Memorandum

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.

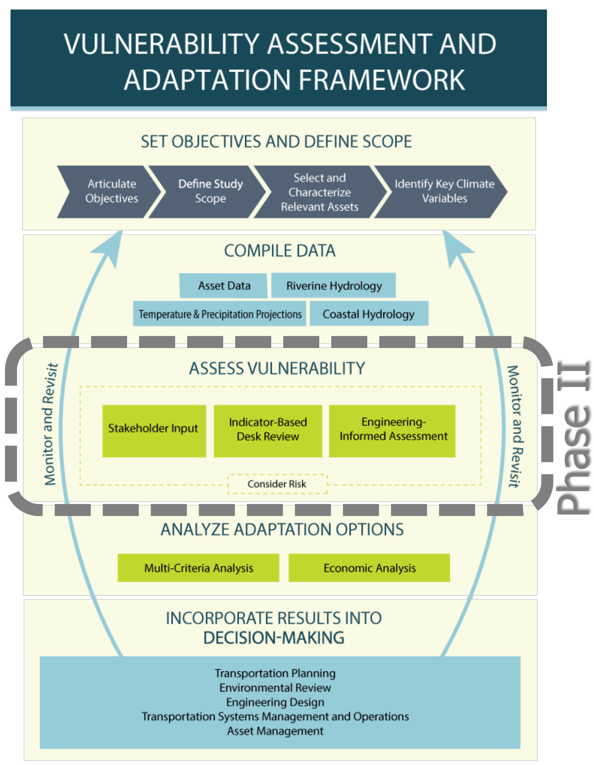


Exhibit A: FHWA Vulnerability Assessment and Adaptation Framework, 3rd Edition

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 my 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**.

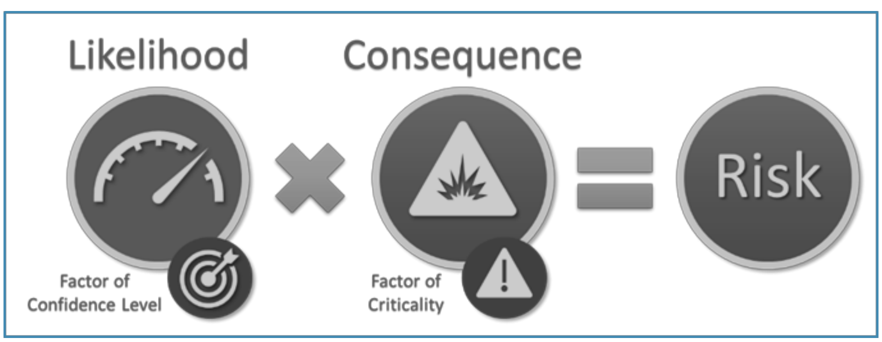


Figure 1: Formula for Calculating Risk

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 LIKELIHOOD	WEIGHTED CONSEQUENCES				
	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.

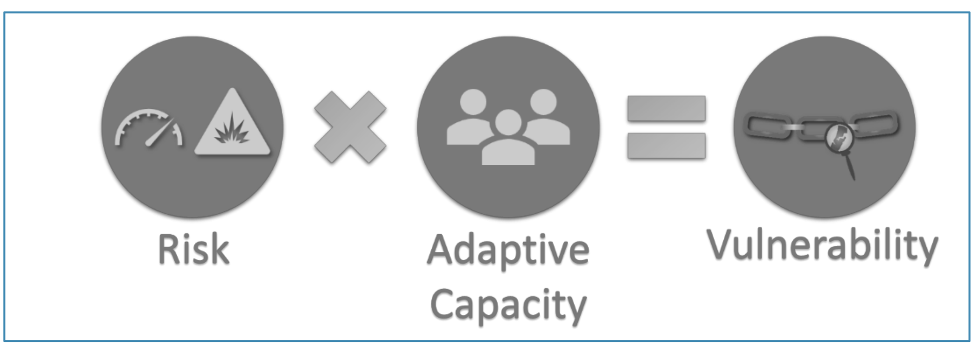


Figure 3: Formula for calculating vulnerability

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

County Boundary

RCI Road Network

Maximum Vulnerability

0-15 (Low)

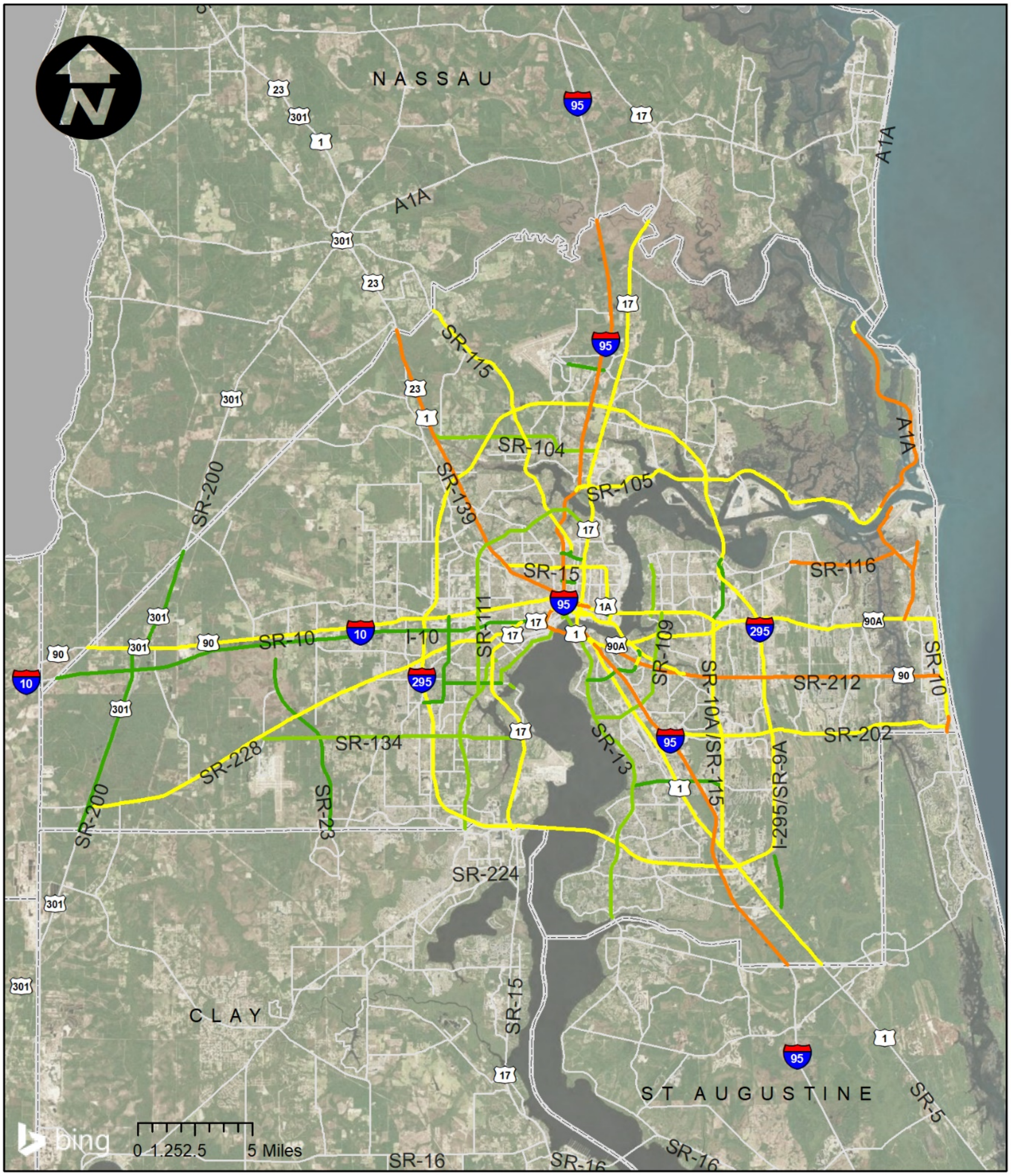
16-29 (Moderate-Low)

30-39 (Moderate)

40 - 49 (Moderate-High)

50-75 (High)

Figure 6: Duval County Vulnerability Score



Legend

County Boundary

RCI Road Network

Maximum Vulnerability

0-15 (Low)

16-29 (Moderate-Low)

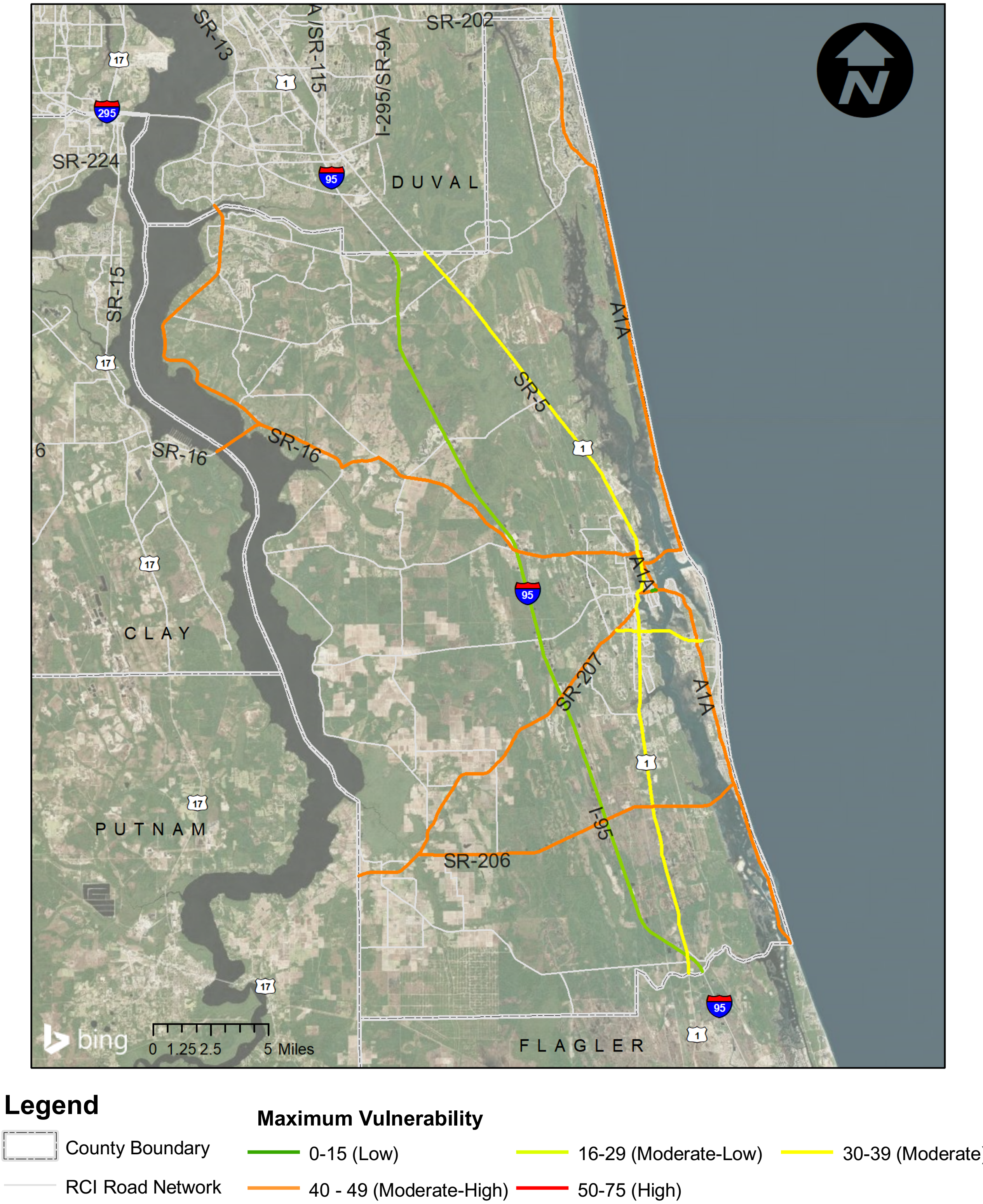
30-39 (Moderate)

40 - 49 (Moderate-High)

50-75 (High)

2.3.3 St. Johns County

Figure 7: St Johns County Vulnerability Score



2.3.4 Nassau County

Figure 8: Nassau County Vulnerability Score

Legend

County Boundary

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 <u>overall system vulnerability is moderate.</u>

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 appropriates strategies to consider.

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