

TO: North Florida TPO  
FROM: RS&H Team  
DATE: August 9, 2019  
RE: Task 1: **Identify Needs**  
Resiliency & Vulnerability Assessment Phase II

## 1 INTRODUCTION

### 1.1 OBJECTIVE

This report is part of a series of deliverables associated with *Phase II* of the **Resiliency & Vulnerability Assessment**, as a precursor evaluation for the update of the North Florida TPO 2045 Long-Range Transportation Plan (LRTP) update. *Resilient infrastructure* has been adopted as a Long-Range Transportation Plan objective for the region.

This study follows the FHWA Vulnerability Assessment and Adaptation Framework as shown and modified in **Exhibit A**:

- The previous *Phase I*, identified objectives, refined scope, and reviewed key climate variables and available data.
- *Phase II* provides a methodology to assess risk, identify vulnerabilities and provide a toolbox of potential solutions.

This memorandum identifies vulnerable roadways based on event likelihood, magnitude of consequence, and asset adaptive capacity. Using available environmental and asset data, a list of affected segments and their calculated relative vulnerability is presented for each county within the North Florida TPO area.

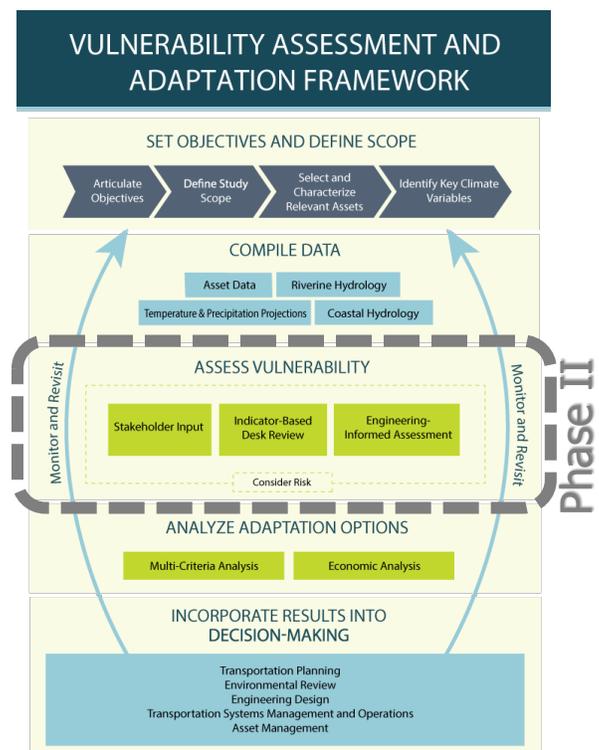


Exhibit A: FHWA Vulnerability Assessment and Adaptation Framework, 3<sup>rd</sup> Edition

## 1.2 STUDY AREA

The area of study comprises the North Florida TPO service boundary. This region includes the Florida counties of Clay County, Duval County, Nassau County and St Johns County.

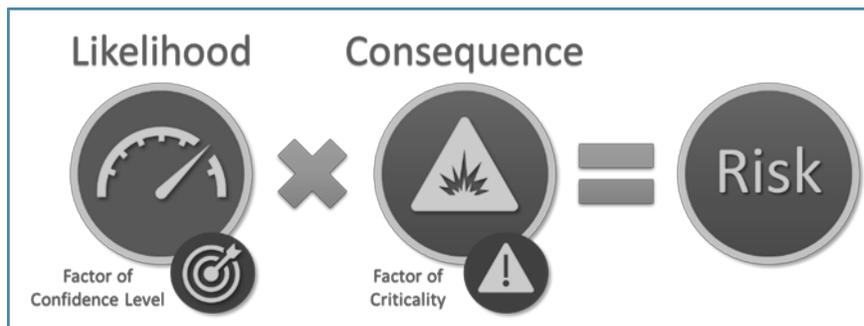
The area is characterized by proximity to the Atlantic Ocean as well as the St Johns River, Florida's primary commercial and recreational waterway. The study area encompasses over 3,000 square miles and a population of nearly 1.4 million. The area is served by multiple interstates (I-95, I-10, I-295), expressways (First Coast Expressway), and numerous national, state, and local roads. The focus of this study, however, relies on I-10, I-95, I-295, U.S. routes, and state routes due to their significance and scale of available data.

## 2 ASSESS VULNERABILITY

The first step to climate change adaptation is to identify vulnerabilities to climate change impacts. Physical assets such as roads, bridges and facilities may be vulnerable to damage or failure as a result of flooding or other impacts. Similarly, operations may also be disrupted by such events. Identifying vulnerabilities requires first conducting a **risk assessment** by evaluating the likelihood and consequence of assets being affected by expected climate impacts. Then, vulnerability can be assessed by looking at the system's ability to adapt to the identified risks.

### 2.1 ASSESSING RISK

**Risk** is defined as the assessed potential for adverse effects to assets or operations resulting from a specific climate impact. It is calculated by multiplying the likelihood of a given climate stressor impacting an asset or aspect of operations by the consequence to the asset if it occurs. The formula for calculating risk is shown in **Figure 1**.



**Figure 1: Formula for Calculating Risk**

**Likelihood** is the degree of certainty that an asset or operation will be affected by a climate stressor. For example, if a coastal highway is susceptible to flooding from storm surge from a Category 3 hurricane, and the probability of a Category 3 storm occurring within the study

period is high, it is likely that the highway could be affected. Table 1 and Table 2 shows the scale used to estimate likelihood and confidence level, respectively.

Likelihood and exposure were measured using category 3 (Saffir-Simpson Hurricane Wind Scale) storm surge inundation maps. Storm surge impact data was collected from the UF GeoPlan Sea Level Scenario Sketch Planning Tool transportation infrastructure layers (2017), based on Florida Department of Emergency Management (FDEM) storm surge data and available for the entire service area. This dataset provided indicated whether a segment would be impacted by a hypothetical storm surge 3 scenario, and the extent of the impact. Due to the return frequency of hurricanes in our area of the data, this Climate projection has a moderately high degree of certainty with an assigned likelihood of “As likely as not” within the next 20 years.

Highlighted in **Table 1** is the Likelihood identified for a Category 3 storm within the next 20 years, as the probability of recurrence of such event is 30 years.

Scale Factor	Likelihood	Definition
5	Very Likely	=>90% probability of occurrence
4	Likely	>=66% probability of occurrence
3	As likely as not	=50% probability of occurrence
2	Unlikely	<=33% probability of occurrence
1	Very Unlikely	<0.1% probability of occurrence

**Table 1: Likelihood Scale**

The likelihood is weighted by the confidence level assigned to the climate projection. Because future climate impacts are predicted through modeling, a wide range of confidence levels in these predictions exist. While some impacts such as sea level rise are predicted with high confidence, others, such as an increase in extreme precipitation events, are assigned lower confidence levels. **Table 2** shows the scale used to assign confidence level to climate projections. The highlighted confidence level was selected based on NOAA modeling capabilities.

Scale Factor	Confidence Level	Definition
1	High	Climate projection has a high degree of certainty
0.66	Medium	Climate projection has a moderate degree of certainty
0.33	Low	Climate projection has a low, or unknown, degree of certainty

**Table 2: Confidence Level Scale**

**Consequence** is defined as the result or effect of the climate stressor’s impact on an asset or operation. Consequence can be thought of as the degree of damage or disruption that would occur due to an acute or chronic impact. **Table 3** shows the scale used to assign consequence. Total centerline miles impacted by storm surge along route was used as the measurement variable using a “weakest-link” segment analysis.

Scale Factor	Likelihood	Definition
1	Negligible	No impacts along segment
2	Minor	Less than 500 ft of impact
3	Moderate	Close to half mile of impact
4	Major	Under a mile of impact
5	Severe	Miles of impact

**Table 3: Consequence Scale**

Consequence is weighted by a **criticality factor** to assign higher importance to more critical assets. Critical assets are those whose damage or failure would lead to a significant disruption of the transportation system at the most vulnerable times.

**Table 4** shows the scale used to assign criticality to assets. Segments that belong to an evacuation route are considered highly critical.

Scale Factor	Criticality	Definition
1	High	Evacuation routes.
0.66	Medium	Urban streets not part of an evacuation route.
0.33	Low	Rural roads not part of an evacuation route.

**Table 4: Criticality Scale**

The risk calculation is the product of likelihood weighted by confidence level and consequence weighted by criticality. More likely climate impacts, higher climate projection confidence levels, more significant consequences, and more critical assets result in higher risk scores. Conversely, less likely climate impacts, lower confidence in climate projections, less significant consequences, and less critical assets result in lower risk scores. Due to the uncertainty of a category 3 storm surge, risk measurements are attenuated for all assets at this stage.

Once assets’ risk scores have been calculated, they can be ranked and prioritized using a risk assessment matrix as shown in **Figure 2**. The matrix shows that risk increases as likelihood (weighted by confidence level) and consequence (weighted by criticality) increase.

WEIGHTED CONSEQUENCES					
WEIGHTED LIKELIHOOD	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Very Unlikely (1)	LOW (1)	LOW (2)	LOW (3)	LOW (4)	LOW (5)
Unlikely (2)	LOW (2)	LOW (4)	MODERATE (6)	MODERATE (8)	MODERATE (10)
As likely as not(3)	LOW (3)	MODERATE (6)	MODERATE (9)	HIGH (12)	HIGH (15)
Likely (4)	LOW (4)	MODERATE (8)	HIGH (12)	HIGH (16)	EXTREME (20)
Very Likely (5)	LOW (5)	MODERATE (10)	HIGH (15)	EXTREME (20)	EXTREME (25)

Figure 2: Risk Assessment Matrix

## 2.2 IDENTIFYING VULNERABILITIES

Vulnerability is defined as the degree to which assets or operations are susceptible to and unable to cope with adverse effects of climate change based on the existing condition of the asset/operation. Once the level of risk has been established for each asset and climate stressor, vulnerability is calculated as the product of risk and adaptative capacity.

Figure 3 shows the formula for calculating vulnerability.

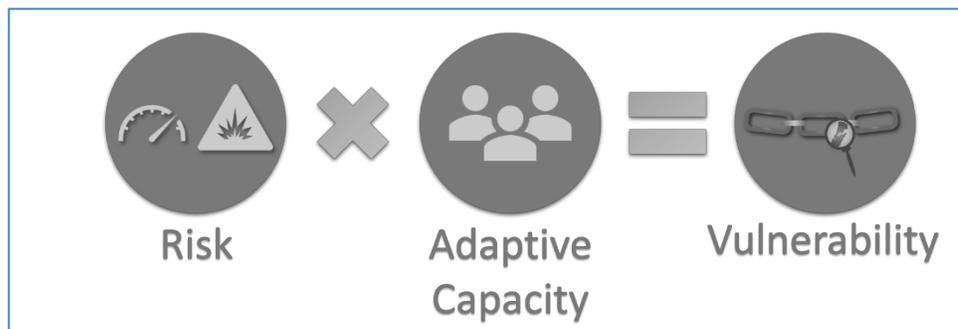


Figure 3: Formula for calculating vulnerability

Adaptive capacity is the ability of the transportation system to cope with the consequences of climate impacts. For example, redundancies in the system in the form of alternate routes indicate higher adaptive capacity because traffic could be redirected if a critical roadway is closed due to flooding. Greater adaptive capacity results in a lower vulnerability score because it shows that the system is better prepared to respond to climate impacts.

**Table 5** shows the definitions used to assign adaptive capacity scores to assets. Detour length, as measured by the National Bridge Inventory was used to assign the worst-case detour scenario to a segment. The overall assumption is that detours of less than a mile are not as impactful as those of greater than a mile, given that in most freeway interchanges are spaced between 1-3 miles. Detours greater than 6 miles are assigned low adaptive capacity.

Scale Factor	Adaptive Capacity	Definition
1	High	Little detour impact due to bridge impairment, less than a mile
0.66	Medium	Up to 6-mi detour along route
0.33	Low	Impact may require detours longer than 6 miles

**Table 5: Adaptive Capacity Scale**

*Just as with risk, assets can be ranked by vulnerability using a matrix to facilitate decision-making about adaptation options.*

**Figure 4** shows a vulnerability matrix, where higher levels of adaptive capacity result in lower vulnerability. In the case of transportation assets such as bridges and roadways, they can also be mapped to show the level of risk at different locations. A color-coding scheme is used to display the level of vulnerability determined for each asset. It should be noted that due to the moderate likelihood of the evaluated storm surge conditions (i.e. storm surge of a Category 3

hurricane), no assets can reach “High” vulnerability scoring. The maximum attainable score under this scenario is a 45.

**Figure 4: Vulnerability Matrix**

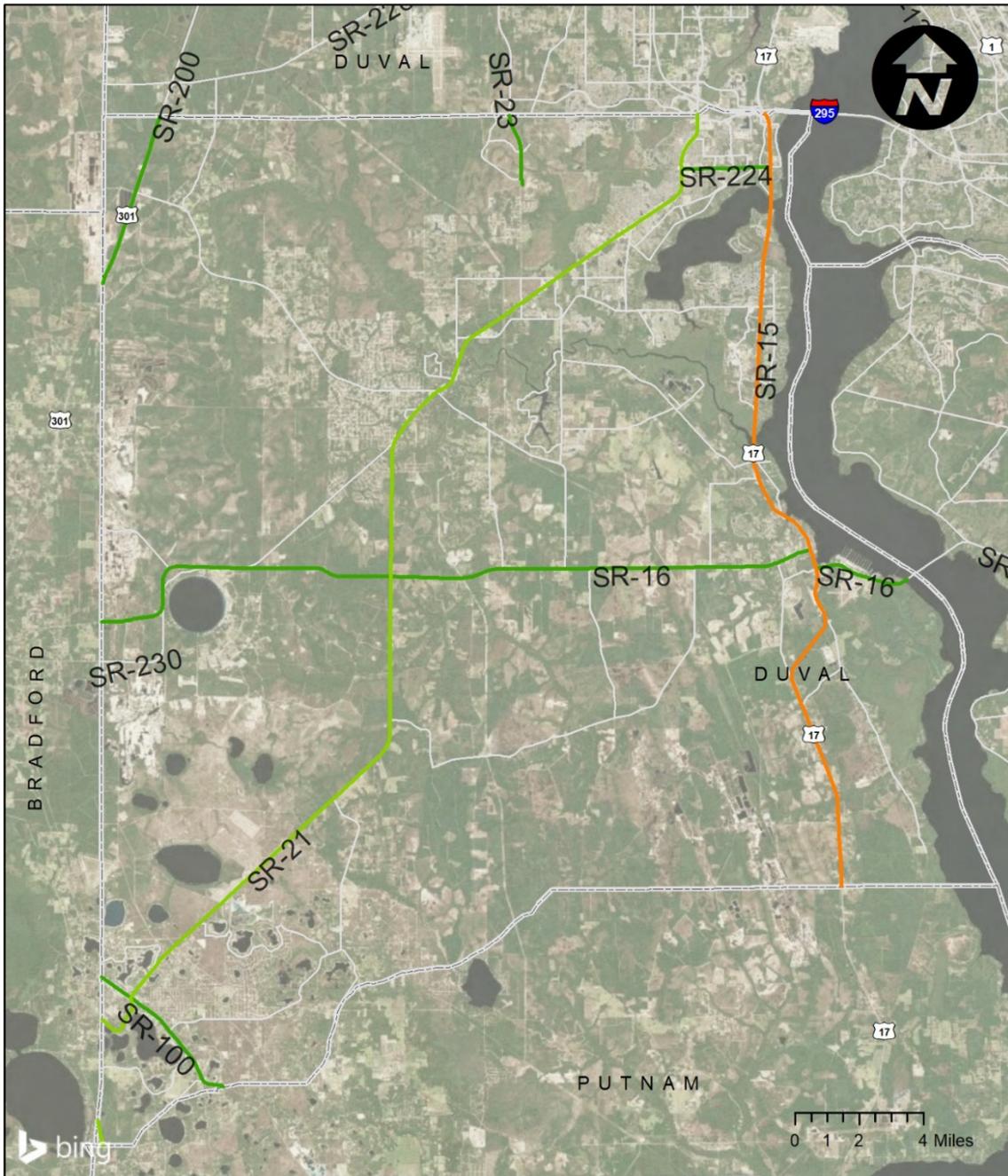
### 2.3 RESULTS

The following subsections show the spatial and tabular values for each county.

#### 2.3.1 Clay County

	ADAPTIVE CAPACITY		
RISK	High (1)	Medium (2)	Low (3)
Low (5)	LOW (5)	LOW (10)	LOW (15)
Moderate (10)	LOW (10)	MODERATE (20)	MODERATE (30)
High (15)	LOW (15)	MODERATE (30)	MODERATE (45)
Extreme (20)	MODERATE (20)	MODERATE (40)	HIGH (60)
Extreme (25)	MODERATE (25)	HIGH (50)	HIGH (75)

**Figure 5: Clay County  
Vulnerability Score**



**Legend**

2.3.1 Duval County  
RCI Road Network

**Maximum Vulnerability**

- 0-15 (Low)
- 16-29 (Moderate-Low)
- 30-39 (Moderate)
- 40 - 49 (Moderate-High)
- 50-75 (High)







### 2.3.5 Vulnerability Index

The following tables summarized the most critical vulnerability index value associated with a facility/roadway. Duplication will occur on state routes and U.S. routes that share segments in common. Roadway data includes major existing facilities at the time of UF Geoplan analysis or most recent available information (2017 or earlier).

#### **Vulnerability Index by Segment/County (1 Low – 75 Highest)**

INTERSTATES	CLAY	DUVAL	NASSAU	ST JOHNS
I-10	-	6	6	-
I-295	-	30	-	-
I-95	-	45	45	27

STATE ROUTES	CLAY	DUVAL	NASSAU	ST JOHNS
SR-9B	-	2	-	-
SR-10	-	30	6	-
SR-100	3	-	-	-
SR-102	-	4	-	-
SR-103	-	12	-	-
SR-104	-	24	-	-
SR-105	-	30	-	-
SR-109	-	18	-	-
SR-111	-	18	-	-
ST-115	-	30	18	-
SR-116	-	45	-	-
SR-13	-	24	-	-
SR-152	-	8	-	-
SR-16	15	-	-	45
SR-200	-	6	45	-
SR-202	-	30	-	-
SR-206	-	-	-	45
SR-207	-	-	-	45
SR-21	27	27	-	-
SR-212	-	45	-	-
SR-224	2	-	-	-
SR-228	-	9	-	-
SR-230	1	-	-	-
SR-312	-	-	-	30
SR-23*	6	4	-	-
IPG	N/A			

\*Note: Assessment precedes First Coast Expressway infrastructure

US ROUTES	CLAY	DUVAL	NASSAU	ST JOHNS
A1A	-	45	45	45
US-1	-	45	30	30
US-17	45	30	18	-
US-23	-	45	-	-
US-301	9	6	-	9
US-90	-	45	-	-

### 3 CONCLUSIONS

The North Florida region is characterized by a multimodal, multi-asset network that can be subject to coastal flooding, riverine flooding, and stormwater issues. Different transportation elements may require different types of adaptation strategies to increase resilience. A high-level vulnerability assessment may consider different stressors and the likelihood of their occurrence. Employing storm surge for a Category 3 storm and understanding that there may be some likelihood of these conditions occurring within the next 20 years, this report identified roadways that may require additional attention, including hardening. Considering several impacts, such as the importance of the route (evacuation routes), urban environments and network resilience (detour length), the overall system vulnerability is moderate.

Among major thoroughfares and state routes, the following segments are highlighted:

- In Clay County, US-17 stands out as a segment of moderate-high vulnerability.
- In Duval County, I-95, A1A, SR-212 (Beach Blvd) and SR-116, have been identified as the segments of moderate-high vulnerability.
- In Nassau County, A1A and I-95 have been identified as moderate-high vulnerability roadways.
- In St Johns County, A1A, SR-206 and SR-207 stand out as moderate-high vulnerability roadways.

If successfully planned and implemented, adaptation strategies can potentially reduce future economic, environmental and social costs associated with flooding risks. Task 2: **Develop Strategies**, the second technical memorandum identifies scenarios and appropriate strategies to consider.

**References:**

Florida Adaptation Planning Guidebook. FDEP, 2018.

Hillsborough County MPO: Vulnerability Assessment and Adaptation Pilot Project, Cambridge Systematics, 2014. [http://www.planhillsborough.org/wp-content/uploads/2013/10/NoAppendix\\_Hillsborough-MPO\\_FHWA-Pilot-Final-Report1.pdf](http://www.planhillsborough.org/wp-content/uploads/2013/10/NoAppendix_Hillsborough-MPO_FHWA-Pilot-Final-Report1.pdf)

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[https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing and current research/gulf coast study/phase2 task3/task 3.2/page04.cfm#Toc395171917](https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/gulf_coast_study/phase2_task3/task_3.2/page04.cfm#Toc395171917)

National Bridge Inventory in Florida, FLGDL, June 2017.  
<http://www.fgdl.org/metadataexplorer/explorer.jsp>

Sea Level Scenario Sketch Planning Tool, University of Florida GeoPlan Center, 2017.

Transportation Infrastructure Layers (SLS), University of Florida Geoplan Center, 2017.

Vulnerability Assessment and Adaptation Framework, 3<sup>rd</sup> Edition, Federal Highway Administration Office of Planning, Environment, & Realty, 2017.  
[https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation framework/](https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/)

# RS&H Memorandum

TO: North Florida TPO

FROM: RS&H Team

DATE: January 2, 2019

RE: Task 1: **Stormwater Infrastructure Systems**  
NFTPO - Resiliency & Vulnerability Assessment (5.22)

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This memorandum describes the methodology for mapping potentially vulnerable stormwater infrastructure in North Florida. The methodology section describes the identified areas as well as data availability. The Maps section shows areas that may benefit from stormwater management projects, including the construction, installation or improvement of culverts, drain pipes, pumping stations, flood protection and stabilization measures for roads and bridges, floodgates and detention or retention basins. As other hazards and regional risks assessment are continually updated, this information can be used to further refine the current state of transportation resiliency planning for the North Florida region.

## Methodology

### Surface Network

The surface network is composed of North Florida roads on the FDOT RCI dataset (Roadway Characteristics Inventory) and the network model features for the future First Coast Expressway (for reference only). The RCI classification includes all segments with a functional classification of arterial or collector, as well as a few local roads that meet the RCI criteria:

- Construction/reconstruction records in the Department's Financial Management (FM) System
- Roadways with bridges or railroad crossings
- On or proposed for the NHS
- On or proposed for the Florida Freight System or
- On or proposed for the Strategic Intermodal System (SIS) or SIS connector

The dataset used available roadway segments characteristics on the RCI and the *USACE Intermediate Rate for 2013 Sea Level Rise curve (C2MHHW40FT)* and the *100-year floodplain (DFIM100FT)* from *Federal Emergency Management Agency (FEMA) Digital Flood Rate Insurance Maps*. As the RCI was not intended to provide a geospatial survey of all roadway features, a limited number of attributes can be explored, and caution should be exercised understanding the general location of segments.

The following RCI characteristics were identified as proxies for areas already under stormwater system strain or subject to future consideration:

- Facilities with no reported curb or gutter/drainage
- Two-lane highways or one-lane facilities (as reported by RCI) and
- Facilities with a poor or very poor pavement condition

Additional considerations were made for the following events:

- Facilities crippled by a 100-year flood; as defined as 50% or more of the roadway centerline impacted and
- Facilities with segments impacted by sea level rise; as those with centerline segments of 1 ft or more impacted by 2050

A raster stormwater impact density layer was created using ArcMap Spatial Analyst (Figure 1). The raster considers the presence of the five (5) listed characteristics above, with sea level rise segments receiving double their weight. Segments that met most of the previous criteria for areas of concern are shaded darker than those with limited or none. The squared pattern is associated with the analysis and is not intended to represent a buffer. The produced raster can be utilized to further refine and study areas of interest.

Overall, areas were classified in three (3) categories of *Stormwater Flood Risk*:

- Low concern (low) – areas that do not appear to have segment-level stormwater issues. Location-based issues may not be discernable through this screening tool.
- Some attention (med) – areas with some indication of stormwater system impacts as the recurrence of flooding events increases. These segments met two or less areas of concern and are not within a flooding event, for example, facilities with poor pavement condition. These segments are lightly shaded in Figure 1.
- Consideration (high) – areas that should be reviewed for existing or future stormwater management needs due to increased probability of flooding events that may exceed design criteria. These segments include areas with poor pavement condition or lack of drainage that overlap nearby flooding or sea level rise events and have been identified in Table 1.

For an initial test evaluation, it was determined that facilities that exhibited at least one type of flooding event or an equivalent of three (3) RCI characteristics would be classified under Consideration (high) and therefore represent a potentially high level of storm impact and/or flood risk.

## Evaluation

All counties appear to be similarly affected in their stormwater infrastructure. As expected, areas near the coast and the St Johns River are more likely to receive impacts. Across the region, roadways near the coast, the Intracoastal Waterway and the St. Johns River appear more susceptible to impacts. Areas of concern include Kingsley Lake Drive in Clay County; Heckscher Drive (SR-105) in Duval County, SR-13 and SR A1A in St. Johns County, and SR-200 in Nassau County, as well as parts of major interstates (I-95, I-295, and I-10). While all counties appear to present areas of some concern, most are concentrated near the Jacksonville Beaches, St. Augustine and Fernandina Beach. See Table 1 and Figure 1 for locations and segments within the North Florida TPO region.

**Table 1: Segments for Stormwater Risk Consideration**

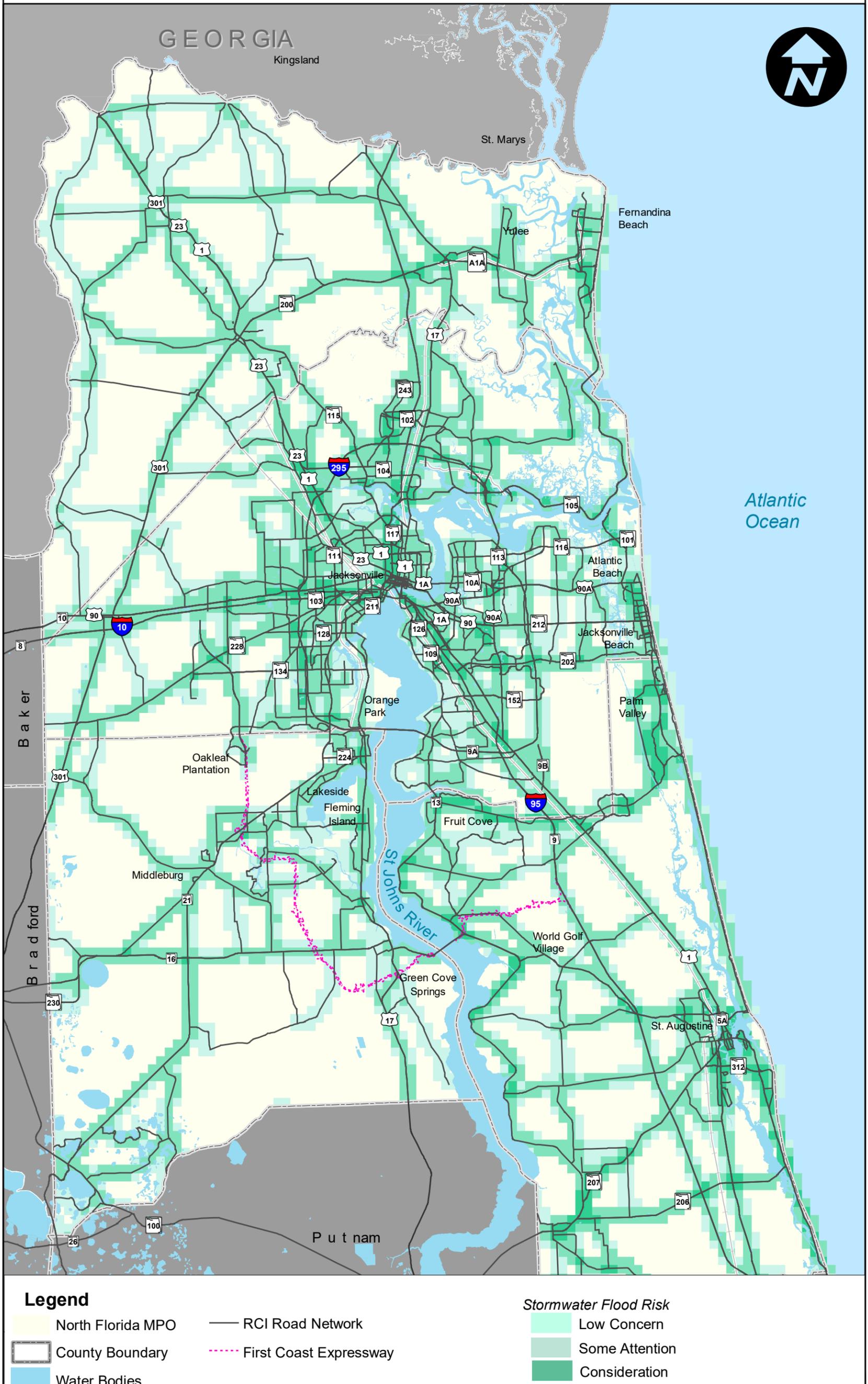
<i>Name</i>	<i>Functional Class</i>	<i>Begin Segment</i>	<i>End Segment</i>	<i>Evacuation Route</i>	<i>Federal Aid</i>
<b>Clay County</b>					
Parkwood Dr	Urban: Major Collector	0	2.579	No	Surface Transportation Program (STP)
Kingsley Lake Dr	Rural: Minor Collector	0	1.508	No	
<b>Duval County</b>					
I-10	Rural: Principal Arterial / Interstate	0	21.441	Yes	National Highway System (NHS)
Chaffee Rd	Urban: Major Collector	0	1.266	No	Surface Transportation Program (STP)
Mother Hubbard Dr S	Urban: Major Collector	0	1.324	No	Surface Transportation Program (STP)
Jones Rd	Urban: Major Collector	0	11.392	No	Surface Transportation Program (STP)
12th Ave S	Urban: Major Collector	0	2.825	No	Surface Transportation Program (STP)
4th Ave N	Urban: Major Collector	0	0.943	No	Surface Transportation Program (STP)
Hogan Rd	Urban: Major Collector	0	0.723	No	Surface Transportation Program (STP)
Spring Park Rd	Urban: Major Collector	0	2.196	No	Surface Transportation Program (STP)
Seagate Ave	Urban: Major Collector	0	0.66	No	Surface Transportation Program (STP)

<b>Name</b>	<b>Functional Class</b>	<b>Begin Segment</b>	<b>End Segment</b>	<b>Evacuation Route</b>	<b>Federal Aid</b>
Broad St	Urban: Minor Arterial	0	2.437	No	Surface Transportation Program (STP)
Chaffee Rd	Urban: Minor Arterial	0	3.22	No	Surface Transportation Program (STP)
Dunn Ave	Urban: Minor Arterial	0	7.567	Yes	Surface Transportation Program (STP)
Zoo Pkwy	Urban: Minor Arterial	0	15.061	Yes	Surface Transportation Program (STP)
Beaver St W	Urban: Minor Arterial	0	21.802	Yes	Surface Transportation Program (STP)
Brentwood Ave	Urban: Minor Arterial	0.686	13.587	Yes	Surface Transportation Program (STP)
Riverside Ave	Urban: Minor Arterial	6.787	7.428	Yes	Surface Transportation Program (STP)
AC Skinner Pkwy	Urban: Minor Collector (Fed Aid)	0	3.898	No	Surface Transportation Program (STP)
Southside Blvd	Urban: Principal Arterial - Freeway And Expressway	0	15.968	Yes	National Highway System (NHS)
J T Butler Blvd	Urban: Principal Arterial - Freeway And Expressway	0	13.022	Yes	National Highway System (NHS)
Atlantic Blvd	Urban: Principal Arterial - Other	0	19.84	Yes	National Highway System (NHS)
Philips Hwy	Urban: Principal Arterial - Other	0	17.294	Yes	National Highway System (NHS)
State St	Urban: Principal Arterial - Other	0	15.154	Yes	National Highway System (NHS)
Highway Ave	Urban: Local	0	2.685	No	
Trout River Blvd	Urban: Local	0	1.052	No	
W Forsyth St	Urban: Local	0	1.457	Yes	
<b>Nassau County</b>					
I-95	Rural: Principal Arterial / Interstate	0	12.226	Yes	National Highway System (NHS)
US-17	Rural: Principal Arterial - Other	0	13.375	Yes	National Highway System (NHS)

<b>Name</b>	<b>Functional Class</b>	<b>Begin Segment</b>	<b>End Segment</b>	<b>Evacuation Route</b>	<b>Federal Aid</b>
Amelia Rd	Urban: Local	2.196	3.726	Yes	Surface Transportation Program (STP)
Pages Dairy Rd	Urban: Major Collector	0.348	4.914	Yes	Surface Transportation Program (STP)
<b>St Johns County</b>					
CR 13	Rural: Major Collector	0	5.398	Yes	Surface Transportation Program (STP)
Nocatee Pkwy	Rural: Major Collector	0	8.22	Yes	Surface Transportation Program (STP)
CR-214	Rural: Minor Collector	0	14.968	No	
CR 204	Rural: Minor Collector	0	5.597	Yes	
SR-207	Rural: Principal Arterial - Other	0	17.762	Yes	National Highway System (NHS)
US-1	Rural: Principal Arterial - Other	0	18.692	Yes	National Highway System (NHS)
Race Track Rd	Urban: Major Collector	0	9.175	No	Surface Transportation Program (STP)
St George St	Urban: Major Collector	0	0.674	No	Surface Transportation Program (STP)
SR-A1A	Urban: Minor Arterial	0	7.151	Yes	Surface Transportation Program (STP)
May St	Urban: Minor Arterial	0	0.803	Yes	Surface Transportation Program (STP)
SR-312	Urban: Minor Arterial	0	2.827	Yes	Surface Transportation Program (STP)
SR-16	Urban: Principal Arterial - Other	0	2.305	Yes	National Highway System (NHS)

In conclusion, the roadway segments contained in Table 1 represent a *first pass* at evaluating regional facilities that could be considered for future evaluation due to the likely increased probability for flooding in some storm events, and possible exceedance of design criteria. In subsequent study tasks, a more deliberative evaluation of these and potentially other at-risk facilities will be evaluated as part of the 2045 LRTP process.

Figure 1: Stormwater Risk Consideration



Notes: Assumes existing conditions; data unavailable for planned FCX. See narrative for assumptions and limitations.  
 Sources: UF GeoPlan Center, Florida Division of Emergency Management, North Florida TPO, FDOT TDA.