lowest resolution of the USGS NED available for use throughout the state of Florida is 10 meters (1/3 arc second).

and egress to interstate corridors. Additional bridge structures associated with the remaining corridors will be assessed at a later date.

[13] Assessment of bridges for risks is problematic due to the availability of bridge deck data. Since DEMs provide elevations for a terrain's surface, the DEM may not include the actual bridge deck for assessing the bridge's elevation. Instead, the reported elevation may include the depths of a water way, the elevation of another transportation facility crossed, or no elevation may be reported due to the waterway crossed missing from the DEM. This analysis then decided to assess bridge approaches instead. Future analysis should include bridge deck elevations for assessing potential flooding scenarios.

- There are a few gaps and areas with older data inland within this statewide DEM. However, they can be alleviated by inclusion of more recent DEMs.

Data sources used to develop the coastlines in the GeoPlan DEM include Northwest Florida WMD LiDAR data collected in 2006 and Florida Division of Emergency Management's LiDAR project data for the Statewide Regional Evacuation Study Program (SRESP) collected from 2007 to 2009. Inland areas of Florida utilized data derived from Florida Fish and Wildlife Commission.

Additional DEMs

Additional DEMs were identified and used to update portions of the GeoPlan statewide DEM. These DEMs included more recent elevation data and/or data with a higher resolution, with a focus on inland areas. These included: USGS NED DEMs, WMD DEMs, and the NOAA Coastal DEMs.

I. **USGS NED DEMs.** The updated data sources from 2013 to 2017 were used for the following areas:

   a. Portions of Escambia, Walton, Jefferson, Madison, Taylor, Lafayette, Gilchrist, Suwannee, Baker, Columbia, Union, Bradford, Martin, Palm Beach, Broward, Highlands, Monroe, Orange, Glades, DeSoto, and Miami-Dade Counties.

   b. Entire Counties: Osceola and Citrus.

   The resolution for these updates are 10 meters. For coastal counties, the portions covered are inland and do not include any coastal areas.

II. **Water Management District (WMD) DEMs.** The following DEMs were used:

   a) Entire Counties: Lake (3 meters, South Florida WMD), Polk (3 meters, South Florida WMD), Orange (3 meters, South Florida WMD).

   b) Portion of Eastern Charlotte County (1.5 meters, South Florida WMD).

   c) The Herbert Hoover Dike Project (3 meters, South Florida WMD) which primarily cover portions of Highlands, Okeechobee, and Glades Counties. The DEM also covers small portions of Charlotte, DeSoto, and Hardee Counties.

   d) Kingsley to Rodman and Satsuma (1-meter, St. Johns River WMD) which covers portions of Putnam and Clay Counties.

III. **NOAA Coastal DEMs.** The following DEMs were used:

   a) 2014 Central Florida Coastal DEM which covers the entirety of Indian River County, the majority of Brevard and St. Lucie Counties, and a portion of Okeechobee County.

   b) 2015 Miami Coastal DEM which covers coastal areas of Miami-Dade and Broward Counties.

   c) 2015 Pensacola Costal DEM which covers coastal areas of Escambia and Santa Rosa Counties.

   d) 2014 Tampa Bay DEM which covers coastal areas of Sarasota, Manatee, Hillsborough Counties as well as the entirety of Pinellas County and the southwestern portion of Pasco County.

All NOAA Coastal DEMs are 10 meters in resolution. Please note that all NOAA Coastal DEMs include data from the SRESP's LiDAR project as well as other data sources including but not limited to US Army Corps of Engineers (USACE) LiDAR data and hydrographic surveys from the USACE and WMDs.

All elevation data used was adjusted to the statewide DEM's projection and measurements. In areas of overlap, either age of data or resolution took priority depending on the overlap. The final statewide DEM was used for the flooding assessment. This assessment was done at a high-level statewide view for planning purposes only[14].

3.2.4 Storm Surge

Storm surge depth inundation data used for the project was collected from the Florida Division of Emergency Management (FDEM) in September of 2017. The data is processed by FDEM as a result from the Sea, Lake and Overland Surges from Hurricane (SLOSH) model. The SLOSH model is NOAA's numerical storm surge prediction model that is used by NOAA's National Hurricane Center as well as emergency management departments throughout the nation.

Results from the SLOSH model are based off the most recently available basin data at the time of the runs:

- Panhandle area (2010-2013) – Escambia County east to Citrus/Hernando County line as well as from Nassau to the Flagler/Putnam/Volusia County line, which also includes storm surge areas associated with the St. John's River; and,
- Peninsula area (2016/2017) – the remaining areas of the state of Florida potentially impacted by surge.

A series of runs were completed using the SLOSH model, utilizing various storm track headings and speeds for each area of the state that is representative of storm behavior. The MOMs[15] of the final results are used to develop the final outputs of storm surge depth inundation for each area of the state. The MOMs are the maximum potential storm tide values for each category of storm.

Elevation data is then subtracted from the depth information of the MOMs to provide the final storm surge heights. Elevation data used for the processing includes the SRESP's LiDAR data and the 2015 Miami-Dade Coastal DEM from NOAA[16]. The results are stored within ArcGIS products. The final depths reported statewide are represented by a grid code as shown in **Table 2**.

[14] Further analysis of any areas impacted with the use of the elevation data from this DEM for site- specific and local should include additional analysis.

[15] MOMs stand for maximum of MEOWs. MEOWs stand for Maximum Envelope of High Water. Think of MOMs as the maximum of the maximums.

[16] The elevation data utilized by FDEM for the processing storm surge depth inundation for the state is not significantly different from the updated statewide DEM developed for this project. In addition, in several areas, the elevation data utilized by FDEM has a higher resolution for coastal areas than the updated statewide DEM. Therefore, it was determined that reprocessing the data using the updated statewide DEM would not be in the best interest of this task.

Raster Grid Code	Panhandle Depths (Feet)	Peninsula Depths (Feet)
1	Dry/Inland	Dry/Inland
2	0.0-0.5	0.0-1.0
3	0.5-1.5	1.0-1.5
4	1.5-3.0	1.5-3.0
5	3.0-5.0	3.0-6.0
6	5.0-7.0	6.0-9.0
7	7.0-10.0	9.0-12.0
8	10.0-15.0	12.0-15.0
9	15.0-20.0	15.0-20.0
10	20.0-42.0	20.0-42.0

Table 2: Storm Surge Inundation Depth Ranges by Grid Code

For the storm surge assessment, storm surge depth inundation is overlaid on transportation infrastructure files using ESRI ArcGIS geoprocessing tools to identify highway corridors and bridges that could be potentially impacted by a grid code cell. For each highway corridor segment and bridge approach identified to be impacted by storm surge, the infrastructure is graded to the highest potential range of inundation. Storm surge depth inundation for Categories 1, 3, and 5 hurricane storm events were used for the assessment as shown in **Figures 10, 11, and 12**. As shown in the figures, as the intensity of the hurricane storm event increases, so does the extent in which inundation moves from the coastline areas (Category 1) further inland (Category 5). This distinction is important to note as storm surge related to a hurricane storm event with the intensity of the Category 5 will have the potential to impact more facilities than a Category 1 or 3.

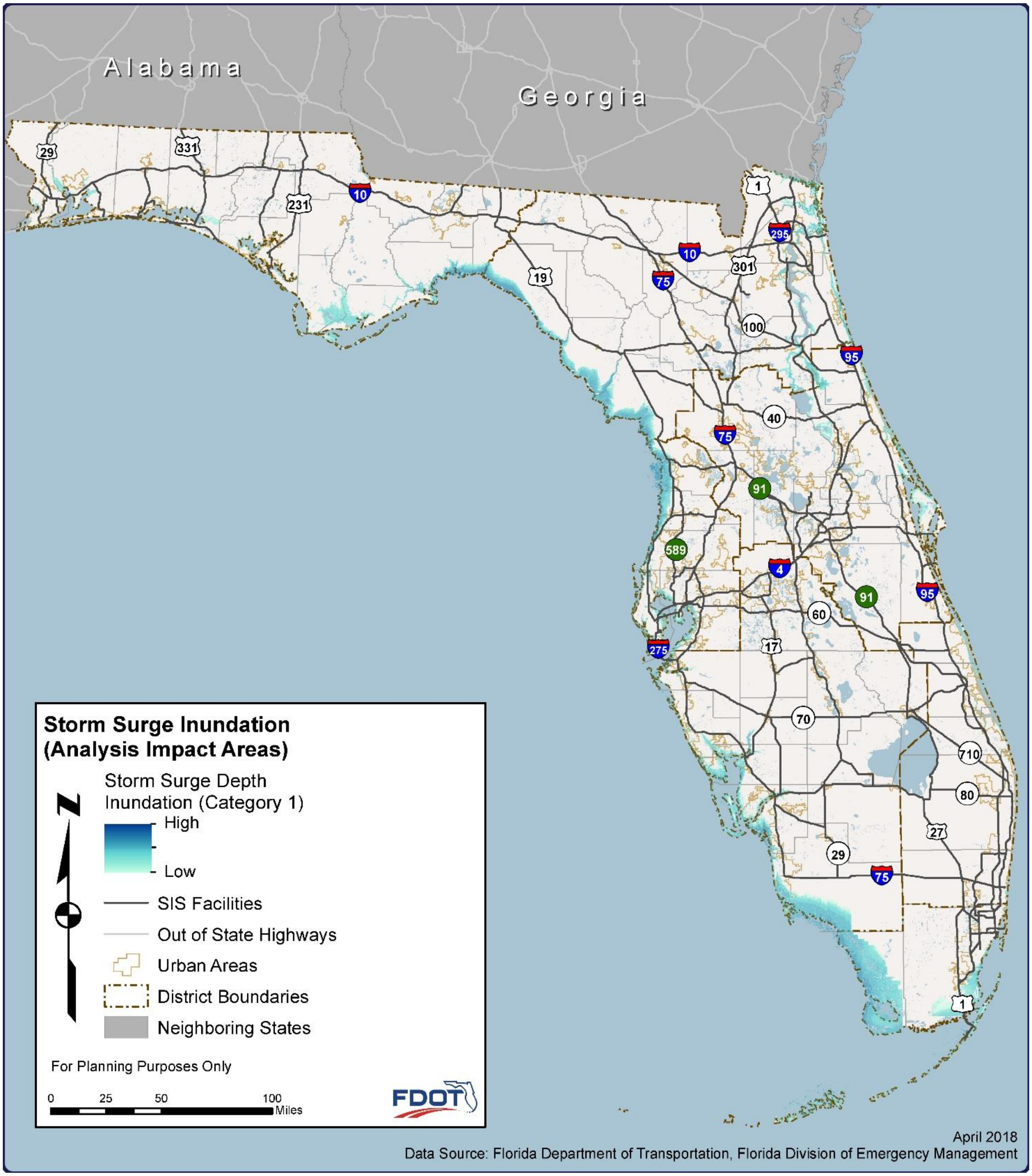

Figure 10: Storm Sturge Inundation Areas – Category 1 Hurricane Storm Event

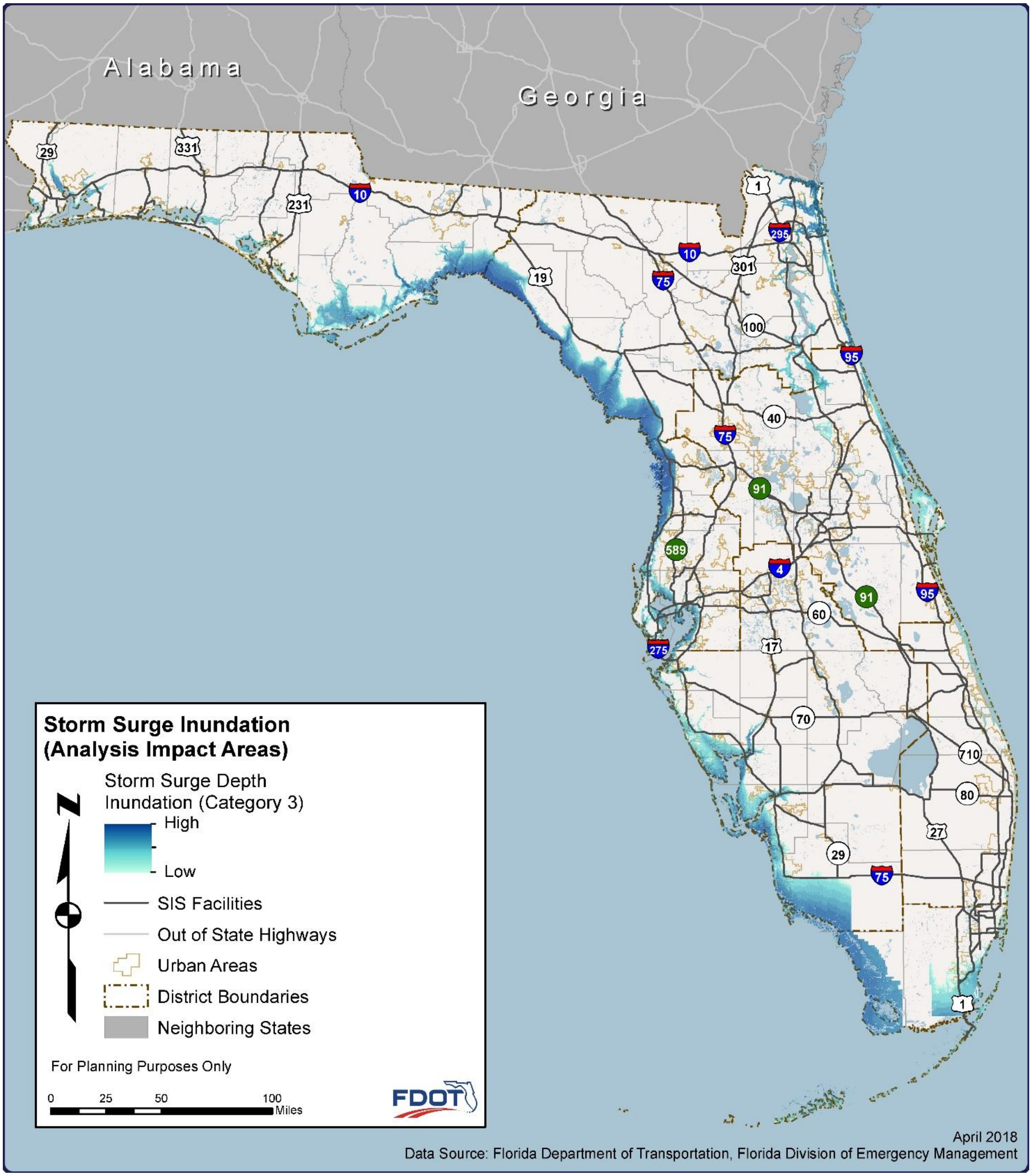

Figure 11: Storm Surge Inundation Areas – Category 3 Hurricane Storm Event

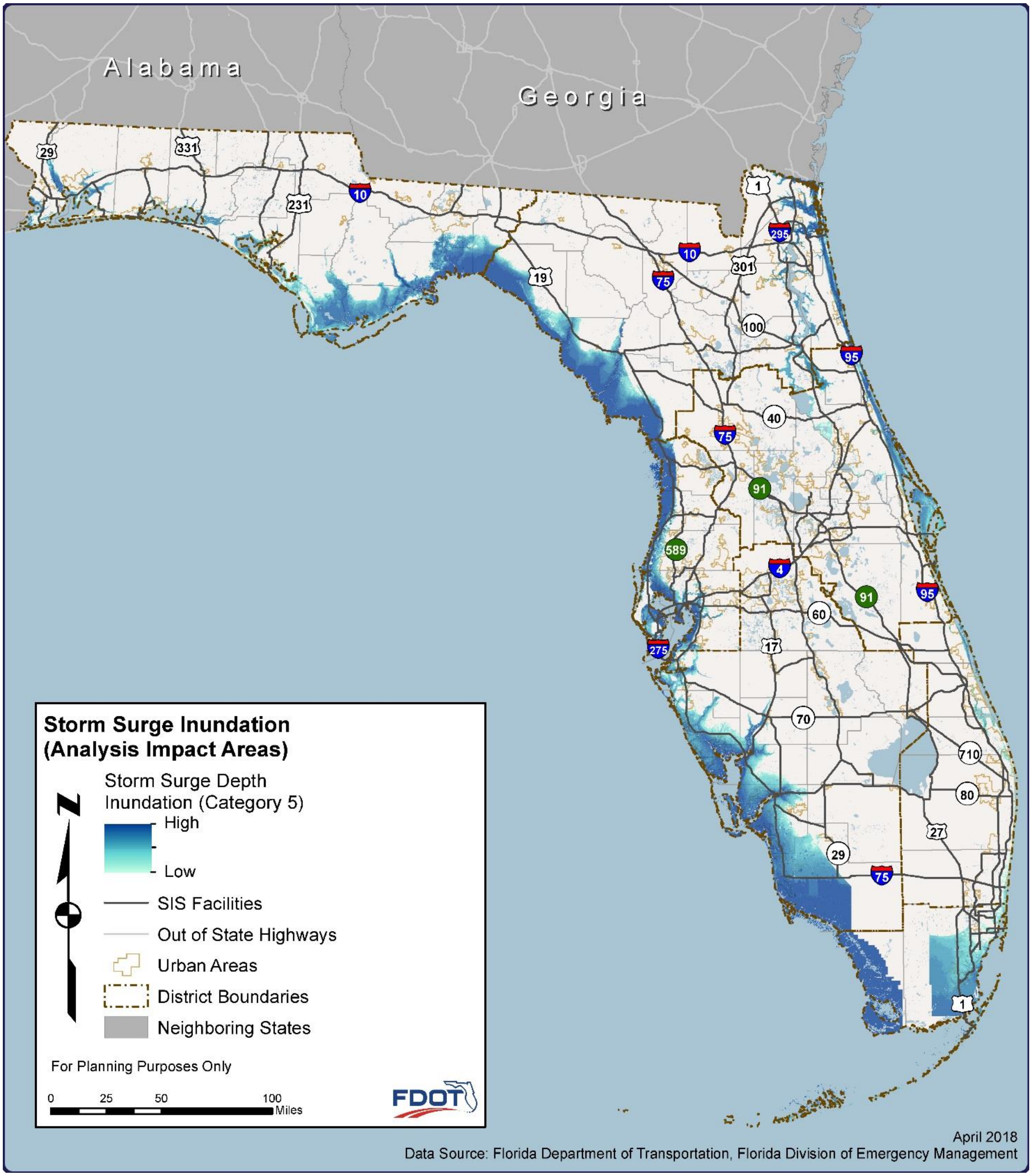

Figure 12: Storm Surge Inundation Areas – Category 5 Hurricane Storm Event

3.2.5 Flooding

The assessment of flooding, which includes coastal and inland flooding, was completed separately from the storm surge assessment. Transportation infrastructure was assessed against flooding risks associated with flood hazard areas throughout the state. The data was sourced from the statewide digital flood insurance map (DFIRM) data from the Federal Emergency Management Agency (FEMA). The assessment focused on 100-year floodplain areas which had identified base flood elevation (BFE) data. BFE is the computed elevation to which floodwater is anticipated to rise during a base flood event. **Figure 13** displays the 100-year floodplain areas within the state of Florida while **Figure 14** displays those 100-year floodplain areas with BFE data.

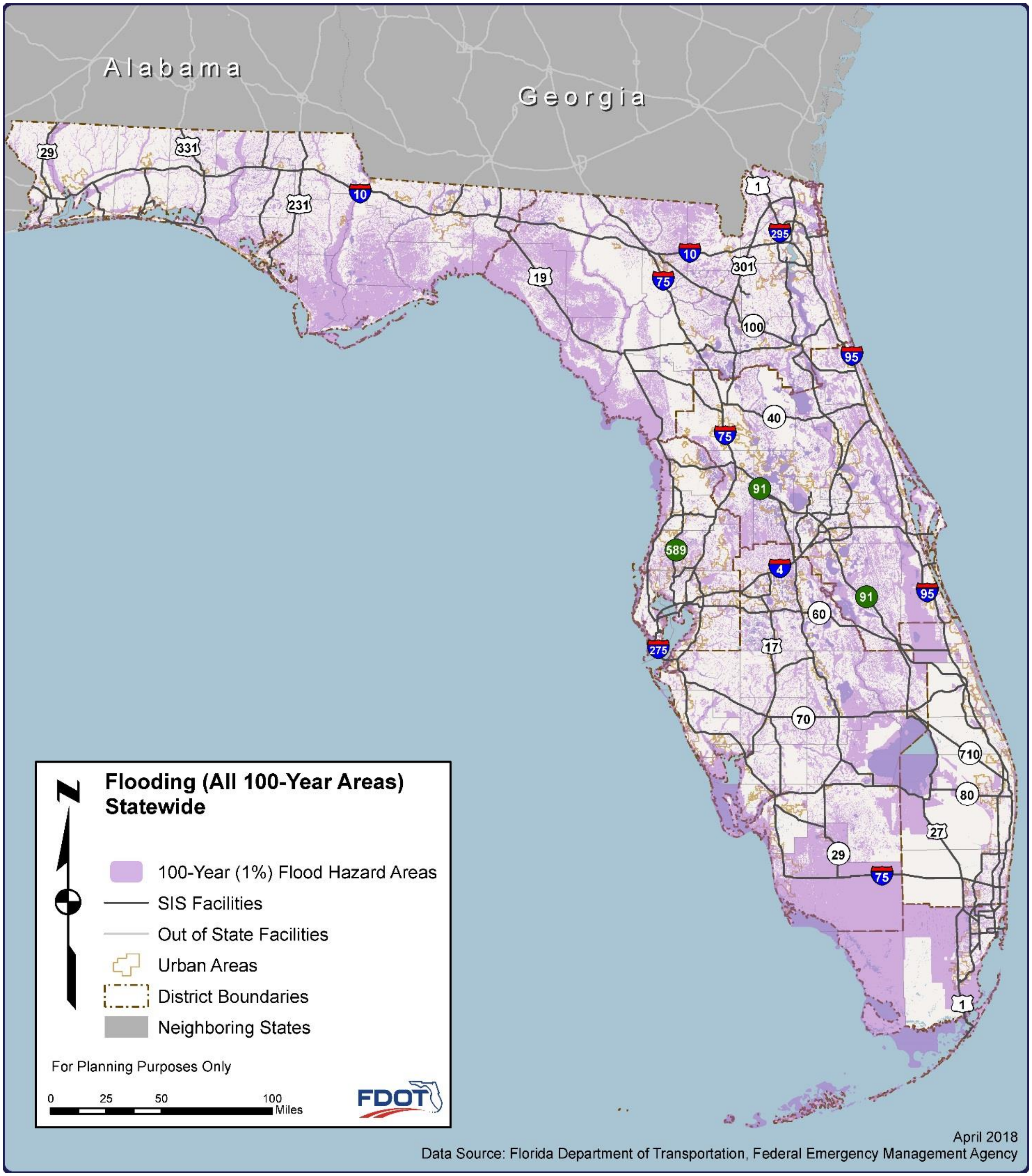

Figure 13: 100-Year Flood Hazard Areas

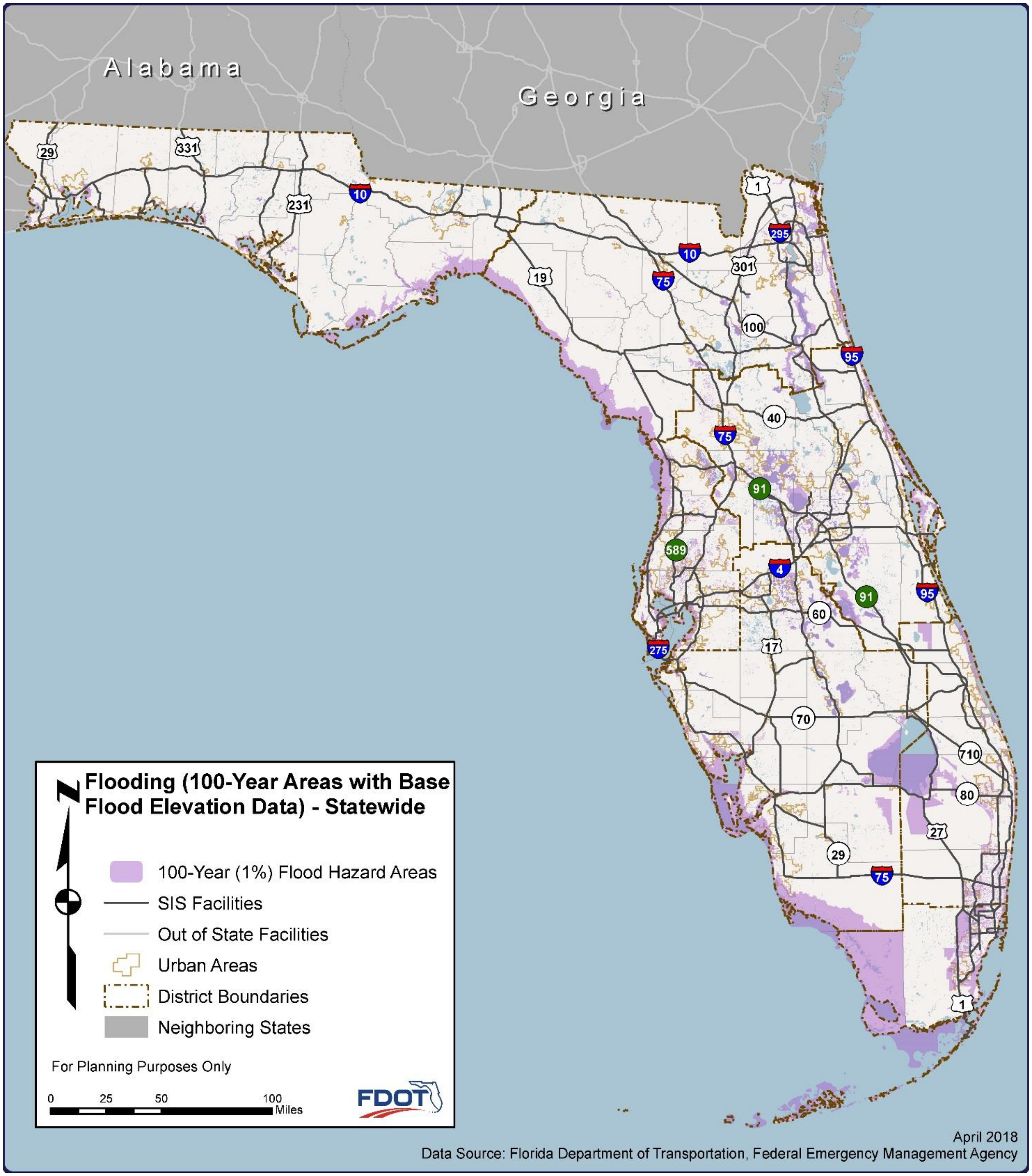

Figure 14: 100-Year Flood Hazard Areas with Available Base Flood Elevations

For the assessment, elevation values calculated from the updated statewide DEM were used. The lowest elevation data associated with a specific roadway segment or bridge approach is evaluated against the BFE of the intersected floodplain area using ESRI ArcGIS geoprocessing tools. The amount of potential flooding impact is then calculated from this evaluation. The segment or bridge approach is then assessed for highest potential flooding impact.

3.2.6 Sea Level Rise

The final risk assessed was the impacts of sea level rise on SIS corridors and military access facilities under analysis. Unlike the other assessments, this assessment was a compilation and review of previous results calculated by the UF GeoPlan Center for the Sea Level Rise (SLR) Inundation Surface Calculator tool. The SLR tool was developed to be used by FDOT has a decision-support tool for long-term planning regarding impacts from sea level rise.

As part of the project, UF GeoPlan Center assessed transportation infrastructure data from FDOT to identify impacts due to sea level rise. The assessment utilized sea level rise inundation surfaces developed for the SLR tool. The sea level rise inundation was developed from:

- United States Army Corps of Engineers (USACE) Sea-Level Change Curve Calculator (2015.46);
- 2013 US SLR projections;
- 2012 NOAA SLR projections;
- NOAA tide gauge data; and,
- NOAA tidal surfaces.

Transportation infrastructure was intersected against the sea level rise inundation surfaces to determine the impacts.

The sea level rise assessment for this task involved a review of those facilities impacted by 1 and 2-foot projections of sea level rise. Since the products of the transportation infrastructure results are organized in future year increments (2040, 2050, etc.), staff first identified the tidal stations utilized for the SLR tool analysis and which counties these tidal stations were associated with. Then, the USACE Sea-Level Change Curve Calculator was used to help identify the appropriate future year products to use for each county based on the tidal station. Those future year products that were identified to be required for 1 and 2-foot analysis were then downloaded and results organized by projection.

3.2.7 Scoring

As previously described, flooding and storm surge assessment were completed separately. The scoring of facilities was based on the highest level of impact observed for each highway corridor and bridge.

A total of six assessments were completed for the storm surge inundation depth analysis. Each assessment was completed for transportation infrastructure type (highway corridor and bridges) and by hurricane storm event type: Category 1, Category 3, and Category 5. If a facility was impacted during an assessment, then it was scored based on the highest potential range of storm surge. The higher range of impact a facility intersect translates to having a higher probability of impact in comparison to facilities impacted at lower ranges. **Table 3** provides the depth ranges and associated scoring for both highway corridors and bridges used in all three assessments.

Raster Grid Code	Panhandle Depths (Feet)	Peninsula Depths (Feet)	Level of Impact
1	Dry/Inland	Dry/Inland	Not Assessed
2	0.0-0.5	0.0-1.0	Low (1)
3	0.5-1.5	1.0-1.5	
4	1.5-3.0	1.5-3.0	
5	3.0-5.0	3.0-6.0	
6	5.0-7.0	6.0-9.0	Medium (2)
7	7.0-10.0	9.0-12.0	
8	10.0-15.0	12.0-15.0	High (3)
9	15.0-20.0	15.0-20.0	
10	20.0-42.0	20.0-42.0	

Table 3: Storm Surge Depth Inundation Scoring Based on Depth Ranges

Flooding assessment required only two assessments as one set of flooding hazard data was used for assessing both highway corridors and bridges. Similar to storm surge inundation depth assessments, if a facility was impacted during an assessment, then it was scored based on the highest potential of flooding. For this assessment, the higher amount calculated from the difference in BFE data and elevation values, the higher the probability of flooding could be observed. Unlike the storm surge assessments, separate scoring metrics were developed for highway corridors and bridges. **Tables 4 and 5** provide the potential flooding impact and associated scoring for highway corridors and bridges.

Potential Flooding Impact (Feet)	Level of Impact
None	Not Assessed
0.0-1.0	Low (1)
1.0-3.0	
3.0-6.0	Medium (2)
6.0-10.0	
10.0-15.0	High (3)
15.0-20.0	
20.0+	

Table 4: Flooding Scoring Based on Potential Impact (Highway Corridors)

Potential Flooding Impact (Feet)	Level of Impact
None	Not Assessed
0.0-1.0	Low (1)
1.0-2.0	
2.0-3.0	Medium (2)
3.0-4.0	
4.0+	High (3)

Table 5: Flooding Scoring Based on Potential Impact (Bridge Structures)

To review impacts on SIS transportation infrastructure from exposure to flooding and storm surge, composites were developed to identify which impacted facilities experienced a higher to lower exposure to flooding and storm surge risks. Composite scoring is the same for both highway corridors and bridges.

1) Rank 1 (High Exposure)
   a. Level of Potential Exposure: High Flooding Impact + High Storm Surge Impact, High Flooding Impact + Medium Storm Surge Impact, Medium Flooding Impact + High Storm Surge Impact, High Flooding Impact + Low Storm Surge Impact, Low Flooding Impact + High Storm Surge Impact, High Flooding Impact + No Storm Surge Impact, No Flooding Impact + High Storm Surge Impact

2) Rank 2 (Medium Exposure)
   a. Level of Potential Exposure: Medium Flooding Impact + Medium Storm Surge Impact, Low Flooding Impact + Medium Storm Surge Impact, Medium Flooding Impact + Low Storm Surge Impact, Medium Flooding Impact + Medium Storm Surge Impact, No Flooding Impact + Medium Storm Surge Impact, Medium Flooding Impact + No Storm Surge Impact

3) Rank 3 (Low Exposure)
   a. Level of Potential Exposure: Low Flooding Impact + Low Storm Surge Impact, No Flooding Impact + Low Storm Surge Impact, Low Flooding Impact + No Storm Surge Impact

This identified those facilities which experience high, medium and low exposure to one or both risks. However, understanding that resources required to alleviate issues for all impacted facilities are limited, the concept of adaptive capacity was incorporated to prioritize impacted transportation infrastructure. To identify and prioritize impacted facilities, annual average daily traffic (AADT) volumes were utilized. By using AADT volumes, facilities were prioritized based on the amount of traffic they carried and how many potential trips are impacted with the loss of facility due to one or both risks. The most recent AADT volume data available statewide was for the year 2016 which was collected from telemetered and portable traffic collection stations for the entire statewide system. After review of the AADT volumes, staff developed a scoring system to be utilized for prioritization as shown in **Table 6**.

Total Traffic Volume (AADT)	Potential Detour Impact
0 to 54,156	Low (1)
54,157 to 109,838	Medium (2)
109,839 to 306,000	High (3)

Table 6: Potential Detour Impact by 2016 AADT Ranges

The potential scoring for each highway corridor segment was assessed against this priority ranking. The final composite scoring with prioritization is as follows:

1) Tier 1 – Rank 1 + High Detour Impact
2) Tier 2 – Rank 2 + High Detour Impact, Rank 1 + Medium Detour Impact, Rank 2 + Medium Detour Impact
3) Tier 3 – Rank 1 + Low Detour Impact, Rank 2 + Low Detour Impact, all Rank 3 combinations

Tier 1 facilities are those facilities which not only experience the highest level of potential exposure but also carry the highest amount of traffic. Due to these segments being critical for the movement of people and goods, any potential improvements to these facilities are considered a higher priority. Tier 3 facilities are considered the lowest priority due to either low traffic and/or low levels of potential impact.

3.3 Other Critical Facilities

Along with SIS highway corridors and bridge facilities, the current effort also considered access from and to critical facilities like bulk fuel facilities/seaports and public shelters with an emphasis on disaster response and recovery. However, the results of these assessments were not included in the final vulnerability assessments. This section documents the assessment done for critical facilities thus far. Future work should consider incorporating and expanding on assessment of these facilities as the results identify corridors significant for fuel distribution and local/regional evacuations to shelters.

3.3.1 Bulk Fuel Facilities / Seaports

To address supply of fuel after an extreme weather/storm disruption, a preliminary analysis of locations of seaports – classified as major (Everglades, Tampa Bay, Jaxport, Canaveral, and Manatee) and minor (Fort Pierce, Palm Beach, and Panama City) based on the total volume of bulk fuel handled – and bulk fuel facilities and facilities that are within three tiers of 50, 100, and 150 miles from these facilities is shown in **Figure 15**. This analysis can be further expanded to determine the population covered by the accessibility buffers, detour planning to major population centers given the results from the vulnerability assessment. This may help plan service in any areas of concern from a fuel supply perspective.

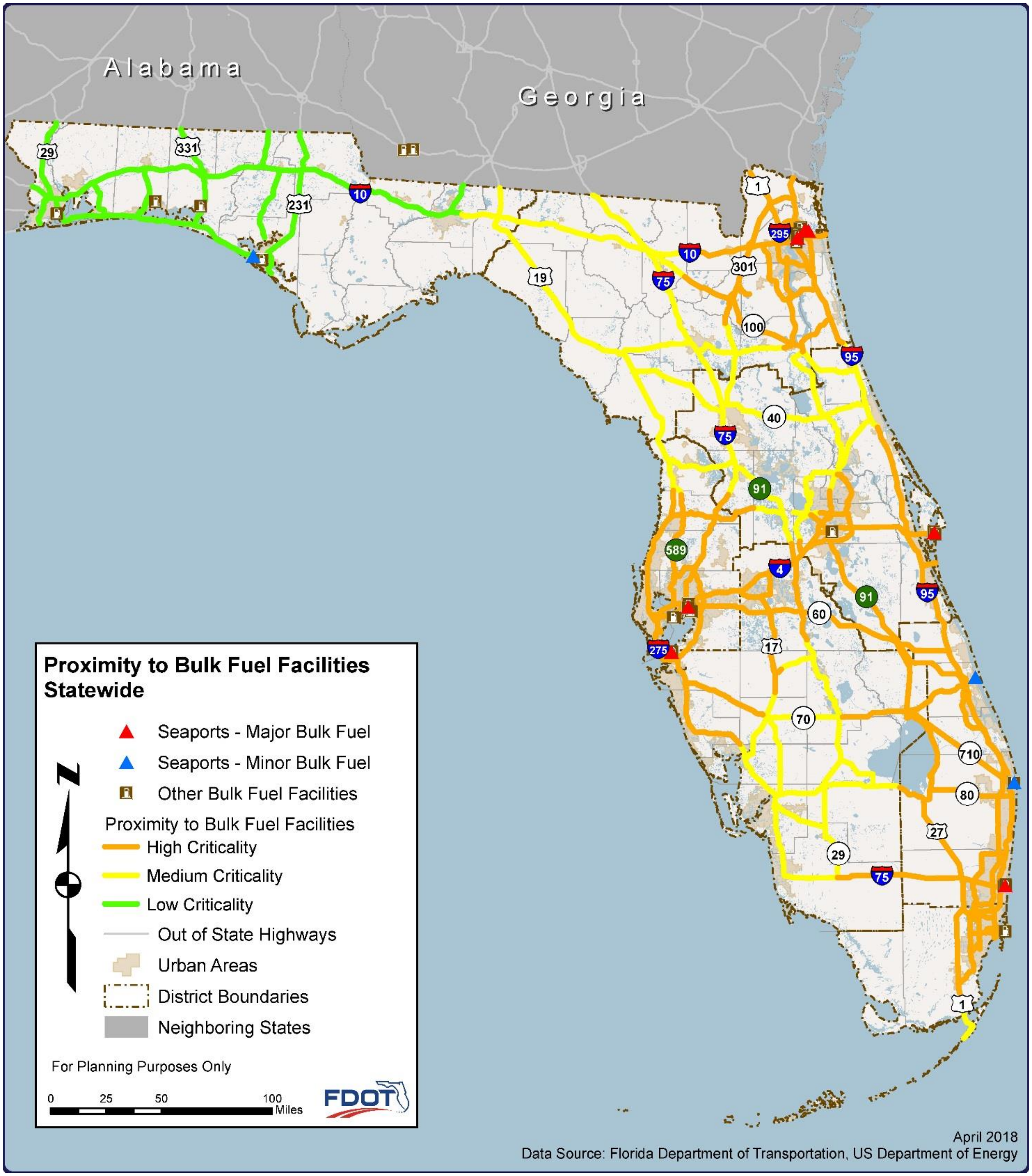

Figure 15: Proximity to Bulk Fuel Facilities

3.3.2 Public Shelters

Sections of the SIS network that provide access to public shelters have been identified based on their proximity to indicate the level of criticality of SIS roadway facilities in providing access to emergency public shelters (within a three-mile vicinity to the shelters) for emergency planning needs. The 3-mile buffer was developed from facilities that provide access to more than seven shelters within the 3-mile vicinity are designated as highly critical; facilities that provide access between two and six public shelters within the 3-mile vicinity are considered to be medium critical and those SIS facilities which have less than two facilities in a 3-mile vicinity are categorized as low in criticality.

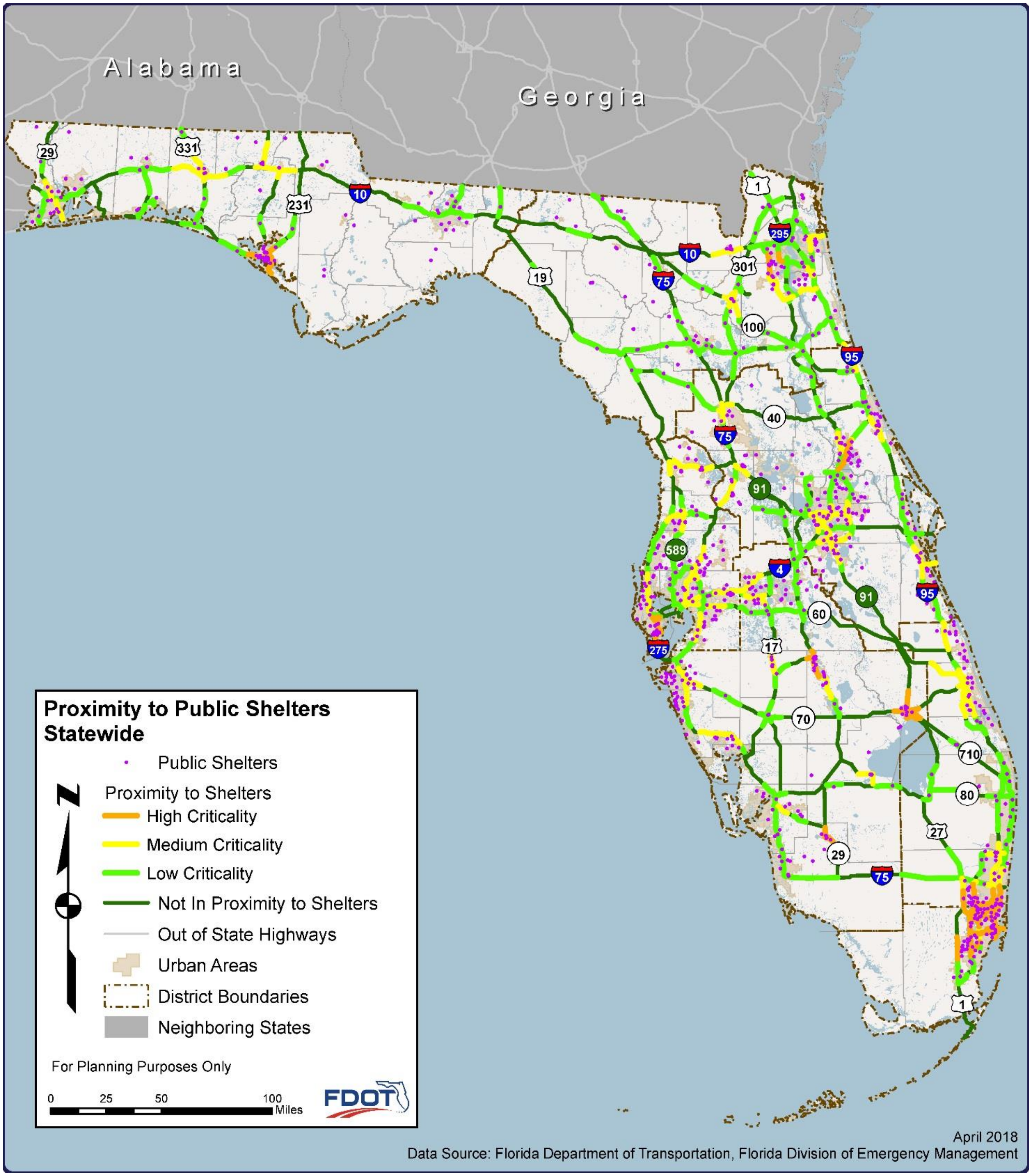

Figure 16: Proximity to Public Shelters

4.0 Results

Given the significance of extreme weather impacts due to events where water is the climate stressor – coastal and inland flooding impacts due to severe thunderstorms and hurricane storm events, this effort studied their impact on the resilience of SIS network. It may be noted that Florida has 3.5 million people at risk of coastal flooding and currently has more than 3,600 square miles of area in the 100-year coastal floodplain[17], which indicates the extent of exposure for people living in those areas and the roadway infrastructure that provides them with access and connectivity.

Cities Most Vulnerable to Coastal Flooding Today

Top 25 cities and their populations at risk (thousands) within FEMA's 100-year coastal floodplain

1.	New York	245
2.	Miami	126
3.	Pembroke Pines, Fla.	116
4.	Coral Springs, Fla.	115
5.	Miramar, Fla.	93
6.	St. Petersburg, Fla.	88
7.	Davie, Fla.	87
8.	Fort Lauderdale, Fla.	85
9.	Miami Beach, Fla.	85
10.	Hialeah, Fla.	76
11.	Sunrise, Fla.	74
12.	Pompano Beach, Fla.	73
13.	Hollywood, Fla.	69
14.	Lauderhill, Fla.	66
15.	Charleston, S.C.	64
16.	Cape Coral, Fla.	59
17.	Tamarac, Fla.	58
18.	Margate, Fla.	50
19.	Tampa, Fla.	50
20.	Fountainebleau, Fla.	48
21.	Miami Gardens, Fla.	44
22.	Country Club, Fla.	43
23.	Atlantic City, N.J.	37
24.	North Lauderdale, Fla.	37
25.	Kendale Lakes, Fla.	37

CLIMATE CENTRAL

Figure 17: Cities Most Vulnerable to Coastal Flooding Today (Source: US cities at risk of coastal flooding, Climate Central[18])

As shown in **Figure 17**, 22 of the 25 cities vulnerable to coastal flooding today are located in Florida. Florida also has the highest population of any state at risk due to storm surge inundation as **Figure 18** indicates that almost 7.6 million residents of Florida are at risk of storm surge inundation due to a Category 5 storm[19].

[17] States at Risk, Florida's Climate Threats. http://statesatrisk.org/florida/coastal-flooding

[18] U.S. Cities Most Vulnerable to Major Coastal Flooding and Sea Level Rise

http://www.climatecentral.org/news/us-cities-most-vulnerable-major-coastal-flooding-sea-level-rise-21748

[19] National Hurricane Center, NOAA, Population at Risk from Storm Surge Inundation, https://www.nhc.noaa.gov/nationalsurge/

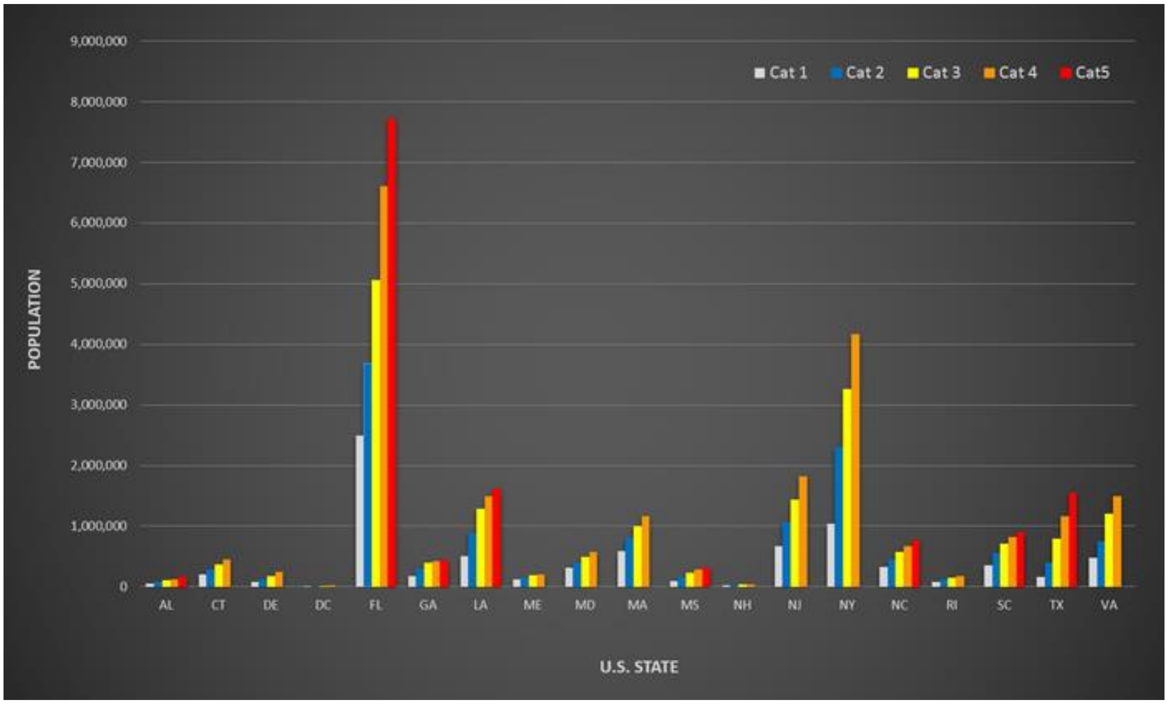

Figure 18: Population at Risk from Storm Surge Inundation by State

4.1 Storm Surge and Flooding

For the purposes of this effort, two[20] types of inundation exposure were analyzed for the assessment of SIS network's vulnerability in consultation with FDOT:

» Inland Flooding – 1% return (100-year flood zones)

» Storm surge – Category 1, 3, and 5 hurricanes (Saffir Simpson Scale)

4.2 Vulnerability Assessment:

As described in Section 3, the project team used a GIS-based approach to perform an inundation exposure assessment due to storm surge and coastal/inland flooding. SIS Corridors and MAFs, as well as bridge structures, were overlaid with flooding inundation extents to be evaluated for potential exposure to inundation from storm surge and the 1% chance flood event.

[20] Though sea level rise was reviewed for this effort, the intent of the vulnerability assessment was on current conditions. Sea level rise projections for 1 to 2 feet are generally forecasted, even at USACE High Rate, to reach these projections around 2040 or later depending on location. However, reviewing sea level rise results can potentially help in identifying facilities which may require future improvements – particularly if those facilities are already impacted by either storm surge or other flooding events. **Appendix C** contains the listing and mapping of facilities impacted by 1 and 2-foot projections from the review.

4.2.1 Exposure Analysis:

Storm Surge:

Storm surge depth inundation ranges are defined as the greatest depth and extent of coastal flooding associated with the selected hurricane category at specific locations based on multiple SLOSH model simulations. The assessment reviewed depth inundation ranges for Categories 1, 3, and 5 hurricane storm events. Storm surge inundation exposure maps showing SIS roadways and bridges are shown in **Figure 19** and **Figure 20**. Just over a fifth of the total centerline miles of the SIS roadway network being studied (983 miles) is at risk of inundation due to storm surge corresponding to a Category 5 hurricane flooding and has the potential to impact 23 percent of the SIS network-wide daily vehicle miles traveled (about 49 million daily VMT). Potential storm surge flooding corresponding to a Category 1 storm is estimated to impact 5 percent of SIS network-wide daily VMT, while 160 centerline miles of SIS roadways are estimated to be at risk of flooding as shown in **Table 7**.

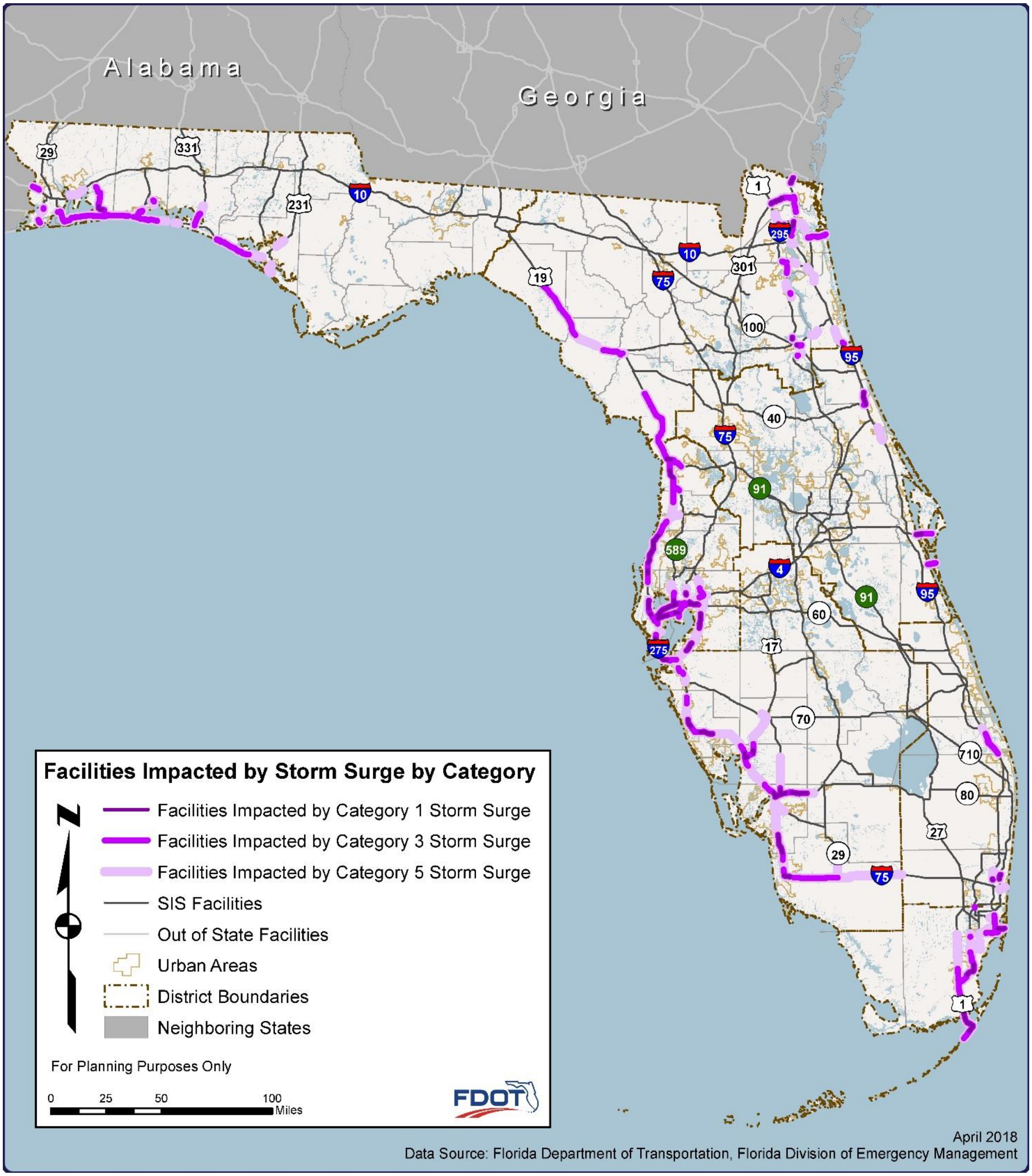

Figure 19: SIS Highway Corridors at Risk of Inundation by Storm Surge by Category

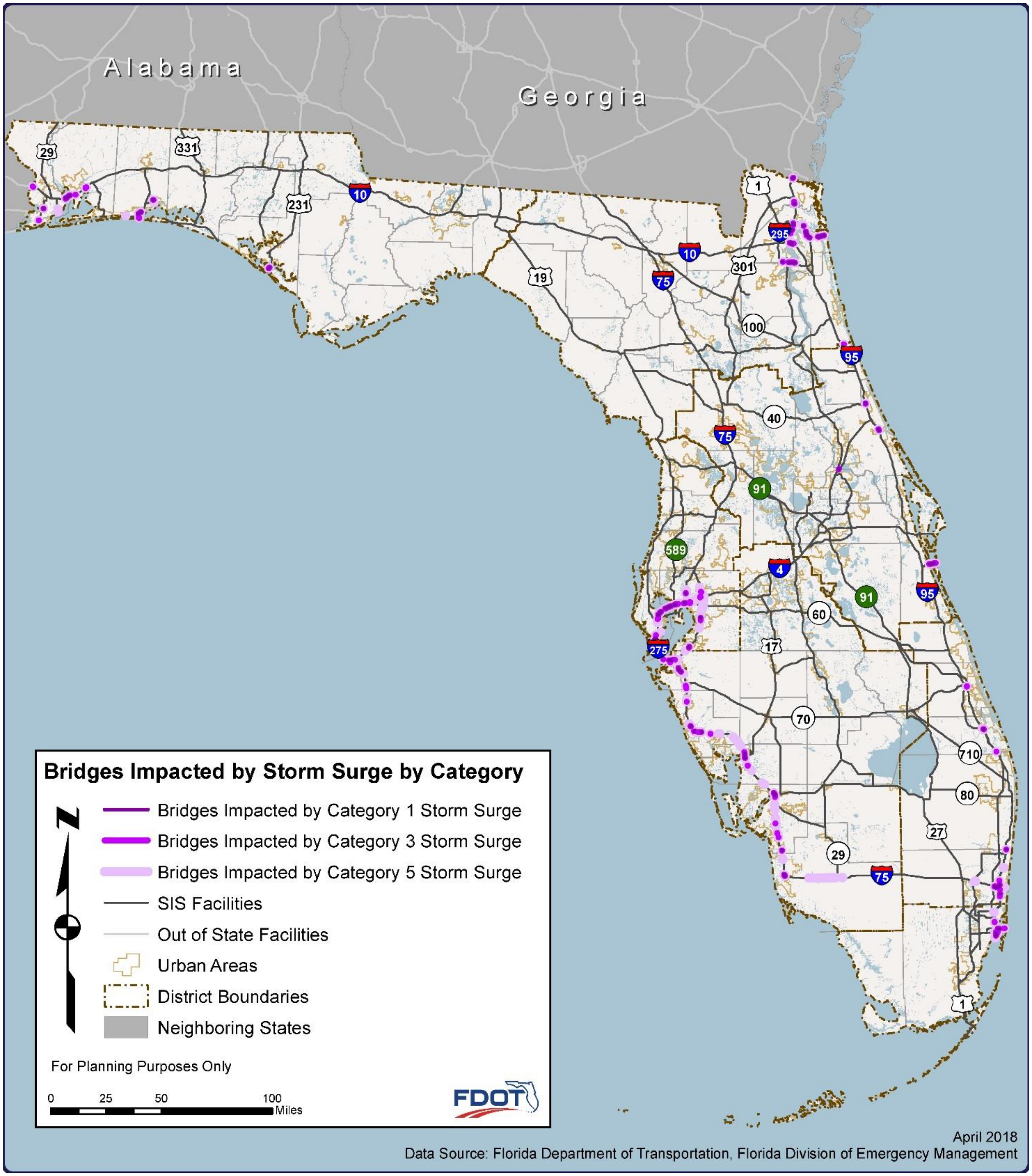

Figure 20: SIS Corridor Bridges at Risk of Inundation by Storm Surge by Category

Surge Corresponding to Storm Category	Centerline Miles at Risk	DVMT Potentially Impacted	Share of Centerline Miles at Risk Statewide (%)	Share of Statewide DVMT Impacted (%)
Category 1	160	10,659,236	3%	5%
Category 3	621	28,832,722	13%	13%
Category 5	983	48,751,372	21%	23%

Table 7: SIS Highway Corridor Impacted by Storm Surge by Category

When bridges are assessed separately, potential storm surge inundation corresponding to Category 5 flooding is estimated to impact 74 centerline miles of bridge segments, while storm surge corresponding to Category 1 flooding puts 47 miles of SIS bridge segments at risk of inundation.

Surge Corresponding to Storm Category	Centerline Miles at Risk	DVMT Potentially Impacted	Share of Centerline Miles at Risk Statewide (%)	Share of Statewide DVMT Impacted (%)
Category 1	47.10	2,632,835	28%	36%
Category 3	57.99	3,042,668	35%	41%
Category 5	74.17	3,633,872	45%	49%

Table 8: SIS Bridges Impacted by Storm Surge by Category

Even though the facilities above, both highway corridors and bridges, are identified to be impacted, some have a higher potential for significant flooding by storm surge than others. Section 3.2.7 of this report provided details describing the different exposure levels. Those with the highest potential of significant flooding exposure are identified as High while those who have the lowest potential is identified as Low. **Figures 21** through **26** show the exposure level of each of the impacted facilities previously shown in **Figures 19** and **20** for each category. As described in Section 3.2.4, as the hurricane storm event intensity increases, so does the reach of storm surge – meaning that more facilities are impacted by a Category 5 compared to a Category 1. Please refer to **Appendix A** for lists of top 10 SIS highway network segments and bridges by category by exposure and depth inundation range.

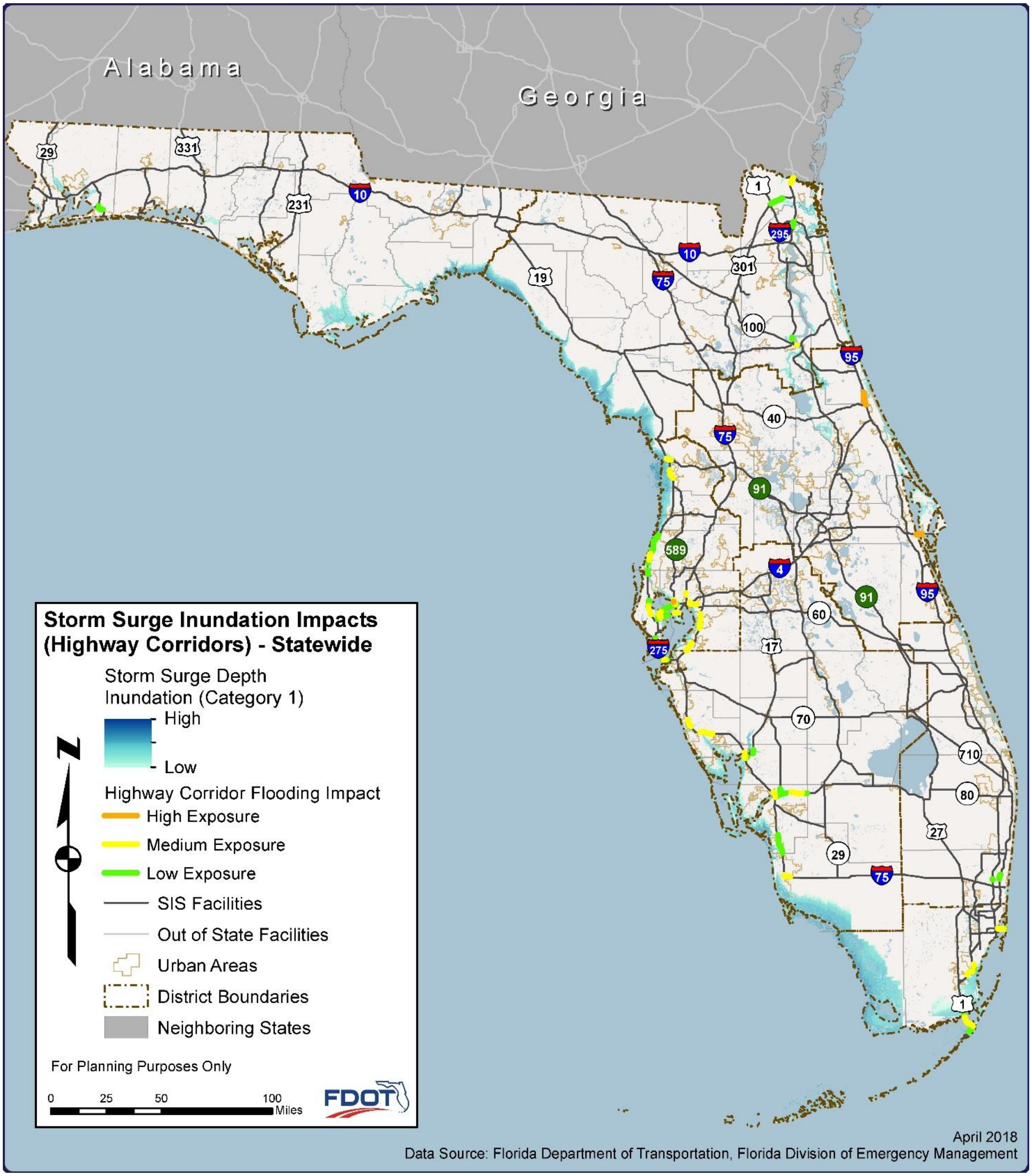

Figure 21: Storm Surge Inundation Impacts (Highway Corridors) – Category 1

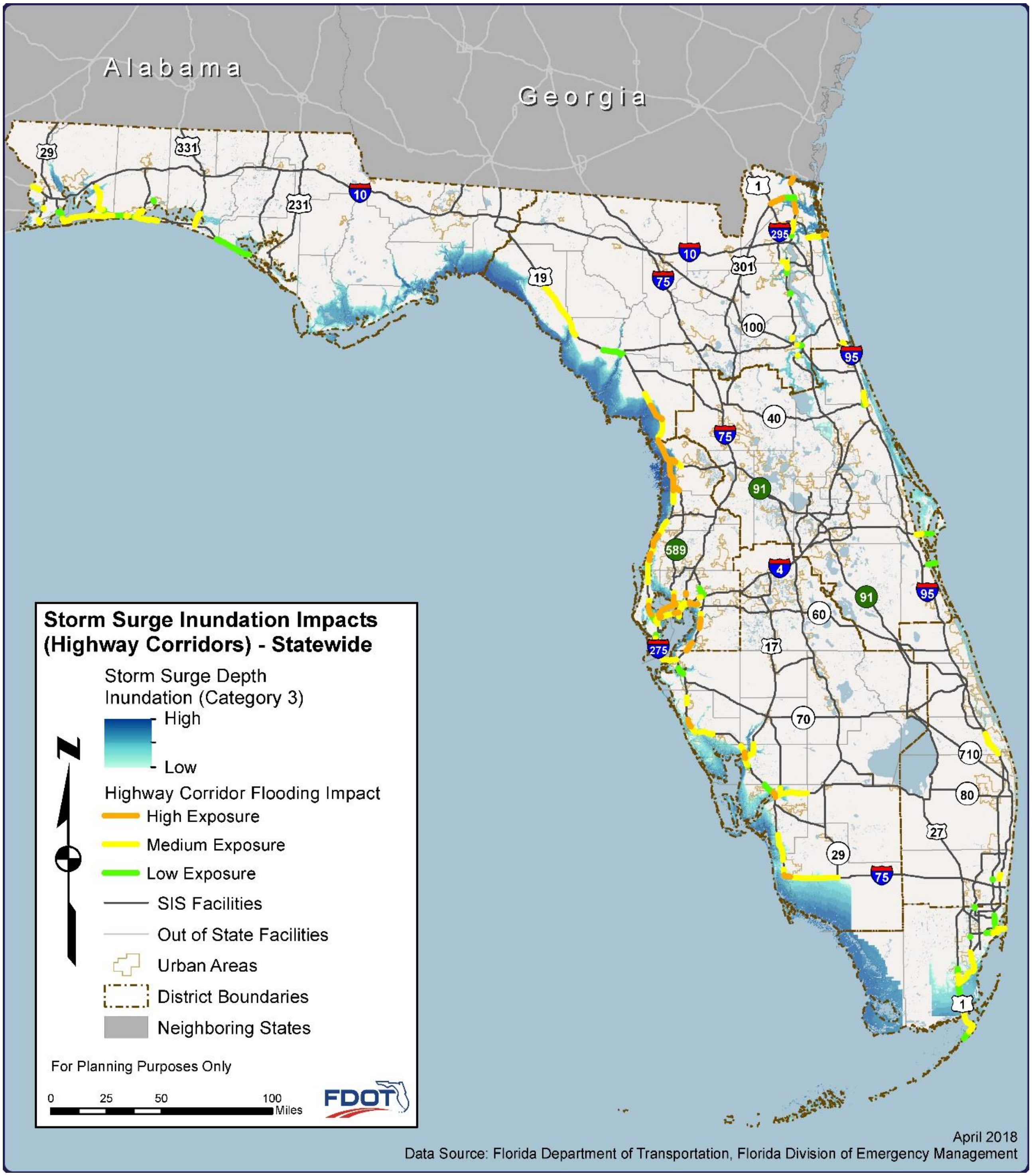

Figure 22: Storm Surge Inundation Impacts (Highway Corridors) – Category 3

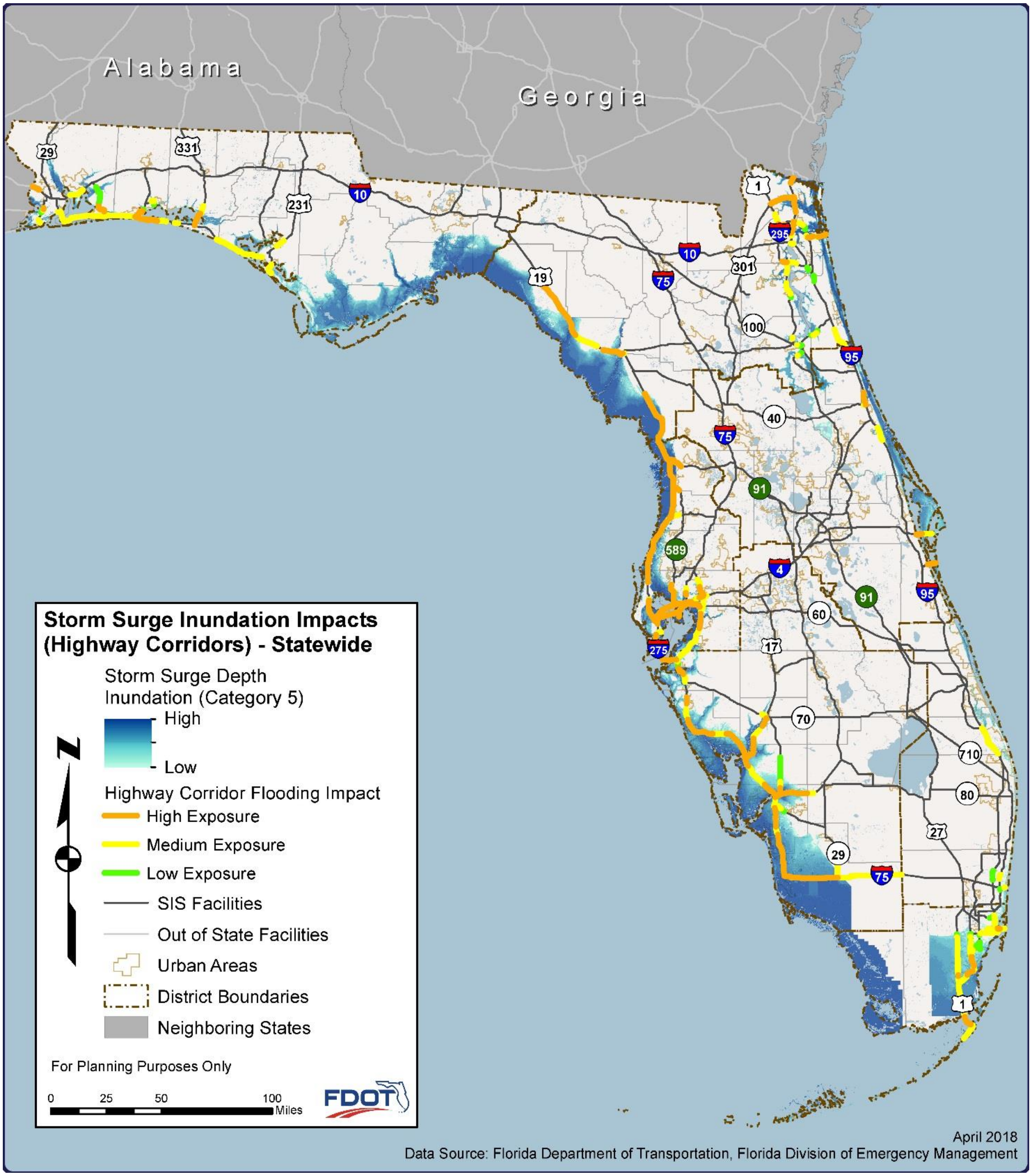

Figure 23: Storm Surge Inundation Impacts (Highway Corridors) – Category 5

Figure 24: Storm Surge Inundation Impacts (Bridges) – Category 1

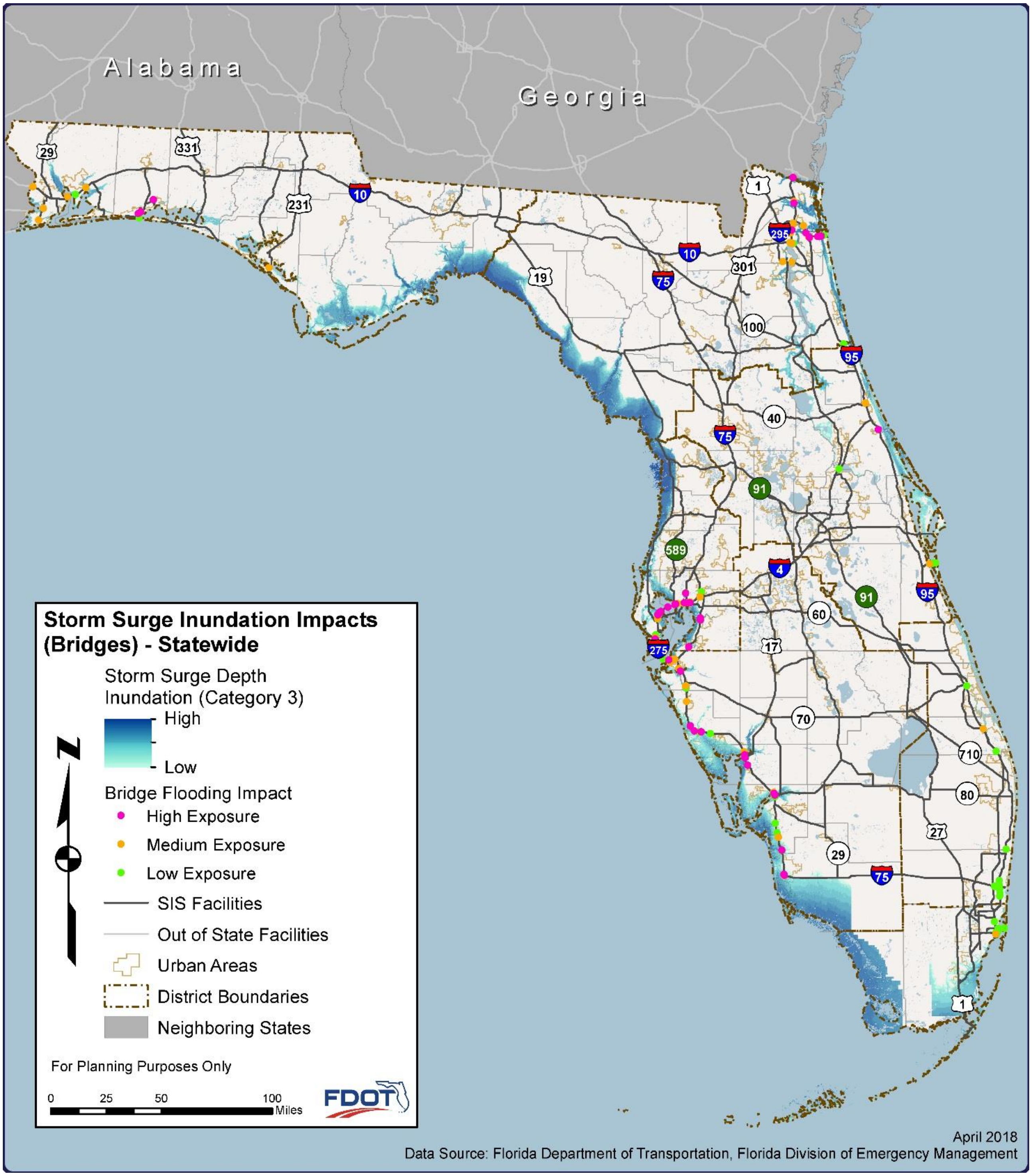

Figure 25: Storm Surge Inndation Impacts (Bridges) – Category 3

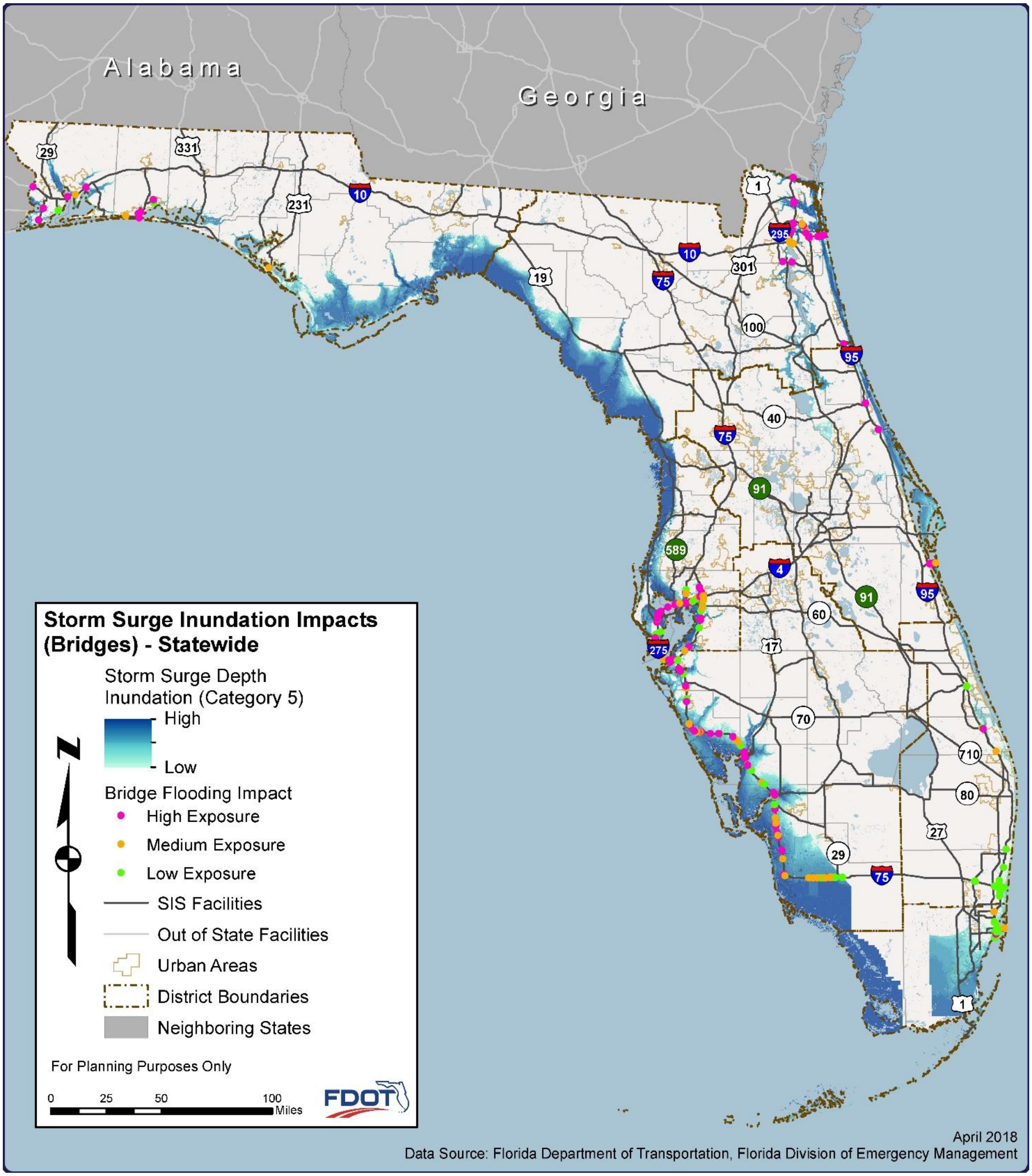

Figure 26: Storm Surge Inundation Impacts (Bridges) – Category 5

Coastal and Inland Flooding:

FEMA flood risk data from the statewide 100-year (one percent annual chance of recurrence) Digital Flood Insurance Rate Maps (DFIRM) have been used to conduct exposure analysis with the SIS network asset data. Exposure levels were characterized for inland flooding by potential flooding height with Low having the lowest range of flooding exposure to High having the highest range. **Figure 27** shows the highway corridors which are at potential risk of inundation to inland flooding by exposure level while **Figure 28** shows the results for bridges.

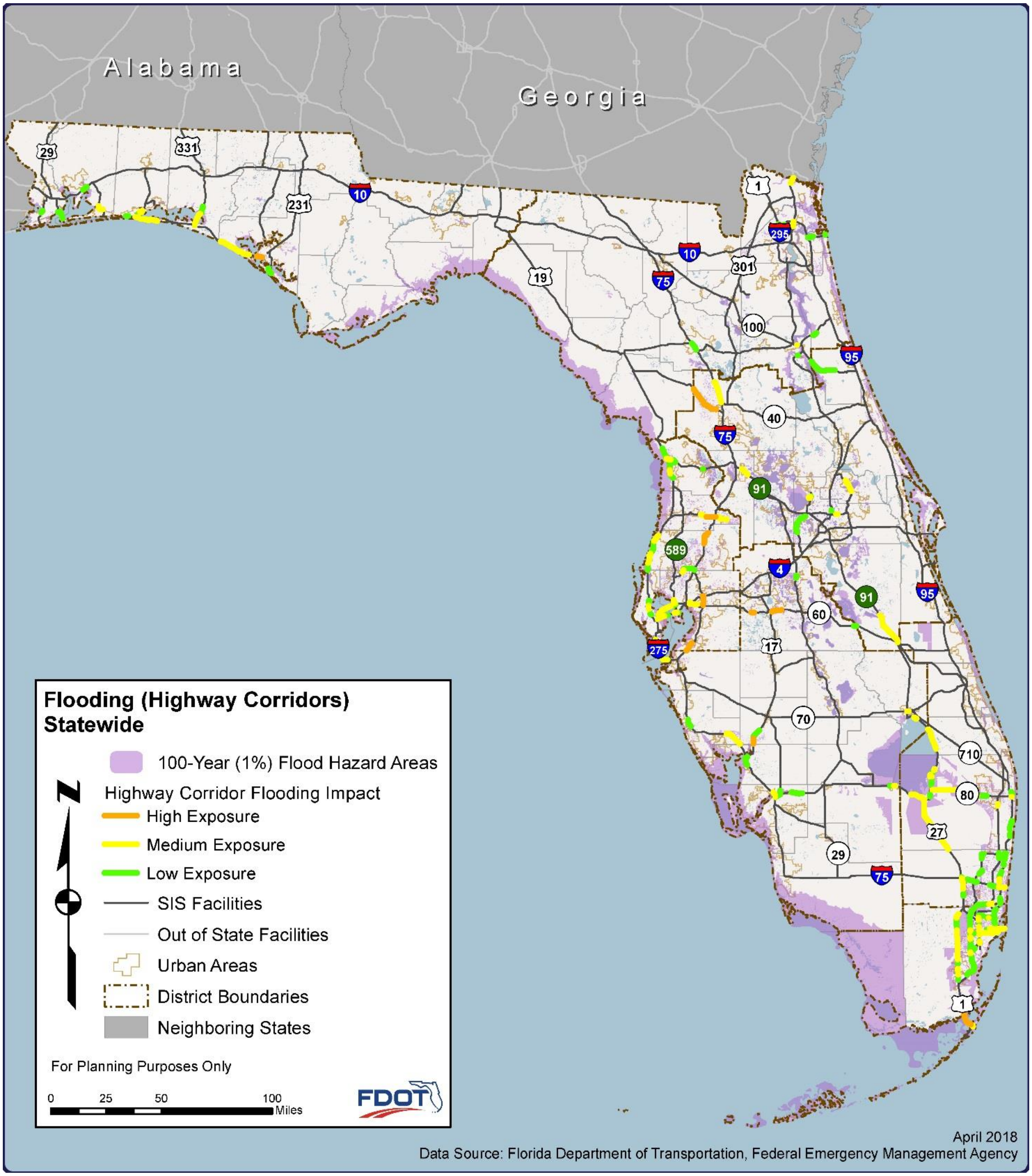

Figure 27: Flooding Impacts Due to a 100-Year Flood Event (Highway Corridors)

While a Low exposure to flooding of up to 3 feet has the potential to impact 6.6 percent or 14 million daily vehicle miles traveled on the SIS highway network, 62 centerline miles of SIS network are at risk of inundation due to flood depth of 10 feet or higher, which have been characterized as being impacted by high exposure levels. **Table 9** shows SIS centerline miles at risk of exposure classified by exposure tier and impacted daily VMT and the share of roadway segment extents and VMT of total SIS network extent and daily VMT.

Exposure Level	Centerline Miles at Risk	DVMT Potentially Impacted	Share of Centerline Miles at Risk Statewide (%)	Share of Statewide DVMT Impacted (%)
Low	215	14,091,774	4.5%	6.6%
Medium	268	10,998,858	5.6%	5.1%
High	62	2,195,720	1.3%	1.0%

Table 9: SIS Highway Corridor Impacted by Flooding Exposure Level

When bridges are assessed separately, as described in Section 3.2.7, exposure levels are different in terms of potential flooding depth with High exposure impacts associated with 4+ feet, Medium with 2 to 4 feet, and Low with less than 2 feet. It has been calculated that 45 centerline miles of bridge segments are at risk of potential High exposure level impacting over 2 million daily VMT as shown in **Table 10**.

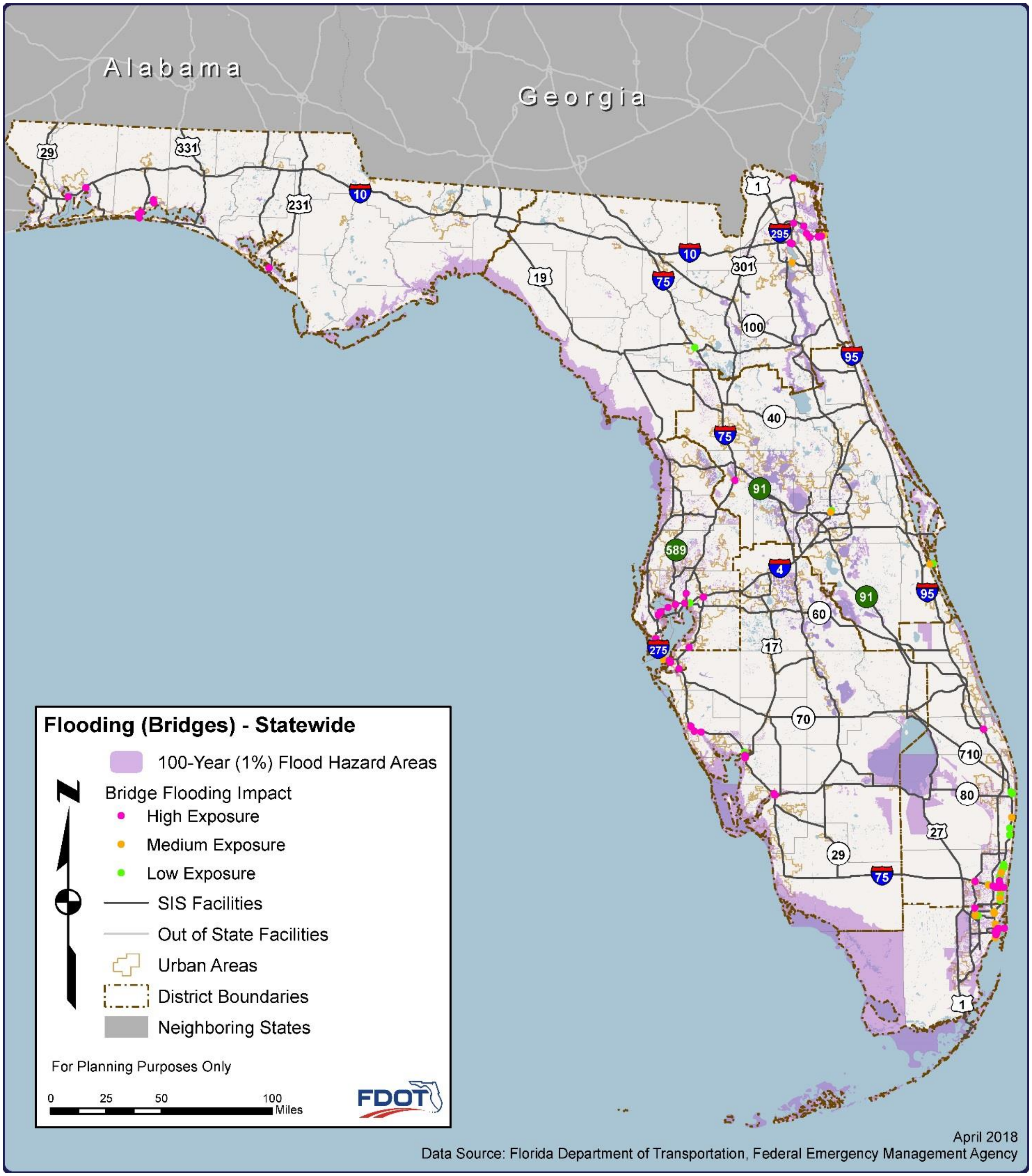

Figure 28: Flooding Impacts Due to a 100-Year Flood Event (Highway Corridors)

Exposure Level	Centerline Miles at Risk	DVMT Potentially Impacted	Share of Centerline Miles at Risk Statewide (%)	Share of Statewide DVMT Impacted (%)
Low	4	235,657	2.6%	3.2%
Medium	13	683,461	7.8%	9.3%
High	45	2,157,266	26.9%	29.2%

Table 10: SIS Corridor Bridges Impacted by Flooding by Exposure Level

Along with these DFIRM data for flood exposure calculations, the team also sought expert and stakeholder input from FDOT's Central and District offices and other stakeholders for information on known flooding locations, which would provide ground-truth verification. However, this information was not uniformly provided as the response was varied across the districts.

4.2.2 Vulnerability Screening Results:

Vulnerability is a function of exposure, sensitivity, and adaptive capacity, defined to be consistent with the Federal Highway Administration's Climate Change & Extreme Weather Vulnerability Assessment Framework[21]. With the exposure analysis conducted for various assets and characterized by exposure rank, sensitivity and adaptive capacity have been added to those maps to create a composite vulnerability assessment analysis to incorporate the sensitivity of roadway assets (highway segments and bridges).

Exposure Composite:

For exposure, the project team assessed potential flooding impacts from storm surge and 100-year flooding events on the SIS network under study. The results from these two assessments were combined into a composite exposure ranking. The intent of the composite exposure ranking is to bring together all facilities identified to be impacted by storm surge, flooding, or both. **Figures 29** through **31** show the results as they pertain to highway corridors while **Figures 32** through **34** show the results for bridges. As described in Section 3.2.7, there are three exposure ranks: Rank 1, Rank 2, and Rank 3. Rank 1 includes all facilities to have a High exposure level to storm surge, flooding or both. Rank 2 includes all facilities to have a Medium exposure level to storm surge, flooding or both, with no impacted facilities being identified as having High exposure. Rank 3 includes those facilities not ranked as Rank 1 or Rank 2. Of the ranked facilities, facilities ranked Rank 1 would be the most significant to further assess as these facilities have the highest potential for significant storm and/or impacts from a 100-year flooding events.

[21] Vulnerability Assessment and Adaptation Framework, Federal Highway Administration,

https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/

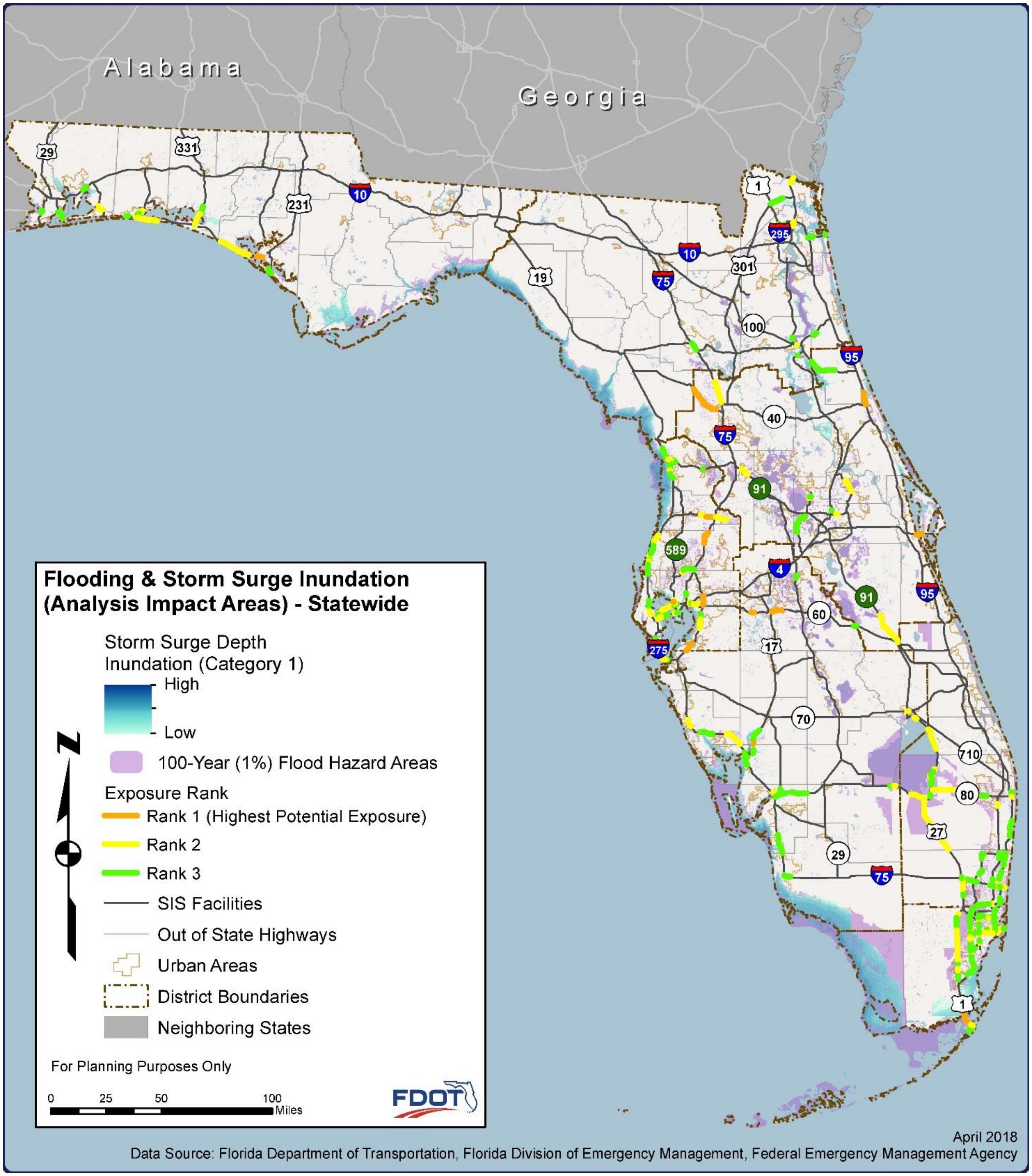

Figure 29: Exposure Ranking for SIS Highway Corridors (Category 1 Storm Surge and Flooding)

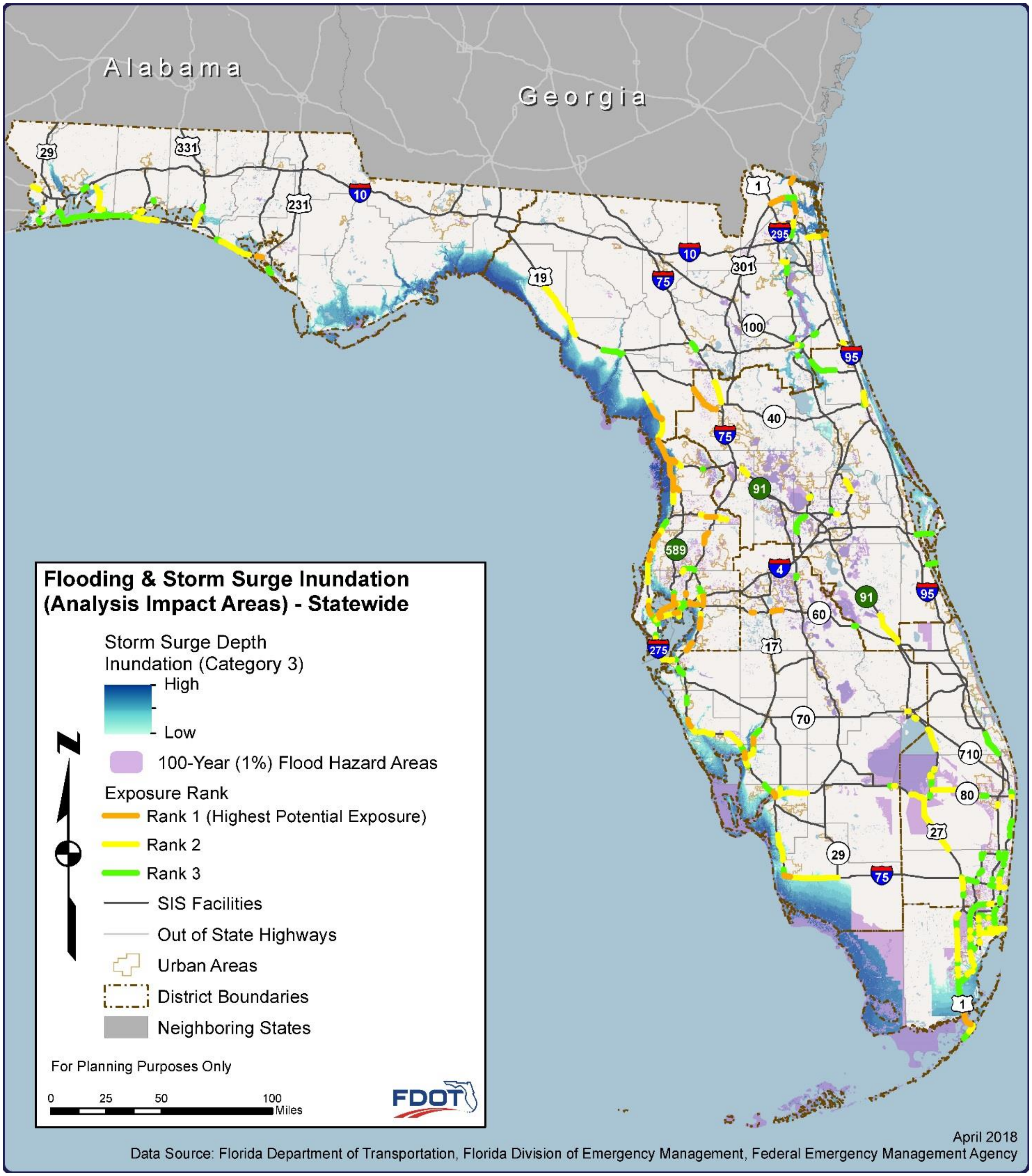

Figure 30: Exposure Ranking for SIS Highway Corridors (Category 3 Storm Surge and Flooding)

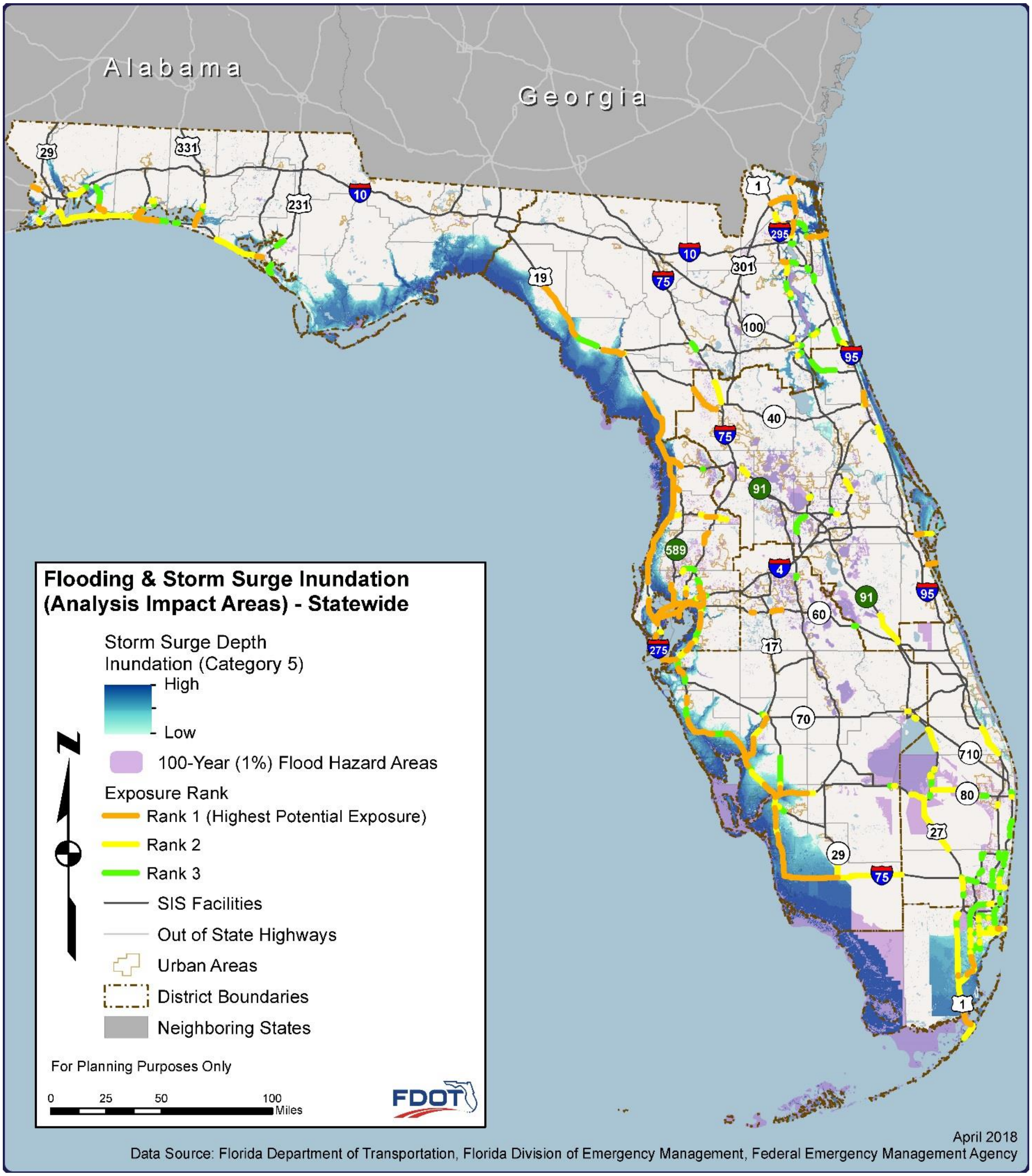

Figure 31: Exposure Ranking for SIS Highway Corridors (Category 5 Storm Surge and Flooding)

Figure 32: Exposure Ranking for SIS Bridges (Category 1 Storm Surge and Flooding)

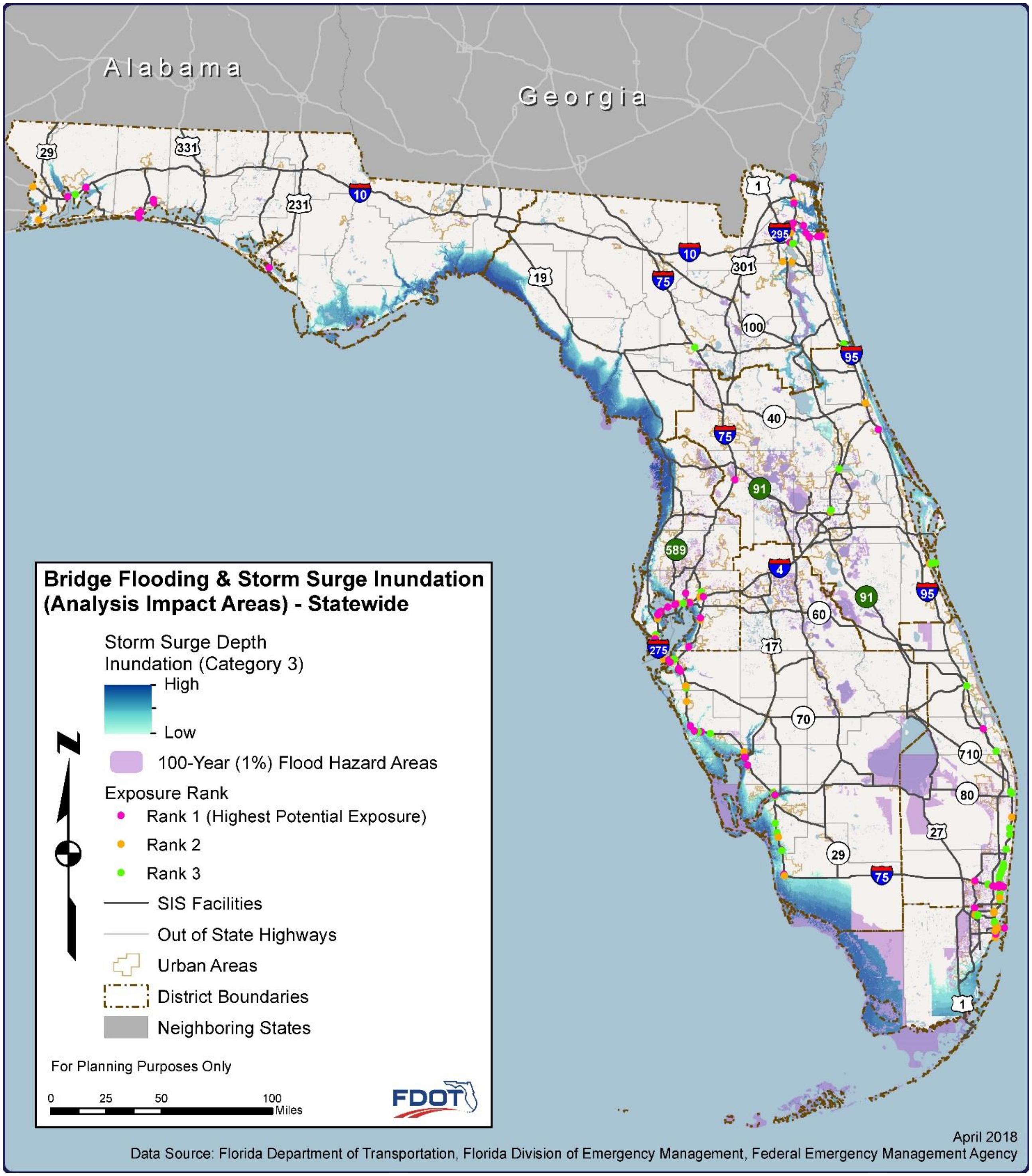

Figure 33: Exposure Ranking for SIS Bridges (Category 3 Storm Surge and Flooding)

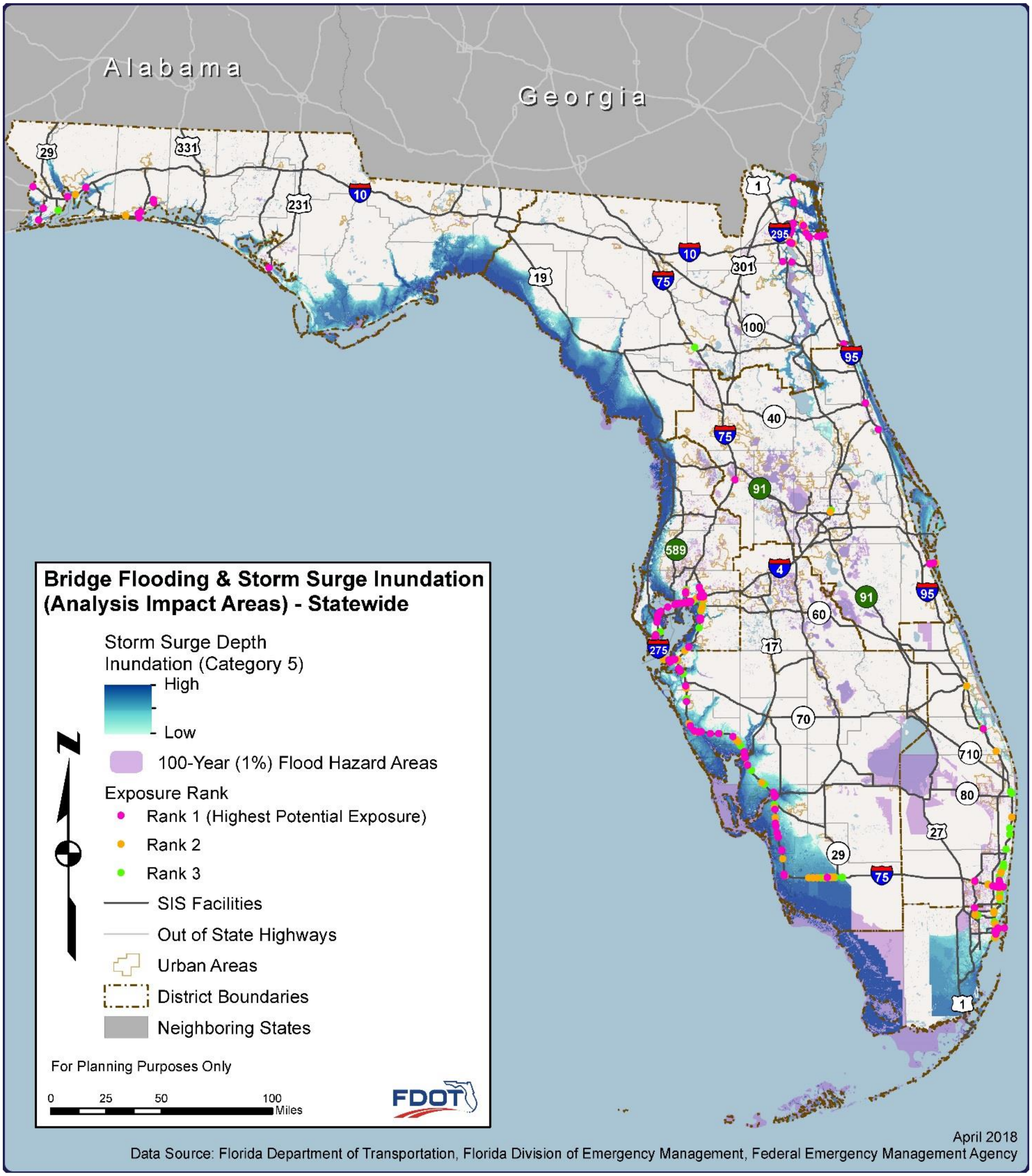

Figure 34: Exposure Ranking for SIS Bridges (Category 5 Storm Surge and Flooding)

Sensitivity:

Asset condition was used as a proxy for sensitivity to flood exposure as a detailed asset level sensitivity determination is not in the scope of this network level analysis. While pavement condition rating was used as a sensitivity indicator, sufficiency rating was used for bridge condition. Scour criticality of bridges was also used as a sensitivity indicator to be more likely to be at risk of damage due to flood exposure. A maps and tables section showing sensitivity results, indicators and thresholds used for the assessment are included in **Appendix B**. For the final composite of vulnerability analysis, exposure and adaptive capacity was used. Sensitivity was not included at this time into the final composite.

Adaptive Capacity:

As described previously, 2016 AADT volumes were used to prioritize vulnerable facilities identified under the exposure assessments. This traffic volume data was used as a proxy for determining the adaptive capacity of a SIS roadway asset (highway segment or bridge). The objective was to get at the amount of traffic that needs to be detoured in case of a potential disruption, or detour impact potential, as well as the distance through which it needs to be detoured to calculate total detour VMT. However, as this is a network-level assessment, a proxy for detour potential was assumed to be correlated to AADT and the availability of local roadway network for detour purposes meant that the detour lengths were not critical at a systemic view, especially when the network analysis does not include any modeling for local roadway network.

Vulnerability Composite Maps:

The vulnerability composite maps are a result of vulnerability screening considering both exposure and adaptive capacity which were qualitatively tiered and combined into a unified composite tier of vulnerability on a scale of high, medium, and low measure of potential exposure and detour potential (which was used as a proxy to adaptive capacity). **Figures 35, 36,** and **37** show vulnerability composite maps of three exposure assessments (as shown in **Figures 29** through **31** above) and its impact on roadway segments with the highest detour impact for highway corridors. These maps show vulnerable SIS highway corridors classified into three tiers of vulnerability: Tier 1, Tier 2, and Tier 3. Tier 1 facilities are the most critical at highest risk of impact due to storm surge and flooding while also carrying the highest amount of traffic compared to other segments of the network. Meanwhile, Tier 3 facilities are the least critical due to lower traffic volumes carried and/or lower potential exposure to storm surge and flooding.

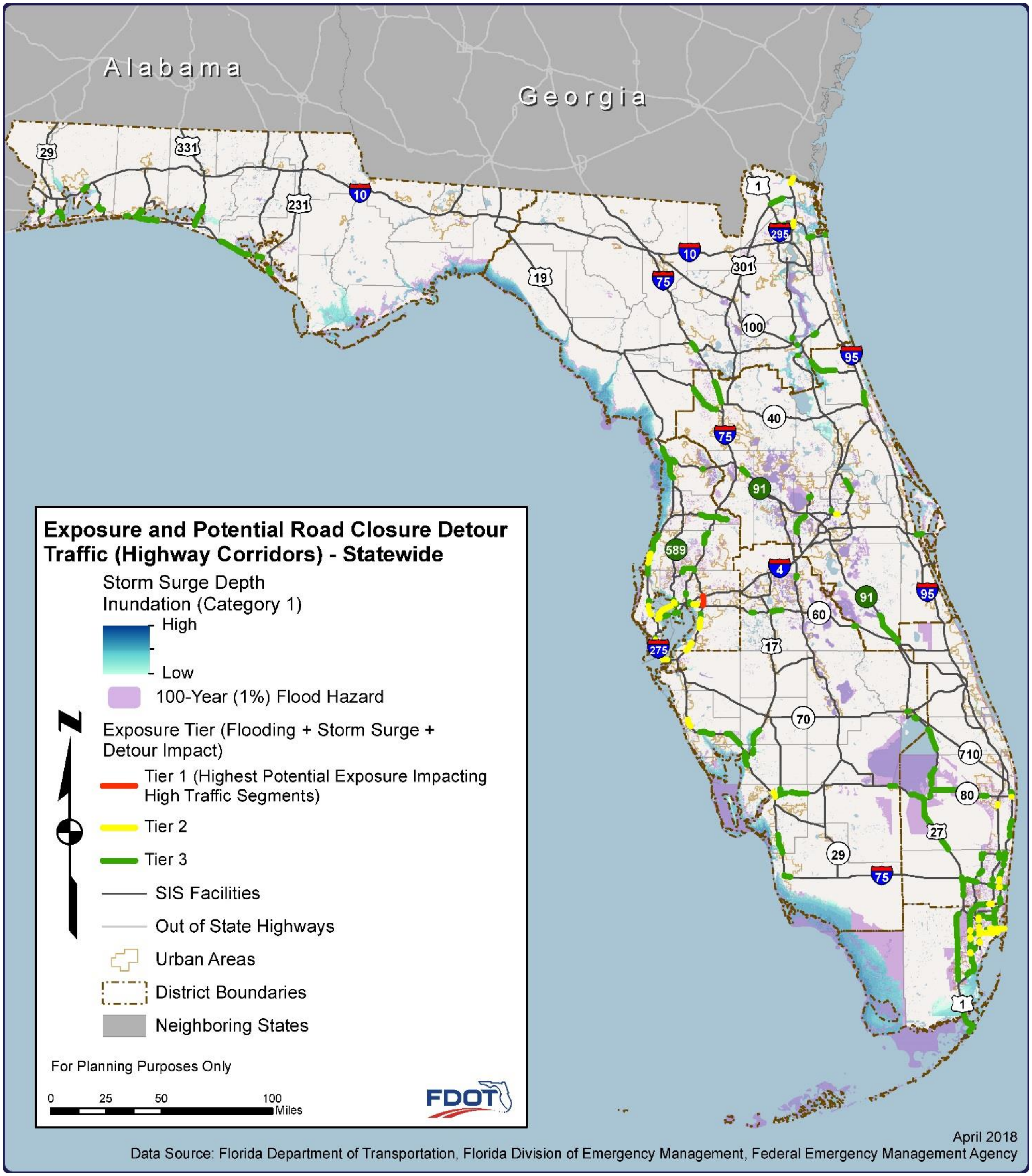

Figure 35: Vulnerability Composite Based on Category 1 Storm Surge and Flooding (Highway Corridors)

Figure 36: Vulnerability Composite Based on Category 3 Storm Surge and Flooding (Highway Corridors)

Figure 37: Vulnerability Composite Based on Category 5 Storm Surge and Flooding (Highway Corridors)

Table 11 shows the results of the worst-case scenario with a Category 5 storm surge with a summary of SIS highway corridors vulnerable to flood hazard due to flooding (coastal, inland, and surge). The summary indicates that 49 centerline miles of SIS highway corridors are characterized as highly vulnerable – due to high exposure, high sensitivity and carrying high traffic volumes.

Tier	Centerline Miles at Risk	DVMT Potentially Impacted	Share of Centerline Miles at Risk Statewide (%)	Share of Statewide DVMT Impacted (%)
1	49	7,060,823	1.0%	3.3%
2	194	16,958,535	4.1%	7.9%
3	1,015	37,622,210	21.3%	17.5%

Table 11: Composite Vulnerability Summary of SIS Highway Corridors

As described in Section 3.2.7, bridges are assessed in a similar fashion for vulnerability composites as highway corridors. **Figures 38, 39,** and **40** show the vulnerable bridges along the SIS as organized by composite tier.

Figure 38: Vulnerability Composite Based on Category 1 Storm Surge and Flooding (Bridges)

Figure 39: Vulnerability Composite Based on Category 3 Storm Surge and Flooding (Bridges)

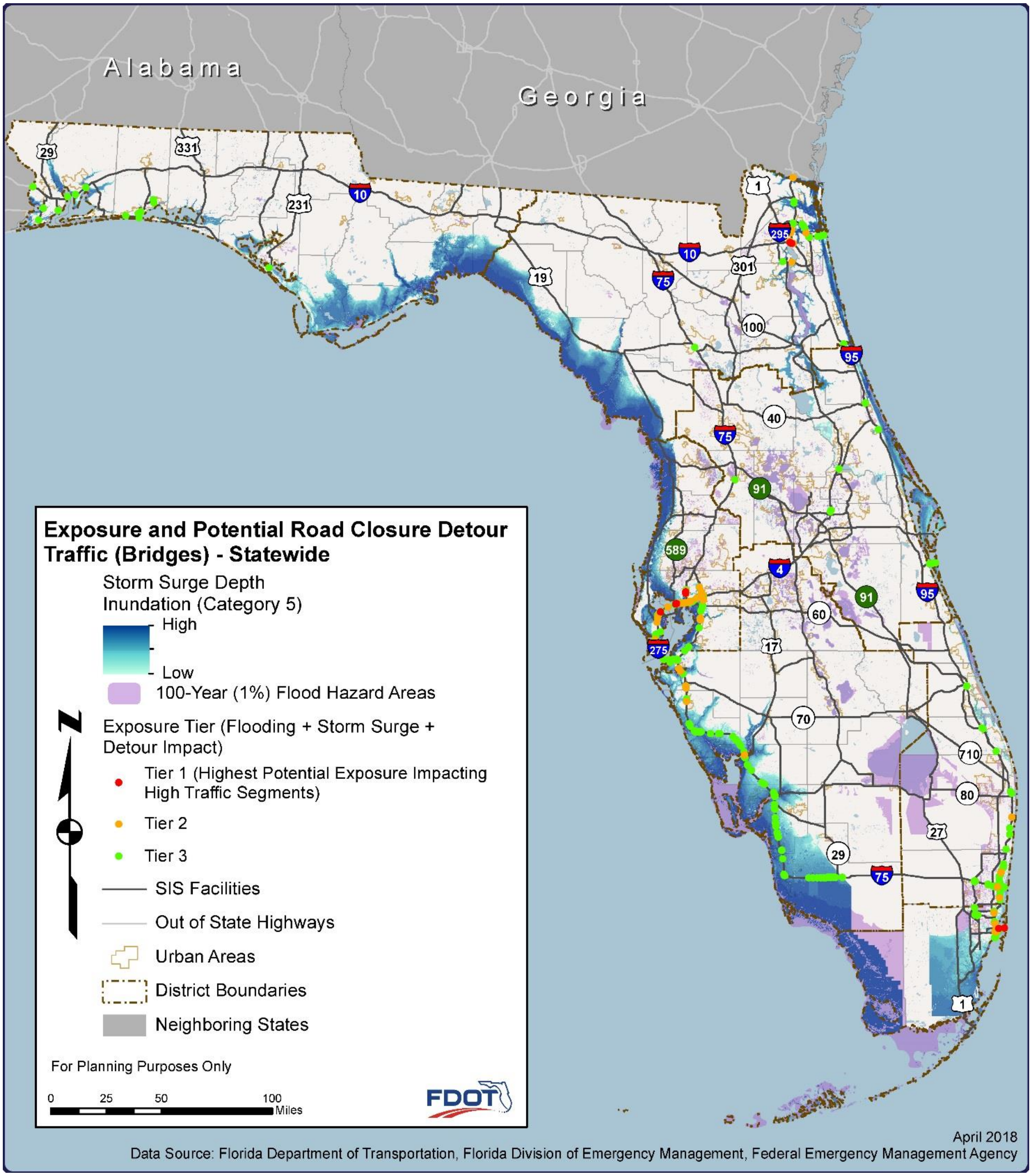

Figure 40: Vulnerability Composite Based on Category 5 Storm Surge and Flooding (Bridges)

Table 12 shows the results of the worst-case scenario with a Category 5 storm surge with a summary of SIS bridges vulnerable to flood hazard due to flooding (coastal, inland, and surge). The summary indicates that 2 centerline miles of SIS highway corridors are characterized as highly vulnerable – due to high exposure, high sensitivity and carrying high traffic volumes. These 2 miles consist of 11 bridge structures which are located in Duval, Hillsborough, Miami-Dade, and Pinellas Counties. **Appendix A** contains the listing of these facilities.

Tier	Centerline Miles at Risk	DVMT Potentially Impacted	Share of Centerline Miles at Risk Statewide (%)	Share of Statewide DVMT Impacted (%)
1	2	239,604	1.0%	3.2%
2	28	2,235,440	16.9%	30.3%
3	58	1,783,796	35.1%	24.2%

Table 12: Composite Vulnerability Summary of SIS Bridges

4.3 Hurricane Irma Case Study

A limited review of the traffic volumes during the Hurricane Irma storm event was completed to see how traffic volumes changed and which highway corridors received significant impacts from evacuating and returning traffic. Data was requested from the FDOT pertaining to telemetered traffic collection sites along the following interstate corridors: I-10, I-275, I-295, I-4, I-75, I-95, and the Florida Turnpike (SR 91)[22].

The data collected was 24-hour continuous traffic counts for all total vehicle volumes from September 4th to 15th of 2017 to provide a picture of evacuating and return traffic volumes. Preparation for evacuation and early voluntary evacuations began on the 4th with Florida Governor Rick Scott issuing a state of emergency for all counties within the state. Mandatory evacuations would soon follow. Hurricane Irma's outer bands hit the Florida Keys at night on September 9th and made land fall the following day. The storm had left Florida by September 11th, moving into Georgia. Evacuees returning after the storm started to pour onto Florida's highways on September 12th.

Assessment of traffic volumes looked at both directions of traffic passing a specific traffic collection site. Overall impact used peak daily traffic volumes as was compared against 2016 AADT volumes which were used for risk assessments for the main portions of this task. Those collection sites which observed significantly high traffic volumes were further analyzed for daily volumes for the entire time period assessed.

[22] The Florida Turnpike is not an interstate corridor, but its significance to Florida's transportation system is equal to the other interstate corridors identified.

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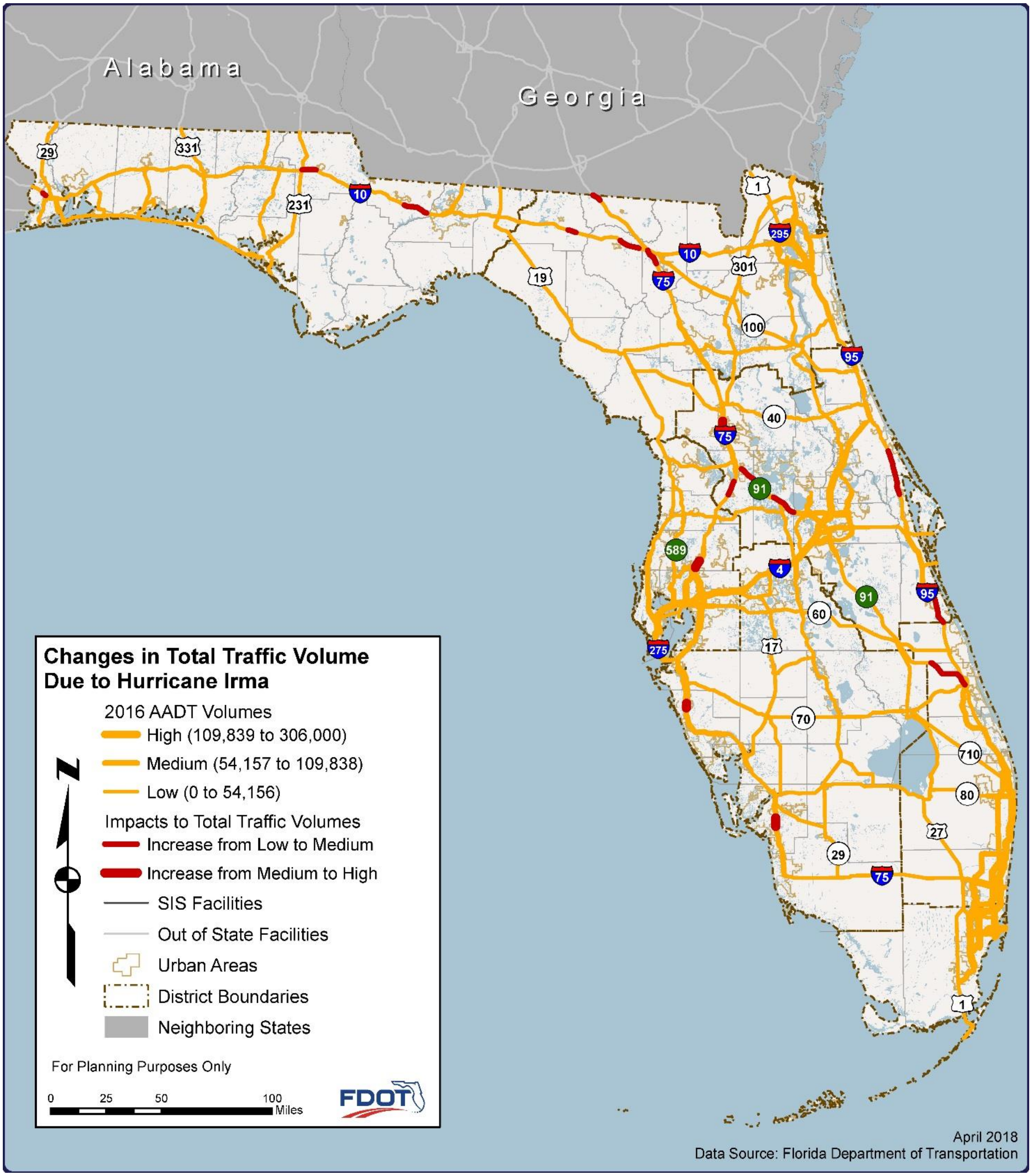

Figure 41: Impacts to Traffic Volumes Due to Hurricane Irma

As shown in **Figure 41**, there are several locations along Florida's interstate system which saw significant increases in traffic volumes due to evacuating or returning traffic. The impacts at these collection site areas are summarized in **Table 13**. For most of the sites, the heaviest traffic was seen between September 7th to 8th while only two sites saw their heaviest traffic from return traffic. Some of the most significant increases in traffic were seen along I-10 with a few areas found on I-75 and I-95. **Figures 42 and 43** show traffic flows along I-75 at Collection Site 290320 in Columbia County and I-10 at Collection Site 530218 in Jackson County over the course of multiple storm days. For both collection sites, when compared to 2016 AADT volumes, the daily volumes generally stay above previous year annual average daily volumes. – especially at Collection Site 290320 which is the segment of I-75 which leads to the I-75 / I-10 interchange.

Collection Site	County	Facility	Location on Facility	AADT (2016)	Peak Daily Volume During Irma	Day of Highest Peak Volume	Amount of Increase	Proportion of Increase (%)
120184	Lee	I-75	1.7 MI South of Daniels Pkwy	98,964	109,899	9/6/2017	10,935	11.05%
140190	Pasco	I-75	1.0 MI North of SR 56	89,288	111,783	9/7/2017	22,495	25.19%
170225	Sarasota	I-75	0.7 MI North of SR 72 At Proctor Rd Op	106,049	116,244	9/7/2017	10,195	9.61%
180358	Sumter	I-75	0.5 MI North of SR 48 O/P, Bushnell	52,372	67,548	9/13/2017	15,176	28.98%
290320	Columbia	I-75	Between I-10 and US 90	23,000	105,997	9/7/2017	82,997	360.86%
360317	Marion	I-75	0.23 MI North of Williams Rd O/P	90,745	126,501	9/8/2017	35,756	39.40%
359902	Madison	I-10	1.81 MI East of CR-53	27,701	62,228	9/8/2017	34,527	124.64%
320112	Hamilton	I-75	At State Line, 0.5 MI North of SR 143	42,653	96,751	9/7/2017	54,098	126.83%
370238	Suwannee	I-10	0.15 MI West of CR 136	29,822	58,737	9/8/2017	28,915	96.96%
480156	Escambia	I-10	0.6 MI West of SR 297	43,754	66,012	9/8/2017	22,258	50.87%
500220	Gadsden	I-10	250 FT West of CR 268 Overpass	31,810	66,487	9/8/2017	34,677	109.01%
530218	Jackson	I-10	1 MI East of US 231	23,999	59,922	9/8/2017	35,923	149.69%
700322	Brevard	I-95	0.9 MI South of Aurantia Rd	32,680	69,163	9/7/2017	36,483	111.64%
700134	Brevard	I-95	3.34 MR South of SR 514	42,764	85,405	9/7/2017	42,641	99.71%
970421	St. Lucie	SR 91/ FL Turnpike	North of Okeechobee Rd/SR 70	34,244	60,802	9/7/2017	26,558	77.56%
970417	Palm Beach	SR 91/ FL Turnpike	South of Indiantown Rd/SR 706	49,311	70,756	9/7/2017	21,445	43.49%
970428	Lake	SR 91/ FL Turnpike	Southeast of CR 561	51,735	76,828	9/7/2017	25,093	48.50%
979931	Sumter	SR 91/ FL Turnpike	South of CR 468	45,903	61,343	9/13/2017	15,440	33.64%

Table 13: Summary of Increases in Traffic Flows Due to Hurricane Irma

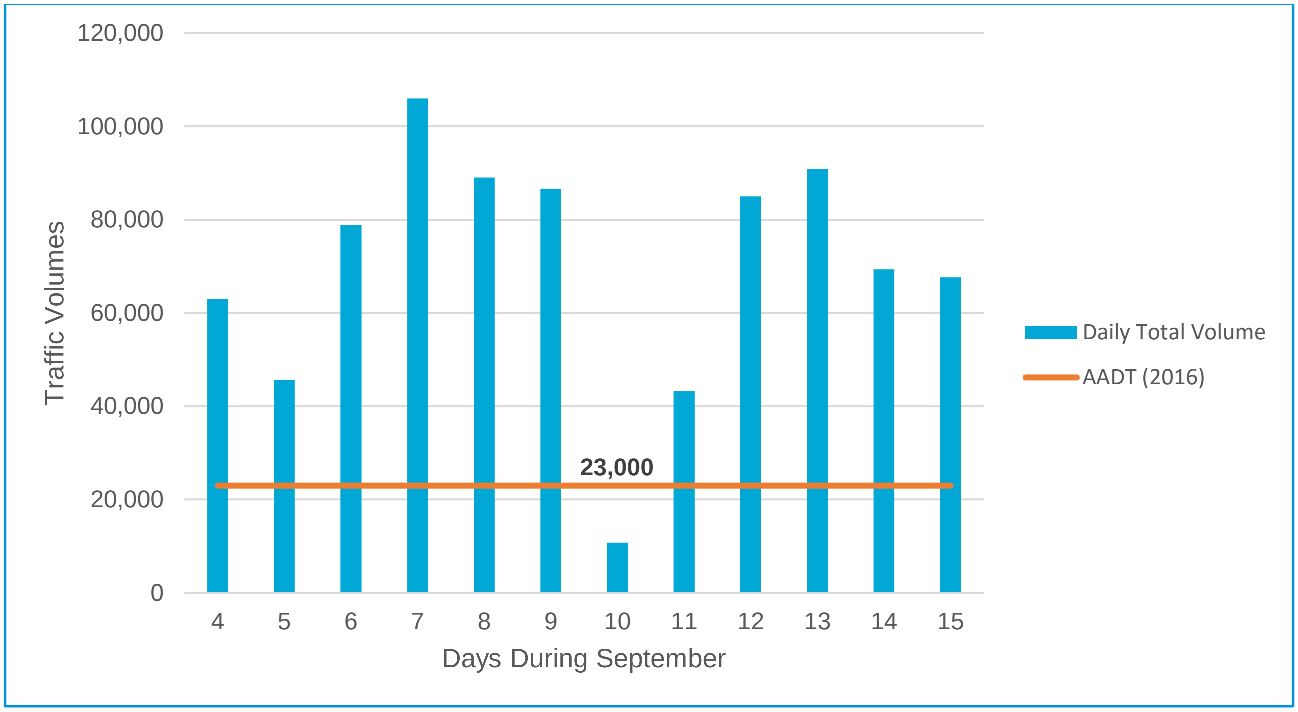

Figure 42: Collection Site 290320, I-75, Between I-10 and US 90 (Columbia County)

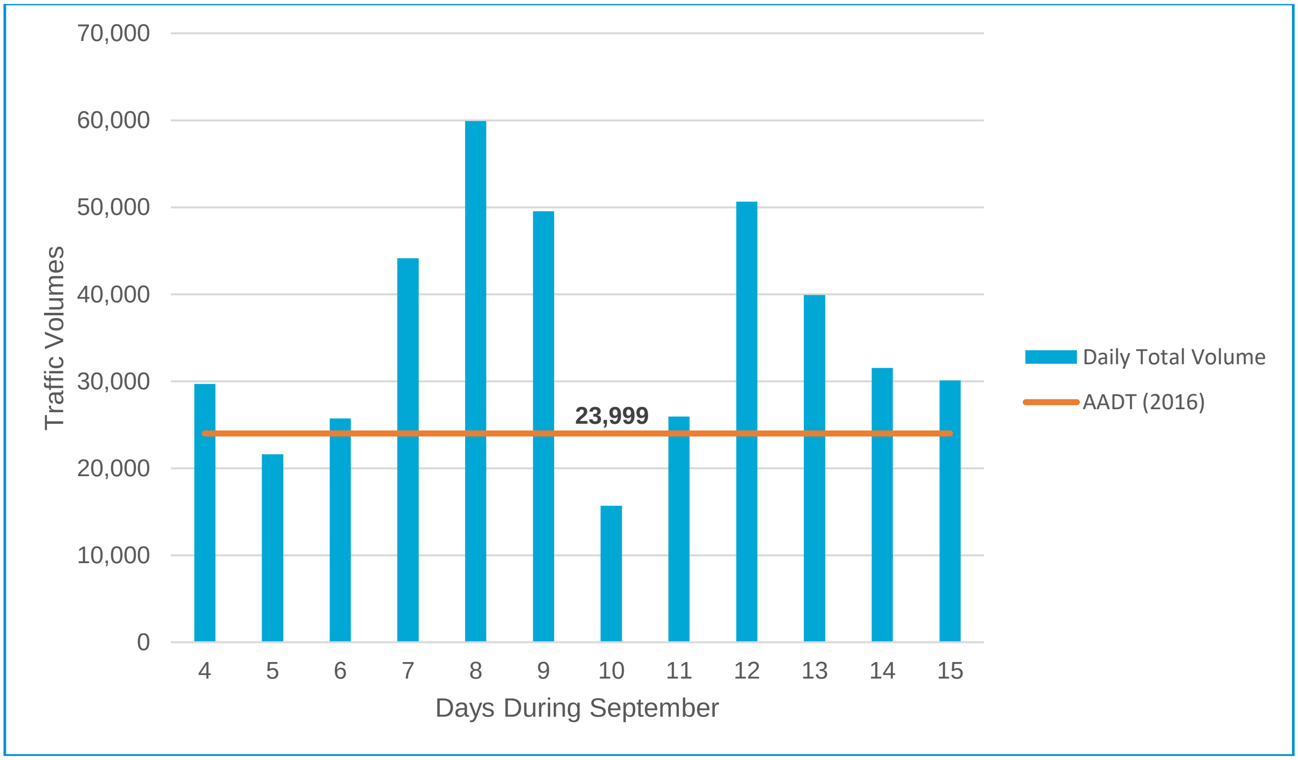

Figure 43: Collection Site 530218, I-10, 1 Mile East of US 231 (Jackson County)

Even with a limited review, there is significant amount of information to show the impacts from Hurricane Irma traffic which provide a glimpse at traffic behaviors. It is recommended that additional study be conducted looking at the remainder of the SIS network with the available count data from this period to assess other corridors. Information from this assessment could also possibly be used for adaptive capacity analysis in the future.

5.0 Recommendations

5.1 Other Studies

The logical conclusion to the vulnerability assessment is to identify and develop tailored adaptation strategies to enhance resilience of the SIS network and integrate this process into SIS policy planning and overall management of Florida's transportation system.

5.1.1 Perform Additional Multimodal Assessments

SIS Highway Corridors and Military Access Facilities were the emphasis of this analysis. SIS connectors, rail, and hubs (seaports and airports in particular) may also warrant vulnerability assessment. The airport and seaport master planning processes should incorporate resilience investigations; however, if not, it is an area for consideration.

5.1.2 Develop Adaptation Strategies

Results of vulnerability assessment are often put into action by way of developing or selecting adaptation strategies that are the logical remedial action taken to improve resilience of transport facilities. Identification of a range of possible adaptation strategies is not included under the current scope at this time. Depending on availability of additional resources, the project team should assist FDOT in identifying and recommending tailored and case-specific adaptation options for a select tier of assets that may face a high likelihood of impacts. For these assets, FDOT can consider conducting benefit cost analysis of proposed adaptation options and detailed engineering assessments.

5.1.3 Integrate Assessment Outcomes into FDOT's Decision Support Systems

The eventual conclusion to the vulnerability and risk assessment approach and a tailored list of recommended adaptation strategies is to include them into agency planning and overall practice. For this there may be additional tools that need to be developed including the above-mentioned benefit-cost analysis tool to estimate costs of remedial actions. For planning, this may take the form of a prioritization tool, which ranks proposed investments characterized by potential risk and vulnerability of the system by costs of inaction, remedial action in the form of a range of adaptation measures, and a proposed planning cycle for making such investments. The project team, based on availability of additional resources, can assist FDOT in incorporating the results of the vulnerability and risk framework into their decision support systems in areas including planning and programming, asset management, trends and data, maintenance, emergency response planning and operations.

5.1.4 Detouring for Critical Facilities

A more comprehensive analysis of detour impacts and potential for SIS facilities and locations and available system redundancy, especially given the interaction with local roadway network is an important consideration for evacuation and disaster response planning. For dealing with detouring impact potential for SIS facilities, the current approach used a proxy approach which assumed that the higher the AADT, the higher FDOT's prioritization to address system redundancy to address potential impacts on disruption to the facility and consideration of system redundancy to cope with likely impacts due to detours.

One of the ways to assess the impacts of potential detours and inherent system redundancy is to use travel demand models to implement detour management plans by employing select link analyses for potential disruptions. Modeling methods and tools may be developed to assess system-level detour impact analyses due to disruptions caused by total or partial loss of service due to closures, impassable sections or roadways due to flooding, network performance measures that capture such impacts.

5.1.5 Strategy Selection

FHWA's adaptation framework highlights two most commonly used methods for selecting potential adaptation options for implementation:

- Multi-criteria analysis; and
- Economic analysis.

Multi-criteria analysis enables consideration of a range of determinants that could play into decision-making for selection of a given adaptation strategy or option, without necessarily providing a quantitative basis like a cost-benefit ratio or other similar monetized or quantifiable benefits. Some of these criteria that are suggested by FHWA's framework include:

- Multi-stressor resilience,
- Costs – capital and life-cycle,
- Institutional and technical feasibility of strategy/project execution,
- Public acceptance,
- Equity impacts, and
- Scope and scale of impact (and thereby the response).

Using economic analysis for selection of adaptation strategies may include using analysis methods including benefit-cost analysis (BCA) and economic impact analysis (EIA) to allow for comparison of potential strategies and their costs to evaluate and compare the long-term benefits and costs of each potential adaptation strategy to be considered as an option for increasing SIS network or asset-level resilience.

5.2 Coordination

5.2.1 Other Offices

The information gained from the vulnerability assessment is relevant to almost all FDOT offices. Emergency management, maintenance/drainage, design, environmental management, and work program are some of the offices whose missions are related to reducing risks and improving system resiliency.

The team suggests that a crowd-sourcing initiative with an on-line mapping platform be created for internal sourcing of known and/or persistent flooding locations from FDOT District offices and other stakeholders. This will help FDOT obtain a more comprehensive locational database of flooding locations with scope for commenting and tagging information that might be useful for asset maintenance, operations, and emergency response perspective.

5.2.2 Districts

The information also is important to FDOT District offices. Some regions, such as South Florida and Tampa Bay, have already performed assessments and are now working to incorporate the knowledge into project development processes and decision making. Other FDOT Districts have not yet had an opportunity to perform assessments and this information will help guide future actions.

5.3 Policy and Tools

Long range planning processes should incorporate resiliency evaluations as sections of the SIS network are at risk of exposure to extreme weather impacts including flooding. As noted previously, modal master planning efforts should consider implications of potential flooding or storm impact. Some communities have taken a scenario approach. Policy and systems planning guidance reflect FDOT’s goals and objectives of evacuation and emergency management may be needed.

The SIS Strategic Investment Tool (SIT), used for prioritizing SIS Highway projects, is one tool to be evaluated for further incorporating resiliency measures. Discussion and policy direction is important regarding the types of amounts of investments that will be placed in areas where repeated flooding may be possible. For example, when does it become appropriate to look at enhancing alternate routes so that damaged facilities can be decommissioned as part of a managed retreat. Any decisions reached should be done in collaboration with metropolitan planning organizations and local governments with local and regional responsibilities.

Appendix A

Impacted SIS Corridors, Military Access Facilities and identified Bridge Structures

The following sections provide centerline and daily vehicle miles traveled (DVMT) results for all storm surge categories and 100-year flooding event, exposure composites, and overall vulnerability composites for those SIS highway corridors and bridge structures identified for the project. Listing of top ten impacted facilities are also contained within this appendix for each assessment. These facilities are identified generally by the level of impact (and for vulnerability composite, highest amount of traffic as well). Facilities which abut other facilities and have the similar level of impact (and for vulnerability composite, the same amount of traffic) are combined for the table listing.

1.0 Category 1 Storm Surge Tables

Exposure Level	Centerline	DVMT	Centerline (%)	DVMT (%)
Low	129	8,474,697	2.7%	3.9%
Medium	22	1,764,424	0.5%	0.8%
High	8	420,115	0.2%	0.2%

Table 1: SIS Highway Corridors Impacted by Exposure Level

Exposure Level	Centerline	DVMT	Centerline (%)	DVMT (%)
Low	33	1,776,814	20.1%	24.1%
Medium	14	856,021	8.4%	11.6%
High	-	-	0.0%	0.0%

Table 2: SIS Bridges Impacted by Exposure Level

Name	County	From	To	Centerline	DVMT
I-95/SR 9	Volusia	SR 40	US 1	5.59	282,497
SR 528/BEACHLINE EXP	Brevard	US 1/BEACHLINE EXP INTERCHANGE	COURTNEY PKWY	2.66	135,776
SR 589/SR 60	Hillsborough	N OF SR 60/MEMORIAL HWY EXIT 2A	S OF COURTNEY CAMPBELL CSWY/SR 60	0.07	1,841
US 19/SR 55	Pinellas	BAY DR	BELLEAIR RD	1.50	117,964
SR 60	Hillsborough	S OF SR 60/MEMORIAL HWY EXIT 1B	N OF SR 60/MEMORIAL HWY EXIT 2A	0.44	62,463
I-75/SR 93	Lee	PALM BEACH BLVD	BAYSHORE RD	2.32	159,804
I-75/SR 94	Sarasota	N OF PINEBROOK RD	SR 681	3.47	294,525
I-95/SR 9	Nassau	US 17	FL/GA STATELINE	2.61	171,906
I-75/SR 93A	Hillsborough	BIG BEND RD	GIBSONTON DR	4.18	503,810
I-75/SR 93A	Hillsborough	MANATEE/HILLSBOROUGH COUNTY LINE	21ST AVE SE	4.38	293,527

Table 3: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
I-75 SB OVER ALAFIA RIVER	Hillsborough	ALAFIA RIVER	0.29	21,683
I-75 NB AT ALAFIA RIVER	Hillsborough	ALAFIA RIVER	0.29	21,683
I-75 SB OVER L. MANATEE	Hillsborough	LITTLE MANATEE RIVER	0.26	8,777
I-75 OVER PEACE RIVER	Charlotte	PEACE RIVER	1.53	99,320
I-95 NB (SR-9)	Nassau	ST. MARY'S RIVER	0.24	15,622
I-275 (SR-93) / HILLSBOROUGH RIVER	Hillsborough	HILLSBOROUGH RIVER	0.06	9,633
I-75 (SR-93) NB OVER MYAKKA RIVER	Sarasota	MYAKKA RIVER	0.09	2,873
I-75 SB (SR-93) OVER CURRY CREEK	Sarasota	CURRY CREEK	0.03	1,204
I-75 SB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635
I-75 NB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635

Table 4: Top Ten Impacted Facilities (Bridges)

2.0 Category 3 Storm Surge Tables

Exposure Level	Centerline	DVMT	Centerline (%)	DVMT (%)
Low	264	13,428,254	5.5%	6.3%
Medium	249	9,526,011	5.2%	4.4%
High	108	5,878,457	2.3%	2.7%

Table 5: SIS Highway Corridors Impacted by Exposure Level

Exposure Level	Centerline	DVMT	Centerline (%)	DVMT (%)
Low	14	776,064	8.4%	10.5%
Medium	23	1,034,513	13.8%	14.0%
High	21	1,232,091	12.9%	16.7%

Table 6: SIS Bridges Impacted by Exposure Level

Name	County	From	To	Centerline	DVMT
SR 60/SR 589	Hillsborough	S OF SR 60/MEMORIAL HWY EXIT 1B	N OF COURTNEY CAMPBELL CSWY/SR 60	0.89	74,298
US 19/SR 55	Pinellas	BAY DR	BELLEAIR RD	1.50	117,964
I-75/SR 93	Lee	PALM BEACH BLVD	BAYSHORE RD	2.32	159,804
I-275/SR 93/I-275	Hillsborough	SLIGH AVE	E BIRD ST	0.84	142,129
US 19/SR 55/S SUNCOAST BLVD	Citrus	HERNANDO/CITRUS COUNTY LINE	SR 44	14.49	65,367
I-75/SR 93A	Hillsborough	BIG BEND RD	GIBSONTON DR	4.18	503,810
I-4/SR 400/SR 618 CONNECTOR	Hillsborough	11TH AVE	E OF 39TH ST	1.38	19,085
US 19/SR 55/US 19	Pinellas	BRYAN DAIRY RD	126TH AVE	0.61	34,048
SR 44/NE 5TH ST	Citrus	US 19/SR 55	ROCK CRUSHER RD	3.44	90,528
SR 618/SELMON EXPY	Hillsborough	E OF 28TH ST	78TH ST	3.65	425,859

Table 7: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
I-75 SB OVER ALAFIA RIVER	Hillsborough	ALAFIA RIVER	0.29	21,683
I-75 NB AT ALAFIA RIVER	Hillsborough	ALAFIA RIVER	0.29	21,683
I-75 OVER PEACE RIVER	Charlotte	PEACE RIVER	1.53	99,320
I-275 (SR-93) / HILLSBOROUGH RIVER	Hillsborough	HILLSBOROUGH RIVER	0.06	9,633
I-75 NB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635
DICK MISENER BRIDGE SB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
DICK MISENER BRIDGE NB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
I-75 SB / IMPERIAL RIVER	Lee	IMPERIAL RIVER	0.05	2,288
I-75 SB OVER TIDAL MARSH	Lee	TIDAL MARSH	0.18	6,210
I-75 NB / CALOOSAHATCHEE RIVER	Lee	CALOOSAHATCHEE RIVER	0.74	25,668

Table 8: Top Ten Impacted Facilities (Bridges)

3.0 Category 5 Storm Surge Tables

Exposure Level	Centerline	DVMT	Centerline (%)	DVMT (%)
Low	193	12,151,401	4.1%	5.7%
Medium	327	14,500,008	6.8%	6.7%
High	463	22,099,964	9.7%	10.3%

Table 9: SIS Highway Corridors Impacted by Exposure Level

Exposure Level	Centerline	DVMT	Centerline (%)	DVMT (%)
Low	14	681,472	8.7%	9.2%
Medium	12	554,133	7.4%	7.5%
High	48	2,398,267	28.8%	32.5%

Table 10: SIS Bridges Impacted by Exposure Level

Name	County	From	To	Centerline	DVMT
SR 60/SR 589	Hillsborough	S OF SR 60/MEMORIAL HWY EXIT 1B	N OF COURTNEY CAMPBELL CSWY/SR 60	0.89	74,298
I-75/SR 93	Sarasota	RIVER RD	RANGE LINE RUN	5.93	362,977
SR 31	Lee	SR 80	.11 MI S OF WILSON PIGOTT BRIDGE	2.13	20,968
SR 31	Lee	N OF APPROACH TO WILSON PIGOTT BRIDGE	TEMPLE CHRISTIAN SCHOOL	1.26	11,322
I-75/SR 93	Lee	N OF CORKSCREW RD	LEE/COLLIER COUNTY LINE	8.67	871,033
I-75/SR 93	Collier	LEE/COLLIER COUNTY LINE	IMMOKALEE RD	3.13	303,350
US 19/SR 55	Pinellas	BAY DR	BELLEAIR RD	1.50	117,964
I-75/SR 93	Lee	PALM BEACH BLVD	BAYSHORE RD	2.32	159,804
I-275/SR 55/US19	Manatee	Mile Post 10.005	Mile Post 11.07	1.06	63,900
SR 80/PALM BEACH BLVD	Lee	SR 31	BUCKINGHAM RD	2.49	87,220

Table 11: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
I-75 SB OVER ALAFIA RIVER	Hillsborough	ALAFIA RIVER	0.29	21,683
I-75 NB AT ALAFIA RIVER	Hillsborough	ALAFIA RIVER	0.29	21,683
I-75 OVER PEACE RIVER	Charlotte	PEACE RIVER	1.53	99,320
I-275 (SR-93) / HILLSBOROUGH RIVER	Hillsborough	HILLSBOROUGH RIVER	0.06	9,633
I-75 NB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635
DICK MISENER BRIDGE SB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
DICK MISENER BRIDGE NB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
I-75 SB / IMPERIAL RIVER	Lee	IMPERIAL RIVER	0.05	2,288
I-75 SB OVER TIDAL MARSH	Lee	TIDAL MARSH	0.18	6,210
I-75 NB / CALOOSAHATCHEE RIVER	Lee	CALOOSAHATCHEE RIVER	0.74	25,668

Table 12: Top Ten Impacts Facilities (Bridges)

4.0 100-Year Flooding Event Tables

Exposure Level	Centerline	DVMT	Centerline (%)	DVMT (%)
Low	215	14,091,774	4.5%	6.6%
Medium	268	10,998,858	5.6%	5.1%
High	62	2,195,720	1.3%	1.0%

Table 13: SIS Highway Corridors Impacted by Exposure Level

Exposure Level	Centerline	DVMT	Centerline (%)	DVMT (%)
Low	4	235,657	2.6%	3.2%
Medium	13	683,461	7.8%	9.3%
High	45	2,157,266	26.9%	29.2%

Table 14: SIS Bridges Impacted by Exposure Level

Name	County	From	To	Centerline	DVMT
US 27/SR 500/BONNIE HEATH BLVD	Marion	LEVY/MARION COUNTY LINE	NW HIGHWAY 225A	1.41	25,981
I-75/SR 93	Pasco	N OF STANLEY BRANCH	S OF BLANTON RD	4.29	253,755
I-75/SR 93A	Hillsborough	SR 60/ADAMO RD	SR 574	4.48	116,376
US 98/SR 50/CORTEZ BLVD	Hernando	SPRING LAKE HWY	LA ROSE RD	14.46	111,365
US 98/SR-30A/15 ST/TYNDALL PKWY	Bay	BECK AVE	GRACE AVE	1.85	46,300
I-75/SR 93A	Hillsborough	HILLSBOROUGH/MANATEE COUNTY LINE	21ST AVE	5.62	224,760
SR 60/E CANAL ST	Polk	CHURCH AVE	KID ELLIS RD	1.40	222,662
I-75/SR 93A	Hillsborough	SR 574	SR 400	2.73	345,724
US 1/SR 5/OVERSEAS HWY	Monroe	MIAMI-DADE/MONROE COUNTY LINE	N OF LAKE SURPRISE	4.84	99,200
US 17/SR 35	DeSoto	CHARLOTTE/DESOTO COUNTY LINE	SW CR 761	4.38	293,527

Table 15: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
RAMP A OVER US-92(SR600)	Hillsborough	US-92 (SR-600)	0.04	702
RAMP B OVER US-92	Hillsborough	US-92 (SR-600)	0.04	720
DICK MISENER BRIDGE SB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
DICK MISENER BRIDGE NB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
SR-679 EB TO I-275 NB	Pinellas	US-19 SR-55 54TH AVE S	0.19	856
I-275 SB TO SR-679 WB	Pinellas	US-19 SR-55 SR-679	0.24	2,118
I-275 NB / FRENCHMENS CREEK	Pinellas	FRENCHMENS CREEK	0.04	1,243
I-275 NB / FRENCHMENS CREEK	Pinellas	FRENCHMENS CREEK	0.04	1,243
I-95 NB OVER NW 17 ST	Miami-Dade	NW 17TH ST	0.33	27,889
Dupont Bridge	Bay	St. Andrews Bay (ICWW)	0.52	10,660

Table 16: Top Ten Impacted Facilities (Bridges)

5.0 Category 1 Storm Surge and Flooding Exposure Composite Tables

Rank	Centerline	DVMT	Centerline (%)	DVMT (%)
Rank 1	70	2,615,834	1.5%	1.2%
Rank 2	276	11,829,400	5.8%	5.5%
Rank 3	253	16,275,153	5.3%	7.6%

Table 17: SIS Highway Corridors Impacted by Exposure Level

Rank	Centerline	DVMT	Centerline (%)	DVMT (%)
Rank 1	45	2,157,266	26.9%	29.2%
Rank 2	14	740,664	8.4%	10.0%
Rank 3	9	530,794	5.7%	7.2%

Table 18: SIS Bridges Impacted by Exposure Level

Name	County	From	To	Centerline	DVMT
SR 589/SR 60	Hillsborough	N OF SR 60/MEMORIAL HWY EXIT 2A	S OF COURTNEY CAMPBELL CSWY/SR 60	0.07	1,841
I-75/SR 93A	Hillsborough	HILLSBOROUGH/MANATEE COUNTY LINE	21ST AVE	5.62	224,760
US 1/SR 5/OVERSEAS HWY	Monroe	MIAMI-DADE/MONROE COUNTY LINE	N OF LAKE SURPRISE	4.84	99,200
I-275/SR 55/SKYWAY BRG	Pinellas	.7 MI S OF PINELLAS/HILLSBOROUGH COUNTY LINE	I-275 EXIT 16	14.46	111,365
US 1/SR 5/SOUTH DIXIE HIGHWAY	Miami-Dade	MIAMI-DADE/MONROE COUNTY LINE	.74 MI N OF MILEMARKER 115	5.62	224,760
I-95/SR 9	Volusia	SR 40	US 1	5.59	282,497
SR 528/BEACHLINE EXP	Brevard	US 1/BEACHLIEN EXP INTERCHANGE	COURTNEY PKWY	2.66	135,776
US 27/SR 500/BONNIE HEATH BLVD	Marion	LEVY/MARION COUNTY LINE	NW HIGHWAY 225A	1.41	25,981
I-75/SR 93	Pasco	N OF STANLEY BRANCH	S OF BLANTON RD	4.29	253,755
I-75/SR 93A	Hillsborough	SR 60/ADAMO RD	SR 574	4.48	116,376

Table 19: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
DICK MISENER BRIDGE SB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
DICK MISENER BRIDGE NB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
I-275 NB / FRENCHMENS CREEK	Pinellas	FRENCHMENS CREEK	0.04	1,243
I-275 NB / FRENCHMENS CREEK	Pinellas	FRENCHMENS CREEK	0.04	1,243
I-75 SB (SR-93) OVER CURRY CREEK	Sarasota	CURRY CREEK	0.03	1,204
I-75 NB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635
I-75 SB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635
I-75 OVER PEACE RIVER	Charlotte	PEACE RIVER	1.53	99,320
HOWARD FRANKLAND SB	Pinellas	OLD TAMPA BAY	3.01	257,013
HOWARD FRANKLAND NB	Pinellas	TAMPA BAY	3.01	257,013

Table 20: Top Ten Impacted Facilities (Bridges)

6.0 Category 3 Storm Surge and Flooding Exposure Composite Tables

Rank	Centerline	DVMT	Centerline (%)	DVMT (%)
Rank 1	165	7,780,650	3.5%	3.6%
Rank 2	425	15,647,253	8.9%	7.3%
Rank 3	367	21,333,200	7.7%	9.9%

Table 21: SIS Highway Corridors Impacted by Rank

Rank	Centerline	DVMT	Centerline (%)	DVMT (%)
Rank 1	48	2,342,387	29.1%	31.7%
Rank 2	17	797,937	10.1%	10.8%
Rank 3	9	547,799	5.3%	7.4%

Table 22: SIS Bridges Impacted by Rank

Name	County	From	To	Centerline	DVMT
SR 60/SR 589	Hillsborough	S OF SR 60/MEMORIAL HWY EXIT 1B	S OF COURTNEY CAMPBELL CSWY/SR 60	0.51	64,304
SR 618/SELMON EXPY	Hillsborough	E OF 28TH ST	78TH ST	3.65	425,859
US 19/SR 55	Pinellas	BAY DR	BELLEAIR RD	1.50	117,964
I-75/SR 93	Lee	PALM BEACH BLVD	BAYSHORE RD	2.32	159,804
SR 60/SR 589	Hillsborough	S OF COURTNEY CAMPBELL CSWY/SR 60	S OF INDEPENDENCE PKWY	0.73	19,173
SR 60	Hillsborough	LA SALLE ST	S OF SR 60/MEMORIAL HWY EXIT 1B	0.45	64,155
US 19/SR 55/N SUNCOAST BLVD	Citrus	2ND ST	S OF 6th AVE	1.44	30,953
SR 44/NE 5TH ST	Citrus	US 19/SR 55	ROCK CRUSHER RD	3.44	90,528
US 19/SR 55/S SUNCOAST BLVD	Citrus	GROVER CLEVELAND BLVD	LONGFELLOW ST	1.77	46,150
I-4/SR 400/SR 618 CONNECTOR	Hillsborough	E OF 39TH ST	11TH AVE	1.38	19,085

Table 23: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
DICK MISENER BRIDGE SB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
DICK MISENER BRIDGE NB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
I-75 NB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635
I-75 OVER PEACE RIVER	Charlotte	PEACE RIVER	1.53	99,320
HOWARD FRANKLAND SB	Pinellas	OLD TAMPA BAY	3.01	257,013
HOWARD FRANKLAND NB	Pinellas	TAMPA BAY	3.01	257,013
I-275 (SR-93) / HILLSBOROUGH RIVER	Hillsborough	HILLSBOROUGH RIVER	0.06	9,633
I-75 NB / CALOOSAHATCHEE RIVER	Lee	CALOOSAHATCHEE RIVER	0.74	25,668
I-75 SB/CALOOSAHATCHEE RIVER	Lee	CALOOSAHATCHEE RIVER	0.74	25,668
I-75 SB OVER TIDAL MARSH	Lee	TIDAL MARSH	0.18	6,210

Table 24: Top Ten Impacted Facilities (Bridges)

7.0 Category 5 Storm Surge and Flooding Exposure Composite Tables

Rank	Centerline	DVMT	Centerline (%)	DVMT (%)
Rank 1	513	23,924,222	10.8%	11.1%
Rank 2	461	18,663,512	9.7%	8.7%
Rank 3	283	18,973,279	5.9%	8.8%

Table 25: SIS Highway Corridors Impacted by Rank

Rank	Centerline	DVMT	Centerline (%)	DVMT (%)
Rank 1	64	3,126,645	38.7%	42.4%
Rank 2	11	465,060	6.4%	6.3%
Rank 3	12	613,675	7.3%	8.3%

Table 26: SIS Bridges Impacted by Rank

Name	County	From	To	Centerline	DVMT
I-275/SR 55/SKYWAY BRG	Pinellas	.7 MI S OF PINELLAS/HILLSBOROUGH COUNTY LINE	I-275 EXIT 16	14.46	111,365
SR 618/SELMON EXPY	Hillsborough	E OF 28TH ST	78TH ST	3.65	425,859
SR 60/SR 589	Hillsborough	S OF SR 60/MEMORIAL HWY EXIT 1B	S OF INDEPENDENCE PKWY	1.70	147,632
I-275/SR 55/US19	Manatee	Mile Post 10.005	Mile Post 11.07	1.06	63,900
US 19/SR 55	Pinellas	BAY DR	BELLEAIR RD	1.50	117,964
I-95/SR 9	Nassau	US 17	FL/GA STATELINE	2.61	171,906
I-75/SR 93	Lee	PALM BEACH BLVD	BAYSHORE RD	2.32	159,804
US 19/SR 55	Pasco	GULF DR	RIDGE RD	3.05	166,334
I-275/SR 93	Pinellas	ROOSEVELT BLVD	ULMERTON RD	1.31	130,800
US 92/SR 600/GANDY BLVD	Pinellas	4TH ST	E OF 2ND ST	0.12	6,448

Table 27: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
DICK MISENER BRIDGE SB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
DICK MISENER BRIDGE NB	Pinellas	TAMPA BAY MAXIMO POINT	0.54	15,889
SR-679 EB TO I-275 NB	Pinellas	US-19 SR-55 54TH AVE S	0.19	856
I-275 SB TO SR-679 WB	Pinellas	US-19 SR-55 SR-679	0.24	2,118
I-275 NB / FRENCHMENS CREEK	Pinellas	FRENCHMENS CREEK	0.04	1,243
I-275 NB / FRENCHMENS CREEK	Pinellas	FRENCHMENS CREEK	0.04	1,243
I-75 SB (SR-93) OVER CURRY CREEK	Sarasota	CURRY CREEK	0.03	1,204
I-75 NB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635
I-75 SB (SR-93) OVER SALT CREEK	Sarasota	SALT CREEK	0.06	2,635
I-75 NB (SR-93) OVER CURRY CREEK	Sarasota	CURRY CREEK	0.02	946

Table 28: Top Ten Impacted Facilities (Bridges)

8.0 Category 1 Storm Surge and Flooding Vulnerability Composite Tables

Tier	Centerline	DVMT	Centerline (%)	DVMT (%)
Tier 1	4	568,386	0.1%	0.3%
Tier 2	66	7,294,534	1.4%	3.4%
Tier 3	530	22,857,467	11.1%	10.6%

Table 29: SIS Highway Corridors Impacted by Tier

Tier	Centerline	DVMT	Centerline (%)	DVMT (%)
Tier 1	1	202,237	0.8%	2.7%
Tier 2	23	1,838,924	14.2%	24.9%
Tier 3	43	1,387,563	26.0%	18.8%

Table 30: SIS Bridges Impacted by Tier

Name	County	From	To	Centerline	DVMT
I-75/SR 93A	Hillsborough	SR 574	SR 400	1.40	222,662
I-75/SR 93A	Hillsborough	SR 60/ADAMO RD	SR 574	2.73	345,724
SR 60	Hillsborough	LA SALLE ST	N OF SR 60/MEMORIAL HWY EXIT 2A	0.90	126,618
I-275/SR 93	Pinellas	SR 688	S OF BIG ISLAND	0.59	82,566
SR 618/SELMON EXPY	Hillsborough	E OF 28TH ST	78TH ST	3.65	425,859
I-75/SR 93A	Hillsborough	BIG BEND RD	GIBSONTON DR	4.18	503,810
US 19/SR 55	Pinellas	BAY DR	BELLEAIR RD	1.50	117,964
I-75/SR 94	Sarasota	N OF PINEBROOK RD	SR 681	3.47	294,525
I-75/SR 93	Lee	PALM BEACH BLVD	BAYSHORE RD	2.32	159,804
I-75/SR 93A/I-75	Hillsborough	HILLSBOROUGH/MANATEE COUNTY LINE	21ST AVE	5.62	224,760

Table 31: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
I-275 (SR-93) / HILLSBOROUGH RIVER	Hillsborough	HILLSBOROUGH RIVER	0.06	9,633
FULLER WARREN BR# 2 S. APP.	Duval	SAN MARCO/PALM/ST J RIV.	0.41	65,874
JULIA TUTTLE CAUSEWAY	Miami-Dade	INTRACOASTAL WATERWAY	0.41	47,736
FULLER WARREN BR# 4 N APP	Duval	RIVERSIDE AVE/ST J RIVER	0.45	72,413
JULIA TUTTLE CAUSEWAY	Miami-Dade	ALTON ROAD	0.06	6,581
I-75 SB OVER ALAFIA RIVER	Hillsborough	ALAFIA RIVER	0.29	21,683
I-75 OVER PEACE RIVER	Charlotte	PEACE RIVER	1.53	99,320
HOWARD FRANKLAND SB	Pinellas	OLD TAMPA BAY	3.01	257,013
HOWARD FRANKLAND NB	Pinellas	TAMPA BAY	3.01	257,013
I-95 NB (SR-9)	Nassau	ST. MARY'S RIVER	0.24	15,622

Table 32: Top Ten Impacted Facilities (Bridges)

9.0 Category 3 Storm Surge and Flooding Vulnerability Composite Tables

Tier	Centerline	DVMT	Centerline (%)	DVMT (%)
Tier 1	21	3,104,491	0.4%	1.4%
Tier 2	111	10,489,028	2.3%	4.9%
Tier 3	825	31,167,582	17.3%	14.5%

Table 33: SIS Highway Corridors Impacted by Tier

Tier	Centerline	DVMT	Centerline (%)	DVMT (%)
Tier 1	1	215,824	0.9%	2.9%
Tier 2	25	1,982,698	15.3%	26.9%
Tier 3	47	1,489,601	28.3%	20.2%

Table 34: SIS Bridges Impacted by Tier

Name	County	From	To	Centerline	DVMT
I-275/SR 93	Hillsborough	NE OF HOWARD FRANKLIN BRIDGE	SR 60	1.71	302,493
I-275/SR 93	Pinellas	4TH ST	SW OF HOWARD FRANKLIN BRIDGE	5.28	902,196
I-275/SR 93	Hillsborough	SLIGH AVE	E BIRD ST	0.84	142,129
SR 60	Hillsborough	I-275	N OF SR 60/MEMORIAL HWY EXIT 2A	1.52	214,179
I-275/SR 93	Pinellas	SR 688	4TH ST	0.59	82,566
SR 618/SELMON EXPY	Hillsborough	39TH ST	78TH ST	2.92	388,731
I-75/SR 93A	Hillsborough	BIG BEND RD	GIBSONTON DR	4.18	503,810
I-75/SR 93A	Hillsborough	SR 60/ADAMO RD	SR 574	2.73	345,724
I-95/SR 9/I-95	Broward	2ND ST	SUNRISE BLVD	1.15	343,800
SR 826/PALMETTO EXPWY	Miami-Dade	25TH ST	S OF SR 826 NB/SB EXITS	0.07	18,531

Table 35: Top Ten Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
I-275 (SR-93) / HILLSBOROUGH RIVER	Hillsborough	HILLSBOROUGH RIVER	0.06	9,633
I-275 OVER BIG ISLAND GAP	Pinellas	BIG ISLAND GAP	0.06	7,923
I-275 (SR-93) OVER MEMORIAL BLVD	Hillsborough	SR-60 (MEMORIAL BLVD)	0.03	5,664
FULLER WARREN BR# 2 S. APP.	Duval	SAN MARCO/PALM/ST J RIV.	0.41	65,874
JULIA TUTTLE CAUSEWAY	Miami-Dade	INTRACOASTAL WATERWAY	0.41	47,736
FULLER WARREN BR# 4 N APP	Duval	RIVERSIDE AVE/ST J RIVER	0.45	72,413
JULIA TUTTLE CAUSEWAY	Miami-Dade	ALTON ROAD	0.06	6,581
I-75 OVER PEACE RIVER	Charlotte	PEACE RIVER	1.53	99,320
HOWARD FRANKLAND SB	Pinellas	OLD TAMPA BAY	3.01	257,013
HOWARD FRANKLAND NB	Pinellas	TAMPA BAY	3.01	257,013

Table 36: Top Ten Impacted Facilities (Bridges)

10.0 Category 5 Storm Surge and Flooding Vulnerability Composite Tables

Tier	Centerline	DVMT	Centerline (%)	DVMT (%)
Tier 1	49	7,060,823	1.0%	3.3%
Tier 2	194	16,958,535	4.1%	7.9%
Tier 3	1,015	37,622,210	21.3%	17.5%

Table 37: SIS Highway Corridors Impacted by Tier

Tier	Centerline	DVMT	Centerline (%)	DVMT (%)
Tier 1	2	239,604	1.0%	3.2%
Tier 2	28	2,235,440	16.9%	30.3%
Tier 3	58	1,783,796	35.1%	24.2%

Table 38: SIS Bridges Impacted by Tier

Name	County	From	To	Centerline	DVMT
I-275/SR 93	Hillsborough	E OF ALBANY AVE	DOYLE CARLTON DR	0.99	213,192
I-275/SR 93	Hillsborough	ASHLEY DR	E OF TAMPA ST	0.03	7,344
I-275/SR 93	Hillsborough	JEFFERSON ST	LAMAR AVE	0.14	29,398
I-275/SR 93	Hillsborough	SR 60	DALE MABRY HWY	1.68	313,673
I-275/SR 93	Pinellas	4TH ST	SW OF HOWARD FRANKLIN BRIDGE	5.28	902,196
I-275/SR 93	Hillsborough	SLIGH AVE	E BIRD ST	0.84	142,129
I-4/SR 400	Hillsborough	US 301/FORT KING HWY	EUREKA SPRINGS RD	0.82	131,109
SR 821/HEFT	Miami-Dade	SW 152ND ST	S OF SW 184TH ST	2.35	374,825
I-75/SR 93A	Hillsborough	SR 574	SR 400	1.40	222,662
I-4/SR 400	Hillsborough	21ST ST	W OF 38TH ST	1.09	172,992
I-75/SR 93A	Hillsborough	N OF GIBSONTON DR	AMBERDALE CT	2.15	317,125

Table 39: Top Eleven Impacted Facilities (Highway Corridors)

Name	County	Facility/Waterbody Crossed	Centerline	DVMT
I-275 (SR-93) / HILLSBOROUGH RIVER	Hillsborough	HILLSBOROUGH RIVER	0.06	9,633
I-275 OVER BIG ISLAND GAP	Pinellas	BIG ISLAND GAP	0.06	7,923
I-275 (SR-93) OVER MEMORIAL BLVD	Hillsborough	SR-60 (MEMORIAL BLVD)	0.03	5,664
I-275 (SR-93) OVER CR-587 (WESTSHORE BL	Hillsborough	CR-587 (WESTSHORE BLVD)	0.04	6,372
FULLER WARREN BR# 2 S. APP.	Duval	SAN MARCO/PALM/ST J RIV.	0.41	65,874
I-275 OVER BIRD ST.	Hillsborough	BIRD STREET	0.03	5,408
I-275 OVER WATERS AVE	Hillsborough	WATERS AVENUE	0.03	4,200
I-275 (SR-93) OVER YUKON ST	Hillsborough	YUKON STREET	0.05	7,800
JULIA TUTTLE CAUSEWAY	Miami-Dade	INTRACOASTAL WATERWAY	0.41	47,736
FULLER WARREN BR# 4 N APP	Duval	RIVERSIDE AVE/ST J RIVER	0.45	72,413
JULIA TUTTLE CAUSEWAY	Miami-Dade	ALTON ROAD	0.06	6,581

Table 40: Top Eleven Impacted Facilities (Bridges)

Appendix B

Sensitivity Thresholds and Maps

As described in the main report, as part of the assessment of vulnerability, sensitivity assessments were conducted on SIS Corridors and Military Access Facilities (MAFs) as well as identified bridge structures. The following sections provide information regarding the sensitivity criteria and thresholds as well as the results of the sensitivity assessment for all facilities.

1.0 SIS Corridors and MAFs

Pavement conditions were sourced from Florida Department of Transportation's (FDOT) Transportation Data and Analytics office. The data is as recent as February 2, 2018 and was developed from Feature 230, PAVECOND, from the FDOT RCI. **Table 1** describes the pavement condition rating system and the subsequent scoring assigned for the assessment. **Figure 1** shows pavement conditions for the entire SIS network under study.

Pavement Condition Scale	Pavement Condition Description	Assessment Scoring
0.0-1.0	Very Poor: Virtually impassable. 75% or more deteriorated.	High
1.0-2.0	Poor: Large potholes and deep cracks exist. Discomfort at slow speeds.	
2.0-3.0	Fair: Rutting, map cracking and extensive patching.	Medium
3.0-4.0	Good: First class ride with only slight surface deterioration.	Low
4.0-5.0	Very Good: Only new or nearly new pavement.	

Table 1: Pavement Condition Scale and Sensitivity Scoring

Of the facilities assessed, none were rated below a 2 by FDOT. However, there are two facilities that were rated a 2 and therefore scored a High under the sensitivity assessment for highway corridors. These two facilities belong to SR 54 and abut each other from US 41 to West of Cypress Creek Road in Pasco County. Beyond these two facilities, there are at least 63 corridor segments rated as a 2.5 under the pavement condition scale. Even though these facilities have scored a Medium under the sensitivity assessment, they are on the lower end with the potential to approach a rating of 2 in the future. These corridor segments can be found along SR 528/Beachline Expressway, US 92, Dale Mabry Highway (to MacDill Air Force Base), US 98, and US 441/SR 80.

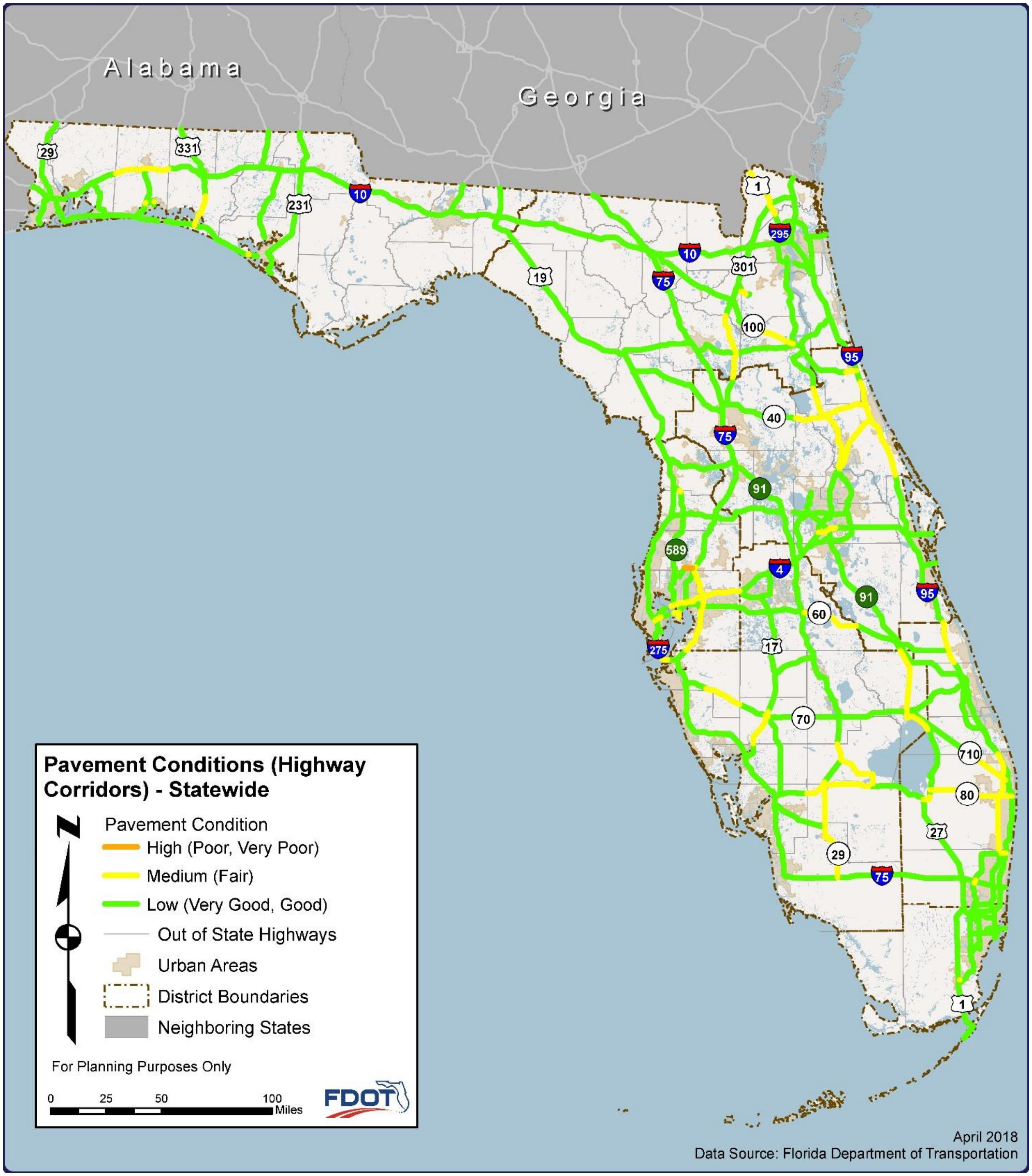

Figure 1: SIS Corridors and MAFs Pavement Conditions

2.0 Bridge Structures

Assessment of bridges for the sensitivity assessment differed from highway corridors as two bridge characteristic rating systems were used instead of one. The bridge assessment looked at both sufficiency rating and scour critical as described in the main report. Sufficiency ratings were pulled from the FDOT's 2018 Quarter 1 Bridge Information Report while scour critical ratings were pulled from the National Bridge Inventory (NBI). The 2018 report was released on January 2, 2018. Information from NBI was published on December 7, 2017. **Table 2** provides the sufficiency rating ranges and the subsequent scoring assigned for the assessment. **Table 3** provides the scour critical rating codes, descriptions and the subsequent scoring assigned for the assessment.

Sufficiency Rating	Assessment Scoring
0-60.0	High
60.0-70.0	
70.0-80.0	Medium
80.0-90.0	Low
90.0-100	

Table 2: Bridge Sufficiency Ratings and Sensitivity Scoring

Scour Critical Code	Description
N	Bridge not over waterway (including flood waterways).
U	Bridge with "unknown" foundation that has not been evaluated for scour. Since risk cannot be determined, flag for monitoring during flood events and, if appropriate, closure.
T	Bridge over "tidal" waters that has not been evaluated for scour but considered low risk. Bridge will be monitored with regular inspection cycle and with appropriate underwater inspections. ("Unknown" foundations in "tidal" waters are coded as U.)
9	Bridge foundations (including piles) on dry land well above flood water elevations.
8	Bridge foundations determined to be stable for assessed or calculated scour conditions; calculated scour is above top of footing.
7	Countermeasures have been installed to correct a previously existing problem with scour. Bridge is no longer scour critical.
6	Scour calculation/evaluation has not been made.
5	Bridge foundations determined to be stable for calculated scour conditions; scour within limits of footing or piles.
4	Bridge foundations determined to be stable for calculated scour conditions; field review indicates action is required to protect exposed foundations from effects of additional erosion and corrosion.
3	Bridge is scour critical; bridge foundations determined to be unstable for calculated scour conditions: - Scour within limits of footing or piles. - Scour below spread-footing base or pile tips.
2	Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations. Immediate action is required to provide scour countermeasures.
1	Bridge is scour critical; field review indicates that failure of piers/abutments is imminent. Bridge is closed to traffic.
0	Bridge is scour critical. Bridge has failed and is closed to traffic.

Table 3: Bridge Scour Critical Codes and Sensitivity Scoring

There is only one bridge for the entire state that is coded a “T” for scour critical and it is the bridge which connects Trumbo Point to Key West in Monroe County. Therefore, the code was not considered critical for consideration. Those bridges identified to have unknown conditions (codes U and 6) that have not been evaluated were not scored due to the lack of information. Over 1,400 bridges in the state of Florida have unknown conditions of which only one was associated with bridges under analysis for this project. Expanded bridge assessments should take note of these bridge structures since an evaluation is not available for them but they can be at risk. Finally, though a score is associated with codes 1 and 0, there are no bridges in the state with these codes. The most severe code to be found in Florida is a 2.

The results of the bridge sensitivity assessments are shown in the following figures**. Figure 2** shows the results of bridge conditions due to sufficiency rating while **Figure 3** shows the results due to scour critical ratings.

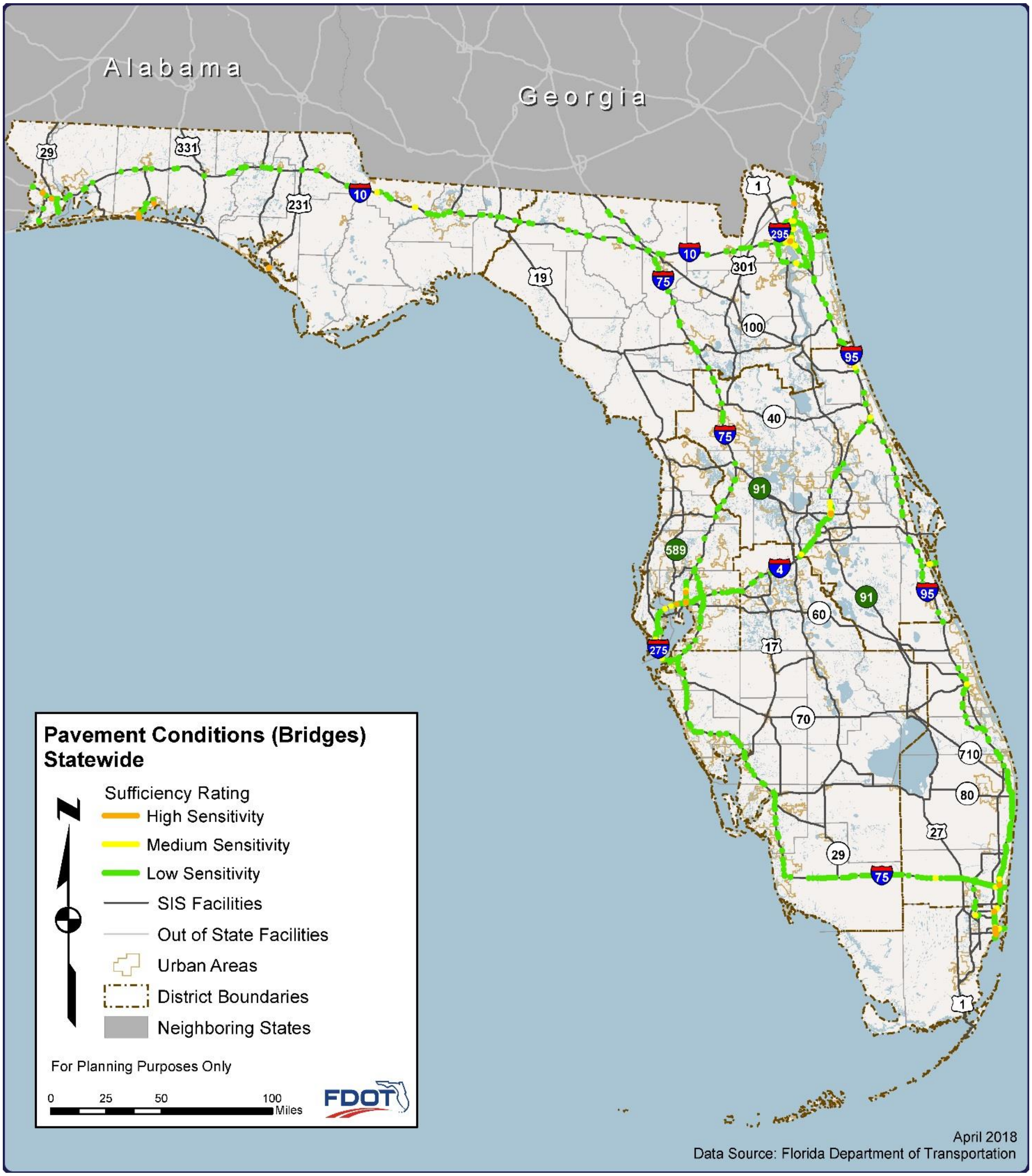

Figure 2: SIS Bridges Pavement Conditions Based on Sufficiency Ratings

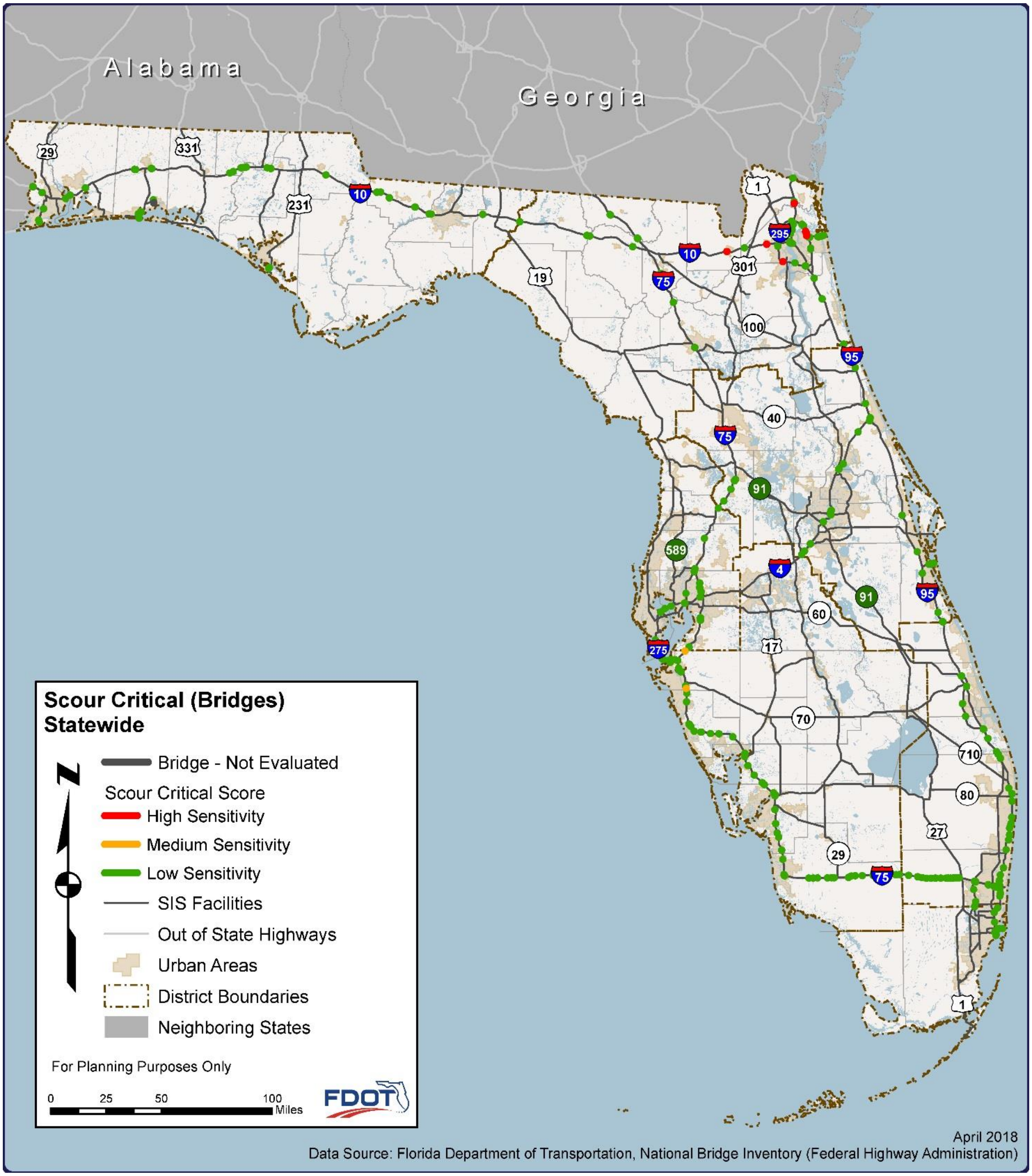

Figure 3: Scour Critical Conditions for SIS Bridges

Appendix C

Facilities Impacted by Sea Level Rise

1.0 Sea Level Rise: 1 Foot Projection Impacted Facilities

Name	County	From	To	Centerline	DVMT
SR 207	St. Johns	MAIN ST	SR 206	1.87	35,041
SR A1A/SR 200	Nassau	ALLIGATOR CREEK	GRIFFIN RD	5.59	48,068
I-95/SR 9	Duval	TALLULAH AVE	ZOO PKWY	1.37	147,698
I-95/SR 9	Volusia	BREVARD/VOLUSIA COUNTY LINE	OLD DIXIE HWY	13.94	926,852
I-95/SR 9	Volusia	GRANADA BLVD	US 1	1.71	86,135
I-95/SR 9	Volusia	N OF CANAL ST	TAYLOR RD	1.92	77,949
I-75/SR 93	Charlotte	DUNCAN RD	S OF HARBORVIEW RD	0.76	49,490
US 17/SR 35	Charlotte	WASHINGTON LOOP RD	WASHINGTON LOOP RD	0.51	5,457
I-75/SR 93	Charlotte	CHARLOTTE/LEE COUNTY LINE	CHARLOTTE/DESOTO COUNTY LINE	6.70	435,630
US 19/SR 55/SE US-19	Dixie	300TH ST	DIXIE/GILCHRIST COUNTY LINE	2.92	35,043
I-4/SR 400/SR 618 CONNECTOR	Hillsborough	E OF 39TH ST	11TH AVE	1.38	19,085
SR 60	Hillsborough	W JOHN F KENNEDY BLVD	S OF SR 60/COURTNEY CAMPBELL CSWY	0.52	73,170

Table 1: Facilities Impacted by 1 Foot Sea Level Rise Projections

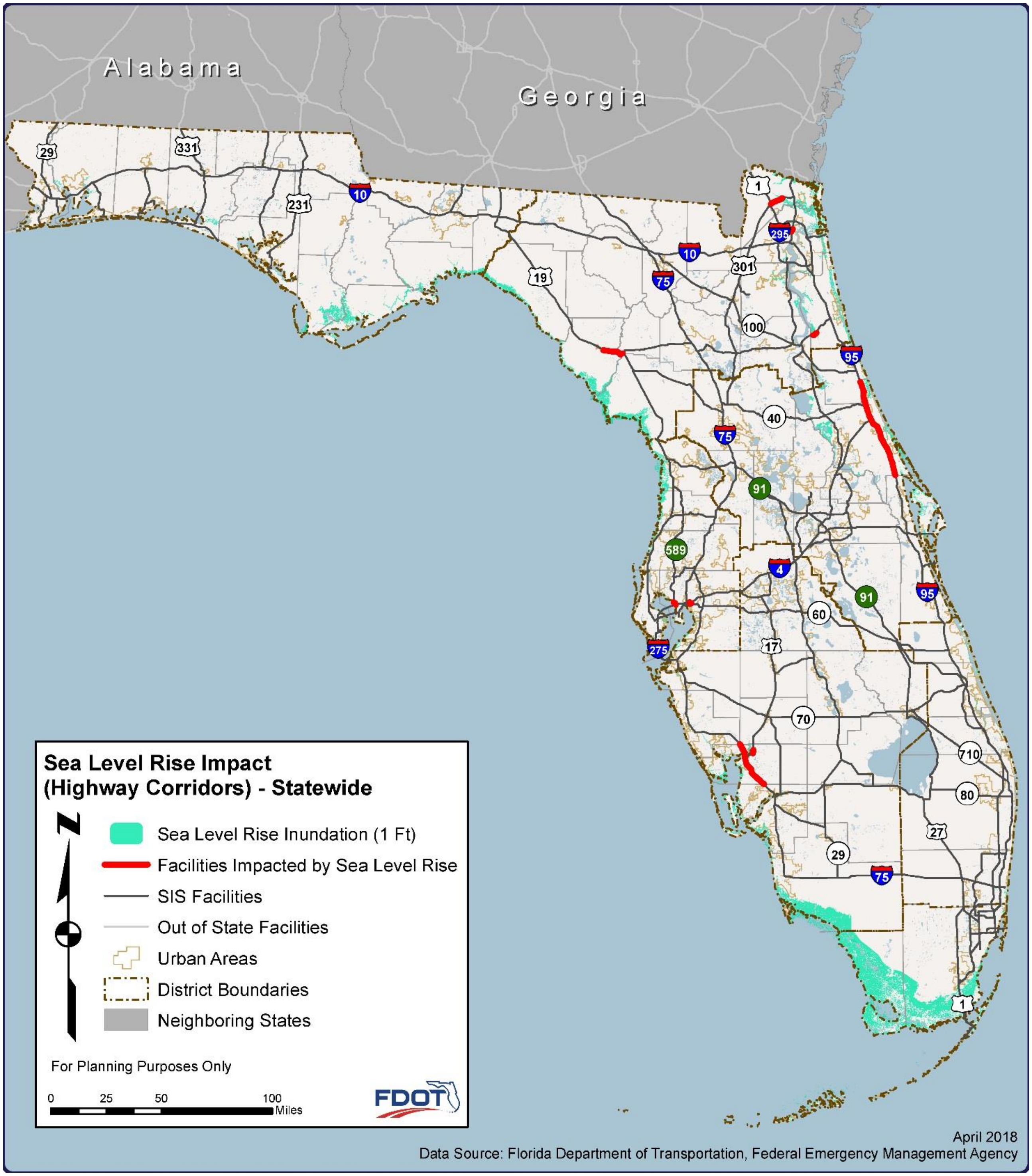

Figure 1: Facilities Impacted by 1 Foot Sea Level Rise Projections

2.0 Sea Level Rise: 2 Foot Projection Impacted Facilities

Name	County	From	To	Centerline	DVMT
I-275/SR 93/I-275	Manatee	SR-55	E OF BISHOP HARBOR RD	2.07	83,697
I-275/SR 93/I-275	Manatee	E OF SR-55	E OF 36TH AVE E	3.76	191,793
I-75/SR-93	Sarasota	UNIVERSITY PARKWAY	N OF KINGS HWY	42.62	5,668,557
I-275/SR 55/SKYWAY BRG	Pinellas	S OF PINELLAS POINT DR S	SUNSHINE SKWY BRG	4.30	254,313
I-275/SR 93/I-275	Pinellas	ROOSEVELT BLVD N	ULMERTON RD	1.31	130,890
I-275/SR 55/I-275	Pinellas	W OF 58TH AVE S	SUNSHINE SKYWAY LN S	0.99	58,425
US 92/SR 600/GANDY BLVD	Pinellas	4TH ST N	2ND ST N	0.12	6,424
I-275/SR-93	Pinellas	W OF SR 60	S OF 39TH AVE S	18.58	3,204,975
I-275/SR-93	Pinellas	S OF 39TH AVE S	SUNSHINE SKYWAY LN S	10.38	614,361
SR 589/SR-589	Hillsborough	N OF SR 60	S OF SR 60	0.38	10,083
SR 694/GANDY BLVD	Pinellas	W OF SR 689	E OF SR 689	0.02	1,383
I-4/SR 400/I-4/SR 618 CONNECTOR	Hillsborough	S OF I-4	E OF 34TH ST	1.38	70,278
SR 694/GANDY BLVD	Pinellas	E OF SR 689	W OF ROOSEVELT BLVD N	0.37	11,759
SR 694/GANDY BLVD	Pinellas	W OF SR 689	E OF SR 689	0.10	5,640
SR 60/SR-60	Hillsborough	S OF SR 60	W OF GEORGE J BEAN PKWY	0.44	62,480
MEMORIAL HIGHWAY	Hillsborough	N OF SR 60	S OF SR 60	0.93	24,518
MEMORIAL HIGHWAY	Hillsborough	S OF SR 60	W JOHN F KENNEDY BLVD	1.70	240,167
US 92/SR 600/W GANDY BLVD	Hillsborough	W OF CULBREATH KEY WAY	S WEST SHORE BLVD	0.79	28,354
SR 589/SR-589	Hillsborough	S OF SR 60	S OF SR 60	0.07	1,859
SR 694/GANDY BLVD	Pinellas	W OF ROOSEVELT BLVD N	4TH ST N	0.17	5,260
SR 116/MCCORMICK RD	Duval	W OF HOLLY OAKS LAKE RD E	MONUMENT RD	1.73	43,195
SR 207/SR-207	St Johns	MERRYFIELD LN	MAIN ST	1.01	15,548
SR 116/FT CAROLINE RD	Duval	W OF MILLCOE RD	W OF HOLLY OAKS LAKE RD E	0.87	21,742

Name	County	From	To	Centerline	DVMT
SR 207/SR-207	St Johns	MAIN ST	SR 206	1.87	35,041
SR A1A/SR-200	Nassau	W OF PETREE RD	GRIFFIN RD	5.59	48,068
I-95/SR 9/I-95	Duval	ZOO PKWY	SR 111	1.37	147,698
I-4/SR 400/I-4	Volusia	US-17-92	S OF DIRKSEN DR	3.24	356,290
I-195/SR 112/JULIA TUTTLE CSWY	Miami-Dade	W OF N BAY RD	ALTON RD	0.12	13,364
I-95	Volusia	OLD DIXIE HWY	N OF STUCKAWAY RD	45.81	3,893,570
I-4	Volusia	US-17-92	W OF ANDROS ISLES BLVD	28.08	3,089,033
I-95/SR 9/I-95	Volusia	US-1	SR-40	5.61	283,166
I-95/SR 9/I-95	Volusia	TAYLOR RD	N OF SR-44	6.30	256,193
SR-836	Miami-Dade	N OF W FLAGLER	W OF MACARTHUR CSWY	13.38	2,628,882
SR 836/DOLPHIN EXPRESSWAY	Miami-Dade	SR-826	W OF SR-969	0.26	50,258
I-195/SR-112	Miami-Dade	NW 11TH AVE	ALTON RD	4.90	700,650
I-75/SR 93/I-75	Charlotte	S OF HARBOR VIEW RD	SR-35	2.50	162,723
SR 80/PALM BEACH BLVD	Lee	JOEL BLVD	W OF TOWNSEND CANAL RD	2.13	33,411
US 17/SR 35/US-17	Charlotte	WASHINGTON LOOP RD	WASHINGTON LOOP RD	1.68	17,943
I-75	Charlotte	E HILLSBOROUGH BLVD	N OF SLATER RD	22.01	1,430,742
US 19/SR 55/SE US-19	Dixie	SE 55A HWY	W OF KENTUCKY AVE	9.57	114,821

Table 2: Facilities Impacted by 2 Foot Sea Level Rise Projection

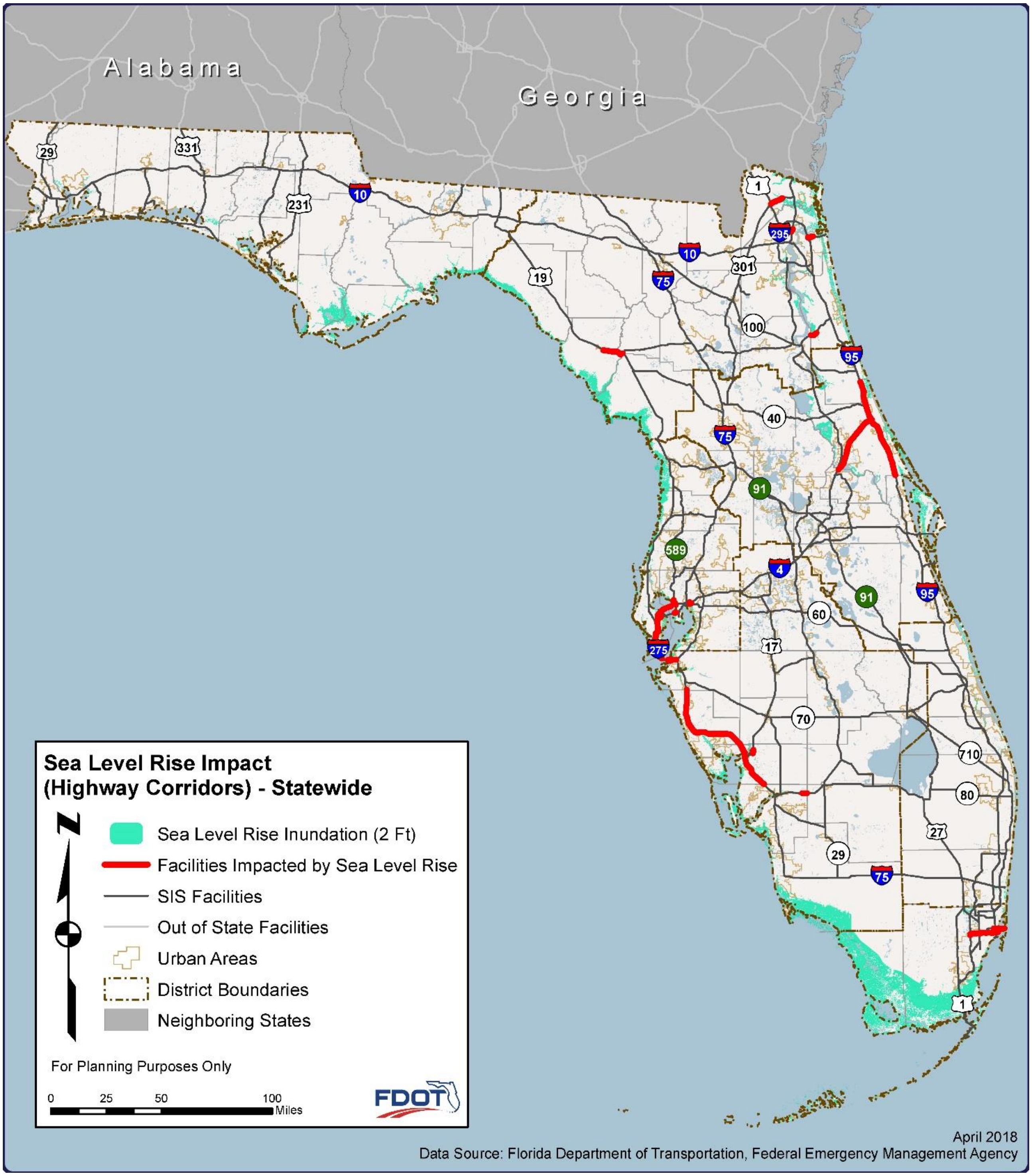

Figure 2: Facilities Impacted by 2 Foot Sea Level Rise Projections