RESILIENT TAMPA BAY: TRANSPORTATION PILOT PROGRAM PROJECT

RESILIENT TAMPA BAY: TRANSPORTATION PILOT PROGRAM PROJECT

The preparation of this report has been financed in part through grants from the Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation, under the Metropolitan Planning Program, Section 104(f) of Title 23, U.S. Code. The contents of this report do not necessarily reflect the official views or policy of the U.S. Department of Transportation.

Hillsborough County Metropolitan Planning Organization
601 E. Kennedy Boulevard, 18th Floor
Tampa, FL 33602
(813) 272-5940
www.planhillsborough.org

Table of Contents

List of Tables

List of Figures

Executive Summary

Located on the west coast of Florida and near the Gulf of Mexico, the Tampa Bay region is an important state hub for the tourism, higher education, commercial shipping, medical services, business/financial services, defense/national security, and agricultural sectors. The region is also one of the most vulnerable areas in the country. Extreme weather events such as storm surge, flooding, and heavy precipitation events are threatening transportation facilities across the region, creating potential risks of damages in infrastructure, increases in repair and maintenance costs, and disruption to normal operations of transportation systems. Due to climate trends, this region faces additional threats from increasing temperatures, intensifying precipitation events, and rising sea levels.

As the Tampa Bay region continues to face these weather and climate challenges, new federal requirements state that future Long Range Transportation Plan (LRTP) updates must address "improving the resiliency and reliability of the transportation system and reducing or mitigating the stormwater impacts of surface transportation ..." To assist in meeting the new federal mandate as well as support state, regional and local organizations to integrate appropriate strategies into their transportation planning process, this document reports on an assessment of the Tampa Bay region's[1] exposure/vulnerability to potential extreme weather challenges and provides strategies to prepare for, respond to, and recover from those impacts. The information can be used immediately and over time to enhance the region's transportation facilities and operation.

The main objective of the assessment was to provide adaptation strategies, or projects, for inclusion in each MPO's LRTP. With that end goal in mind, steps were taken throughout the project to categorize and prioritize transportation infrastructure, namely roads. The following steps outline the analyses results for use in LRTP preparation as well as other purposes.

- To understand the potential impacts from extreme weather and climate change, eleven scenarios were developed to model hurricanes, sea level rise, and heavy precipitation events as well as their combined effects in the three-county Tampa Bay region[2]. The resulting information is available to partner agencies for separate or supplemental analysis, such as by Local Mitigation Strategy working groups.

- To perform detailed transportation and econometric analysis, two scenarios were chosen: a Category 3 Storm plus a High (NOAA) sea level rise projection, and 9 inches of precipitation/rain over 24 hours (one day). High, moderate, and low scores (termed vulnerability throughout this report) were assigned to roads depending on the depth of potential inundation. Section 2.1.1 explains more about the scenarios and choices.

- To categorize roads by importance, a stakeholder survey was conducted to determine priorities among eleven different items, such as traffic volumes, population density, proximity to important facilities like hospitals and power plants, and access to vehicles (zero-car households). High, moderate, and low

[1] For the assessment, the region consists of Hillsborough, Pinellas, and Pasco Counties. The study was managed by the Hillsborough MPO, with Forward Pinellas, Pasco MPO, FDOT District 7, and the Tampa Bay Regional Planning Council as partners.

[2] This document is created as part of the Resilient Tampa Bay Transportation stakeholders' proactive effort to prepare for potential extreme weather risks and to ensure the transportation system's safety, mobility, and infrastructure security. The analyses of hazards/events should not be viewed as a prediction of occurrence.

criticality classifications were assigned based on a road's score (termed its criticality). Section 2.2 provides more details.

- There are nine combination of criticality and vulnerability (see Figure 2-11). High resilience projects are termed those with High or Moderate criticality and High or Moderate vulnerability. (The top three categories.) These classifications are used to assign adaption strategies and associated costs.

- An adaptation tool box (see Chapter 3.0) was created to identify various adaptation strategies and explain the benefits and constraints of each. The toolbox describes the strategies most appropriate for specific threats and conditions in which each works best. For example, enhanced drainage works well in areas with available median or shoulder clearance and less so in coastal areas with sheet flow into the Gulf or Bay.

- To determine how best to identify and cost estimate adaptation strategies for roads in the region, the MPOs identified six representative projects, two in each county, using criticality and vulnerability information. The purpose was to perform high level concept design for the six projects, develop planning level cost estimates for the projects, and then use the information to apply adaptation strategies with associated costs to all vulnerable roads in the region. (See Section 4.1.)

- To evaluate the benefits versus costs of implementing adaptation strategies, econometric analyses were performed. These analyses evaluated the impacts from the loss of each (individually) representative project as well as the impacts of all roads impacted by the Category 3 with High sea level rise and the 9-inch per day rain event. To evaluate the length of time an outage impacts the economy, modeling for 2-days, 1-week, 2-weeks, and a month was performed. For example, implementing adaptation strategies for Gandy Boulevard or Gulf Boulevard is beneficial should the asset unavailable for travel for as little as two days. Yet, it would be regionally beneficial to enhanced US 19 and Roosevelt Boulevard should they be out for a month. (Sections 4.2 and 4.3 provide details on the econometric analysis and cost/benefit tradeoffs, respectively.)

- To evaluate current short-term spending on maintenance, drainage, and coastal projects, the Capital Improvement Program (CIP) budgets for the counties, municipalities and FDOT were assessed. Fair amounts are spend on routine road maintenance and drainage, with beach nourishment and other coastal projects also being implemented. The drainage and coastal adaptation strategies identified here function like existing projects through local/regional programs. However, the enhancement to improve the roads (beyond maintenance) are beyond what is typically considered. (See Section 4.4.)

- Chapter six identifies recommendations for incorporating adaptation strategies into the LRTPs. It is recommended that high resilience projects be included because the adaptation costs outweigh replacement costs. However, these costs are substantial. By narrowing to projects for highly critical and highly vulnerable locations, or starting with drainage improvements, the investment needs can be scaled back. This chapter also identifies other recommendations for continued coordination and next steps.

This document consists of six chapters: introduction, needs determination, adaptation strategy toolbox, cost and benefit analysis, public and stakeholder engagement, and recommendations. Following the introduction in Chapter one, Chapter two describe the impact of eleven climate scenarios on the transportation network in Tampa Bay Region. Mobility, connectivity, socioeconomic, equity, and emergency operation factors were considered to identify areas where climate threads could cause the biggest impact. Transportation facilities were prioritized by their vulnerability and criticality, and locations of potential improvements were identified. Chapter three provides an overview of the adaptation strategies and identified potential improvements to candidate projects. Chapter four describes the estimated costs of implementing adaptation strategies, and compares them with the potential economic loses if infrastructure is inundated. Chapter five provides an overview of stakeholder and public engagement in the preparation of this report. Chapter six provides recommendations for including resiliency strategies in the decision-making process of transportation planning.

This document is created as part of the Resilient Tampa Bay Transportation stakeholders' proactive effort to prepare for potential extreme weather risks and to ensure the transportation system's safety, mobility, and infrastructure security. The analyses of hazards/events should not be viewed as a prediction of occurrence.

1.0 Introduction

The Tampa Bay region is an important state hub for tourism, higher education, commercial shipping, medical services, business/financial services, defense/national security, and agricultural sectors. The region is also one of the most vulnerable areas in the country, experiencing frequent storm events and flooding. While it has not been directly impacted by a major hurricane in nearly 100 years, the region has experienced a series of close calls, most recently during the 2017 hurricane season. Due to climate change, the region faces additional threats from sea level rise and increasing frequency of severe inland flooding from heavy precipitation events.

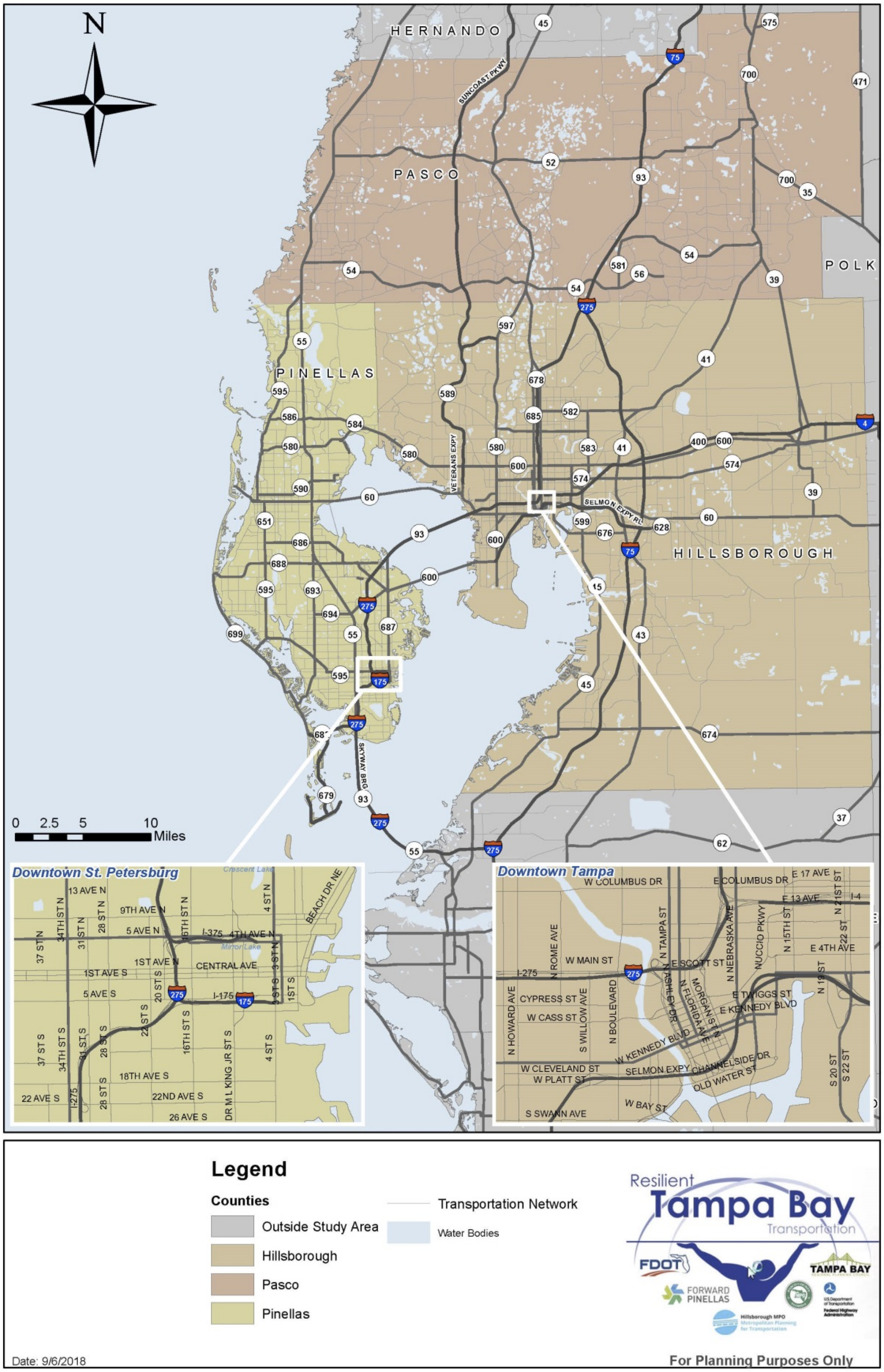
As the Tampa Bay region continues to face these climate challenges, understanding individual assets and overall system vulnerability to key climate hazards will allow state and local agencies to integrate appropriate measures and strategies into their planning process, project development, asset management, and day-to-day operations. New federal requirements state that future Long Range Transportation Plan (LRTP) updates must address "improving the resiliency and reliability of the transportation system and reducing or mitigating the stormwater impacts of surface transportation ..."

To assist in meeting the new federal mandate as well as inform the LRTP updates for Tampa Bay's three Metropolitan Planning Organizations (Hillsborough, Pasco, and Pinellas MPOs) and the regional LRTP, the Resilient Tampa Bay Transportation stakeholders, consisting of the three MPOs, Tampa Bay Regional Planning Council, and the Florida Department of Transportation District 7, has conducted a regional climate vulnerability study in the three counties with the awarded FHWA *Resilience and Durability to Extreme Weather* grant.

The study assessed the potential climate vulnerability and risks on the transportation network due to storm surge, inland flooding, and sea level rise; screened and prioritized critical transportation facilities; identified adaptation strategies and candidate projects; compared potential economic impact and adaptation costs, and provided recommendations for the inclusion of resiliency strategies in the transportation planning's decision making process.

The study focused on roadway infrastructure in Hillsborough, Pinellas, and Pasco counties. The Tampa Bay regional travel demand model served as the base network for scenario development and evaluation. An indicator-based desk review approach was used in the quantitative analysis part of the study. Stakeholder input was obtained and incorporated regarding important (critical) roads, and it should be noted that the study should not be viewed as a predictor of occurrence(s).

Figure 1-1 Study Area



2.0 Needs Determination

A first step in identifying potential investments for the LRTPs was to identify infrastructure needs based on model projections of water-related weather and climate impacts. Storm surge, sea level rise, and precipitation events will create challenges to the transportation systems' infrastructure safety, operational efficiency, and emergency management. This section analyzed the impacts of coastal storms, sea level rise, and heavy precipitation events to identify potential at-risk transportation facilities in the Tampa Bay region.

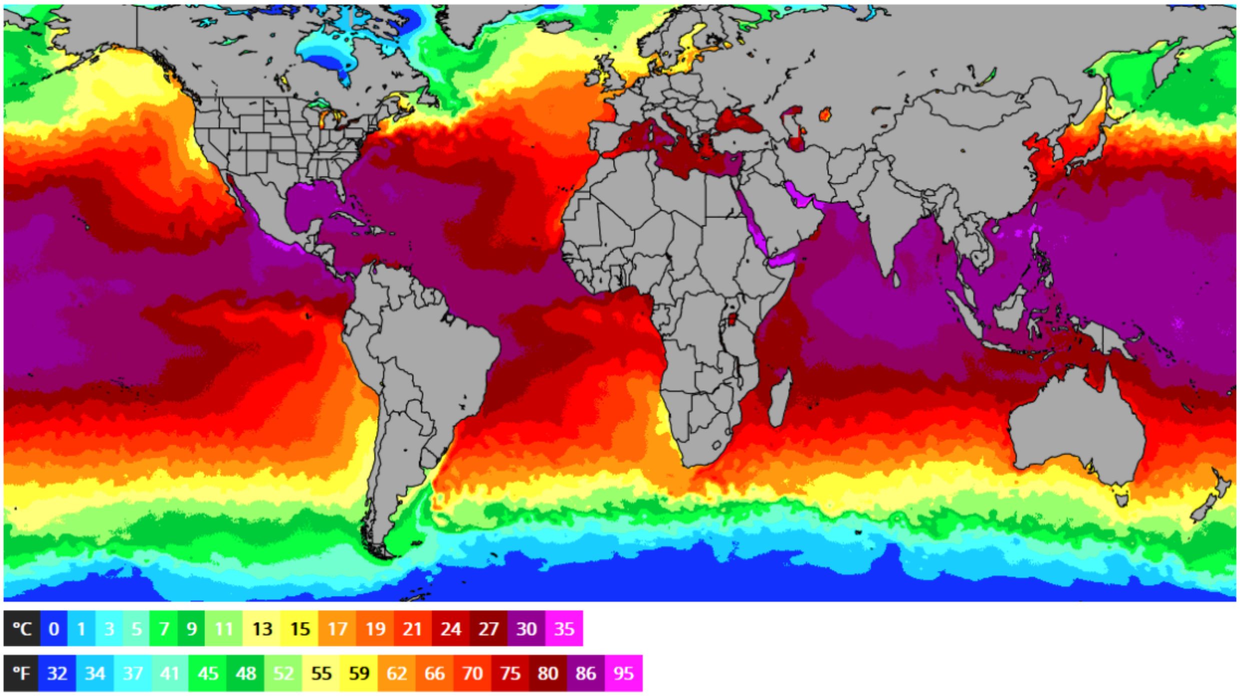
2.1 Climate Scenarios

Tampa Bay is no exception to threats from extreme weather events facing many coastal regions. While the region has not been directly impacted by a major hurricane in nearly 100 years, a series of close calls, most recently experienced during 2017's Hurricane Irma, indicates the looming threat of a major hurricane event to the region. Although the threat of destruction from storm surge flooding has not been in the forefront of citizen minds, the three counties have been planning for post-disaster redevelopment and hazard mitigation.

Due to climate change, the region faces additional threats from sea level rise and severe inland flooding. Approximately 39 percent of the region's population lives in areas at risk of flooding, and nearly 40 percent of the region's 1.1 million jobs are in zones susceptible to hurricane storm surge. In 2015, Karen Clark & Co., a risk management firm, stated in their "Most Vulnerable US Cities to Storm Surge Flooding Report" that the Tampa - St. Petersburg area is the most vulnerable US metropolitan area for flooding damage. A direct hit from a Category 4 storm with peak winds of 150 mph could result in potential losses of $175 billion to the area.

Evidence has been mounting that conditions are becoming more commonplace to increasing storm frequency and higher precipitation rates. As these factors continue to appear, the probability for higher rates of precipitation events can't be ignored. In the early summer of 2019, the western Atlantic and Gulf of Mexico had astonishingly high surface temperatures. The Atlantic had areas greater than 80 degrees F and the Gulf had areas as high as 95 degrees F.

To fulfill the objectives set out in this project, several climate-based assessments had to be made. The team agreed upon the analyses of sea level rise, tropical storm events, and significant rain events. Tampa Bay's geographic location ruled out other infrastructure stressors such as snowfall/blizzards, earthquakes/tsunamis, and other location-specific hazards



The map above is updated daily and shows the ocean water temperature as recorded on 10th Jul 2019

Source: www.seatemperature.org

2.1.1 Scenario Development

Eleven scenarios were developed to model hurricanes, sea level rise, and heavy precipitation events as well as their combined effects in the three-county Tampa Bay region:

- Sea Level Rise High Projection (NOAA)
- Sea Level Rise Intermediate-Low Projection (NOAA)
- Category 1 Storm
- Category 1 Storm plus Sea Level Rise High Projection
- Category 1 Storm plus Sea Level Rise Intermediate-Low Projection
- Category 3 Storm
- **Category 3 Storm plus Sea Level Rise High Projection**
- Category 3 Storm plus Sea Level Rise Intermediate-Low Projection
- Category 5 Storm
- **Precipitation - 9 inches of rain over 24 hours (1 day)**
- Precipitation - 11 inches each day for 3 days (33 total inches)

Details about the modeling of scenarios are shown below. The bold scenarios were used for the detailed analysis presented throughout the remainder of this document, including in the identification of adaptation strategies and projects. A Category 3 storm plus High Sea Level Rise was selected as a moderate risk approach for protecting transportation assets. Traditional emergency management, focused on protecting people, would evaluate the worst-case scenario of Category 5[3]. A review of the Category 5 impacts showed a very large area of potential impact. This study is focused on identifying and ultimately enhancing transportation assets to avoid potential compromise of infrastructure and support rapid recovery. With this asset management lens, a more moderate scenario was chosen to prioritize the most critical and vulnerable facilities.

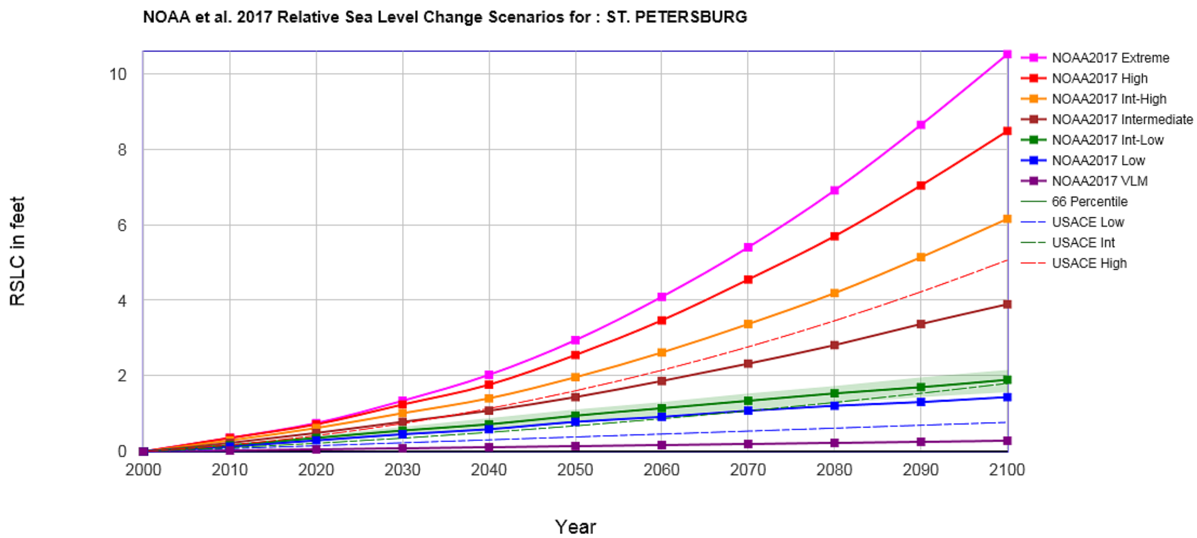
Sea Level Rise

Tampa Bay's geographic location and topography lends itself to rapid changes with slight variation in sea level. The combination of low slopes and low elevation add up to an increased vulnerability with sea surface level changes. Based on elevation alone, the image shows a considerable area of Tampa Bay that is under 6 ft elevation. Additionally, coastline areas tend to have a more concentrated population.

Elevation 6ft or lower

This study will focus on the 2045 horizon due to the -LRTPs being developed by the MPOs of Hillsborough, Pasco, and Pinellas. The next variable needed to determine the sea level rise is the methodology to use for timeline horizon values. Three distinct methodologies that have curves for the surface level values over time can be used: Intergovernmental Panel on Climate Change (IPCC), U.S. Army Corps of Engineers (USACE), and National Oceanic and Atmosphere Administration (NOAA). The team chose the NOAA et al. 2017 SLR curves due to a past and updated document released for the Tampa Bay area by the Climate Science Advisory Panel (CSAP). Previously, CSAP has recommended using the NOAA curve from 2012.

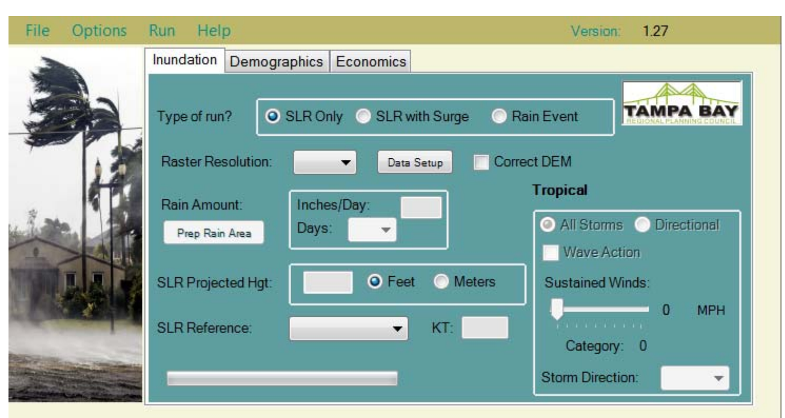
[3] Category 5 inundation is extensive throughout the region. For efficiencies, scenarios that incorporated sea level rise were not prepared.

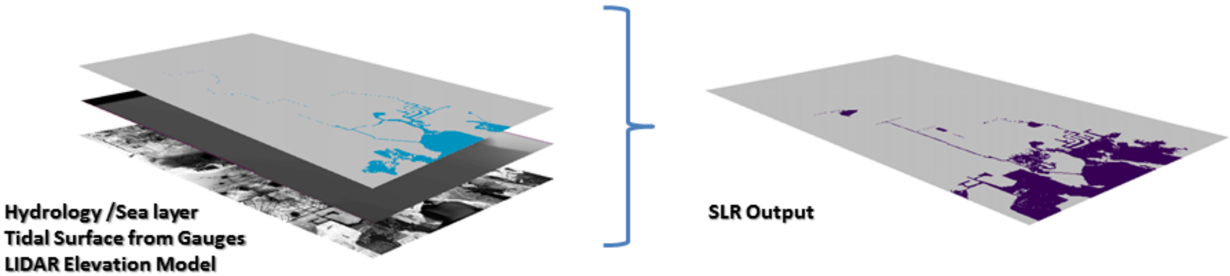


This The study launched before the updated CSAP recommendations. However, using the same logic expressed in the previous document, the team chose to use the 'High' curve for the upper limits of possible rise and the 'Intermediate Low' for the lower limit. These limits can be roughly translated into what is thought to be the result of continuing climate change at the current rate (or worse) for the upper limit and reducing or slowing down emissions for the lower limit. The team chose CSAP-recommended St. Petersburg tidal gauge for SLR due to the three counties involved in the Study are in and around Tampa Bay region. Counties north of Pasco County should use the Cedar Key tidal gauge.

For the modeling of the sea level inundation at the 2045 horizon, a model was built using GIS. The model consisted of an application created by Tampa Bay Regional Planning Council which can model tidal-based sea level rise depending on parameters selected by the user It is important to not use bathtub model with a single level surface to depict sea level rise. Using a single constant level surface (just adding inundation based on a certain shoreline elevation value) would not depict the true nature of the new shoreline. Current and future shorelines are a result of tidal variations and the sea surface is not level. The tool is agnostic in terms of what data the projected rise will use. Whatever the projected value for the horizon becomes, it can be inputted into the model.

The model uses tidal gauges to distribute the sea surface according to the variations found in the gauges over the entire area of concern. The best elevation available is used, which is a LIDAR digital elevation model. The resulting output is a polygon inundation layer that simulates the coverage of the sea surface for that horizon year chosen.

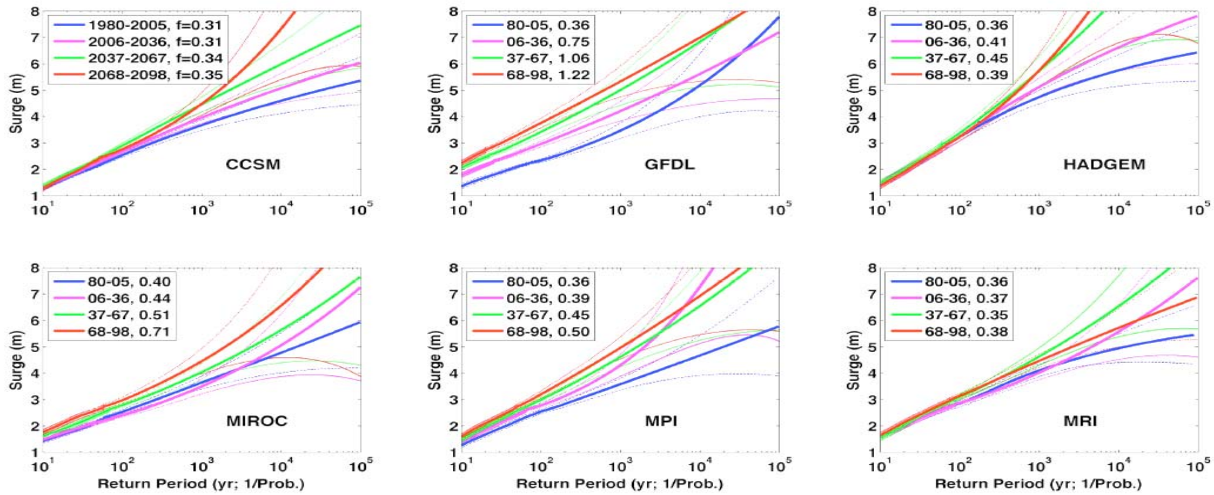




At the 2045 horizon, it appears there is not much inundation from sea level rise alone looking at the regional scale, even at the 'High' curve. However, sea level intrusion can be noticed in certain areas within the Tampa Bay area. The three images below depict the High Curve affecting mostly low-elevation areas.

Storm Surge

Current evidence points to increasing frequency of tropical storms with more environmental moisture trapped in the atmosphere due to warmer ocean surfaces. There is also indication, through observation and modeling, that the strength of the storms will increase as well.

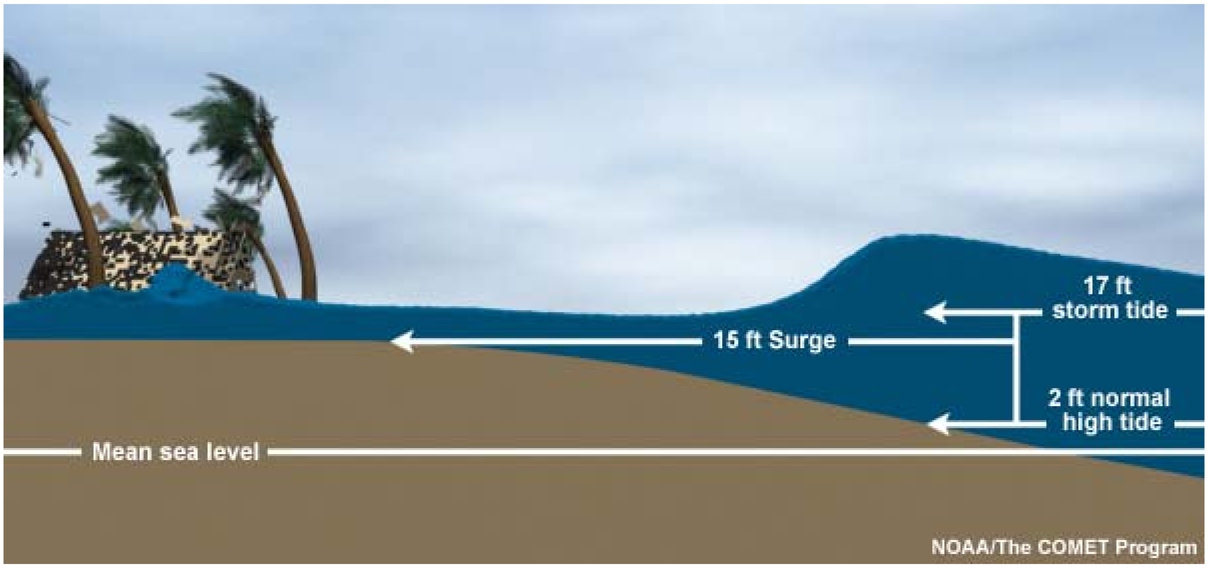


N. Lin, K. Emanuel 2015

The above graphs show storm surge height as a function of return period for Tampa Bay. These were projected using each of the 6 climate models from the IPCC AR5 RCP8.5 scenario, which is considered ‘business as usual’ without reducing the climate change rate. The bright blue lines depict the well-documented past. It is important to pay attention to the bright green and bright red lines, as these are functions of the climate projected to those horizon years with respect to surge height and strong storm frequency. In all models, the surge height is greater for any given return period but increases the longer a return period becomes.

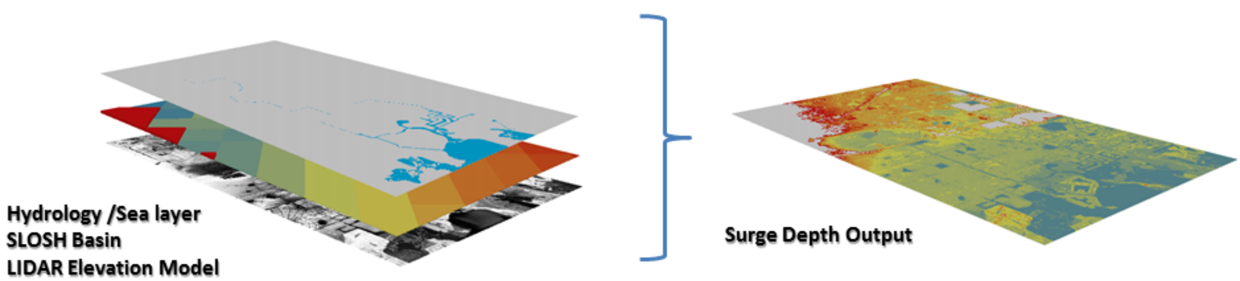
Since Tampa Bay is on the west coast of Florida, the bathymetry of the Gulf of Mexico and Tampa Bay is generally shallow compared to the east coast of Florida. This presents more opportunity for surge buildup with any given wind speed. To approach assessment modeling for this study, hurricane storm tide[4] inundation was modeled first with current conditions (current sea level) of today. Three storms were modeled: Category 1, Category 3, and Category 5. The models use the Maximum of Maximums (MOM) from tens of thousands of simulated storms from the National Hurricane Center’s (NHC) SLOSH model. Simulated storms moving from all forward directions retain the highest surge values and represent a worst-case scenario for the storm category modeled.

[4] The combination of storm surge and existing tide level gives the total surge height of Storm Tide

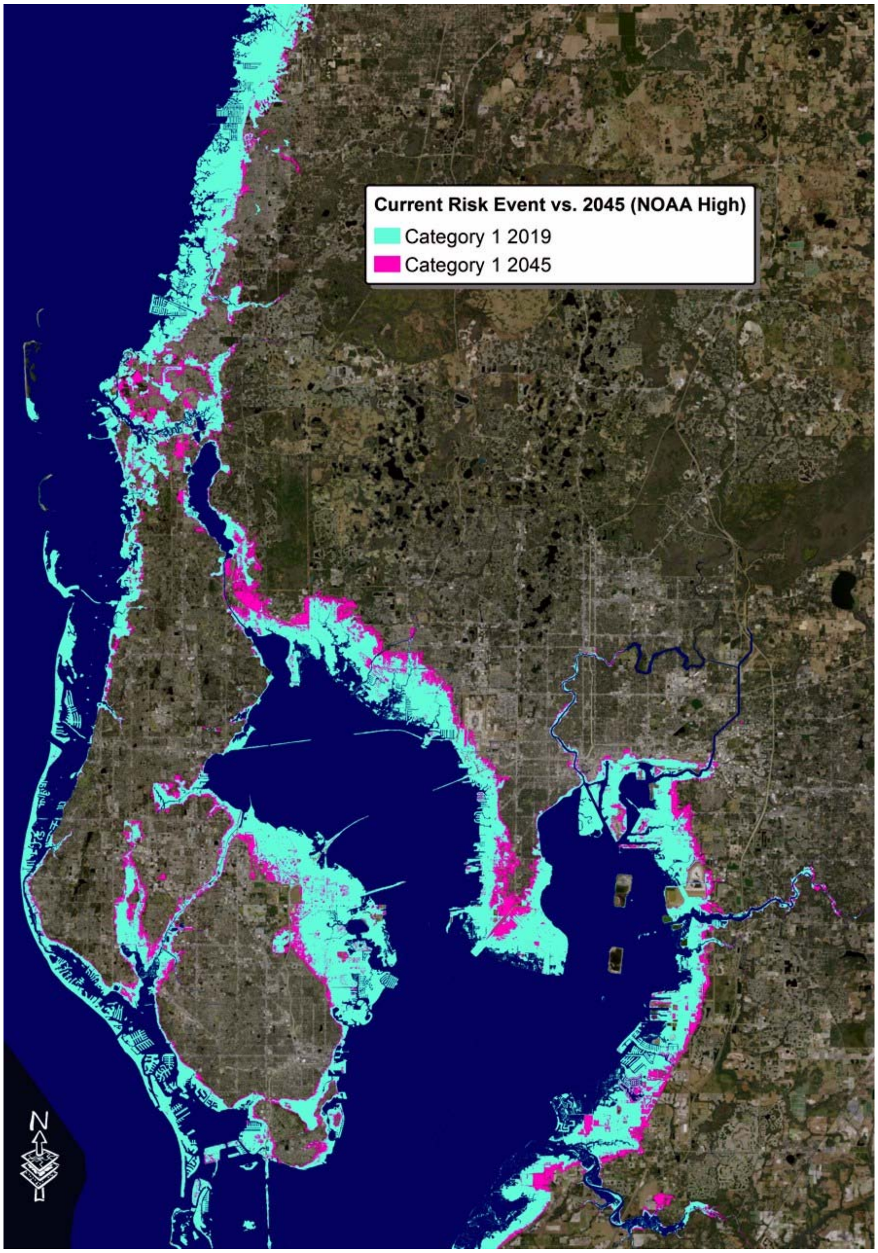


Courtesy of NOAA

The project modeling uses the same tool mentioned previously with the only difference in the input parameter being 0.0 ft SLR. The results were modeled for the counties when the new SLOSH (Sea, Lake, Overland, Surge, from Hurricanes) basin from the NHC replaced the existing basin in 2016. Counties updated their evacuation zones based on those results. To assess the inundation for the future time horizon of 2045, both the High Curve and Intermediate Low Curve were modeled with storm surge. We did not model Category 5 surge with future sea level rise because the storm's high magnitude is already significant. A one to two feet higher sea surface would not make much difference to a 29 to 39 feet– 39ft of storm tide. It should be noted that the methodology used for this study processed the SLOSH data and the SLR data analyzing them as a single surge layer rather then simply overlaying one layer of data over another. This results in a more integrated representation of the interaction between storm surge and SLR. It should be noted that the methodology used for this study processed the SLOSH data and the SLR data analyzing them as a single surge layer rather then simply overlaying one layer of data over another. This results in a more integrated representation of the interaction between storm surge and SLR.

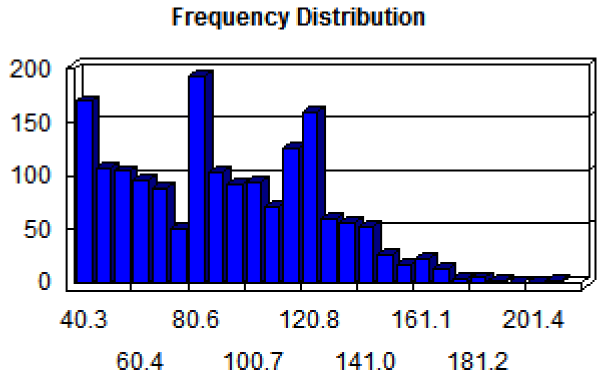


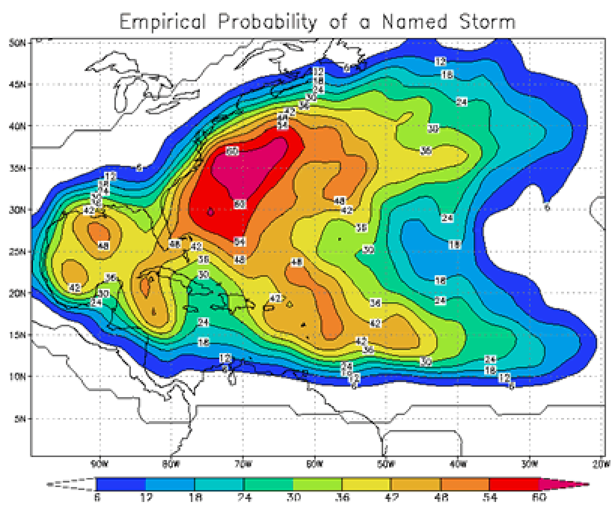
Higher sea levels are giving future tropical storms more fuel for producing surge in coastal areas. It also lowers the tipping point for breaching landmass by having any natural or man-made barriers appear smaller due to the sea level being higher.

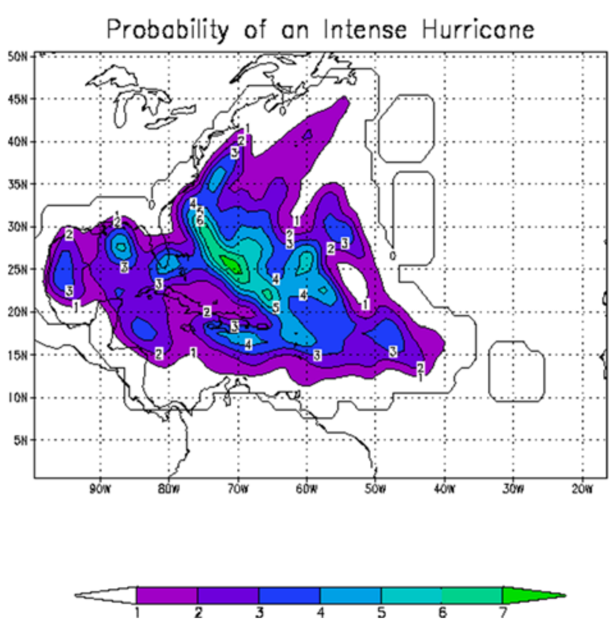


The above image demonstrates the additional inundation that can be expected in 2045 due to surface sea levels being 2.165 ft higher. Modeling is run in reference to Mean Sea Level (MSL) due to the surge model using MOM surge values, which already have high tide built into its output. Modeling in reference to Mean Higher High Water (average of the highest tide per day) would make results artificially higher.

The team chose Category 3 storm models as the representative tropical storm threat. The other two category scenarios (1 and 5) solely added reference and scale to the chosen category. Currently, the Tampa-St. Petersburg area has an 11 percent chance of feeling the impacts of a hurricane in any given year. In the 1,703 recorded storms that had winds over 40 mph, only 42 were Category 5 storms. The remaining storms numbered at 208 in Category 4, 286 in Category 3, 247 in Category 2, and 355 in Category 1.







Graphics courtesy of NOAA Atmospheric Lab

With the statistical data as guidance, two storm categories had a higher probability amongst the five–Category 1 and Category 3. The team chose Category 3 to represent a significant event that could have a likely chance of occurring within the next two decades. Reinforcing the decision was the general assumption of more frequent and stronger storms in the future (alluded to with 6 model graphs previously). The inundation from a Category 3 storm was modeled for the present sea level and the 2045-projected sea level. The 2045 inundation was inserted into the transportation analysis of surface network infrastructure for the three counties of this study.

Precipitation

Resiliency towards future climate changes does not just involve threats from the sea. As mentioned earlier, evidence seems to suggest that higher moisture in the atmosphere increases the chance of more frequent and longer duration of all storms, not solely tropical.

Heavy precipitation events in most parts of the United States have increased in both intensity and frequency since 1901 (*high confidence*). There are important regional differences in trends, with the largest increases occurring in the northeastern United States (*high confidence*). (Ch. 7; Fig. ES.6)

Extreme Precipitation Has Increased Across Much of the United States

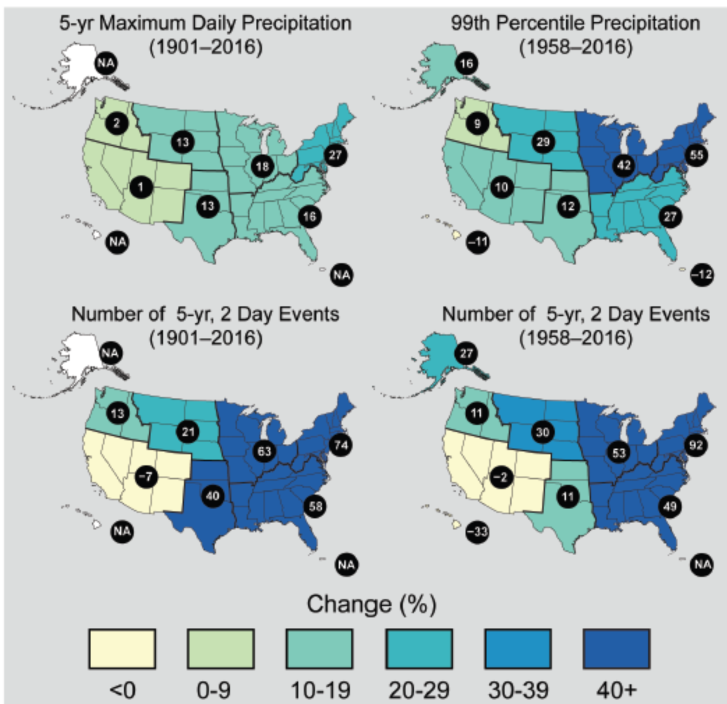
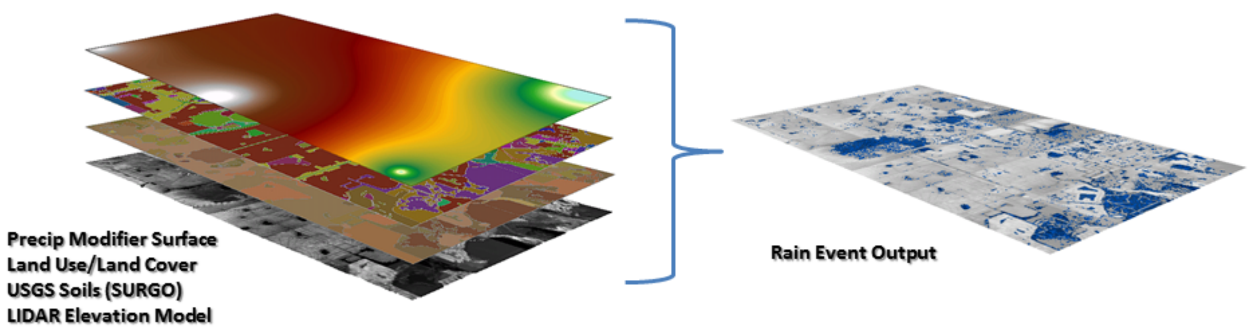


Figure ES.6: These maps show the percentage change in several metrics of extreme precipitation by NCA4 region, including (upper left) the maximum daily precipitation in consecutive 5-year periods; (upper right) the amount of precipitation falling in daily events that exceed the 99th percentile of all non-zero precipitation days (top 1% of all daily precipitation events); (lower left) the number of 2-day events with a precipitation total exceeding the largest 2-day amount that is expected to occur, on average, only once every 5 years, as calculated over 1901–2016; and (lower right) the number of 2-day events with a precipitation total exceeding the largest 2-day amount that is expected to occur, on average, only once every 5 years, as calculated over 1958–2016. The number in each black circle is the percent change over the entire period, either 1901–2016 or 1958–2016. Note that Alaska and Hawai'i are not included in the 1901–2016 maps owing to a lack of observations in the earlier part of the 20th century. *(Figure source: CICS-NC / NOAA NCEI). Based on figure 7.4 in Chapter 7.*

The graphics above from the Global Change Climate Science Special Report essentially show that precipitation events and their intensity are increasing.

For our study to express a more thorough picture of future climate threats, we needed to include inland flooding events that affected the road networks not directly connected to coastal roadway infrastructure. We chose to go beyond using FEMA flood zones found in the FIRM data and maps. The FEMA flood zones, namely zones A and AE, represent a 1-in-100 year chance to arrive at the depicted inundation. This 1% annual event could be fluctuating due the climate moisture levels referenced earlier. We wanted to approach the inland flooding threats based on what-if scenarios. For example, "What if we had X amount of rain in Y days?". To answer such questions, we had to model the rain with chosen parameters.

The model we chose was a ponding and flow accumulation model. It is strictly a surface topography model and does not involve public works drainage infrastructure and facilities. In high volume rain events, the storm drains and outflow will be saturated mimicking a closed system. Data from around the county show that drainage pipes, culverts, and outflow pipes created decades ago are often inadequate with the increase in rain duration and frequency[5]. For a study of the three counties, the magnitude of such a detailed model would prevent results within the allotted timeframe of the project. The model uses four GIS layers and calculates the ability for precipitation to flow into lower areas based on soils and runoff coefficients of land types.

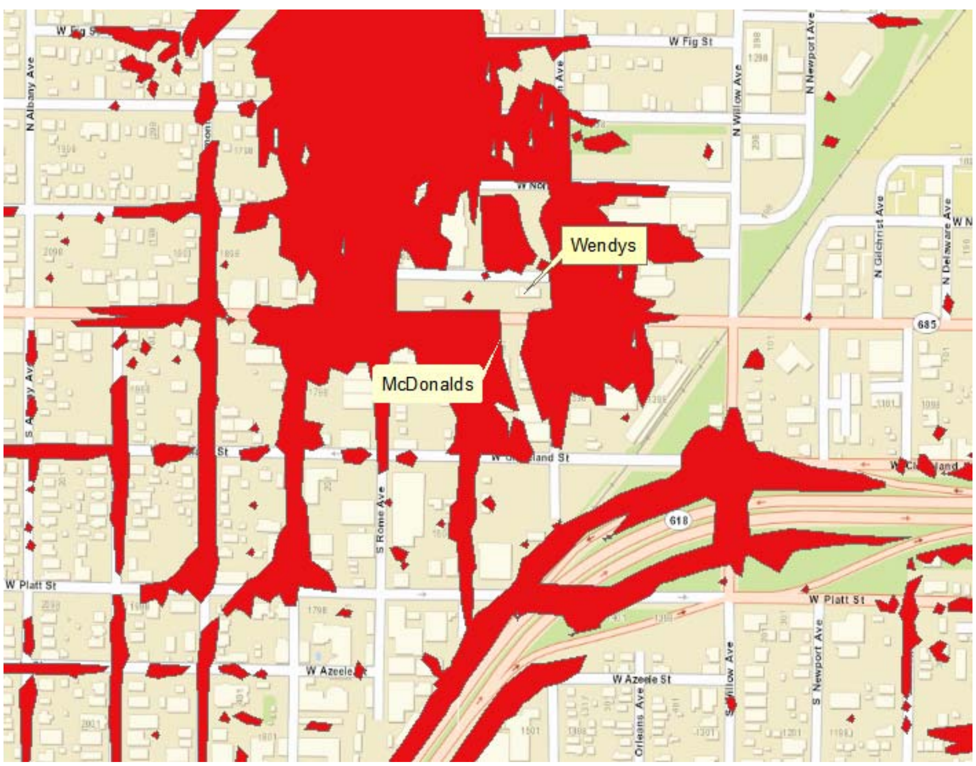


The team decided to model two scenarios for the inland flooding events. One scenario would be chosen as the representative rain event for the roadway surface infrastructure and one would be a substantial event. Historical data for Tampa Bay (Tampa airport back to 1940) goes back to 1891. The biggest 1-day storm recorded was 11.45 inches in 1979. In recent years, the most rain in one day has been around 4 inches – with 4.39 inches (officially) on August 3, 2015. The amount can vary in other areas but can be more. During the 1921 hurricane, the amount recorded was 5.02 inches. Based on this data, the likelihood of 9-inch rain in 24 hours is not inconceivable, especially with the addition of a tropical storm event. This became the representative scenario. and the substantial scenario would align more with a 'Harvey-type' event with 11 inches per day for 3 days – or 33 inches.

After running the representative scenario, we had recent events that the model could test. One such event was the August 2-4, 2015 whereby a low-pressure rain front that stalled over Tampa Bay. Just below it is an example of flooding on Kennedy Blvd. looking towards the west.

[5] https://www.climate.gov/news-features/climate-case-studies/extreme-rainfall-analyses-can-point-right-size-culverts

Kennedy Boulevard, Tampa. August, 2015. Photo: imgur.com



During that event, one single day did not exceed more than 5 inches. However, the combined days left inundation varying from the equivalent of 4 – 11 inches in various spots around the region. The model output above is for the 9-inch scenario. You can see that the inundation (in red) has captured the locations of real-world flooding in the same location.

The rain event modeling is not an exact science. However, it does use historic precipitation data from the PRISM Climate Group for the precipitation modifier layer in the model. This layer modifies rainfall input data slightly based on past summer season averages. This would consider any natural or made-made real world modifiers such as vegetation and heat island effects that spatially present themselves in past precipitation amounts. Our aim was to present areas that have a distinct possibility to flood in high volume rain events. The ponding and accumulation have a direct effect on the surface infrastructure, the focus of analysis in this study.

2.1.2 Impacted Transportation Facilities

In each of the above scenarios, a surface representing the height of water surface from storm surge, sea level rise, or rain was produced by the respective models. The height of the water surface was then compared to the elevation of the ground or roadways using data from the digital elevation model (DEM). Areas of inundation and impacted transportation facilities were identified when the elevation of the ground or roadways were lower than the water surface.

Figure 2-1 summarizes the length of transportation facilities impacted by each scenario in Hillsborough, Pinellas, and Pasco counties. Figure 2-2, Figure 2-3, and Figure 2-4 illustrate the percentage of transportation facilities being impacted by each scenario in Hillsborough County, Pinellas County, and Pasco County respectively. The impacts of sea level rise alone are relatively small to the three-county region’s transportation network, with less than one percent of the roadways projected to be affected. However, the effect grows quickly when sea level rise is combined with storm events. Over 400 centerline miles, or 12% of roadways are projected to be impacted by a Category 1 storm in the three-county region. Category 3 storms and Category 5 storms will impact over 25% and 42% of the roadways in the region. About 100 centerline miles of additional roadways will be impacted when the storms are combined with high sea level rise. The heavy precipitation events could also put the transportation network at risk. Over 10% of each county’s roadways are vulnerable in the 9-inch precipitation scenario. In the scenario of 33 inches of rain over three days, close to half of the region’s transportation network would be inundated.

Figure 2-1 Impacted Transportation Facilities by Scenario

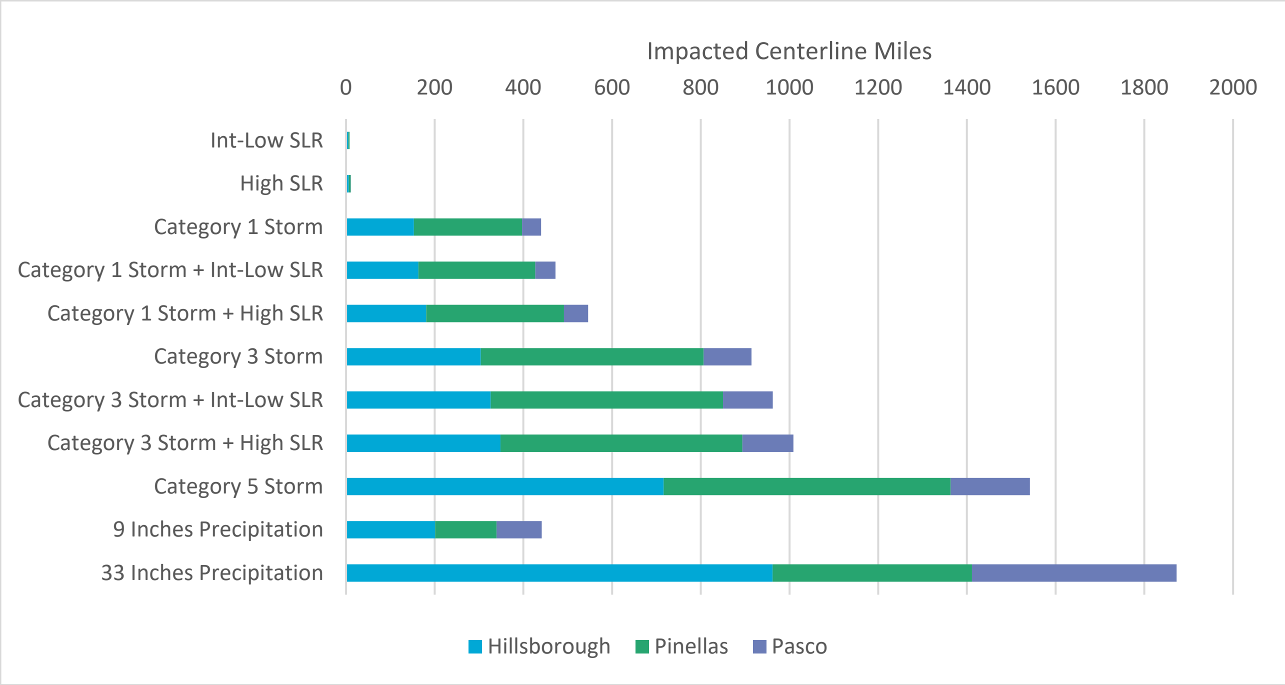


Figure 2-2 Percentage of Transportation Facilities Impacted by Scenario *Hillsborough County*

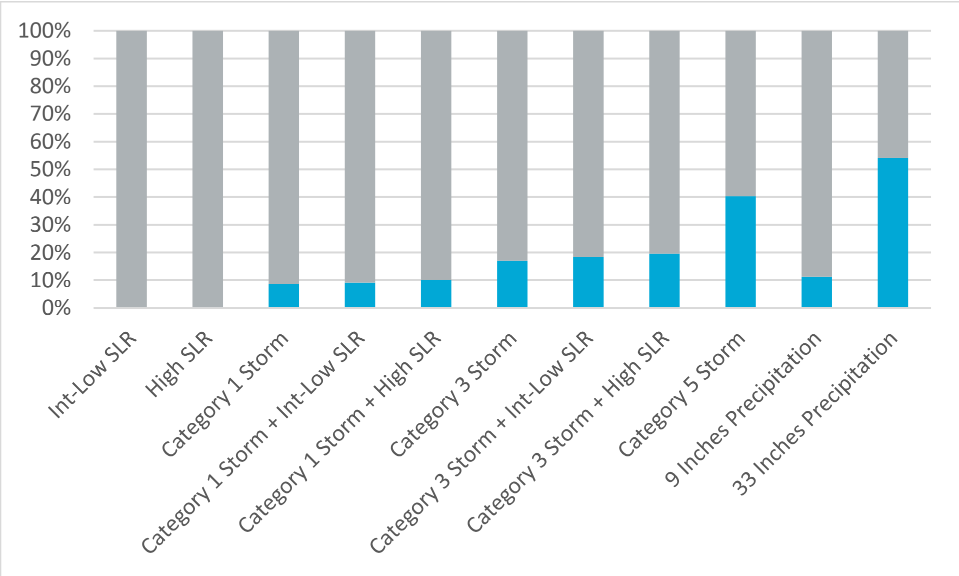


Figure 2-3 Percentage of Transportation Facilities Impacted by Scenario
Pinellas County

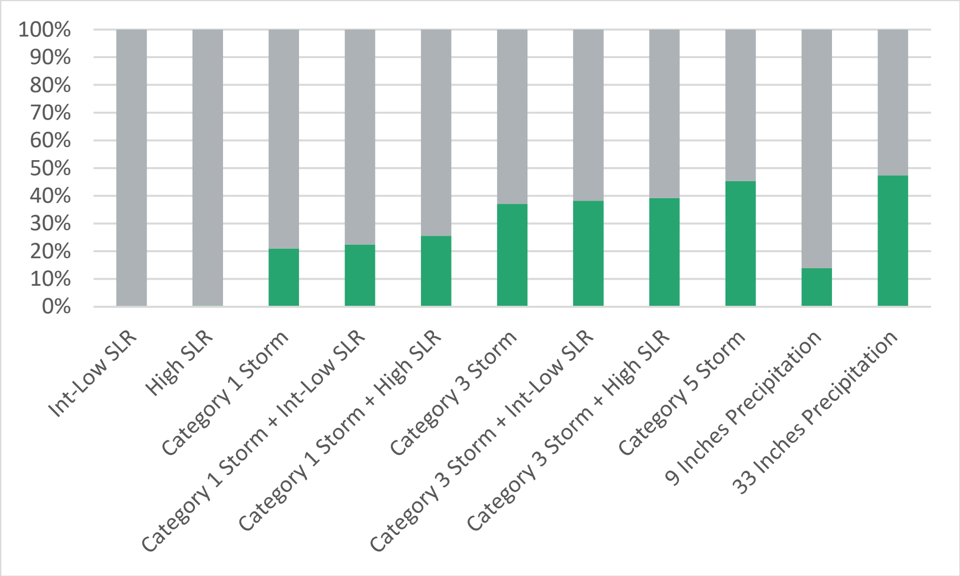
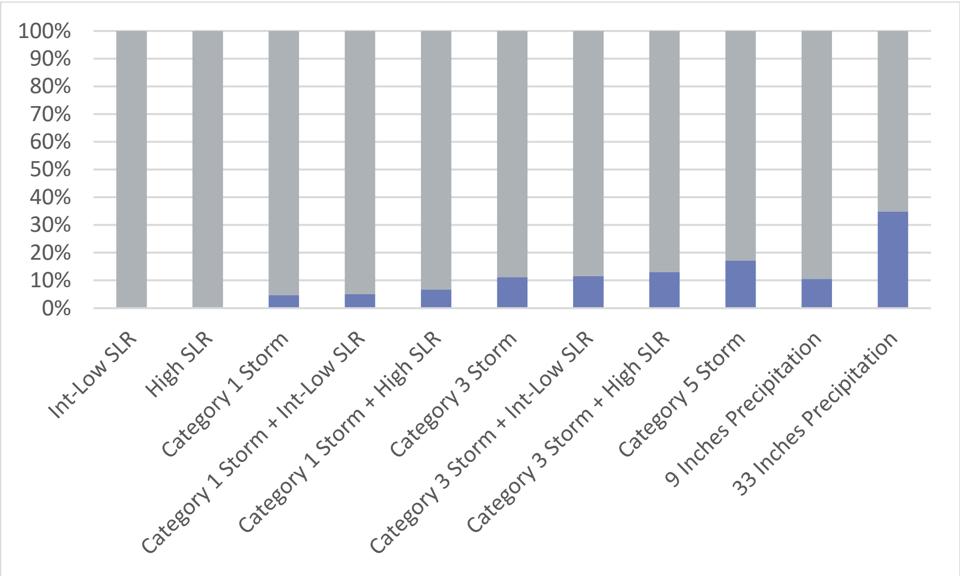


Figure 2-4 Percentage of Transportation Facilities Impacted by Scenario
Pasco County



2.1.3 Transportation Network Vulnerability

Coordinated with the RTBT stakeholders, the study team decided to focus on two scenarios when estimating each transportation facilities' vulnerability: Category 3 storm plus high sea level rise projection, and a precipitation event of 9-inch of rain over 24 hours. The vulnerability of transportation facilities was categorized into "high", "moderate", and "low" based on the maximum inundation depth in either of these two scenarios. The inundation depth was calculated by subtracting the elevation of ground or roadway surfaces from the water surface height.

Figure 2-6 and Figure 2-7 show the vulnerability of transportation facilities in Hillsborough, Pinellas, and Pasco counties for Category 3 storms plus a high sea level rise projection scenario, and 9-inch precipitation scenario, respectively. Areas color-coded in blue represent locations of water surface being higher than the ground or roadway surface.

In the scenario of Category 3 storm plus high sea level rise projection, vulnerable transportation facilities are located along the coastline of the three-county region, including the gulf coast of Pasco County, both western and eastern coasts of Pinellas County, and areas near coastline and further inland areas along rivers of Hillsborough County.

In the precipitation event of 9-inch of rain over a 24-hour scenario, the impact is much more extensive across the whole region, although the depths of inundation are smaller. It should be noted that due to the lack of unified digital elevation model source, the hydrology model is not able to produce meaningful results for the eastern part of Pasco County.

Each roadway segment is color-coded by its depth of inundation in three categories. Segments that are inundated by greater than or equal to 11feet are considered having high vulnerability; segments that are inundated by 6 to 10 feet are considered having moderate vulnerability; segments that are inundated by less than or equal to 5 feet are considered having low vulnerability. Figure 2-5 summarized transportation vulnerability in Hillsborough, Pinellas, and Pasco counties.

Figure 2-5 Transportation Vulnerability by Counties

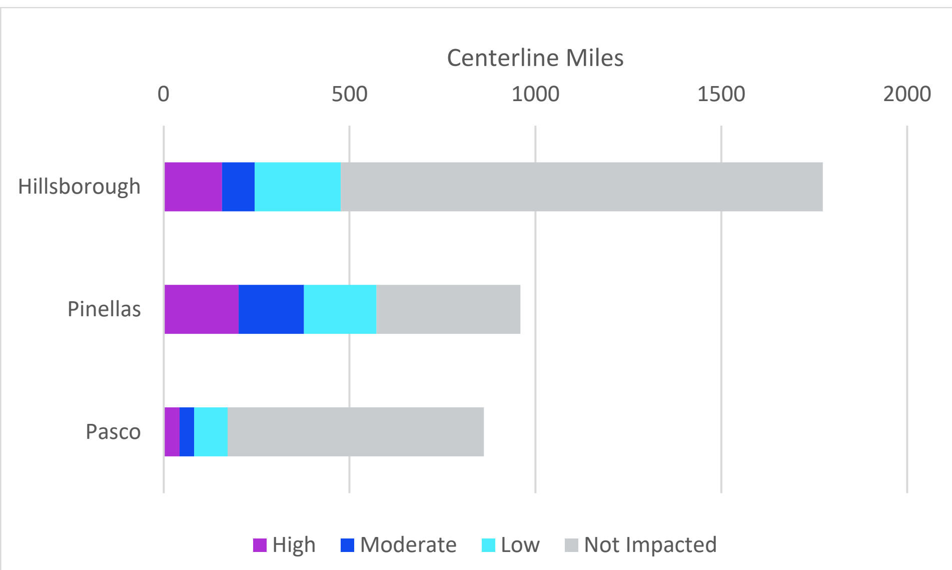


Figure 2-6 Transportation Vulnerability – Based on Category 3 Storm plus High Sea Level Rise Scenario

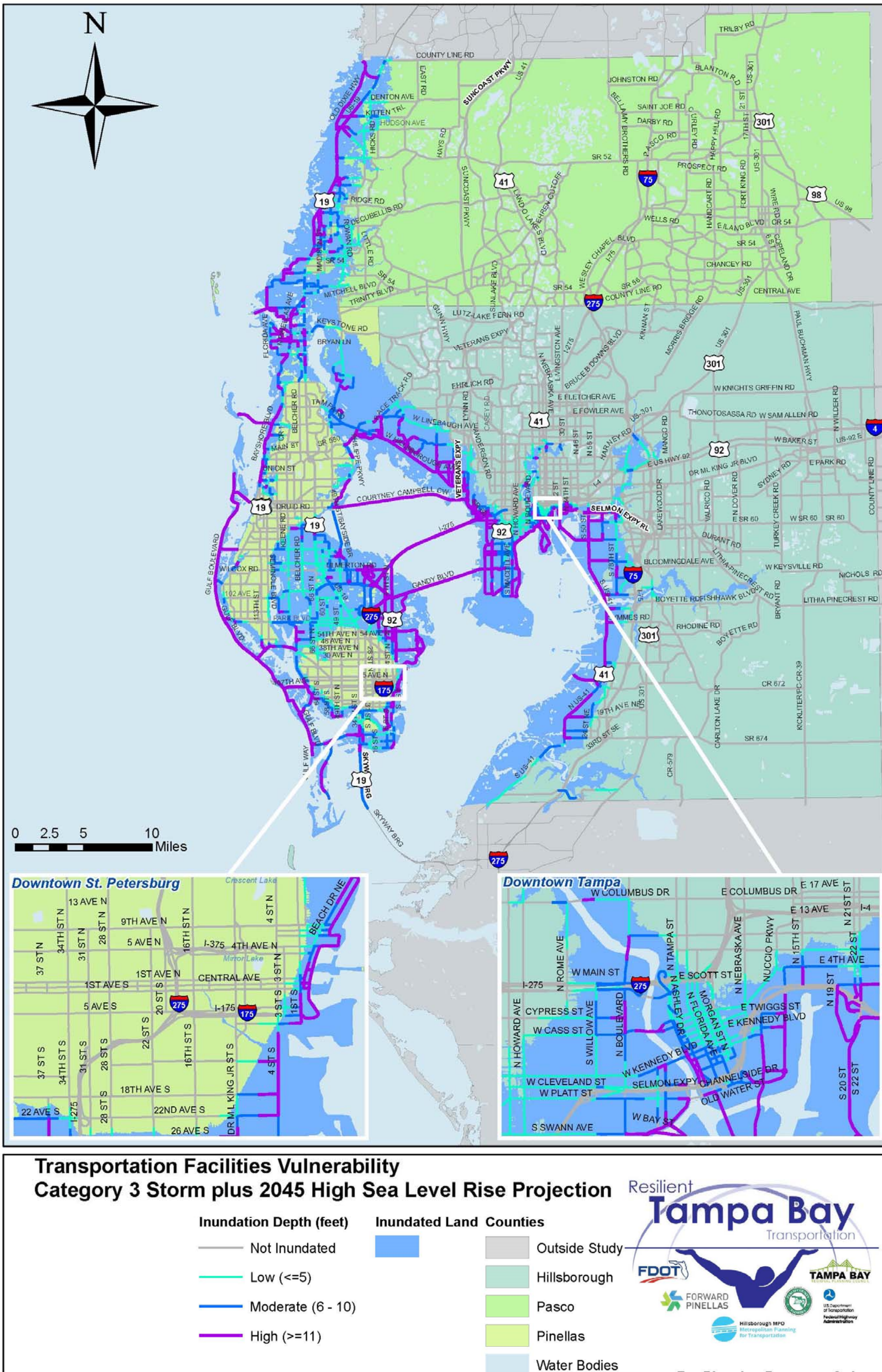
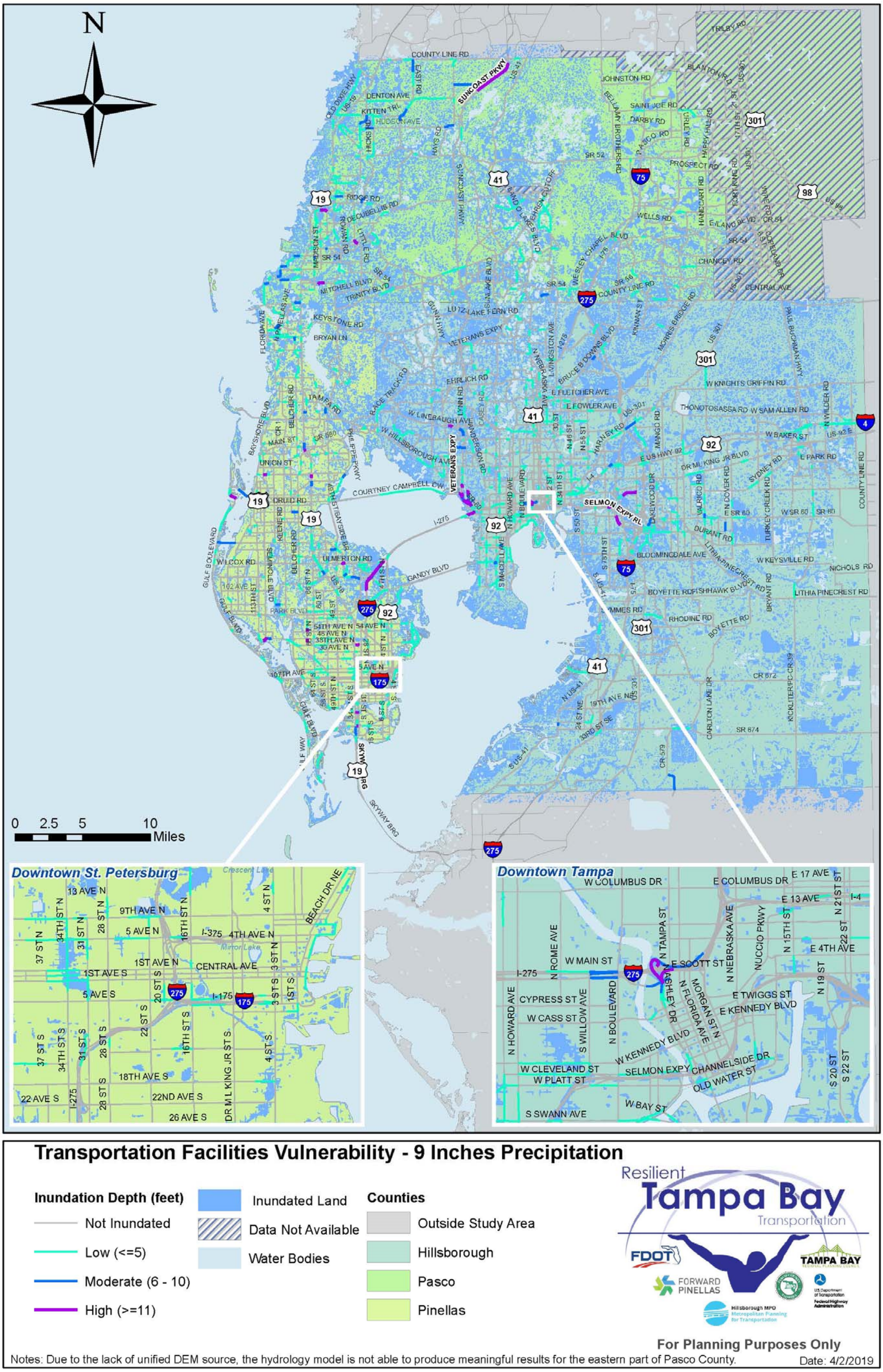


Figure 2-7 Transportation Vulnerability – Based on 9 Inches Precipitation Event Scenario



2.2 Critical Transportation Facilities

This section documents the screening process for prioritizing critical transportation links based on mobility, connectivity, equity, and emergency operations along with socioeconomic factors. The screening process consists of two parts: stakeholder engagement and quantitative analysis. As part of the Resilient Tampa Bay Transportation initiative, the project team reached out to agencies and government stakeholders to learn what they believe are the most important factors influencing the identification of critical transportation infrastructure. The participants of the survey include staff from county planning agencies, county public works departments, city agencies, economic development agencies or chambers, regional organizations, state agencies, transit agencies, and non-profit agencies.

Based on the stakeholder outreach results, 11 factors were selected to determine the criticality of transportation facilities. Each factor has a maximum score reflecting its relative weighting of importance among other factors, as shown in Table 2-1.

A criticality score was calculated for each facility by summing scores from all factors. As shown in Table 2-2, facilities with criticality scores greater than or equal to 14 are considered to have high criticality; facilities with scores lower than 14 and greater than or equal to 11 are considered to have moderate criticality; facilities with scores less than 11 are considered to have low criticality.

Figure 2-8 summarizes the transportation network centerline mileage in Hillsborough, Pinellas, and Pasco counties. Figure 2-9 shows the criticality of transportation facilities in the Tampa Bay region.

Table 2-1 Criticality Determination Factors

Factor	Max Score	Scoring Method	Description
Evacuation Route	3	3, if Yes; 0 otherwise	Whether it is an evacuation Route;
Projected 2040 Traffic volume	3	High - 3, Medium- 2, Low - 1	Projected 2040 Traffic volume, categorized into "high", "moderate", and "low" using natural breaks
Connectivity to major economic and social activity centers	3	High - 3, Medium- 2, Low - 1	Distance to the nearest Hospitals, Shelters, and Power Plants, categorized into "high", "moderate", and "low" using natural breaks
Transit Corridor	2	2 if Yes; 0 otherwise	Whether it is a Transit Corridor
Part of the LRTP Cost Affordable Projects	2	2 if Yes; 0 otherwise	Whether it is part of the 2040 LRTP Cost Affordable Projects
Intermodal Connectivity	1	1 if Yes; 0 otherwise	Whether it is a SIS Port/Rail connectors
Freight Connectivity	1	1 if Yes; 0 otherwise	Whether it is part of the FDOT D7 Tampa Bay Regional Freight Transportation Network (Limited Access Facilities and Regional Freight Mobility Corridors only)
Projected Population density	3	High - 3, Medium- 2, Low - 1	Projected 2040 Population density, categorized into "high", "moderate", and "low" using natural breaks
Projected Employment density	2	High - 2, Low - 1	Projected 2040 Employment density, categorized into "high" and "low" using natural breaks
Percentage of Zero-Car Households	2	High - 2, Low - 1	Percentage of Zero-Car Households, categorized into "high" and "low" using natural breaks
Equity areas	1	1 if Yes; 0 otherwise	Whether it is within Environmental Justice Zones as identified by the metropolitan planning organizations
Max Total Score	23		

Table 2-2 Criticality Determination

Total Score	Criticality
5 to 10	Low
11 to 13	Moderate
14 to 20	High

Figure 2-8 Summary of Transportation Network Criticality by Counties

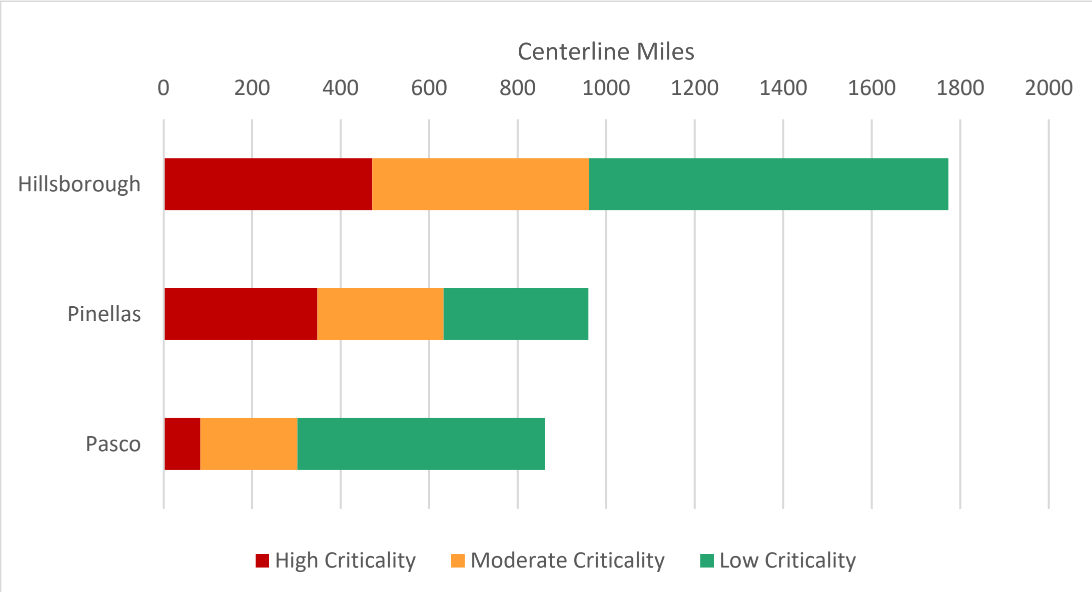
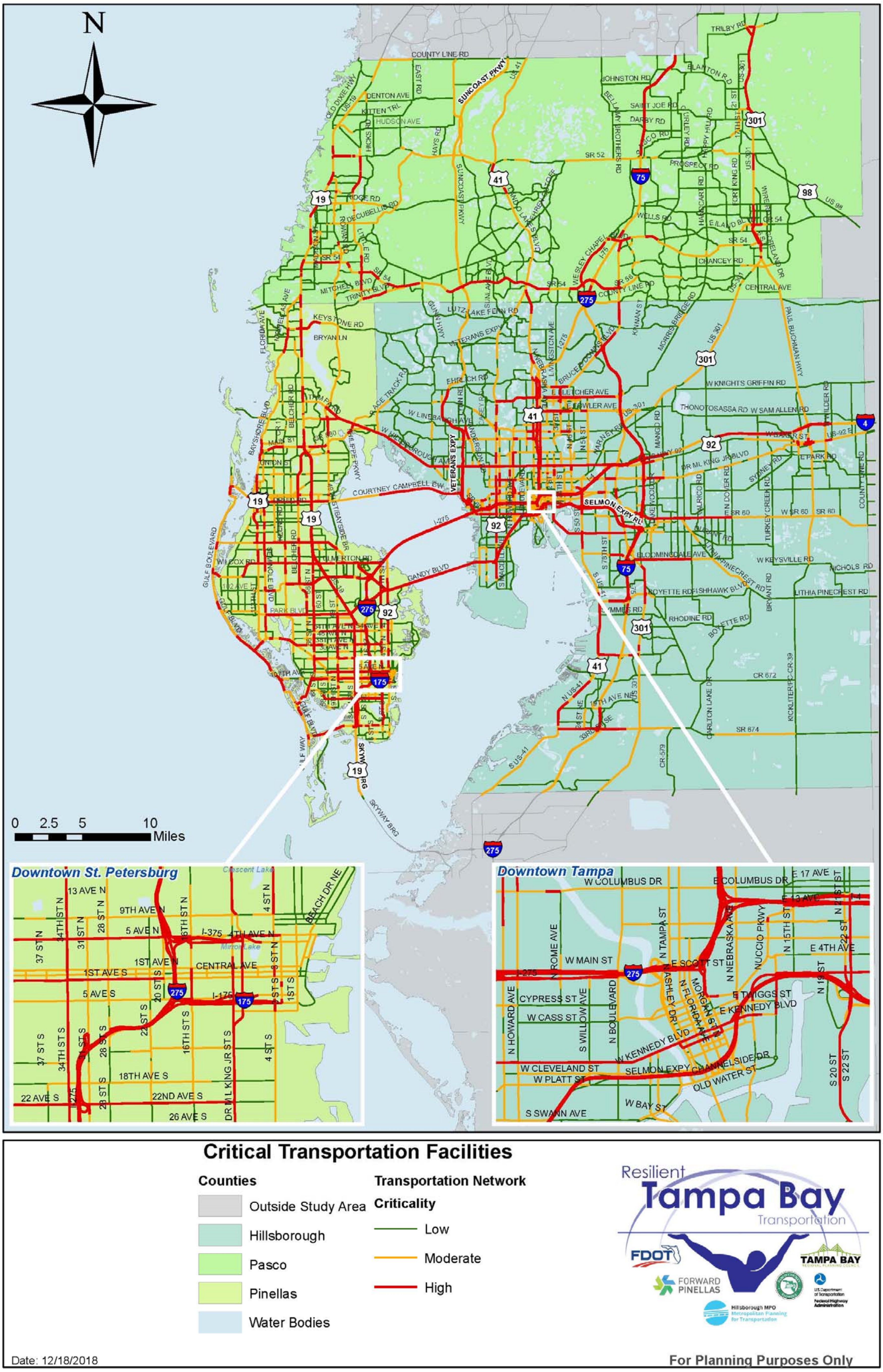


Figure 2-9 Transportation Network Criticality



2.3 Prioritization

A composite analysis was conducted to evaluate each transportation segment's resilience priority, which considered a transportation segment's vulnerability and criticality, as shown in Figure 2-10.

Working with staff in the RTBT, high resilience priority facilities are defined as transportation segments with high criticality and high or moderate vulnerability in either a Category 3 storm plus high sea level rise scenario, or a 9-inch precipitation event scenario.

Figure 2-11 and Figure 2-12 show the composite of vulnerability and criticality of transportation facilities in the Category 3 storm plus high sea level rise scenario, or the 9-inch precipitation event scenario, respectively. Facilities with both high vulnerability and high criticality are color-coded in dark purple with thick lines, these include many short segments located near the coastline, and longer segments such as US 19 in Pasco County, Gulf Boulevard and Roosevelt Boulevard in Pinellas County, Gandy Boulevard, I-275, West Hillsborough Avenue, and US 41 in Hillsborough County.

Figure 2-10 Composite Analysis: Vulnerability and Criticality

Vulnerability		Criticality: Low	Criticality: Moderate	Criticality: High
Vulnerability	High	High Vulnerability, Low Criticality	High Vulnerability, Moderate Criticality	High Vulnerability, High Criticality
Vulnerability	Moderate	Moderate Vulnerability, Low Criticality	Moderate Vulnerability, Moderate Criticality	Moderate Vulnerability, High Criticality
Vulnerability	Low	Low Vulnerability, Low Criticality	Low Vulnerability, Moderate Criticality	Low Vulnerability, High Criticality

Table 2-3 summarizes the centerline miles of transportation facilities by their vulnerability and criticality in Hillsborough, Pinellas, and Pasco counties. A detailed list of facilities with high or moderate vulnerability and high criticality can be found in Appendix D.

Table 2-3 Summary of Transportation Facilities by Vulnerability and Criticality

Centerline Miles

		Transportation Facilities (Centerline Miles)		
		Hillsborough	Pinellas	Pasco
Vulnerability - Criticality	High-High	66	80	5
	High-Moderate	35	60	13
	Moderate-High	30	62	2
	High-Low	57	61	24
	Low-High	59	79	5
	Moderate-Moderate	21	50	10
	Moderate-Low	37	64	27
	Low-Moderate	69	49	21
	Low-Low	103	68	63
	Not Impacted-High	320	128	72
	Not Impacted-Moderate	362	125	176
	Not Impacted-Low	615	134	442

Note: Centerline miles

Figure 2-11 Composite Analysis: Vulnerability and Criticality
Vulnerability based on Category 3 Storm Plus High Sea Level Rise Scenario

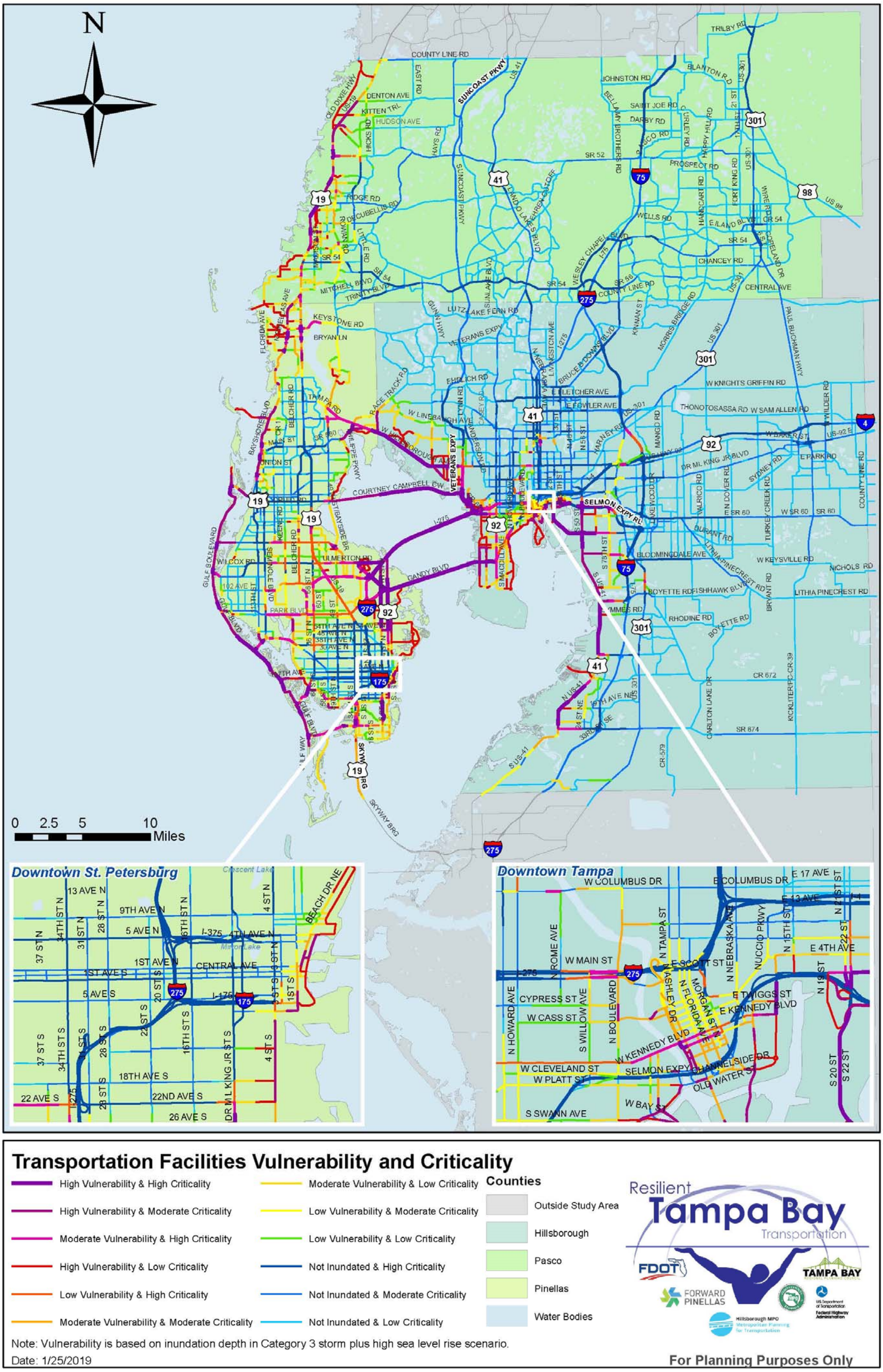
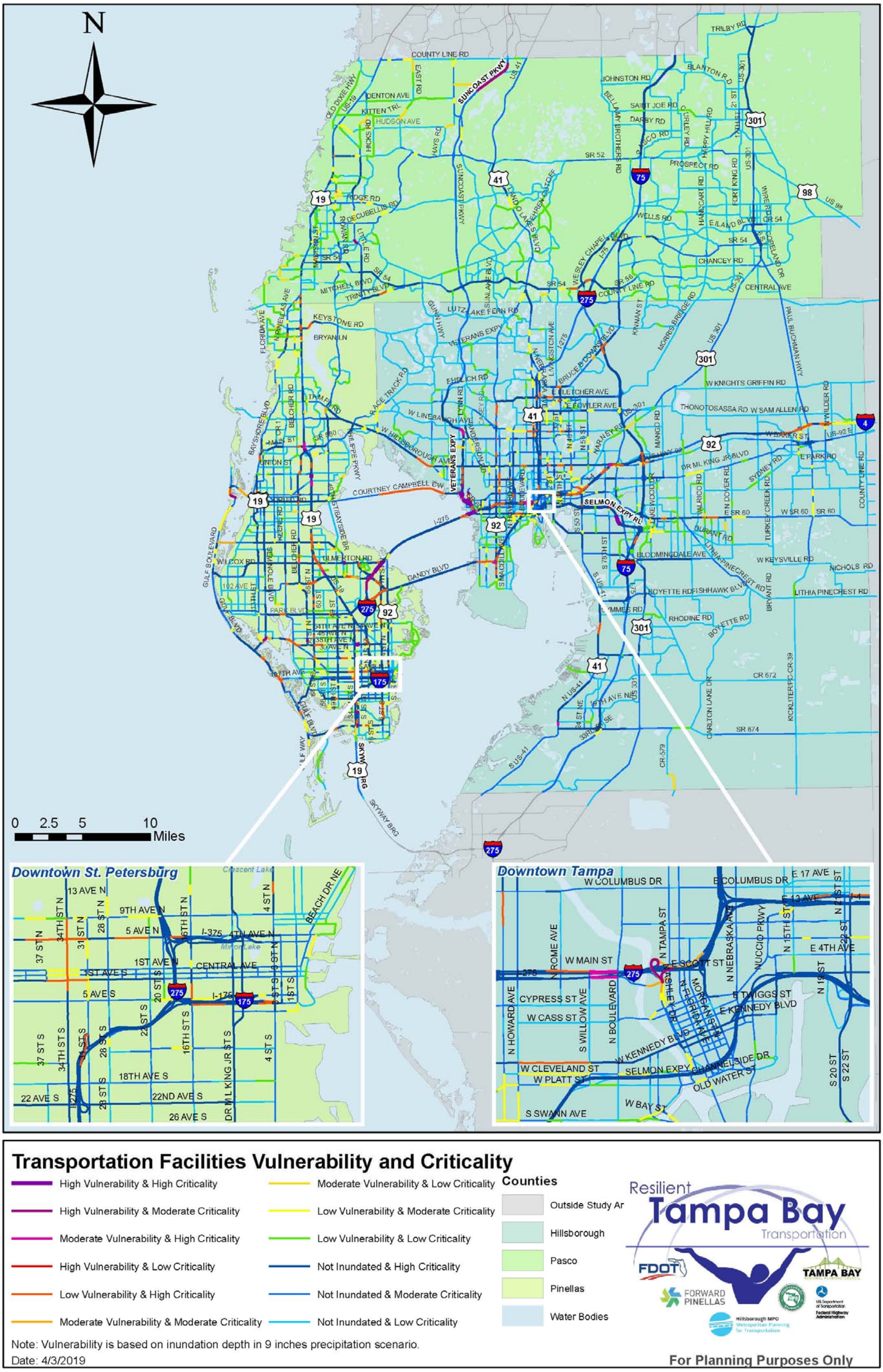


Figure 2-12 Composite Analysis: Vulnerability and Criticality
Vulnerability based on 9 Inches Precipitation Scenario



2.4 County Representative Projects

Understanding transportation asset criticality and vulnerability to key climate hazards will allow state and local agencies to integrate appropriate adaptation and mitigation measures and strategies into their planning process, project development, asset management, and day-to-day operation. To assist in meeting the new federal mandate as well as inform the LRTP updates for three MPOs and the regional LRTP, the Hillsborough MPO, Pinellas MPO, and Pasco MPO, in coordination with the Tampa Bay Regional Planning Council, and the Florida Department of Transportation District 7, selected two representative projects in each county. The selection of the representative projects considered both the corridors criticality to the region's mobility, connectivity, and emergency operations (Chapter 3), and their vulnerability to storms and heavy precipitation events (Chapter 2). Locations of representative projects in Hillsborough, Pinellas, and Pasco counties are shown in Figure 2-13. These locations will receive more in-depth analysis for adaptation strategies, economic impacts, as well as benefits and cost comparisons in the latter sections. They can serve as pilot projects and help inform project development and evaluation in other locations in the Tampa Bay region.

Hillsborough County:

- Gandy Blvd from 4th St to S Dale Mabry Hwy
- Big Bend Rd from US-41 to I-75

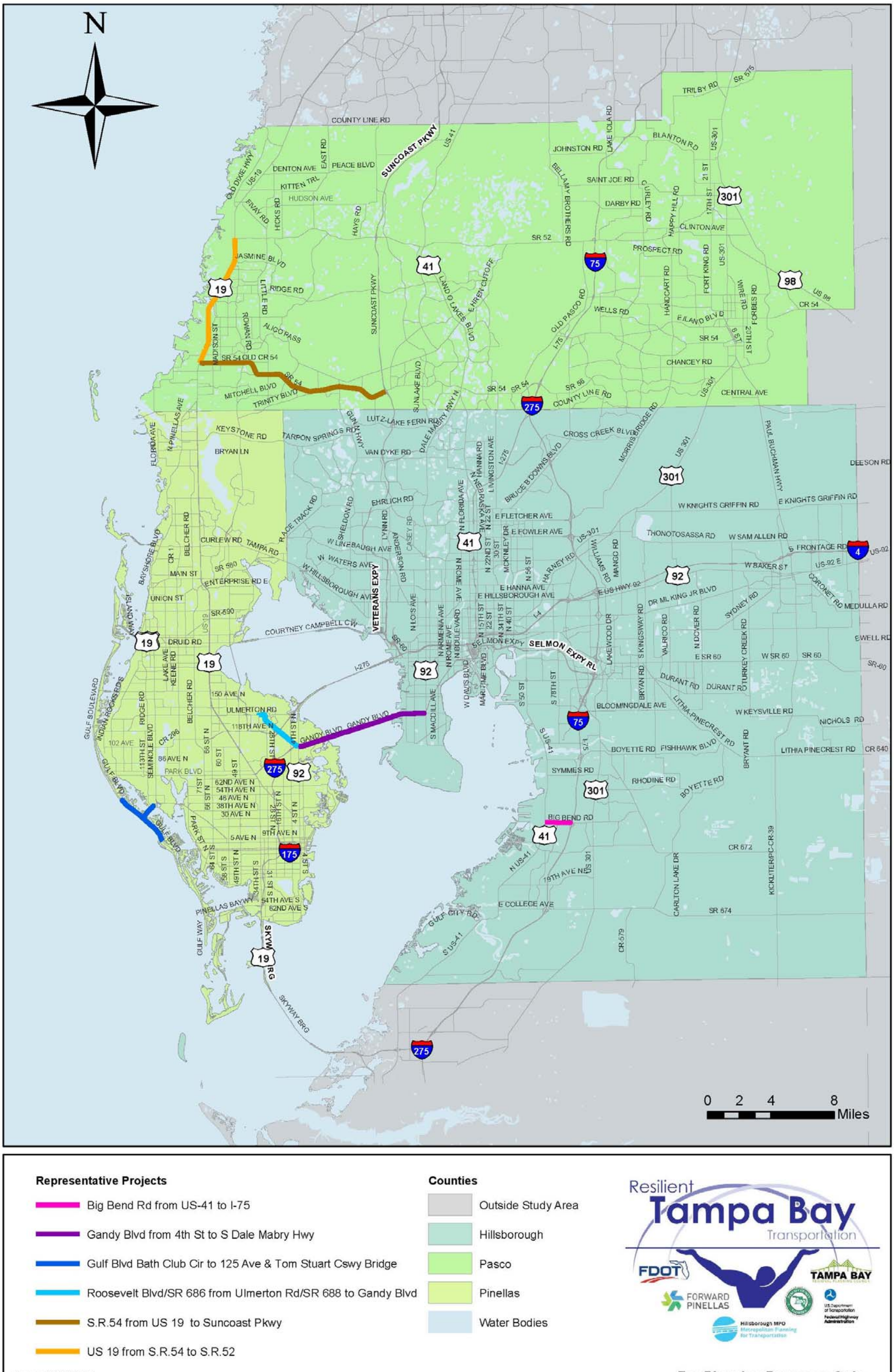
Pinellas County

- Gulf Boulevard from Bath Club Circle to 125th Ave & Tom Stuart Causeway Bridge
- Roosevelt Boulevard from Ulmerton Road to Gandy Boulevard

Pasco County

- US 19 from S.R.54 to S.R.52
- S.R. 54 from US 19 to Suncoast Pkwy

Figure 2-13 County Representative Projects



3.0 Adaptation Strategy Toolbox

The options available to designers and planners for adapting to climate change in the transportation sector are composed of options from enhanced drainage to pavement improvements to more nature-based strategies. The options selected for individual cases are dependent on factors including available budget, the topography, and exposure to the specific type of impact. The challenge for planners is determining the appropriate option given the situation that the asset is confronted with in a specific time period. The transportation adaptation toolkit is designed to support this decision-making process by providing the general circumstance under which the option may be appropriate and the vulnerabilities that a specific option may seek to mitigate.

The following sections introduce each option with the following structure:

- Adaptation Summary – A brief description of the adaptation and the vulnerabilities it is usually used as a protection against.
- Appropriate Conditions – The conditions under which the adaptation should be considered.
- Limitations – A brief description of the limitations for a given solution that should be considered by a decision-making authority.

The toolkit is intended to support and guide decision-making activities. It is not intended to replace the advice and design expertise of an engineering firm. Detailed analysis of a given site may dictate that the initial toolbox recommendations may need to be altered due to restrictions of specific topography or cost considerations.

Choosing an Adaptation Option

The selection of an appropriate adaptation option(s) will depend on both budget and design parameters. In terms of budgetary considerations, adaptation options will vary considerably in terms of cost. For example, raising a road profile will potentially have a greater cost impact than enhancing the road surface. However, raising the profile may provide longer-term benefits and may be a preferred choice from a life-cycle costing perspective. In terms of design parameters, much of the selection of appropriate adaptation options will be based on the topography and surrounding development. For example, where development has occurred close to a road, the ability to widen swales or other drainage structures may be limited.

To assist in deciding between adaptation options, the table below provides the conditions under which an adaptation may be appropriate to consider, and which options may be less appropriate. In either case, the table should be used as a guideline and not as a design specification. Individual local conditions may overrule a recommendation.

The options table below lists the 12 options introduced in this manual. The table provides an indicator of which circumstance may be appropriate for each option. This does not imply that the options will be unavailable under other circumstances. Rather, it implies options where it might be preferred or practical as indicated.

Figure 3-1 Options Table

	Minimal Topography Changes	Available Median for Alteration	Minimal Clearance to the Side of the Road	Coastal or Beach Exposure	Existing Drainage Swales	Open Access on Side of Roadway	Residential or Commercial Properties
Swales or Ditches		O	X	X	O	O	
Retention or Detention Ponds			X	X		O	
Enhanced Road Surface			O				O
Enhanced Sub-Surface			O				O
Hardened Shoulders			X			O	
Raise Profile	O		X				
Permeable Pavements							O
Protected or Depressed Medians		O					
Revetments and Sea Walls				O			
Wave Attenuation Devices				O			
Beach and Dune Nourishment				O			
Vegetation (can be used in both coastal and inland scenarios)	O	O	O	O	O	O	O
O: Preferred Circumstance X: Not Applicable							

The focus of this effort is to provide adaptation options for both inundation and storm surge threats to transportation assets. The adaptations described here assume that inundation and surge threats are transient in nature and do not represent a continuous condition over an extended period as would be the case for infrastructure affected by sea level rise. As introduced above, each option is detailed with the conditions under which it should be considered and the adaptation protection it provides.

NOTE: When implementing any of these options, it is necessary to have a detailed engineering analysis done for the specific site to determine appropriate designs and applicability.

3.1 Coastal Asset Protection

The protection of coastal road assets presents multiple options depending on the placement of the asset and the desired intervention location. In addition to the hardening approach, there are multiple options that can be employed that are removed from the asset itself including offshore solutions such as breakwaters, wave attenuation devices, and onshore solutions, of which the focused solutions are beach nourishment and natural shorelines. In each case, these solutions present an opportunity to protect assets against storm surge or wave action prior to the surge reaching full velocity or depth.

Conditions

Exposure to Surge – The existing or proposed roadway is exposed to storm surge forces, from its location on the coast and the projected surge, has a depth that places the road at risk for extended inundation or severe surge forces.

Threats

Storm Surge – Coastal protections are intended to protect a coastal asset from damage inflicted by a surge event. The protection may not be complete, but it is intended to be a significant reduction from the original possibility presented by the surge event.

3.1.1 Natural Shorelines

Where possible, a natural solution should be emphasized to combat storm surge from Category 3 storms. Natural shorelines are a broad category that includes options such as vegetation, edging, sills, beach nourishment, and a combination of vegetation with sand dunes[6]. The selection of each approach is dependent on several factors including exposure, wave action, and topography. The following sections highlight two of the more common applications of natural shorelines.

[6] SAGE 2015. Natural and Structural Measures for Shoreline Stabilization, SAGE: Systems Approach to Geomorphic Engineering

3.1.2 Solution A1 – Beach Nourishment and Dune Restoration

A natural alternative to the sea walls and revetments introduced for storm surge protection is the use of sand dunes and beach nourishment. Sand dunes provide natural protection for coastal roads by providing a barrier between the roadway and the seaward ocean forces. Over time, natural processes slowly build sand dunes on coastal areas and then erode the sand dunes through storm surges and wave actions. This process continues an endless cycle if left without interference. However, coastal roads and the interference of human development to the natural processes requires this sand dune regeneration process to be increased through artificial means.

https://commons.wikimedia.org/wiki/File:Beach_restoration_device.jpg
https://commons.wikimedia.org/wiki/File:Beach_restoration_device.jpg

Figure 3-2 Beach nourishment process. Sand is being deposited on the beach from dredging operations offshore.

Although the design requirements for sand dunes is specific to the individual beach and road scenario, the process for restoring and creating sand dunes is standardized. Specifically, the process requires a barge to be anchored offshore where a temporary pipeline can then be extended from the barge to the shore. A large pump is then used to pump sand from the sea bottom through the pipe onto the beach where front-end loaders are then used to distribute the sand appropriately on the beach and where required into sand dunes.

Costs for this approach can vary widely, however a series of case histories established by coastal states[7] and coastal dune restoration guidelines[8] provide general guidelines. Specifically, these studies have

[7] California (2002). California beach restoration Study, Department of Boating and Waterways and State Coastal Conservancy, January 2002.

[8] Fournier, M., undated, 'Standards for Creating and Restoring Sand Dunes: from Massachusetts to North Carolina (ed. by Miller & Skaradek, Cape May Plant Material Center, and RPS, USDA, NRCS).

found a cost of over $700,000 per 0.25 miles of coastline. However, this approach provides a natural alternative to the other methods and can provide auxiliary benefits to the local community. These benefits are estimated at over three times the initial cost with a potential reduction of risk of 30% - 50%[9].

A recent option that is being introduced by The Netherlands is a sand engine approach that provides longer-term nourishment[10]. Further study and analysis would be required to determine the effectiveness of this approach.

(Credit: Ann Tihansky, USGS. Public domain.)

Figure 3-3 Artificial sand dunes create a barrier between coastal flooding and properties.

Benefit: The benefit of utilizing a beach nourishment approach is that it relies solely on natural materials and enhances the natural conditions and barriers that beaches provide for flooding. The extension of the beach through beach nourishment provides and extended barrier between the shoreline and populated areas. The enhanced dunes raise the profile of the barrier and provide extra protection against wave and tidal action. The combination of the solutions enhances the natural ecosystem by providing additional areas for wildlife nesting and the expansion of protected areas.

From a cost perspective, beach nourishment is relatively costly from a life-cycle perspective. The $2.8 million per mile is a cost that will be incurred on a regular basis as beach nourishment must be replenished. The frequency of this replenishment will vary depending on the frequency of storms, tidal conditions, and the extent of the beach nourishment. A planning window between 5-10 years is reasonable for incremental replenishment of the beach. However, the protection that beach nourishment provides can far outweigh these costs as many properties will gain protection as well as increasing the amount of beach available for tourism.

3.1.3 Solution A2 – Vegetation as Erosion Control

A second natural approach to reducing erosion on the seaward side of a road in scenarios where there is only minor to moderate wave or overtopping actions in conjunction with storm surge is to use vegetation as binder on the seaward slopes. Specifically, grassy vegetation and shrubs can be used to combat erosion in slight to moderate conditions. Dune grass and marsh grass have proven to be effective in

[9] Reguero, B. G., Beck, M. W., Bresch, D. N., Calil, J., & Meliane, I. (2018). Comparing the cost effectiveness of nature-based and coastal adaptation: A case study from the Gulf Coast of the United States. *PloS one*, *13*(4), e0192132. doi:10.1371/journal.pone.0192132

[10] Fast Company (2013). "This Dutch "Sand Engine" uses nature's Destructive Power to Protect From Flooding," Fast Company May 9, 2013.

reducing erosion as well as shrubs appropriate to local conditions[11]. Typically, this approach is combined with sand dune restoration to provide an additional level of stability to the sand dune structures. This approach also is locally dependent on conditions and soils that may not be appropriate for inland areas.

Benefit: Vegetation has always been a natural barrier against flooding and the effects of water flow or wave action. The root systems of plants help to bind together soils and reduces the amount of erosion that takes place during flooding events. The vegetation also helps to filter water that is entering the drainage system. The combination of these benefits serves to create a natural filtration and holding system in many different geographic conditions.

The cost-benefit for vegetation is very favorable for locations that choose to follow this path. Once the vegetation is mature, there is little maintenance that is required for the community. However, there is a period when the vegetation is first put in place that protection of the area will be required. Specifically, protection is needed using barriers to protect the vegetation and individuals to check on the plantings. This initial expenditure is offset by the long-term viability and affordability of the solution. Dunes supported by vegetation can significantly enhance the ability of the natural barrier to stay in place and better withstand tidal and storm surge forces at the coast.

Figure 3-4 Using beachgrass to control erosion of sand dunes.

3.1.4 Solution B – Revetments and Sea Walls for Direct Asset Protection

Coastal roads that are directly exposed to wave action and surge events can be extremely susceptible to erosion on the seaward side due to increased flows during surge events. The concept of hardening the seaward side is to provide protection against increased hydrologic action and specifically protect the roadbed from direct exposure to the elements. To accomplish this protection, the seaward side of the

[11] Western Carolina (2009). Principles of Property Damage Mitigation, Western Carolina university, http://www.wcu.edu/coastalhazards/Libros/, Last reviewed, November 2009.

road embankment will be hardened using a revetment or seawall that is placed along the slope where exposure to water may occur[12].

The distinction between revetments and seawalls is one of functional purpose. Revetments are layers of protection on the top of a sloped surface to protect the underlying soil. Seawalls are walls designed to protect against large wave forces. They are rigid structures or rubble mound structures specifically designed to withstand large wave forces. Some types of larger seawalls such as the Galveston Seawall also protect against overtopping. These larger structures are not common in the US because they require extensive marine structural design. Rubble mound seawalls are much more common in the US. They look like revetments but contain larger stones to withstand larger waves. Because of their similarities in function, the Federal Highway Administration (FHWA) uses the two terms seawall and revetment interchangeably [13].

Figure 3-5 Example of seawall for coastal defense combined with a revetment in front to dissipate wave energy.

For revetments, the FHWA recommends a design approach based on determining a design wave and using Hudson's equation to estimate stone size for embankments subject to wave action. The fundamental philosophy is that the revetment will be efficient at absorbing non-catastrophic wave energy. Figure 5 shows a typical revetment design cross-section.

During a storm surge event, road embankments not ordinarily exposed to wave action may experience further erosion due to higher water levels. In order to prevent erosion during such extreme events, this embankment should also be armored according to a revetment design.

[12] FHWA, 2008. Hydraulic Engineering Circular 25
[13] By Credit:Public Domain, https://en.wikipedia.org/w/index.php?curid=9889940

Benefits: The benefit of a sea wall system is that it provides a time-proven solution to protecting coastal assets against many different conditions including storm surge, wave action, and tidal changes. Sea walls can also provide natural areas for sea life and protection for visitors to the shore. They have proven to be long-lasting and require minimum maintenance in comparison to other natural solutions. Seawalls are a technology that is well-studied and often the expertise that is required to construct the barriers can be found locally.

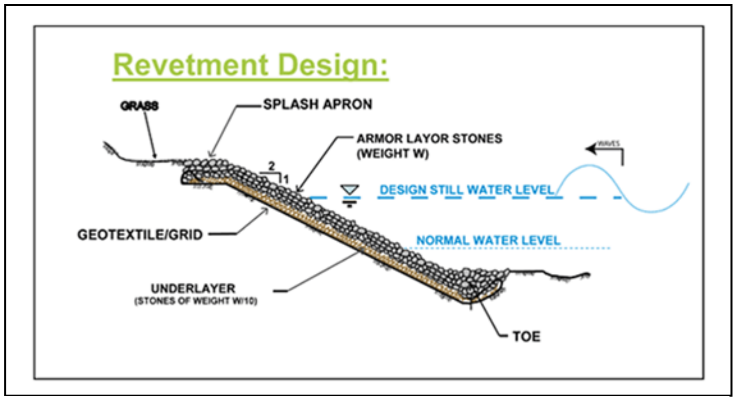


Figure 3-6 Typical cross-section of revetment after FHWA guidelines.

From a life-cycle perspective, revetments can be a significant benefit in that they require minimal maintenance over the design life if are constructed properly and built to a level that will withstand future risks. This second part is critical in terms of life-cycle costs. If the revetment is constructed to a level that does not anticipate future threats, then overtopping can start to occur and create damage to the top of the structure. Therefore, proper design analysis is required to ensure the seawall meets its required design life.

3.1.5 Solution C – Wave Attenuation Devices

In contrast to a revetment which is a direct-asset protection strategy, wave attenuation devices (WADs) can be used to protect on-shore infrastructure from an offshore location. WADs reduce the force of waves striking the coast by dissipating energy when waves encounter them. A field experiment was conducted at the Greenshores Coastal Restoration Inc. (CRI)[14] wave-attenuation-device site in Pensacola, Florida in order to quantify the wave height and wave energy reduction achieved by wave attenuation devices. Wave height and wave energy measurements were taken from an offshore area and from various locations in the protected near shore area. The field measurements show that WADs can reduce the wave height and wave energy by over 80%.

There are two main commercial types of WADs. The first type is usually made with concrete and submerged to the ocean floor and can be seen in Figure 3-7. This type of WAD has minimal impact on the live bottom due to its small footprint. Additionally, they act as an artificial reef and facilitate local fish populations. The second type is a floating WAD (Figure 3-8). Floating WADs are completely portable and do not require major construction to move.

The effective use of wave attenuation devices is dependent on the potential increase in wave activity and the subsequent storm surge in the area where the asset is located. As previous studies on wave action in the Tampa Bay region have found, the difference between the outer areas of Tampa Bay and the inner

[14] http://www.livingshorelinesolutions.com/uploads/Wave_Attenuation_Study_2007.pdf

regions is significant in terms of wave impacts[15]. However, anticipated hurricane strength and the accompanying storm surge could change this dynamic in the future.

Benefits: Wave attenuation devices are a newer defense against increased wave action in comparison to seawalls, as they provide an opportunity to protect significant lengths of coastline against major events such as hurricanes. The ability of the devices to reduce wave force prior to reaching shore is a significant benefit when considering strong wave forces that pose risks to assets.

Figure 3-7 Wave attenuation devices[16]

[15] https://tbeptech.org/TBEP_TECH_PUBS/2009/TBEP_03_09_FieldMeasurementsofWaveAction.pdf

[16] http://www.tbo.com/news/business/pyramid-key-to-saving-egmont-key-20140526/

Figure 3-8 Floating wave attenuation device[17]

3.2 Raised Road Profile

In situations where extended inundation is possible due to storm surge or precipitation events, enhancing drainage may not be enough to avoid damages to critical roads. Additionally, in areas where the topography results in a road being in a low-lying area that naturally collects water, it may be difficult or cost-prohibitive to put systems in place that remove water under inundation scenarios. Finally, there are critical roads that the area is dependent upon to serve as emergency routes. These roads must be kept accessible for the maximum amount of time possible. In all these cases, the solution may be to raise the profile of the road, or at least critical parts of the road such as an intersection, to ensure the road remains viable throughout an emergency.

Conditions

Exposure to Inundation – The existing or proposed roadway is anticipated to experience inundation due to either severe precipitation events or storm surge conditions.

Roadway Criticality – Where a roadway is considered critical and other drainage options will be insufficient, raising the profile is an option.

Adjoining Area Compatibility – A primary consideration for raising the profile is the ability for the raised roadway to connect with adjoining roads or properties.

[17] http://www.whisprwave.com/products/wave-attenuators/medium-floating-wave-attenuator/

Threats

Storm Surge – A raised profile will provide roadways protection the from surge events if the culvert culverts or other flow structures are included with the design to prevent excessive erosion due to the roadway acting as a dam structure.

Precipitation Inundation - A raised profile can protect against precipitation events by providing greater runoff possibilities and reduce or eliminate the pooling of water that will result in damage to surface and base elements.

Sea level rise and nuisance flooding - A raised profile can protect against increased flooding situations due to increases in sea level or the impacts of seasonal high tides.

3.2.1 Solution – Raise Profile

In order to analyze the benefits of elevating a roadway, the possible storm surge or other inundation scenario must be analyzed to determine the appropriate height to raise the profile. Specifically, in this scenario, the potential storm surge from a Category 3 storm must be considered as well as the length of time projected for sustained inundation. For example, if a Category 3 storm is projected to have an inundation depth of 10 feet for a period of 8 hours, then raising the profile to any height lower than 10 feet plus a safety margin would not produce the results desired for emergency management.

Avoiding permanent inundation is extremely valuable for multiple reasons. If the roadway is clear of water, this will allow for emergency vehicles to continue to use the roadway as needed. Furthermore, overtopping can cause significant stresses on the roadway due to weir flow. Therefore, understanding the potential threat of a situation is critical to designing an appropriate profile for the given road at a given location.

The final solution for raising the profile of a road will require a transportation engineering firm to look at the impact on access and egress for adjoining properties. Additionally, the design will have significant impacts on the local area drainage functionality. However, in cases where a road is critical for emergency operations, these considerations should be weighed against the essential nature of the road in facilitating emergency operations.

Benefits: Raising the profile of a road is a significant investment. However, the return for the population focuses on the significant reduction in potential damage to a road from flood events. Since roads are susceptible to both surface erosion and erosion of the road base, protection from water and flood events is a critical consideration. The raising of the road profile is intended to raise the critical vulnerabilities of the road above the threat of flood events. By channeling the water through culverts under the road or utilizing techniques to harden the roads, they can be protected from flood events and extend its lifespan.

The cost-benefit of raising the profile focuses on the comparison of projected damages and the initial cost of raising the profile. The investment cost is focused on the initial outlay for raising the profile. Subsequent to the initial cost, the maintenance of the road returns to the typical expenditures incurred with any road on an annual basis. Additionally, once the road is raised, there is no further cost that is needed to maintain the raised profile. This one-time investment can then be offset by the protection offered to the road itself as well as the surrounding structures.

3.3 Enhanced Drainage

The high water table found in Florida requires proactive drainage under normal conditions. The lack of ability to move water through natural gravity or through limited groundwater absorption requires transportation assets to be protected by retention ponds or swales that hold water away from an asset. The challenge presented by surge or increased precipitation is that the drainage structures in place may not be designed to hold the increase in water volume. In these cases, the water may settle on a roadway or begin to produce erosive qualities as it resides adjacent to the base for an extended period. The challenge for designers is to implement a solution that removes this threat.

Conditions

Minimal Topography – The area has minimal changes in topography which allows greater flexibility to arrange and expand drainage structures.

Available Expansion – There must be available space to expand the retention structures. This can be expanded swales or ditches on the side of the roadway or expanded detention/retention pond areas in open areas adjacent to the transportation asset.

Development Flexibility – The existing or proposed development must have required access or right-of-way to allow for the expansion of the structures.

Threats

Storm Surge – Enhanced drainage structures will provide a diversion of storm surge waters from transportation assets. However, the enhanced drainage will provide greater assistance in protecting against extended inundation than against the initial or return surge waters.

Precipitation Inundation – Enhanced drainage will provide protection against precipitation inundation by providing enhanced ability for draining water away from the transportation asset. Appropriate for both localized inundation threats and wider spread threats.

3.3.1 Solution A – Increased Swales or Ditches

Increasing the size of drainage swales or, in specific instances, drainage pipes, will allow the system to drain a greater capacity of water away from the roadway when combined with appropriate camber of the roadway itself. In this option, the existing drainage structures, including both ditches or piping, will need to be resized to handle the increased volume of water that is projected from the inundation or surge events. The Federal Highway Administration provides specific guidance in sizing and implementing appropriate drainage structures for specific circumstances[18]. Figure 8 shows typical structural designs based on FHWA recommendations.

---

[18] Urban Drainage Design Manual, Hydraulic Engineering Design Circular No. 22, FHWA-NHI-10-009, Federal Highway Administration

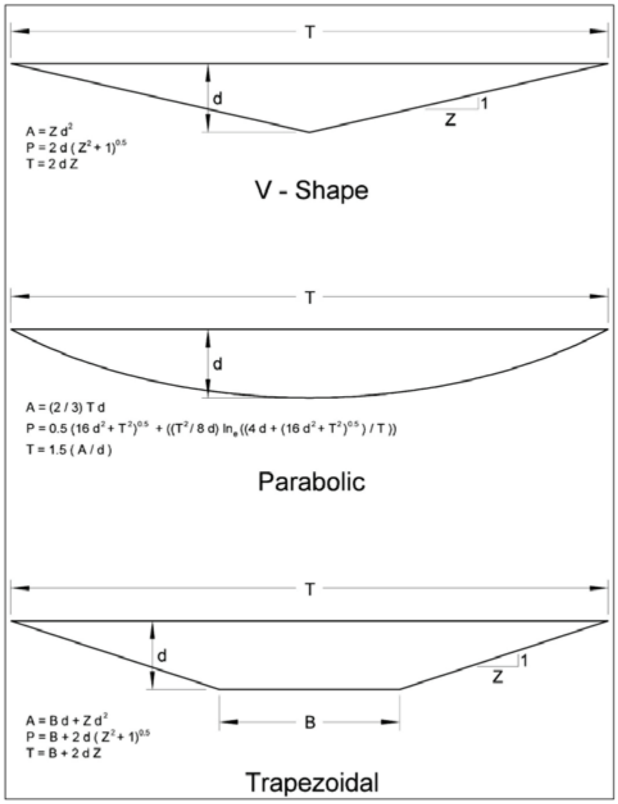


Figure 3-9 Typical design structures for drainage channels as per FHWA-NHI-10-009

http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/stormwater/biofiltration_swale.html

Figure 3-10 Example of a swale used for stormwater management from roadway runoff.

One problem associated with storm water runoff is the stability and durability of the slopes, ditches, and embankments. One identified method for preventing erosion of these earthen structures is to reinforce them with concrete surface treatments. Such treatment decreases floodwater concentration and promotes flow to designated reservoirs. One should note that ditches are used on many standard highway construction projects to control runoff from the highway surface[19] (Figure 9). Impermeable geotextile can be placed between the subbase and the subgrade to avoid such saturation. This should be coupled with a draining layer to let water flow from the subgrade to the lateral drain[20].

Benefits: Drainage swales are a traditional method for moving water away from a road base, holding water before it enters a storm sewer system, and reducing the flow of water due to a flood event. The expansion of swales provides additional capacity in the system and thus increases the protection against flood events. There are few downsides to this solution, especially in areas where water enters the system on a regular basis to reduce the opportunity for standing water to serve as insect breeding areas. In areas where there is appropriate width next to a road, swales are a preferred solution to controlling flood events.

The economic benefits of this type of solution result from a combination of the reduced damage caused by inundation and the increased control of the water flow entering the stormwater system. These benefits can be substantial in areas where regular flooding occurs, and inundation of roads is a regular threat. However, there does need to be a consideration of maintenance for swales as these structures can get filled with debris or have the drains blocked by vegetation that may grow in the swale area. This maintenance should be taken into consideration when specifying the placement of such structures.

3.3.2 Solution B – Increased Retention or Detention Ponds

"The temporary storage or detention/retention of excess storm water runoff as a means of controlling the quantity and quality of storm water releases is a fundamental principle in storm water management and a necessary element of a growing number of highway storm drainage systems."[21]

[19] Landphair H, McFalls J, Thompson D, 2000.

[20] Climate Change, Energy, Sustainability and Pavements, 2014.

[21] Urban Drainage Design Manual, Hydraulic Engineering Design Circular No. 22, FHWA-NHI-10-009, Federal Highway Administration

The control of storm water or storm surge anticipated by enhanced precipitation and storm surge scenarios will be essential in Florida due to the inability to naturally move water. In instances where greater holding capacity is required above roadside swales/piping, retention or detention ponds should be considered if the area is available to construct or expand such structures (Figure 10). The structures will provide a level of protection against inundation causing both surface and base damage including both erosion and surface damage.

As with the design of swales and channels, the FHWA provides design guidance for the sizing of pond structures. These structures can be effective in cases where large amounts of water need to be retained prior to the release into the storm water system. The projected 9-inch precipitation events are examples of conditions under which retention/detention ponds can be appropriate.

By US EPA - US Environmental Protection Agency (EPA). Washington, DC. "National Menu of Stormwater Best Management Practices: Dry Detention Ponds.", Public Domain, https://commons.wikimedia.org/w/index.php?curid=3830576

Figure 3-11 Example of a detention pond used for stormwater management from roadway runoff.

Benefits: Retention and detention ponds serve to hold water and reduce the amount of flow into storm sewers. Where there is area to install such a system, ponds have proven over time to significantly reduce flooding due to overwhelmed systems. Ponds can also serve to enhance the natural environment by providing homes to wildlife and providing resting areas for birds such as ducks and cranes as they traverse longer areas. Overall, the solution of using ponds can be extremely effective if the area required to host such a structure is available.

The cost-benefit considerations for retention and detention ponds focus primarily on initial construction costs. These structures can be a significant investment in terms of both the cost of construction as well as the land required to support the structure. However, the land utilized may not be usable without the structure as it may lay in a floodplain area that will not support structures. This balancing of considerations should be offset by the significant benefit these ponds provide in terms of holding water that could be inundating adjacent roads and property. Maintenance is required for the structures to ensure proper drainage out of the pond as well as drainage structures leading to the pond.

3.3.3 Solution C – Depressed or Raised Medians

A second potential use of medians in protecting vulnerable infrastructure is to either depress the median and use it as an equivalent to a swale on the side of the road for drainage or raise the median and use it as an additional barrier to slowing the movement of the water across the roadway. The depression of the median will provide an intermediate barrier between the two sets of traffic lanes to decrease the potential impact of flooding. The level of depression will depend on a combination of drainage requirements and safety standards. However, the depressed median can serve as an effective protection against floods moving completely across the roadway. The use of a depressed median may also require the installation of increased drainage structures such as storm sewer pipes if large amounts of water may be expected.

The raising of the median would require enhancing the depth of the base and then placing vegetation on top to provide a natural barrier to the flow of water across the roadway. This enhancement will allow the median to act as a separator between the lanes and reduce the amount of flow or depth of the water inundating the roads and entering the drainage swales. It will not eliminate the flooding, but it can reduce the amount of water entering the drainage system at one time.

Benefits: The median in a roadway can serve multiple purposes in addition to its role as a roadway divider for safety purposes. In terms of flooding, medians can serve as a barrier to slow or prevent water as it moves across the roadway. When medians are depressed, the median can serve as a holding area like a small drainage swale. This can enhance the drainage of water away from the road base and increase the rate at which the flood event is transferred from the road. When the median is raised, it serves as a barrier to assist in separating the roadway and reducing the area in which the water is in contact with the road surface. It is essentially acting like a small dam in the center of the road to prevent wider effects of the event. In extended flat areas where there is little topography to naturally prevent flood action, the median can be an effective deterrent to the effects of flooding.

The use of the median as a flood control barrier or drainage component has a long-term benefit of reducing damage to road surfaces as well as to stormwater systems. However, this approach does require annual maintenance considerations. The use of vegetation on the median requires maintenance to ensure that proper growing conditions exist as well as potential annual expenditures to augment existing vegetation. Using a depressed median to assist in drainage has similar maintenance requirements as drainage swales. Ensuring that drains are clear, and that excess vegetation does not block water drainage paths are an essential part of the success of this approach.

3.3.4 Green Stormwater Infrastructure

A second approach to addressing drainage threats is to focus on green infrastructure. This is an area that is receiving increased attention by designers and engineers as it provides both a natural approach to stormwater protection and enhances the aesthetic quality of the location where it is developed. Although green solutions are an approach to drainage, these solutions are presented here as a grouping to consider as solutions to the overall threats to stormwater drainage.

NOTE: Green infrastructure can generally be considered wherever more traditional engineered approaches are considered. Green infrastructure can replace or complement more traditional approaches.

Benefits: Green infrastructure introduces an opportunity to either combine natural landscape and vegetation with engineered solutions or to implement a natural solution to stormwater management. There are few downsides to this approach. There are primarily benefits both to the natural landscape and to introducing or reintroducing green elements to a built environment. The enhanced ability to filter water with natural plant materials, the ability to reduce flow rates, and the ability to create natural barriers in areas such as parking lots are all benefits provided by green infrastructure. There are additional maintenance costs to green infrastructure, but early implementation studies have demonstrated that life-cycle payback in benefits can outweigh the additional maintenance costs.

The cost-benefit of green infrastructure varies across case histories and locations. According to studies looking across multiple cities and projects, benefits have been an order of magnitude greater than traditional approaches and reductions in stormwater entering the system have been up to 70%[22],[23], [24] However, a common baseline through previous uses of green infrastructure is that the additional filtering provided by green infrastructure is a significant benefit for the community. Additionally, green infrastructure provides an aesthetic addition to local communities that may not be able to be quantified in traditional cost-benefit calculations. These intangible benefits need to be considered to offset the additional annual costs that may be incurred by some green infrastructure solutions. The overall consideration in terms of implementing this approach is whether the community prefers to incorporate natural materials into stormwater management and is committed to maintaining the areas during the critical first year as they become established.

Option 1 – Bioswales

Bioswales are an enhancement to traditional drainage swales. Rather than having a narrow drainage swale adjacent to a roadway, a bioswale combines the drainage swale with a natural planting area. By turning the swale into a green location, the bioswale adds several features beyond drainage functions. Specifically, the bioswales slow, infiltrate, and filter stormwater flows (Figure 12).

The use of a bioswale can be effective when the area adjacent to the roadway provides for the placement of a bioswale. Typically, a bioswale can be placed in any location where traditional drainage swales can be located. The type of vegetation used can be adjusted to local conditions.

Typical bioswale as per EPA, "What is Green Infrastructure?"

Typical bioswale with directed drainage from roadway as per Soil Science Society.

Figure 3-12 Typical bioswale

[22] Economides, Christopher (2014). "Green Infrastructure: Sustainable Solutions in 11 Cities Across the US," Columbia University Water Center.

[23] US EPA (2013). "Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs," EPA 841-R-13-004.

[24] https://www.epa.gov/green-infrastructure/performance-green-infrastructure

Planter Boxes

Planter boxes provide a green stormwater option for areas where sidewalks and development restrict the use of bioswales due to the lack of clearance adjacent to a roadway. In these areas, the insertion of a green element can slow stormwater runoff that is occurring because of impervious surfaces such as sidewalks, allowing rainwater to flow onto a street and create excess stormwater flow (Figure 13). Planter boxes collect and absorb runoff from sidewalks, parking lots, and streets and are ideal for space-limited sites in dense urban areas as a streetscaping element.

An advantage of a planter box option is that it can be designed to fit almost any location. If it has vegetation that is appropriate for the location, proper soil conditions, and was constructed to allow for appropriate water retention, a planter box can be a cost---effective means for stormwater retention.

Typical planter box as per EPA, "What is Green Infrastructure?"

Michigan Avenue bioretention planter box
Source: Tetra Tech, Inc.

Planter box with directed drainage from roadway as per Southeast Michigan Council of Governments.

Figure 3-13 Typical planter box

Green Streets

An option for green infrastructure as a tool for stormwater management when initially designing a roadway or to redesigning an existing roadway is the insertion of a green street concept. Green streets are a concept where green areas are incorporated into the design of the street or adjoining frontage or sidewalk areas. Rather than limiting the green area to an adjacent area such as in a bioswale, a green street concept incorporates the green elements directly into the streetscape. Like bioswales, the green street elements serve to filter and reduce stormwater. As illustrated in Figure 14, the green streets can be designed in accordance with the local requirements for the street design.

The Florida area provides ample opportunities to include green street concepts because of its limited topography. The Floridian landscape challenges many roadways with adjoining areas to allow for broader use of greenspace, and ample rainfall to ensure that the vegetation can survive the climate. The types of vegetation used can be customized to local conditions.

Typical green street design as per EPA, "What is Green Infrastructure?"

Typical green street with integrated sidewalks

Figure 3-14 Typical green street

Green Parking

Parking lots are a significant challenge for stormwater management. The large, impervious surfaces create conditions where high intensity precipitation events lead directly to excessive stormwater runoff. With the increasing development of commercial districts with large parking areas, the challenge of parking area runoff continues to elevate in importance. One option to consider from a green infrastructure perspective is the use of green parking concepts. In this approach, the perimeter of the parking lot is bordered with a green area. In cases where a large parking lot exists, these green areas can also be used intermittently within the parking lot (Figure 15).

A green parking concept can include multiple types of specific green infrastructure alternatives. Bioswales, planter boxes, and permeable pavers are only a few of the options that are available to the parking area developers. These options can also be inserted retroactively in existing parking areas. The green parking concept is being used effectively in many climate conditions as it provides an opportunity to combine local vegetation and design options appropriate to local conditions.

Typical green parking lot design as per EPA, "What is Green Infrastructure?"

Typical green parking area with integrated planting areas and permeable pavers as per Massachusetts Executive Office of Energy and Environmental Affairs.

Figure 3-15 Typical green parking lot

3.4 Enhanced Road Surface

Inundation and storm surge can cause multiple damage scenarios for road surfaces. Issues including wash boarding, alligator cracking, and transverse cracking are only a few of the potential impacts that the movement of water over a road surface can create (**Error! Reference source not found.**). In terms of t he subbase of a road, erosion from moving water can occur at both the base and subbase levels. Figure 3-17 illustrates a typical road subbase cross-section.[25] Enhancing the surface and/or the subbase will allow a road to enhance resistance against either inundation or water movement.

Figure 16a: Typical alligator cracking.

Figure 16b: Typical transverse cracking.

Figure 3-16 Typical alligator cracking

[25] Geotechnical Aspects of Pavements, Publication No. FHWA-NHI-10-009, Federal Highway Administration

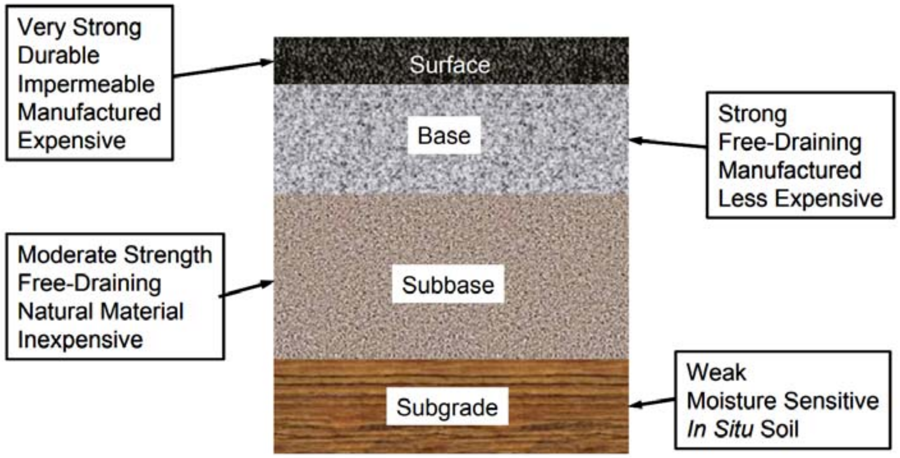


Figure 3-17 Typical design of a road and substructure as per FHWA-NHI-05-037

Conditions

Exposure to Threats – The existing or proposed roadway is exposed to either inundation or storm surge or both. In areas where minimal other protections are available such as swales, this exposure is of greater threat.

Roadway Criticality – Where a roadway is considered critical and raising the profile may be inappropriate, enhancing the roadway structure is appropriate.

Type of construction project – For a road maintenance project, enhancing layers below the surface may impact maintenance of traffic considerations.

Threats

Storm Surge – Enhanced roadway structures will provide greater resistance to the flow of water across the top of the roadway that may erode the wearing surface. Additionally, enhanced base structures will provide greater drainage capacity which will provide greater resistance to erosion caused by moving water.

Precipitation Inundation – Enhanced surface structure and base structures will provide both greater drainage capacity and greater runoff capability to resist the negative effects of standing water.

3.4.1 Solution A – Enhanced Road Surface

The road surface of a typical hot mixed asphalt (HMA) asset is comprised of several asphalt courses as shown in Figure 3-18[26]. As illustrated, the surface course of a road is designed to provide the quality of service for cars and trucks while the binder and/or base course provides structural stability. The failure of either of these courses can cause deterioration of the road and ultimately failure at an accelerated rate. As an adaptation for projected inundation, precipitation events, and storm surge, the surface course can be enhanced through additional thickness while the binder course can use enhanced materials and formulation to reduce the effects of the projected threats. A typical solution is to enhance the surface course with an additional 2" of surface course materials, or to enhance the binder course with larger aggregate that enable greater drainage to the base.

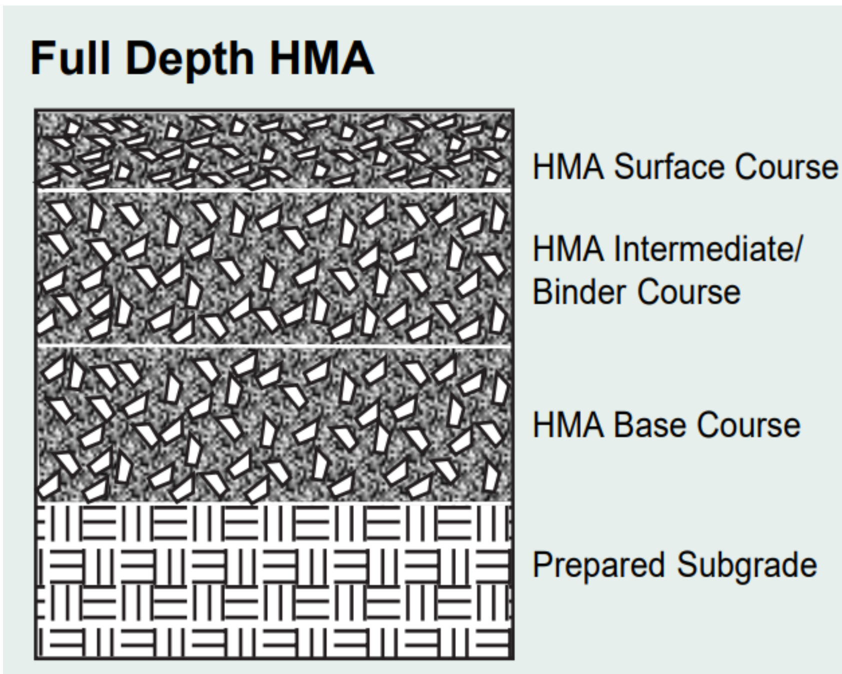


Figure 3-18 Typical design of a road structure as per FHWA HMA Pavement Mix Type Selection Guide

3.4.2 Solution B – Enhanced Sub-Surface

As illustrated in Figure 17 above, the subsurface of a road structure is composed of multiple layers to provide both structural and drainage properties for the road. In cases where inundation is projected, the length of time that the water remains on the surface of the road will reduce the projected lifespan of the road by weakening the base. Additionally, currents from storm surge can erode the base when exposed by cracks in the road surface. As a defense against these potential effects, the thickness of the subbase layers can be enhanced to both provide additional drainage, structural strength, and resistance to flow

[26] HMA Pavement Mix Type Selection Guide, National Asphalt Pavement Association, Federal Highway Administration, 2001.

damages. Recommended enhancements can include thickness enhancements from 4” to 6” depending on engineering requirements.

3.4.3 Solution C – Complete Rebuild

In some situations, where substantial improvement is planned for other reasons, a complete rebuild of a roadway should be considered. During this rebuild, options such as enhanced drainage, enhanced road surface, hardened shoulders, and an enhanced or depressed median can be considered as part of the redesign.

Benefits: Enhancing a road surface and/or subsurface provides significant benefits in terms of increasing resistance to flood and other water-related damages. The increased base depth in a subsurface provides greater opportunity for drainage as well as a greater foundation for the road surface to support vehicular traffic. In areas where significant commercial traffic exists, this enhanced foundation will allow the road to absorb the greater weight with minimal negative effects. Similarly, the increased thickness of the surface course will allow the road to resist cracking due to water infiltrating through cracks to the base. Although the cost of increasing the thickness of the base or surface layer will be an additional cost when first placed, the reduction in maintenance costs to repair cracks or potholes is a significant advantage for the local population.

From a cost-benefit perspective, the overall category of enhancing a road surface has a benefit of strengthening the road and extending its design lifespan. The overall benefit will be to reduce maintenance and ensure continuation of service. The cost-benefit of this approach is summarized by the value of a functioning road system to the public. Historically, industry has seen an 18% savings in production costs for every dollar invested in roads[27]. Retaining design lifecycle to ensure continued serviceability is the underlying focus for enhancing road surfaces.

Depending on the combination of solutions selected, the degree of enhancement to design lifespan will vary. For example, if the road surface itself is enhanced, there is increased surface resistance to damage, increasing the likelihood of the road reaching its design lifespan. However, this may not extend the lifespan. In contrast, enhancing the subbase or rebuilding the road with enhanced specifications, while more costly to implement, are more likely to extend the lifespan. These considerations should be included in the overall planning of the road adjustment in consideration of the priority for the project.

[27] Productivity and the Highway Network, Federal Highway Administration, https://www.fhwa.dot.gov/policy/otps/060320b/

3.5 Enhanced (Hardened) Shoulders and/or Medians

Damages to pavements and roads from surge and inundation can be reduced in specific circumstances[28] by hardening the sides or shoulders of roadways and/or of roadway medians. These protections will differ depending on whether the roadway is exposed directly to wave action from the coast or whether it is inland and requires protection from storm surge. In terms of coastal protection, the direct wave attack on the seaward side of the road requires the ability to dissipate the energy from repeated waves breaking against the side of the road. On the inland side, both the initial flow of water from storm surge and the parallel flow of water to lower spots in the road as a storm surge recedes can cause damage. Additionally, the issue of weir flow is a concern for damages. Under weir flow conditions, the road embankment acts like a broad crested weir to the incoming storm surge. As the surge exceeds the elevation water flows across the road and down the landward side at super critical flows. The super critical flows scour the shoulder material and can create devastating damages. Figure 3-19 illustrates weir flow damage.

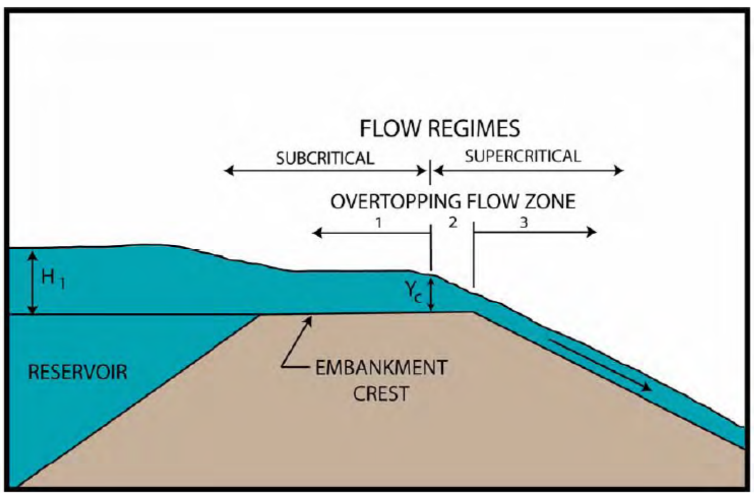


Figure 3-19 Weir flow leading to failure of embankment

In areas where an extra area of road extends with little or no topographic variation, the road may act as a natural barrier to the extension of inundation events and/or serve as an opportunity to reduce damage to the overall road by limiting inundation to one side of the roadway. Specifically, in the same manner, the shoulder or side of a roadway may be hardened using riprap, concrete, or other materials, the median of a roadway can be hardened to create a barrier or diversionary element in a critical emergency thoroughfare.

Conditions

Exposure to Surge – The existing or proposed roadway is exposed to storm surge forces either with coastal exposure or inland exposure.

[28] FHWA, 2008.

Exposure to Runoff – Where a road is elevated over the surrounding area, excessive precipitation events can cause heavy local runoff. In these cases, runoff can cause erosion to occur along the side of the road, endangering shoulders and roadways.

Exposure to Surge – The existing or proposed roadway is exposed to storm surge forces that extend across a roadway for an extended length.

Threats

Storm Surge – Hardened shoulders will provide greater resistance to surge flows, both initial and weir flows. Hardened medians provide an opportunity to divert surge flows or reduce their impact on a specific roadway.

Precipitation Inundation – Hardened shoulders will provide greater resistance to enhanced runoff that cause erosion to occur in localized areas along the roadway.

Storm Surge and Inundation – Depressed medians provide an opportunity for an intermediate barrier for water moving across a roadway.

3.5.1 Solution A – Enhanced or Armored Shoulders

The armoring of roadway shoulders and sides will vary depending on the specific circumstances. Roads which have coastal exposure should consider the use of armoring that can withstand high velocity flows. This type of armoring includes sheet piling and gabions. The sheet piling should be located on the shoulder where supercritical flows are most likely to occur. Buried gabions can be used to resist overtopping flows that may be lower but parallel to the road during a storm event. A concrete revetment system is another option to reduce erosion from overtopping. In this case, the system should be comprised of heavy blocks, vertical and horizontal interlocking cables and anchors to resist hydraulic forces from overtopping. Capabilities of interlocking blocks have been confirmed in laboratory tests[29].

Other options for coastal exposure, as well as inland areas where strong flows may be experienced, is to use natural riprap construction. In this approach, boulders or similar large elements can be used to protect the road against wave or flow actions. The size of the individual elements will be dependent on the type of exposure that the road will experience.

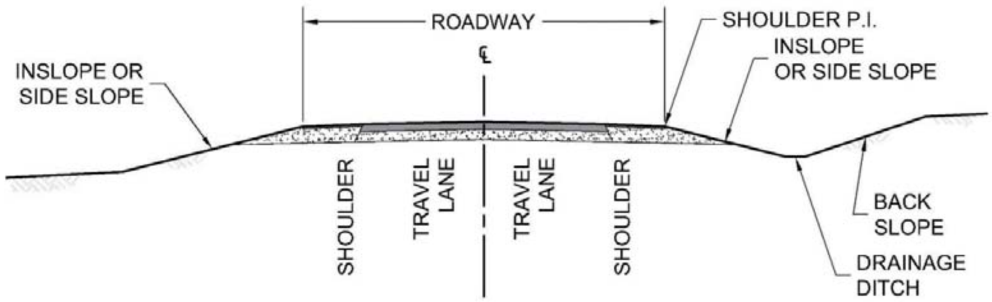
In areas where the road is inland and will experience less intense flows, hardening of shoulders may include changing the surface of the shoulder to concrete paving to enhance protection, using riprap in vulnerable areas to divert flows away from the road surface and base, and using piling in select areas to protect key points such as intersections.

Figure 3-20 illustrates the section of roadway where hardening may be appropriate for both the shoulder and the adjoining slopes[30]. Figure 20 illustrates an actual application of a soil mat to prevent erosion and harden a shoulder against water flow impact.

---

[29] FHWA, 2008.

[30] "Design Considerations for Embankment Protection During Road Overtopping Events," Marr et al, University of Minnesota, MN/RC 2017-21, 2017.



After MN/RC 2017-21

Figure 3-20 Diagram of typical roadway with shoulders and slopes where appropriate hardening materials can be placed to protect the main roadway.

Benefits: The side of a roadway is susceptible to erosion due to water either draining off the road surface or from water pooling or moving alongside the roadway. In either case, moving water is creating a situation where material can be eroded from the road base. If this action can continue without repair, then the erosion will start impacting the road foundation. This ultimately can lead to the road surface beginning to break away and down an embankment. This creates the necessity to protect the sides of the road from moving water as much as possible. The shoulder hardening accomplishes this task with minimum impact to the overall design of the road and surrounding area.

Putting appropriate drainage is a key component of retaining the design life of a road. In cases where wet conditions exist, such as in places where inundation and storm surge are prevalent, inadequate drainage can increase maintenance by 10% - 15% at a minimum. In cases where slopes, heavy traffic, or exposure to coastal impacts exist, this figure can rise dramatically due to inadequate drainage. The final number will depend on local conditions, but a general rule will be that damage numbers will tend to increase as risks continue to rise.

https://www.prestogeo.com/applications/roads-highways/road-shoulder-stabilization/

Figure 3-21 Installation of soil mats on a shoulder to reduce erosion and protect the road base against damage from water flow events.

3.5.2 Solution B – Protected Medians

The armoring of medians may be accomplished using multiple material approaches like armoring the sides of roadways. For example, a concrete revetment system comprised of heavy blocks, vertical and horizontal interlocking cables and anchors to resist hydraulic forces may be used in areas where extreme surge is anticipated and the potential to raise the median exists. Other options include the use of riprap construction where boulders or similar large elements can be used to protect the median against flow actions. The size of the individual elements will be dependent on the type of exposure that the road will experience.

In areas where the median will experience less intense flows, hardening of medians may include concrete structures to divert flows away from the road surface and base, and using piling in select areas to protect key points such as intersections.

Benefits: Medians can provide the same opportunities for protection and the same risks of damage as the side of roads. In areas where a median is depressed, opportunities exist for water to erode a road base. In these cases, additional hardening, either through rock or concrete, will reduce the ability of the water to erode roadway material. Like shoulders, hardening a median can have significant benefits with a minimum of negative impacts.

The cost perspective on medians is like that of increasing drainage. Inadequate drainage will increase erosion on the sides of the road as well as at the median. The 10%-15% increase in damage can also be seen at the median. However, the enhanced median will provide additional benefits besides the protection from erosion. The advantages to drainage and stormwater will increase as reflected in the benefits provided by swales. This dual benefit creates an advantageous scenario for medians that exceeds many other options.

3.6 Permeable Pavement

Permeable pavements, also referred to as porous pavements, are loadbearing, durable highway surfaces that have an underlying layered structure that temporarily stores water prior to infiltration into soil or drainage to a controlled outlet. The advantage of such a pavement system is that it can help to reduce runoff volume during periods of peak flow and minimize flooding. According to the California Storm Water Quality Association[31], permeable pavements have the following limitations:

Appropriate only for gentle slopes;

Can become clogged if improperly installed or maintained; and

Appropriate only for highways with low traffic volumes, axle loads, and travel speeds (< 30 mph)

These limitations make permeable pavements appropriate in limited situations. However, these pavements are receiving increased attention for their potential application and may be an appropriate solution in specific scenarios.

[31] https://www.casqa.org/sites/default/files/BMPHandbooks/BMP_NewDevRedev_Section_4.pdf

Conditions

Exposure to Inundation – The existing or proposed roadway is anticipated to experience inundation due to either severe precipitation events or storm surge conditions.

Appropriate Usage – If the inundation scenario is projected in an area which meets the limitations for the use of permeable pavements, then permeable pavements may be an option.

Threats

Storm Surge – Permeable pavement can reduce the amount of time in which the road experiences inundation from a storm surge event.

Precipitation Inundation - Permeable pavement can reduce the amount of time in which the road experiences inundation from a precipitation event.

3.6.1 Solution – Permeable Pavements

The design elements associated with the construction and maintenance of porous pavements include initial grading, paving, and excavation of up to four feet of soil. Once excavated, a sight well, stone fill, and filter fabric are installed. Finally, the area is seeded and landscaped appropriately. A schematic representation of a porous pavement design, including the major construction elements, is provided in Figure 3-22.

The benefit of this form of solution is that permeable pavement will reduce the runoff associated with traditional pavement by allowing greater drainage into the soil. The design lifespan remains the same and typical maintenance remains the same according to existing studies[32]. However, as stated previously, the load capacity of permeable pavements is less than traditional pavements thus making it usable more for side roads or parking areas rather than main thoroughfares (Figure 3-23).

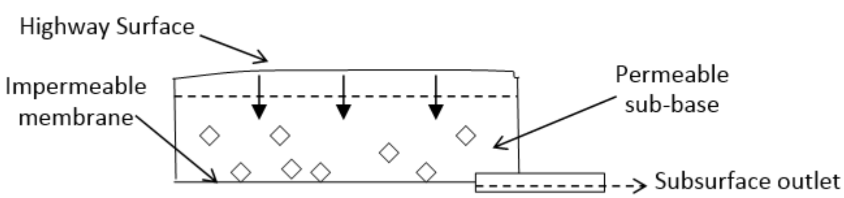


Figure 3-22 Typical cross section of permeable pavement

[32] Virginia DCR Stormwater Design Specification No 7 http://vwrrc.vt.edu/swc/NonPBMPSpecsMarch11/VASWMBMPSpec7PERMEABLEPAVEMENT.html

Benefits: The primary benefit of introducing permeable pavements is this material allows water to drain through the pavement surface rather than redirecting it to the median or the side as in typical impervious pavements. By draining water through the surface, the road surface reduces the amount of time that it suffers damage from inundation. The challenge with this approach is that permeable pavements are not proven to be as strong as traditional pavements and are thus not used in all conditions. However, there is an opportunity to examine areas such as parking lots and other areas that incur standing water, but do not see as heavy a traffic load, to find opportunities to test this approach.

http://landscapeonline.com/research/article-a.php?number=13303

Figure 3-23 Installation of permeable pavers in a parking area to enhance drainage in a large space.

The cost-benefit of permeable pavements encompasses a broad range of elements. The most notable component of this solution is the reduction in runoff into the stormwater system. Studies have shown that runoff can be reduced by 50% in some instances[33],[34]. However, this can be very dependent on the location of the pavements, whether they are being used in a parking lot or on a roadway, and on the density of the soil beneath the pavements. The cost component of the analysis is also dependent on the location. However, the current state of studies indicates that the overall savings from reduced runoff, reduced particulates in the water, and reduced erosion will offset initial increases in cost.

[33] https://sustainabletechnologies.ca/app/uploads/2015/01/PP-Tech-Brief-Final.pdf

[34] https://stormwater.pca.state.mn.us/index.php?title=MS4_fact_sheet_-_Pervious_Pavements

4.0 Cost and Benefit Analysis

4.1 Cost Estimation of Adaptation Strategies

It is important to compare the cost and benefit when evaluating potential investments for inclusion in the LRTPs. This chapter will discuss the estimated cost of applying adaptation strategies to locations with needs and compare that with the potential economic loss of not investing in adaptation options.

4.1.1 Approach

The process of estimating construction costs for roadway improvements generally begins with an evaluation of the actual costs for similar projects in the region. Costs can be derived from reviewing historical cost databases and bid tabulations from other projects, or by estimating the labor and equipment needed to complete a specific work element. Costs were evaluated as if the adaptation strategies would be done on their own. Most likely, they will be combined with existing capacity or maintenance projects. With the cost estimation approach used here where Design, CEI and contingency are all percentages of the costs, there is very little overlap that can be saved when combining with another project.

For this planning level effort, the Florida Department of Transportation's (FDOT) cost-per-mile models were referenced where applicable. These models are frequently used to develop long-range estimates during planning stages. For scenarios involving relatively short distances, costs were developed using the FDOT historical cost database. This database is updated regularly and includes data for every construction contract executed by FDOT. City and County data were reviewed to ensure consistency.

The cost per mile values provided by FDOT are for construction only. Project costs were increased by 12% of construction costs to allow for Design and 15% to allow for Construction Engineering & Inspection

Where cost-per-mile figures were used, additional costs have been applied to allow for the fact that existing minor bridges, box culverts, traffic signals, and local agency utilities will have to be rebuilt.

Asphalt Pavement is by far the most common pavement type used in the Tampa Bay region. Portland Cement Concrete pavement does have its advantages though, and should be considered for certain applications, especially in flood-prone areas. Because of its initial lower cost, asphalt is generally specified for new construction by public agencies. It requires milling and resurfacing every 14-20 years, and that work does not create huge disruptions by affecting only the top 2-4 inches of the roadway surface. Obviously, when new development warrants capacity improvements, more significant work such as widening is included.

When analyzing life-cycle costs, concrete is not only competitive, but frequently wins. It is a much more durable pavement surface, so it does not have to be maintained (resurfaced) as often as asphalt. Furthermore, in low lying areas, when constructed with proper base and underdrains, concrete has been shown to withstand submersion better than asphalt.

For this analysis, asphalt pavement prices have been used for generation of cost estimates. Unless a roadway gets reconstructed for a significant length, concrete will not be competitive.

Right-of-way (ROW) acquisition is sometimes needed when implementing adaptation strategies, such as creating detention/retention ponds, natural shorelines, and some asset protection strategies. While right-of-way costs can sometimes be as high as the actual construction costs, the generic nature of many of the improvements that might be made across a wide variety of conditions prevent making a reasonable determination of whether additional right-of-way will be required. The common use of retaining walls has reduced the need for right-of-way acquisition on many projects, especially in urban areas. In this analysis, right-of-way acquisition cost was only included for detention/retention ponds and was estimated as 100% of construction cost for planning purposes.

Roadways that are on the fringes of urban areas, that is, those that are more likely to have been constructed or widened within the last 30-40 years, are more likely to have sufficient right-of-way to fit the needed improvements. While the right-of-way might not be as much as the agency would like, a common modification, such as constructing retaining walls to reduce or eliminate gradual side slopes, make it possible to fit the improvements within a smaller area than would have been previously required. This is possible because effective use of retaining walls reduces the impact that would occur if side slopes were to be extended at standard side slope ratios. In many cases, such as on urban arterial roadways and interstate highways in older, established areas, capacity improvements such as lane additions have been constructed without major right-of-way acquisitions using this technique. Modern retaining walls such as Mechanically Stabilized Earth (MSE) walls have become the most common method of constructing walls in tight quarters and are considerably cheaper than building cast-in-place concrete walls. The additional modifications that are required in urban areas certainly cost more than a similar project on the urban fringes, and this is reflected in the cost per mile tables published by FDOT.

Narrow coastal roads, such as Gulf Boulevard in Pinellas County, have been constrained by restaurants and other small businesses that cater to the high tourist traffic. Many of these businesses were constructed over 50 years ago, and as such, were permitted to build their facilities and parking lots close to the road. In these areas, it would not be economically or politically viable to widen or raise the roadway to make it less vulnerable to storm surge or localized flooding. For example, raising Gulf Boulevard by as little as two feet would require the reconstruction of numerous commercial entrances and parking lots.

The larger the project, the smaller the unit prices for individual items of work that make up the finished project. For example, the mobilization activities that would be required to construct a small intersection, such as equipment rental, company overhead, and other administration costs, might be like the mobilization costs of a considerably larger project. Those costs, when applied to a larger project, reduce the overall overhead cost when looked at on a per-mile basis.

The costs for projects discussed within this report have been estimated as if there will be no other construction at those sites. However, because of development in the region, and the ever-increasing need for capacity improvements, it would be beneficial for agencies to incorporate the recommendations outlined herein when considering other improvements in their capital improvement plans. Granted, the costs for a needed roadway improvement would be higher if these recommendations were incorporated, but the long-term costs, such as reduced impacts to traffic, improved drainage, and hardening of the pavement, could be worth the increased initial effort.

Costs are current, based on year 2019, so inflationary adjustments will need to be made to estimate future costs.

Table 4-1 Per-Mile Cost of Adaptation Strategies

	Solution	Cost Per Mile	Description
Coastal Protection	Beach Nourishment and Dune Restoration	$2,000,000	
	Natural Shoreline	$6,716,700	Design & Permitting & Construction (Deep water/High wake)
	Sea Walls	$1,919,000	Design & Permitting & Construction (Deep water/High wake)
	Wave Attenuation Devices	$2,000,000	per mile
	Revetments	$2,476,320	per mile
	Vegetation as Erosion Control	$15,840	per mile
Avoidance	Raise Roadway Profile	$16,127,000	Raise roadway profile 4 feet
	Raise Roadway: six-lane urban	$16,127,000	Raise profile 4 feet
	Raise Roadway: four-lane urban	$14,385,000	Raise profile 4 feet
	Raise Roadway: four-lane rural	$6,943,000	Raise profile 4 feet
	Raise Roadway: two-lane rural	$4,801,000	Raise profile 2 feet
	Raise Profile at intersections	$6,199,000	Raise profile 4 feet at major intersections for 500 feet in all directions, assume two per mile
Drainage Enhancement	Detention / Retention Ponds	$4,198,000	Include ROW cost as 100% of construction cost
	Enhanced Swales / Ditches	$2,099,000	Widen existing ditch on one side to 10-foot flat bottom with 4:1 side slopes, 6-foot depth
	Enhance Drainage on Roadside	$2,099,000	Widen existing ditch on one side to 10-foot flat bottom with 4:1 side slopes, 6-foot depth
	Permeable Pavements	$443,520	Per mile, calculated using $7/sqf, assumed 12 ft width, $84 per roadway foot
Asset Protection	Enhance Subbase	$4,536,000	twice as enhance road surface
	Enhance Road Surface	$2,268,000	Mill 1", resurface with 3 inches new asphalt, resulting in 2 inches additional pavement
	Harden Shoulders / Protected Medians	$540,000	Add soil mat on both sides, 15-foot width
	Turf reinforcement matting on shoulders	$540,000	Add soil mat on both sides, 15-foot width
	Tied block rolled mat on shoulder	$2,811,000	Add heavy duty tied block soil mat on both sides, 15-foot width
	Vegetation	$15,840	per mile

Costs for items of work not generally completed on FDOT projects were derived from other projects in the West Florida region or from material suppliers.

Costs to replace an existing road should it be damaged or compromised are similar to the per-mile and per-intersection costs listed above (see Avoidance). As such, those figures are referenced in the document for comparisons.

4.1.2 Cost Estimation of Representative Projects

In this section, all six of the demonstration projects are included with the threats and the possible interventions. Each project is provided as an example of where and how an adaptation strategy can be implemented for a specific scenario.

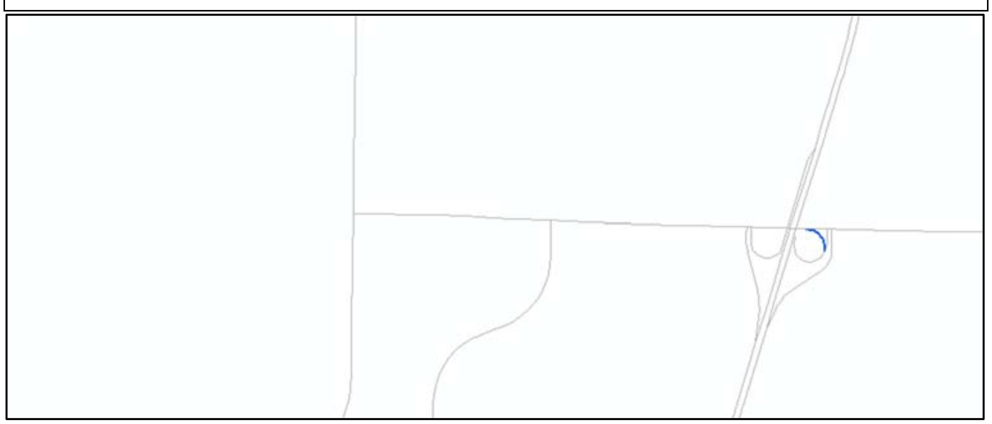
Project 1: Big Bend Road

A straight section of road with a 30’ increase in elevation from west to east, primarily in the first mile of the western end. There is low to moderate concern from a Category 3 event, limited to the western section of the road. There is opportunity for increasing the drainage on the side of the roads as there is existing drainage in place and open space on both sides of the road.

County:	Hillsborough County
Length:	1.68 Miles
Bridge Over Water:	No
Direct Exposure to Ocean:	No
Number of Lanes:	4
Surface:	Asphalt
Conditions:	Minimal topography, drainage in place, open median, tree line on sides
Concerns:	Surge creates damage to surface and base

Figure 4-1 Big Bend Road

9-inch precip event:	No direct flooding on asset
Length of flooding:	0 miles
Depth of flooding:	NA



Cat 3 high event:	Flooding on western section of asset
Length of flooding:	0.75 miles
Depth of flooding:	Low to Moderate

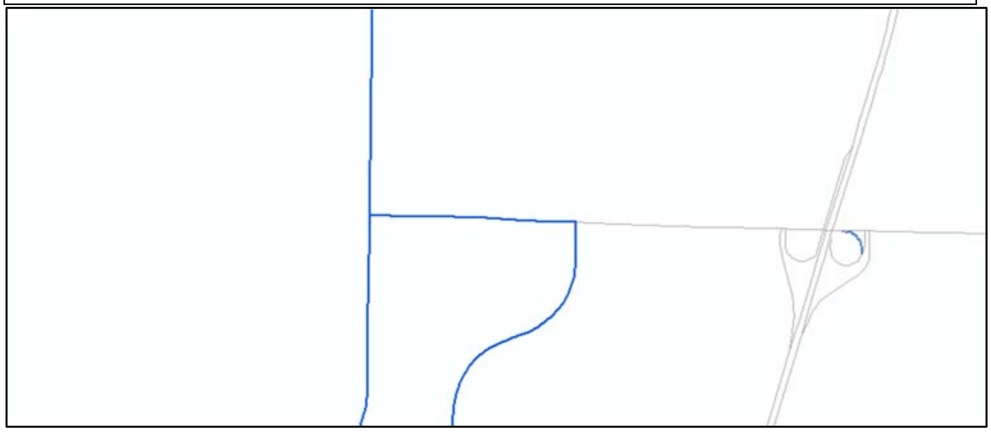
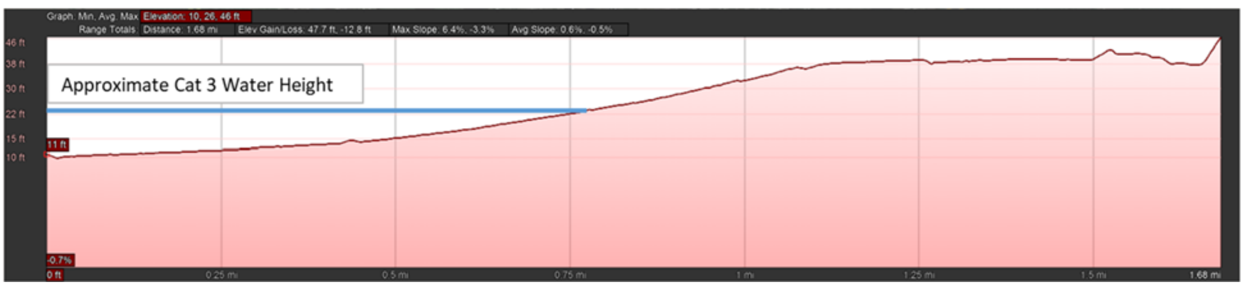


Figure 4-2 Big Bend Road Elevation Profile



Adaptation Options:

Option A: Widen existing ditch on one side to a 10-foot flat bottom with 4:1 side slopes, 6-foot depth

Cost: $1,574,000

Option B: Mill 1", resurface with 3 inches new asphalt, resulting in 2 inches additional pavement

Cost: $1,701,000

Option C: Add soil mat on both sides, 25-foot width

Cost: $405,000

Funding needed for recommended options (A+B+C): $3,680,000

The regional economic impacts of having Big Bend Road out of service for two days in the first year afterward is $6.7 million, with $2.9 million and $3.3 million benefitting Hillsborough and Pinellas Counties, respectively. (See Table 4-7.)

Project 2: Gandy Boulevard

Two approaches to the Gandy Blvd bridge are highly vulnerable to flooding from both a precipitation event and a Category 3 hurricane event. The project focuses on 8.35 miles of road that covers both approaches to the bridge. Studies are planned to investigate replacing the bridge structure and associated studies and cost estimating could require water flow modeling for pier and structure requirements. For these reasons, incorporating bridge replacement was not feasible. Due to considerations required to raise the profile of the bridge, the preferred option to address the threats is to raise the profile of Gandy Boulevard approaches and not the bridge itself. The costs of raising a replaced bridge are like the costs of replacing the bridge.

County: Hillsborough and Pinellas

Length: 8.35 Miles. Cost to replace the bridges are not included

Bridge Over Water: Yes

Direct Exposure to Ocean: Yes

Number of Lanes: 4

Surface: Asphalt

Conditions: Low profile at entrance to bridge. Minimal deviation to inundation potential.

Concerns: Weakening of base due to flows, extended inundation due to low profile

Figure 4-3 Gandy Boulevard

9-inch precip event:	Flooding on both bridge approaches
Length of flooding:	3.25 miles
Depth of flooding:	Low

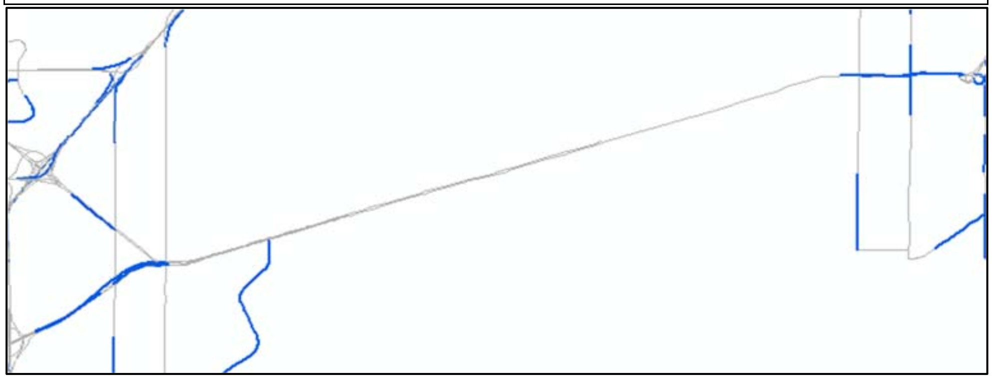


Figure 4-4 Gandy Blvd Elevation Profile – Western Approach

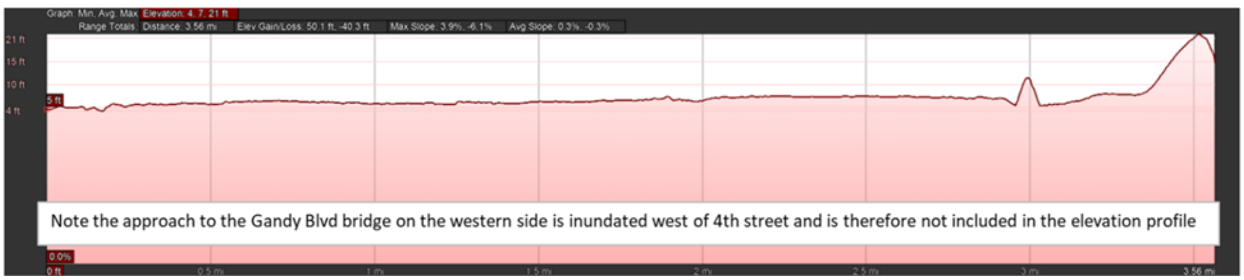
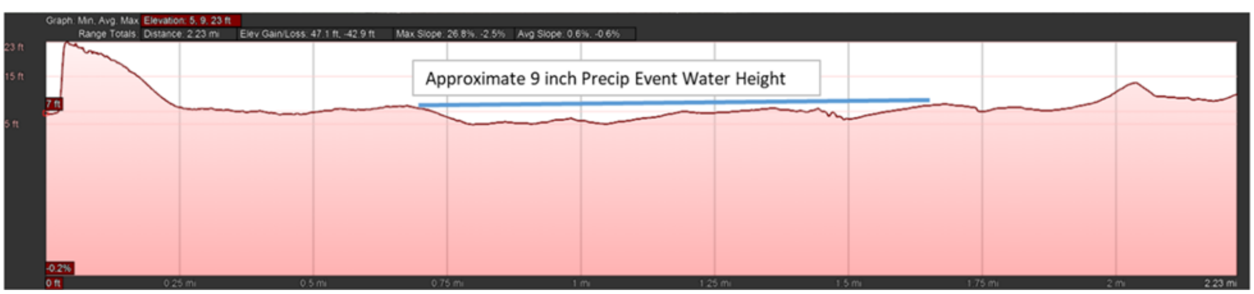
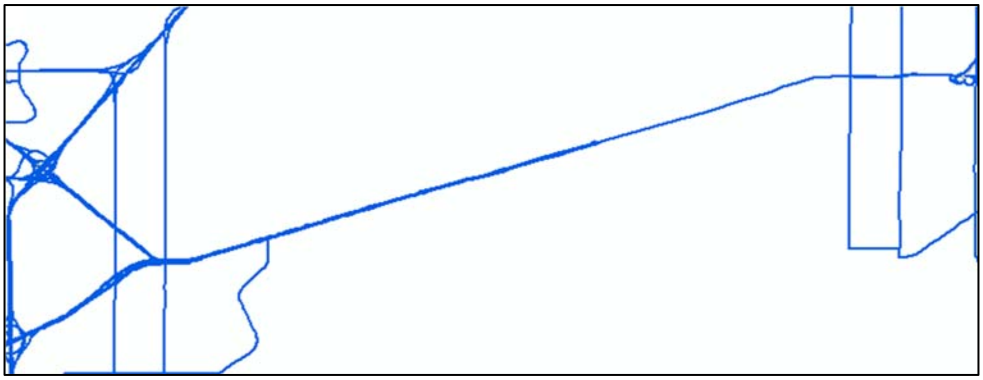


Figure 4-5 Gandy Blvd Elevation Profile – Eastern Approach



Cat 3 high event:	Completely flooded
Length of flooding:	8.35 miles
Depth of flooding:	High



The Cat 3 High sea level rise profile is not provided because the project is completely inundated.

Both approaches have areas with elevations of approximately 5 feet.

Adaptation Options:

Option A: Raise roadway profile by 4 feet near bridge entrances

Cost: $46,751,000

If the bridges are reconstructed as two separate projects, assume each project will cost 70% of the total, or $32,726,000

Option B: Widen existing ditch on one side to a 10-foot flat bottom with 4:1 side slopes, 6-foot depth

Cost: $6,822,000

Option C: Add soil mat on both sides, 25-foot width, and consider wave attenuation devices

Cost: $1,755,000

Funding needed for recommended options (A, constructing in two phases): $74,029,000 (bridge replacement costs are separate)

The regional economic impacts of having Gandy Boulevard out of service for two days in the first year afterward is $223 million, nearly three times the costs of adjusting the profile for the bridge approaches. Approximately $106 million, $110 million, and $14.1 million in benefits would accrue to Hillsborough, Pinellas and Pasco Counties, respectively. (See Table 4-8.)

Project 3: Gulf Boulevard

A 4.95-mile stretch of road running along the coast in Pinellas County. The road is primarily flat and adjacent to seashore properties. The road is vulnerable to flooding from a precipitation event along two sections that span 0.67 miles. However, during a Category 3 event, the entire length of road is subject to inundation. The adjacent development creates a minimal number of options for protecting the road by raising the profile or enhancing the shoulders. This is a good opportunity to examine a natural shoreline approach where beach nourishment and dunes could provide needed protection. Both Gulf Boulevard and the Tom Stuart Causeway have similar characteristics and similar suggested adaptation strategies.

County: Pinellas

Length: 4.95 Miles

Bridge Over Water: Yes

Direct Exposure to Ocean: Yes

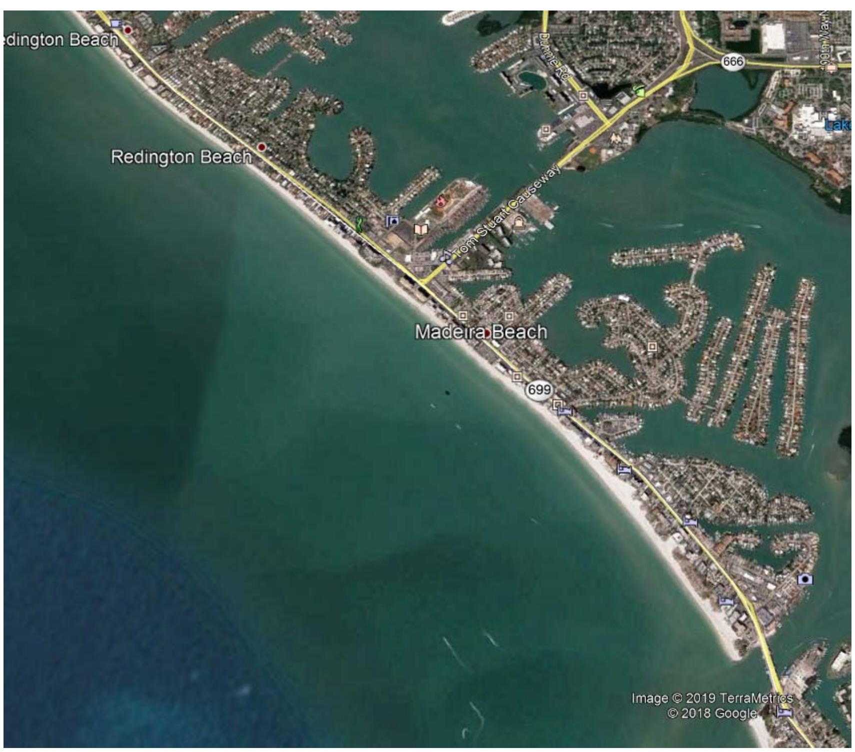
Number of Lanes: 4

Surface: Asphalt

Conditions: Built-up areas on both sides of road, flat topography from beach to shopping areas

Concerns: Minimal opportunity to enhance road due to topography and development

Figure 4-6 Gulf Boulevard



9-inch precip event:	Flooding in 2 sections (east on Tom Stuart causeway and southern section on Gulf Blvd)
Length of flooding:	0.67 miles
Depth of flooding:	Low

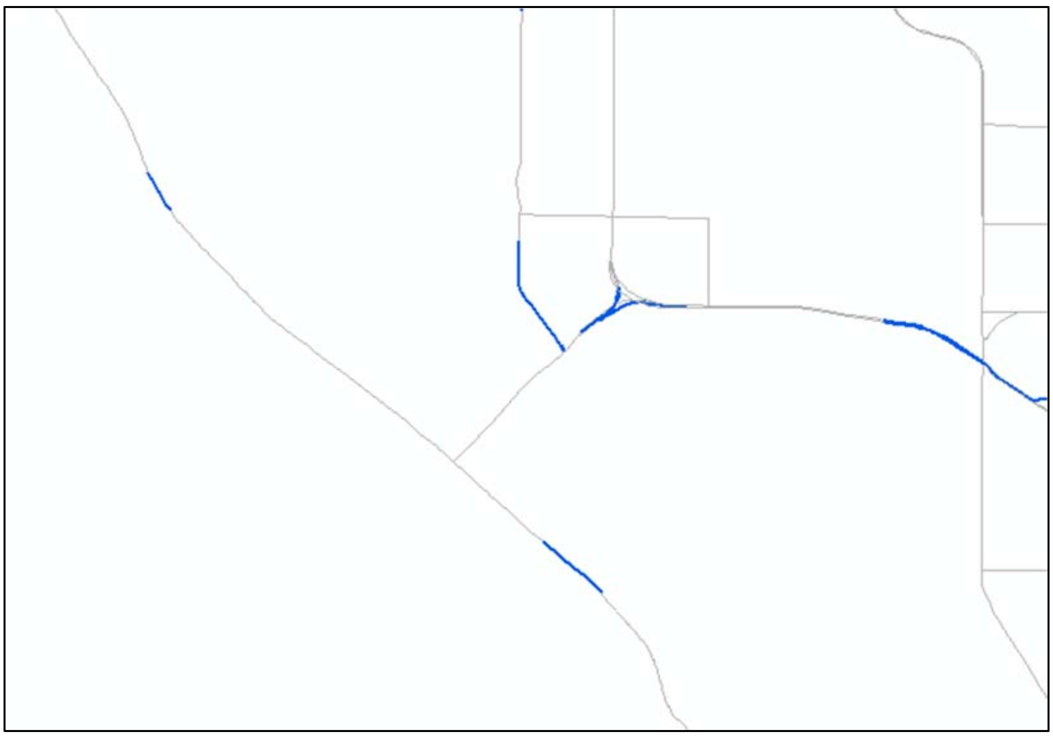
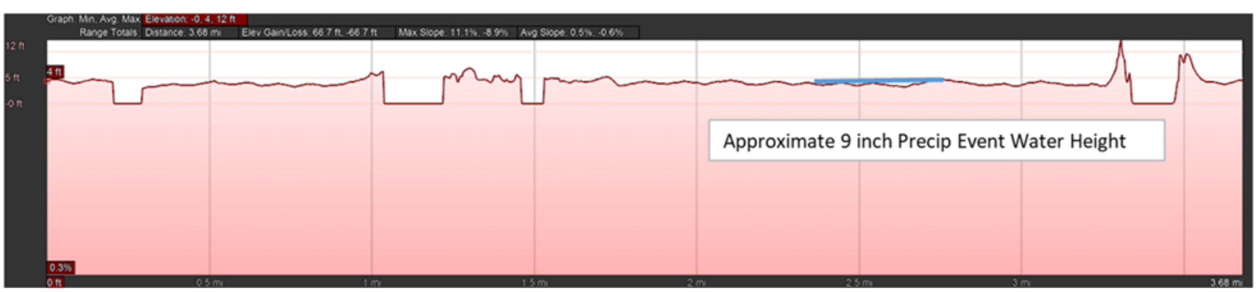
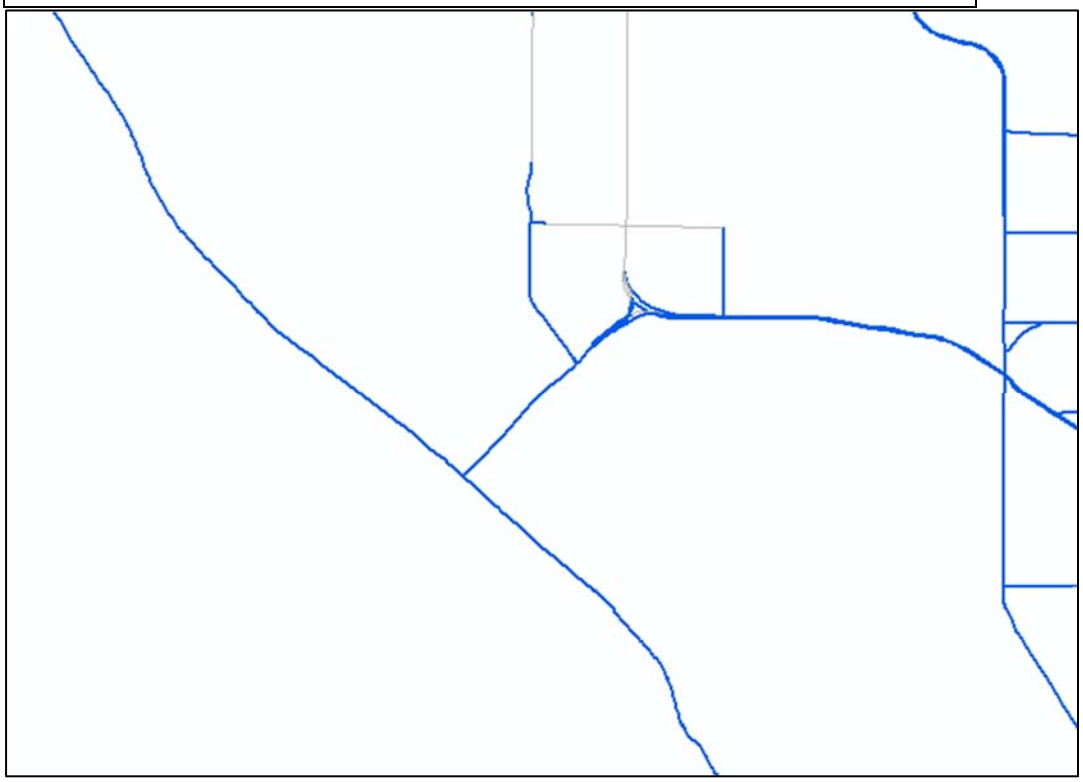


Figure 4-7 Gulf Blvd Elevation Profile



Cat 3 high event:	Completely flooded
Length of flooding:	4.95 miles
Depth of flooding:	High



The Cat 3 High sea level rise profile is not provided because the project is completely inundated.

Adaptation Options:

Option A: Consider natural shoreline options such as beach enhancement to provide topographic protection

Cost: $9,900,000

Option B: Adding cross drains (assume 36-inch pipes, 5 per mile) and widening swales where there is available space.

Cost: $2, 483,000

Option C: Wave attenuation devices

Cost: $9,900,000

Funding needed recommended options (A +B): $12,383,000

The regional economic impacts of having Gulf Boulevard out of service for two days in the first year afterward is $25.5 million, nearly double the costs of recommended adaptation strategies. Approximately $4 million, $13 million, and $9 million in benefits would accrue to Hillsborough, Pinellas and Pasco Counties, respectively. (See Table 4-11.)

Project 4: Roosevelt Boulevard

A 2.86-mile stretch of road with a slight downward slope from northwest to southeast. The road runs through an area with open space on both sides for much of its length. It also encompasses two primary intersections. The road is highly vulnerable to inundation from a Category 3 event with minimal flooding projected from a precipitation event. The focus on a temporary event such as a hurricane makes the road a good candidate for enhancing the road surface. There are additional opportunities to widen the drainage areas and complement the road surface hardening.

County: Pinellas

Length: 2.86 Miles

Bridge Over Water: No

Direct Exposure to Ocean: No

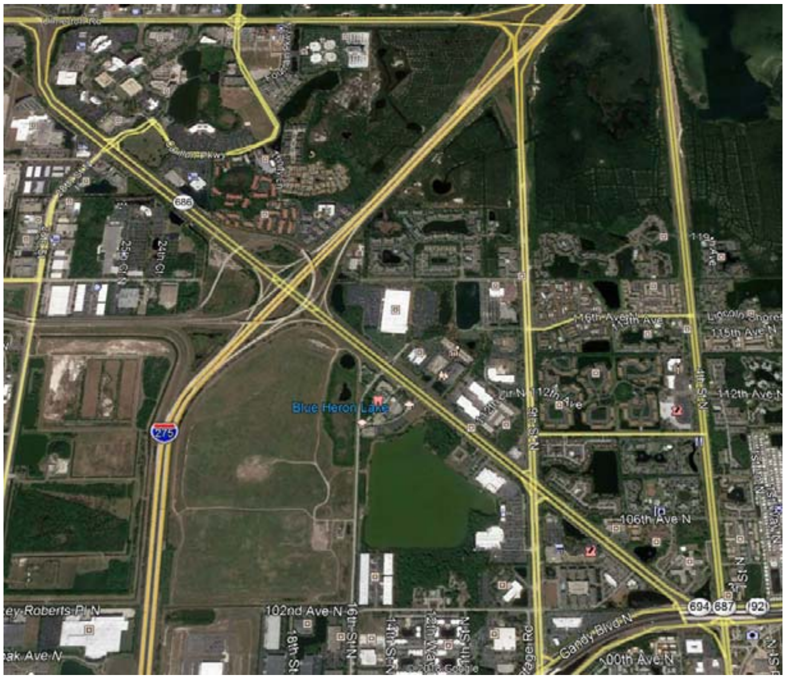
Number of Lanes: 4

Surface: Asphalt

Conditions: Low profile along road, minimal median protection, drainage swales in several places

Concerns: No protection against surge or inundation damage

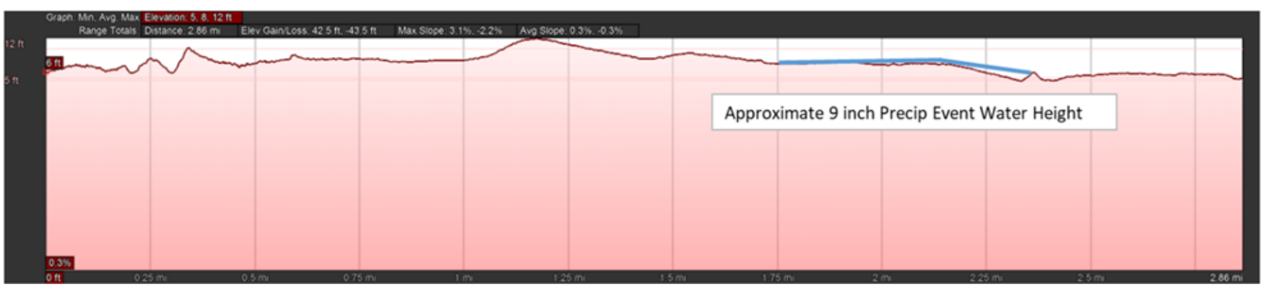
Figure 4-8 Roosevelt Blvd



9-inch precip event:	Flooding in 2 sections (intersection with Ulmerton and between 9th and 275)
Length of flooding:	0.87 miles
Depth of flooding:	Low

Cat 3 high event:	Completely flooded
Length of flooding:	2.86 miles
Depth of flooding:	High

Figure 4-9 Roosevelt Blvd Elevation Profile



The Cat 3 High sea level rise profile is not provided because the project is completely inundated.

Adaptation Options:

Option A: Mill 1", resurface with 3 inches new asphalt, resulting in 2 inches additional pavement

Cost: $6,486,000

Option B: Widen existing ditch on one side to 10-foot flat bottom with 4:1 side slopes, 6-foot depth

Cost: $6,003,000

Option C: Raise median and add soil mat to protect from erosion

Cost: $3.938,000

Funding needed for recommended options (A+B+C): $16,427,000

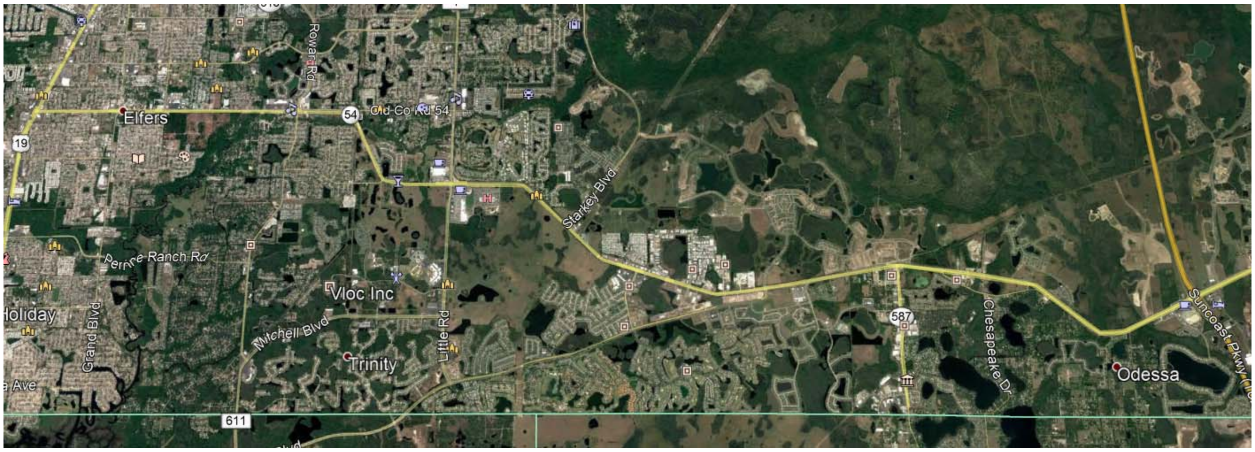
The regional economic impacts of having Roosevelt Boulevard out of service for two days in the first year afterward is $4.9 million, is approximately one fourth the costs of recommended adaptation strategies. Approximately $2.7 million, $1.3 million, and $0.8 million in benefits would accrue to Hillsborough, Pinellas and Pasco Counties, respectively. (See Table 4-12.) The economic benefits indicate implementing a single strategy might be more cost effective. Stormwater related improvements, such as Option B and Option C, could provide community benefits for many more less intense storms than a Category 3 hurricane or 9-inches of rainfall. The benefits of the adaptation strategies shown here reflect a single event only.

Project 5: S.R. 54

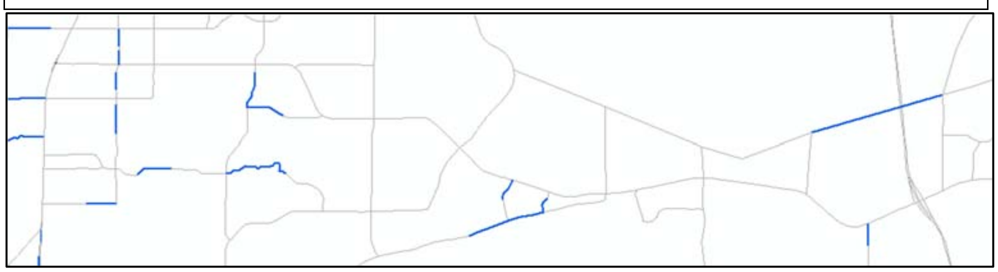
S.R. 54 is a 12.8-mile stretch of road that goes through several elevation changes, varying from a low of 30' to a high of 65' over its distance. The extended length of the road travels through multiple land uses from highly developed residential areas to open areas. This leads to a variety of potential interventions, each of which may be more viable at different areas. In terms of vulnerability, the road is primarily at risk from a Category 3 event in the more populated area around Seven Springs Boulevard At this intersection, it may be most appropriate to widen existing drainage ditches to reduce the threat from a hurricane event. However, it is also appropriate to think of solutions that may be appropriate going forward such as using vegetation or green infrastructure to reduce the vulnerability of areas that may be developed at a future time.

County:	Pasco
Length:	12.80 Miles
Bridge Over Water:	No
Direct Exposure to Ocean:	No
Number of Lanes:	6
Surface:	Asphalt
Conditions:	West end has commercial areas, but large open areas on both sides. Evidence of road wear on asphalt
Concerns:	Little protection from inundation and surge in any area

Figure 4-10 S.R. 54



9-inch precip event:	No direct flooding on asset
Length of flooding:	N/A
Depth of flooding:	N/A



Cat 3 high event:	Flooding east and west of intersection at Seven Springs Blvd
Length of flooding:	0.97 miles
Depth of flooding:	Low

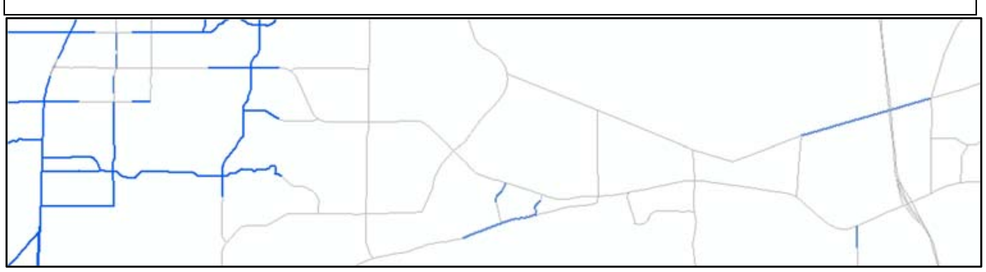
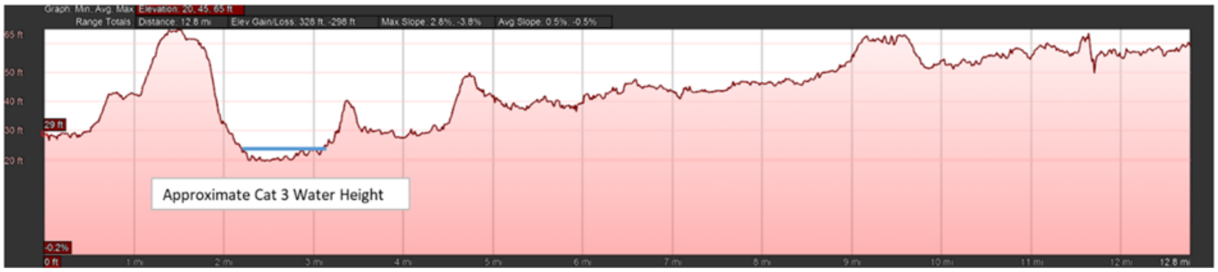


Figure 4-11 S.R. 54 Elevation Profile



The 9-inche precipitation profile is not provided because the project has no direct flooding in this scenario.

Adaptation Options:

Option A: Mill 1", resurface with 3 inches new asphalt, resulting in 2 inches additional pavement

Cost: $6,486,000

Option B: Widen existing ditch on one side to 10-foot flat bottom with 4:1 side slopes, 6-foot depth

Cost: $6,003,000

Option C: Raise median and add soil mat to protect from erosion

Cost: $3,938,000

Funding needed for recommended options (A+B+C): $16,427,000

The regional economic impacts of having SR 54 out of service for two days in the first year afterward is $5.1 million, is approximately one third the costs of recommended adaptation strategies. Approximately $2.5 million, $1.8 million, and $0.8 million in benefits would accrue to Hillsborough, Pinellas and Pasco Counties, respectively. (See Table 4-10.) SR 54 is a large project with different characteristics in the west and east. Refining the project into smaller segments would likely show cost effectiveness in the western areas. The eastern area of SR 54 is in a development phase and has an opportunity to implement transportation infrastructure to address potential perils of storms, so that future retrofits are not needed.

Project 6: US 19

U.S. 19 is a road segment of 8.45 miles that runs along an inland waterway, adjacent to properties that face the waterway. The road has a drop of elevation of about 15’ from the north to the south. There is little protection in place to guard against a Category 3 hurricane and a precipitation event. Development along the road limits the options that may be implemented without incurring additional charges for impacting locally developed areas. However, the potential flooding makes raising the profile of the road a viable alternative to protect it as well as adjacent properties.

County: Pasco

Length: 8.45 Miles

Bridge Over Water: Yes

Direct Exposure to Ocean: No

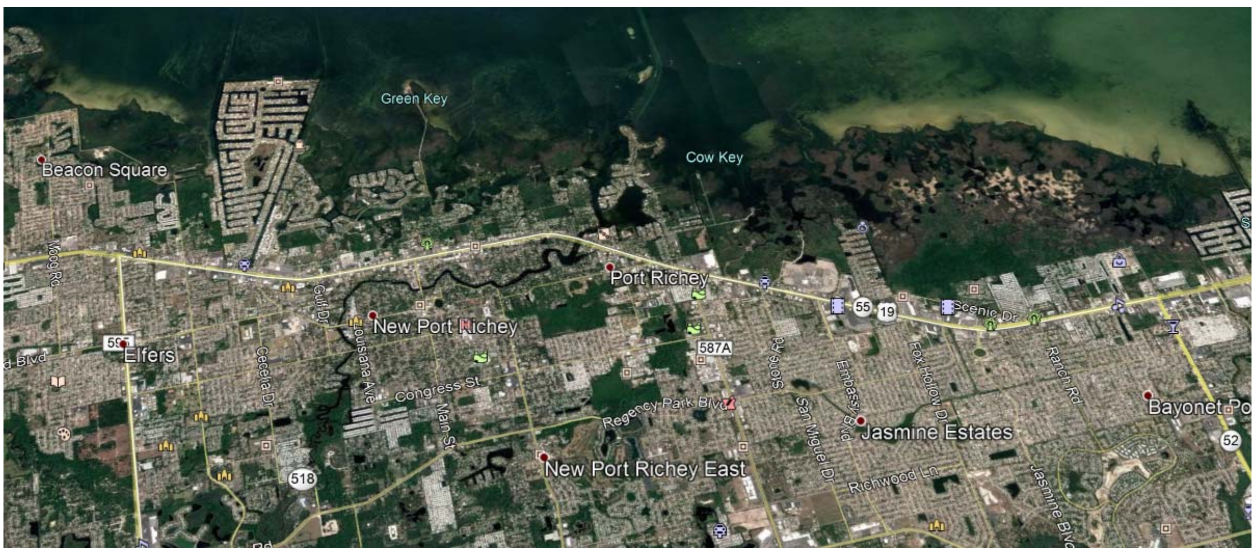
Number of Lanes: 6

Surface: Asphalt

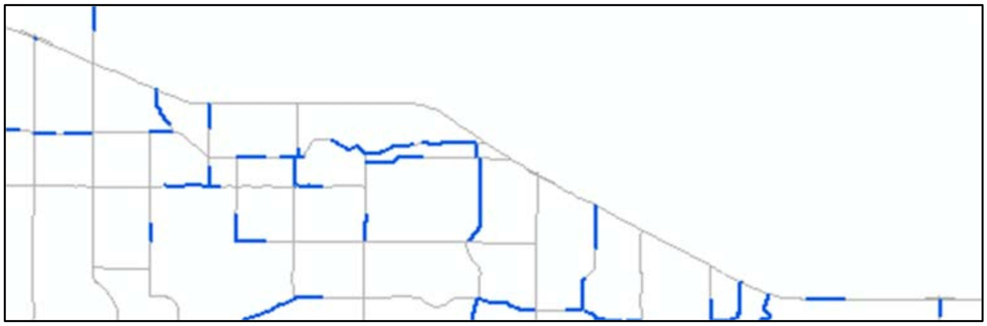
Conditions: Both sides of road have light commercial development. West side is open to residential areas

Concerns: Very little protection in place. Wide streets and corridors provide little protection.

Figure 4-12 US 19



9-inch precip event:	Flooding in northern section between Jasmine Blvd and 52
Length of flooding:	0.67 Miles
Depth of flooding:	Low



Cat 3 high event:	Completely Flooded
Length of flooding:	8.45 miles
Depth of flooding:	High

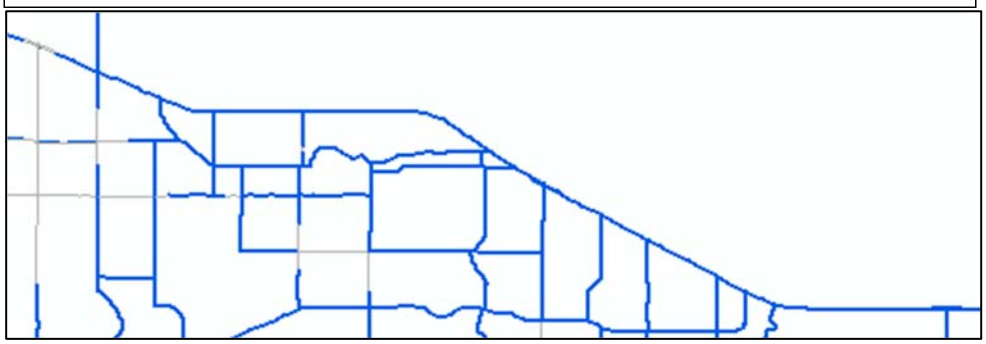
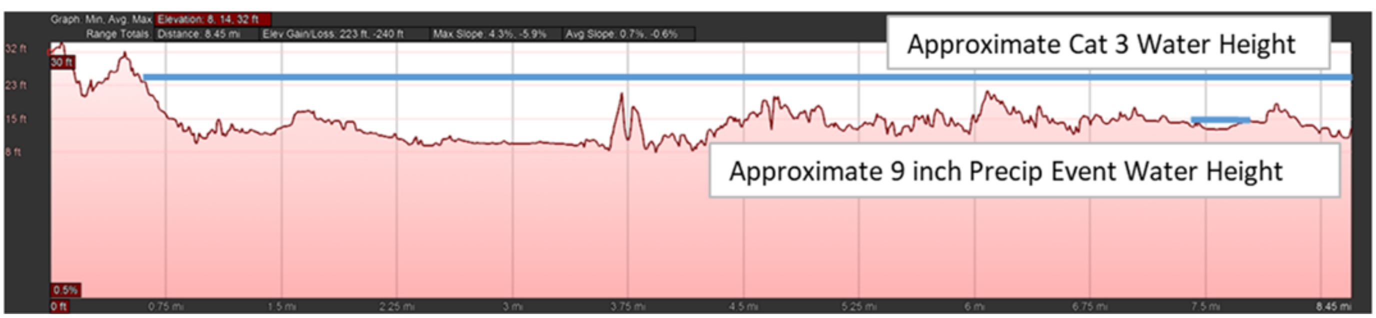


Figure 4-13 US 19 Elevation Profile



The Cat 3 High sea level rise profile is not provided because the project is completely inundated.

Adaptation Options:

Option A: Add soil mat on both sides, 25-foot width and raise profile of roads.

Cost: $136,273,000

Option B: Another option would be to enhance the natural shoreline.

Cost: $16,900,000

Option C: Add soil mat on both sides, 25-foot width

Cost: $4,563,000

Option D: Raise profile 4 feet at major intersections for 500 feet in all directions, assume two per mile.

Cost: $49,582,000

Funding needed for recommended options (A): $136,273,000

Raising the profile of US 19 is a major project that may be difficult to fund. As such, an alternate project would be the raise the intersections first and later raise the segments. As such combining options (B+C+D) for a cost of $71,045,000 is an alternate consideration.

The regional economic impacts of having US 19 out of service for two days in the first year afterward is $25.6 million, is approximately one fifth the costs of recommended adaptation strategies and less than one third the costs of the alternate recommendation. Approximately $4.2 million, $12.8 million, and $8.6 million in benefits would accrue to Hillsborough, Pinellas and Pasco Counties, respectively. (See Table 4-9.) Raising the profile of the road is an expensive recommendation; however it could potentially allow for additional emergency evacuation and response and recovery actions. A higher road may have the benefit of protecting property and people east of US 19, if it were to act as a surge buffer.

4.1.3 Cost Estimation of Other Adaptation Needs

In addition to the county representative projects, adaptation costs are also estimated for impacted transportation facilities in Category 3 storms with high sea level rise scenario and the 9-inch precipitation scenario. The purpose is to assist partners in future planning until future analyses are performed.

In each scenario, four types of strategies were considered for each impacted road segment based on their criticality and vulnerability: avoidance, drainage enhancement, asset protection, and coastal protection. As shown in, avoidance, or raised roadway profiles, were assigned to locations of high criticality and high vulnerability, as well as locations of new construction that are projected to have high or moderate vulnerability. Three types of drainage enhancement strategies are considered: detention/retention ponds, enhanced swales/ditches, and depressed medians. Asset protection strategies include enhance subbase, harden shoulders/protected medians, enhance road surface, and add vegetation. In addition, coastal protection strategies were also assigned for locations near the coastline or intercoastal shoreline (Table 4-3). The table shows that more strategies, and strategies providing more robust benefits in a variety of situations were assigned to highly critical and highly vulnerable locations. The strategies assigned were scaled down based on criticality and vulnerability. Over time, these facilities also may warrant more aggressive strategies.

Table 4-2 Applying the Strategies to Other Needs

Status	Criticality	Vulnerability	Avoidance	Drainage Enhancement	Asset Protection
New Project	Any	High or Moderate	Raise Roadway Profile	Detention / Retention Ponds	Enhance Subbase
Existing Roadway	High	High	Raise Roadway Profile	Detention / Retention Ponds	Enhance Subbase
Existing Roadway	High	Moderate		Detention / Retention Ponds	Enhance Subbase
Existing Roadway	High	Low		Enhanced Swales / Ditches	Harden Shoulders / Protected Medians
Existing Roadway	Moderate	High		Detention / Retention Ponds	Enhance Road Surface
Existing Roadway	Moderate	Moderate		Depressed Medians	Vegetation
Existing Roadway	Moderate	Low		Depressed Medians	Vegetation
Existing Roadway	Low	High		Enhanced Swales / Ditches	Harden Shoulders / Protected Medians
Existing Roadway	Low	Moderate		Depressed Medians	Vegetation
Existing Roadway	Low	Low		Depressed Medians	Vegetation

Table 4-3 Applying the Strategies to Other Needs – Coastal Protection

Coastal Protection	Location
Beach Nourishment and Dune Restoration	1/8 mile to coastline
Natural Shoreline	Not Applicable. Requires locational evaluation. Beach Nourishment and Dune Restoration is used as a representative.
Sea Walls	At shoreline
Wave Attenuation Devices	1/8 mile to shoreline
Revetments	Not Applicable. Requires locational evaluation. Beach Nourishment and Dune Restoration is used as a representative.

The per-mile costs of each strategy (Table 4-1) was used to calculate the total cost of adaptation strategies in the three counties. Table 4-4 summarized the adaptation cost of high-resilience priority[35] segments in the three counties; Table 4-5 shows the adaptation cost of moderate and low-resilience priority segments.

It should be noted that this is a simplified desk-based analysis attempting to estimate the adaptation needs for transportation planning purposes. The assignment of strategies has not been verified by field investigation or engineering studies. Further research will be needed for the design and implementation of adaptation strategies.

Table 4-4 Cost Estimation of Adaptation Needs for High Resilience Priority Segment ($Million)

High Resilience Priority Segments					
	Avoidance	Drainage Enhancement	Asset Protection	Coastal Protection	Sum
Hillsborough	$957	$427	$391	$92	$1,866
Pinellas	$1,425	$660	$594	$139	$2,818

Table 4-5 Cost Estimation of Adaptation Needs for Moderate – Low Resilience Priority Segment ($Million)

Moderate - Low Resilience Priority Segment					
	Avoidance	Drainage Enhancement	Asset Protection	Coastal Protection	Sum
Hillsborough	$19	$885	$262	$11	$1,177
Pinellas	$20	$530	$157	$	$707

4.2 Economic Impact Analysis

This chapter analyzed the key combined impacts of a two-day disruption to six representative projects and two extreme weather events. This was in terms of total loss to Gross Regional Product (GRP) and personal income (or wages) across all three counties along with the associated changes to the efficiency of the regional road network.

Overall, TBRPC found that the economic (GRP) impacts of each scenario range from relatively small losses (-$5.1 million) for a disruption of traffic on a segment of SR 54, to devastating impacts from the regional impacts of a Category 3 hurricane (-$1.3 billion). In all cases, TBRPC found economic impacts

[35] High resilience priority facilities are defined as transportation segments with high criticality and high or moderate vulnerability in either the category 3 storm plus high sea level rise scenario, or the 9-inch precipitation event scenario (Section 2.32.32.3).

throughout the three-county study area from each representative project. Due to Pasco County's 'bedroom community' status as a home to many commuters, disrupted transportation facilities in Pasco had unusually large impacts on Pinellas and Hillsborough counties.

Compared to the loss of property and years of reconstruction costs, which have exceeded tens of billions of dollars in recent years with hurricanes Katrina, Irma and Harvey, the costs associated with transportation efficiency impacts are significant if secondary to capital stock (housing and commercial buildings) losses in those hurricanes and may have as long lasting residual impacts as the costs of reconstruction itself.

4.2.1 Approach

Extreme weather events restrict access to the Tampa Bay area regional road network and cause output losses to the Tampa Bay area economy. Wind, debris, heavy rain and flooding may impair or even disable major transportation links, forcing many auto and truck trips to re-route and others to simply not take place at all. The effects of longer or deferred trips, slower travel speeds, and lower overall accessibility influence short-term traffic patterns but may also yield long-term economic impacts.

Along with additional travel for commuters, line-haul costs comprise a substantial portion of overall regional congestion costs. Escalated truck operating costs, especially in bad weather conditions and exacerbating pre-existing congestion, means more money must be spent n warehousing and logistics costs, and extended but relatively less productive work shifts. Consequently, the costs of regionally produced intermediate goods rise (the inputs of tires and engines that make the final good of a truck, for example), increasing final costs to consumers. Those increased costs make local businesses less competitive over time compared to communities with more resilient transportation infrastructure or fewer extreme weather events.

Even when the precipitating event is short-lived, the ripple effects of cost and price adjustments can take years to return to pre-event conditions, depending upon the magnitude of the impact and its geographic reach in adversely impacting transportation efficiency. Accordingly, TBRPC modeled scenario impacts not just in the event year, 2045, but each year through 2050 to account for the post-event impacts.

In this section, TBRPC discusses the methodology for importing output from Tampa Bay Regional Planning Model[36] (TBRPM) results for six representative projects and two extreme weather scenarios into REMI TranSight. We also discuss the implications of the long-term effects of variations in the duration of each scenario.

Using REMI TranSight to simulate the economic impacts of extreme weather

TBPRC conducts transportation economic studies using computer simulations with Regional Economic Models Inc. (REMI)'s TranSight, the premier software package for analyzing the economic impacts of transportation investments. TranSight simulations, however, evaluate the impact one project/group of projects have on the economic efficiency of the regional transportation system itself and not on the impact on the loss of access to adjacent land uses.

[36] Appendix A describes the travel demand modeling performed to support the econometric analysis.

For example, while there are no jobs on the bridges spanning Tampa Bay removing any one bridge would substantially impact the overall economic efficiency of the entire transportation system, causing significant economic losses in the model. On the other hand, if a small road supporting lots of jobs, with alternative routes, should become inaccessible due to flooding, its loss would not substantially impair regional average travel speeds and trip lengths because there are alternative routes Consequently, economic impacts would be limited even though in the "real world" many jobs would be inaccessible. TranSight's simulations do not consider individual land uses per se.

Instead, those TranSight simulations, or scenarios compare and contrast travel demand outputs such as changes in vehicle miles traveled and vehicle hours traveled for investments such as new roadways or transit corridors. These transportation indicators are associated with various alternative actions or a baseline.

Just as the TBRPM compares before and after conditions of a set of projects against a baseline of expected transportation indicators, TranSight compares the financial impacts of extreme events against a baseline of economic conditions to answer "what-if" questions about the relationship between transportation and the economy.

TranSight tracks the interrelationships between different socioeconomic and industrial sectors of the economy to produce a detailed account on the flow of goods and services impacted by the transportation system's efficiency. When a project or an event changes the performance of the transportation system, various transportation indicators or model outputs signal to TranSight how a change in system performance might be reflected in the economy.

As an example, let us say that an added lane or additional transit service cuts average travel times by a minute along a transportation corridor. Moreover, that the baseline employment for Hillsborough County in 2018 is 860,000. That change in commuter speed ultimately lowers the cost of labor for businesses, making them more competitive while decreasing commuting costs for commuters and raising real disposable income. If that one-minute decrease in travel time enables adding 1,000 jobs (+1,000 jobs) to the economy, then the total number of jobs is 861,000. On the other hand, a below baseline change of 1,000 jobs (-1,000 jobs) results in 859,000 jobs in the County. Each of the tables in Section 4 (Tables 4.2 through 4.9) report change relative to the baseline (Table 4.1).

Modeling Transportation Costs within REMI TranSight

REMI TranSight is a module of REMI PI+, using TBRPM outputs for changes in trips, Vehicle Hours of Travel (VHT) and Vehicle Miles of Travel (VMT). Those outputs are then used in three different input variables of the Transportation Cost Matrix within REMI TranSight.

Those variables are:

- Commuter Costs
- Transportation Costs
- Accessibility Costs

Commuter Costs

The commuter cost matrix reflects changes in commuting time (measured in hours per commuter trip) between and within regions. Commute savings or losses are assumed to accrue entirely to firms. TranSight derives the region-to-region changes in commuter time from the transportation model output of changes in the VHT/trip ratio for each mode.

Transportation Costs

TranSight quantifies transportation cost savings from the difference between the alternative and baseline scenarios in the ratio of VMT to VHT. This approach captures the offset between shorter travel times and additional miles traveled. In other words, the principal driver of cost savings is the change in average travel velocity on the region's road network, which reduces the effective distance between sellers and their markets.

Accessibility Costs

Accessibility connects business and consumer interests in terms of intermediate inputs and consumer goods. Expansions of network capacity facilitate greater flow of inputs to production, augmenting the variety of available goods and thereby enhancing regional productivity, particularly for industries with heavy dependence on intermediate inputs and transportation. Moreover, the Accessibility matrix component accounts for residual bias toward local purchases unexplained by the transportation costs component. The mathematical procedure for deriving each of these costs is given in Appendix C-1.

Baseline Forecasts and Economic Impacts

Both TranSight and conventional travel demand models compare current conditions versus planned future conditions. In simulating economic impacts to the economy, TranSight measures 'shocks' or economic impacts of a transportation project to a baseline forecast. Baseline forecasts are reference points that economic analysts use to judge the direction and magnitude of potential economic impacts. They are not important in themselves other than placing employment change and other impacts, in the context of the overall economy, due to shock such as extreme weather events,

A summary table of the hypothetical results would show total values of the differences between the baseline and the alternative impact. In the following section, TBRPC identifies the baseline used by REMI TranSight for Gross Regional Product and Personal Income.

Extreme Weather Event Duration and Economic Impacts

Because REMI TranSight is configured with one-year increments as the unit of time, studying phenomena shorter than one-year requires some adjustments to the magnitude of the impact. For example, if a job program were to create 52,000 jobs in one year and we were interested in only one week of equivalent impact, we would analyze the creation of 1,000 jobs as a week's proportionate share of 52 weeks (1 year). While this approach does not formally restrict the model in terms of year-long effects, it does approximate the overall magnitude of a week's impact.

However, one consequence of a short analysis period is that some components of the TranSight analysis that are more realistic over the course of more than a year. For example, economic migration due to a change in regional economic conditions may be less realistic over a shorter period. Therefore, TBRPC urges caution in interpreting the inter-county results in Section 4.

Another consequence of short analysis periods is that the weather is unreliable to fit into a single week and guaranteed to return to full operation at the end of a week. Severe storms may flood roads. But debris, soil subsidence and structural damage may result in disruptions that last for longer time periods. In order to estimate the range of economic impacts from increasing durations, TBRPC modeled the Travel Demand results in TranSight in 2-day, 1-week, 2-week and 1-month intervals. All scenarios were run with the same procedure, by adjusting the week-long default magnitude of the scenario by the change in time in the TranSight model input interface. For example, if the TranSight input were 100 units for a one-week impact, TBRPC entered 200 units for a two-week impact.

As expected, the results for each of the scenarios conformed to a roughly proportionate change to the duration of the event. Gandy Blvd, however, was an exception. Because of a small difference in commuting costs between Pinellas and Hillsborough counties over one-week, preliminary results indicated that a one-month disruption of Gandy Blvd would have negative impacts for Hillsborough County but benefits for Pinellas County. It is because increases to transportation costs in Pinellas would be much lower than in Hillsborough County, making Pinellas more 'competitive.' TBRPC deemed this result unrealistic, given the importance of Gandy to Pinellas County and the artificial adjustment of the two-week and one-month scenarios to a two-day scenario impact.

With that caveat, TBRPC found that adjusting each representative project and two weather events by the duration of the disruption generally yielded results that scale proportionately. Those impacts are shown in graphs at the end of Section **Error! Reference source not found.** for spacing reasons. Tables for longer d uration periods are available by request from TBRPC.

4.2.2 Economic Impact of Representative Projects/Scenarios

TBRPC analyzed the economic impacts of transportation system disruptions from six representative projects and two extreme weather scenarios, the 9-inch rain event and the Category 3 hurricane using Remi TranSight (Version 4.0). Using outputs generated from the Tampa Bay Regional Planning Model (TBRPM) for the year 2045, TBRPC modeled the potential impacts of each event disrupting selected transportation links for a week.

Results are reported using the following indicators:

- Gross Regional Product; and
- Personal income (or wages)

Gross Regional Product is defined as the sum of the gross values added of all residents engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs). The term is the same as Gross Domestic Product, reduced to a regional context. Personal Income is the aggregate of all sources of income to households across wages, supplemental income, rental income, and transfer payments.

While all data in the following tables are reported in 2018 dollars, Table 4-6 provides the baseline Gross Regional Product and Personal Income for each county in 2045, benchmarking the net differences reported in the following tables.

Table 4-6 Baseline Gross Regional Product and Personal Income, by County

County/Year	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	$184,501.9	$188,346.8	$192,485.6	$196,710.2	$201,032.1	$205,459.1
Pasco	$20,737.6	$21,191.1	$21,678.1	$22,174.9	$22,682.9	$23,196.4
Pinellas	$108,660.3	$111,211.9	$113,970.1	$116,800.4	$119,718.3	$122,711.6
Total	$313,899.8	$320,749.7	$328,133.7	$335,685.4	$343,433.2	$351,367.2
Gross Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	$130,176.9	$136,304.5	$142,752.3	$149,533.1	$156,653.6	$164,163.0
Pasco	$42,957.2	$45,253.5	$47,671.3	$50,216.3	$52,897.4	$55,697.6
Pinellas	$99,604.3	$104,284.6	$109,237.0	$114,441.2	$119,947.3	$125,745.0
Total	$272,738.4	$285,842.6	$299,660.5	$314,190.6	$329,498.4	$345,605.6

Source: TBRPC Remi TranSight, 4.0, 2019.

Hillsborough Projects

Hillsborough County is the most populous county in the Tampa Bay region and has the largest economy in the region. Hillsborough's projects are Gandy Boulevard and Big Bend. Gandy spans Tampa Bay between Tampa and Pinellas County. Big Bend provides access to TECO's Big Bend power plant in Apollo Beach.

Table 4-7 Gandy Blvd Economic Impacts – Two Days of Impact

	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	-$105.8	-$24.5	-$16.3	-$9.6	-$5.8	-$3.9
Pasco	-$14.1	$0.5	$0.9	$1.0	$1.0	$0.8
Pinellas	-$110.0	-$30.3	-$22.1	-$14.6	-$10.1	-$7.5
Total	-$229.9	-$54.3	-$37.6	-$23.3	-$15.0	-$10.6
Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	-$68.6	-$9.6	-$2.7	$2.7	$5.9	$7.3
Pasco	-$5.1	-$1.3	$0.7	$0.9	$0.7	$0.2
Pinellas	-$107.7	-$16.3	-$12.7	-$5.9	-$1.7	$0.8
Total	-$181.5	-$27.2	-$14.7	-$2.3	$4.9	$8.3

Source: TBRPC Remi TranSight, 4.0, 2019.

Gandy Blvd is the most economically significant link in this analysis, with a two-day interruption costing the regional economy $229.9 million dollars throughout 2045, with ripple effects distorting prices and demand for goods and services between the counties through 2050.

Those impacts, however, are uneven across the counties. Since Gandy is a vital link between Hillsborough and Pinellas, its role in supporting both economies mean that its disruption would hurt the competitiveness of firms in both counties vis-à-vis Pasco County businesses, which sees gains in GRP from 2046 onward. Personal income in Pasco, however, declines until 2047. That is because many Pasco residents commute to jobs in either Hillsborough or Pinellas and the cost of their commutes are indirectly raised by rerouting traffic and increased congestion from disrupting Gandy Boulevard, adversely impact their real disposable income.

Compared to Gandy Blvd, Big Bend is a relatively small facility in terms of its regional economic impact. Even though the magnitude of the impact disconnecting Big Bend is enough to raise costs for businesses and commuters, its impact on the regional transportation network does not shift relative costs among the counties to convey an advantage to one county over the others.

Table 4-8 Big Bend Economic Impacts – Two Days of Impact

	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	-$2.9	-$0.3	-$0.3	-$0.2	-$0.2	-$0.1
Pasco	-$0.5	$0.0	$0.0	$0.0	$0.0	$0.0
Pinellas	-$3.3	-$0.2	-$0.2	-$0.1	-$0.1	-$0.1
Total	-$6.7	-$0.6	-$0.5	-$0.4	-$0.3	-$0.2
Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	-$2.2	-$0.5	-$0.4	-$0.4	-$0.3	-$0.3
Pasco	-$0.7	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1
Pinellas	-$2.4	-$0.4	-$0.3	-$0.2	-$0.2	-$0.2
Total	-$5.4	-$0.9	-$0.8	-$0.7	-$0.6	-$0.5

Source: TBRPC Remi TranSight, 4.0, 2019.

Pasco Projects

Pasco County is the smallest of the three counties in terms of population and employment, with fewer jobs per resident than Hillsborough or Pinellas. Pasco fits into the regional economy as a bedroom community with more residents traveling daily to work in either larger county, compared to commuter in-flows. Two projects were selected in Pasco County for analysis, US 19 and SR 54.

Table 4-9 US 19 Economic Impacts – Two Days of Impact

	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	-$4.2	-$0.5	$0.0	$0.1	$0.2	$0.2
Pasco	-$8.6	-$0.5	-$0.3	-$0.1	-$0.1	-$0.1
Pinellas	-$12.8	-$6.1	-$4.7	-$3.4	-$2.5	-$2.0
Total	-$25.6	-$7.1	-$5.0	-$3.4	-$2.4	-$1.8
Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	$2.3	-$0.7	$0.6	$0.9	$1.1	$1.2
Pasco	-$6.3	-$0.4	-$0.7	-$0.8	-$1.0	-$1.2
Pinellas	-$14.8	-$2.2	-$1.9	-$0.8	-$0.2	$0.2
Total	-$18.8	-$3.3	-$2.0	-$0.8	-$0.1	$0.2

Source: TBRPC Remi TranSight, 4.0, 2019.

Unlike projects in the other two counties, Pasco GRP losses are only a third of the total regional GRP loss in 2045 and less than half of the regional personal income loss. This is because US 19 is a regionally important facility and disruptions in Pasco County have impacts on the much larger economies of Pinellas and Hillsborough.

Moreover, as shown Table 5.3, even though there is a loss of GRP in Hillsborough County as the result of this disruption, Hillsborough sees a small gain in personal income. Keeping in mind that REMI TranSight does not distinguish between two days duration events or one year duration events, only the magnitude of the impact in one year, Hillsborough would become a relatively more attractive place to live because the transportation, accessibility, and commuting cost increases are not as high as in other counties (even though there are still cost increases that would be sustained over time).

As shown in Appendix C, Hillsborough residence-adjusted employment has increased, meaning that there is an increase in people living within Hillsborough and working outside the county. Because they are living in Hillsborough, personal income increases within the county. Even though there is a net decrease in population and labor force, there is still a net increase in residence adjusted employment. For example, if ten people move out of a region and 5 people move in and work in a different region, there is still a net decrease of five people. But there would be a residence adjusted increase of five people.

Table 4-10 SR 54 Economic Impacts – Two Days of Impact

	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	-$2.5	-$0.3	-$0.2	-$0.1	$0.0	$0.0
Pasco	-$1.8	-$0.5	-$0.4	-$0.3	-$0.2	-$0.2
Pinellas	-$0.8	$0.1	$0.1	$0.1	$0.1	$0.1
Total	-$5.1	-$0.7	-$0.4	-$0.2	-$0.1	-$0.1
Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	-$0.6	-$0.1	$0.2	$0.3	$0.3	$0.3
Pasco	-$3.7	-$0.2	-$0.5	-$0.5	-$0.6	-$0.6
Pinellas	$0.4	$0.0	$0.1	$0.2	$0.2	$0.2
Total	-$3.9	-$0.4	-$0.2	-$0.1	-$0.1	-$0.1

Source: TBRPC Remi TranSight, 4.0, 2019.

As with the US 19 project, Pasco GRP losses are only a third of the total GRP loss in 2045 but incurs almost all the personal income loss. This finding suggests that commuter traffic flows from Pasco to the other counties while relatively few workers from other counties use SR 54 to access jobs in Pasco.

Moreover, as shown in **Error! Reference source not found.**, though there is a loss of GRP in Pinellas C ounty as a result of this disruption, Pinellas sees a small gain in personal income. Pinellas resident employees who commute to jobs outside of Pinellas pay relatively less for transportation, raising their real personal income. Over longer disruption durations, Pinellas would become a relatively more attractive place to live because the transportation, accessibility, and commuting cost increases are not as high as in other counties (even though there are still cost increases).

Pinellas Projects

Pinellas has the second highest population in the Tampa Bay Area and the second highest number of jobs. The two pilot projects are Gulf Boulevard and Roosevelt Boulevard.

Table 4-11 Gulf Blvd Economic Impacts – Two Days of Impact

	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	-$4.2	-$0.5	$0.0	$0.2	$0.2	$0.2
Pasco	-$8.6	-$0.5	-$0.3	-$0.1	-$0.1	-$0.1
Pinellas	-$12.7	-$6.1	-$4.7	-$3.4	-$2.5	-$1.9
Total	-$25.5	-$7.0	-$5.0	-$3.4	-$2.4	-$1.8
Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	$2.3	-$0.7	$0.6	$0.9	$1.1	$1.2
Pasco	-$6.3	-$0.4	-$0.7	-$0.9	-$1.0	-$1.2
Pinellas	-$14.6	-$2.2	-$1.8	-$0.8	-$0.2	$0.2
Total	-$18.7	-$3.3	-$1.9	-$0.8	-$0.1	$0.2

Source: TBRPC Remi TranSight, 4.0, 2019.

Gulf Boulevard impacts raise the cost of doing business in Pinellas and Pasco counties along with the relative cost of labor for their resident workers. As such, Hillsborough resident employees accrue a comparative advantage over businesses and labor in the other two counties, seeing gains in personal income through 2050.

Table 4-12 Roosevelt Blvd Economic Impacts – Two Days of Impact

	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	-$2.7	-$0.3	-$0.2	-$0.1	$0.0	$0.0
Pasco	-$1.3	-$0.1	$0.0	$0.0	$0.0	$0.0
Pinellas	-$0.8	-$0.2	-$0.1	-$0.1	-$0.1	$0.0
Total	-$4.9	-$0.5	-$0.3	-$0.2	-$0.1	-$0.1
Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	-$1.9	-$0.3	-$0.2	-$0.1	$0.0	$0.0
Pasco	-$1.2	$0.0	-$0.1	-$0.1	-$0.1	-$0.2
Pinellas	-$0.9	-$0.2	-$0.1	$0.0	$0.0	$0.0
Total	-$3.9	-$0.6	-$0.4	-$0.3	-$0.2	-$0.1

Source: TBRPC Remi TranSight, 4.0, 2019.

Like Big Bend in Hillsborough County, Roosevelt's overall disruption impacts are relatively small. But as a key link to I-275, disruption of this segment impacts Hillsborough County's economy more than Pinellas or Pasco.

9-Inch Rain Event and Category 3 Hurricane

The last two scenarios affect all three counties. A 9-inch rain event primarily impacts Hillsborough County and the principal impacts are related to flooding. A Category 3 hurricane primarily impacts Pinellas County, with wind obstructing roads with debris and storm surge flooding low-lying areas. Both scenarios have devastating impacts on the Tampa Bay Area, as shown in the following two tables.

Table 4-13 9 Inch Storm Event Economic Impacts – Two Days of Impact

	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	-$448.2	-$72.8	-$47.0	-$26.2	-$14.4	-$8.4
Pasco	-$26.4	-$5.0	-$2.7	-$1.1	-$0.5	-$0.3
Pinellas	-$302.1	-$78.9	-$57.3	-$38.1	-$26.4	-$19.5
Total	-$776.6	-$156.7	-$107.0	-$65.4	-$41.3	-$28.2
Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	-$296.5	-$47.4	-$24.4	-$5.1	$6.8	$13.2
Pasco	-$56.2	-$8.2	-$5.7	-$4.5	-$4.7	-$5.8
Pinellas	-$277.1	-$48.6	-$35.1	-$17.4	-$6.1	$0.7
Total	-$629.8	-$104.2	-$65.2	-$27.0	-$4.0	$8.2

Source: TBRPC Remi TranSight, 4.0, 2019.

Table 4-14 Category 3 Storm Economic Impacts – Two Days of Impact

	2045	2046	2047	2048	2049	2050
Gross Regional Product (Millions of Fixed 2018 Dollars)						
Hillsborough	-$254.4	-$54.2	-$28.7	-$11.6	-$2.6	$0.9
Pasco	-$43.8	-$11.3	-$6.9	-$3.9	-$2.5	-$2.1
Pinellas	-$1,019.6	-$234.7	-$174.0	-$118.9	-$84.6	-$63.6
Total	-$1,317.8	-$300.2	-$209.7	-$134.5	-$89.8	-$64.8
Personal Income (Millions of Fixed 2018 Dollars)						
Hillsborough	-$55.8	-$32.3	$15.9	$32.8	$43.1	$46.9
Pasco	-$89.5	-$16.9	-$12.4	-$10.5	-$10.8	-$12.6
Pinellas	-$950.4	-$171.5	-$151.1	-$100.8	-$67.6	-$45.7
Total	-$1,095.7	-$220.6	-$147.6	-$78.5	-$35.3	-$11.4

Source: TBRPC Remi TranSight, 4.0, 2019.

Event Duration and Economic Impacts

Extreme weather events vary in their duration, often imposing costs on the economy long after the event itself has passed due to roads damaged by soil subsidence, inoperable streetlights and obstructed driving lanes. This section depicts the economic effects of variations in event duration for each event in the previous sections across a 2-day, 1-week (the duration used in the preceding sections), 2-week and 1-month period for regional GRP impact totals. As can be seen, the compromise of these facilities can result in economic impacts that may not be fully recovered in five years.

Figure 4-14 US 19 Gross Regional Product Impacts by Event Duration

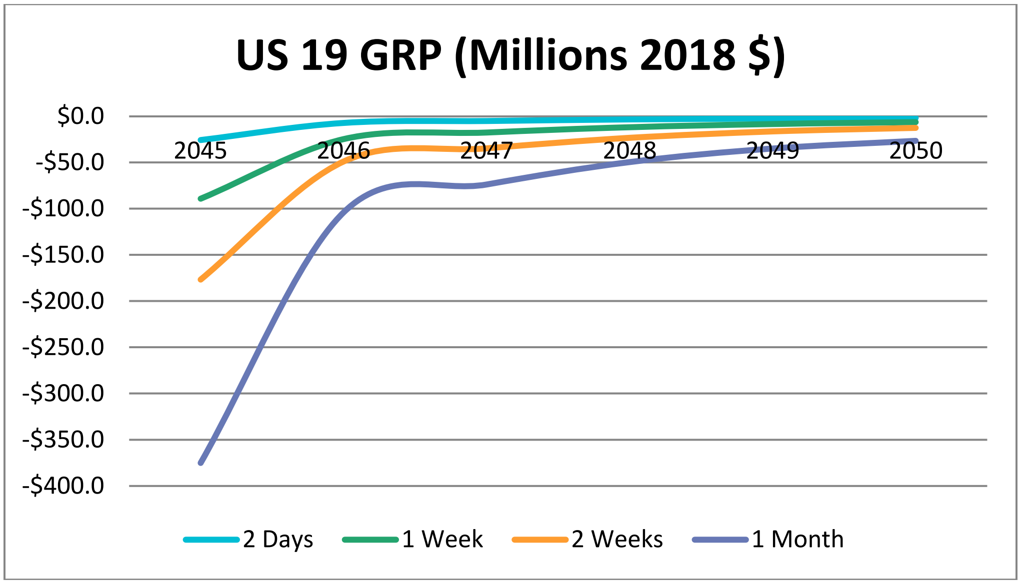


Figure 4-15 SR 54 Gross Regional Product Impacts by Event Duration

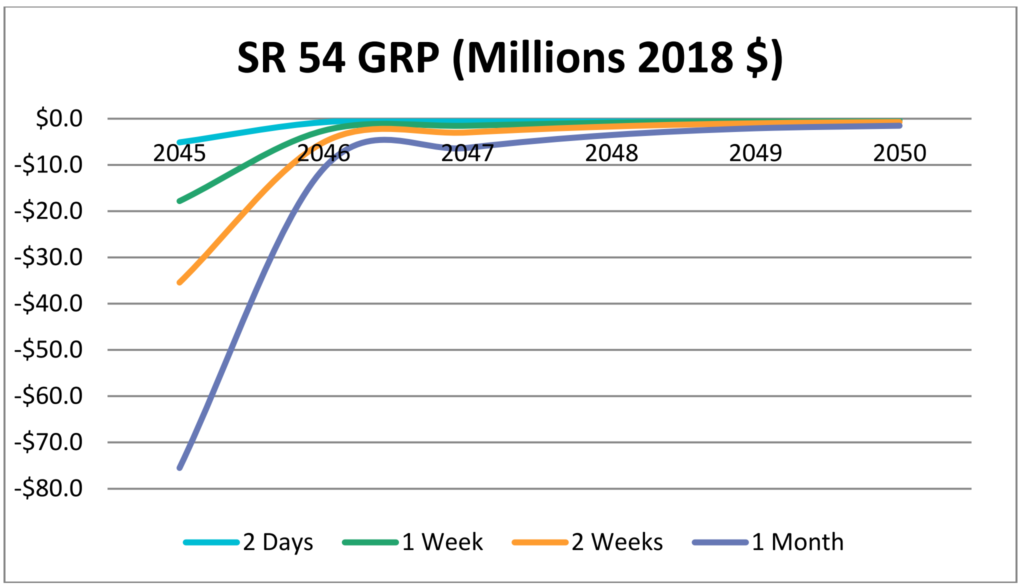


Figure 4-16 Gulf Blvd Gross Regional Product Impacts by Event Duration

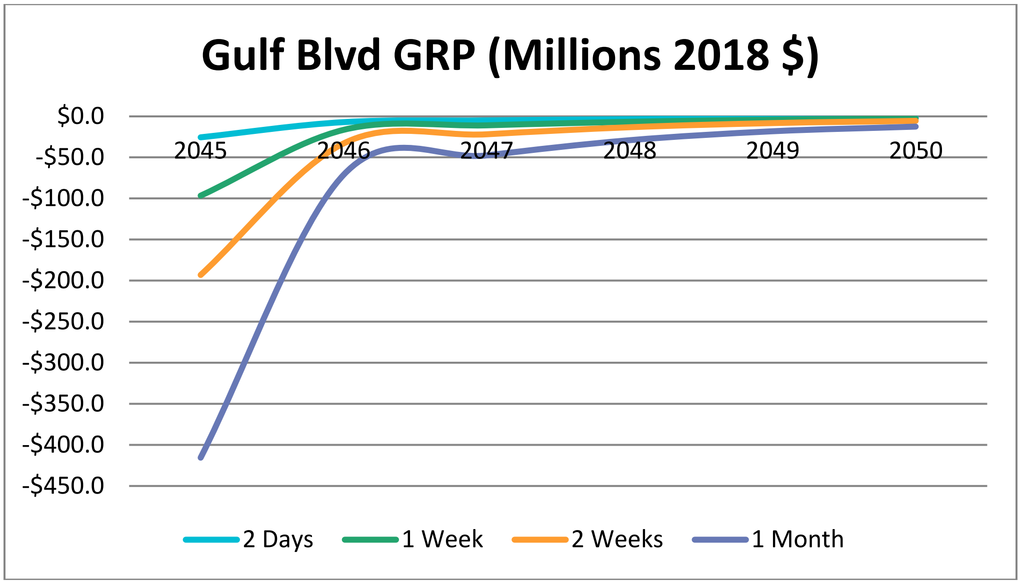


Figure 4-17 Roosevelt Gross Regional Product Impacts by Event Duration

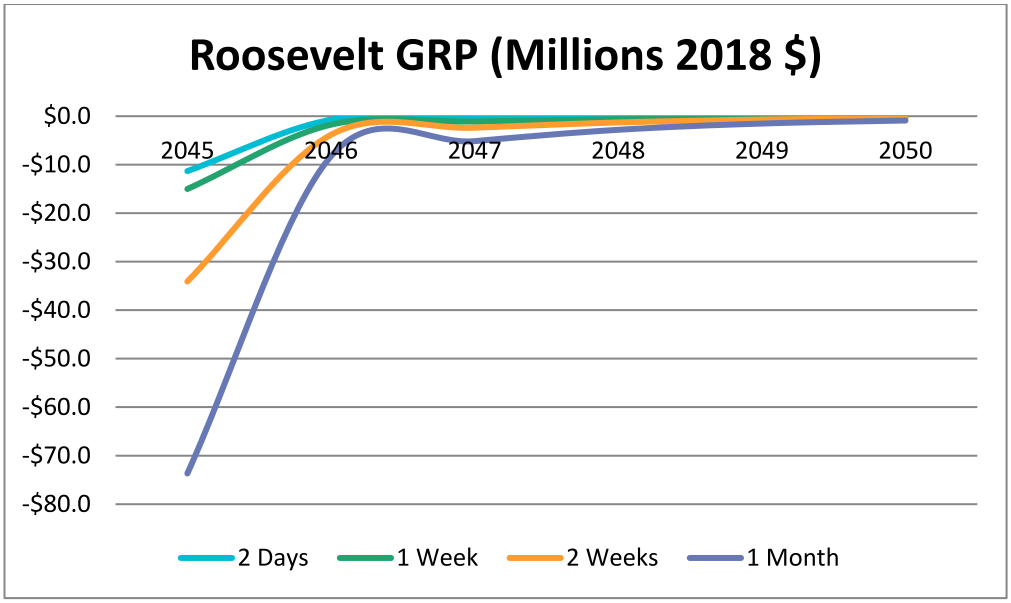


Figure 4-18 Gandy Gross Regional Product Impacts by Event Duration

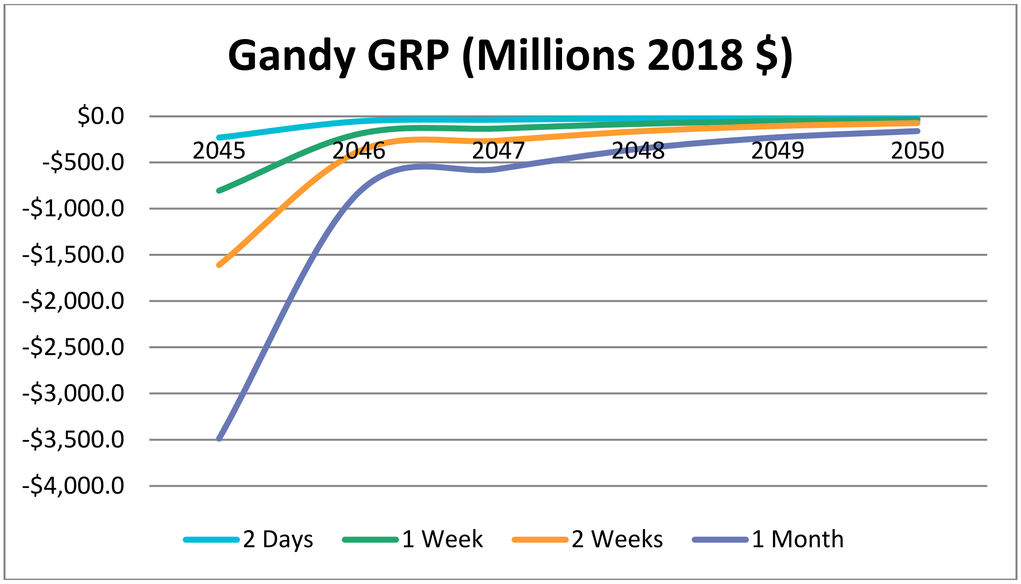


Figure 4-19 Big Bend Gross Regional Product Impacts by Event Duration

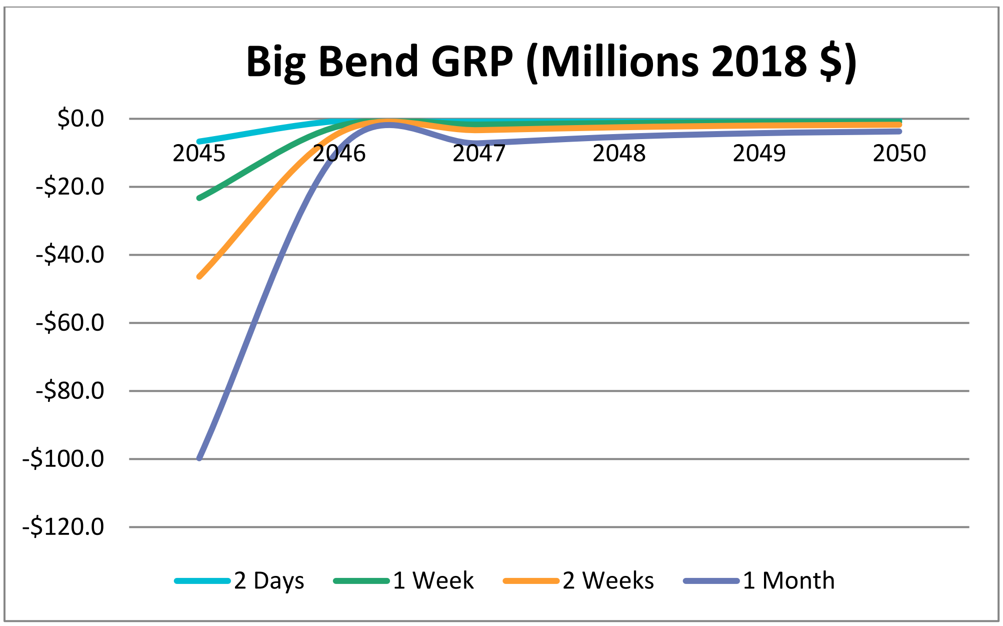


Figure 4-20 9 Inch Rain Event Gross Regional Product Impacts by Event Duration

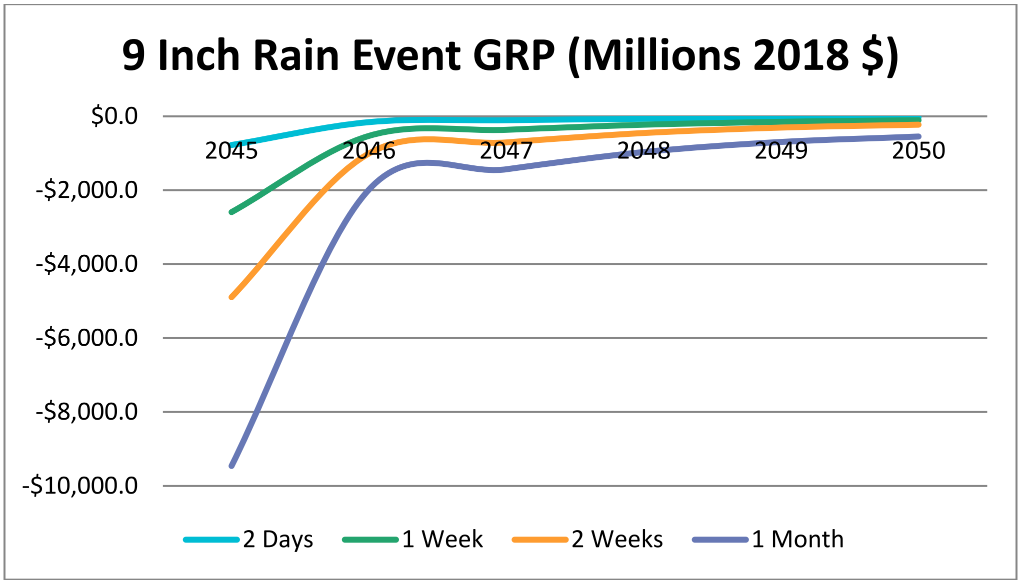
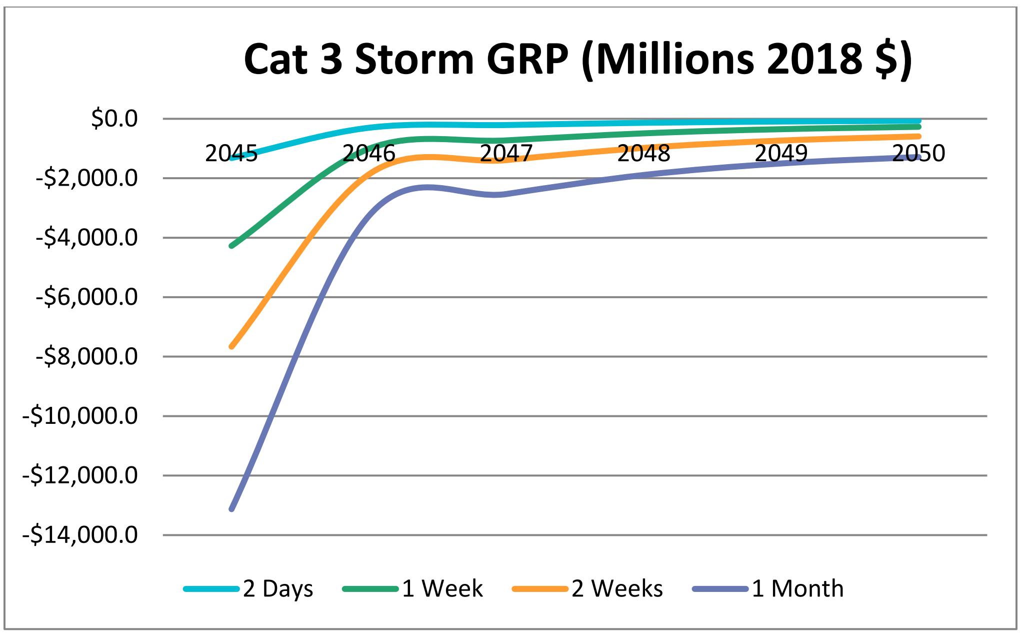


Figure 4-21 Cat 3 Storm Gross Regional Product Impacts by Event Duration



4.3 Cost and Benefit Comparison

4.3.1 Adaptation Cost and Potential Economic Loss

This section compared the potential economic impacts and adaptation costs for eight scenarios. This included the locations of six county representative projects being inundated and Category 3 storms plus the high sea level rise scenario and 9-inch precipitation in 24 hours scenario. The benefit of adaptation strategies is measured by the potential economic impact they mitigate when compared to no investment. The economic impact is represented using the 2045 annual total loss of Gross Regional Product (GRP) and 2045 annual total loss of personal income caused by roadway inundation of 2 days, 1 week, 2 weeks, and 1 month. The adaptation cost is represented by the cost of implementing adaptation strategies at county-representative project locations and other vulnerable areas.

In Cost-Benefit Analyses, both costs and benefits occur in the future while decisions about whether those benefits exceed costs must be made today. For projects in the immediate future, costs are subtracted from benefits. We can say that positive net benefits justify a project while negative net benefits do not. However, public investment decisions frequently involve investments (costs) in the immediate future, as in adaptation costs to a capital investment program. Benefits, such as avoided costs from the economic losses, that occur in the future must be discounted to present values in order to compare them with present day investment costs. Costs used reflect the recommended adaptation strategy option(s).

Discounting to present values, however, is not the same thing as adjusting future costs to inflation. Let us say that a friend offers you ten dollars today or ten dollars (leaving inflation aside) in a year. Most people would choose having the ten dollars today because that money can be put to productive use. right away, as opposed to money offered in the future. Economists use a discount rate to account for people's reference for immediate payment by subtracting a percentage value from today's money each year out by an amount that represents its opportunity cost, or cost of capital, of not spending the money today.

In this analysis, we use a real discount rate of 4 percent as recommended by Florida Department of Transportation[37]. While the Federal Highway Administration recommends using a 7 percent real interest rate[38], this discount rate was based on long-term government debt yields from 1973-2003. Today, 7 percent is high relative to prevailing interest rates for private investment and much higher for prevailing treasury notes and bonds real interest rates[39]. As such, TBRPC felt it was appropriate to match FDOT's discount rate.

As with the economic analysis, this cost benefit study is only focused on the costs (or avoided costs) of Gross Regional Product impacts to the efficiency of the transportation system itself. Property value impacts or impacts to residents and businesses are not explicitly considered in the analysis. Moreover, the analysis does not consider the likelihood of more frequent extreme weather events or more intense events. Instead, we look exclusively look at one time costs of adaptation measures and one time

---

[37] https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/content/planning/policy/economic/macroimpacts0115.pdf?sfvrsn=5d49079b_0

[38] https://cms.dot.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/284031/benefit-cost-analysis-guidance-2017.pdf

[39] https://www.whitehouse.gov/wp-content/uploads/2017/11/Appendix-C-revised.pdf

'benefits' of avoiding 100 percent of the potential economic damage associated with an extreme weather event in 2045.

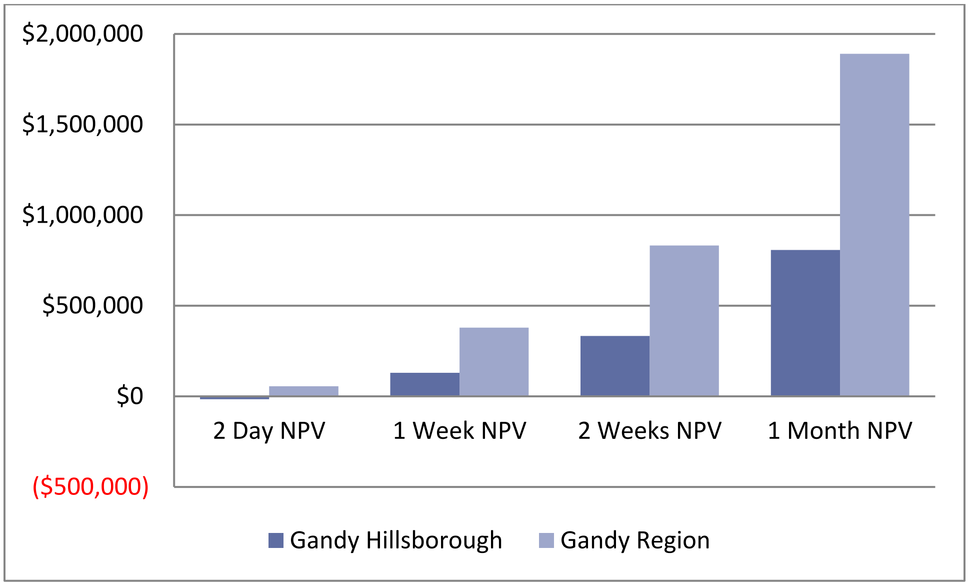
In the following analysis, TBRPC calculated Net Present Values for avoided costs to Gross Regional Product at the county level and at the regional (three county) level for each representative project. Different resiliency investment scenarios were tested across two -day, 1-week, 2-week and 1-month duration scenarios in 2045. If extreme weather events become more frequent and/or more intense than once in the next 25 years, net present values will increase significantly.

Listed below are the assumptions TBRPC used in analyzing the benefit-cost of the adaptation measures identified by CS.

- Discount Rate of 4%
- Extreme Weather Events occur once in 2045 and are not more frequent or more intense
- Economic impacts are exclusively focused on the transportation costs of the overall efficiency of the regional transportation network. Extreme weather impacts on access to property, property values and taxes, property damage, closed businesses and lost sales and employment are **excluded** from this analysis
- Capital investments happen in the very near future. If adaptation measures are staggered, results will be different
- Impacts can occur in 2-day, 1-week, 2-week or 1-month intervals

Results indicate that due to the interconnected nature of the metropolitan economy, the region as a whole sometimes benefits more from adaptation measures taken by individual counties facing direct impacts. For example, Gandy Boulevard has a negative Net Present Value for a two-day duration event in Hillsborough County while the region's total impact is positive. That is because Hillsborough bears the cost of the adaption measure through its own capital program while the other two counties benefit without having to pay for the adaption measure`.

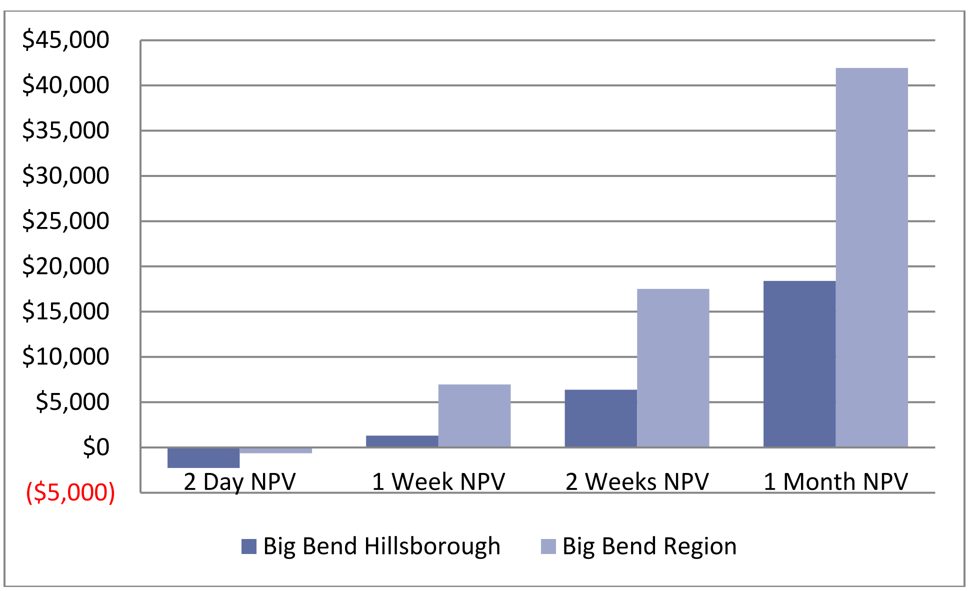
Figure 4-22 Gandy Net Present Value of Adaptation Measures by Event Duration (2018 $1,000s)



With greater duration events, both Hillsborough and the Region benefits from the adaptation investments increase substantially. There is a greater return for each successively higher level of assumed risk about future events.

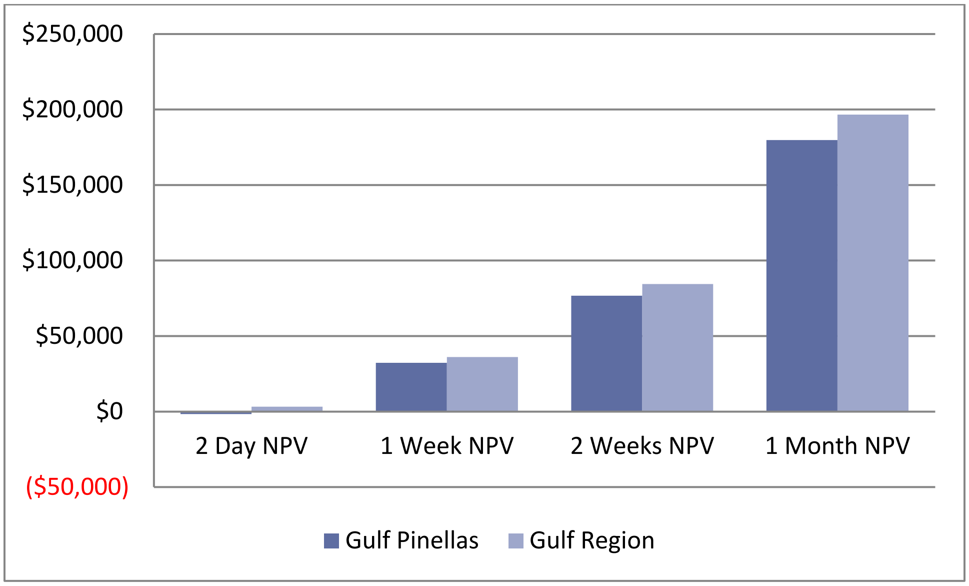
Big Bend's adaptation measures return similar net present values from regional impacts relative to county impacts, because the entire region benefits from Hillsborough County's investments in adaptation measures.

Figure 4-23 Big Bend Net Present Value of Adaptation Measures by Event Duration (2018 $1,000s)



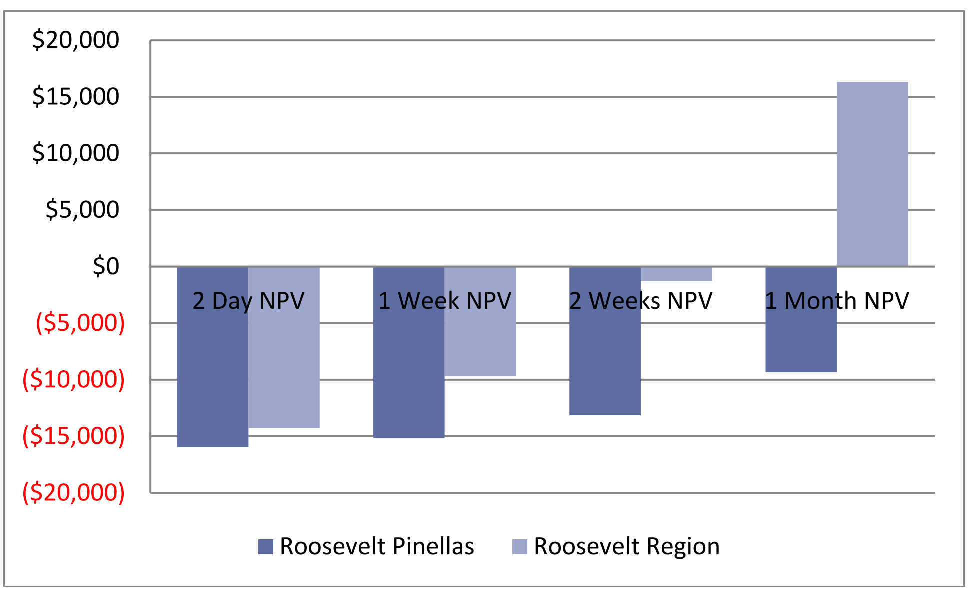
In Pinellas County, Net Present Value impacts for Gulf Boulevard are nearly identical between Pinellas and the region, as shown in Figure 4-24.

Figure 4-24 Gulf Blvd Net Present Value of Adaptation Measures by Event Duration (2018 $1,000s)



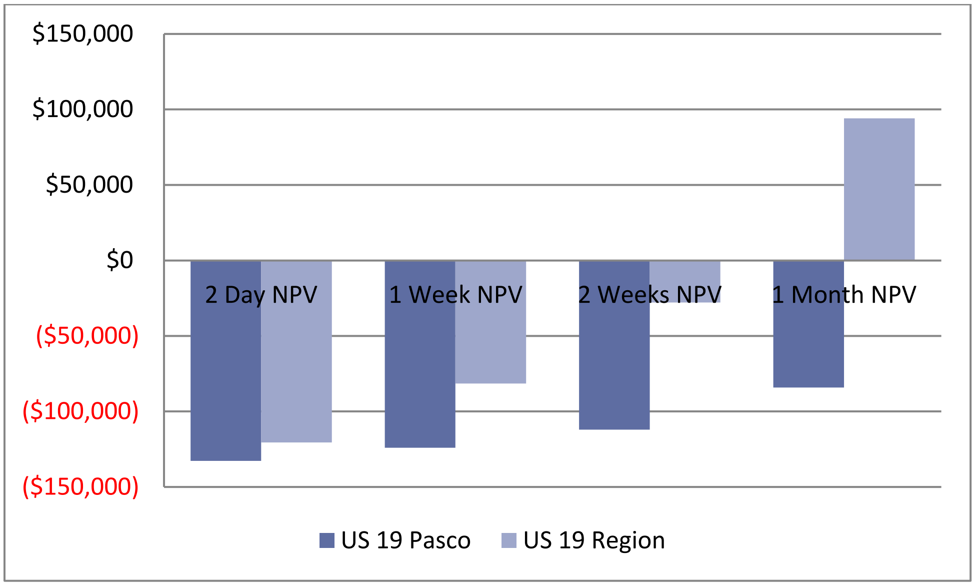
That is because Gulf Boulevard mostly impacts Pinellas trips and therefore avoided costs primarily benefit Pinellas residents and businesses. On the other hand, Roosevelt Boulevard adaptation measures primarily benefit Hillsborough County (and Pasco, to a lesser extent) over costs to Pinellas. As shown in Figure 4-25, Pinellas pays the costs of adaptation measures but does not benefit relative to the cost through any of the duration scenarios.

Figure 4-25 Roosevelt Net Present Value of Adaptation Measures by Event Duration (2018 $1,000s)



A nearly identical pattern of impacted county costs versus regional benefits obtains in Pasco County with US 19. There is no duration scenario in which US 19 adaptation costs pay for themselves for Pasco County, but there are regional benefits at the 1-month duration. This analysis was performed on the main recommended project costing $136 million. For the alternate project of $71 million, the tradeoffs would be seen earlier.

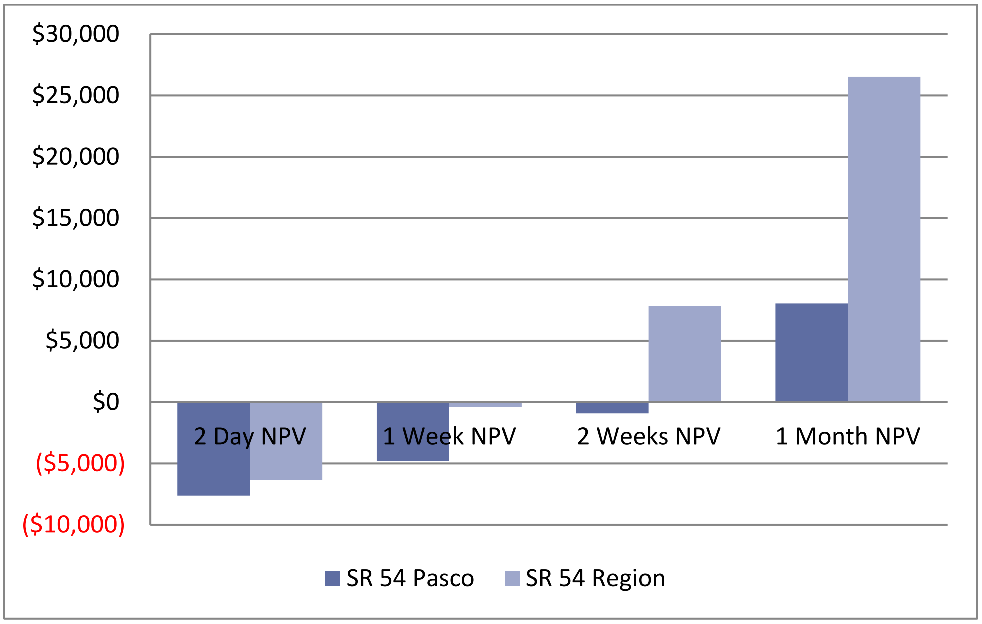
Figure 4-26 US 19 Net Present Value of Adaptation Measures by Event Duration (2018 $1,000s)



There is no duration scenario in which US 19 adaptation costs pay for themselves for Pasco County, but there are regional benefits at the 1-month duration.

SR 54, on the other hand, shows strong gains to regional Net Present Values as durations increase, becoming positive at the 1-month duration level. Overall, however, Pasco's net present value returns from adaptation investments are poor due to the high cost for some mitigation measures and long periods of time between capital investment and 2045, when the benefits from a major storm become evident.

Figure 4-27 SR 54 Net Present Value of Adaptation Measures by Event Duration (2018 $1,000s)



The figures below illustrate the economic impact to each county in the Category 3 storms plus high sea level rise scenario, and the 9-inch precipitation scenario. The economic impact is compared with the cost of potential adaptation strategies in each county, including the two representative projects in each county, and potential strategies for high resilience priority locations, as well as the Moderate & Low Resilience Priority Needs. All costs of adaptation strategies are shown as net present values using the method describe previously. The intention is to help inform the decision of whether to include these potential adaptation projects in LRTPs, by estimating under what situation, an adaptation investment will be close to or smaller than the potential economic loss of not investing, and therefore is worth being included in the LRTP.

For example in Figure 4-28 and Figure 4-29, the annual loss in GRP in Hillsborough County will be close to the cost of implementing the two county representative project plus the cost of addressing high resilience priority needs, when the transportation network is inundated for 14 days (2 week) due to a 9-inch precipitation event or for 30 days (1 month) due to a Category 3 Storm with High sea level rise. The annual loss in GRP Hillsborough County will be equal to the funding needed to address all adaptation needs when there are over 30 days (1 month) the transportation facilities are closed due to 9-inch precipitation events.

For Pinellas County, the annual loss in GRP in will be greater than the cost of implementing the two county representative projects plus the cost of addressing high resilience priority needs, when the transportation network is inundated for about 10 days (1.5 week) due to a Category 3 Storm. The annual loss in GRP Pinellas County will be almost equal to the funding needed to address all adaptation needs when there are 14 days (2 weeks) the transportation facilities are closed due to a Category 3 Storm.

For Pasco County, the annual loss in GRP in will be greater than the cost of implementing the two county representative project when the transportation network is inundated for about 14 days (2 week) due to a

Category 3 Storm or over three weeks due to a 9-inch precipitation event. The annual loss in GRP Pasco County will be greater to the funding needed to address additional high resilience priority needs when there are over three weeks the transportation facilities are closed due to a Category 3 Storm.

It should be noted that adaptation projects are not guaranteed to mitigate 100% of the economic impacts. On the other hand, while the annual economic impact is used here for comparison, the benefit of adaptation projects could last for decades once build.

Figure 4-28 Category 3 Storm plus High SLR Scenario
Hillsborough County: 2045 Economic Impact vs. Adaptation Cost

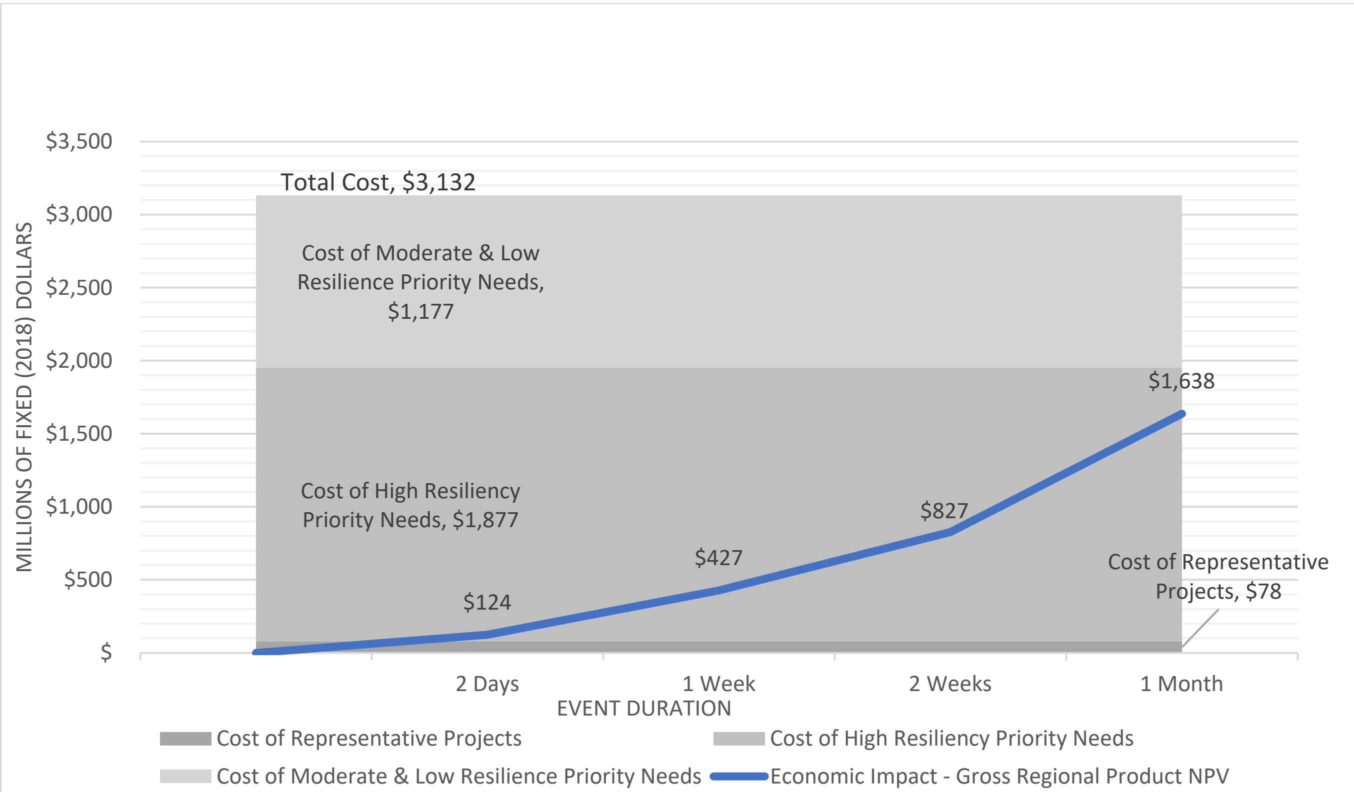


Figure 4-29 9 Inches Precipitation Scenario
Hillsborough County: 2045 Economic Impact vs. Adaptation Cost

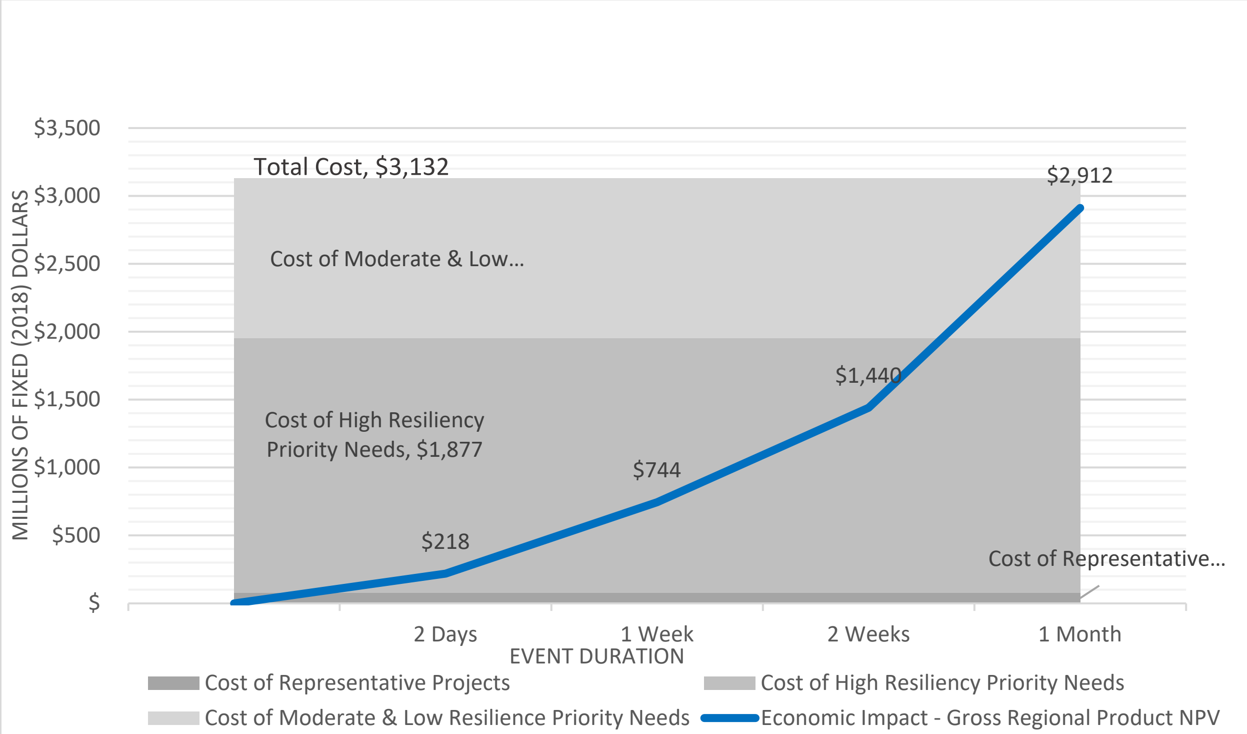


Figure 4-30 Category 3 Storm plus High SLR Scenario
Pinellas County: 2045 Economic Impact vs. Adaptation Cost

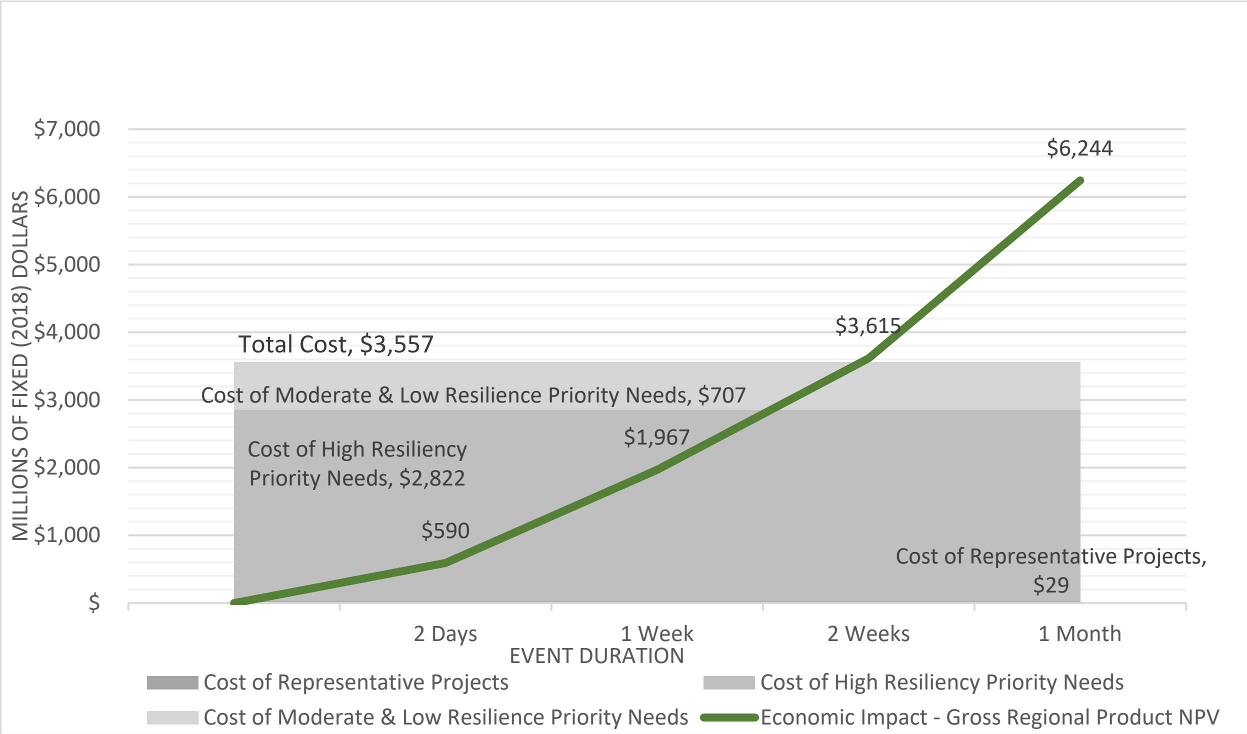


Figure 4-31 9 Inches Precipitation Scenario
Pinellas County: 2045 Economic Impact vs. Adaptation Cost

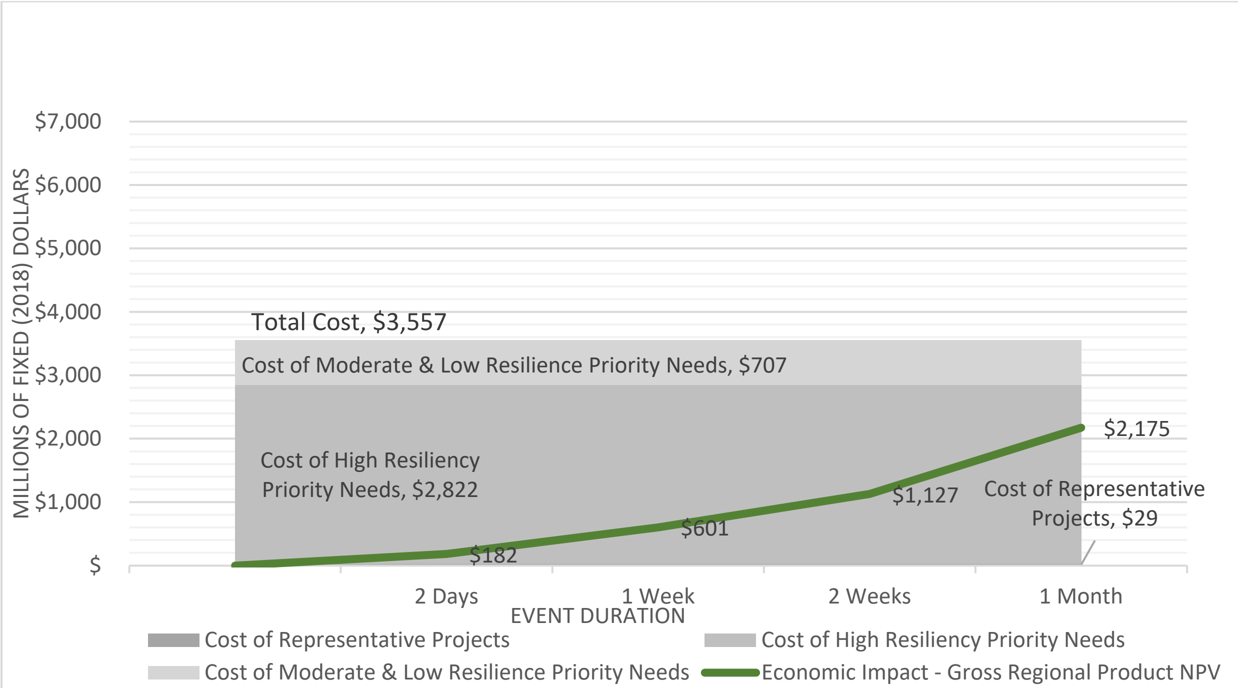


Figure 4-32 Category 3 Storm plus High SLR Scenario
Pasco County: 2045 Economic Impact vs. Adaptation Cost

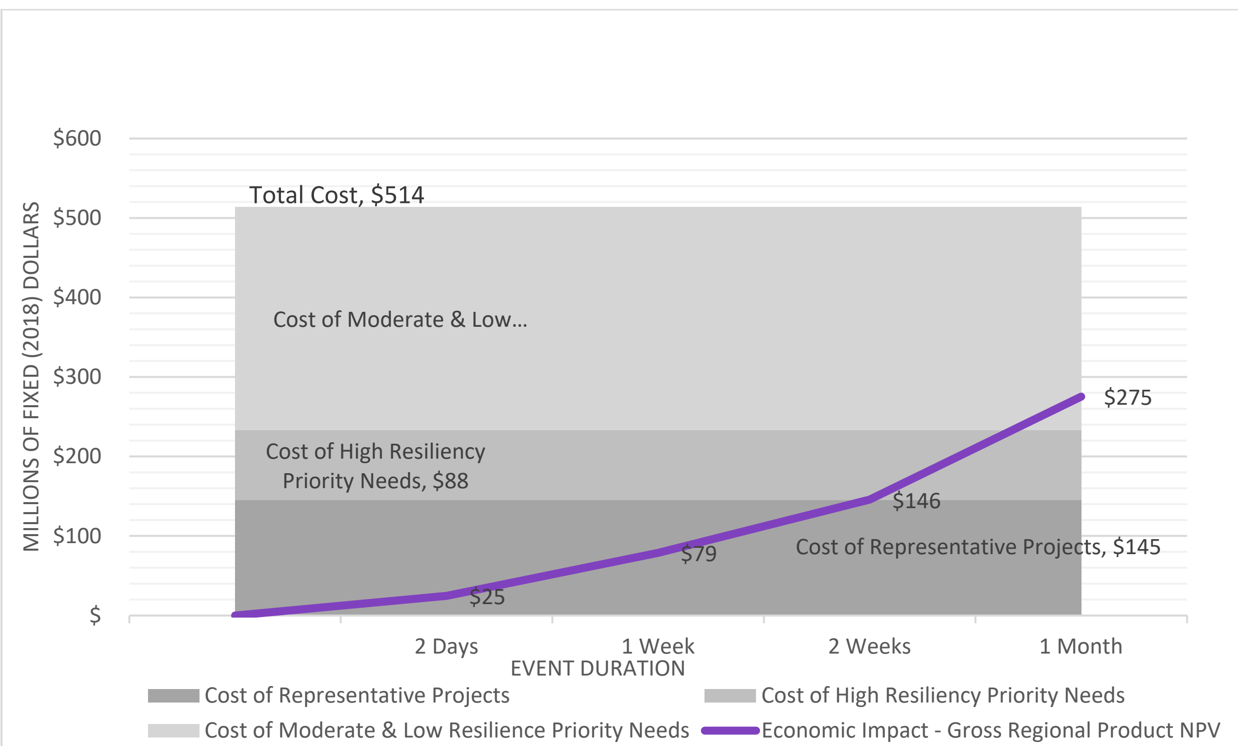
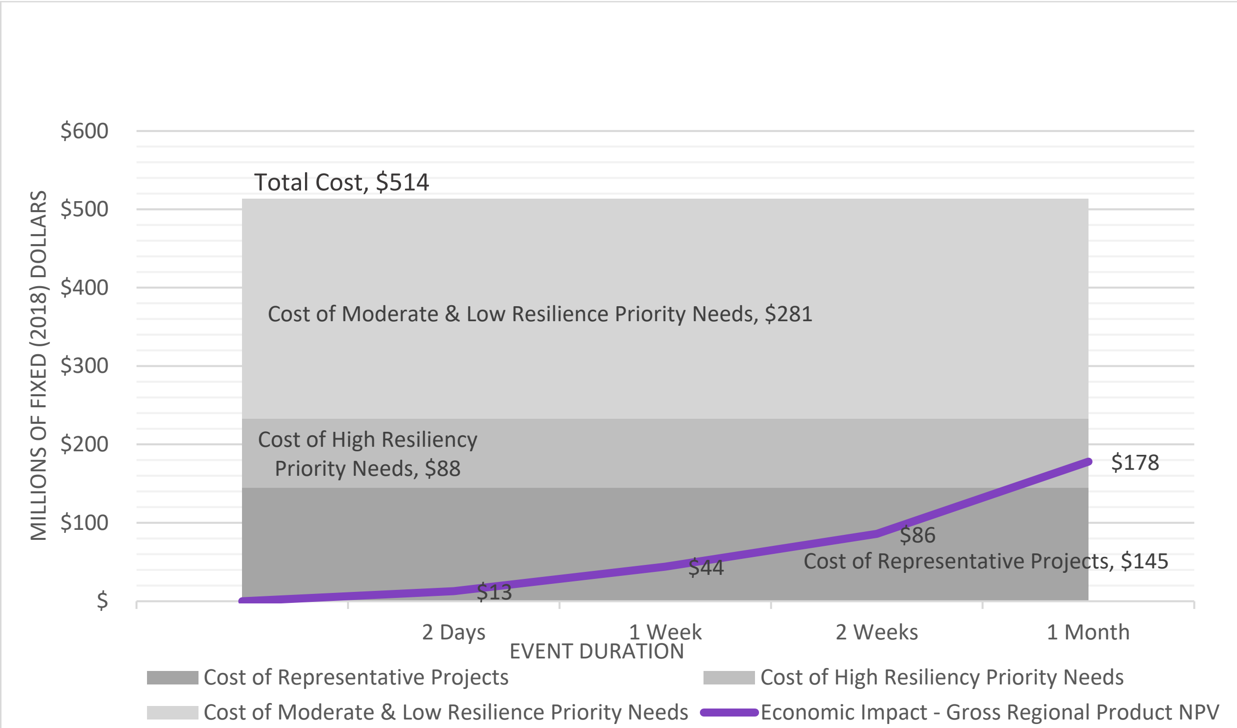


Figure 4-33 9 Inches Precipitation Scenario
Pasco County: 2045 Economic Impact vs. Adaptation Cost



4.3.2 Adaptation Cost and Rebuild Cost

In addition to potential economic loss due to roadway closure, extreme weather events could cause damage to the infrastructure itself, adding cost of repairing or rebuilding the destructed assets to the region's burden, and causing additional inconvenience and economic loss during the construction.

Figure 4-34, Figure 4-35, and Figure 4-36 compare the adaptation cost and rebuild cost of representative projects, high resilience priority needs, and moderate and low resilience priority needs in the three counties. The rebuild cost is estimated using the per-mile cost of raising roadway profiles as discussed in Section 4.1, which in reality could be higher given the additional post-disaster clean-up cost that would occur. The raising the profile version of these costs are used because it is likely that adaptation measures will be incorporated with any rebuild redesign and the costs can account for those changes. Adaptation strategies are proactive and, in most cases, less expensive ways to address potential threats from extreme weather and climate events.

Figure 4-34 Adaptation Cost and Rebuild Cost for Representative Projects

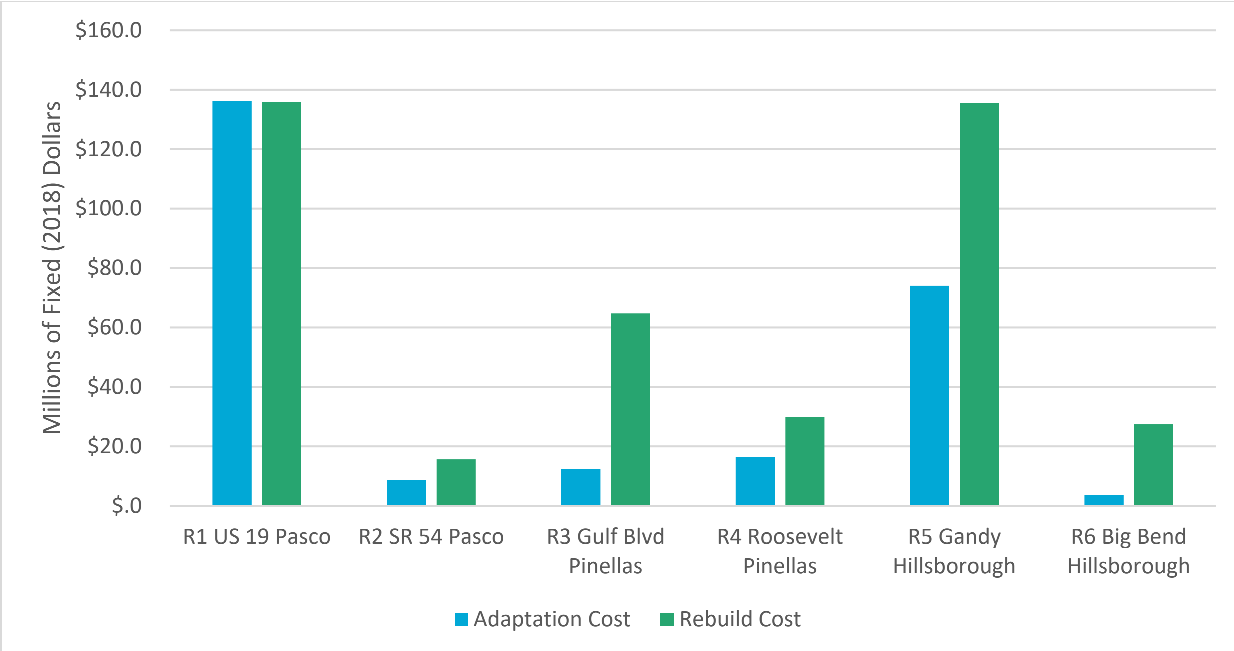


Figure 4-35 Adaptation Cost and Rebuild Cost for High Resilience Priority Needs

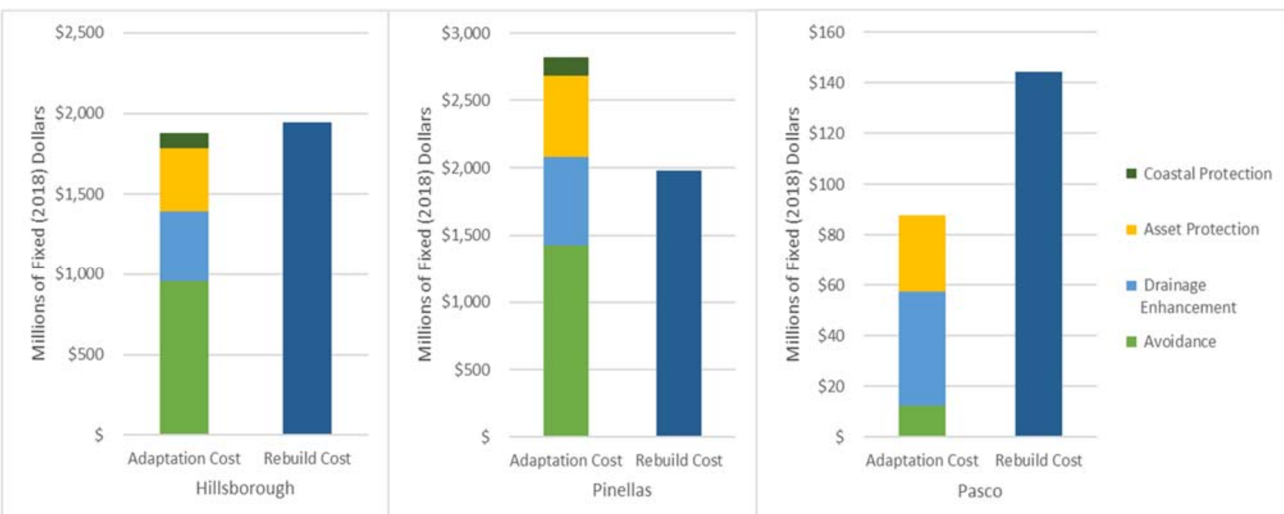
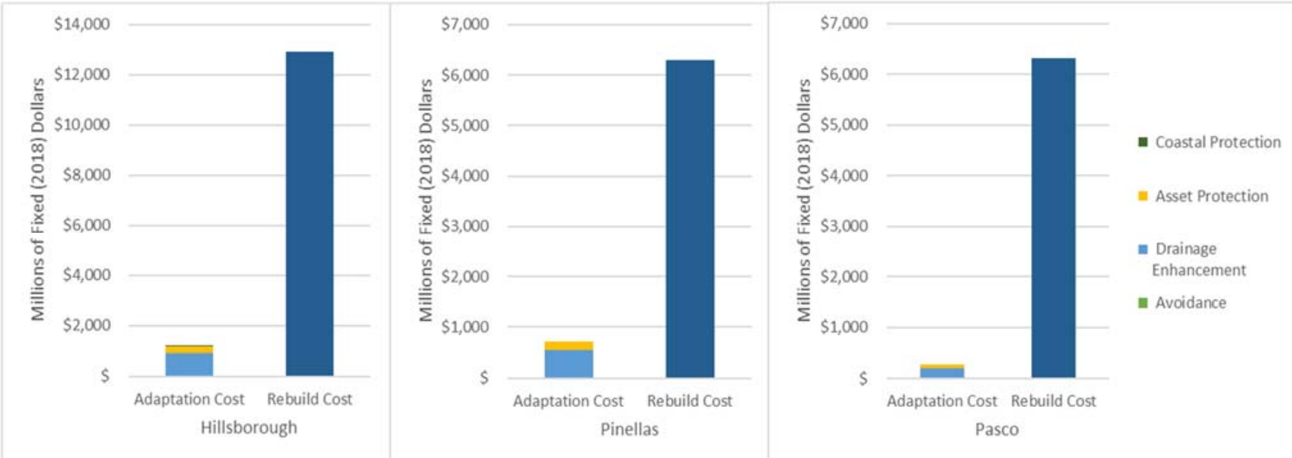


Figure 4-36 Adaptation Cost and Rebuild Cost for Moderate and Low Resilience Priority Needs



4.4 Adaptation Costs versus Current Investments

According to the current 5-year Capital Improvement Program budget in each county, as shown in Table 4-15, Hillsborough County, Pinellas County, and Pasco County each have about $650 million, $102 million, and $106 million budget for bridges and pavement maintenance and stormwater treatment in the fiscal year 2020 to 2024 timeframe. To assist planning for future years, the total adaptation funding needs over the life of LRTP (2025-2045, 20 years), as shown in Table 4-16, were divided by 4 to obtain the future 5-year funding needs, as shown in Table 4-17**Error! Reference source not found.**.

As a whole, the annual spending as reflected in the current 5-year budget for Hillsborough County would cover the cost for the county representative projects and high resilience priority needs. However, that would assume that revenue resources could be used across categories and that existing capital improvement needs are not covered. Both those situations are improbable and funding for adaptation strategies will need to be in addition to current methods, with the exception of coordination on drainage improvements. For Pinellas County, the current budget level would cover the county representative projects and Pasco County's current level of funding would cover the cost for the county representative projects and high resilience priority needs.

Table 4-18 and Table 4-19 shows the comparison of current budget and future funding needs broken down by categories. The infrastructure and drainage category include adaptation strategies of raising profile, enhance drainage, and asset protection. Raising the profile and asset protection (primarily shoulder enhancements) are new elements not generally included in bridges and pavement maintenance funding. The coastal protection category includes beach nourishment, nature shorelines, etc. as described in Chapter 3.

It should be noted that facilities that are routinely impacted by flooding can require 10-15% more maintenance.

Given the large costs associated the high resilience projects, Table 4-15 shows the costs for the highly critical and highly vulnerable locations versus all high resilience locations (i.e., those high critical/moderate vulnerability or moderate criticality/high vulnerability). The highly critical/highly vulnerable roads were assigned more comprehensive adaptation strategies, including raising the profile, which explains the large costs as compared to the high resilience projects.

Table 4-15 Current 5-Year CIP Budget ($Million)

		Bridges and Pavement	Stormwater	Total
Hillsborough[40]	FDOT	$201.5	$15.2	$216.8
	County	$179.3	$113.4	$292.7
	Municipalities	$37.1	$104.1	$141.2
	Subtotal	**$417.9**	**$232.7**	**$650.6**
Pinellas	FDOT[41]	$37.1		$37.1
	County[42]	$3.3	$61.7	$65.0
	Subtotal	**$40.4**	**$61.7**	**$102.1**
Pasco	FDOT[43]	$5.6		$5.6
	County[44]	$67.0	$33.1	$100.1
	Subtotal	**$72.6**	**$33.1**	**$105.7**
Tri-County	**Total**	**$530.9**	**$327.5**	**$858.4**

[40] Hillsborough County Capital Improvement Program Budget FY 2018/2019 – FY 2022/2023

[41] FDOT Work Program Pinellas County Maintenance Projects, 2020 - 2024

[42] Pinellas County Capital Improvement Program Budget 2020 - 2024,

[43] FDOT Work Program Pasco County Maintenance Projects, 2020 - 2024

[44] Pasco County Capital Improvement Program Budget 2020 - 2024,

Table 4-16 Total Adaptation Funding Needs ($Million)

	Representative Projects	High Resilience Priority Needs	Moderate-Low Resilience Priority Needs	Total Funding Needs
Hillsborough	$77.7	$1,877.3	$1,177.5	$3,132.5
Pinellas	$28.8	$2,821.9	$706.8	$3,557.5
Pasco	$145.0	$87.8	$280.7	$513.6
Tri-County Total	$251.6	$4,787.0	$1,458.2	$6,496.8

Table 4-17 Comparison of Current Budget and Future 5-Year Funding Needs ($Million)

County	Current 5-Year Budget	Future 5-Year Funding Needs			
		Representative Projects	High Resilience Priority Needs	Moderate-Low Resilience Priority Needs	Total
Hillsborough	$650.6	$19.4	$469.3	$294.4	$783.1
Pinellas	$102.1	$7.2	$705.5	$176.7	$889.4
Pasco	$105.7	$36.3	$22.0	$70.2	$128.4
Tri-County Total	$858.4	$62.9	$1,196.8	$364.6	$1,624.2

Table 4-18 Total Adaptation Funding Needs by Category ($Million)

	Representative Projects		High Resilience Priority Needs		Moderate-Low Resilience Priority Needs		Total	
	Infrastructure & Drainage	Coastal Protection	Infrastructure & Drainage	Coastal Protection	Infrastructure & Drainage	Coastal Protection	Infrastructure & Drainage	Costal Protection
Hillsborough	$77.7		$1,785.4	$91.9	$1,166.8	$10.7	$3,029.9	$102.6
Pinellas	$18.9	$9.9	$2,678.9	$143.0	$706.8	$.0	$3,404.6	$152.9
Pasco	$145.0		$87.8	$.0	$280.7	$.0	$513.6	$.0
Tri-County Total	$241.7	$9.9	$4,552.2	$234.9	$2,154.3	$10.7	$6,948.1	$255.5

Table 4-19 Comparison of Annual Current Budget and Future Funding Needs by Category ($Million)

	Future 5-Year Funding Needs								Current 5-Year Budget
County	Representative Projects		High Resilience Priority Needs		Moderate-Low Resilience Priority Needs		Total		
	Infrastructure & Drainage	Coastal Protection	Infrastructure & Drainage	Coastal Protection	Infrastructure & Drainage	Coastal Protection	Infrastructure & Drainage	Costal Protection	
Hillsborough	$3.9	$0.0	$89.3	$4.6	$58.3	$0.5	$151.5	$5.1	$130.1
Pinellas	$0.9	$0.5	$133.9	$7.1	$35.3	$0.0	$170.2	$7.6	$20.4
Pasco	$7.3	$0.0	$4.4	$0.0	$14.0	$0.0	$25.7	$0.0	$21.1
Tri-County Total	$12.1	$0.5	$227.6	$11.7	$107.7	$0.5	$347.4	$12.8	$171.7

Table 4-20 Cost by Criticality/Vulnerability (not including representative projects)

(Millions of Fixed (2018) Dollars)						
Hillsborough						
	Avoid/ Protect	**Drainage**	**Coastal Protection**	**Total**	**Cost of Rebuild**	**Total Minus Rebuild**
High Resilience	$1,392.076	$456.775	$91.893	$1,940.745	$1,987.500	-$46.756
High/High	$1,249.986	$253.954	$71.960	$1,575.900	$966.647	$609.253
Difference	$142.090	$202.822	$19.933	$364.845	$1,020.853	
Percentage	89.8%	55.6%	78.3%	81.2%	48.6%	
Pinellas						
	Avoid/ Protect	**Drainage**	**Coastal Protection**	**Total**	**Cost of Rebuild**	**Total Minus Rebuild**
High Resilience	$2,039.717	$858.827	$89.974	$2,988.517	$3,718.576	-$730.059
High/High	$1,851.998	$376.261	$89.974	$2,318.233	$1,154.341	$1,163.892
Difference	$187.719	$482.565	$.000	$670.284	$2,564.235	
Percentage	90.8%	43.8%	100.0%	77.6%	31.0%	
Pasco						
	Avoid/ Protect	**Drainage**	**Coastal Protection**	**Total**	**Cost of Rebuild**	**Total Minus Rebuild**
High Resilience	$65.293	$154.147	$.000	$219.440	$885.305	-$665.865
High/High	$19.221	$3.905	$.000	$23.126	$13.687	$9.439
Difference	$46.072	$150.242	$.000	$196.314	$871.618	
Percentage	29.4%	2.5%		10.5%	1.5%	

5.0 Public Engagement

The RTBT initiative coordinated with agencies and the general public in multiple ways.

Project Management

- The *Tampa* Bay *Transportation Management* Area Leadership Group (TMA) served as the oversight for the effort.
- Three MPOs working together, Pinellas County MPO (Forward Pinellas), Pasco MPO, and Hillsborough County MPO provide management direction, with Hillsborough MPO taking the lead and administering the FHWA grant.
- The *ONE BAY* Resilient Communities Working Group served as a steering committee and sounding board for the plan, particularly with respect to public outreach.
- The three county Local Mitigation Strategy Working Groups provided technical support and comments during development of the project

Coordination Approach

RTBT focused it efforts on transportation infrastructure. Other organizations are performing similar vulnerability assessments on other types of infrastructure, more refined geographic area, or looking at social vulnerabilities. Some of these projects and agencies active in Tampa Bay are:

- Pinellas County Restore Act Vulnerability Assessment
- Hillsborough County Perils of Flood Act Matrix of Impacts Initiative
- University of South Florida School of Community Design
- University of South Florida Department of Urban Planning
- FDOT District 7 Gandy Boulevard PD&E
- FDOT District 7 Community Liaison and Drainage Engineer
- Public Works from the three counties

Best Practices and Conferences

- Federal Highway Administration and MPO Peer exchanges
- Women's Transportation Society Annual Conference
- American Planning Association Florida Conference
- Association of MPO's Annual Meeting

- Transportation Resilience Conference
- Transportation Research Board

Public Outreach

Public ou reach utilized the committee MPO committees as well as established county and regional organizations which was comprised with members of the public, private sector experts, and agency representations.

Hillsborough MPO, Forward Pinellas, and Pasco County Outreach included the following groups from Fall 2018 and is anticipated through Spring 2020.

- Citizens Advisory Committees
- Technical Advisory Committees
- Transportation Disadvantaged Local Coordinating Boards
- County Local Mitigation Strategy Working Groups
- MPO Boards

One Bay Resilient Communities Meetings hosted by the Tampa Bay Regional Planning Council

- Regional Project Kick-off, Winter 2018
- Status, Spring 2019
- Preliminary Interim Results, Fall 2019
- Final results, Winter 2020

To help determine criticality, a public and agency survey was prepared to gauge what roadways were most important to the region and for what reasons. The survey asked what factors are important to determine criticality, such as hurricane evacuation, projected traffic volumes, or intermodal connectivity. It asked what area factors should be used to determine criticality, such as project population and percentage of zero-car households. Lastly it asked what activities or destinations respondents consider critical from an access perspective, such as shelters and hospitals, or educational or military institutions. The results of the survey were used to identify and weight the variables factored into the criticality assessment. (Section 2.2 of the report describes how the results were used.)

6.0 Summary and Recommendations

The transportation network in the Tampa Bay region faces challenges from extreme weather events. Heavy rain results in localized flooding, King Tide high tides are seeing water appear on roads, and storm surge and rain from hurricanes will inundated roads and may result in flooding throughout the region. Based on the results of this assessment, about 11 percent of the region's roadways are highly vulnerable to storms, sea level rise, and heavy precipitation, an additional eight percent of the roadways are of moderate vulnerability. Among these high or moderate vulnerable roadways, over one third are facilities that are highly critical to the region's safety, mobility, and economy.

Inundation of these roadways (defined as high resilience priority roadways in the document) will cause significant economic impact, including loss in Gross Regional Product (GRP) and personal income. Based on the comparison at Section 4.3.1, the loss in GRP alone will be close to or greater than the cost implementing adaptation strategies to high resilience priority needs when the transportation network is inundated for approximately 14 days due to Category 3 storm plus sea level rise or 9-inch precipitation events. Flooding from a single rain event typically subsides in a few hours or days. Similarly, storm surge typically ebbs after a few days, however, flooding from rain can last for several or more.

In addition, extreme weather events could cause damage to the infrastructure itself through washouts or other structural issues, adding cost of repairing or rebuilding the compromised assets to the region's burden. Based on the results from Section 4.3.2, compared to the rebuilding, adaptation strategies are proactive and in most cases less expensive ways to address potential threats from extreme climate events, not including the additional inconvenience, economic loss, and impact on emergency evacuation that might occur during the construction.

It is recommended that the adaptation strategies for high resilience priority locations be considered for inclusion in the three MPO's LRTPs. The cost of implementing adaptation strategies for these locations outweighs the cost of rebuilding. However, these costs are projected to be substantial and in addition to costs for current transportation needs. **As an alternate, implementing projects that relate to highly critical and highly vulnerable locations is an excellent first step.** The planning and implementation of adaptation projects should be closely coordinated with existing or future capital or maintenance and rehabilitation investments in the LRTP and county/municipal transportation, stormwater and beach enhancement plans.

The high criticality and high vulnerability projects include adaptation strategies of raising the profile (avoid), enhancing drainage, bolstering the road base or shoulders (protect), and coastal protection. Coastal protection strategies such as beach nourishment, sea walls, and wave attenuation can protect not only transportation facilities, but also properties and other assets in the region. It is important to work with various agencies and stakeholders to plan and fund these strategies. Including them in the LRTP would benefit transportation; however, given the indirect link, other benefactors and implementing agencies, implementing these strategies are recommended to be pursued outside the LRTP.

Raising the profile is a purposeful and effective strategy. However, there often are concerns about access and impacts to adjacent residences and businesses, and implementing these projects require information sharing and public input. As such, **implementing drainage solution adaptation strategies is an appropriate short-term solution while proactively seeking opportunities to implement other strategies**. Also, stormwater funding generally is available through other resources such as stormwater fees or capital improvement bonding, which would allow transportation funding to be geared toward protection and avoidance solutions.

The protection strategies are designed to ensure an asset recovers should it be inundated due to flooding (rain or hurricane related). These strategies include shoring up the road surface and subbase through deeper pavement, subbases that can be flooded, vegetative solutions to stabilize shoulders, and coastal/shoreline solutions to reduce wave and surge effects. During maintenance and rehabilitation projects for all high resilience projects, it is recommended that at a minimum protective measures be considered as noted.

New capacity projects in the region, as well as major rehabilitation such as the Gandy Boulevard bridge, should consider the vulnerability and criticality determinations identified in this study and incorporate adaptation strategies where appropriate. Most of the projects identified in this report address retrofitting assets to address resilience and reliability through adaptation. For new or replaced facilities, regional entities should take the opportunity to embed adaptation elements.

Following the FHWA vulnerability assessment and adaptation framework, this study evaluated the transportation facilities in the Tampa Bay region based on their potential vulnerability/exposure and criticality. It is also recommended that agencies in the Tampa Bay region continue to implement other areas of the FHWA framework. For example, this study did not include bridge or pavement conditions in the assessment. **A near-term next step would be to align assets with potential structural issues with adaptation strategies identified here for inclusion in improvement plans where feasible**.

As noted above**, multiple partners are needed to implement adaptation strategies identified to protect transportation infrastructure**. One option to begin this coordination would be to select a subarea for more detailed and coordinated identification of adaptation strategies benefiting property and buildings as well as transportation. A subarea study could allow for sub basin or regional water flow modeling to assess the capacity needs of stormwater infrastructure. This could be done by identifying adaptation action areas or through informal coordination. Municipalities most likely already include this type of coordination in their capital planning program. Including the MPOs and FDOT in the discussions could be beneficial.

The Section 3.0 of this document provided examples of adaptation options for the counties' representative projects and conducted an index-base assignment of strategies to transportation facilities for planning purposes. Facilities with higher criticality and higher vulnerability were assigned with more comprehensive and generally more expensive strategies as compared to locations with lower criticality and vulnerability. As a result, the cost could be overestimated for some locations while underestimated for others. These estimates also do not include water modeling that may be required for bridges or riverine areas. Detail engineering assessments through project development and design will be needed to validate and select suitable strategies and provide more refined cost estimates.

This econometric analysis performed in this assessment clearly points to the continued need for the three MPOs to work cooperatively. That analysis showed that a specific adaptation strategy may be implemented by a single county, yet the economic benefits (or impacts) accrue to the entire region.

Lessons learned and FHWA framework suggestions primarily relate to studying a large geographic area in a systematic, comprehensive approach. Some recommendations are:

- There is a need to continue to align GIS and travel demand models. In this project, a GIS-based analysis approach was used. Converting the information to tables was labor intensive given the segmentation and information in the travel demand model.

- In Florida, water is a major weather and climate stressor. Hydrologists can assist in identifying areas with potential vulnerabilities to risk. Similarly, to assign adaptation strategies to every road segment in the network, required some assumption based on criticality and vulnerability rankings given the large number of links. Working at a large scale or across disciplines is a challenge to continue to be addressed.

- It is possible to recommend non-transportation solutions (e.g., green infrastructure and natural solutions) that will benefit communities as well as transportation systems. Working with partners to implement these strategies, particularly as related to funding across agencies, could be enhanced.

- Of major need are planning level tools to evaluate the costs and benefits of implementing various adaptation strategies. This project provides one way to identify costs of construction and the costs of no action. A piece missing is to determine the vulnerabilities and benefits if a specific action is taken. For example, when raising the elevation of infrastructure, it is possible to assess whether the road will be sufficiently high to withstand flooding. However, if a natural shoreline is implemented, how does one gauge if the asset is protected from flooding/surge vulnerability.

Appendix A. Travel Demand Model Methodology

Travel demand modeling was intended to be used in REMI Transight analysis which required results in a very specific format of vehicle demand metrics (VMT, VHT and number of trips) by county to county origin-destination (OD) pairs45. The default output from the Tampa Bay Regional Planning Model (TBRPM) provides link level demand at the aggregate level region-wide. The model does not provide outputs in the required Transight format hence it was therefore necessary to perform select zone analysis to get OD demand for specific county-county zone pairs for the REMI analysis. The approach used was to modify the default assignment procedure by time period to incorporate select zone analysis for each of the 63 possible permutations of County OD patterns.

The processing order for this analysis began with running the TBRPM model with the relevant disconnected links for each scenario to establish the OD demand based on model link closures. The links were disconnected using Cube Network functions when path skimming and assignment were undertaken. Once the OD demand trip tables were available, these were then run in the select link assignments described previously for each time period.

The CAT 3 High and the 9" precipitation events produce the largest impacts as would be expected given the number of links affected. The next highest impact scenario is the Gandy Boulevard scenario which removes one of only three Trans Bay crossings in the region. Because of the reduction in assigned trips owing to OD redistribution, the link demand metric reduction in VMT and VHT in some instances behaved in the opposite manner than would be initially expected. In the cases where VMT and VHT increased, trip OD redistribution produced rerouting to available alternate facilities, often being lower in classification with attendant lower speeds and capacities.

Overall, this analysis shows that the TBRPM model is very sensitive to link disruptions, producing large changes in trip distribution patterns within the region. Further analysis may be warranted to determine assignment rerouting effects without the impact of OD demand adjustments in the trip distribution step. It is important to remember that the model is a tool and should be used complementarily with appropriate planning level judgment to better guide decision making regarding resilience to climate events.

[45] Hillsborough County Capital Improvement Program Budget FY 2018/2019 – FY 2022/2023

[45] FDOT Work Program Pinellas County Maintenance Projects, 2020 - 2024

45 Pinellas County Capital Improve

Appendix B. Regional Travel Demand Model Results, Inter-County Flows

Figure B-6-1 US 19 from S.R.54 to S.R.52 - Pasco

Project/Event Impacts on 2045 Baseline Travel Characteristics							
Origin County	Destination County	Auto VMT	Auto VHT	Auto Trips	Truck VMT	Truck VHT	Truck Trips
Hillsborough	Hillsborough	-0.23%	0.16%	-0.05%	0.06%	0.27%	0.02%
Hillsborough	Pasco	3.14%	2.59%	-1.12%	4.86%	7.61%	5.37%
Hillsborough	Pinellas	-3.91%	-2.47%	0.53%	-4.26%	-5.76%	-4.97%
Pasco	Hillsborough	-55.69%	-50.95%	-1.12%	-51.09%	-44.05%	5.37%
Pasco	Pasco	8.39%	8.91%	27.23%	14.41%	17.39%	29.80%
Pasco	Pinellas	-3.80%	-0.76%	-4.89%	-6.14%	-3.25%	-6.36%
Pinellas	Hillsborough	124.80%	104.47%	0.53%	105.53%	80.94%	-4.97%
Pinellas	Pasco	-3.80%	-0.76%	-4.89%	-6.14%	-3.25%	-6.36%
Pinellas	Pinellas	-9.84%	-7.95%	-23.14%	-14.02%	-14.42%	-24.30%
Total Impacts		-0.75%	0.11%	-0.58%	-0.38%	0.25%	-0.37%

Figure B-6-2 S.R.54 from US 19 to Suncoast - Pasco

Project/Event Impacts on 2045 Baseline Travel Characteristics							
Origin County	Destination County	Auto VMT	Auto VHT	Auto Trips	Truck VMT	Truck VHT	Truck Trips
Hillsborough	Hillsborough	0.08%	0.55%	0.03%	0.10%	0.39%	0.00%
Hillsborough	Pasco	0.81%	1.89%	-0.07%	-1.49%	0.10%	-1.51%
Hillsborough	Pinellas	-0.59%	0.12%	-0.40%	-0.19%	0.47%	-0.18%
Pasco	Hillsborough	0.81%	1.89%	-0.07%	-1.49%	0.10%	-1.51%
Pasco	Pasco	-0.54%	0.61%	-2.21%	-1.39%	-0.22%	-2.37%
Pasco	Pinellas	0.84%	1.94%	0.48%	-0.73%	0.19%	-0.60%
Pinellas	Hillsborough	-0.50%	0.35%	-0.40%	-0.05%	1.07%	-0.18%
Pinellas	Pasco	0.84%	1.94%	0.48%	-0.73%	0.19%	-0.60%
Pinellas	Pinellas	-0.04%	0.47%	0.02%	-0.15%	0.51%	-0.04%
Total Impacts		0.00%	0.71%	-0.45%	-0.35%	0.30%	-0.49%

Figure B-6-3 Gulf Boulevard/SR 699 from Bath Club Circle to 125th Ave & Tom Stuart Causeway Bridge - Pinellas

Project/Event Impacts on 2045 Baseline Travel Characteristics							
Origin County	Destination County	Auto VMT	Auto VHT	Auto Trips	Truck VMT	Truck VHT	Truck Trips
Hillsborough	Hillsborough	-0.19%	0.14%	-0.06%	0.04%	0.20%	0.00%
Hillsborough	Pasco	3.06%	2.89%	-1.34%	4.55%	7.63%	5.17%
Hillsborough	Pinellas	-3.69%	-2.65%	0.71%	-4.54%	-6.39%	-5.13%
Pasco	Hillsborough	-55.87%	-50.88%	-1.34%	-51.26%	-43.81%	5.17%
Pasco	Pasco	8.84%	8.76%	26.63%	14.08%	16.94%	29.23%
Pasco	Pinellas	0.25%	0.46%	0.15%	0.12%	0.37%	0.09%
Pinellas	Hillsborough	125.34%	104.09%	0.71%	104.91%	79.74%	-5.13%
Pinellas	Pasco	0.25%	0.46%	0.15%	0.12%	0.37%	0.09%
Pinellas	Pinellas	-8.59%	-7.69%	-21.62%	-12.74%	-13.95%	-23.03%
Total Impacts		-0.22%	0.17%	-0.24%	-0.09%	0.26%	-0.13%

Table B-4 Roosevelt Boulevard/SR 686 from Ulmerton Road/SR 688 to Gandy Blvd - Pinellas

		Project/Event Impacts on 2045 Baseline Travel Characteristics					
Origin County	Destination County	Auto VMT	Auto VHT	Auto Trips	Truck VMT	Truck VHT	Truck Trips
Hillsborough	Hillsborough	-0.19%	0.15%	-0.02%	0.05%	0.32%	0.02%
Hillsborough	Pasco	-0.49%	0.08%	-0.30%	-0.10%	0.73%	-0.11%
Hillsborough	Pinellas	-0.10%	0.10%	-0.06%	0.89%	1.29%	0.59%
Pasco	Hillsborough	-0.49%	0.08%	-0.30%	-0.10%	0.73%	-0.11%
Pasco	Pasco	-0.19%	0.46%	-0.01%	0.02%	0.74%	0.00%
Pasco	Pinellas	0.58%	0.72%	0.37%	0.61%	0.93%	0.26%
Pinellas	Hillsborough	0.09%	0.33%	-0.06%	0.63%	1.04%	0.59%
Pinellas	Pasco	0.58%	0.72%	0.37%	0.61%	0.93%	0.26%
Pinellas	Pinellas	0.21%	0.49%	-0.09%	0.20%	0.79%	0.00%
Total Impacts		-0.10%	0.28%	-0.04%	0.11%	0.57%	0.03%

Figure B-5 Gandy Blvd from 4th St to S Dale Mabry Hwy - Hillsborough

		Project/Event Impacts on 2045 Baseline Travel Characteristics					
Origin County	Destination County	Auto VMT	Auto VHT	Auto Trips	Truck VMT	Truck VHT	Truck Trips
Hillsborough	Hillsborough	-16.67%	-16.43%	-0.09%	-11.56%	-10.98%	-0.12%
Hillsborough	Pasco	-9.42%	-9.73%	0.02%	-5.21%	-4.53%	0.06%
Hillsborough	Pinellas	-35.67%	-36.76%	-2.57%	-22.34%	-22.11%	-4.89%
Pasco	Hillsborough	-9.42%	-9.73%	0.02%	-5.21%	-4.53%	0.06%
Pasco	Pasco	-11.15%	-10.65%	0.01%	-5.22%	-4.16%	0.01%
Pasco	Pinellas	-29.63%	-29.72%	-0.26%	-18.06%	-18.31%	0.03%
Pinellas	Hillsborough	-37.10%	-36.45%	-2.57%	-25.39%	-24.52%	-4.89%
Pinellas	Pasco	-29.63%	-29.72%	-0.26%	-18.06%	-18.31%	0.03%
Pinellas	Pinellas	-32.84%	-33.12%	-0.59%	-22.08%	-21.99%	-0.61%
Total Impacts		-20.28%	-20.03%	-0.29%	-12.91%	-12.38%	-0.33%

Figure B-6 Big Bend Rd from US-41 to I-75 – Hillsborough

		Project/Event Impacts on 2045 Baseline Travel Characteristics					
Origin County	Destination County	Auto VMT	Auto VHT	Auto Trips	Truck VMT	Truck VHT	Truck Trips
Hillsborough	Hillsborough	-0.02%	3.25%	-0.05%	0.03%	2.27%	-0.03%
Hillsborough	Pasco	0.02%	0.86%	-0.04%	0.02%	1.19%	-0.04%
Hillsborough	Pinellas	-0.27%	0.17%	-0.13%	0.23%	0.88%	0.13%
Pasco	Hillsborough	0.02%	0.86%	-0.04%	0.02%	1.19%	-0.04%
Pasco	Pasco	-0.07%	0.66%	0.01%	0.04%	0.74%	-0.01%
Pasco	Pinellas	0.22%	0.39%	0.19%	0.07%	0.38%	0.09%
Pinellas	Hillsborough	0.17%	0.63%	-0.13%	0.59%	1.25%	0.13%
Pinellas	Pasco	0.22%	0.39%	0.19%	0.07%	0.38%	0.09%
Pinellas	Pinellas	-0.01%	0.29%	0.00%	-0.08%	0.47%	0.00%
Total Impacts		-0.02%	1.62%	-0.02%	0.02%	1.47%	-0.01%

Figure B-7 9 Inch Rain Event

Project/Event Impacts on 2045 Baseline Travel Characteristics							
Origin County	Destination County	Auto VMT	Auto VHT	Auto Trips	Truck VMT	Truck VHT	Truck Trips
Hillsborough	Hillsborough	7.14%	79.24%	-6.36%	-1.15%	84.09%	-6.91%
Hillsborough	Pasco	11.27%	54.61%	-2.81%	-6.92%	27.21%	-6.08%
Hillsborough	Pinellas	3.01%	76.09%	-21.86%	-13.63%	52.75%	-30.58%
Pasco	Hillsborough	11.27%	54.61%	-2.81%	-6.92%	27.21%	-6.08%
Pasco	Pasco	14.75%	38.94%	-4.28%	1.22%	39.56%	-4.29%
Pasco	Pinellas	15.09%	38.52%	-20.86%	-7.95%	13.46%	-25.85%
Pinellas	Hillsborough	-4.34%	38.19%	-21.86%	-5.74%	44.11%	-30.58%
Pinellas	Pasco	15.09%	38.52%	-20.86%	-7.95%	13.46%	-25.85%
Pinellas	Pinellas	6.42%	40.33%	-9.84%	5.15%	55.82%	-7.02%
Total Impacts		8.68%	59.34%	-7.44%	-0.20%	64.22%	-7.19%

Figure B-8 Category 3 Hurricane

Project/Event Impacts on 2045 Baseline Travel Characteristics							
Origin County	Destination County	Auto VMT	Auto VHT	Auto Trips	Truck VMT	Truck VHT	Truck Trips
Hillsborough	Hillsborough	-46.15%	-43.32%	-41.99%	-41.23%	-39.71%	-42.62%
Hillsborough	Pasco	-31.31%	-29.62%	-21.08%	-31.41%	-29.09%	-17.79%
Hillsborough	Pinellas	-99.64%	-99.59%	-99.61%	-99.88%	-99.87%	-99.80%
Pasco	Hillsborough	-31.31%	-29.62%	-21.08%	-31.41%	-29.09%	-17.79%
Pasco	Pasco	-32.91%	-31.32%	-27.49%	-24.77%	-21.93%	-25.95%
Pasco	Pinellas	-98.82%	-98.60%	-97.24%	-98.29%	-98.00%	-96.68%
Pinellas	Hillsborough	-99.25%	-99.23%	-99.61%	-99.75%	-99.76%	-99.80%
Pinellas	Pasco	-98.82%	-98.60%	-97.24%	-98.29%	-98.00%	-96.68%
Pinellas	Pinellas	-90.64%	-88.99%	-74.72%	-94.17%	-93.02%	-81.31%
Total Impacts		-57.74%	-55.10%	-49.63%	-52.62%	-50.84%	-50.18%

Appendix C. TranSight Methodology (V. 4.0)

Commute Costs

$$\Delta CC_{ij} = 1 + \frac{1}{8} * \sum_k \left[\left(\%H_k^{alt} * \frac{VHT_{ij}^{alt}}{trips_{ij}^{alt}} \right) - \left(\%H_k^{base} * \frac{VHT_{ij}^{base}}{trips_{ij}^{base}} \right) \right]$$

where

ΔCCij = Change in commuter costs between regions *i* and *j* (hours)

$\%H_k^{base}$ = Percent of **VHT** between *i* and *j* traveled on mode *k*: baseline scenario

VHT_k^{base} = Vehicle hours traveled between *i* and *j* on mode *k*: baseline scenario

$trips_k^{base}$ = Vehicle **Trips** traveled between *i* and *j* on mode *k*: baseline scenario

$\%H_k^{alt}$ = Percent of **VHT** between *i* and *j* traveled on mode *k*: alternative scenario

VHT_k^{alt} = Vehicle hours traveled between *i* and *j* on mode *k*: alternative scenario

$trips_k^{alt}$ = Vehicle **Trips** traveled between *i* and *j* on mode *k*: alternative scenario

$$\%H_k^S = \frac{VHT_{ij}^S * Occ * CCRatio}{\sum_{ij} VHT_{ij}^S}$$

where

$\%H_k^S$ = Percent of **VHT** between *i* and *j* traveled on mode *k*: scenario *S*

VHT_k^S = Vehicle hours traveled between *i* and *j* on mode *k*: scenario *S*

Occ = Vehicle occupancy on mode *k*

CCRatio = Commuting costs mode ratios for mode *k*

Transportation Costs

$$\Delta TC_{ij} = \frac{(VMT_{ij}^{base} / VHT_{ij}^{base})}{(VMT_{ij}^{alt} / VHT_{ij}^{alt})}$$

where

ΔTCij	= Change in transportation costs between regions *i* and *j*
VMT_{ij}^{base}	= Vehicle miles traveled between *i* and *j*: baseline scenario
VHT_{ij}^{base}	= Vehicle hours traveled between *i* and *j*: baseline scenario
VMT_{ij}^{alt}	= Vehicle miles traveled between *i* and *j*: alternative scenario
VHT_{ij}^{alt}	= Vehicle hours traveled between *i* and *j*: alternative scenario

Accessibly Costs

$$\Delta AC_{ij} = \frac{(Trips_{ij}^{base} / VHT_{ij}^{base})}{(Trips_{ij}^{alt} / VHT_{ij}^{alt})}$$

where

ΔACij	= Change in accessibility costs between regions *i* and *j*
$Trips_{ij}^{base}$	= Vehicle **Trips** between *i* and *j*: baseline scenario
VHT_{ij}^{base}	= Vehicle hours traveled between *i* and *j*: baseline scenario
$Trips_{ij}^{alt}$	= Vehicle **Trips** between *i* and *j*: alternative scenario
VHT_{ij}^{alt}	= Vehicle hours traveled between *i* and *j*: alternative scenario

Appendix D. Detailed Summary Tables for Project Impacts (2-Day)

Figure D-1 US 19, Pasco Detailed Economic Impacts

Category	2045	2046	2047	2048	2049	2050
Hillsborough						
Total Employment (individual jobs)	-19.69	-2.58	0.21	1.37	1.83	1.79
Private Non-Farm Employment (individual jobs)	-19.03	-2.14	0.44	1.46	1.82	1.73
Residence Adjusted Employment (individual jobs)	1.21	-2.86	3.50	4.53	4.91	4.69
Population (individuals)	-6.11	-5.69	-3.97	-2.32	-0.79	0.45
Labor Force (individuals)	-4.36	-3.12	-1.96	-0.89	0.05	0.80
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-4.21	-0.46	-0.05	0.15	0.23	0.23
Output (Millions of Fixed 2018 Dollars)	-7.19	-0.89	-0.15	0.21	0.36	0.37
Value Added (Millions of Fixed 2018 Dollars)	-4.18	-0.47	-0.05	0.15	0.23	0.23
Personal Income (Millions of Fixed 2018 Dollars)	2.27	-0.67	0.63	0.90	1.09	1.15
Disposable Personal Income (Millions of Fixed 2018 Dollars)	1.87	-0.58	0.50	0.73	0.89	0.95
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-1.31	-0.15	0.29	0.37	0.42	0.42
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00
Pasco						
Total Employment (individual jobs)	-76.31	-2.86	-1.04	-0.04	0.23	0.12
Private Non-Farm Employment (individual jobs)	-74.03	-1.52	-0.18	0.55	0.68	0.50
Residence Adjusted Employment (individual jobs)	-12.13	-10.97	-11.44	-11.33	-10.94	-10.36
Population (individuals)	-7.05	-9.15	-11.99	-14.17	-15.78	-16.87
Labor Force (individuals)	-6.65	-6.92	-8.68	-9.78	-10.43	-10.70
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-8.61	-0.48	-0.27	-0.14	-0.09	-0.08
Output (Millions of Fixed 2018 Dollars)	-14.60	-0.87	-0.48	-0.24	-0.15	-0.14
Value Added (Millions of Fixed 2018 Dollars)	-8.63	-0.49	-0.27	-0.14	-0.09	-0.08
Personal Income (Millions of Fixed 2018 Dollars)	-6.30	-0.43	-0.72	-0.84	-1.02	-1.22
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-5.06	-0.34	-0.59	-0.71	-0.88	-1.07

Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-4.52	0.02	-0.22	-0.28	-0.37	-0.45
PCE-Price Index (2009=100, nation)	0.01	0.00	0.00	0.00	0.00	0.00
Pinellas						
Total Employment (individual jobs)	-48.95	1.37	4.04	7.07	7.84	7.38
Private Non-Farm Employment (individual jobs)	-45.94	3.60	5.78	8.36	8.77	8.04
Residence Adjusted Employment (individual jobs)	-87.21	1.10	0.85	4.55	5.92	6.09
Population (individuals)	-60.70	-44.56	-35.72	-27.22	-19.87	-13.80
Labor Force (individuals)	-42.82	-26.21	-20.91	-15.67	-11.12	-7.36
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-12.78	-6.12	-4.69	-3.37	-2.51	-1.95
Output (Millions of Fixed 2018 Dollars)	-20.74	-10.00	-7.60	-5.40	-3.98	-3.06
Value Added (Millions of Fixed 2018 Dollars)	-12.54	-5.91	-4.51	-3.21	-2.37	-1.83
Personal Income (Millions of Fixed 2018 Dollars)	-14.76	-2.18	-1.87	-0.84	-0.18	0.23
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-12.31	-2.01	-1.72	-0.85	-0.28	0.08
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-22.03	-0.17	-0.79	-0.38	-0.16	-0.03
PCE-Price Index (2009=100, nation)	0.03	0.00	0.00	0.00	0.00	0.00

Source: TBRPC Remi TranSight, 4.0, 2019.

Figure D-2 SR 54, Pasco Detailed Economic Impacts

Category Units	2045	2046	2047	2048	2049	2050
Hillsborough						
Total Employment (individual jobs)	-13.69	0.10	0.76	1.04	1.08	0.97
Private Non-Farm Employment (individual jobs)	-13.25	0.37	0.92	1.13	1.12	0.98
Residence Adjusted Employment (individual jobs)	-7.09	0.29	1.56	1.81	1.84	1.71
Population (individuals)	-4.72	-3.62	-2.66	-1.77	-1.00	-0.38
Labor Force (individuals)	-3.49	-2.11	-1.42	-0.84	-0.36	0.02
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-2.55	-0.32	-0.17	-0.07	-0.02	-0.01
Output (Millions of Fixed 2018 Dollars)	-4.47	-0.58	-0.31	-0.14	-0.05	-0.02
Value Added (Millions of Fixed 2018 Dollars)	-2.56	-0.33	-0.17	-0.07	-0.02	-0.01
Personal Income (Millions of Fixed 2018 Dollars)	-0.65	-0.12	0.16	0.26	0.32	0.35

Disposable Personal Income (Millions of Fixed 2018 Dollars)	-0.55	-0.12	0.12	0.21	0.26	0.28
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-1.31	-0.01	0.07	0.10	0.12	0.12
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00
Pasco						
Total Employment (individual jobs)	-10.05	1.08	1.22	1.33	1.19	0.96
Private Non-Farm Employment (individual jobs)	-9.43	1.57	1.62	1.65	1.46	1.18
Residence Adjusted Employment (individual jobs)	-9.81	-6.11	-5.65	-5.05	-4.42	-3.82
Population (individuals)	-8.83	-8.49	-8.80	-8.85	-8.72	-8.44
Labor Force (individuals)	-8.05	-5.33	-5.44	-5.31	-5.06	-4.71
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-1.76	-0.49	-0.37	-0.27	-0.21	-0.17
Output (Millions of Fixed 2018 Dollars)	-2.99	-0.87	-0.64	-0.46	-0.35	-0.29
Value Added (Millions of Fixed 2018 Dollars)	-1.77	-0.50	-0.37	-0.27	-0.21	-0.17
Personal Income (Millions of Fixed 2018 Dollars)	-3.65	-0.20	-0.53	-0.55	-0.59	-0.63
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-2.95	-0.19	-0.46	-0.48	-0.53	-0.56
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-3.44	-0.04	-0.22	-0.23	-0.25	-0.26
PCE-Price Index (2009=100, nation)	0.01	0.00	0.00	0.00	0.00	0.00
Pinellas						
Total Employment (individual jobs)	-6.54	-0.48	-0.07	0.02	0.07	0.08
Private Non-Farm Employment (individual jobs)	-6.48	-0.46	-0.08	0.01	0.05	0.06
Residence Adjusted Employment (individual jobs)	0.31	-0.29	0.80	0.83	0.82	0.75
Population (individuals)	0.89	0.46	0.49	0.51	0.55	0.58
Labor Force (individuals)	0.65	0.26	0.28	0.30	0.33	0.34
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-0.81	0.08	0.10	0.10	0.09	0.07
Output (Millions of Fixed 2018 Dollars)	-1.46	0.14	0.18	0.17	0.15	0.13
Value Added (Millions of Fixed 2018 Dollars)	-0.81	0.08	0.10	0.10	0.09	0.07
Personal Income (Millions of Fixed 2018 Dollars)	0.37	-0.04	0.15	0.17	0.18	0.18
Disposable Personal Income (Millions of Fixed 2018 Dollars)	0.31	-0.03	0.12	0.14	0.15	0.15
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	0.46	-0.03	0.07	0.07	0.07	0.07
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00

Source: TBRPC Remi TranSight, 4.0, 2019.

Figure D-3 Gulf Blvd, Pinellas Detailed Economic Impacts

Category Units	2045	2046	2047	2048	2049	2050
Hillsborough						
Total Employment (individual jobs)	39.49	0.14	1.37	1.73	1.80	1.62
Private Non-Farm Employment (individual jobs)	38.84	-0.17	1.18	1.57	1.64	1.46
Residence Adjusted Employment (individual jobs)	30.00	-0.45	3.99	4.58	4.77	4.54
Population (individuals)	2.19	2.28	3.29	4.13	4.82	5.27
Labor Force (individuals)	2.02	2.12	2.52	2.92	3.23	3.41
Gross Domestic Product (Millions of Fixed 2018 Dollars)	5.39	-0.48	-0.20	-0.06	0.01	0.03
Output (Millions of Fixed 2018 Dollars)	8.58	-0.89	-0.40	-0.15	-0.01	0.03
Value Added (Millions of Fixed 2018 Dollars)	5.36	-0.48	-0.20	-0.06	0.01	0.03
Personal Income (Millions of Fixed 2018 Dollars)	4.38	0.09	1.03	1.21	1.32	1.35
Disposable Personal Income (Millions of Fixed 2018 Dollars)	3.63	0.08	0.86	1.01	1.11	1.14
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-0.28	0.08	0.42	0.47	0.50	0.50
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00
Pasco						
Total Employment (individual jobs)	-65.93	-2.73	-1.18	-0.33	-0.06	-0.09
Private Non-Farm Employment (individual jobs)	-64.09	-1.68	-0.54	0.10	0.26	0.18
Residence Adjusted Employment (individual jobs)	-7.76	-8.20	-8.83	-8.94	-8.79	-8.45
Population (individuals)	-2.90	-5.04	-7.63	-9.71	-11.31	-12.46
Labor Force (individuals)	-2.86	-4.35	-6.01	-7.12	-7.86	-8.27
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-7.22	-0.29	-0.14	-0.05	-0.02	-0.02
Output (Millions of Fixed 2018 Dollars)	-12.24	-0.52	-0.24	-0.08	-0.03	-0.04
Value Added (Millions of Fixed 2018 Dollars)	-7.24	-0.29	-0.14	-0.05	-0.02	-0.02
Personal Income (Millions of Fixed 2018 Dollars)	-5.19	-0.31	-0.49	-0.59	-0.73	-0.89
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-4.16	-0.22	-0.39	-0.48	-0.62	-0.77
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-3.08	0.04	-0.12	-0.17	-0.24	-0.32
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00
Pinellas						
Total Employment (individual jobs)	-159.79	-8.73	-3.33	1.28	3.40	4.05

Private Non-Farm Employment (individual jobs)	-155.47	-5.92	-1.36	2.65	4.35	4.71
Residence Adjusted Employment (individual jobs)	-160.12	-8.51	-6.15	-1.42	0.95	2.01
Population (individuals)	-60.08	-49.49	-43.22	-36.32	-29.76	-23.89
Labor Force (individuals)	-40.65	-29.90	-25.77	-21.38	-17.22	-13.50
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-25.87	-3.94	-2.79	-1.77	-1.14	-0.77
Output (Millions of Fixed 2018 Dollars)	-43.61	-6.59	-4.60	-2.88	-1.82	-1.20
Value Added (Millions of Fixed 2018 Dollars)	-25.64	-3.86	-2.71	-1.70	-1.09	-0.72
Personal Income (Millions of Fixed 2018 Dollars)	-22.04	-4.02	-3.47	-2.38	-1.62	-1.08
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-18.29	-3.54	-3.07	-2.16	-1.51	-1.05
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-17.83	-0.91	-1.27	-0.86	-0.61	-0.45
PCE-Price Index (2009=100, nation)	0.02	0.00	0.00	0.00	0.00	0.00

Source: TBRPC Remi TranSight, 4.0, 2019.

Figure D-4 Roosevelt, Pinellas Detailed Economic Impacts

Category Units	2045	2046	2047	2048	2049	2050
Hillsborough						
Total Employment (individual jobs)	-15.11	-0.74	-0.16	0.24	0.41	0.44
Private Non-Farm Employment (individual jobs)	-14.65	-0.44	0.04	0.36	0.49	0.49
Residence Adjusted Employment (individual jobs)	-13.58	-0.80	-0.12	0.30	0.50	0.56
Population (individuals)	-4.99	-4.24	-3.70	-3.10	-2.51	-1.98
Labor Force (individuals)	-3.77	-2.67	-2.22	-1.77	-1.36	-1.00
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-2.70	-0.26	-0.16	-0.07	-0.03	-0.01
Output (Millions of Fixed 2018 Dollars)	-4.82	-0.47	-0.28	-0.13	-0.05	-0.01
Value Added (Millions of Fixed 2018 Dollars)	-2.71	-0.27	-0.16	-0.07	-0.03	-0.01
Personal Income (Millions of Fixed 2018 Dollars)	-1.85	-0.34	-0.20	-0.09	-0.02	0.03
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-1.55	-0.30	-0.18	-0.09	-0.03	0.01
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-1.35	-0.10	-0.08	-0.04	-0.01	0.00
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00
Pasco						
Total Employment (individual jobs)	-11.17	-0.01	0.14	0.22	0.22	0.17

Private Non-Farm Employment (individual jobs)	-1.74	-1.65	-1.73	-1.71	-1.65	-1.56
Residence Adjusted Employment (individual jobs)	-0.82	-1.16	-1.61	-1.96	-2.22	-2.39
Population (individuals)	-0.77	-0.93	-1.22	-1.40	-1.51	-1.56
Labor Force (individuals)	-1.33	-0.08	-0.05	-0.03	-0.02	-0.02
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-2.24	-0.15	-0.09	-0.05	-0.03	-0.03
Output (Millions of Fixed 2018 Dollars)	-1.33	-0.08	-0.05	-0.03	-0.02	-0.02
Value Added (Millions of Fixed 2018 Dollars)	-1.20	-0.04	-0.10	-0.12	-0.14	-0.17
Personal Income (Millions of Fixed 2018 Dollars)	-0.96	-0.02	-0.08	-0.10	-0.12	-0.15
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-0.74	0.02	-0.03	-0.04	-0.05	-0.06
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-11.17	-0.01	0.14	0.22	0.22	0.17
PCE-Price Index (2009=100, nation)	-1.74	-1.65	-1.73	-1.71	-1.65	-1.56
Pinellas						
Total Employment (individual jobs)	0.00	0.00	0.00	0.00	0.00	0.00
Private Non-Farm Employment (individual jobs)	-4.85	-0.45	-0.13	0.11	0.21	0.24
Residence Adjusted Employment (individual jobs)	-4.70	-0.34	-0.05	0.16	0.25	0.26
Population (individuals)	-5.67	-0.46	-0.05	0.20	0.33	0.37
Labor Force (individuals)	-2.46	-2.04	-1.74	-1.41	-1.09	-0.81
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-1.69	-1.23	-1.03	-0.82	-0.62	-0.45
Output (Millions of Fixed 2018 Dollars)	-0.84	-0.20	-0.13	-0.08	-0.05	-0.03
Value Added (Millions of Fixed 2018 Dollars)	-1.47	-0.33	-0.22	-0.13	-0.08	-0.05
Personal Income (Millions of Fixed 2018 Dollars)	-0.83	-0.19	-0.13	-0.08	-0.05	-0.03
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-0.86	-0.19	-0.11	-0.05	0.00	0.03
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-0.72	-0.17	-0.10	-0.05	-0.01	0.01
PCE-Price Index (2009=100, nation)	-0.83	-0.05	-0.04	-0.02	0.00	0.00

Source: TBRPC Remi TranSight, 4.0, 2019.

Figure D-5 Gandy, Hillsborough Detailed Economic Impacts

Category	2045	2046	2047	2048	2049	2050
Hillsborough						
Total Employment (individual jobs)	-814.58	-15.76	31.88	62.11	70.67	66.46
Private Non-Farm Employment (individual jobs)	-781.40	5.78	46.34	71.37	76.31	69.75
Residence Adjusted Employment (individual jobs)	-695.64	-19.53	39.00	66.98	74.89	70.33
Population (individuals)	-452.01	-345.43	-276.13	-209.93	-151.99	-105.05
Labor Force (individuals)	-337.64	-201.94	-154.08	-110.13	-73.40	-44.15
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-162.69	-31.31	-19.52	-10.44	-5.42	-3.03
Output (Millions of Fixed 2018 Dollars)	-285.76	-56.07	-34.96	-18.88	-9.93	-5.62
Value Added (Millions of Fixed 2018 Dollars)	-163.24	-31.38	-19.46	-10.32	-5.28	-2.88
Personal Income (Millions of Fixed 2018 Dollars)	-88.42	-17.50	-3.72	4.22	8.88	10.87
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-74.29	-15.90	-4.33	2.39	6.42	8.20
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-136.41	-0.74	-0.97	1.77	2.99	3.26
PCE-Price Index (2009=100, nation)	0.16	-0.01	0.00	0.00	0.00	0.00
Pasco						
Total Employment (individual jobs)	-100.67	-13.77	-5.04	-0.45	1.26	1.24
Private Non-Farm Employment (individual jobs)	-98.39	-12.78	-4.72	-0.50	1.07	1.02
Residence Adjusted Employment (individual jobs)	-19.58	-11.08	-11.13	-9.26	-7.18	-5.21
Population (individuals)	-15.95	-15.18	-18.41	-20.90	-22.46	-23.07
Labor Force (individuals)	-16.57	-8.82	-11.84	-12.72	-12.87	-12.36
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-7.84	1.02	1.48	1.63	1.53	1.29
Output (Millions of Fixed 2018 Dollars)	-13.27	1.59	2.47	2.77	2.63	2.23
Value Added (Millions of Fixed 2018 Dollars)	-7.93	1.01	1.48	1.63	1.54	1.30
Personal Income (Millions of Fixed 2018 Dollars)	-1.22	-2.33	1.95	2.65	2.69	2.22
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-0.96	-1.93	1.50	2.01	1.99	1.57
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-7.60	0.64	1.16	1.24	1.06	0.73
PCE-Price Index (2009=100, nation)	0.04	-0.01	0.00	0.00	0.00	0.00
Pinellas						
Total Employment (individual jobs)	-1328.92	-10.14	39.86	89.53	104.22	99.72

Private Non-Farm Employment (individual jobs)	-1278.35	24.00	64.65	106.96	116.30	108.04
Residence Adjusted Employment (individual jobs)	-1656.13	-14.00	-10.07	44.45	64.53	66.96
Population (individuals)	-889.00	-676.60	-559.25	-442.76	-340.00	-253.66
Labor Force (individuals)	-618.96	-401.86	-329.67	-257.14	-192.97	-139.07
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-250.96	-65.27	-47.91	-31.87	-22.10	-16.29
Output (Millions of Fixed 2018 Dollars)	-422.10	-112.81	-82.36	-54.70	-37.76	-27.67
Value Added (Millions of Fixed 2018 Dollars)	-249.34	-64.54	-47.16	-31.16	-21.43	-15.67
Personal Income (Millions of Fixed 2018 Dollars)	-250.33	-36.85	-31.21	-16.68	-7.50	-1.83
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-208.43	-33.51	-28.52	-16.23	-8.35	-3.39
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-301.97	-3.57	-12.33	-6.74	-3.88	-2.24
PCE-Price Index (2009=100, nation)	0.42	-0.03	-0.01	0.00	0.00	0.00

Source: TBRPC Remi TranSight, 4.0, 2019.

Figure D-6 Big Bend, Hillsborough Detailed Economic Impacts

Category Units	2045	2046	2047	2048	2049	2050
Hillsborough						
Total Employment (individual jobs)	-15.55	-1.16	-0.83	-0.53	-0.40	-0.38
Private Non-Farm Employment (individual jobs)	-14.96	-0.74	-0.50	-0.27	-0.19	-0.20
Residence Adjusted Employment (individual jobs)	-15.18	-1.40	-1.02	-0.69	-0.52	-0.46
Population (individuals)	-7.88	-7.70	-7.60	-7.21	-6.65	-6.05
Labor Force (individuals)	-5.72	-4.68	-4.43	-4.07	-3.66	-3.22
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-2.91	-0.34	-0.27	-0.21	-0.17	-0.15
Output (Millions of Fixed 2018 Dollars)	-5.82	-0.64	-0.52	-0.40	-0.33	-0.29
Value Added (Millions of Fixed 2018 Dollars)	-2.98	-0.35	-0.28	-0.21	-0.17	-0.15
Personal Income (Millions of Fixed 2018 Dollars)	-2.24	-0.52	-0.44	-0.36	-0.30	-0.26
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-1.88	-0.46	-0.39	-0.33	-0.29	-0.25
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-1.97	-0.32	-0.32	-0.27	-0.23	-0.20
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00
Pasco						

Total Employment (individual jobs)	-4.50	-0.18	-0.08	-0.01	0.00	-0.01
Private Non-Farm Employment (individual jobs)	-4.35	-0.09	-0.01	0.04	0.05	0.03
Residence Adjusted Employment (individual jobs)	-1.40	-1.14	-1.17	-1.14	-1.09	-1.02
Population (individuals)	-1.03	-1.21	-1.47	-1.67	-1.80	-1.88
Labor Force (individuals)	-0.95	-0.84	-1.00	-1.09	-1.13	-1.14
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-0.48	-0.04	-0.03	-0.02	-0.01	-0.01
Output (Millions of Fixed 2018 Dollars)	-0.82	-0.08	-0.05	-0.03	-0.03	-0.02
Value Added (Millions of Fixed 2018 Dollars)	-0.48	-0.05	-0.03	-0.02	-0.01	-0.01
Personal Income (Millions of Fixed 2018 Dollars)	-0.75	-0.06	-0.08	-0.09	-0.10	-0.12
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-0.60	-0.05	-0.07	-0.08	-0.09	-0.11
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-0.50	-0.02	-0.04	-0.04	-0.05	-0.06
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00
Pinellas						
Total Employment (individual jobs)	-14.54	-0.67	-0.47	-0.22	-0.11	-0.09
Private Non-Farm Employment (individual jobs)	-14.06	-0.38	-0.27	-0.08	0.00	0.00
Residence Adjusted Employment (individual jobs)	-13.74	-0.69	-0.58	-0.31	-0.19	-0.14
Population (individuals)	-5.17	-4.75	-4.54	-4.16	-3.73	-3.28
Labor Force (individuals)	-3.45	-2.87	-2.70	-2.45	-2.17	-1.88
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-3.27	-0.22	-0.18	-0.13	-0.10	-0.09
Output (Millions of Fixed 2018 Dollars)	-4.64	-0.37	-0.30	-0.22	-0.17	-0.14
Value Added (Millions of Fixed 2018 Dollars)	-3.04	-0.21	-0.17	-0.12	-0.10	-0.08
Personal Income (Millions of Fixed 2018 Dollars)	-2.39	-0.35	-0.31	-0.24	-0.19	-0.16
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-1.98	-0.31	-0.28	-0.22	-0.18	-0.15
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-1.65	-0.17	-0.19	-0.15	-0.13	-0.11
PCE-Price Index (2009=100, nation)	0.00	0.00	0.00	0.00	0.00	0.00

Source: TBRPC Remi TranSight, 4.0, 2019.

Figure D-7 9 Inch Rain Event Detailed Economic Impacts

Category Units	2045	2046	2047	2048	2049	2050
Hillsborough						
Total Employment (individual jobs)	-2334.47	-56.94	47.19	120.17	143.86	138.90
Private Non-Farm Employment (individual jobs)	-2247.03	-1.13	84.82	144.78	159.53	148.68
Residence Adjusted Employment (individual jobs)	-2119.84	-58.99	38.15	108.98	134.04	132.14
Population (individuals)	-1129.91	-873.41	-716.64	-562.84	-426.33	-312.98
Labor Force (individuals)	-850.50	-522.37	-409.85	-305.45	-216.99	-144.85
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-448.16	-72.81	-47.00	-26.19	-14.41	-8.42
Output (Millions of Fixed 2018 Dollars)	-785.25	-130.54	-84.20	-47.30	-26.28	-15.50
Value Added (Millions of Fixed 2018 Dollars)	-449.80	-73.29	-47.13	-26.13	-14.26	-8.23
Personal Income (Millions of Fixed 2018 Dollars)	-296.45	-47.37	-24.41	-5.10	6.84	13.19
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-248.31	-42.72	-23.42	-7.09	3.14	8.73
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-336.42	-4.83	-8.48	-1.50	1.94	3.39
PCE-Price Index (2009=100, nation)	0.34	-0.03	-0.01	0.00	0.00	0.00
Pasco						
Total Employment (individual jobs)	-212.79	-14.01	1.76	11.44	13.29	10.92
Private Non-Farm Employment (individual jobs)	-203.02	-7.06	7.03	15.46	16.49	13.62
Residence Adjusted Employment (individual jobs)	-166.49	-99.65	-93.90	-83.24	-72.20	-61.57
Population (individuals)	-149.69	-140.85	-148.42	-152.17	-152.67	-150.17
Labor Force (individuals)	-139.59	-86.33	-91.94	-91.37	-88.32	-83.29
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-26.38	-5.01	-2.74	-1.13	-0.46	-0.34
Output (Millions of Fixed 2018 Dollars)	-45.66	-9.06	-4.87	-1.96	-0.73	-0.49
Value Added (Millions of Fixed 2018 Dollars)	-26.46	-5.05	-2.74	-1.12	-0.44	-0.31
Personal Income (Millions of Fixed 2018 Dollars)	-56.24	-8.18	-5.68	-4.47	-4.70	-5.76
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-45.41	-7.03	-5.17	-4.38	-4.74	-5.75
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-59.88	-0.17	-1.87	-1.67	-2.10	-2.74
PCE-Price Index (2009=100, nation)	0.21	-0.02	0.00	0.00	0.00	0.00
Pinellas						
Total Employment (individual jobs)	-1599.06	-51.84	21.04	85.24	107.43	105.64

Private Non-Farm Employment (individual jobs)	-1540.80	-12.05	49.91	105.49	121.40	115.22
Residence Adjusted Employment (individual jobs)	-1835.44	-51.43	-8.38	58.70	84.69	87.83
Population (individuals)	-978.77	-752.69	-621.97	-491.35	-375.41	-277.90
Labor Force (individuals)	-681.59	-447.35	-366.83	-285.45	-213.03	-152.14
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-302.05	-78.85	-57.26	-38.11	-26.40	-19.48
Output (Millions of Fixed 2018 Dollars)	-501.64	-131.54	-94.58	-62.25	-42.50	-30.91
Value Added (Millions of Fixed 2018 Dollars)	-297.74	-76.87	-55.46	-36.52	-24.99	-18.22
Personal Income (Millions of Fixed 2018 Dollars)	-277.11	-48.64	-35.15	-17.44	-6.09	0.74
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-230.71	-43.56	-32.08	-17.14	-7.44	-1.48
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-334.65	-6.18	-13.42	-6.74	-3.25	-1.37
PCE-Price Index (2009=100, nation)	0.46	-0.04	-0.01	-0.01	0.00	0.00

Source: TBRPC Remi TranSight, 4.0, 2019.

Figure D-8 Category 3 Hurricane Detailed Economic Impacts

Category Units	2045	2046	2047	2048	2049	2050
Hillsborough						
Total Employment (individual jobs)	-1251.65	-60.32	62.93	127.96	148.58	141.04
Private Non-Farm Employment (individual jobs)	-1200.15	-26.26	84.43	140.10	154.20	142.54
Residence Adjusted Employment (individual jobs)	-734.64	-61.75	156.33	214.22	230.66	216.87
Population (individuals)	-696.79	-532.58	-395.28	-267.02	-155.71	-67.58
Labor Force (individuals)	-518.90	-302.00	-210.53	-127.50	-58.82	-5.03
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-254.40	-54.19	-28.73	-11.65	-2.65	0.91
Output (Millions of Fixed 2018 Dollars)	-444.95	-99.12	-53.51	-22.97	-6.64	0.02
Value Added (Millions of Fixed 2018 Dollars)	-254.95	-54.65	-28.87	-11.63	-2.54	1.06
Personal Income (Millions of Fixed 2018 Dollars)	-55.85	-32.29	15.90	32.81	43.11	46.88
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-47.69	-28.96	11.31	25.66	34.53	37.96
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-208.12	0.06	9.46	14.71	17.15	17.24
PCE-Price Index (2009=100, nation)	0.32	-0.03	-0.01	0.00	0.00	0.00
Pasco						
Total Employment (individual jobs)	-316.04	-27.41	0.07	16.10	19.25	15.26

Private Non-Farm Employment (individual jobs)	-299.39	-14.77	10.08	24.03	25.74	20.83
Residence Adjusted Employment (individual jobs)	-292.53	-177.72	-167.34	-149.57	-131.05	-113.26
Population (individuals)	-268.22	-254.53	-266.96	-273.50	-274.77	-271.15
Labor Force (individuals)	-248.78	-156.09	-164.71	-163.87	-158.92	-150.73
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-43.81	-11.26	-6.93	-3.92	-2.51	-2.08
Output (Millions of Fixed 2018 Dollars)	-75.70	-20.07	-12.15	-6.74	-4.19	-3.40
Value Added (Millions of Fixed 2018 Dollars)	-43.83	-11.32	-6.92	-3.88	-2.46	-2.02
Personal Income (Millions of Fixed 2018 Dollars)	-89.46	-16.86	-12.42	-10.47	-10.84	-12.63
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-72.25	-14.41	-11.08	-9.83	-10.44	-12.15
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-101.05	-2.66	-4.83	-4.52	-5.18	-6.22
PCE-Price Index (2009=100, nation)	0.37	-0.03	-0.01	0.00	0.00	0.00
Pinellas						
Total Employment (individual jobs)	-5978.98	-287.97	-72.07	128.35	207.92	218.53
Private Non-Farm Employment (individual jobs)	-5789.59	-159.04	22.32	196.29	256.74	253.88
Residence Adjusted Employment (individual jobs)	-6593.31	-279.76	-227.66	-20.31	70.96	100.60
Population (individuals)	-3043.35	-2418.20	-2070.74	-1710.23	-1381.86	-1097.87
Labor Force (individuals)	-2096.12	-1446.94	-1227.41	-1000.79	-793.91	-615.04
Gross Domestic Product (Millions of Fixed 2018 Dollars)	-1019.56	-234.72	-174.01	-118.93	-84.61	-63.63
Output (Millions of Fixed 2018 Dollars)	-1725.68	-391.54	-287.61	-194.59	-136.78	-101.71
Value Added (Millions of Fixed 2018 Dollars)	-1013.35	-229.26	-169.06	-114.55	-80.73	-60.19
Personal Income (Millions of Fixed 2018 Dollars)	-950.43	-171.47	-151.12	-100.82	-67.59	-45.68
Disposable Personal Income (Millions of Fixed 2018 Dollars)	-790.28	-152.38	-134.77	-92.46	-64.19	-45.29
Real Disposable Personal Income (Millions of Fixed 2018 Dollars)	-975.00	-35.09	-60.73	-41.31	-30.67	-24.07
PCE-Price Index (2009=100, nation)	1.21	-0.12	-0.03	-0.02	-0.01	0.00

Source: TBRPC Remi TranSight, 4.0, 20

Appendix E. Climate Scenarios

Category 1 Storm

Category 1 Storm plus Sea Level Rise High Projection

Category 1 Storm plus Sea Level Rise Intermediate-Low Projection

Category 3 Storm

Category 3 Storm plus Sea Level Rise High Projection

Category 3 Storm plus Sea Level Rise Intermediate-Low Projection

Category 5 Storm

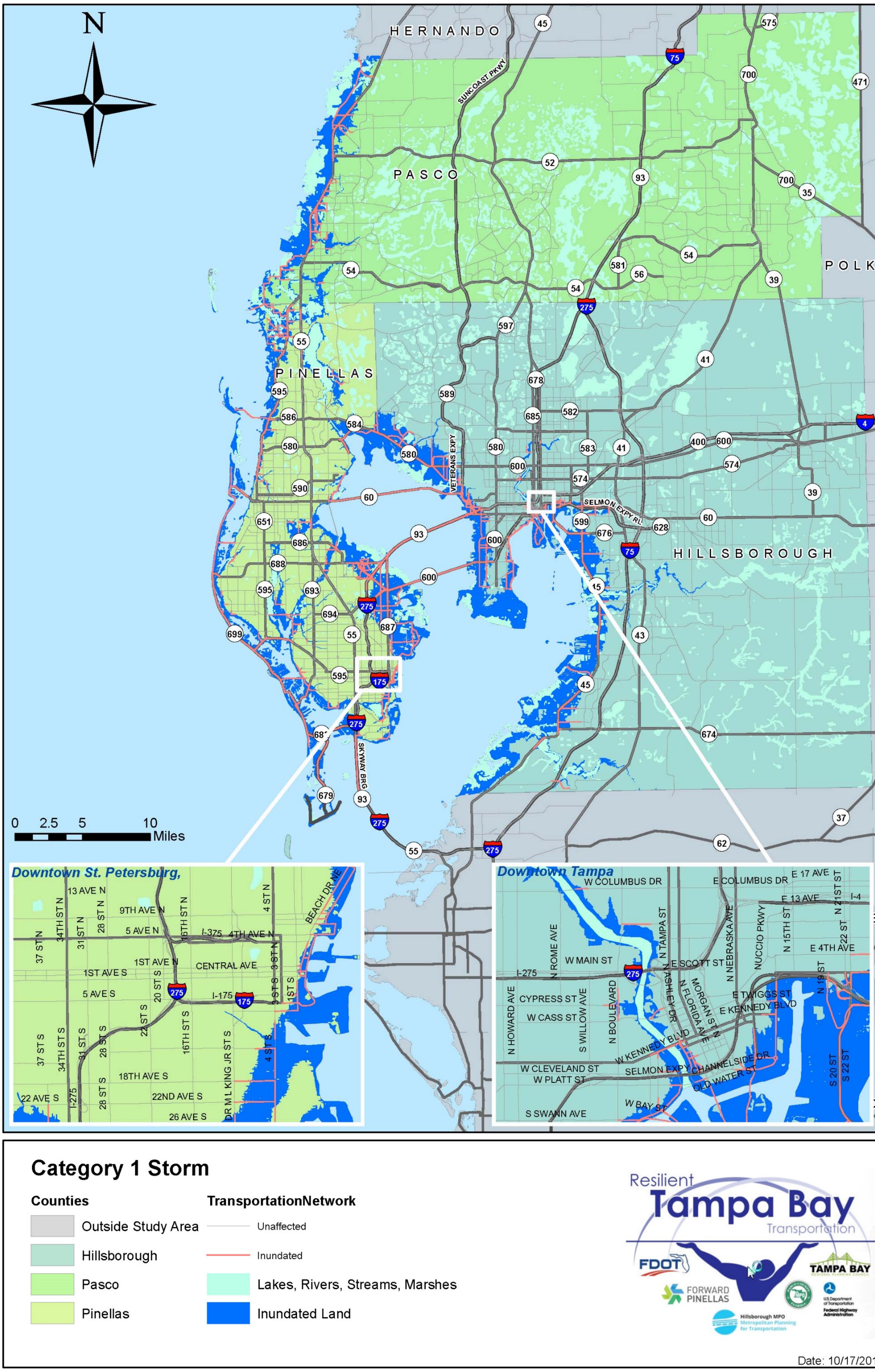
Precipitation - 9 inches of rain over 24 hours (1 day)

Precipitation - 11 inches each day for 3 days (33 total inches)

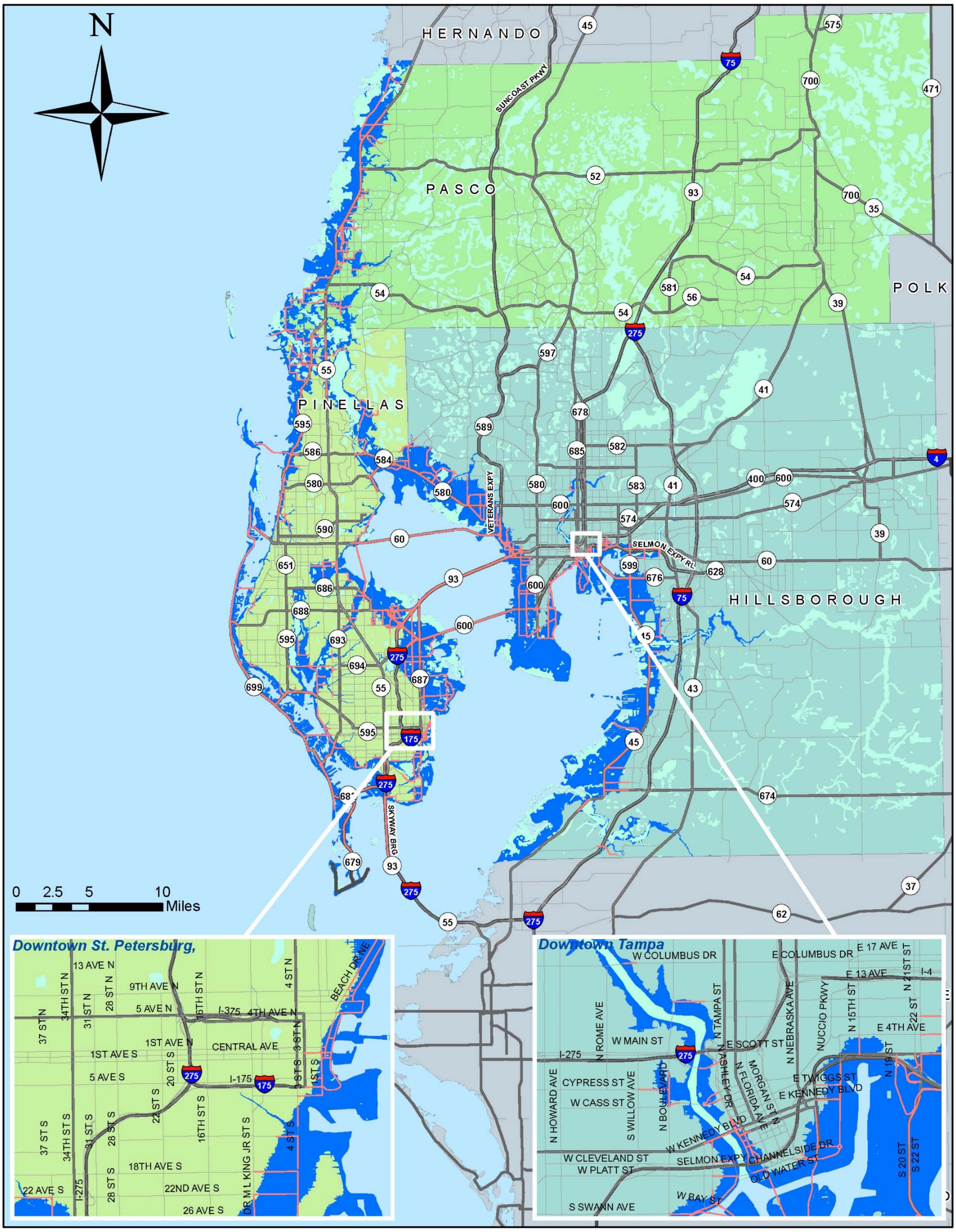
Summary of impact on Hillsborough County High Criticality Segments

Summary of impact on Pinellas County High Criticality Segments

Summary of impact on Pasco County High Criticality Segments



N
HERNANDO
PASCO
PINELLAS
HILLSBOROUGH
POLK
SUNCOAST PKWY
VETERANS EXPY
SELMON EXPY RL
SKYWAY BRG
0 2.5 5 10
Miles
Downtown St. Petersburg,
Downtown Tampa
Category 1 Storm
Counties
Outside Study Area
Hillsborough
Pasco
Pinellas
TransportationNetwork
Unaffected
Inundated
Lakes, Rivers, Streams, Marshes
Inundated Land
Resilient Tampa Bay Transportation
Date: 10/17/2018



Category 1 Storm
Plus 2045 NOAA High Sea Level Rise Projection

Counties

- Outside Study Area
- Hillsborough
- Pasco
- Pinellas

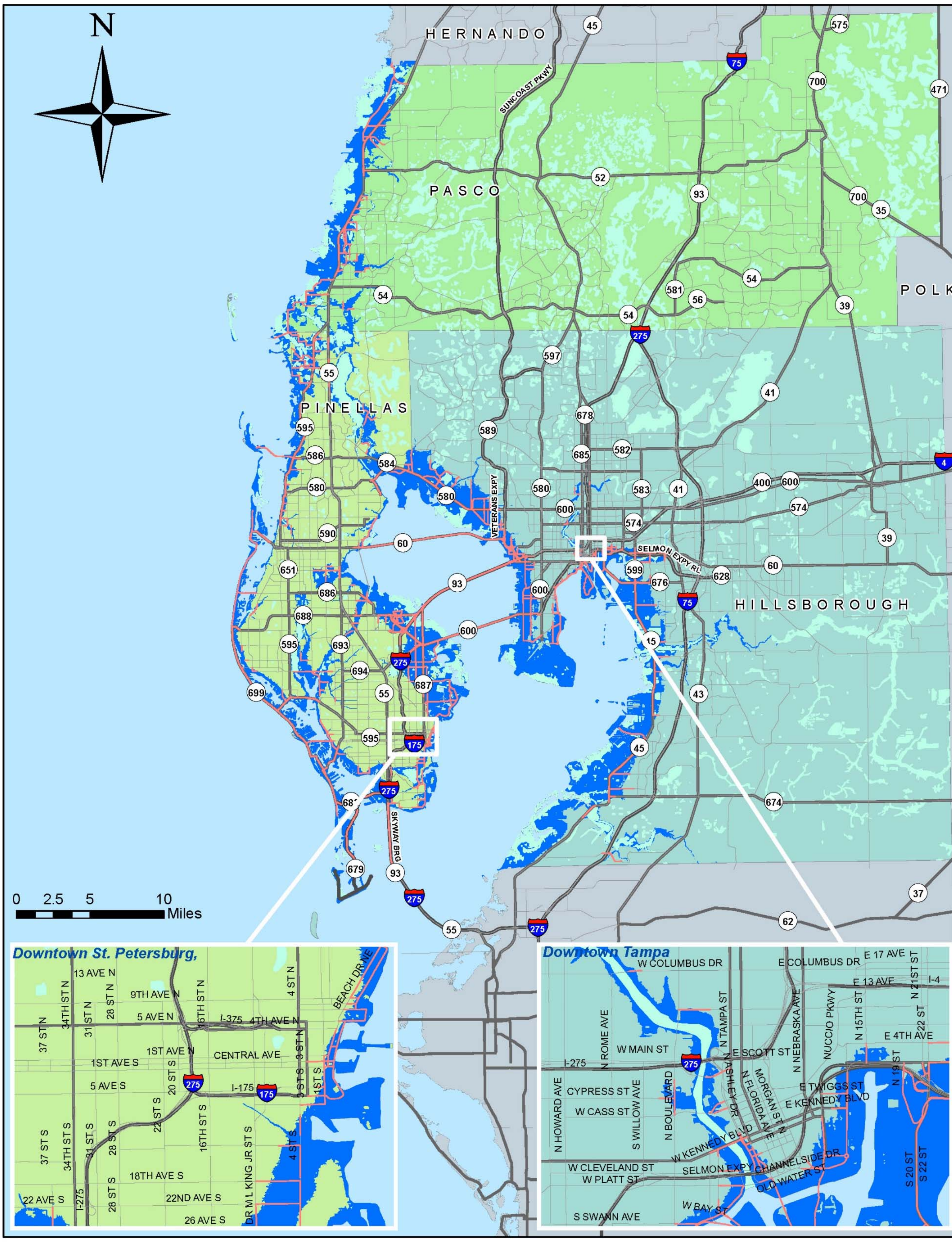
TransportationNetwork

- Unaffected
- Inundated
- Inundated Land
- Lakes, Rivers, Streams, Marshes

Resilient Tampa Bay Transportation

FDOT · FORWARD PINELLAS · TAMPA BAY · Hillsborough MPO · U.S. Department of Transportation Federal Highway Administration

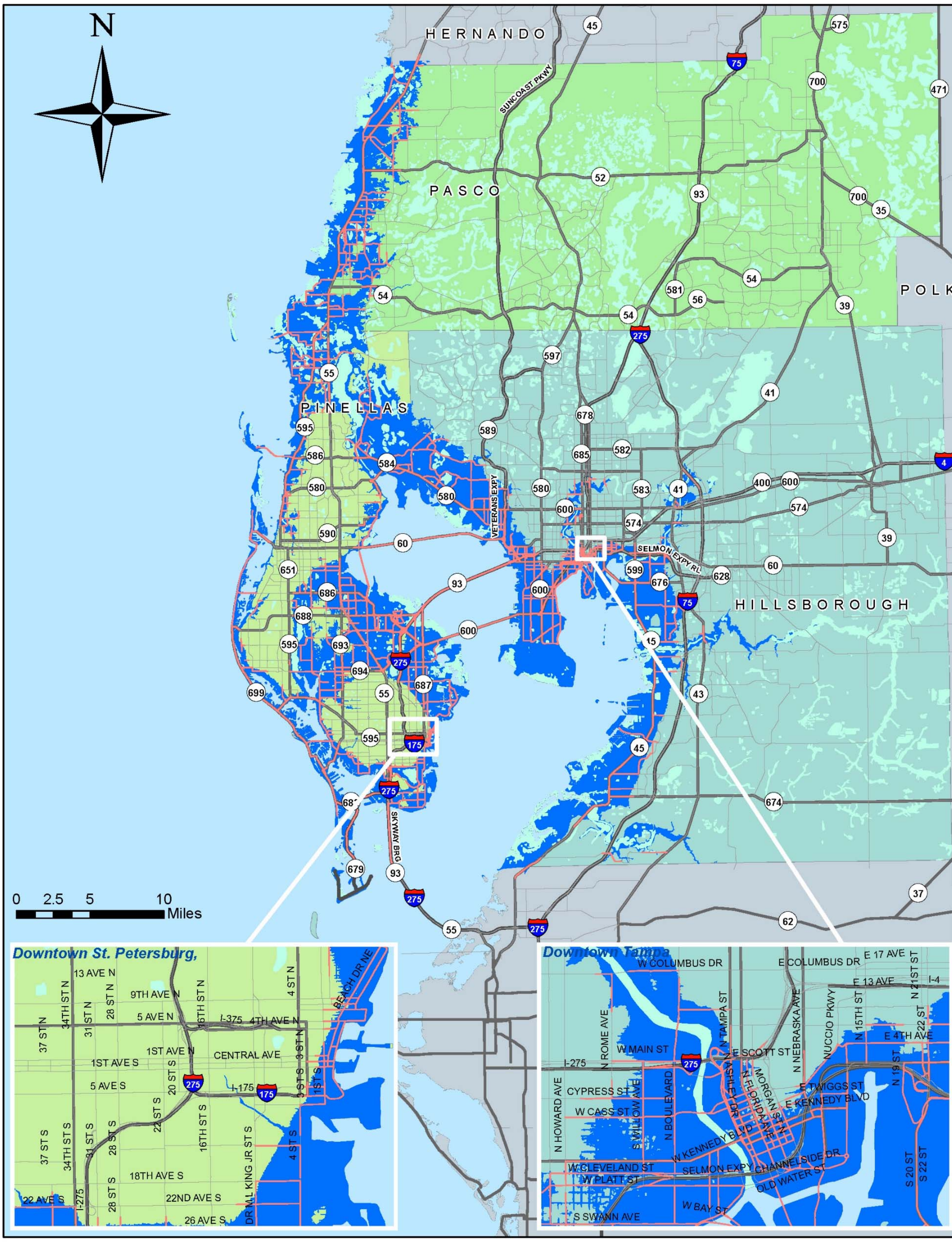
Date: 10/17/2018



Category 1 Storm
Plus 2045 NOAA Intermediate Low Sea Level Rise Projection

Counties	TransportationNetwork
Outside Study Area	Unaffected
Hillsborough	Inundated
Pasco	Lakes, Rivers, Streams, Marshes
Pinellas	Inundated Land

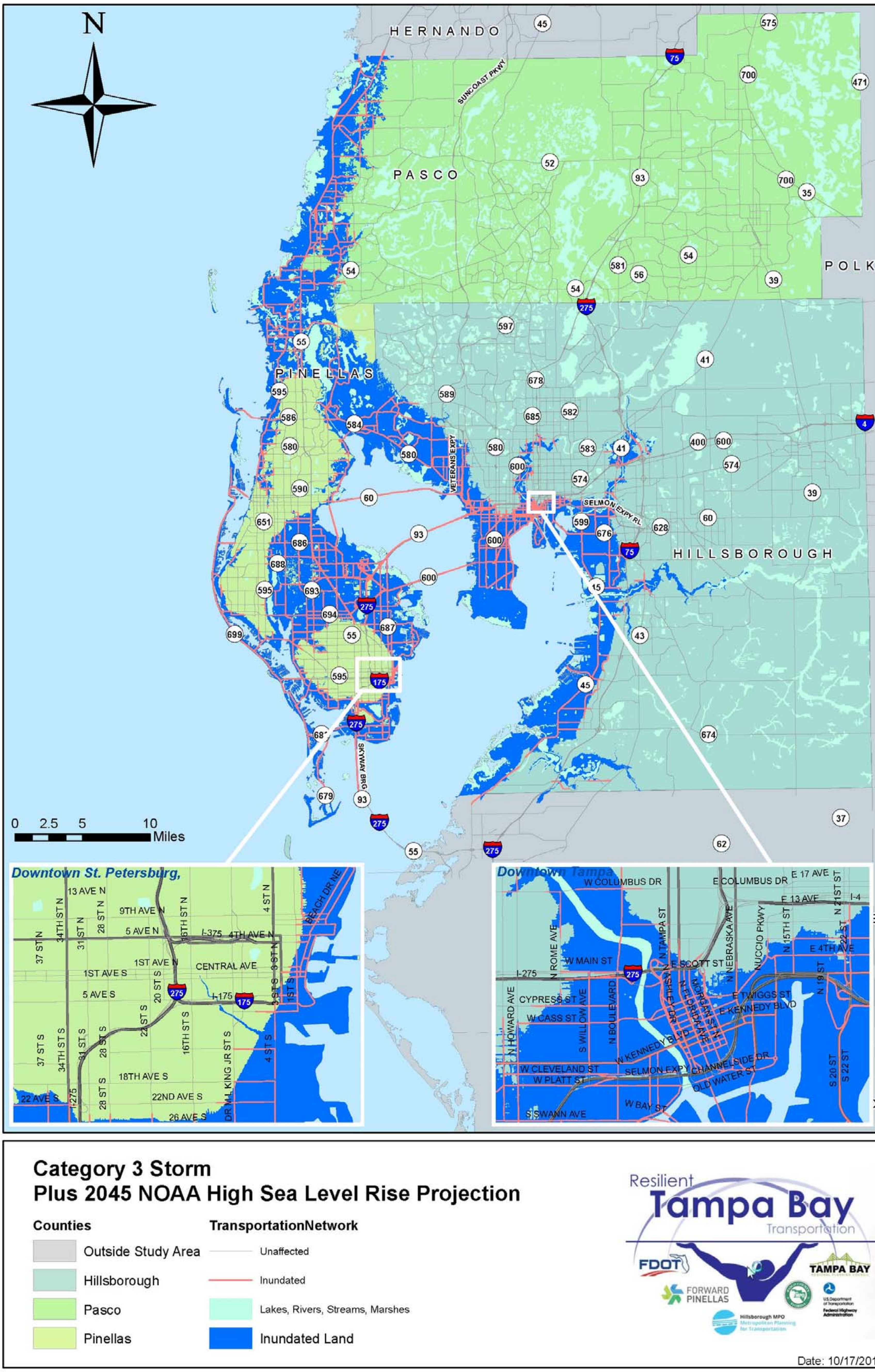
Date: 10/17/2018

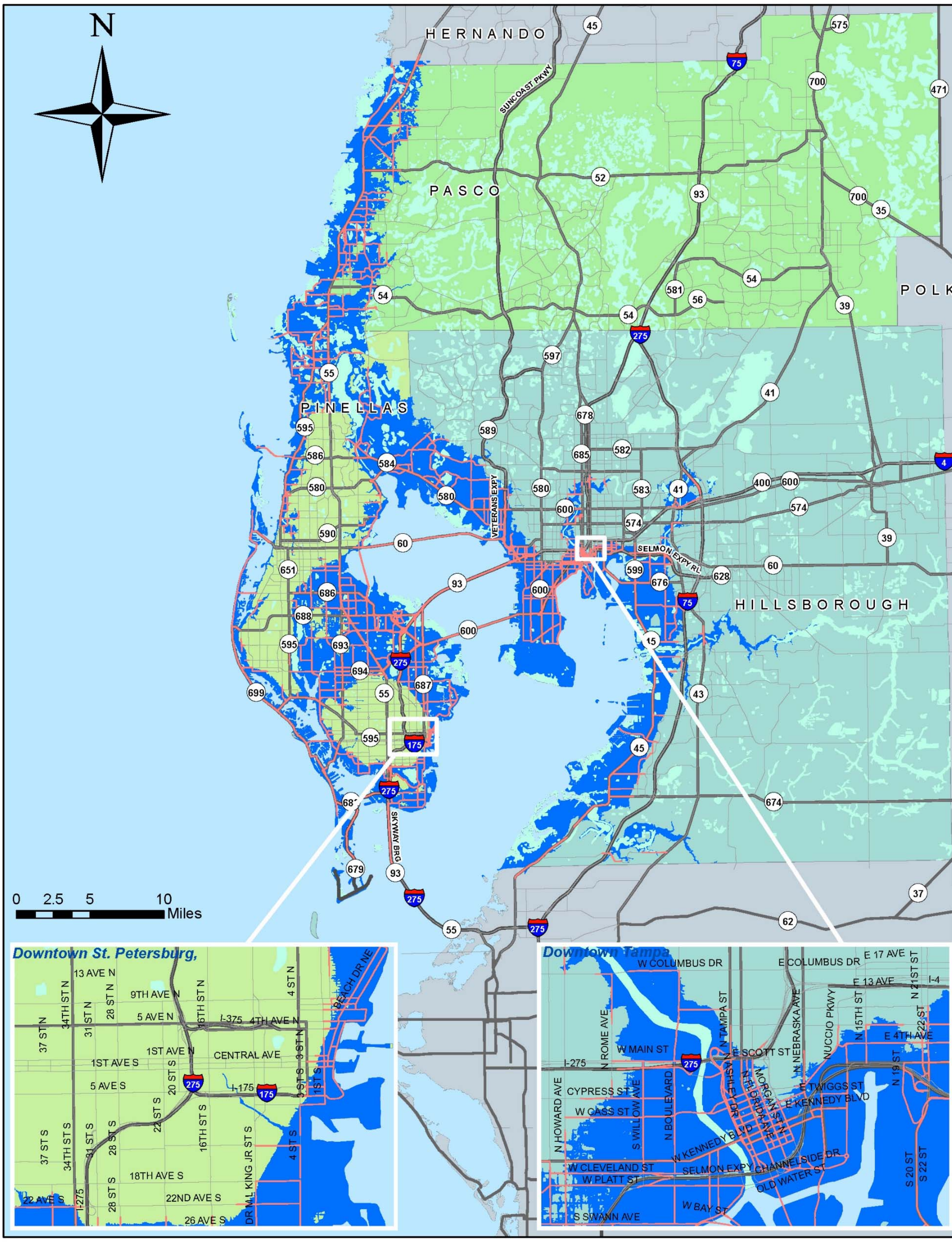


Category 3 Storm

Counties	TransportationNetwork
Outside Study Area	Unaffected
Hillsborough	Inundated
Pasco	Lakes, Rivers, Streams, Marshes
Pinellas	Inundated Land

Date: 10/17/2018


N
HERNANDO
PASCO
POLK
PINELLAS
HILLSBOROUGH
SUNCOAST PKWY
VETERANS EXPY
SELMON EXPY RL
SKYWAY BRG
0 2.5 5 10 Miles
Downtown St. Petersburg,
Downtown Tampa
Category 3 Storm
Plus 2045 NOAA High Sea Level Rise Projection
Counties
Outside Study Area
Hillsborough
Pasco
Pinellas
TransportationNetwork
Unaffected
Inundated
Lakes, Rivers, Streams, Marshes
Inundated Land
Resilient Tampa Bay Transportation
FDOT
FORWARD PINELLAS
TAMPA BAY
Date: 10/17/2018

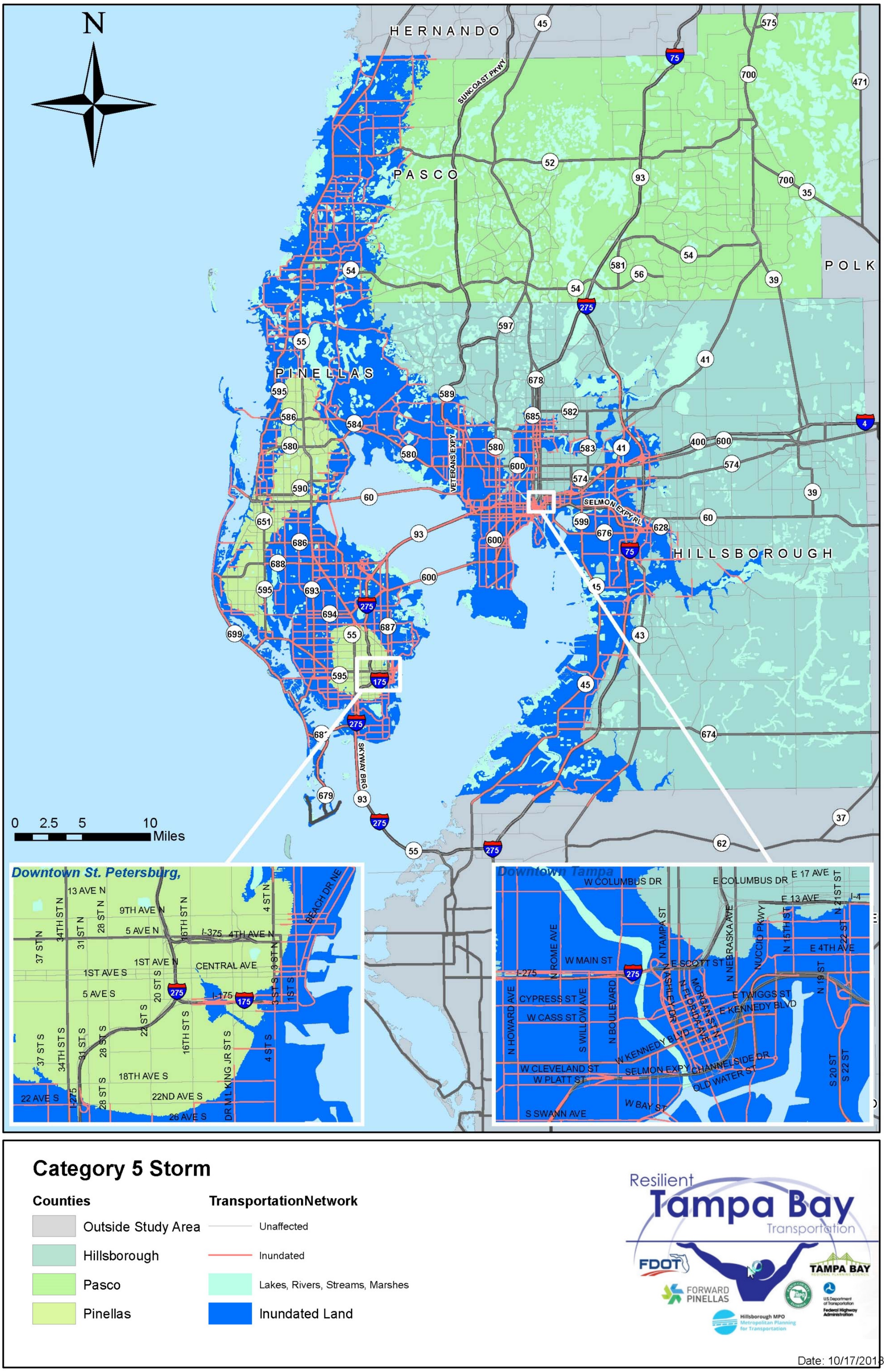


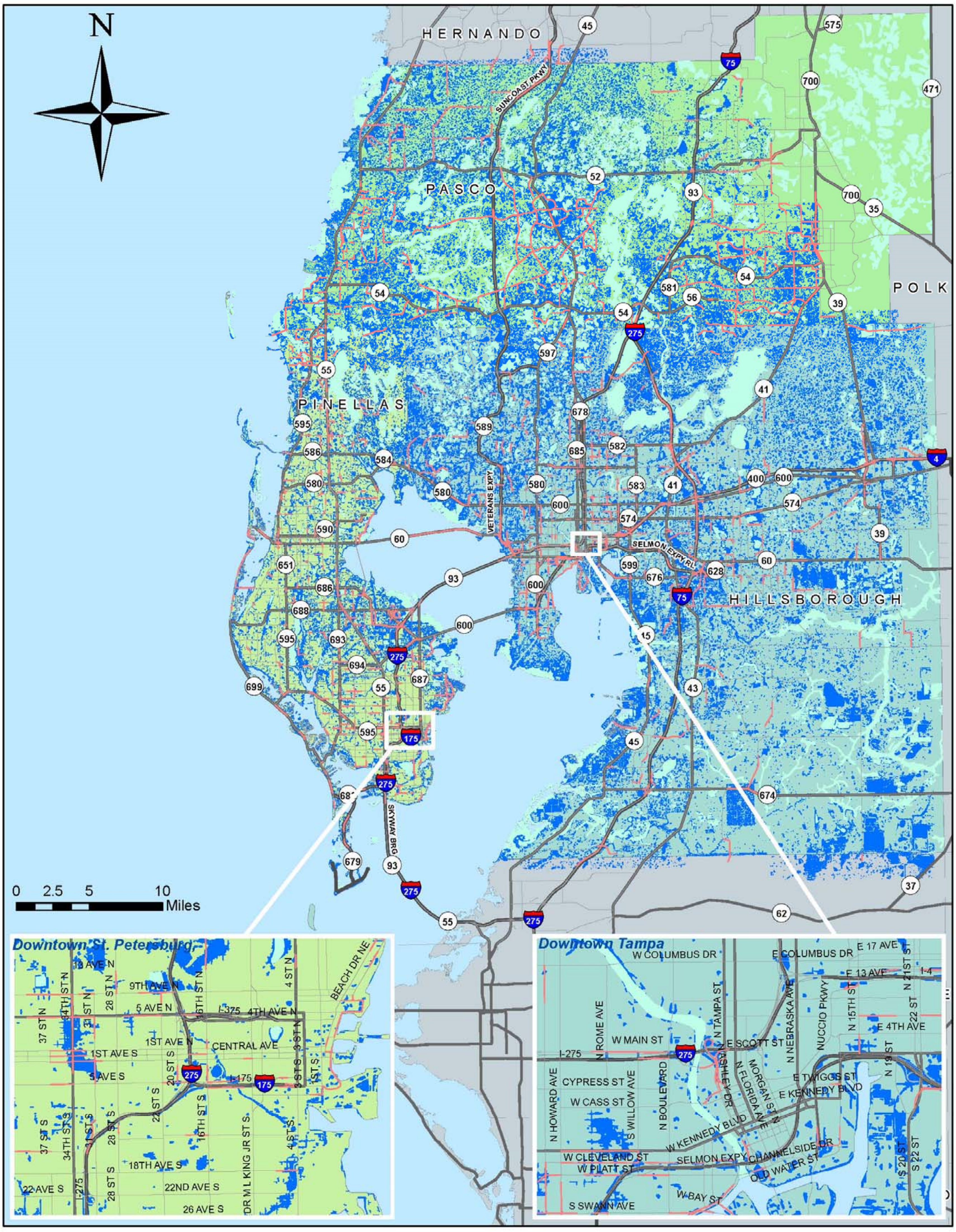
Category 3 Storm
Plus 2045 NOAA Intermediate Low Sea Level Rise Projection

Counties	TransportationNetwork	
Outside Study Area	Unaffected	
Hillsborough	Inundated	
Pasco	Lakes, Rivers, Streams, Marshes	
Pinellas	Inundated Land	

Resilient Tampa Bay Transportation

Date: 10/17/2018


N
HERNANDO
PASCO
PINELLAS
HILLSBOROUGH
POLK
SUNCOAST PKWY
VETERANS EXPY
SELMON EXPY
SKYWAY BRG
0 2.5 5 10
Miles
Downtown St. Petersburg,
Downtown Tampa
Category 5 Storm
Counties
Outside Study Area
Hillsborough
Pasco
Pinellas
TransportationNetwork
Unaffected
Inundated
Lakes, Rivers, Streams, Marshes
Inundated Land
Resilient Tampa Bay Transportation
FDOT
FORWARD PINELLAS
TAMPA BAY
Hillsborough MPO
Date: 10/17/2018



Precipitation Modeling – 9 Inches in 24 Hours

Counties

- Outside Study Area
- Hillsborough
- Pasco
- Pinellas

Transportation Network

- Unaffected
- Inundated
- Lakes, Rivers, Streams, Marshes
- Inundated Land

Resilient Tampa Bay Transportation

Notes: Due to the lack of unified DEM source, the hydrology model is not able to produce meaningful results for the eastern part of Pasco County.

Date: 11/21/2018

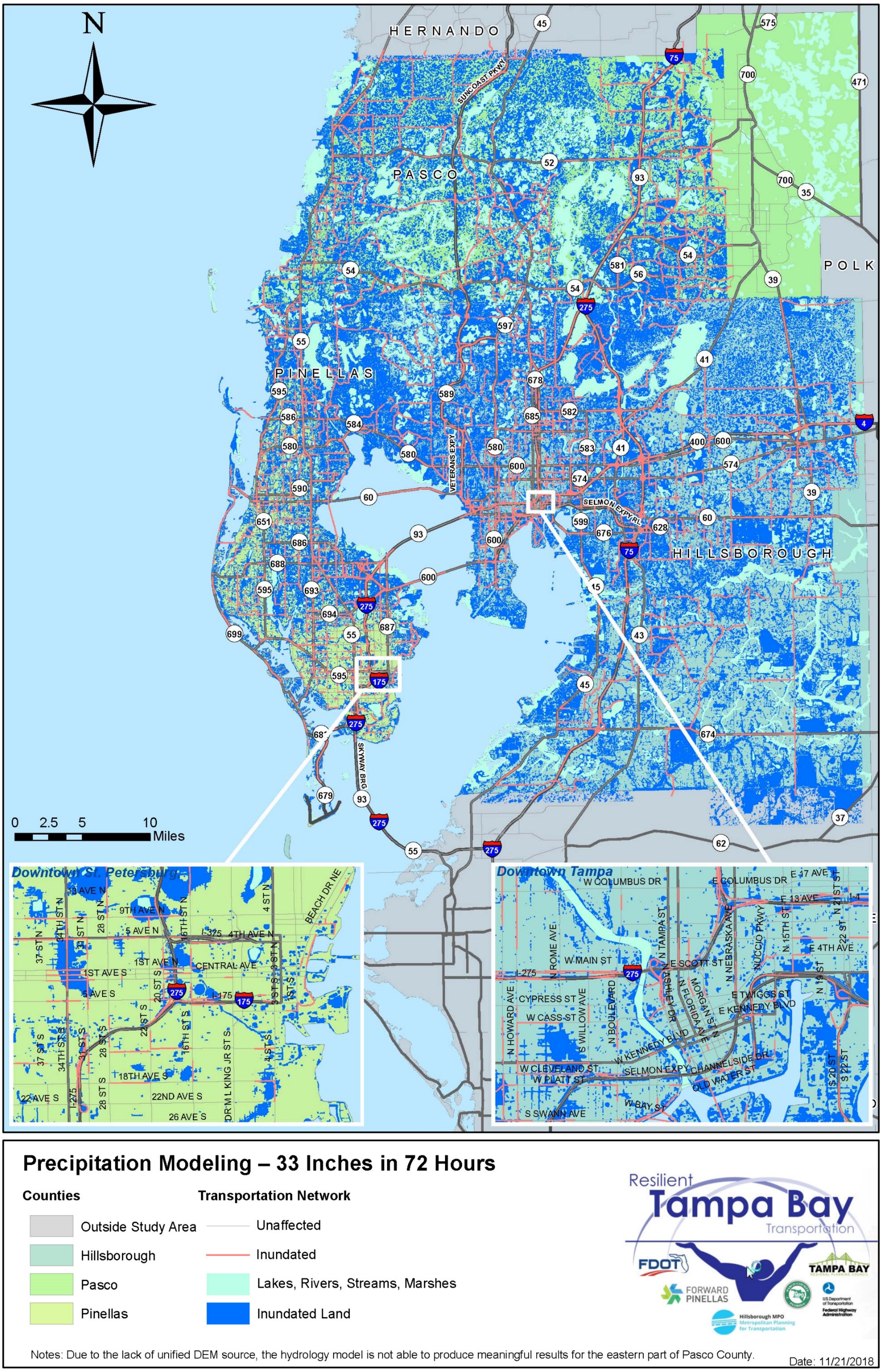

N
HERNANDO
PASCO
PINELLAS
HILLSBOROUGH
POLK
0 2.5 5 10
Miles
Downtown St. Petersburg
Downtown Tampa
Precipitation Modeling – 33 Inches in 72 Hours
Counties
Outside Study Area
Hillsborough
Pasco
Pinellas
Transportation Network
Unaffected
Inundated
Lakes, Rivers, Streams, Marshes
Inundated Land
Resilient Tampa Bay Transportation
Notes: Due to the lack of unified DEM source, the hydrology model is not able to produce meaningful results for the eastern part of Pasco County.
Date: 11/21/2018

Table E-1 Hillsborough County High Criticality Segments

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low	Category 3 Storm	Category 3 Storm + Int-Low	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
1	Sun City Center Blvd	SR 674 / US 41	Pebble Beach Blvd / SR 674	5.0	21.0	14.6	16	5%	33%	9%	33%	33%	33%	39%	0%	43%
2	I 75	Exit 240A	19Th Ave	1.7	10.8	16.0	16	43%	48%	48%	64%	67%	64%	75%	0%	58%
3	US 41	3Rd Ave	27Th Ave	2.1	8.3	14.3	15	100%	100%	100%	100%	100%	100%	100%	12%	73%
4	US 41	Mirabay Blvd / Spindle Shell Way	Flamingo Dr	1.8	7.0	14.0	14	54%	100%	69%	100%	100%	100%	100%	0%	0%
5	US 301 S	Mallard Farm Rd	Dixon Dr	0.4	2.5	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	100%
6	Big Bend Rd	Simmons Loop / Simmons Rd	Big Bend Rd / Lincoln Rd	0.8	4.5	14.5	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	CR 672	US 41	I 75	1.6	9.5	15.0	15	0%	27%	27%	48%	48%	48%	95%	0%	27%
8	US 41	CR 672	Alice Ave / Gibsonton Dr / US 41 S	4.0	15.8	14.1	16	100%	100%	100%	100%	100%	100%	100%	22%	47%
9	US 41	Pennsylvania Ave / US 41 S	N/A	0.3	1.1	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
10	Gibsonton Dr	Alafia St	I 75	1.7	6.4	14.2	16	0%	22%	22%	68%	68%	68%	100%	0%	15%
11	I 75	Symmes Rd	Gibsonton Dr	0.0	2.4	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
12	Boyette Rd	Gibsonton Dr / US 301 / US 301 S	#N/A	0.1	0.9	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	US 301 S	Cone Grove Rd	Connecting Rd / Duncan Rd	2.9	17.5	14.6	16	0%	0%	0%	33%	45%	45%	54%	0%	0%
14	Bloomingdale Ave	CR 676A / US 301	Gornto Rd	4.8	13.3	14.6	17	0%	0%	0%	0%	0%	0%	81%	0%	44%
15	CR 676A	I 75	Valleydale Dr	0.2	0.5	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
16	CR 676A	78Th St	Magnolia Park blvd	1.0	3.6	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
17	I 75	Gibsonton Dr	Brandon Blvd	19.9	195.5	15.8	19	0%	0%	0%	3%	9%	7%	56%	4%	69%
18	50Th St	Port Sutton Rd / US 41	31St Ave	1.3	8.0	14.1	15	100%	100%	100%	100%	100%	100%	100%	0%	10%
19	SR 60	Brandon Town Center Dr	Strawberry Ridge Blvd	6.6	42.4	15.3	18	0%	0%	0%	0%	0%	0%	0%	21%	29%
20	SR 60	I 75	Falkenburg Rd	0.6	4.6	14.0	14	0%	0%	0%	0%	0%	0%	81%	0%	0%
21	US 301	Selmon Expy	Palm River Rd	0.9	4.3	14.2	16	0%	0%	0%	0%	0%	0%	92%	0%	46%
22	I 75	Hobbs St / Woodberry Rd	Grand Regency Blvd / Woodberry Rd / York Dr	0.3	1.1	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
23	SR 574	Dr Martin Luther King Jr Blvd / Williams Rd	Queen Palm Dr	1.5	7.9	14.8	16	0%	0%	0%	0%	0%	0%	41%	0%	41%
24	US 41	Causeway Blvd	I 4	7.6	32.5	15.5	18	55%	62%	62%	82%	87%	83%	96%	0%	49%
25	SR 60	Orient Rd	34Th St	1.3	5.2	14.3	15	0%	64%	36%	78%	78%	78%	100%	0%	30%
26	Adamo Dr	26Th St	Channel Dr	3.6	15.5	15.5	19	71%	71%	71%	76%	76%	76%	76%	0%	31%
27	78Th St	SR 618	N/A	0.1	0.2	14.0	14	0%	100%	100%	100%	100%	100%	100%	0%	0%
28	US 301	Broadway Ave	21St Ave	0.7	2.9	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	70%
29	Columbus Dr	CR 574 / Ramp	Orient Rd	0.6	1.2	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
30	Dr Martin Luther King Jr Blvd	Orient Rd	US 301	0.8	4.8	14.9	15	0%	0%	0%	0%	0%	0%	100%	0%	0%
31	SR 599	44Th St	21St Ave / Melburne Blvd	0.0	0.5	14.0	14	0%	0%	0%	0%	0%	0%	100%	100%	100%
32	SR 599	Palm River Rd / US 41	21St Ave / Melburne Blvd	2.0	11.2	17.0	20	47%	47%	47%	63%	63%	63%	74%	9%	34%
33	Channelside Dr	Kennedy Blvd	14Th St	0.4	1.7	16.5	18	69%	69%	69%	69%	69%	69%	69%	0%	25%
34	Edison Ave	Occident St / SR 60	11Th St	4.1	21.1	15.1	16	18%	30%	18%	70%	93%	77%	99%	14%	25%

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low	Category 3 Storm	Category 3 Storm + Int-Low	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
35	US 92	Mango Ave	Euclid Ave	2.3	8.6	15.5	17	0%	19%	0%	100%	100%	100%	100%	46%	95%
36	Jefferson St	US 41 Bus	Kennedy Blvd	0.1	0.2	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
37	Jackson St	Ashley Dr / Kennedy Blvd / SR 60	Jefferson St	0.4	1.3	15.3	16	24%	36%	24%	100%	100%	100%	100%	0%	0%
38	Nebraska Ave	SR 45 / Zack St	Cass St / Nuccio Pky / SR 45	0.1	0.1	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
39	Selmon Expy	Gandy Blvd	I 75	14.4	114.9	15.6	18	0%	2%	1%	12%	14%	13%	40%	5%	14%
40	Gandy Blvd	US 92	SR 573	5.1	18.0	17.3	19	96%	98%	96%	99%	99%	99%	99%	42%	42%
41	US 92	Perez Park Dr	Mobile Villa Dr	0.0	1.4	14.0	14	0%	0%	0%	0%	0%	0%	100%	48%	100%
42	Hillsborough Ave	Race Track Rd	Orient Rd	17.6	106.0	16.1	19	38%	38%	38%	46%	49%	47%	66%	17%	33%
43	I 4	I 275	Mango Rd	10.2	116.9	16.4	20	0%	0%	0%	2%	2%	2%	55%	11%	55%
44	I 275	Howard Frankland Bridge	Bearss Ave	18.0	191.2	18.4	20	21%	24%	22%	30%	33%	30%	54%	7%	35%
45	Courtney Campbell Cswy	Causeway Bridge	Veterans Expy	6.7	27.7	14.4	17	98%	98%	98%	100%	100%	100%	100%	80%	86%
46	George J Bean Pkwy	Terminal Pky	Veterans Expy	0.6	4.0	14.8	16	75%	75%	75%	82%	82%	82%	82%	17%	75%
47	Veterans Expy	SR 60	Ehrlich Rd	10.5	109.5	15.7	20	24%	28%	25%	48%	53%	50%	86%	19%	55%
48	US 92	Corona St	Cayuga St	5.3	25.7	15.1	19	0%	0%	0%	40%	51%	42%	98%	16%	45%
49	I 4	Exit 14	Park Rd	8.8	49.0	14.2	15	0%	0%	0%	0%	0%	0%	0%	38%	62%
50	Baker St	Park Rd / SR 601 / US 92	Wilder Rd	0.5	2.0	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
51	Baker St	SR 39 / US 92	Michigan Ave	0.0	1.1	14.7	15	0%	0%	0%	0%	0%	0%	0%	0%	46%
52	Reynolds St	Davis St	Pennsylvania Ave	0.8	1.6	14.1	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
53	Wheeler St	Park St	Herring St	0.3	0.9	14.1	15	0%	0%	0%	0%	0%	0%	0%	0%	31%
54	Collins St	Drane St / SR 39	Reynolds St	0.1	0.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
55	Alexander St	Granfield Ave	Baker St / US 92	0.3	0.9	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	22%
56	Thonotosassa Rd	Plant Ave	Alexander St / Oak Ave	0.1	0.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	100%
57	Baker St	Alexander St / US 92	Plant Ave / Risk St	0.0	0.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
58	Baker St	Lemon St	#N/A	0.1	0.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
59	US 92	SR 583	#N/A	0.0	0.1	16.5	17	0%	0%	0%	0%	0%	0%	0%	0%	0%
60	40Th St	Ellicott St	#N/A	0.4	1.5	14.0	14	0%	0%	0%	0%	0%	0%	0%	100%	100%
61	22Nd St	Frierson Ave	Hillsborough Ave	0.1	0.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
62	22Nd St	Chelsea St	Osborne Ave	0.5	1.0	14.2	15	0%	0%	0%	0%	0%	0%	0%	0%	29%
63	15Th St	Cayuga St	Osborne Ave	0.1	0.1	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
64	SR 574	Central Ave	Taliaferro Ave	0.1	0.5	17.2	19	0%	0%	0%	0%	0%	0%	0%	0%	0%
65	Lake Ave	Central Ave	Taliaferro Ave	0.1	0.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
66	15Th St	15Th St / Nuccio Pky	14Th Ave / 15Th St	0.1	0.1	17.8	18	0%	0%	0%	0%	0%	0%	0%	0%	0%
67	Avenida Rep de Cuba	14Th Ave / 14Th St / AVE Republica De Cuba	13Th Ave / 14Th St	0.0	0.1	20.0	20	0%	0%	0%	0%	0%	0%	0%	0%	0%
68	14Th Ave	15Th St	14Th St / AVE Republica De Cuba	0.0	0.1	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
69	13Th Ave	14Th St	15Th St	0.1	0.1	17.0	17	0%	0%	0%	0%	0%	0%	0%	0%	0%
70	Nuccio Pky	10Th Ave	Palm Ave	0.0	0.1	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low	Category 3 Storm	Category 3 Storm + Int-Low	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
71	7Th Ave	21St St	22Nd St	0.0	0.1	14.0	14	0%	0%	0%	0%	100%	100%	100%	0%	0%
72	Floribraska Ave	Elmore Ave	Taliaferro Ave	0.1	0.2	18.5	19	0%	0%	0%	0%	0%	0%	0%	0%	0%
73	Cass St	Governor St	Central Ave	0.0	0.2	14.0	14	0%	0%	0%	0%	100%	0%	100%	0%	0%
74	Short Emery St	Cass St	Central Ave / Scott St	0.2	1.4	14.0	14	0%	0%	0%	0%	100%	0%	100%	0%	17%
75	Scott St	Tampa St / US 41 Bus	Jefferson St	0.3	0.9	16.6	17	0%	0%	0%	0%	0%	0%	0%	0%	0%
76	I 275	Kay St / Tampa St / US 41 Bus	Scott St / Tampa St / US 41 Bus	0.0	0.2	16.0	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
77	N Blvd	Laurel St / N Blvd	Green St	0.1	0.2	18.4	20	0%	0%	0%	0%	0%	0%	0%	0%	0%
78	Rome Ave	I 275	I 275	0.0	0.1	17.0	17	0%	0%	0%	0%	0%	0%	100%	0%	0%
79	Howard Ave	Howard Ave / Laurel St	Green St	0.1	0.2	17.2	18	0%	0%	0%	0%	0%	0%	0%	0%	0%
80	Armenia Ave	Laurel St	I 275	0.0	0.1	18.4	19	0%	0%	0%	0%	0%	0%	0%	0%	0%
81	Himes Ave	Laurel St	Green St	0.1	0.3	17.7	19	0%	0%	0%	0%	0%	0%	42%	0%	0%
82	Lois Ave	Lemon St / Lois Ave	Gray St	0.2	0.7	15.8	20	0%	0%	0%	60%	60%	60%	60%	0%	0%
83	Lois Ave	Cypress St	Laurel St	0.3	1.0	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	100%
84	Cypress St	Lois Ave	Manhattan Ave	0.3	1.5	15.2	18	0%	0%	0%	66%	66%	66%	66%	0%	0%
85	Columbus Dr	Fremont Ave	Rome Ave	0.1	0.5	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	100%
86	Boy Scout Blvd	CR 587 / SR 589 / West Shore Blvd	Manhattan Ave	0.4	2.4	14.0	14	0%	0%	0%	32%	100%	48%	100%	0%	0%
87	Columbus Dr	Jim Walter Blvd / SR 589	Columbus Dr / Grady Ave	0.3	1.6	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	49%
88	Columbus Dr	SR 616 / US 92	Himes Ave	0.2	1.5	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
89	Cimino Ave	Columbus Dr	Armenia Ave / Tampa Bay Blvd	0.5	1.1	14.2	15	0%	0%	0%	31%	100%	78%	100%	0%	69%
90	Himes Ave	Columbus Dr	Dewey St	0.3	1.2	14.0	14	0%	0%	0%	0%	0%	0%	100%	100%	100%
91	Armenia Ave	Columbus Dr	Wishart Blvd	0.4	3.5	14.4	15	0%	0%	0%	0%	0%	0%	100%	18%	32%
92	SR 574	Dr Martin Luther King Jr Blvd / US 92	Albany Ave	1.5	6.5	14.7	16	0%	0%	0%	0%	16%	0%	100%	10%	26%
93	Himes Ave	Tampa Bay Blvd	Osborne Ave	1.0	4.1	14.5	15	0%	0%	0%	0%	0%	0%	100%	90%	90%
94	Habana Ave	Eddy Dr / Habana Way	Wilder Ave	0.5	1.9	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	48%
95	Dale Mabry Hwy	SR 580	#N/A	0.0	0.1	17.0	17	0%	0%	0%	0%	0%	0%	0%	0%	0%
96	Armenia Ave	Hillsborough Ave	Sligh Ave	1.0	4.0	14.2	15	0%	0%	0%	0%	0%	0%	0%	0%	45%
97	Sligh Ave	Armenia Ave	Albany Ave	0.2	1.0	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
98	Lambright St	Dale Mabry Hwy / Pine Crest Blvd / SR 580 / SR 598	Garsh Loop	0.1	0.3	14.0	14	0%	0%	0%	0%	0%	0%	100%	100%	100%
99	Dale Mabry Hwy	Powhatan Ave / SR 580	Sligh Ave	0.8	4.8	14.8	15	0%	0%	0%	0%	0%	0%	100%	32%	32%
100	Sligh Ave	I 275	Exit 48 / Taliaferro Ave	0.1	0.2	19.0	19	0%	0%	0%	0%	0%	0%	0%	0%	0%
101	Waters Ave	CR 584 / SR 580	N/A	0.1	0.5	15.0	15	0%	0%	0%	0%	0%	0%	100%	100%	100%
102	Waters Ave	Armenia Ave / CR 584	Fremont Ave	0.3	1.4	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
103	Waters Ave	N Blvd	Branch Ave	0.6	2.4	14.0	14	0%	0%	0%	0%	0%	0%	84%	0%	16%
104	Dale Mabry Hwy	Dale Mabry Hwy	Lake Carroll Way / SR 597	0.7	4.4	14.6	15	0%	0%	0%	0%	0%	0%	0%	31%	68%
105	Florida Ave	J L Young Jr Apts	Bougainvillea Ave	1.4	7.6	14.0	14	0%	0%	0%	0%	0%	0%	80%	32%	70%
106	Busch Blvd	N Blvd	Florida Ave / US 41 Bus	0.5	2.1	14.0	14	0%	0%	0%	0%	0%	0%	100%	100%	100%

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low	Category 3 Storm	Category 3 Storm + Int-Low	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
107	Busch Blvd	I 275	I 275	0.2	1.2	15.0	15	0%	0%	0%	0%	0%	0%	100%	0%	0%
108	Busch Blvd	16Th St / SR 580	18Th St	0.2	1.1	14.0	14	0%	0%	0%	0%	0%	0%	0%	100%	100%
109	Busch Blvd	30Th St	Hidden Shadow Dr / Orangeview Ave	0.7	4.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	39%	39%
110	Spectrum Blvd	40Th St / SR 580	Busch Gdns / Mckinley Dr	0.1	0.4	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
111	Seminole Ave	Seminole Ave	Waters Ave	0.2	0.7	18.0	19	0%	0%	0%	0%	0%	0%	100%	0%	0%
112	Bird St	Seminole Ave	Lamar St	0.1	0.2	18.5	19	0%	0%	0%	0%	0%	0%	0%	0%	0%
113	Waters Ave	CR 584 / Seminole Ave	Huntley Ave	0.1	0.5	17.7	20	0%	0%	0%	0%	0%	0%	50%	0%	0%
114	Nebraska Ave	Hillsborough Ave / US 41	Broad St	4.4	17.7	15.7	17	4%	4%	4%	13%	19%	19%	49%	5%	43%
115	Anderson Rd	Anderson Ave / CR 584 / Waters Ave	Linebaugh Ave	1.1	6.3	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	99%
116	Linebaugh Ave	SR 589	#N/A	0.1	0.5	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
117	Dale Mabry Hwy	Hudson Ln	Stall Rd	0.8	4.5	14.0	14	0%	0%	0%	0%	0%	0%	0%	100%	100%
118	30Th St	113Th Ave	SR 582	0.2	1.0	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	100%
119	SR 583	50Th St	SR 583	0.5	3.1	14.5	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
120	Fowler Ave	Central Ave	Leroy Collins Blvd	2.7	19.0	15.9	19	0%	0%	0%	0%	0%	0%	0%	0%	67%
121	Fletcher Ave	Dale Mabry Hwy / SR 597	Nebraska Ave	3.4	13.4	14.3	18	0%	0%	0%	0%	0%	0%	0%	0%	10%
122	131St Ave	27Th St	Bruce B Downs Blvd / Holly Dr	0.2	0.4	14.0	14	0%	0%	0%	0%	0%	0%	0%	100%	100%
123	Florida Ave	Bearss Ave / CR 582 / US 41 Bus	Sinclair Hills Rd	0.2	1.0	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
124	Bearss Ave	CR 582 / Florida Ave / US 41 Bus	Nebraska Ave / US 41	0.5	2.4	14.4	18	0%	0%	0%	0%	0%	0%	0%	0%	0%
125	Nebraska Ave	Fletcher Ave	CR 582	1.3	5.1	14.7	15	0%	0%	0%	0%	0%	0%	0%	29%	60%
126	Bearss Ave	Gregory Dr / Turtle Creek Cir	Bruce B Downs Blvd	0.8	4.8	14.6	16	0%	0%	0%	0%	0%	0%	0%	45%	70%
127	Magnolia Dr	CR 582A / Fletcher Ave	N/A	0.1	0.3	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
128	Bruce B Downs Blvd	#N/A	Elm Leaf / Skipper Rd	1.7	11.4	15.1	18	0%	0%	0%	0%	0%	0%	0%	0%	31%
129	CR 582A	12Th St / Coastal Key Rd	Hidden River Pky / Morris Bridge Rd	5.3	29.4	16.2	19	0%	0%	0%	0%	0%	0%	3%	9%	24%
130	US 41	Chapman Rd / Nebraska Ave	Crenshaw Lake Rd / Whitaker Rd	0.8	4.1	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	100%
131	CR 581	Palm Springs Blvd / Tampa Palms Blvd	Hunters Green Dr	2.3	18.7	14.6	16	0%	0%	0%	0%	0%	0%	0%	0%	61%
132	Bruce B Downs Blvd	CR 581 / Pebble Creek Dr	County Line Rd	1.7	13.6	14.8	15	0%	0%	0%	0%	0%	0%	0%	0%	41%
133	US 41	Newberger Rd	Land O Lakes Blvd / Willow Bend Pky	0.8	5.0	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	100%
134	Bougainvillea Ave	Central Ave	Florence Ave	0.1	0.1	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table E-2 Pinellas County High Criticality Segments

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low SLR	Category 3 Storm	Category 3 Storm + Int-Low SLR	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
1	I 275	54Th Ave	62Nd Ave	8.5	65.1	15	19	4%	15%	6%	27%	28%	28%	36%	8%	38%
2	I 275	Gandy Blvd	Howard Frankland Bridge	8.5	87.1	15	19	60%	65%	62%	98%	98%	98%	99%	7%	49%
3	I 175	I 275	4Th St	1.2	8.4	17	19	0%	0%	0%	2%	2%	2%	65%	17%	16%
4	I 375	I 275	5Th St	1.3	6.5	16	17	0%	0%	0%	0%	0%	0%	7%	0%	14%
5	22Nd Ave	Luana Ln	16Th St	4.0	17.7	15.5	20	0%	12%	0%	41%	58%	54%	69%	6%	6%
6	Pinellas Bay Way	Sun Blvd	Harbor Way	2.5	9.0	14.3	15	76%	76%	76%	76%	76%	76%	76%	17%	17%
7	54Th Ave	34Th St	12Th St	1.4	5.7	14.2	16	7%	29%	11%	72%	89%	72%	89%	28%	50%
8	Gulf Blvd	30Th Ave / Pass A Grille Way	SR 682 / SR 699	0.4	0.7	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
9	Gulf Blvd	58Th Ave	68Th St	0.5	2.1	14.3	15	100%	100%	100%	100%	100%	100%	100%	53%	53%
10	SR 693	Blind Pass Rd / SR 699	Bay St	2.3	12.0	14.6	17	79%	79%	79%	92%	92%	92%	100%	4%	35%
11	Blind Pass Rd	78Th Ave	79Th St	0.0	0.1	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
12	Gulf Blvd	99Th Ave	116Th St	1.3	4.5	14.0	14	100%	100%	100%	100%	100%	100%	100%	44%	44%
13	Treasure Island Cswy	107Th Ave / Gulf Blvd	107Th Ave / 1St St	0.1	0.6	14.0	14	100%	100%	100%	100%	100%	100%	100%	100%	100%
14	54Th Ave	54Th Ave	SR 682	0.0	0.3	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
15	US 19	54Th Ave	SR 694	8.1	48.5	15.9	18	9%	15%	9%	19%	33%	25%	36%	11%	46%
16	31St St	24Th Ave	22Nd Ave	0.1	0.1	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
17	31St St	10Th Ave	Melrose Ave	0.2	0.4	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
18	49Th St	11Th Ave	The Pinellas Trl	0.2	1.0	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
19	7Th Ave	54Th Ave / SR 682	Burlington Ave	3.0	15.3	14.3	16	49%	54%	54%	68%	68%	68%	74%	38%	38%
20	8Th St	9Th Ave / 9Th St / Dr Martin Luther King Jr St	I 375	1.2	3.9	16.7	19	0%	0%	0%	0%	0%	0%	0%	0%	0%
21	5Th Ave	8Th St	3Rd St	0.0	1.3	15.6	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
22	3Rd St	3Rd Ave	2Nd Ave / SR 687	0.1	0.2	14.0	14	0%	0%	0%	0%	100%	0%	100%	0%	0%
23	3Rd St	5Th Ave	Delmar Ter	0.1	0.2	15.0	15	0%	0%	0%	100%	100%	100%	100%	0%	0%
24	4Th St	6Th Ave	Delmar Ter	0.1	0.5	15.2	18	0%	0%	0%	0%	80%	0%	100%	0%	0%
25	4Th St	1St Ave S	1St Ave N	0.0	0.5	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
26	9Th St	SR 687	22Nd Ave	0.0	0.1	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
27	16Th St N	I 375	Burlington Ave	0.1	0.6	15.7	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
28	16Th St	5Th Ave / Dunmore Ave	Central Ave	0.4	1.3	14.6	17	0%	0%	0%	0%	0%	0%	0%	30%	30%
29	1St Ave	49Th St	20Th St	2.4	4.8	15.2	17	0%	0%	0%	0%	0%	0%	0%	21%	24%

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low SLR	Category 3 Storm	Category 3 Storm + Int-Low SLR	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
30	1St Ave	Pasadena Ave	58Th St	1.2	2.5	15.6	16	0%	0%	0%	0%	0%	0%	100%	0%	0%
31	Pinellas Way	Central Ave / Pasadena Ave / SR 693	66Th St	0.2	0.8	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
32	66Th St	1St Ave	Central Ave	0.1	0.2	15.5	16	0%	0%	0%	0%	0%	0%	100%	0%	0%
33	49Th St	5Th Ave	15Th Ave	1.3	5.4	14.5	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
34	5Th Ave	SR 595	I 275	3.6	14.6	14.9	17	0%	0%	0%	0%	0%	0%	20%	37%	61%
35	Dr Martin Luther King Jr St	9Th Ave	22Nd Ave	0.8	2.9	15.1	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
36	4Th St	9Th Ave	33Rd St	1.4	6.1	14.3	15	0%	0%	0%	0%	13%	13%	34%	10%	0%
37	22Nd Ave	Dr Martin Luther King Jr St	US 92	0.5	2.0	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
38	22Nd Ave	28Th St	16Th St	1.0	4.0	15.2	18	0%	0%	0%	0%	0%	0%	0%	25%	38%
39	22Nd Ave	37Th St	US 19	0.3	1.0	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
40	22Nd Ave	49Th St	40Th St	0.8	3.0	14.0	14	0%	0%	0%	0%	0%	0%	0%	67%	67%
41	22Nd Ave	SR 693	58Th St	1.0	4.1	14.2	15	0%	0%	0%	0%	0%	0%	100%	0%	53%
42	SR 595	Tyrone Blvd	22Nd Ave	0.1	0.7	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
43	SR 693	5Th Ave / 66Th St	26Th Ave	1.3	7.5	14.7	15	0%	0%	0%	0%	0%	0%	100%	26%	77%
44	49Th St	22Nd Ave	36Th Ave	0.9	3.3	14.4	15	0%	0%	0%	0%	0%	0%	0%	0%	6%
45	Driveway	30Th Ave / SR 693	51St Ter / 66Th St	1.4	8.2	15.1	17	0%	0%	0%	6%	74%	53%	100%	19%	65%
46	38Th Ave	68Th St	60Th St	0.9	3.7	14.0	14	0%	0%	0%	28%	100%	55%	100%	72%	100%
47	38Th Ave	80Th St / Tyrone Blvd / US 19 Alt	71St St	0.8	3.0	14.0	14	0%	0%	0%	0%	39%	0%	100%	39%	100%
48	38Th Ave	49Th St	40Th St	0.7	3.0	14.3	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
49	38Th Ave	33Rd St	Dr Martin Luther King Jr St	1.9	7.7	14.7	16	0%	0%	0%	0%	0%	0%	0%	15%	15%
50	Dr Martin Luther King Jr St	28Th Ave	36Th Ave / Foster Hill Dr	0.5	2.0	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
51	Dr Martin Luther King Jr St	38Th Ave	42Nd Ave / Monticello Blvd	0.2	0.9	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
52	50Th Ave	24Th St	23Rd St	0.1	0.1	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
53	54Th Ave N	62Nd St	I 275	3.4	14.4	14.6	17	0%	0%	0%	0%	0%	0%	22%	4%	25%
54	35Th St	42Nd St	34Th St / 62Nd Ave / US 19 N	0.7	2.8	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	36%
55	Haines Rd	31St St / 62Nd Ave	US 19 N	0.5	1.1	15.9	17	0%	0%	0%	0%	44%	44%	100%	0%	44%
56	Gulf Blvd	125Th Ave	Bath Club Cir	3.7	14.7	14.2	15	100%	100%	100%	100%	100%	100%	100%	12%	32%
57	SR 666	Gulf Blvd / SR 666 / SR 699	Bay Pines Ter	1.0	4.2	15.2	16	100%	100%	100%	100%	100%	100%	100%	0%	0%
58	Tyrone Blvd N	Bay Pines Blvd / Hoover Blvd	US 19 Alt	1.5	7.3	15.3	17	75%	75%	75%	99%	99%	99%	99%	53%	65%
59	Bay Pines Blvd	100Th Way / Bay Pines Blvd	100Th Way / Bay Pines Blvd	0.3	0.9	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	68%

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low SLR	Category 3 Storm	Category 3 Storm + Int-Low SLR	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
60	Seminole Blvd	54Th Ave / US 19 Alt	72Nd Ave	1.1	5.6	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
61	Gulf Blvd	192Nd Ave	195Th Ave	0.6	0.6	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
62	49Th St	38Th Ave	76Th Ave	2.4	14.3	15.6	16	0%	0%	0%	0%	16%	5%	47%	0%	13%
63	4Th St	#N/A	116Th Ave / Lincoln Shores	4.5	26.6	15.1	18	88%	93%	93%	100%	100%	100%	100%	5%	34%
64	Dr Martin Luther King Jr St	57Th Ave	73Rd Ave	1.0	4.1	14.0	14	100%	100%	100%	100%	100%	100%	100%	58%	58%
65	Dr Martin Luther King Jr St	77Th Ave	118Th Ave	2.5	10.1	15.4	18	98%	98%	98%	98%	98%	98%	98%	28%	71%
66	Seminole Blvd	Johnson Blvd / Village Dr	86Th Ave	0.6	3.5	14.0	14	0%	0%	0%	48%	75%	48%	100%	0%	0%
67	US 19	102Nd Ave	106Th Ave	0.3	1.8	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
68	Connecting Rd	CR 694 / US 19 Alt	43Rd St	5.8	35.0	14.7	17	39%	50%	46%	72%	100%	93%	100%	12%	48%
69	Gandy Blvd	43Rd St	Gandy Bridge	8.3	56.8	16.2	20	67%	72%	71%	98%	98%	98%	98%	11%	58%
70	66Th St	54Th Ave / SR 693	121St Ave	4.2	25.2	14.6	16	0%	8%	0%	82%	94%	82%	99%	12%	66%
71	71St St	Park Blvd / SR 694	90Th Ave / Bayou Club Blvd	1.1	6.2	14.5	15	0%	47%	0%	100%	100%	100%	100%	0%	47%
72	Belcher Rd	68Th St	75Th St	0.8	4.6	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
73	CR 296	102Nd Ave / Seminole Blvd / US 19 Alt	102Nd Ave / 98Th St	0.7	3.0	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
74	Gulf Blvd	SR 688	8Th Ave	0.4	0.8	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
75	SR 688	118Th Ave / SR 688	SR 688	0.5	2.1	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
76	Gulf Blvd	1St St	Causeway Blvd	0.0	0.5	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
77	Wilcox Rd	125Th St / Jackson St	SR 688 / Ulmerton Rd	0.1	0.3	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	100%
78	SR 686	Roosevelt Blvd	34Th St	2.8	18.1	16.2	19	82%	91%	89%	97%	97%	97%	97%	11%	53%
79	Ulmerton Rd	Walsingham Rd	SR 693	5.9	35.2	15.7	18	0%	10%	0%	13%	23%	13%	61%	0%	38%
80	Ulmerton Rd	SR 688 / SR 693	58Th St	1.0	7.9	16.0	18	7%	13%	13%	41%	81%	66%	84%	5%	25%
81	Ulmerton Rd	58Th St / SR 688	50Th Way	0.6	5.0	15.0	15	0%	62%	62%	100%	100%	100%	100%	0%	0%
82	Ulmerton Rd	CR 611 / SR 688	34Th St / Ramp / SR 686	1.3	7.7	14.0	15	41%	48%	41%	97%	97%	97%	97%	5%	33%
83	SR 688	Roosevelt Blvd	49Th St	1.5	8.7	14.8	15	99%	99%	99%	99%	99%	99%	99%	0%	47%
84	Bryan Dairy Rd	34Th St	Endeavor Ave	5.2	26.2	14.8	17	0%	20%	8%	96%	99%	99%	99%	18%	65%
85	Bryan Dairy Rd	Starkey Rd	Endeavor Ave	1.6	9.5	15.0	16	0%	0%	0%	46%	100%	85%	100%	12%	48%
86	Belcher Rd	CR 296 / Ramp	Belle Oak Blvd	2.7	16.3	14.5	16	0%	0%	0%	41%	100%	95%	100%	20%	83%
87	Starkey Rd	122Nd Ave / CR 1	Christie Dr	1.2	5.6	14.0	14	0%	0%	0%	0%	75%	0%	100%	0%	84%
88	9Th Ave	113Th St / SR 688	8Th Ave / Clearwater Largo Rd	1.0	6.2	14.5	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
89	Clearwater Largo Rd	Bay Dr / SR 686 / US 19 Alt	Rosery Rd	0.8	3.1	14.7	16	0%	0%	0%	0%	0%	0%	0%	0%	0%

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low SLR	Category 3 Storm	Category 3 Storm + Int-Low SLR	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
90	Fort Harrison Ave	16Th Ave	C St / Lakeview Rd	1.2	3.6	15.7	17	0%	0%	0%	0%	0%	0%	0%	0%	0%
91	Lakeview Rd	C St / Fort Harrison Ave	Railroad	0.2	0.6	14.7	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
92	Missouri Ave	124Th Ave / Seminole Blvd	Rosery Rd	2.9	17.3	15.4	17	0%	0%	0%	0%	0%	0%	5%	0%	23%
93	CR 1	CR 1 / Willow Ave	Bay Dr / SR 686	0.5	3.1	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	63%
94	Belcher Rd	Bay Dr	Willowbrook Dr	0.3	1.4	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
95	Roosevelt Blvd	12Th St / The Pinellas Trl	CR 611	6.4	36.6	15.4	18	8%	8%	8%	71%	80%	76%	80%	0%	14%
96	Missouri Ave	Jasper St	Belleair Rd	0.5	3.1	14.7	15	0%	0%	0%	0%	0%	0%	0%	0%	61%
97	SR 693	123Rd Ave / Connecting Rd	US 19	1.3	6.3	15.2	16	0%	0%	0%	0%	24%	4%	100%	0%	77%
98	US 19	70Th Ave	Via Granada	15.0	139.5	15.3	20	4%	6%	5%	38%	49%	47%	55%	14%	39%
99	SR 60	CR 669 / Gulfview Blvd	SR 60	0.9	2.8	14.7	16	100%	100%	100%	100%	100%	100%	100%	53%	78%
100	Fort Harrison Ave	Lakeview Rd / Myrtle Ave	Edgewater Dr / Sunset Point Rd	2.8	10.5	15.0	17	15%	15%	15%	15%	15%	15%	34%	35%	49%
101	Memorial Cswy	SR 60	Missouri Ave / Ramp	0.9	4.3	15.8	17	0%	0%	0%	0%	0%	0%	0%	9%	30%
102	Court St	Osceola Ave	Myrtle Ave	0.0	2.6	14.8	16	0%	0%	0%	0%	0%	0%	0%	71%	79%
103	Fort Harrison Ave	Turner St	Court St / SR 60 / US 19 Alt	0.2	0.4	15.0	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
104	Cleveland St	East Ave / The Pinellas Trl	Myrtle Ave	0.1	0.1	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	100%
105	Missouri Ave	Queen St	Rogers St	1.1	6.3	15.9	17	0%	0%	0%	0%	0%	0%	18%	0%	9%
106	Drew St	Connecting Rd	US 19	0.2	0.8	16.0	17	0%	0%	0%	0%	0%	0%	0%	0%	0%
107	Drew St	Belcher Rd	Terrace Dr	0.2	0.4	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	100%
108	Countryside Blvd	11Th St / Druid Rd	121St Ave	4.2	19.5	15.1	18	0%	0%	0%	0%	0%	0%	0%	24%	73%
109	Gulf To Bay Blvd	Starkey Rd	Mcmullen Booth Rd	4.6	26.3	14.7	17	0%	8%	8%	8%	8%	8%	27%	0%	30%
110	Mcmullen Booth Rd	CR 611 / Drew St	Featherwood Ct	0.0	0.3	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
111	McMullen Booth Rd	CR 102 / CR 611 / Enterprise Rd / Mcmullen Booth Rd	CR 611 / Eastland Blvd / Mcmullen Booth Rd	0.2	1.2	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
112	SR 580	3Rd St	US 19	1.3	8.1	14.4	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
113	SR 580	Belcher Rd / Main St	US 19	0.8	3.4	15.0	16	0%	0%	0%	0%	0%	0%	0%	44%	44%
114	SR 580	Bass Blvd / Skinner Blvd	CR 1	1.2	5.8	14.9	15	0%	0%	0%	0%	0%	0%	0%	0%	14%
115	Skinner Blvd	Broadway / Tilden St	Douglas Ave	0.1	0.5	15.0	15	59%	59%	59%	100%	100%	100%	100%	59%	59%
116	Edgewater Dr	Beltrees St	San Salvador Dr	1.7	3.4	15.1	16	95%	100%	100%	100%	100%	100%	100%	22%	63%
117	McMullen Booth Rd	Briar Creek Blvd	Landmark Blvd	1.5	9.0	14.0	14	0%	19%	0%	34%	57%	34%	68%	0%	85%
118	Curlew Rd	Countryside Blvd	SR 584	1.5	9.0	15.0	15	0%	52%	0%	80%	80%	80%	100%	0%	72%
119	US 19 N	Phoenix Ave	Becketts Way	0.1	0.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low SLR	Category 3 Storm	Category 3 Storm + Int-Low SLR	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
120	SR 580	Saint Clair Ave	Saint Petersburg Dr	0.4	1.6	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	100%
121	Forest Lake Blvd	Mears Blvd	Tampa Rd	0.3	1.4	14.0	14	100%	100%	100%	100%	100%	100%	100%	0%	0%
122	Tampa Rd	Bay Dr	Burbank Rd / Tampa Rd	4.3	27.7	14.9	17	12%	67%	17%	96%	96%	96%	96%	0%	11%
123	US 19	Tampa Rd	Pine Ridge Way	1.2	6.4	14.6	15	0%	0%	0%	0%	0%	0%	0%	0%	53%
124	Keystone Rd	Walton Ave	US 19	2.0	7.9	14.3	16	0%	81%	0%	100%	100%	100%	100%	23%	76%
125	US 19	CR 880 / Klosterman Rd / US 19 N	Klosterman Rd	2.8	14.9	14.6	17	1%	76%	16%	94%	94%	94%	98%	18%	69%
126	Tarpon Ave	Pinellas Ave	Safford Ave	0.1	0.3	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	100%
127	Klosterman Rd	Pinellas Ave	Roberts Rd	0.0	0.2	14.0	14	0%	100%	0%	100%	100%	100%	100%	0%	0%
128	Pinellas Ave	Valley Rd	Curlew Pl	1.8	3.7	14.4	15	59%	82%	68%	100%	100%	100%	100%	14%	46%
129	US 19	1St Ave	Brittany Park Blvd	0.3	1.5	14.0	14	0%	0%	0%	0%	100%	100%	100%	0%	0%
130	Belcher Rd	Belleair Rd	Wistful Vista Dr	0.0	0.2	15.0	15	0%	100%	100%	100%	100%	100%	100%	0%	0%

Table E-3 Pasco County High Criticality Segments

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low SLR	Category 3 Storm	Category 3 Storm + Int-Low SLR	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
1	County Line Rd	I 75	#N/A	0.1	0.6	16.0	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	Land O Lakes Blvd	Land O Lakes Blvd / Willow Bend Pky	Dale Mabry Hwy	1.0	5.9	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	I 75	Wesley Chappel Blvd	Tupper Rd	0.9	3.2	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	47%
4	SR 56	Oak Grove Blvd	Paseo Dr	6.5	28.4	14.5	17	0%	0%	0%	0%	0%	0%	0%	18%	57%
5	Bruce B Downs Blvd	Bruce B Downs Blvd / SR 56	Vanguard St	0.5	3.2	14.5	16	0%	0%	0%	0%	0%	0%	0%	0%	100%
6	Wesley Chapel Blvd	SR 54	Magnolia Blvd / SR 54	3.3	14.1	14.5	16	0%	0%	0%	0%	0%	0%	0%	0%	26%
7	Wesley Chapel Blvd	Old Pasco Rd / SR 54	#N/A	0.0	0.5	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
8	I 75	N/A	Exit 279	0.0	2.6	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	100%
9	Wesley Chapel Blvd	Gateway Blvd	Pointe Pleasant Blvd	1.4	8.7	14.4	15	0%	0%	0%	0%	0%	0%	0%	10%	10%
10	Bruce B Downs Blvd	Stockton Dr	Wesley Chapel Blvd	0.8	4.9	14.9	15	0%	0%	0%	0%	0%	0%	0%	0%	89%
11	SR 54	Boyette Rd	SR 54	1.0	4.9	14.5	15	0%	0%	0%	0%	0%	0%	0%	0%	71%
12	SR 54	Altamont Ln	Collier Pky	8.1	48.6	14.5	16	0%	0%	0%	0%	0%	0%	0%	0%	17%
13	Exit 19	SR 589	Ramp / SR 54	0.1	0.2	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
14	Gunn Hwy	Duck Slough Blvd	Monmouth Dr	2.5	14.9	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	47%
15	Trinity Blvd	CR 996 / Robert Trent Jones Pky	Duck Slough Blvd / Grand Lakes Blvd	1.9	7.4	14.5	16	0%	0%	0%	0%	0%	0%	23%	31%	31%
16	SR 54	CR 1 / Little Rd	Starkey Blvd	1.7	10.3	14.8	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
17	Little Rd	Mitchell Blvd / Robert Trent Jones Pky	Old County Rd 54 / Villa Entrada	2.6	15.4	15.2	17	0%	0%	0%	0%	0%	0%	60%	0%	14%
18	SR 54	Crescent Moon Dr	Old County Rd 54	0.4	2.4	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
19	SR 54	CR 595 / Grand Blvd / SR 54	Seven Springs Blvd	1.9	11.1	15.0	15	0%	0%	0%	32%	32%	32%	48%	0%	14%
20	US 19	1St Ave / Phoenix Ave	Continental Dr / US 19 Alt	0.6	3.8	14.0	14	0%	0%	0%	100%	100%	100%	100%	28%	58%
21	US 19	Camry Dr	Beacon Hill Dr	1.3	7.4	14.0	14	0%	20%	0%	68%	76%	68%	100%	0%	23%
22	US 19	High St	Green Key Rd	1.2	7.0	14.6	15	100%	100%	100%	100%	100%	100%	100%	0%	0%
23	Rowan Rd	Baillie Dr / SR 518	Plathe Rd	0.2	1.0	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
24	Rowan Rd	Baillie Dr / SR 518	Plathe Rd	0.2	1.0	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
25	Little Rd	Blueberry Dr	Arevee Dr / Ross Ln	0.1	0.4	14.0	14	0%	0%	0%	0%	0%	0%	100%	0%	0%
26	Ridge Rd	CR 296 / Ramp	Custom Blvd	0.3	1.4	14.0	14	0%	0%	0%	100%	100%	100%	100%	0%	0%
27	Ridge Rd	High St	US 19	0.4	1.6	14.9	15	100%	100%	100%	100%	100%	100%	100%	0%	69%
28	US 19	Grand Blvd	Richey Rd	2.1	10.6	15.0	15	100%	100%	100%	100%	100%	100%	100%	0%	22%
29	US 19	Butch St	Coventry Dr	1.0	6.3	14.0	14	48%	100%	53%	100%	100%	100%	100%	0%	0%

ID	Road Name	From	To	Length (Miles)	Lane Mile	Criticality Score		Percentage of Roadway Impacted								
						Average	Maximum	Category 1 Storm	Category 1 Storm + High SLR	Category 1 Storm + Int-Low SLR	Category 3 Storm	Category 3 Storm + Int-Low SLR	Category 3 Storm + High SLR	Category 5 Storm	9 Inches Precipitation	33 Inches Precipitation
30	Regency Park Blvd	Cutty Sark Dr	Embassy Blvd	0.1	0.3	14.0	14	0%	0%	0%	100%	100%	100%	100%	100%	100%
31	Little Rd	CR 1 / Embassy Blvd / Hilltop Dr / Ramp	SR 52	2.8	17.0	14.5	15	0%	0%	0%	16%	16%	16%	100%	0%	62%
32	SR 52	Waterson St	Elkton Ave	1.5	8.9	14.0	14	8%	32%	32%	100%	100%	100%	100%	8%	63%
33	US 19	SR 52	#N/A	0.2	0.5	14.0	14	100%	100%	100%	100%	100%	100%	100%	26%	100%
34	US 19	Edna Ave	Beach Blvd	0.6	3.7	15.0	15	100%	100%	100%	100%	100%	100%	100%	0%	56%
35	US 41	CR 1 / Willow Ave	SR 52	2.4	9.8	14.2	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
36	I 75	SR 52	Blanton Rd	8.4	67.4	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	90%
37	Trilby Rd	Driveway	US 301	0.4	0.9	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
38	US 98	Louis Ave	Trilby Rd	0.8	1.6	14.6	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
39	US 301	Old Lakeland Hwy / SR 35A / US 98	Brittany Park Blvd	7.4	27.3	15.2	18	0%	0%	0%	0%	0%	0%	0%	0%	0%
40	Lock St	Julian St	SR 578 / US 301 / US 98	0.2	0.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
41	SR 35	Florida Ave	US 301	1.0	2.1	15.0	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
42	US 301	Townsend Rd	CR 52A / Clinton Ave	1.3	5.0	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
43	Gall Blvd	Valley Rd	Walton Ave	3.0	14.4	15.5	17	0%	0%	0%	0%	0%	0%	0%	0%	0%
44	CR 54	Fort King Rd	Orris St	0.8	3.3	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
45	6Th St	4Th Ave	6Th St / 9Th Ave	0.0	2.9	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
46	Gall Blvd	Tucker Rd	Palm Grove Dr	0.2	0.8	14.3	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
47	Gall Blvd	7Th St	South Ave	0.5	2.6	14.5	16	0%	0%	0%	0%	0%	0%	0%	0%	0%
48	Gall Blvd	6Th St / A Ave	A Ave	0.1	0.2	15.0	15	0%	0%	0%	0%	0%	0%	0%	0%	0%
49	South Ave	Gall Blvd	7Th St	0.1	0.1	14.0	14	0%	0%	0%	0%	0%	0%	0%	0%	0%
50	7Th St	Gall Blvd	5Th Ave	0.4	1.2	14.8	15	0%	0%	0%	0%	0%	0%	0%	0%	0%

This page is intentionally left blank.

It's TIME HILLSBOROUGH

Transportation • Innovation • Mobility for Everyone

Hillsborough MPO
Metropolitan Planning for Transportation

Hillsborough County Metropolitan Planning Organization
601 E. Kennedy Boulevard, 18th Floor
Tampa, FL 33602
(813) 272-5940
www.planhillsborough.org