2040 Long Range Transportation Plan – Needs Assessment: Vulnerability Reduction Costs and Benefits

Prepared For:

601 East Kennedy Boulevard
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This report was developed by the Hillsborough Metropolitan Planning Organization in accordance with a grant from the Federal Highway Administration (FHWA). The statements, findings, conclusions and recommendations are those of the author(s) and do not necessarily reflect the views of FHWA or the U.S. Department of Transportation.

1.0 Introduction

Hillsborough County's 2040 Long Range Transportation Plan focuses on the cumulative transportation needs in Hillsborough County through five different investment strategies or programs. This technical memo documents the data collection, assessment methodology, and mitigation measure recommendations for the Vulnerability portion of the Safety and Security investment program. Another technical memo discusses the other portion, Safety, in regard to reducing crashes and fatalities. Vulnerability reduction aims to ensure that transportation assets key to the local economy are protected from storm surge and flooding. The results measure the economic impact of key transportation facilities that were lost due to storms, flooding or sea level rise.

The LRTP update process for the Vulnerability investment program area leveraged the work of a concurrent climate change adaptation project (the "Pilot") conducted as part of Federal Highway Administration's Climate Change Resilience Pilots. Data collection and analysis performed for the Pilot and integral to the LRTP update activities are therefore summarized in this document.

The vulnerability analysis was supported by a host of partners, including:

- Florida Department of Transportation (FDOT);
- Hillsborough County Department of Public Works;
- Tampa Bay Regional Planning Council (TBRPC);
- University of Florida GeoPlan Center; and
- University of South Florida (USF).

The Local Mitigation Strategy Working Group (LMS_WG), convened by Hillsborough County's Hazard Mitigation Program (under the Public Works Department) to participate in the development of the Local Mitigation Strategy, provided advice and feedback at strategic intervals during the process. The LMS_WG is composed of a mix of government officials, representatives from local businesses, and private citizens. The project team engaged the LMS_WG at four separate meetings (October 2013, December 2013, March 2014, and May 2014) to provide briefings, establish and vet key assumptions and approaches, and to obtain expert feedback on preliminary results.

2.0 Technical Approach

The following steps were used to determine the key transportation assets and the approximate economic loss should those facilities fail:

1. Collect relevant data (carried out during a complementary project),
2. Establish risk scenario,
3. Estimate economic impacts of disruption (no build), and
4. Develop risk mitigation investment scenarios and estimate costs and benefits (the latter defined in terms of avoided losses)

Each step is described in greater detail in the remainder of this document.

Hillsborough County and the greater Tampa Bay Region have been spared from a direct hurricane impact since the 1921 storm that hit Tarpon Springs in Pinellas County. Prior, the last severe storm was in 1848. Tampa Bay is in a vulnerable coastal location and is statistically "overdue" for a storm event, according to the National Weather Service.

Source: tbo.com/news/breaking-news/tampas-hurricane-blessing-92-years-of-misses-and-counting-20130911/

Photo source: JACOBS Engineering, 2014.

2.1 Step One: Collect Relevant Data

Transportation infrastructure and operations are fundamental to public safety and quality of life. Hillsborough County's and the Tampa Bay's infrastructure faces three different threats: sea level rise, inland flooding from storm events, and coastal flooding and storm surge from tropical storms. Hillsborough County's vulnerability to sea level rise is significant and has led to better public awareness in recent years because of its low elevation, high population density along the coastline, and strong local economic dependence on coastal and marine-related businesses.

Tampa Bay's coastal water levels have been rising about an inch a decade since the 1950s. Tropical Storm Debby in 2012 caused serious damages and deterioration in transportation infrastructure, which led to significant disruptions to the movement of people and goods — especially to critical locations like Tampa General Hospital. Historically, coastal and inland flooding have always threatened Hillsborough County; however, flood risk factors are expected to increase as sea levels rise (the future intensity and frequency of extreme rainfall events is less certain in the Southeast). Because transportation infrastructure is often a region's strategic investment and expected to last for decades, it is crucial to prepare the Tampa Bay region to adapt to potential future climate conditions while making cost-effective investments over the long-term.

Data collection

Working with the Hillsborough County MPO and partners, the project team identified and obtained the best available data that included regionally-scaled critical asset data, climate data, and topographic data from local, state, and national agencies including the following:

- Hillsborough County MPO,
- Hillsborough County Public Works,

- Tampa Bay Regional Planning Council (TBRPC),
- Florida Department of Transportation (FDOT),
- University of Florida Geo-Facilities Planning and Information Research Center (GeoPlan Center),
- Florida Atlantic University (FAU)
- United States Army Corp of Engineers (USACE),
- National Oceanic and Atmospheric Administration (NOAA), and
- U.S. Geological Survey (USGS).

Asset Inventory

Data were first organized into a matrix for easy maintenance and organization. Asset types are defined as infrastructure vital to Hillsborough County's needs. The following Hillsborough County asset types were analyzed:

- Roadways
- Transit centers
- Rail
- Intermodal facilities
- Education facilities
- MacDill Air Force Base
- Tampa International Airport (TIA)
- Traffic Analysis Zones (TAZs)
- HART transit routes
- Evaluation routes
- Bridges
- Power plants
- Medical centers
- Seaports

Data were then organized into a Transportation Asset Geodatabase (**Figure 1**), which serves as a repository, an analysis tool, and an asset inventory management tool. Spatial data were organized into broad categories that included transportation, climate, topography, and base layers. Tampa Bay Regional Planning Model (TBPRM) roadway network data were used as the roadway assets layer, and TAZs provided basic socio-economic data. Additional activity centers and facilities that generate and/or attract trips were considered during the asset inventory process.

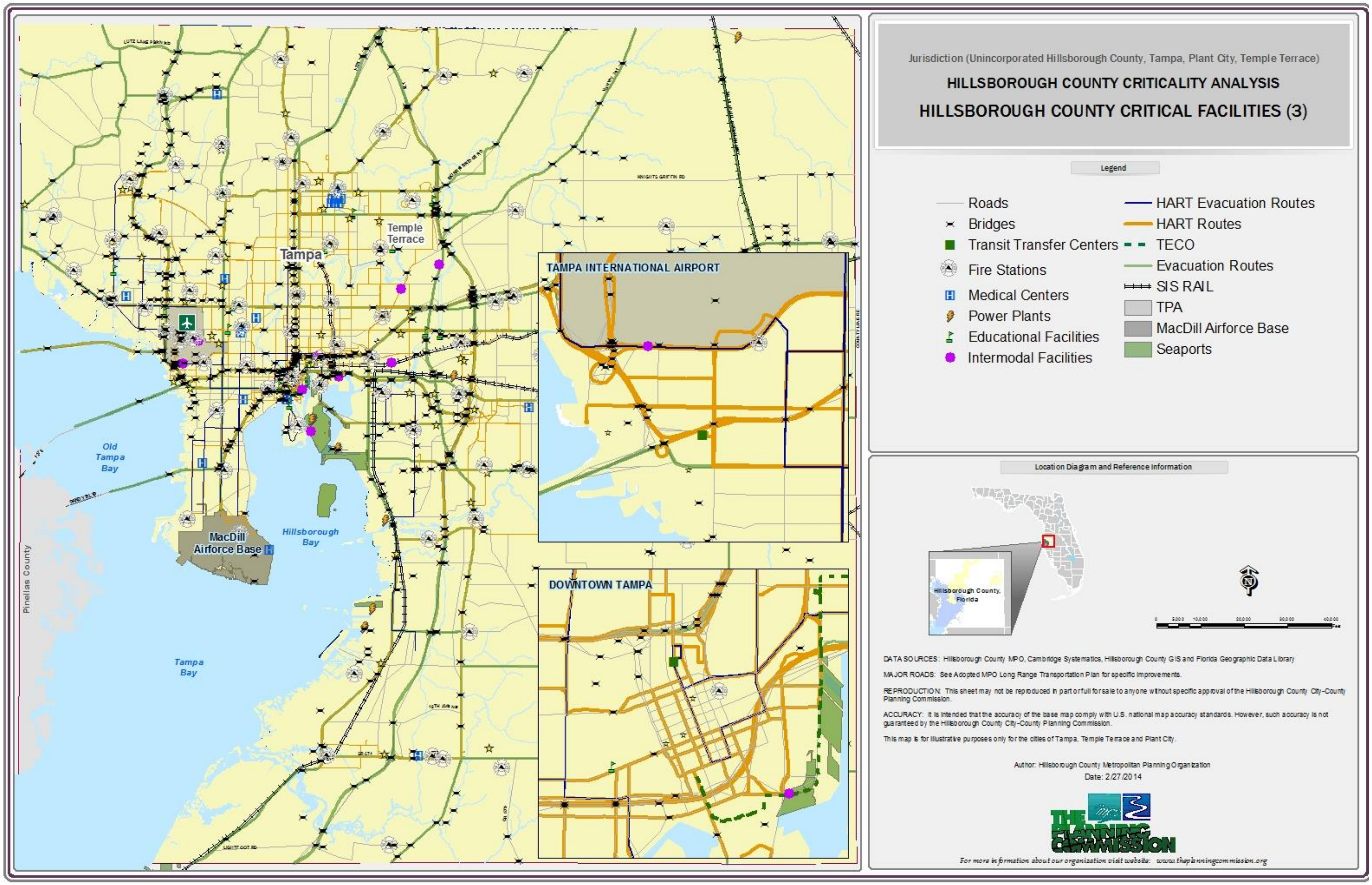

Figure 1. Image from Transportation Asset Geodatabase

Topographic Data

Elevation data were used to calculate water depths in different sea level rise with storm surge scenarios. The Florida Digital Elevation Model (DEM) (LiDAR/DEM) delineates areas which are at risk from flooding caused by projected sea level rise and storm surge. The dataset is a composite DEM, which has a five-meter horizontal resolution and was created using a combination of the following DEMs:

1. Northwest Florida Water Management District (NWFWMD) DEM,
2. NOAA FLIDAR Coastal DEM (data sourced from the NOAA Coastal Services Center),
3. Florida Fish and Wildlife Conservation Commission (FWC) Florida Statewide Five-Meter DEM (clipped to Hillsborough County lines), and
4. Contour Derived DEM (based on two-foot contours from the coastal LiDAR project).

Climate Data

Three climate stressors were taken into consideration for this study: Sea level rise, storm surge, and inland flooding. Climate data collection and analysis for obtaining climate change scenarios evaluated in this study are described in this section.

Sea Level Rise

The sea level rise scenarios chosen for this project are 2040 and 2060 with Mean Higher High Water (MHHW) and Mean Low Water (MLW) (**Table 1**). The Sea Level Scenario Sketch Planning Tool was developed by the GeoPlan Center at the University of Florida, using the sea level rise projection methodology developed by USACE along with tide gage data and sea level trends from the NOAA Center for Operational Oceanographic Products and Services.

Table 1. Sea Level Rise Scenarios Selected

2040 Sea Level Rise		2060 Sea Level Rise	
Scenarios	Depth (in)	Scenarios	Depth (in)
MHHW	30	MHHW	42
MLW	2	MLW	15

Storm Surge

Storm surge occurs when water is pushed towards the shore by powerful winds (**Figure 2**). High winds and low pressure cause water to accumulate at the center of the storm. Strong winds there plow the water to the front of the storm. The water's height depends on many factors that include bathymetry, or the ocean floor’s offshore slope. If the ocean depth is shallow for miles offshore, the storm surge builds up to a higher height than if the ocean depth becomes deep directly offshore. The storm surge builds as it approaches land and the seafloor becomes shallower. The water begins to pile up against the shore until it overtops it. This can happen prior to true landfall, and it can happen in areas outside the direct storm path. The tides affect surge height and vary annually and daily. Sea level rise permanently builds the foundation for the height of storm surge.

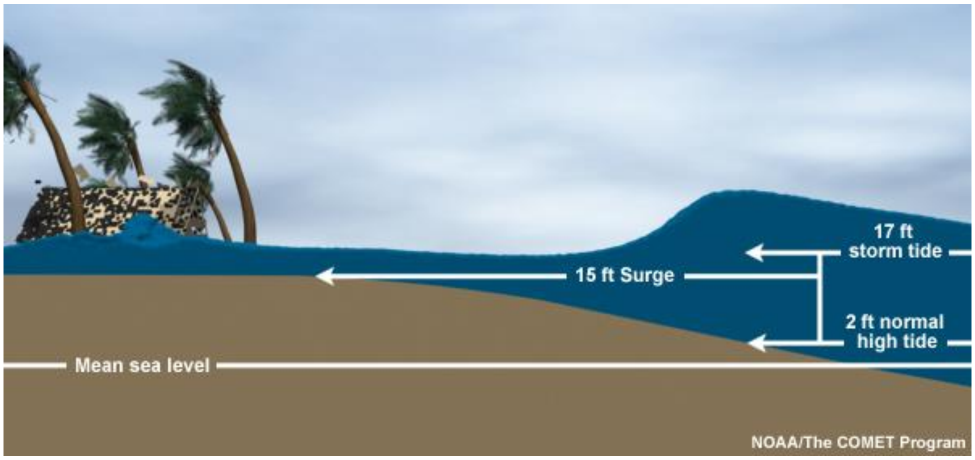

Figure 2. Representative storm surge illustration. Source: NOAA.

Storm Surge Heights

NOAA models storm surge using the Sea, Lake, and Overland Surges from Hurricanes model (SLOSH). SLOSH was developed to estimate storm surge heights based on unique characteristics of the area. For example, surge heights can be determined by historical, hypothetical, or predicted hurricanes. SLOSH also takes into account the atmospheric pressure, size, forward speed, and track data using a set of physics equations that integrate the shoreline, unique bay and river configurations, water depths, bridges, roads, levees, and other physical features[1]. The project team used SLOSH model outputs provided by the Tampa Bay Regional Planning Council (TBRPC). The Pilot project employed a composite of the maximum modeled surge heights across the County (Maximum of Maximums), associated with a collection of thousands of simulated storm events (i.e., unrealistic for a single storm event). The LRTP update, by contract, employed a single simulated Category 3 surge event.

Sea Level Rise with Storm Surge

The SLOSH output is presented as a layer of grid cells covering a chosen basin. Not all cells experience inundation. Additional analysis is required to determine if the land will be inundated and by how much water. Adding sea level rise scenarios to the storm surge height in the spatial analysis shows how much farther inland the water will go and how much deeper it will be. Hydrologic connectivity is another consideration. Storm surge travels inland along low lying areas, canals, and rivers. If it is blocked by elevated land or features such as a sea wall or levee, it is considered dry.

The future sea level rise and storm surge scenarios selected for analysis as part of the Pilot were 1) low projected sea level rise in 2040 with Category 1 storm surge, and 2) high projected sea level rise in 2040 with Category 3 storm surge—only the latter was analyzed for the LRTP update. Although several additional scenarios were generated for consideration, the scenarios ultimately analyzed were chosen collaboratively and reflect the expert judgment and risk tolerance of key partners in the Tampa Bay

[1] http://www.nhc.noaa.gov/surge/slosh.php

region (such as the Regional Planning Council). For more information on the SLOSH model, see the Appendix, part I.

Flood Plains

The Federal Emergency Management Agency's (FEMA's) Digital Flood Insurance Rate Map (DFIRM) is a digital version of the FEMA flood insurance map. DFIRM can be used with Geographic Information Systems (GIS) software. The Standard DFIRM database provides flood zones, base flood elevation, and the floodway status for a particular location. Flood zones in the DFIRM database are identified as a Special Flood Hazard Areas (SFHA). FEMA defines SFHAs as areas that annually have a one percent chance of experiencing the same or more flooding than the base flood, also known as a 100-year flood.

The project team obtained the Florida DFIRM database from the Florida Geographic Data Library (FGDL) website maintained by GeoPlan. According to the metadata, the Hillsborough County data in this database was last updated in 2008. With assistance from the Hillsborough County MPO, the project team was able to obtain more current DFIRM data that are currently under development by Hillsborough County Public Works and Hazard Mitigation Program. Among the 17 watersheds within the County, 15 had been updated as of December 2013 (corresponding with the development of flood maps for this study). Since both databases are important, the project team used SFHAs from the two DFIRMs as the flood zones for this study. The project team also used the County's flooding hot spots. These locations, identified by Department of Public Works staff, experience floods that are of greater depth, duration, and/or more frequent.

Next, critical assets, inundation data, and topographic data were integrated into a geodatabase (**Figure 3**) to facilitate the flood vulnerability analysis[2]. The FEMA SFHA extents and depths were not adjusted, to maintain consistency with officially designated flood hazard areas.

[2] A supplementary analysis of flooding hot spots, performed by the Tampa Bay Times using data from the City of Tampa's stormwater department, may be found at http://www.sptimes.com/2004/07/30/Citytimes/Flood_woes_likely_to_.shtml.

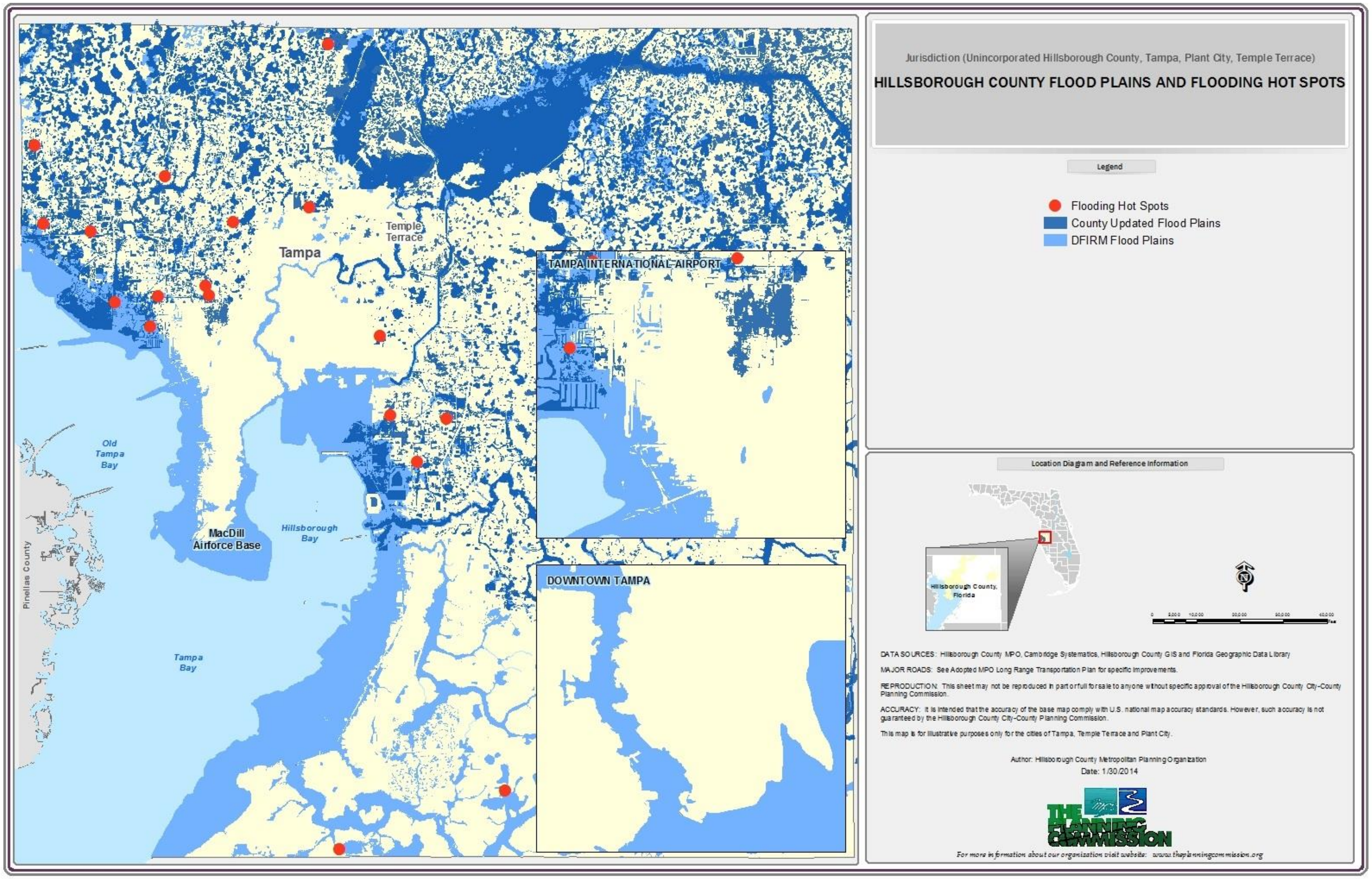

Figure 3. Hillsborough County Flood Plains and Flooding Hot Spots

2.2 Step Two: Establish Risk Scenario

Not every road in Hillsborough County could be studied within the context of this study, so it was important to determine which infrastructure and areas are most critical. An analytical process prioritized destinations and transportation assets that provide access to those destinations. This measure of relative criticality is based on several guiding principles that support Hillsborough County MPO's long range planning objectives, and the overall methodology is illustrated in **Figure 4**.

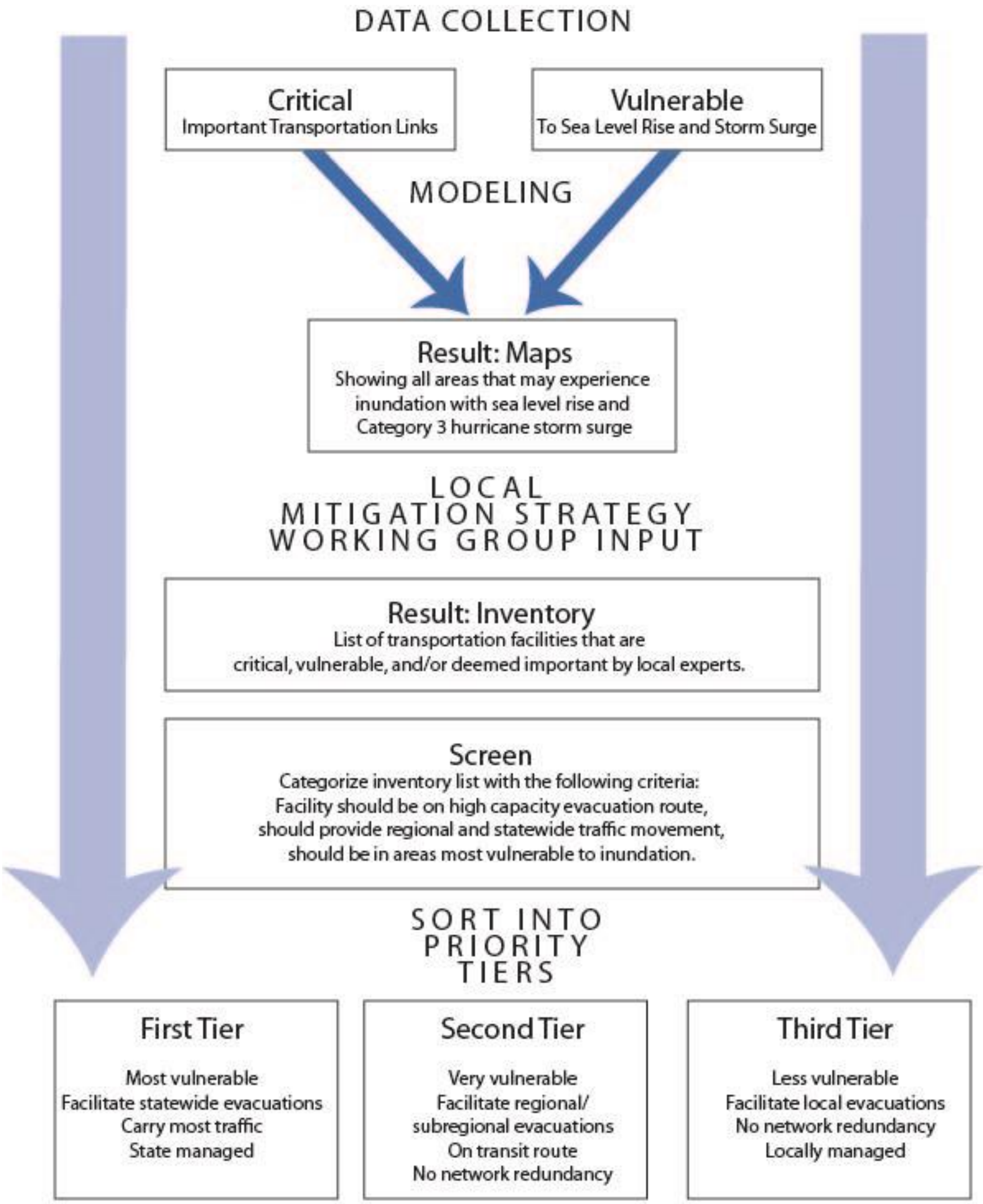

Figure 4. Facility risk analysis methodology

In order to rank the roadways, the project team performed a model-based criticality screening process of the regional roadway network by modifying the traffic assignment step in the TBRPM to assign criticality instead of the traditional “trip assignment” (see Technical Memorandum #1 for details).

Next, each traffic analysis zone (TAZ) and roadway link was assigned a score and ranked based on where the most people travel and which transportation assets they use to get there. **Figure 5** presents the 2040 criticality levels of the TAZs and roadway links in Hillsborough County. The top three percent of TAZs and links were selected as the extremely critical, very high assets.

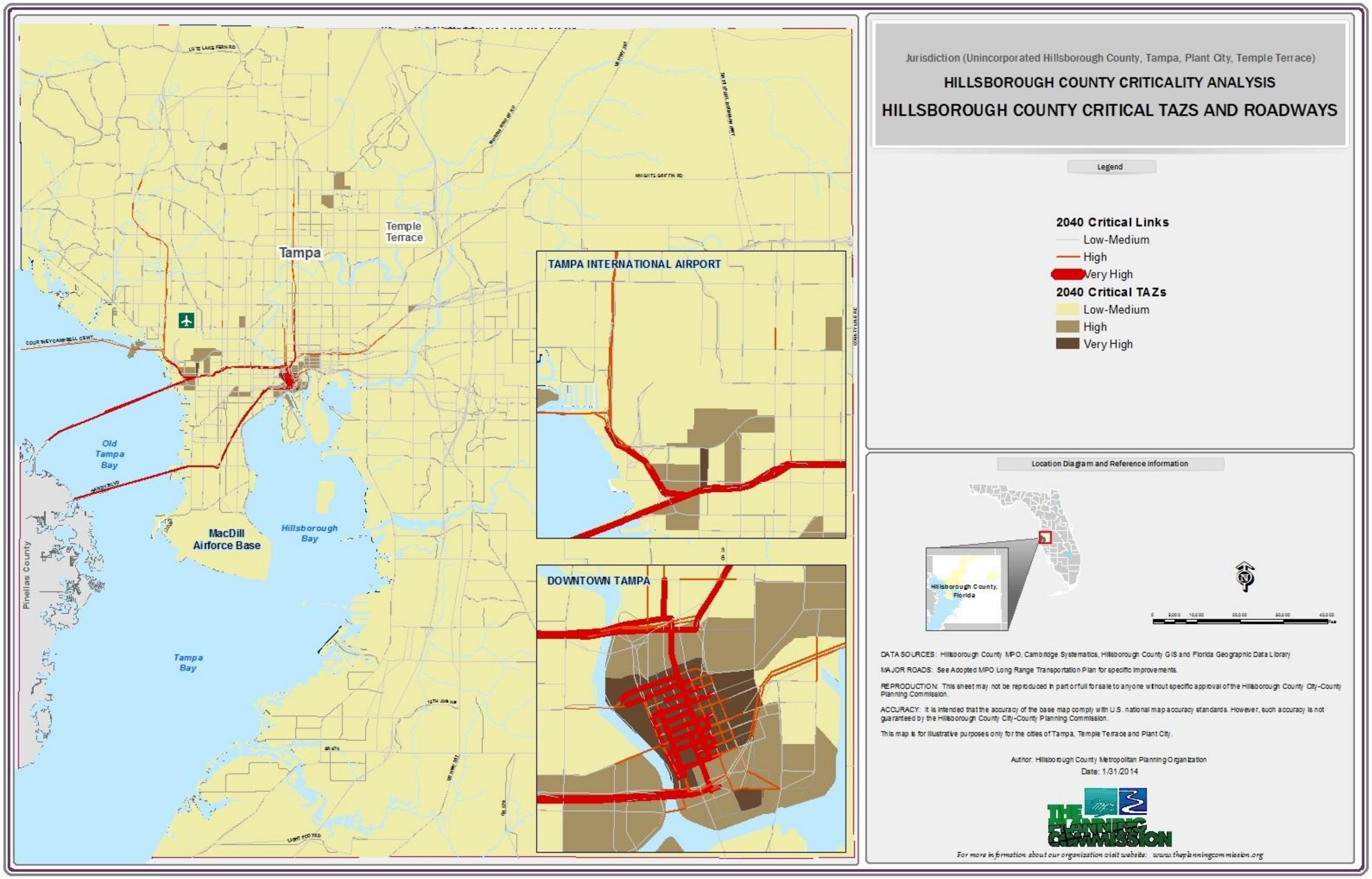

Figure 5. Results of Criticality Screening

Pilot Vulnerability Assessment

The Federal Highway Administration (FHWA) Climate Change and Extreme Weather Vulnerability Assessment framework was leveraged to guide the analysis of potential future inundation caused by sea level rise, storm surge, and inland flooding. The framework was developed by FHWA to provide process guidance for participants in its Climate Change Resilience Pilot programs, including Hillsborough County MPO (see **Figure 6**).

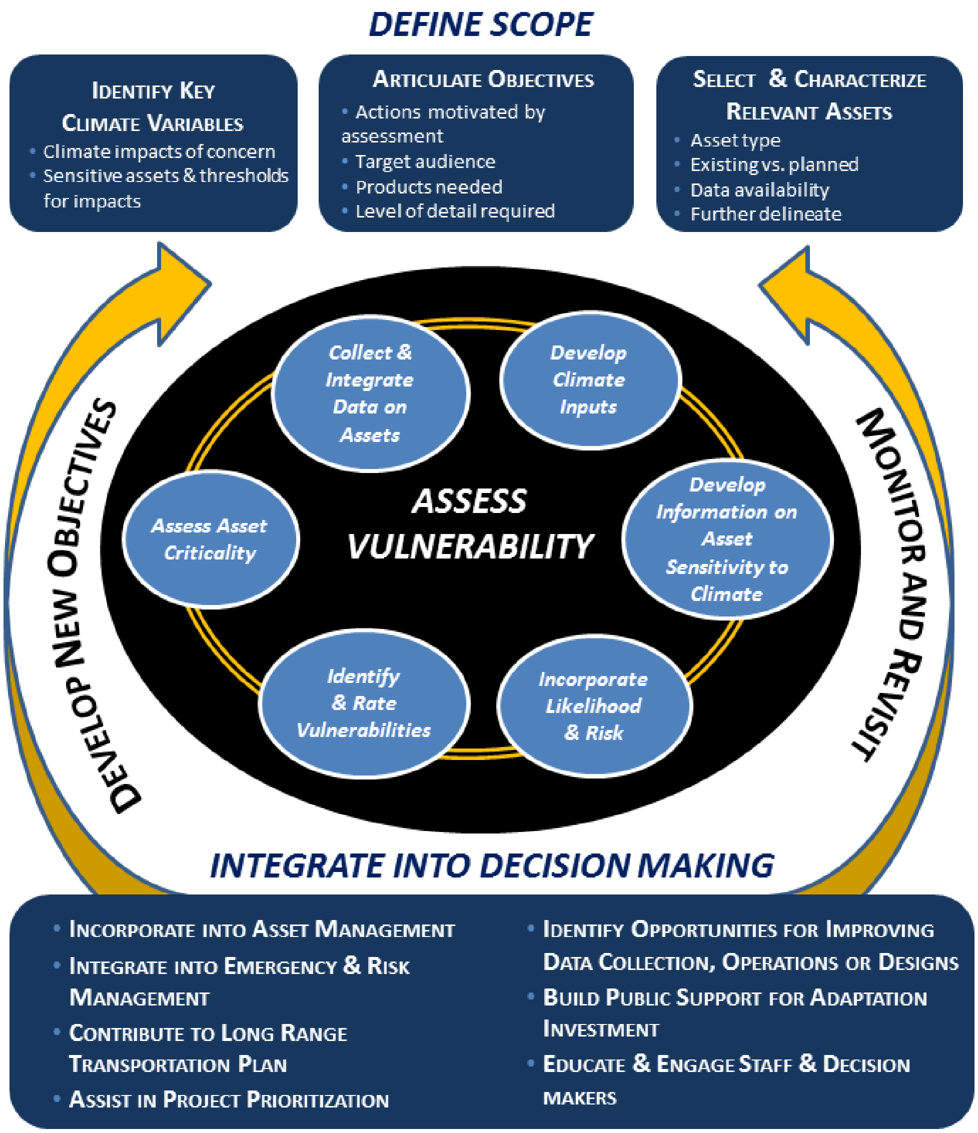

Figure 6. FHWA Vulnerability Assessment Framework (Source: FHWA)

For the FHWA Pilot, GIS was used to spatially overlay the areas of potential inundation with the transportation assets. The roadway links subject to inundation were extracted using a batch geoprocessing technique (developed by GeoPlan and customized by the project team) that intersects overlapping features. The two coastal inundation scenarios for 2040 that were presented to the Local Mitigation Strategy Working

Group for consideration (Category 1 and Category 3 storm surge with sea level rise, supplemented with FEMA flood plains) are shown in **Figures 7** and **8**. The inundation extents represent the Maximum of Maximum, or composite, SLOSH outputs. These results are presented in greater detail in the Pilot Project Technical Memorandum #1 (March 2014).

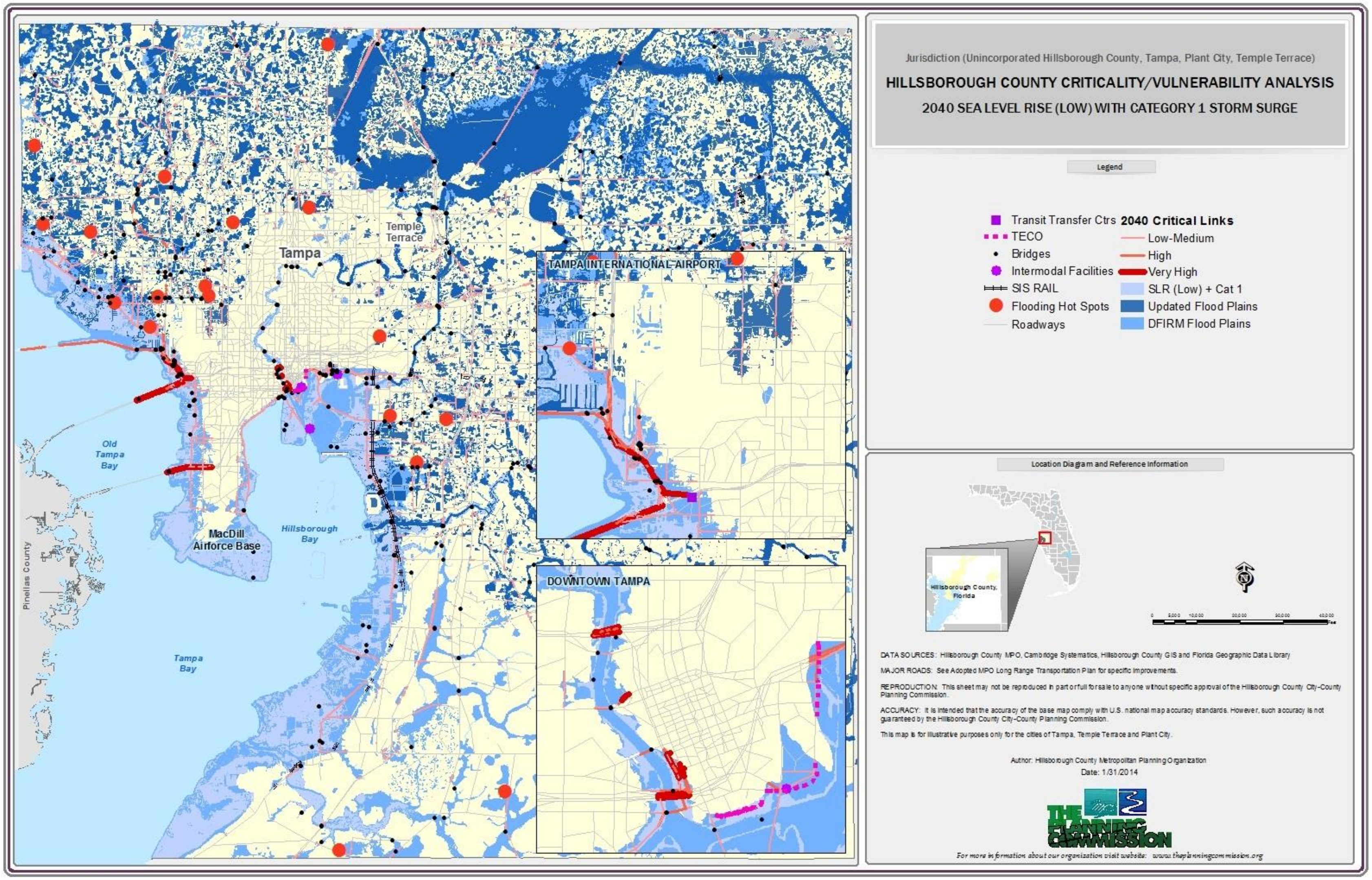

Figure 7. Example 1: 2040 Sea Level Rise (Low) with Category 1 Storm Surge in Combination with Flood Plains

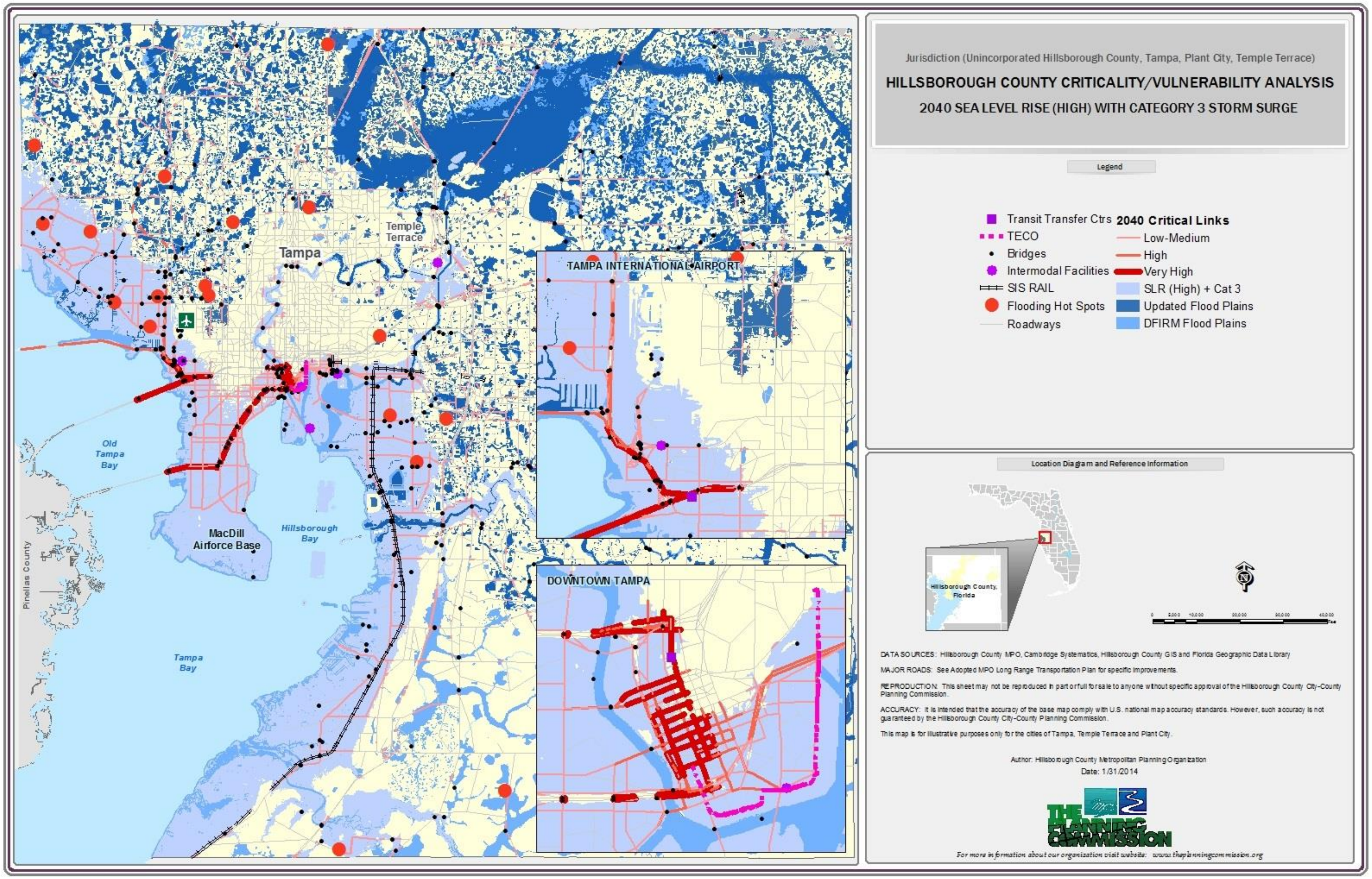

Figure 8. Example 2: 2040 Sea Level Rise (High) with Category 3 Storm Surge in Combination with Flood Plains

Based on this exposure screening analysis, the LMS_WG group identified a number of areas of concern, which were then catalogued into tiers of critical and vulnerable transportation assets (such as roads and bridges) which were then sorted into tiers.

Six assets emerged as the highest priority for immediate further study as part of the Federal Highway Administration (FHWA) Pilot Project, which are further detailed in the Pilot report.

LRTP Risk Assessment

Disruption to the entire County and its transportation assets had to be estimated for the Long Range Transportation Plan. Because storms are unpredictable events—and because the Maximum of Maximums used for the Pilot would over-represent impacts to the regional system—the LRTP analysis was based on a single, simulated storm surge event[3]. With the assistance of TBRPC, the project team identified and generated an illustrative storm surge event with storm track, wind velocity (Category 3), sea level rise (using a "high" scenario from the FDOT-sponsored Sea Level Rise Scenario Sketch Planning Tool), and tidal phase/datum assumptions (**Table 2**).

Table 2. Simulated Storm Surge Parameters

Parameter	Value
Simpson-Saffir Hurricane Category	3 (111-129 mph winds, up to 21 foot surge depths)
Trajectory	Tarpon Springs Hurricane (1921), observed track
Sea Level Rise	High, 2040 (current Mean Sea Level + 14")
Tidal Datum	Mean Higher High Water (projected MSL + 16")

2.3 Step Three: Estimate Economic Impacts Of Disruption (No Build Scenario)

In this step, the project team estimated the impacts of the storm surge simulation developed for the LRTP update, assuming no new risk management investments are implemented. This forms the basis of the "no-build" (no adaptation) disruption scenario.

The inundation polygon created by overlaying the surge simulation with the Digital Elevation Model illustrates potentially submerged areas (**Figure 9**). While **Figure 9** shows inundation across both Pinellas and Hillsborough Counties, only disruption within Hillsborough County was measured as part of the LRTP update.

The roadway facilities were grouped into three categories based on roadway functional classifications identified in TBRPM: Interstates, arterials, and all others (e.g., collectors and local streets). As a proxy

[3] Note that this event is not associated with a specific probability or likelihood. A similar event (Category 3 hurricane, northward landfall), or an event of lesser or greater magnitude, may or may not occur during the analysis period.

intended to simulate a phased recovery, it was assumed that the duration of disruption, or the time it would take for the facility to recover from inundation or a storm event, would differ based on the characteristics of each facility grouping (e.g., design guidelines and specifications and/or post-disaster emergency response priority). This planning-level approach was intended to be broadly illustrative, with the acknowledgement that each facility among the multitude included would recover at varying rates. These disruption groupings are summarized as follows:

- **Baseline/Fully Recovered**: This grouping represents the congested base case, prior to the surge event, as well as the fully recovered network (return to service of all facility types).
- **Full Impact [D0]**: This grouping represents the disruption/loss of capacity of all inundated links.
- **Group 1 Recovery [D1]**: This grouping represents the return to service of the first grouping of more resilient or higher-priority facilities (primarily Interstates).
- **Group 2 Recovery [D2]**: This grouping represents the return to service of the first and second facility groupings (primarily Interstates and arterials).

The links corresponding to each disruption scenario are shown in **Figure 9**, and listed in Appendix E (Full Impact, D0, scenario only).

For each grouping, inundated roadway links were disabled (meaning that no trips could be assigned to them) in the CUBE modeling platform for the entire five-county[4] Tampa Bay Regional Planning Model (TBRPM) area. The assignment procedure was rerun for each grouping, to simulate alternative trip paths (detours around the disabled facilities) and measure the number of trips that could not be assigned to the network because travelers at trip origins and/or destinations cannot access the transportation network (referred to as "lost" trips). The results, measured in terms of additional vehicle miles traveled (VMT) and vehicle hours of delay, were compared with the congested 2035 cost-affordable network (the baseline) – which is also the "fully recovered" network, meaning it has regained full functionality. The 2035 network incorporates improvements expected to be in place as outlined in the 2035 LRTP[5], along with corresponding population, jobs, and other socioeconomic forecasts. 2035 was the latest officially adopted long-range forecast year available at the time the analysis was performed (TBRPM v7.0).

[4] Hillsborough, Pinellas, Pasco, Hernando, Citrus, and a small portion of Manatee Counties.
[5] Please see the 2035 LRTP for information on the cost-affordable improvement program.

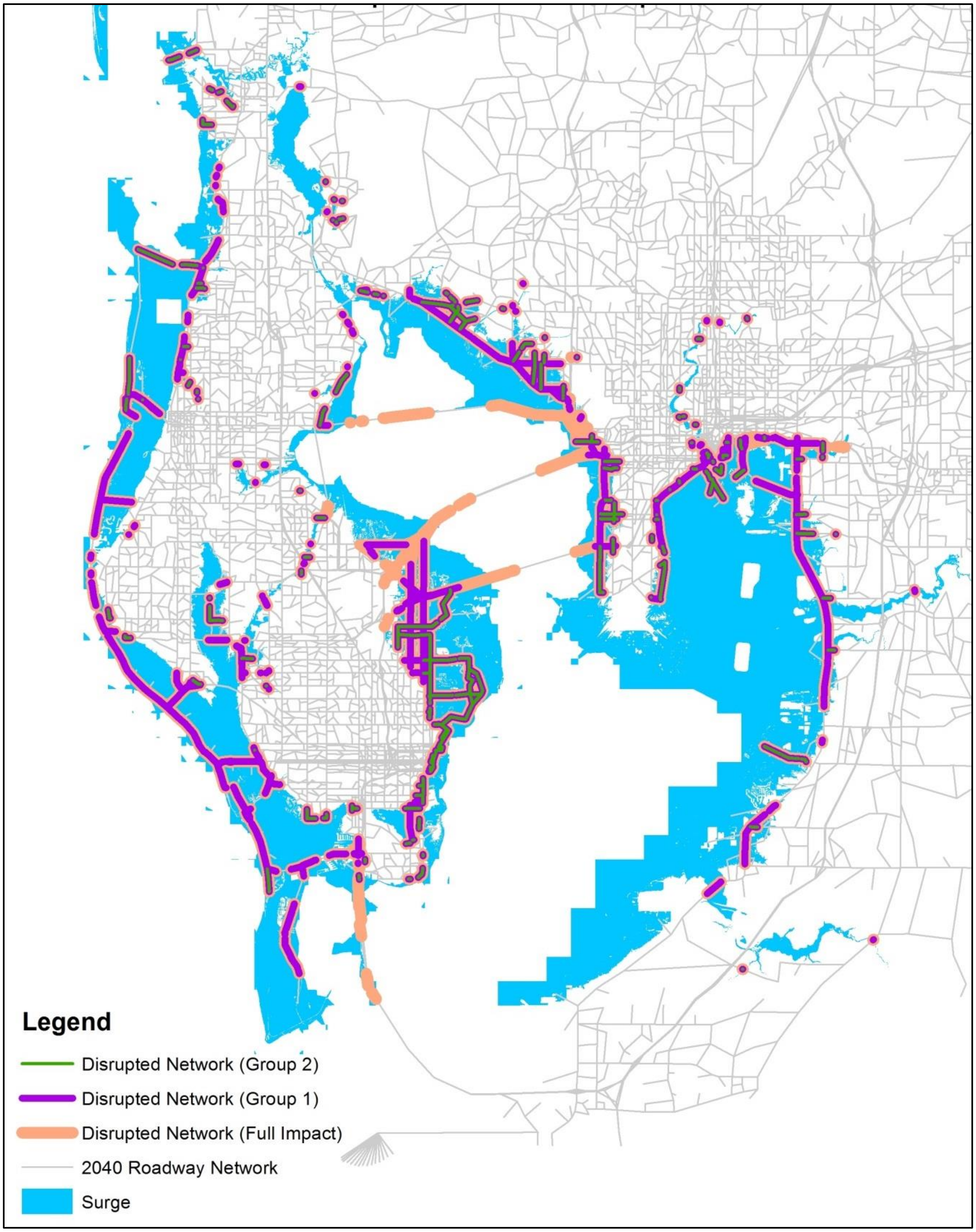

Figure 9. Potentially Disrupted Links in Pinellas and Hillsborough Counties (Simulated Category 3 Storm)

For each travel demand model run, *only* change in hours of delay (person or truck), change in vehicle miles traveled, and lost trips attributed to Hillsborough County were allocated by leisure, commute, and business (on the clock) trips for passenger vehicles and trucks (see **Figure 10** for Lost Trips).

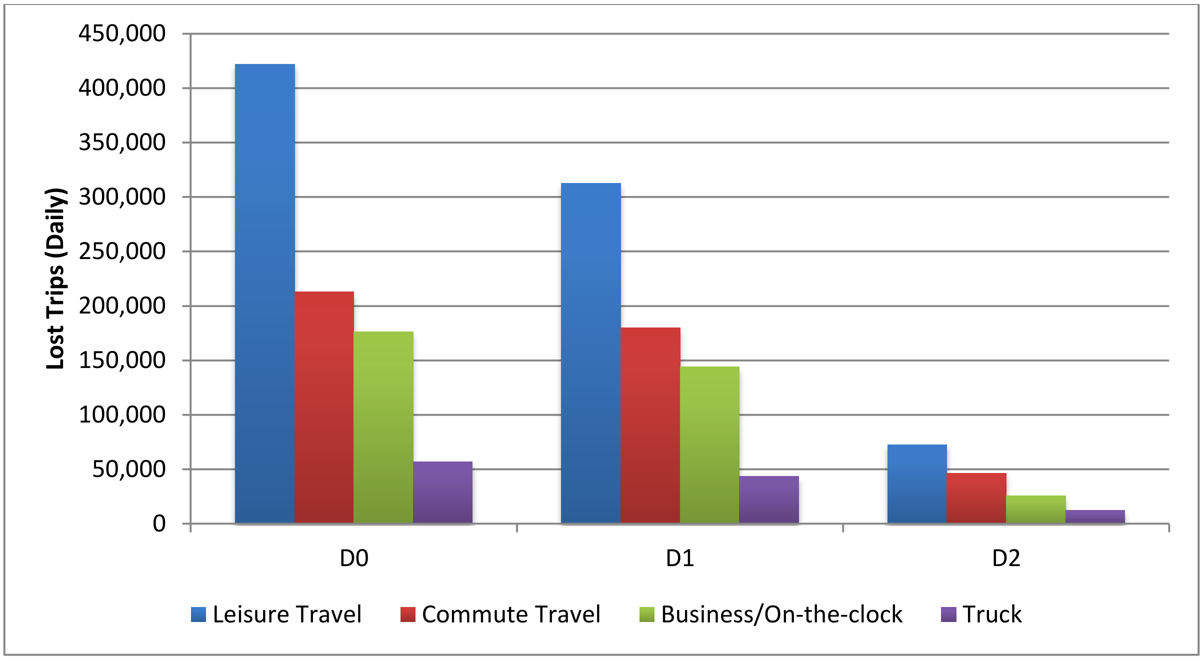

Figure 10. Lost Trips by Scenario (daily)

The results, summarized in **Table 3**, reflect a single "typical" day of disruption (non-holiday Tuesday, Wednesday, and Thursday). These results were scaled to a five-day week for purposes of the subsequent economic analysis. This procedure was also performed for six specific, critical assets as part of the Pilot project (see Pilot Final Report).

Table 3. TBRPM Disrupted Network Results (Full Disruption Scenario - Hillsborough County only)6

Trip Type	Attribute (Units)	Daily Value	Baseline Value	Change
Auto: Leisure Travel	Auto - VMT	27,448,177	27,684,631	-236,454[7]
	Auto - VHT	2,749,985	1,366,328	1,383,657
	Auto - Delay[8]	2,076,683	690,331	1,386,352
	Auto - Lost Trips	422,072	0	422,072
Auto: Commute	Auto - VMT	13,085,057	13,719,037	-633,980
	Auto - VHT	1,276,180	665,812	610,368
	Auto – Delay[3]	955,109	332,212	622,897
	Auto - Lost Trips	212,795	0	212,795
Auto: Business/On-the-clock	Auto - VMT	10,234,952	9,943,371	291,581
	Auto - VHT	1,120,488	524,414	596,074
	Auto - Delay[3]	856,743	267,809	588,934
	Auto - Lost Trips	176,491	0	176,491
Truck	Truck - VMT	3,481,849	3,647,553	-165,704
	Truck - VHT	398,689	175,114	223,575
	Truck - Delay/Idling[3]	319,714	93,344	226,370
	Truck - Lost Trips	57,125	0	57,125

Travel time delay, vehicle miles traveled (VMT), and lost trip outputs from the travel demand model were input into REMI, an econometric modeling tool developed by Regional Economic Models Inc.[9] and parameterized with regionally specific data, to estimate the state and regional economic impacts of storm surge related disruption (only outputs attributed to Hillsborough County were reported).

REMI model outputs are in annual increments. The daily VMT and vehicle hours of delay results were scaled to weeklong periods. REMI captures direct, indirect, and induced impacts of the transportation disruption

[6] All figures reflect the TBRPM 7.0 analysis year of 2035.
[7] Negative VMT would indicate that travel paths are shorter (but likely slower and more congested). All VMT percentage changes derived through the modeling of full disruption are considered negligible.
[8] Delay is measured in hours.
[9] http://www.remi.com/the-remi-model

scenarios and estimates the associated changes in jobs (work hours), income, and gross regional product[10] (GRP). This analysis focuses on changes in business and truck delay, lost trips, and vehicle operating costs (derived through VMT).

Delay

The delay estimates from the travel demand model entered into REMI include business travel and truck travel. Trucking and business delays have direct impacts on production costs (cost of doing business). The value of one-hour of truck delay is counted as the average hourly wage for truck drivers, while business travel is estimated as the average hourly wage rate for the region. These values are consistent with the United States Department of Transportation (USDOT) guidelines for the valuation of travel time.[11] REMI considers these increases in delay as additional production costs. While commuting and leisure delay were captured in the transportation data, travel time increases represent personal opportunity costs and are not considered in REMI since these are not direct out-of-pocket expenditures.

Lost Trips

One of the major impacts of the disruption scenarios is the loss of trips caused by travelers' inability to access the network (either at the point of origin, destination, or both). This analysis accounts for lost commuter and truck trips. For commuter trips, the analysis only accounts for non-salaried workers, which represent six percent of all workers according to the U.S. Bureau of Labor Statistics. The lost commuter trips for non-salary workers were chosen because a missed day at work typically means a direct loss of income. The state minimum wage of $7.93 per hour was the chosen rate representing lost wages and was entered into the REMI model as a reduction in consumer spending.

Lost truck trips can have two impacts on the economy. The first is lost trucking revenues, and the second is the time or inventory cost of those lost trips. This analysis focuses on lost trucking revenues. Truck revenues, or sales, were monetized by applying the average productivity per trucking employee from the REMI forecast to the number of lost trucking trips. The per-hour rate was $61.41. Change in trucking revenues was then modeled as a reduction in trucking sales within the REMI model.

The economic impact of lost business trips was not estimated in this analysis because there is a lack of adequate business data that tracks origin and destinations of business travel and the specific industries impacted. Lost leisure travel trips were also excluded.

Operating Costs

The non-fuel operating costs per mile for autos and trucks were applied to the changes in VMT for each disruption scenario. VMT increases occur when disruptions require more circuitous travel routes. The per-mile operating cost of travel by mode for autos is $0.43 and $0.10 for trucks.[12] Fuel costs were excluded since there was not enough information available to accurately estimate the changes in fuel consumption.

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[10] GRP is the market value of final goods and services produced in Hillsborough County in a year.

[11] USDOT "Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis (Revision 2 – corrected)

[12] Bureau of Transportation Statistics' Research and Innovation Technology Administration (autos) and Owner-Operation Independent Drivers Association (trucks)

The changes in leisure and commuter vehicle operating costs were entered into REMI as changes in consumer spending for vehicles and parts, and offset by the consumer reallocation variable. Business auto and truck travel were counted as changes in spending for vehicles and parts and a change in production costs.

Results

The results in **Table 4** show the estimated losses to the Hillsborough County economy in terms of Gross Regional Product, jobs, and income for the three disruption scenarios over a five-day (business week) period.

Table 4. REMI Summary Results — Hillsborough County Impacts of Network Disruption (Losses)

Disruption Scenarios	GRP ($ millions)	Work Hours	Income[13] ($ millions)
D0 (full disruption)	$109.23	2,098,720	$66.66
D1 (Interstates recovered)	$16.38	361,920	$8.84
D2 (Interstates & arterials recovered)	$3.72	89,440	$2.07

The results constitute a “building block” for each disruption scenario because they can be scaled to estimate ranges of overall loss based on the duration of disruption assumed for each scenario. This building block is also used to calculate the potential losses avoided, should the simulated event occur, by investing in risk management measures.

[13] All values are in millions of 2014 dollars; all values are negative.

2.4 Step Four: Develop Risk Management Investment Scenarios and Costs

In this step, three order-of-magnitude risk management (adaptation) scenarios were developed. The three investment scenarios are Base/Low, Medium, and High levels of investment. Costs (**Tables 5** and **6**) were developed using generic unit costs of selected, representative risk management strategies. FDOT's Generic Cost Per Mile models[14] and unit cost estimates for Hillsborough County (developed by consultant engineers) were used whenever possible, supplemented by manufacturer literature as needed. Basic cost calculations and sources and included in **Appendices B and C**. Unit costs are may fluctuate based on specific site conditions and circumstances, changes in material and labor costs, shifts in regional or national demand, and permitting and other administrative expenses, for example.

Costs

All costs are expressed in current year dollars, and total costs reflect a 20-year planning horizon. The three investment levels reflect the following:

Base/Low – The Base/Low level of investment are current levels of local and state funding spent on stormwater and drainage improvements in Hillsborough County. This includes funding from Hillsborough County; the Cities of Plant City, Tampa, and Temple Terrace; and a portion of FDOT's state highway system operations and maintenance funds spent in Hillsborough County. Current spending is about $31 million annually, including about $10 million/year in stormwater fee revenue collected by Tampa and the County. Over the life of the plan it would cost about $629 million (2014 dollars) to sustain current levels of maintenance[15].

Medium – The Medium level of investment has increased stormwater and drainage funding that include present measures as well as these improvements to low-lying interstates: 1) upgrading single inlets to flanking inlets and higher capacity pipes during routine schedule resurfacing or maintenance, 2) raising the roadway profile of critical Interstates/freeways in vulnerable areas during routine scheduled reconstruction, and 3) installing wave attenuation devices and rip rap (rock/rubble shoreline armoring) to protect facilities near the shoreline from erosion and washouts.

High – The high level of investment are all Medium level investments, plus the full deployment of mitigation strategies applied to arterial roadways as well as the interstates.

Table 5 shows the costs to invest in additional mitigation strategies at the Medium and High levels. The Base/Low level reflects current spending levels as described above. Please see **Appendix C** for more detail.

Appendix D provides a list of potentially vulnerable (low-lying and proximate to the shoreline) roadway segments to which illustrative mitigation strategies were applied (see Table 5).

[14] http://www2.dot.state.fl.us/SpecificationsEstimates/costpermile.aspx
[15] See Appendix B for details and sources.

Table 5. Illustrative Risk Mitigation Investment Costs (2014 dollars)

	Unit	Unit Cost	Base/Low	Medium	High
Raise profile/strengthen base*	Lane mile	$268,883		$20,854,540	$68,807,075
Wave attenuation (WADs)	1 Unit	$750		$3,887,400	$17,628,600
Shoreline protection (riprap)	Linear ft	$350		$5,442,360	$24,680,040
Drainage improvements*	Cent mile	$14,737		$816,566	$816,566
TOTAL				$31,000,866	$111,932,281
TOTAL plus contingency[16]	20%			$37,201,039	$134,318,738
** counts marginal costs only, all costs are approximate*					

Table 6 shows the total costs of each investment level over 20 years in 2014 dollars. The investment levels shown here for the Medium and High investment levels include both current maintenance costs and additional mitigation measures.

Table 6. Total Investment Level Costs (2014 Dollars)

Investment Level	Total Cost of Investment Package Over 20 Years[17]	Marginal Cost of Investment Strategy	Total Cost with 20% Contingency
Base/Low	$629,000,000	-	$754,800,000
Medium	$660,000,000	$31,000,000	$792,000,000
High	$772,000,000	$112,000,000	$926,400,000

A storm Impact Narrative and a Recovery Narrative were developed to illustrate the three different investment scenarios in a storm recovery. The true impacts of a potential storm on the regional transportation system cannot reliably be predicted, and the impact from risk mitigation investments cannot be precisely quantified. However, investing in additional resiliency measures during asset renewal, reconstruction, or replacement will reduce the expected duration of disruption and resulting economic losses.

[16] Contingencies are commonly added to construction cost estimates to help compensate for unforeseen conditions, such as increases in material or labor costs. Contingency costs are provided here only for perspective, and not used in subsequent calculations.

[17] Total cost of the investment package is equivalent to the baseline roadway investment value over 20 years (not time-value adjusted) plus the additional cost of the risk management investment package. Values are rounded.

The narratives represent a "moderate" amount of damage that could result from a Category 3 hurricane and plausible risk reduction benefits from each investment scenario. Avoided losses are considered reduction benefits.

Benefits (Illustrative Impacts, Adaptation, and Recovery Scenarios)

Base Case: Coastal Interstates, particularly bay crossings, suffer washouts at approaches and experience minor structural damage, yielding the equivalent of two-weeks of capacity loss (includes debris removal and inspections). Washouts and erosion on coastal arterials are widespread, a substantial portion of saturated roadway base requires replacement, and some bridges experience severe scouring and approach washouts. This yields the equivalent of four weeks of capacity loss. Local facilities experience similar but more prevalent impacts and are generally designated to be repaired and cleared last, yielding the equivalent of eight weeks of capacity loss.

Medium Investment Scenario (Interstates): Shoreline armoring and wave attenuation minimize approach washouts and erosion on Interstates, although minor repairs and debris removal are required. Elevated coastal roadway profiles, strengthened base, and improved drainage minimize saturation (and associated repairs). Some scouring occurs. Arterials and local roads recover faster because the response effort is more concentrated, as fewer resources are required for Interstate recovery.

High Investment Scenario (Interstates and Arterials): This is the same as Medium, plus mitigation benefits extend to arterial system, and local road recovery is significantly faster because there is a greater concentration of available repair resources and better access to facilities for road crews.

The degree to which the investment is expected to mitigate potential impacts (**Figure 11**) was estimated based on professional judgment and leveraging prevailing risk management plans (e.g., the prevailing Hillsborough County *Post Disaster Redevelopment Plan*[18] and *Economic Analysis of a Hurricane Event in Hillsborough County, FL*[19]) and post-storm damage reports relevant to the region[20].

[18] http://www.hillsboroughcounty.org/index.aspx?NID=1793
[19] http://www.hillsboroughcounty.org/DocumentCenter/Home/View/1027
[20] http://www.dot.state.fl.us/trafficoperations/traf_incident/Hurricane_Response.shtm

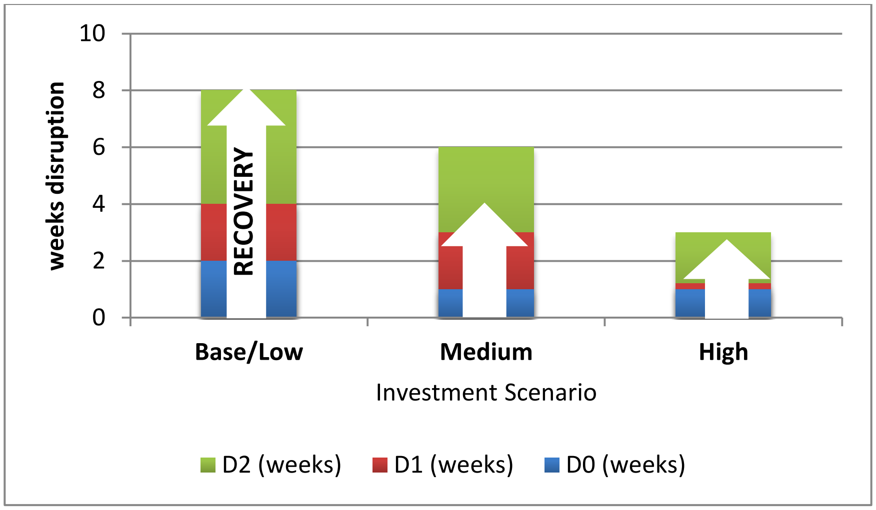

Figure 11. Illustrative Impact/Recovery Timelines, assuming moderate storm impacts

Table 7 provides an estimate of potential disruption durations/recovery times and the associated loss incurred and avoided under the Base/Low, Medium, and High investment scenarios, based on the above narratives.

Table 7. Estimated Avoided Losses (Moderate Impacts Scenario)

Moderate Scenario	Base/Low Investment Level	Medium Investment Level	High Investment Level
D0 (weeks)	2	1	1
D1 (weeks)	4	3	1.2
D2 (weeks)	8	6	3
Economic Loss	**$ 266,094,000**	**$ 153,141,000**	**$ 119,203,200**
Avoided Loss	**$ -**	**$ 112,953,000**	**$ 146,890,800**
Strategy Cost		**$ 31,000,866**	**$ 111,932,281**
Net	**$ -**	**$ 81,952,123**	**$ 34,958,508**

Weeks of disruption are cumulative (e.g., if D2 = 8 weeks, full recovery is achieved after 8 weeks time).

Because recovery is likely to be strategic (focusing on specific critical assets) and variable (dependent on both infrastructure resiliency and the success of county, state, and national post-disaster response agencies), it is recommended that a range of feasible disruption and recovery outputs be considered in future analyses.

Following is a summary of the potential losses and avoided losses (benefits) associated with each illustrative investment scenario:

- Base Case: Assuming no additional risk mitigation investments, an estimated $266 million in direct, transportation-related economic losses occur.

- Medium Investment Scenario (Interstates only): Losses are reduced to an estimated $153 million, avoiding $112 million in losses for a $31 million investment package (not including a construction cost contingency).
- High Investment Scenario (Interstates and arterials): Losses are reduced to an estimated $119 million, avoiding $147 million in losses for a $112 million investment package (again, not including a cost contingency).

3.0 Summary

These results were derived from a sketch-level analysis performed on a regional scale and must be considered illustrative in nature[21]. The general conclusion is that strategic risk management strategies implemented in the course of the normal asset renewal cycle could significantly reduce countywide travel and economic impacts from natural disasters. For example, the Medium package of risk management investments totaling $31 million (before cost contingency, over the next 20 years) would only need to eliminate approximately 1.4 days from the duration of full disruption on Hillsborough County's roadways to achieve rough cost neutrality.

This study's results are, by design, conservative. The estimated economic losses are based directly on one day of countywide travel activity and do not reflect broader or longer-term impacts that include the disruption in supply chains (including fuel), the destruction of buildings and complementary infrastructure (such as power plants and hydrology), business and industry failures, and the potential migration of population and jobs to other regions or states. While the specific Benefit-Cost proposition of these investments would be extremely challenging to derive, the potential value of proactive risk management measures is evident. However, it remains important to ensure that specific strategies are a cost-effective use of scarce resources and are coordinated with investments to address other regional transportation and non-transportation challenges, such as state-of-good repair, congestion relief, and traveler safety.

The next step in this progression will be to identify specific, strategic investments or investment programs for induction into existing project implementation processes and into official disaster risk management documents, such as the Local Mitigation Strategy and Post Disaster Redevelopment Plan.

[21] Results for the critical transportation assets identified in cooperation with the LMS_WG will be available in the Pilot Final Report.

Technical Appendices and Supporting Materials

Appendix A – Storm Surge Simulation

The Tampa Bay Regional Planning Council (TBRPC) created a GIS-based tool to simulate surge on top of sea level rise. SLOSH Depth with Sea Level Rise Tool (**Figure 12**) allows users to input a range of variables, including elevation (via a LIDAR Digital Elevation Model), SLOSH grid, and shoreline vector. First, the tidal level, raster resolution, storm category, and amount of sea level rise are input into the tool. Second, the desired SLOSH grid cells are selected for analysis.

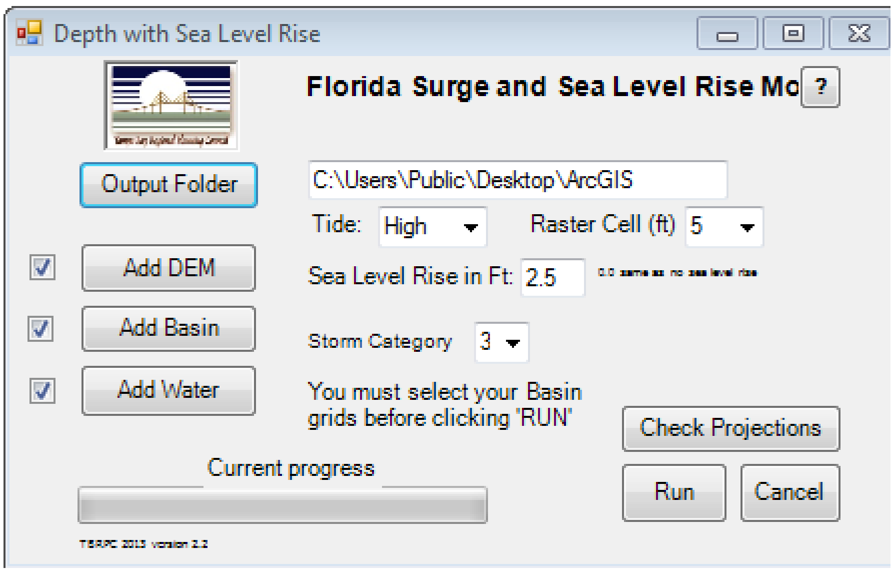

Figure 12. SLOSH Depth with Sea Level Rise Tool, detail

The tool works by converting the grid cell shapes to points and interpolating them with the spline method. Then, surge height is subtracted from the elevation to calculate the area of inundation and to assign each inundated spatial unit with a depth of inundation.

Appendix B - Current Roadway Investment Levels

The following figures were used to determine approximate levels of current spending (the low or baseline investment level) on roadway and stormwater maintenance.

Responsible Agency	Source	Amount in budget ($ millions), annual average, projected cost	Stormwater fee revenue ($millions), annual average	Total capital budget ($ millions)	Percent of total budget
Hillsborough County	Hillsborough County Capital Program FY14- Major and Minor Neighborhood Drainage improvements; CIT, Stormwater Utility Fee[22]	10.2	3.6	159.9	6%
City of Tampa	City of Tampa, FY14-19 CIP - Stormwater improvements[23]	13.5	6.1	87	16%
City of Temple Terrace	Temple Terrace FY14 Annual Budget, Water and Sewer Renewal and Replacement Fund[24]	0.8		7.6	11%
Plant City	Plant City Annual Budget FY13-14 Stormwater Fund and CIP County Line Water Main project[25]	6.9		37	19%
FDOT D7	SHS O&M, less $12M dedicated to resurfacing[26]	9.8		75	13%
TOTAL		**41.15**	**(9.7)**	-	-
	Net Cost to Annual Budgets	**31.45**			

[22] http://www.hillsboroughcounty.org/DocumentCenter/View/10674
[23] http://www.tampagov.net/dept_Mayor/Presentations/files/budget_mayors_presentation_2014.pdf
[24] http://templeterrace.com/ArchiveCenter/ViewFile/Item/979
[25] http://www.plantcitygov.com/DocumentCenter/View/18377
[26] The average percent of total capital budget for the four municipalities is 13%. The same percentage was applied to the FDOT O&M funds.

Appendix C – Costs of Mitigation Strategies (Wave Attenuation)

Roadway centerline miles within 1000' feet of FEMA's VE (high velocity flooding) zone were calculated in GIS. The expected number of 6' x 12' Wave Attenuating Devices (WADs), placed in 2-row close configuration (one unit every 3 linear feet), was calculated, and a cost estimate was generated, assuming $750/unit (a generic industry cost, actual costs may vary). Units of #2 rip rap (for shoreline stabilization) and associated costs ($350/unit) were also calculated. Values for roadways within the VE zone, as well as within 100 and 500 feet, are also shown for perspective.

Roadway Type	Centerline Miles Within VE Zone	Centerline Miles Within 100 ft of VE Zone	Centerline Miles Within 500 ft of VE Zone	Centerline Miles Within 1000 ft of VE Zone
WADs				
Unit	$750			
Interstate	$1,980,000	$2,158,200	$2,560,800	$3,887,400
Arterial	$1,267,200	$8,857,200	$12,421,200	$13,741,200
Rip Rap (#2)				
Linear ft	$350			
Interstate	$2,772,000	$3,021,480	$3,585,120	$5,442,360
Arterial	$1,774,080	$12,400,080	$17,389,680	$19,237,680

Appendix D - Scenarios, Costs, and Impacts on Disruption

Following are summary descriptions of the Impact and Recovery narratives corresponding (generally) to the numerical assumptions of disruption and recovery employed in the analysis (see **Figure 13**, below).

Minor

Impact (No Adaptation)

More consistent with the impacts of a Category 1 or Tropical Storm: A large majority of Interstates suffer negligible structural damage and regain full functionality in 48 hours (after debris removal and inspections). Minimal damage to arterials, but because they are a second tier priority for debris removal and signal/sign repair, restoration of full functionality takes 1 week. Minor damage to local streets, slower drainage, and third tier priority for debris removal delays recovery of lower functional classification roadways to 2 weeks.

Recovery (Adaptation)

Medium and High Investment: Better drainage, stronger roadway base, and wave attenuation result in no discernable structural damage and no extended inundation. Roadways are closed for 24 hours to facilitate post-storm cleanup of debris and inspections.

High: Local roadways recover faster because fewer resources are required for Interstates and arterials (i.e., attention is focused on local streets faster), and because there is minimal disruption in the ability to get road repair crews to their destinations.

Moderate

Impact (No Adaptation)

Coastal Interstates, particularly Bay crossings, suffer washouts at approaches and minor structural damage, yielding a loss of 2 weeks of Interstate functionality (includes debris removal and inspections). Washouts and erosion on coastal arterials are prevalent, a substantial portion of saturated base requires replacement, and some bridges experience severe scouring and approach washouts, yielding the equivalent of 4 weeks of capacity loss. Local facilities experience similar, but more prevalent impacts and are generally designated for repair and clearance last, yielding 8 weeks of capacity loss.

Recovery (Adaptation)

Medium Investment: Shoreline armoring and wave attenuation minimize approach washouts and erosion, although minor repairs and debris removal are required. Elevated coastal roadway profiles, strengthened base, and improved drainage minimize saturation (and associated repairs). Some scouring occurs. Arterials and local roads recover faster because fewer resources are required for Interstate recovery.

High Investment: Same as Medium, but effects extend to arterial system, and local street recovery is significantly faster due to a greater concentration of available repair resources and greater access to facilities by road crews.

Severe

Impact (No Adaptation)

More consistent with a Category 4 (or 5) event: In addition to "Moderate" impacts, Bay crossings are severely damaged, requiring major repairs to decks/structural elements; bridges experience approach washouts and severe scouring, and sections of at-grade Interstate are washed out/eroded/saturated (resulting in 12 weeks of cumulative disruption). Arterials are similarly affected, but even more prevalently, also lose most signals and signs, and are of lower priority for repair (16 weeks). Local roads experience all of these affects, but more prevalently still, and many roadways require complete reconstruction (24 weeks).

Recovery (Adaptation)

Medium/High Investment: Significant damage occurs, particularly affecting bridge decks and structures. Although approach washouts and roadway erosion occur, the magnitude and extent are moderated by countermeasures. Base saturation occurs, but repair needs are minimal due to rapid drainage and strengthened base. Signals/signs still require extensive replacement, debris is extensive. Because the highest priority needs (i.e., Interstates) tax strained resources less, crews are able to reach lower functional class roadways faster, but damage—especially on local streets—is severe and extensive, often requiring reconstruction or full replacement.

Impact Scenarios

Mild	**Investment Levels**		
Scenario	**Base/Low**	**Medium**	**High**
D0 (weeks)	0.4	0.2	0.2
D1 (weeks)	1	1	0.2
D2 (weeks)	2	2	1
Economic Loss	**$ 57,237,600**	**$ 38,665,800**	**$ 24,822,000**
Avoided Loss	**$ -**	**$ 18,571,800**	**$ 32,415,600**
Strategy Cost		**$ 31,000,877**	**$ 111,932,292**
Net	**$ -**	**$ (12,429,077)**	**$ (79,516,692)**
Moderate	**Investment Levels**		
Scenario	**Base/Low**	**Medium**	**High**
D0 (weeks)	2	1	1
D1 (weeks)	4	3	1.2
D2 (weeks)	8	6	3
Economic Loss	**$ 266,094,000**	**$ 153,141,000**	**$ 119,203,200**
Avoided Loss	**$ -**	**$ 112,953,000**	**$ 146,890,800**
Strategy Cost		**$ 31,000,877**	**$ 111,932,292**
Net	**$ -**	**$ 81,952,123**	**$ 34,958,508**
Severe	**Investment Levels**		
Scenario	**Base/Low**	**Medium**	**High**
D0 (weeks)	12	4	4
D1 (weeks)	16	12	6
D2 (weeks)	24	20	16
Economic Loss	**$ 1,406,060,000**	**$ 707,816,000**	**$ 594,690,000**
Avoided Loss	**$ -**	**$ 698,244,000**	**$ 811,370,000**
Strategy Cost		**$ 31,000,877**	**$ 111,932,292**
Net	**$ -**	**$ 667,243,123**	**$ 699,437,708**

Figure 13. Illustrative Impact Scenarios (D0 = Full Disruption; D1 = Interstates recovered; D2 = Interstates and arterials recovered)

Appendix E – Potentially Disrupted Links in Hillsborough County (Simulated Category 3 Storm), Full Impact Scenario

Disrupted Segments (Begin and End Mileposts), Full Impact Scenario (see Figure 9)

BEGIN MILEPOST	END MILEPOST	STREET
0.000	1.092	11TH AVE NW
1.044	1.671	12TH ST NE
0.504	1.004	14TH ST NW
0.000	0.504	14TH ST NW
0.000	6.087	19TH AVE NE
0.000	2.320	19TH AVE NW
0.200	0.551	19TH ST
0.000	0.200	20TH ST
0.180	0.225	20TH ST
0.000	0.180	20TH ST
0.225	0.817	20TH ST
0.000	0.164	21ST ST
0.281	0.356	22ND ST
0.356	0.509	22ND ST
0.000	0.281	22ND ST
0.000	0.257	22ND ST CONNECTOR
0.000	0.240	34TH ST
0.000	0.084	39TH ST
2.003	2.674	50TH ST
1.723	2.473	APOLLO BEACH BLVD
0.000	1.723	APOLLO BEACH BLVD
0.232	0.292	ASHLEY ST
0.000	0.126	ASHLEY ST
0.126	0.232	ASHLEY ST
0.343	0.401	ASHLEY ST
0.292	0.343	ASHLEY ST
0.000	0.625	AZEELE ST
0.251	0.408	BAY TO BAY BLVD
1.530	1.676	BAY TO BAY BLVD
0.000	0.251	BAY TO BAY BLVD
3.980	4.058	BAYSHORE BLVD
1.262	1.819	BAYSHORE BLVD
1.064	1.262	BAYSHORE BLVD
3.857	3.980	BAYSHORE BLVD
2.923	3.857	BAYSHORE BLVD

BEGIN MILEPOST	END MILEPOST	STREET
4.356	4.480	BAYSHORE BLVD
0.000	1.064	BAYSHORE BLVD
4.156	4.356	BAYSHORE BLVD
1.382	2.061	BAYSHORE BLVD
2.463	2.923	BAYSHORE BLVD
1.819	2.463	BAYSHORE BLVD
4.058	4.156	BAYSHORE BLVD
0.000	1.382	BAYSHORE BLVD
0.000	0.394	BENEFICIAL DR
0.000	0.760	BENJAMIN RD
0.000	0.664	BOY SCOUT BLVD
0.420	0.475	BROREIN ST
0.366	0.420	BROREIN ST
0.307	0.366	BROREIN ST
0.249	0.307	BROREIN ST
0.071	0.249	BROREIN ST
0.045	0.167	BROREIN ST
0.000	0.102	CAESAR ST
0.151	0.284	CASS ST
0.000	1.033	CAUSEWAY BLVD
0.000	2.395	CAUSEWAY BLVD
1.002	1.237	CHANNELSIDE DR
0.852	1.002	CHANNELSIDE DR
0.601	0.852	CHANNELSIDE DR
0.411	0.660	CHANNELSIDE DR
0.536	0.601	CHANNELSIDE DR
0.501	0.536	CHANNELSIDE DR
0.293	0.411	CHANNELSIDE DR
0.000	1.171	COCKROACH BAY RD
1.906	1.981	COLUMBUS DR
1.767	1.906	COLUMBUS DR
1.389	1.767	COLUMBUS DR
0.000	1.269	COMMERCE ST
0.457	0.811	COUNTRYWAY BLVD
0.000	0.457	COUNTRYWAY BLVD
0.811	3.031	COUNTRYWAY BLVD
4.973	5.958	COURTNEY CAMPBELL CSWY
4.868	4.973	COURTNEY CAMPBELL CSWY
3.520	4.868	COURTNEY CAMPBELL CSWY
1.714	3.520	COURTNEY CAMPBELL CSWY

BEGIN MILEPOST	END MILEPOST	STREET
5.958	6.036	COURTNEY CAMPBELL CSWY
0.000	1.714	COURTNEY CAMPBELL CSWY
0.042	0.128	CUMBERLAND ST
0.199	0.379	CUMBERLAND ST
0.070	0.676	CYPRESS ST
0.035	0.070	CYPRESS ST
0.000	0.035	CYPRESS ST
3.830	4.082	CYPRESS ST
0.000	1.020	DANA SHORES DR
0.000	0.924	DAVIS BLVD
0.000	0.499	DAVIS BLVD
0.000	0.757	DAVIS BLVD S
0.000	0.887	DAVIS BLVD W
0.887	1.453	DAVIS BLVD W
0.000	1.052	E BAY DR
0.000	0.320	EISENHOWER BLVD N
0.000	0.468	EISENHOWER BLVD N
0.536	1.136	EL PRADO BLVD
2.020	2.196	EL PRADO BLVD
0.000	0.536	EL PRADO BLVD
0.759	0.995	EUCLID AVE
0.533	1.134	EUCLID AVE
0.000	0.533	EUCLID AVE
0.000	0.113	FLORIDA AVE
5.218	5.659	FLORIDA AVE
0.000	0.108	FRANKLIN ST
0.000	0.745	FRONTAGE RD
5.708	6.224	GANDY BLVD
3.086	5.708	GANDY BLVD
0.000	2.713	GANDY BLVD
0.761	1.176	GANDY BLVD
6.224	6.407	GANDY BLVD
0.000	1.299	GEORGE BEAN PKWY
0.000	1.019	GEORGE RD
0.183	0.521	GEORGE RD
0.000	0.183	GEORGE RD
0.000	0.902	GIBSONTON DR
0.000	4.225	GULF CITY RD
0.294	0.379	GUNN ST
0.289	0.517	HANLEY RD

BEGIN MILEPOST	END MILEPOST	STREET
0.061	0.289	HANLEY RD
0.000	0.061	HANLEY RD
0.965	1.058	HANLEY RD
0.000	0.290	HARBOR ISLAND DR
0.000	0.286	HENDERSON BLVD
2.336	3.468	HILLSBOROUGH AVE
1.850	2.336	HILLSBOROUGH AVE
5.654	5.900	HILLSBOROUGH AVE
5.270	5.654	HILLSBOROUGH AVE
6.405	6.795	HILLSBOROUGH AVE
0.844	1.850	HILLSBOROUGH AVE
6.127	6.405	HILLSBOROUGH AVE
0.579	0.844	HILLSBOROUGH AVE
4.851	5.270	HILLSBOROUGH AVE
2.456	2.663	HILLSBOROUGH AVE
3.468	4.851	HILLSBOROUGH AVE
0.000	0.579	HILLSBOROUGH AVE
2.248	2.456	HILLSBOROUGH AVE
0.000	0.582	HOWARD AVE
0.000	0.144	HYDE PARK AVE
0.000	0.200	HYDE PARK BRIDGE
12.580	13.295	I-275
8.369	9.069	I-275
11.238	12.580	I-275
7.647	8.369	I-275
0.000	7.647	I-275
3.403	3.934	I-275
16.428	20.020	I-75
12.123	16.428	I-75
0.000	6.316	I-75
0.207	0.294	ICE PALACE DR
0.169	0.207	ICE PALACE DR
0.054	0.169	ICE PALACE DR
0.000	0.054	ICE PALACE DR
0.669	0.782	INDEPENDENCE PKWY
0.528	0.669	INDEPENDENCE PKWY
0.000	0.528	INDEPENDENCE PKWY
0.000	0.513	INTERBAY BLVD
2.328	2.901	INTERBAY BLVD
0.000	1.044	INTERCHANGE ST / 12TH ST NE

BEGIN MILEPOST	END MILEPOST	STREET
1.008	1.780	JACKSON SPRINGS RD
0.000	1.008	JACKSON SPRINGS RD
3.200	3.249	JACKSON ST
0.459	1.011	KELLY RD
0.000	0.459	KELLY RD
0.090	0.293	KENNEDY BLVD / SR 60
3.113	3.200	KENNEDY BLVD / SR 60
2.994	3.113	KENNEDY BLVD / SR 60
2.536	2.661	KENNEDY BLVD / SR 60
2.410	2.536	KENNEDY BLVD / SR 60
2.347	2.410	KENNEDY BLVD / SR 60
2.179	2.347	KENNEDY BLVD / SR 60
0.000	0.299	KENNEDY BLVD / WEST
0.000	0.536	KENNEDY BLVD / WEST
0.290	0.500	KNIGHTS RUN AVE
0.233	0.493	LAUREL ST
6.864	7.820	LEE ROY SELMON EXPWY
4.685	5.150	LEE ROY SELMON EXPWY
6.222	6.864	LEE ROY SELMON EXPWY
5.801	6.222	LEE ROY SELMON EXPWY
9.253	11.094	LEE ROY SELMON EXPWY
7.994	9.253	LEE ROY SELMON EXPWY
0.000	0.863	LEISEY RD
0.000	5.842	LIGHTFOOT RD
4.231	5.372	LINEBAUGH AVE
1.647	2.308	M L KING BLVD
0.000	1.094	MACDILL AVE
2.027	3.059	MACDILL AVE
0.000	1.275	MADISON AVE
0.000	0.488	MANHATTAN AVE
1.035	1.905	MANHATTAN AVE
1.245	1.813	MANHATTAN AVE
1.050	1.245	MANHATTAN AVE
0.917	1.050	MANHATTAN AVE
1.446	1.571	MARITIME BLVD
1.571	1.617	MARITIME BLVD
0.066	0.206	MAYDELL DR
0.000	0.066	MAYDELL DR
1.346	1.815	MAYDELL DR
0.000	1.395	MCMULLEN LOOP RD

BEGIN MILEPOST	END MILEPOST	STREET
1.977	2.570	MEMORIAL HWY
3.445	3.830	MEMORIAL HWY
3.133	3.445	MEMORIAL HWY
3.067	3.133	MEMORIAL HWY
2.940	3.067	MEMORIAL HWY
3.957	4.330	MEMORIAL HWY
3.830	3.957	MEMORIAL HWY
2.570	2.940	MEMORIAL HWY
0.000	0.101	MERIDIAN ST
0.101	0.486	MERIDIAN ST
0.000	1.403	MILLER MAC RD
0.000	0.383	MONTAGUE ST
0.000	0.123	MORGAN ST
0.369	0.505	N BOULEVARD
0.505	0.753	N BOULEVARD
0.050	0.415	N BOULEVARD
4.596	4.949	NEBRASKA AVE
0.000	0.917	NORTH BOUNDARY
0.250	0.529	O'BRIEN ST
0.000	0.250	O'BRIEN ST
0.914	1.230	OLD MEMORIAL HWY
0.000	0.914	OLD MEMORIAL HWY
0.000	1.846	OLD MEMORIAL HWY
1.230	1.738	OLD MEMORIAL HWY
0.000	0.416	PALM AVE
0.000	1.037	PALM RIVER RD
0.000	0.314	PLANT AVE
0.000	0.055	PLANT BRIDGE
1.362	1.567	PLATT ST
0.000	0.067	PLATT/CHANNELSIDE
0.000	0.070	PLATT/CHANNELSIDE
0.067	0.166	PLATT/CHANNELSIDE
0.000	0.552	RACE TRACK RD
0.000	0.977	RIVERVIEW DR
0.854	1.510	ROME AVE
0.000	0.304	ROME AVE
0.000	0.564	ROME AVE
0.000	0.882	ROWLETT PARK DR
0.340	1.915	SHELDON RD
0.000	0.340	SHELDON RD

BEGIN MILEPOST	END MILEPOST	STREET
1.905	1.977	SHELDON RD
1.846	1.905	SHELDON RD
1.915	2.418	SHELDON RD
3.146	5.090	SHELL POINT RD
0.000	3.146	SHELL POINT RD
1.263	1.768	SLIGH AVE
0.660	1.123	SR 60 / ADAMO DR
1.193	2.094	SR 60 / ADAMO DR
0.764	1.193	SR 60 / ADAMO DR
3.734	4.043	SR 60 / ADAMO DR
0.000	0.764	SR 60 / ADAMO DR
2.094	3.093	SR 60 / ADAMO DR
2.005	2.179	SR 60 / MEMORIAL HWY
0.000	0.811	SR 60 / MEMORIAL HWY
0.811	2.005	SR 60 / MEMORIAL HWY
3.442	3.636	SWANN AVE
0.000	0.671	SWANN AVE
0.000	3.237	SYMMES RD
0.196	0.305	TAMPA ST
0.079	0.196	TAMPA ST
0.000	0.079	TAMPA ST
0.000	0.823	TOWN N COUNTRY BLVD
0.823	1.569	TOWN N COUNTRY BLVD
0.000	0.371	TRASK ST
0.734	0.950	TWIGGS ST
0.041	0.176	TYLER ST
0.000	0.041	TYLER ST
0.000	0.191	TYSON ST
1.106	5.694	US HWY 301
16.288	16.698	US HWY 301
9.197	10.990	US HWY 41
22.032	22.368	US HWY 41
1.819	1.881	US HWY 41
8.135	9.197	US HWY 41
15.534	17.219	US HWY 41
1.521	1.819	US HWY 41
14.271	15.534	US HWY 41
19.266	22.032	US HWY 41
7.613	8.135	US HWY 41
18.233	19.266	US HWY 41

BEGIN MILEPOST	END MILEPOST	STREET
1.374	1.521	US HWY 41
5.770	6.585	US HWY 41
0.000	1.374	US HWY 41
10.990	12.530	US HWY 41
17.642	18.233	US HWY 41
1.881	2.003	US HWY 41
17.219	17.642	US HWY 41
22.368	23.550	US HWY 41
1.362	3.874	VETERANS EXPWY
0.000	0.346	VETERANS EXPWY
0.000	0.400	VETERANS EXPWY
0.000	0.396	VETERANS FRONTAGE N
0.000	0.474	VETERANS FRONTAGE S
0.000	0.442	VETERANS FRONTAGE S
0.000	0.449	WATERS AVE
1.824	2.730	WATERS AVE
0.434	1.185	WEBB RD
0.000	0.434	WEBB RD
0.924	1.901	WESTSHORE BLVD
3.396	3.511	WESTSHORE BLVD
0.000	0.924	WESTSHORE BLVD
1.796	2.126	WESTSHORE BLVD
1.256	1.796	WESTSHORE BLVD
3.208	3.396	WESTSHORE BLVD
3.144	3.208	WESTSHORE BLVD
0.126	0.253	WESTSHORE BLVD
1.060	1.256	WESTSHORE BLVD
0.000	0.126	WESTSHORE BLVD
0.000	1.060	WESTSHORE BLVD
2.686	3.144	WESTSHORE BLVD
2.126	2.686	WESTSHORE BLVD
3.511	3.640	WESTSHORE BLVD
0.036	0.090	WHITING ST
0.000	0.036	WHITING ST

Source: GIS intersection analysis (simulated inundation layer and FDOT roadway layer). Note that Figure 9 depicts inundation intersected with TBRPM v7.0 model segments, but because the resultant attribute file does not include street names the FDOT layer was substituted in order to generate this table. Therefore, minor mismatches are expected.