DRAFT

Basin No. 22

Upper East Coast

08/31/2020

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Executive Summary

Flooding is the most common and costly disaster in the United States. Over 98% of counties in the entire United States have experienced a flood and just one inch of water, causing up to $25,000 in damage (FEMA 2018). Flooding can impact a community's social, cultural, environmental, and economic resources, so making sound, science-based, long-term decisions to improve resiliency are critical to future prosperity and growth. To meet the longer-term goals to protect life and property, in 1990, FEMA created the National Flood Insurance Program's (NFIP) Community Rating System (CRS) program, a voluntary program for recognizing and encouraging community floodplain management activities. Nearly 3.6 million policyholders in 1,444 communities participate in the CRS program, but this is only 5% of the over 22,000 communities participating in the NFIP.

The Florida Department of Emergency Management (FDEM) contracted with FAU to develop data to enable local communities to reduce flood insurance costs through mitigation and resiliency efforts by improving watershed management plans. There are several steps to address the development of watershed plans, including developing a watershed planning template and development of support documents to establish risk associated with community risk within the watershed.

The effort discussed herein focusses on the development procedures for a screening tool to assess risk in Upper East Coast basins, a watershed located in Eastern Florida that combines readily available data on topography, ground, and surface water elevations, tidal information for coastal communities, soils, open space and rainfall to permit an assessment of the risk of inundation of property in the County. Such knowledge permits the development of tools to allow local agencies to develop means to address high-risk properties.

1.0 Introduction

2.0

Upper East Coast basins lie on the Atlantic coast of eastern Florida (showed in Figure 1.1). the Upper East Coast Basin is located on the northern Atlantic coast of Florida. Covering approximately 692 square miles (excluding estuarine areas), it includes the watersheds along the Atlantic Intracoastal Waterway (AICW) from Ponce de Leon Inlet in Volusia County, north through Flagler and St. Johns Counties, to southern Duval County.

Figure-1.1: The Location of the basin

As the watersheds is coastal, so flood risks from king tides, rainfall, wet season thunderstorms, and tropical storm activity are concerns for local officials and the people who live in the watershed. Eastern Palm Beach County is densely populated and heavily urbanized. DEP, the South Florida Water Management District (SFWMD), local governmental, scientific, educational, and citizen organizations are developing strategies for protecting and restoring water quality and quantity of these basins.

2.0 Summary of Watershed

2.1 General Description of Watershed

2.1.1 Climate/Ecology

The climate of these basins is characterized by long, warm, and humid summers and mild winters. The moderating influence of the waters of the Atlantic on maximum temperatures in summer and minimum temperatures in winter is quite strong along the immediate coast but diminishes noticeably a few miles inland. Rainfall also has a much more significant variation in an east-west direction than in a north-south direction. Precipitation occurs during all seasons, but based on mean monthly totals of rainfall, a rainy season of 5 months from June through October brings nearly 65 percent of the annual rainfall.

The moist, unstable air in the survey area results in frequent, short showers. Day-long rains in summer are rare, but they are generally part of a tropical storm when they occur. Winter and spring rains are typically not so intense as the summer thundershowers. Cold continental air must travel over water or flow down the Florida Peninsula to ' reach Palm Beach County area.

2.1.2 Topography and Soils

The basin is situation between the coastal ridge in the eastern part of Florida where the Florida East Coast railroad was built in 1890, which has the elevation ranging from 25 to 50 feet, and the ocean. It contains the Intracoastal waters, which in this basin is the Indian River lagoon. Soils on the coastal ridge are deep, well drained soils. Immediately west of the coastal ridge, the grounds are nearly level or gently sloping, poorly drained, sandy throughout, and not subject to frequent flooding. Soils on the coastal ridge are deep, excessively drained soils. Immediately west of the coastal ridge, the grounds are nearly level or gently sloping, poorly drained, sandy throughout, and not subject to frequent flooding.

The geologic formations underlying the soil profile may be described as two aquifers separated by an impermeable confining zone. The upper, surficial aquifer consists of permeable sands, sandstones, limestones, and shelly coquinoidal limestones of the Fort Thompson and Caloosahatchee Formations. Collectively, these formations are referred to as the Surficial Aquifer

System, which is the principal producing aquifer for the local area. These formations' thickness increases from west to east and is estimated to be 150 feet thick in the site vicinity.

Underlying the surficial aquifer are the lower permeable phosphatic siliciclastic of the Tamiami Formation and upper members of the Hawthorn Group. These sediments are approximately 800 feet thick beneath the subject site and form the confining zone between the surficial aquifer and the lower, artesian Floridan Aquifer. The top of the Floridan Aquifer comprises cavernous and highly permeable limestones of the Suwannee Limestone, the Ocala Limestone, and the Avon Park Formation.

2.1.3 Boundaries/Surface Waters

The critical elements of the Upper east coast basins are Matanzas River, Moultrie Creek, San Julian Creek, St. Augustine Inlet, Matanzas Inlet, Ponce de Leon Inlet, Intracoastal Waterway, Guana River, Stokes Creek , Casa Cola Creek, Sombrero Creek, Pancho Creek, Robinson Creek, Spruce Creek, Tolomato River, Lower Deep Creek, St. Marks Pond Estuary, Tomoka River, Reed Canal, Halifax River, Halifax Canal, Murray Creek, Callalisa, Tiger Creek, Tiger Bay, Smith Creek, St. Joe Canal, Fox Cut, Hulett Branch, Cracker Branch, Pringle Branch, Styles Creek, San Sebastian River, Salt Run, Bennett Swamp, Graham Swamp, and Pellicer Creek.

2.1.4 Hydrogeological Considerations

These formations are referred to as the Surficial Aquifer System, the principal producing aquifer for the local area. At the subject site, the Floridan Aquifer is estimated to be 950 feet deep and 3,000 feet thick. The groundwater flow direction in the surficial aquifer is generally a subdued reflection of the topography and is influenced by variations in soil permeability and nearby water bodies such as ponds, drainage ditches, canals, etc. Under natural conditions, the water table is within 10 inches of the surface for 2 to 4 months in most years and within 10 to 30 inches for most of the remaining year, except during dry periods. Water covers depressions for more than six months each year.

2.1.5 Special Features

The Indian river lagoon basin is an important economic and biological resource within Florida. More than 50 percent of the Florida east coast fish catch and historically 90 percent of Florida's clam harvest came from the basin. The basin is also an important producer of Florida's Indian River citrus. Biological diversity is high, with more than 4,000 animal and plant species recorded, including 36 rare and endangered animal species. The Upper east coast basin encompasses coastal lowlands and marshes interspersed with numerous creeks and small rivers draining east to form a series of shallow bays and lagoons

2.2 Socio-economic Conditions of the Watershed

2.2.1 Demographics

As of the 2015 Census, these basins had 547,337 people, 222,265 households, and 138,332 families. The average household size was 2.4, and the average family size was 3.1. The median age was 48.6 years.

The racial makeup of these basins was 76.5% White, 7.1% Hispanic or Latino of any race, 10.6% Black or African American, 2.6% Asian, 1.9% from two or more races, and 1.3% from some other race.

As of the 2015 Census, the median income for a household in the county was $54786, and the median income for a family was $67573. In these basins, 12.8% of the population were below the poverty line.

2.2.2 Property

The community is primarily residential with small concentrations of commercial activities along the beach, and the larger cities. According to 2015 Census, the total number of housing unit is 276999 among them 54743 units are vacant.

2.2.3 Economic Activity/Industry

Despite the human-induced impacts on natural areas, the physical changes to the ecosystem created tremendous opportunities for population and economic growth, luring year-round and seasonal residents and agricultural and business interests.

Space exploration and the military have a prominent presence. Kennedy Space Center is located on North Merritt Island. The vast tracts of land needed for security and spaceport facilities resulted in the acquisition of 140,000 acres of beaches, dunes, Flatwoods, wetlands, and marshes for the Merritt Island National Wildlife Refuge. The military maintains bases at Patrick Air Force Base and Cape Canaveral Air Force Base. Much of the industry in the Brevard County portion of the basin provides support for space exploration and military operations.

The principal land use in the Upper east coast basin is silviculture, with urban areas found primarily along the coast. Urban development is expected to continue expanding westward from the coast. Sizable areas designated for silviculture, agriculture, and conservation remain in each of the three counties but may be under development pressure. The basin's natural hydrology has been significantly altered by a combination of water control structures, dikes, drainage ditches, and canals.

2.3 Watershed Funding

DEP, the South Florida Water Management District (SFWMD), local governmental, scientific, educational, and citizen organizations are working to develop strategies for protecting and restoring water quality and quantity in these basins. DEP is running different projects to control the concentration of the dissolved oxygen and nutrient concentration in the water of these basins. As both basins lie under the jurisdiction of SFWMD, they are working on different strategies to protect and restore these basins.

3.0 Watershed Analysis

3.1 Data Sets

3.1.1 Topography

Figure 3.1 shows the ground elevation obtained from the USGS. The resolution of the DEM is 3-meter tiles with +/- 4inches of accuracy. The highest points are approximately 71 ft above sea level. The areas in south, southeast, and east of the basins are lower than the northern regions. The coastal regions of the eastern part depict the elevation below 3 ft above the sea level.

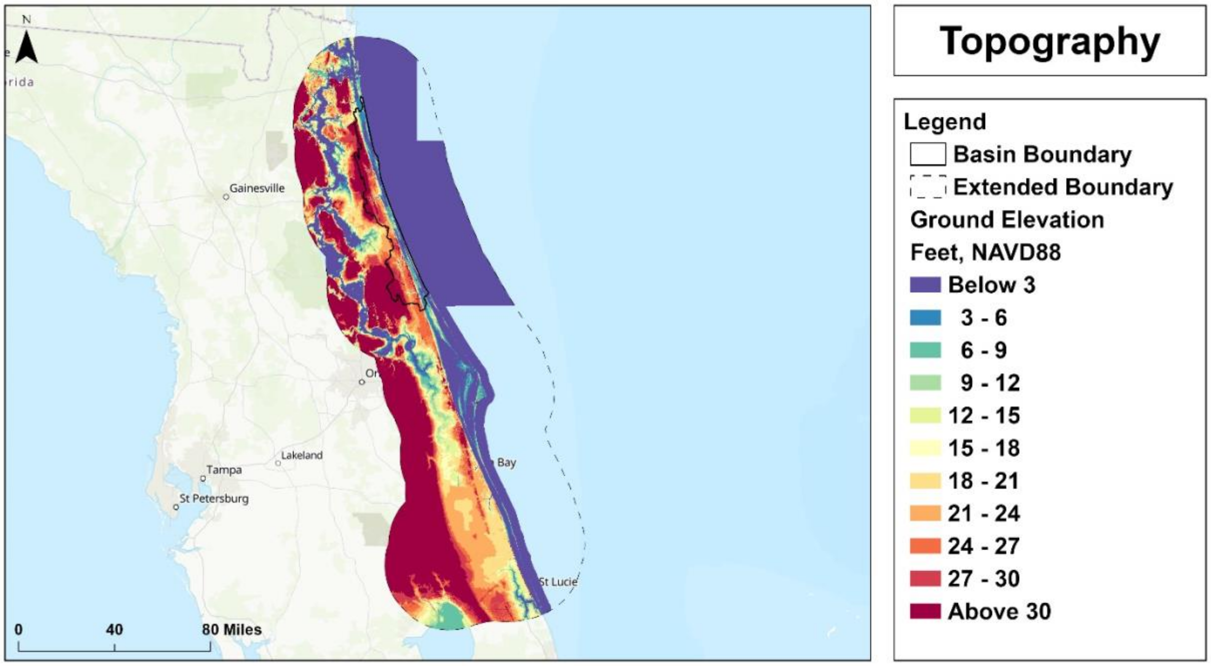


Figure 3.1: Topography of the study area

3.1.2 Groundwater and Surface Water

For the development of the water table surface, three types of water level data were taken, groundwater, surface water, and tidal. Firstly a 25-mile buffer was created as an extended boundary around the study area. A date was then selected based on the maximum number of active groundwater well stations and minimal influence of storm events on the study area. After choosing the date, the data of the groundwater wells and surface water stations were acquired from the South Florida Water Management District (SFWMD) and St. Johns Water Management District (SJWMD). For Tidal, a line of points with approximately 200ft intervals was generated on the coastal boundary inside the extended boundary of the study area. The tidal water level data were collected from NOAA tidal gage station, which was 8721604 Trident Pier, Port Canaveral, Fl station for the study area. The location of the groundwater wells, surface water gage stations, and digitized tidal points are shown in Figure 3.2.

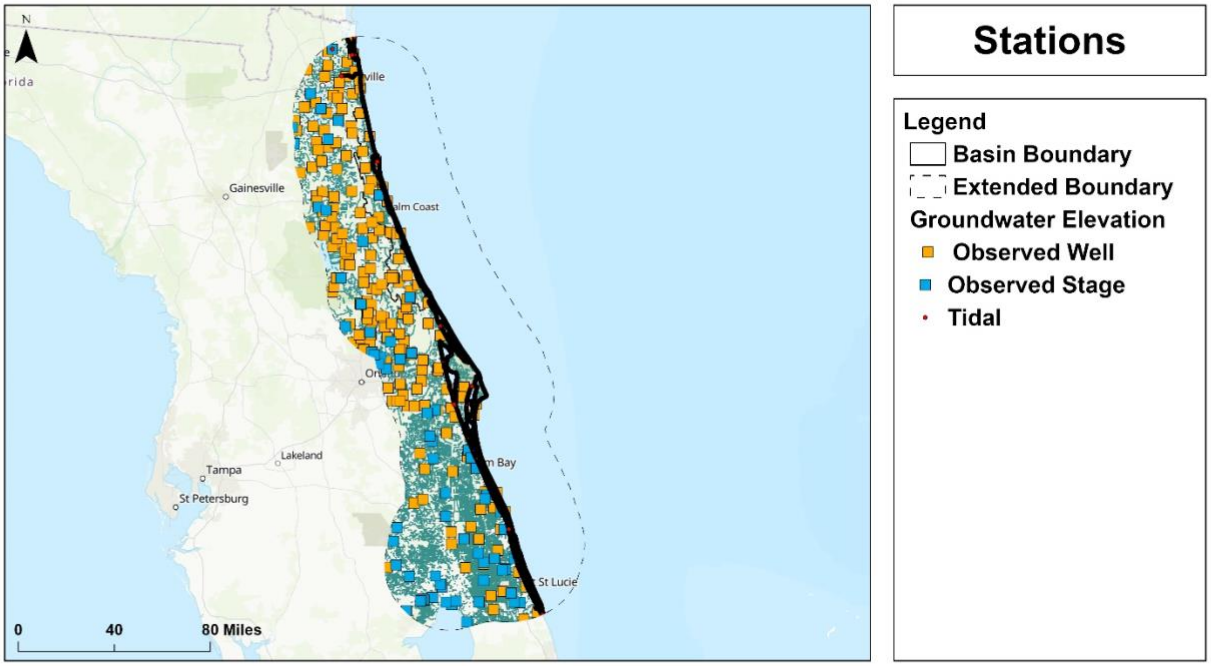


Figure 3.2: Ground water, Surface water and tidal stations

3.1.3 Open Space

The impervious mask shown in Figure 3.3 displays the artificial coverings on the ground elevation where water cannot penetrate through the ground surface. Most of the impervious layer includes roads, parking areas and major urban areas.

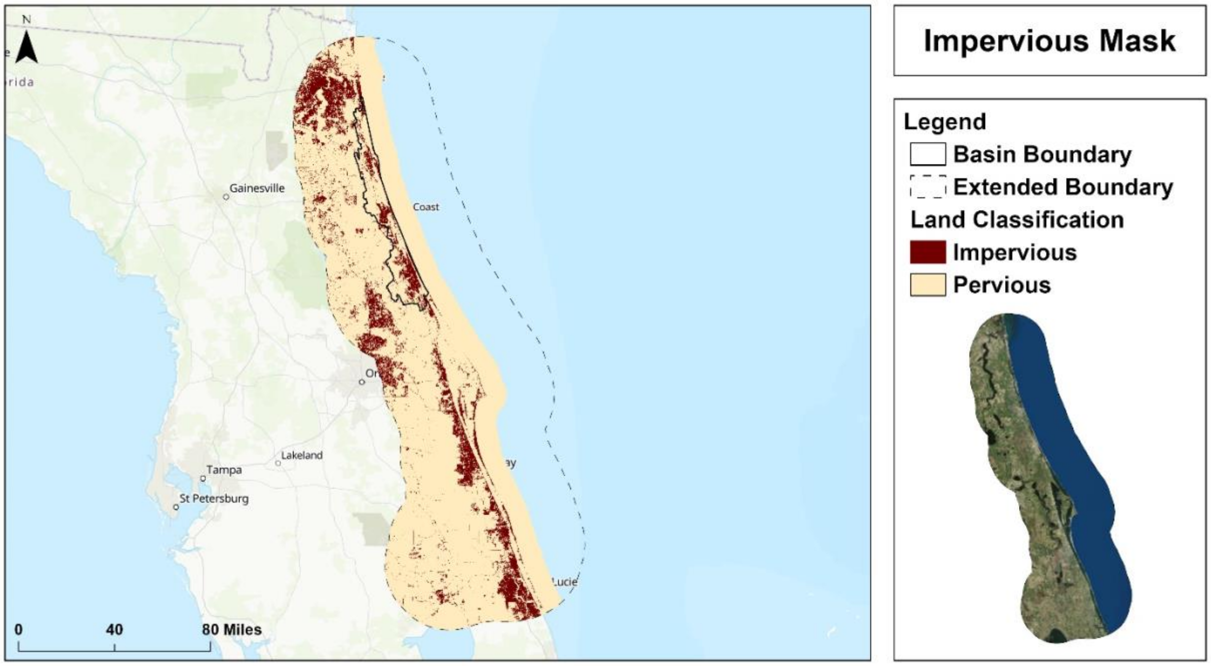


Figure 3.3: Impervious mask of the study area.

The water mask shown in Figure 3.4 displays excess water regions such as river, lakes, canals etc.

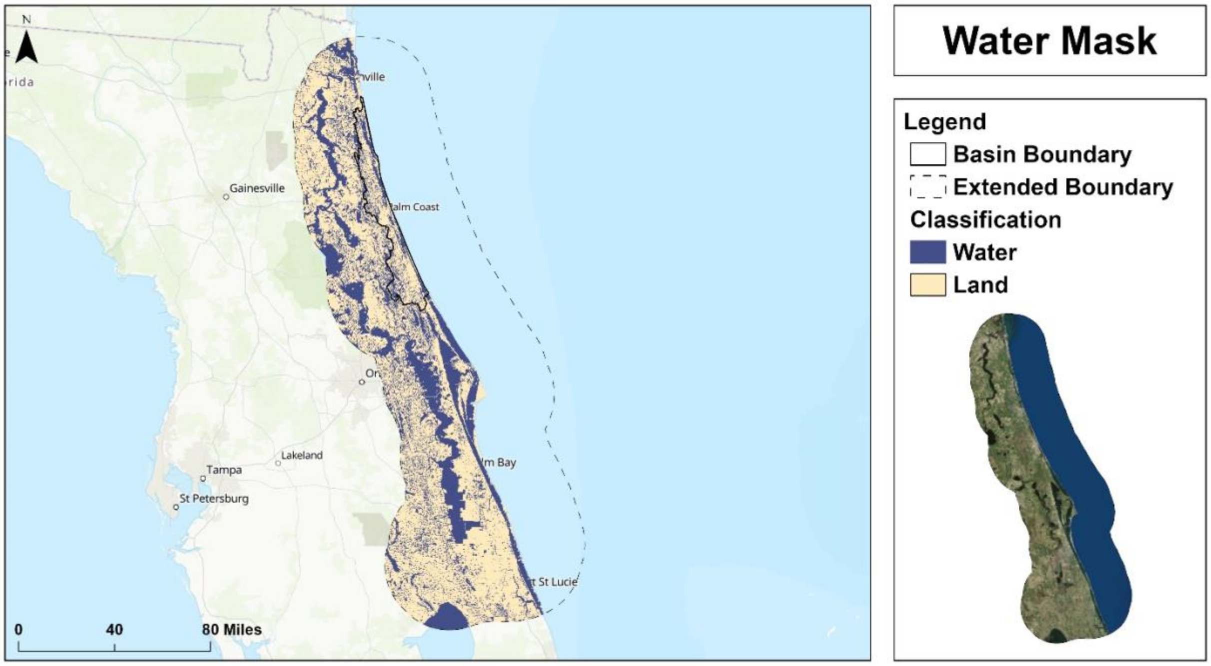


Figure 3.4: Water mask of the study area.

3.1.4 Soil Capacity

The soil capacity map in Figure 3.5 shows the water holding capacity ratio ranging from 0 to 1. Most of the areas water holding capacity lies between 0.15 to 0.2 which lies in the middle region of the study area.

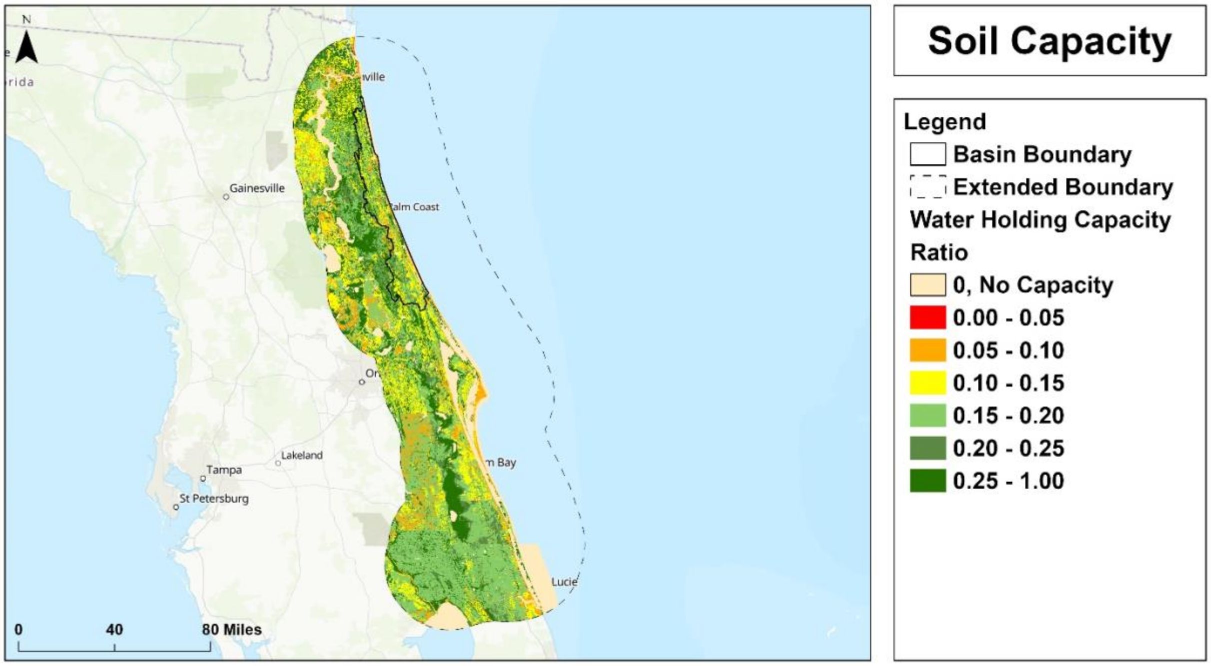


Figure 3.5: Soil capacity map of the study area.

3.1.5 Rainfall

Figure 3.6 shows the precipitation intensity of the study area. For this study, 25 years 3 days rainfall was collected from NOAA. The average rainfall for the basin was 11.54 inches.

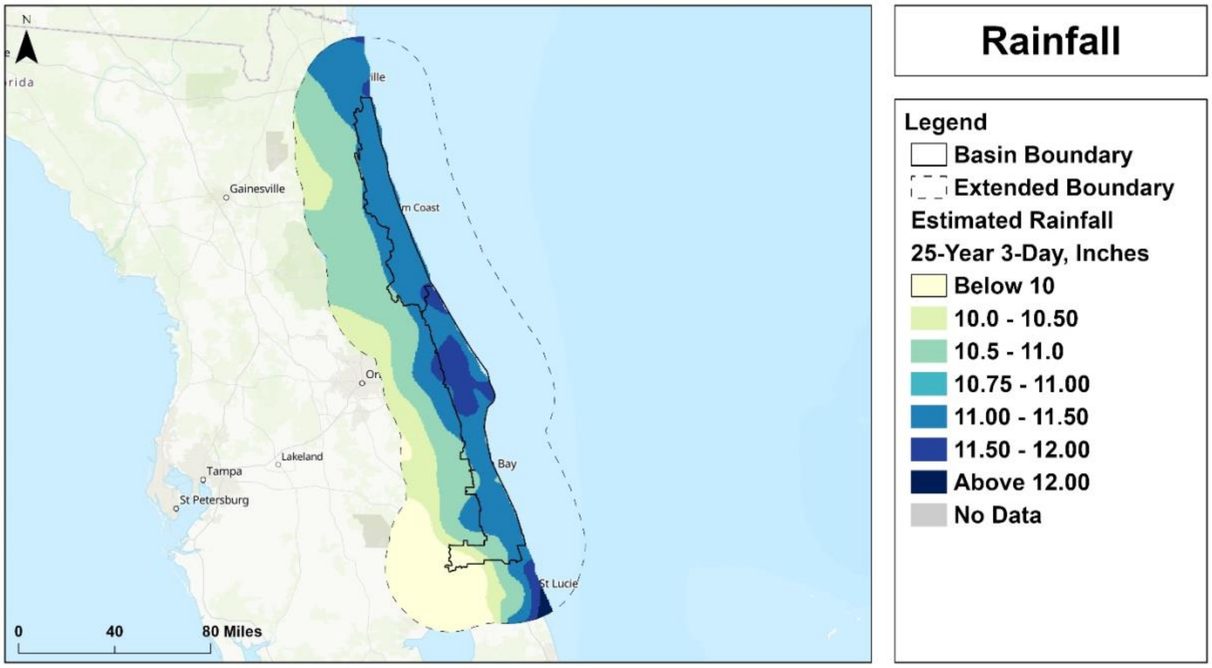


Figure 3.6: Rainfall of the study area.

3.2 Modeling Protocol

There are many contributing factors to flooding in the Upper East Coast Watershed, including the low land elevations, high groundwater table, and low soil storage capacity. To accurately identify land areas within the watershed that are vulnerable to flooding, all these factors were included in the flood risk model. The previously discussed datasets were used to calculate input parameters needed to run a flood simulation model called CASCADE 2001, which was developed by the South Florida Water Management District. The advantage of this model is that it incorporates several characteristics unique to each watershed, including the topography, groundwater, surface water, tides, soil type, land cover, and rainfall. By following FAU's modeling protocol for the Upper East Coast Watershed, all the necessary input parameters to run CASCADE 2001 were either directly calculated or derived from existing datasets. Several surfaces were derived from the data and used to determine characteristics of the watershed, which represent the primary contributing factors to flooding. While a contributing factor such as the land elevation in the watershed can be directly observed using data collection methods such as LiDAR, other factors require further data processing and modeling.

For example, determining water table elevations throughout the watershed requires spatial interpolation and extrapolation methods as well as modeling. Since the high groundwater table greatly contributes to flooding in the region, it is necessary to expend the additional effort to incorporate this factor into the model. Observed water levels are only available at single locations, groundwater wells and surface water stations. This requires several steps to complete.

First, in an intermediate step, a spatial interpolation method called Empirical Bayesian Kriging was used to estimate the water levels between surface water stations. The resulting elevation prediction surface is referred to as the local minimum water table (MINWTE) in literature. Only surface water elevations were used in this interpolation; consequently, the result underestimates the true water table elevation in areas where there are no surface water features and must be adjusted to compensate for higher groundwater elevations. Second, the depths from the land elevations to the local minimum water table elevations were calculated. The two surfaces, MINWTE and depth-to-MINWTE, represent independent variables, or predictors, in the multiple linear regression model. The dependent variable, which is predicted, is the true water table elevation representing both groundwater and surface water. At each of the groundwater wells, the observed water table elevation, predicted MINWTE elevation, and depth-to-MINWTE were determined and used in the multiple linear regression model. Minitab Statistical Software was used to calculate the final regression equation of $WTE = (0.9748 \times MINWTE) + (0.0363 \times \text{Depth to MINWTE}) + 1.8391$. Then, this resulting equation was applied to the entire study area to predict the true water table elevation at every location within its boundaries.

In this region of Florida, groundwater and surface water are closely related and influence one another. Their close interaction is attributed to the high groundwater table and low land elevations. For this reason, both ground and surface water were incorporated into the calculation of the water table elevation by using the multiple linear regression model. This is attributed to the fact that groundwater typically follows topography and the water table is shallow in this region of Florida.

The Modelling of the basins was done using ArcGIS and Cascade software. For modeling purpose, Indian River Lagoon and Upper East Coast basins were combined to acquire more significant outcome. Firstly, The DEM of 3m resolution was collected in small pieces and then merged into a single layer using the Mosaic to new raster tool, a part of the Data management tool.

For the water level data, the readily available ground and surface water level data were collected for October 29, 2017. The location and gage height of the groundwater wells and surface water stations were collected from SFWMD and USGS. In SFWMD, the elevation data was in NGVD 29 datum. To convert these data into NAVD88 datum VERTCON tool from NOAA was used. The tidal water level data were collected from NOAA tidal gage station, which 8721604 Trident Pier, Port Canaveral, Fl station for the study area. Using the ground and surface water and tidal data, the water table elevation surface was calculated through spatial interpolation. This kriging tool was used to get the best result, which is shown in figure 3.6.

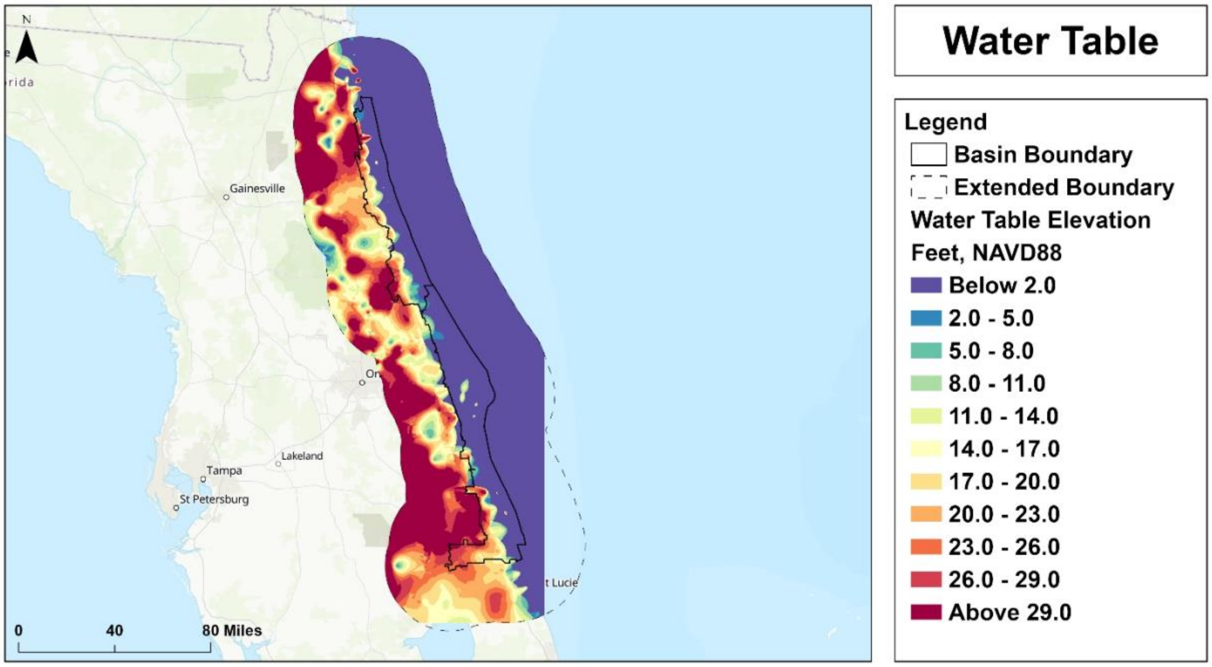


Figure 3.7: Water table Elevation

After this the unsaturated zone (Figure 3.7) was calculated by subtracting the ground elevation with the water elevation. For this the Map algebra tool was used.

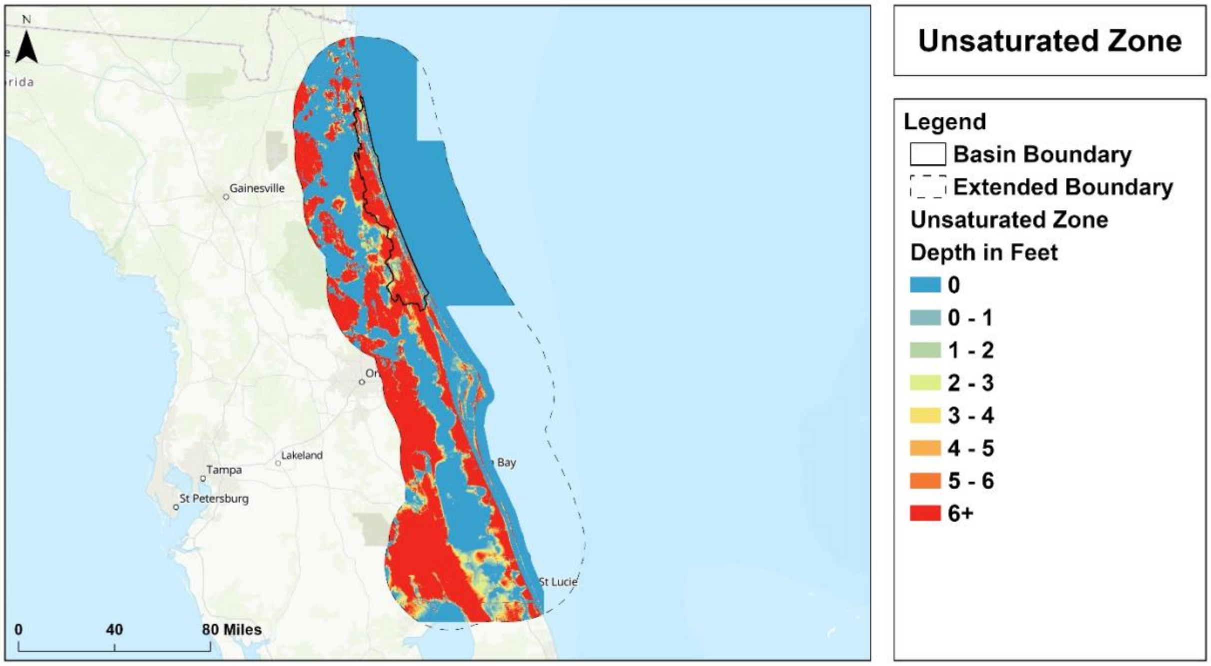


Figure 3.8: Unsaturated Zone

The unsaturated zone shows the depth of soil which is not fully saturated. The result shows that the eastern coastal region is highly unsaturated. Again, using map algebra, the soil storage capacity was calculated using impervious mask, water holding capacity, water mask and unsaturated zone (see Figure 3.8).

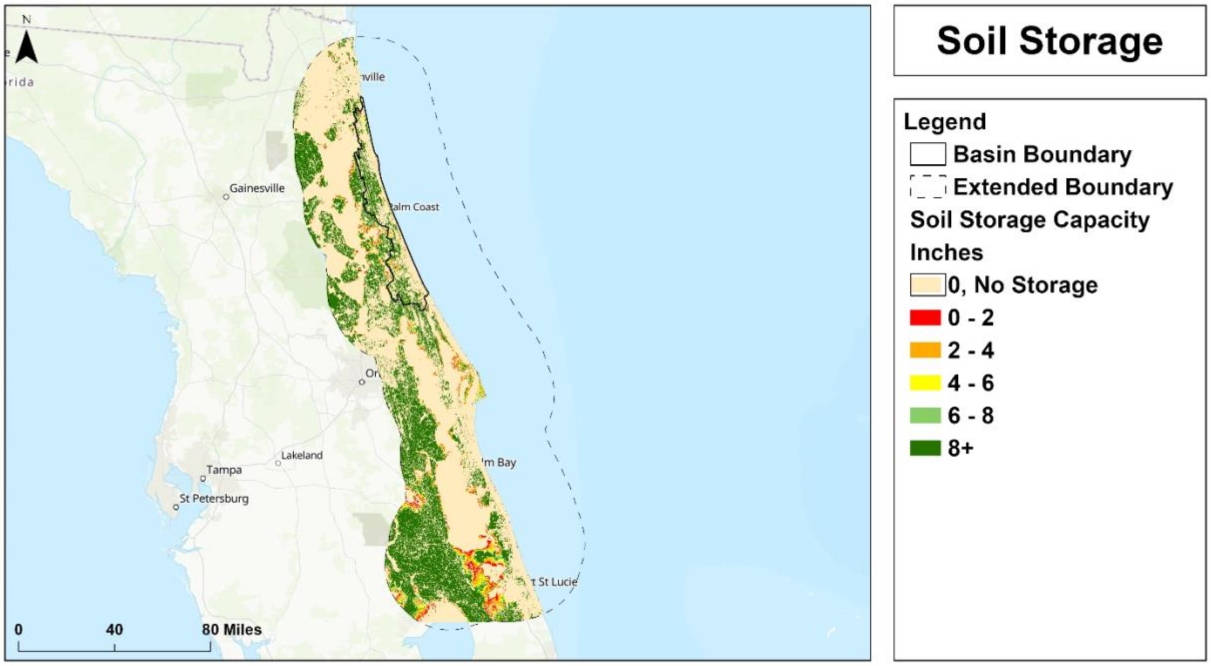


Figure 3.9: Soil Storage Capacity

After this, the ArcHydro tools were used to generate the drainage line and drainage points for the basin. This was done to determine the flow direction and the longest drainage path exiting the basin. The results from the soil storage capacity and drainage network acted as an input for the Cascade.

Cascade is being run using a general dimensionless unit hydrology method for a 3-day 25-year rainfall event. The time of concentration, area in acres, topography, soil storage, and precipitation of each basin is used as an input for Cascade. Running Cascade will give values for the high headwater height for each sub-basin. Given the headwater height, the Z-score can be predicted using Equation 3 in the Raster Calculator

$$Z\ score = \frac{(Head\ water\ height-DEM)}{0.46} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

3.3 Modeling Results

3.3.1 Watershed pathways

The delineation of the catchments and drainage network was completed using the GIS-based Arc Hydro Tools. The resulting flow paths provided insight into the movement of water throughout the watershed and were used to calculate the time required for runoff to reach the point of discharge from the most distant point in the watershed, a required input for CASCADE 2001. First, the length of the longest drainage flow path was calculated in a GIS. Then, by using an assumed drainage velocity of two feet per second, the total time that the Caloosahatchee Watershed will be concentrated during a rainfall event was calculated. From the result of ArcHydro tools (shown in Figure 3.9), most of the drainage lines are exiting in the ocean. From this, the longest flow path was found which was used to estimate the time of concentration.

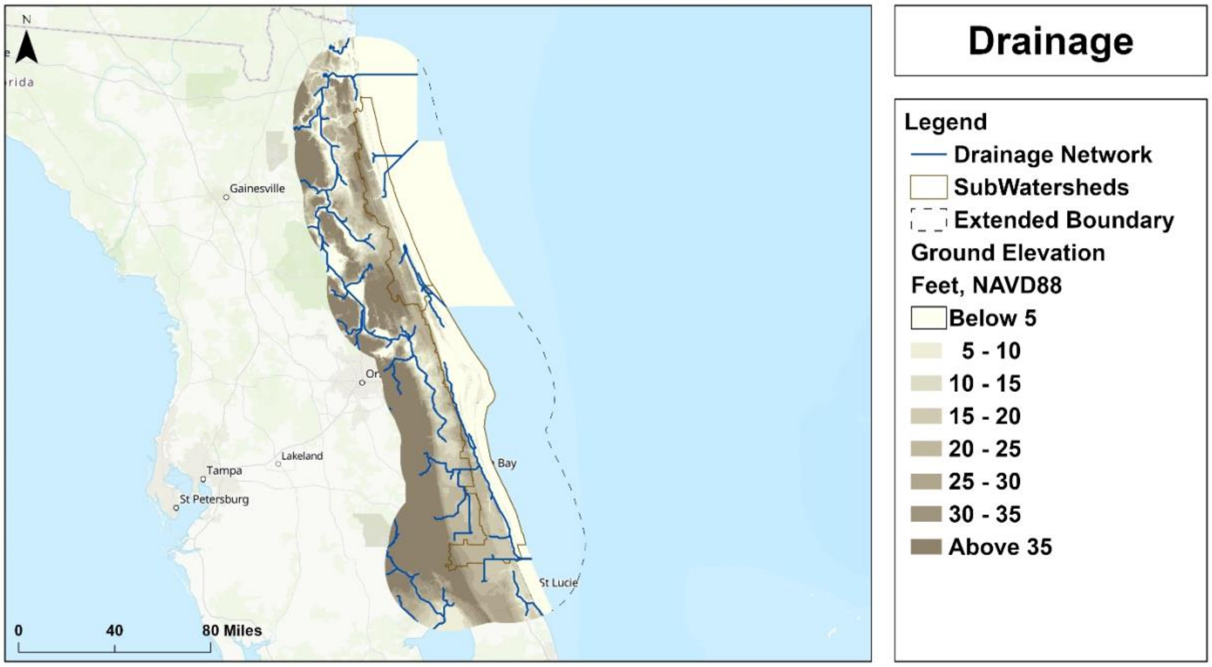


Figure 3.10: Drainage Network

3.3.2 Cascade Results

The input parameters represent factors that influence flooding; for example, the topography, groundwater table elevation, and soil storage capacity. The original datasets and derived surfaces are GIS-compatible, so direct measurements and zonal average statistics were used to calculate the input parameters for each subwatershed. The drainage structures' information was obtained from the U.S. Army Corps of Engineers, the organization operating and maintaining these structures (USACE, 1993). For a 3-day 25-year rainfall event, Cascade gives an output of the expected high headwater height of each of the two basins. The results for the basin as shown in Table 1.

Table 3.1: Inputs and Results of Cascade

	Upper east coast	
Ground Elevation (feet)	High	71.39
	Low	0
Ground Storage (inches)	29.43	
Area (Acres)	3435750	
Time of Concentration (hour)	22.79	
Maximum Head Water Height (feet)	2.55	

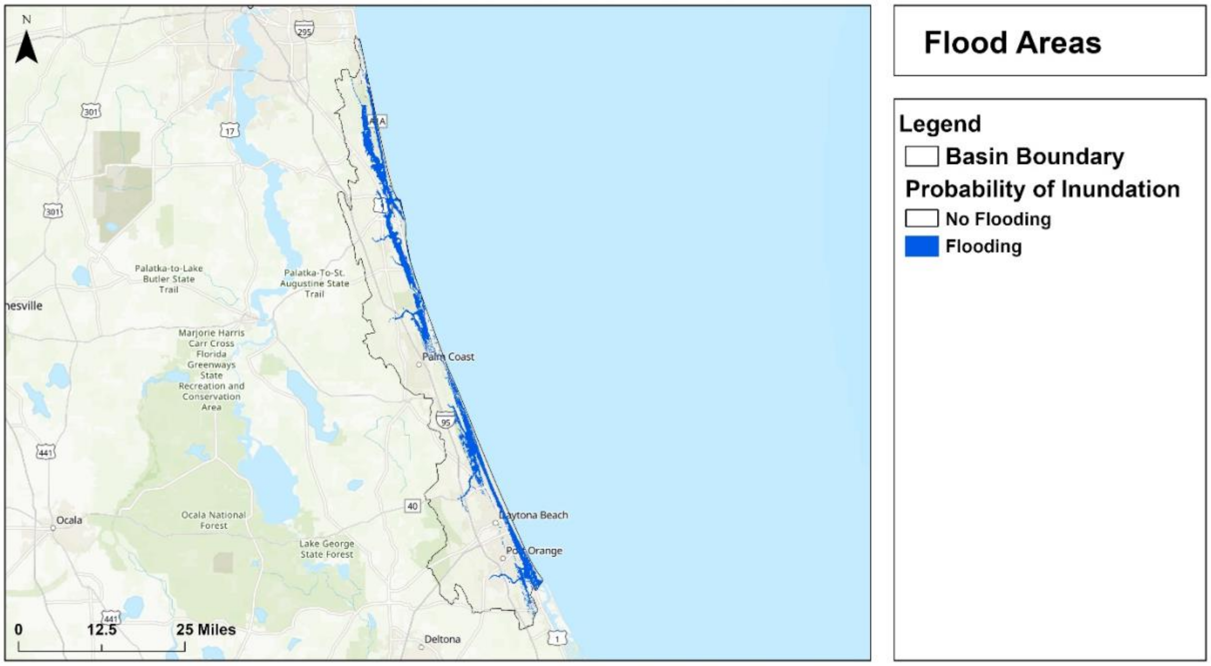


Figure 3.11: Flood inundation map

3.3.3 Vulnerability to Flooding

After identifying areas within the watershed that are prone to flooding, it is important to classify the risk associated with those flooded areas. The results of the CASCADE 2001 simulation provide insight into the Indian River Lagoon Watershed’s flood response to a 3-day 25-year storm. However, by further classifying flood risk as the probability of inundation, it is possible to improve the identification of critical target areas within the watershed. These areas are particularly vulnerable to flooding and are subject to further study. The probability of inundation surface was created by calculating Z-scores to describe the maximum headwater height's relationship to the ground elevations from the LiDAR DEM throughout the Indian River Lagoon Watershed. Specifically, the ground elevation values were subtracted from the maximum headwater height value and then divided by 0.46, a value based on the combined effect of the Root Mean Square Error (RMSE) in the LiDAR DEM data and CASCADE 2001 model.

Figure 3.11 shows the results obtained from using ArcMap and Cascade to predict the likelihood of flooding in the study areas during a 3-day 25-year event. The likelihood of flooding is obtained by using Z-scores to represent confidence levels. Common confidence levels used were z-scores of less than 0 are under 50% likelihood, Z-scores between 0 to 0.675 are 50% - 75% likelihood, Z-scores between 0.675 to 1.282 are 75% - 90% likelihood and Z-scores above 1.282 are over 90% likelihood. The areas around the coast of the basin all have the highest likelihood of flooding. Figure 3.12 and 3.13 show binary flooding map which only focuses the flooding area. The areas having Z score less than 0 is considered as No flooding area and greater than 0 areas are considered as flooding areas.

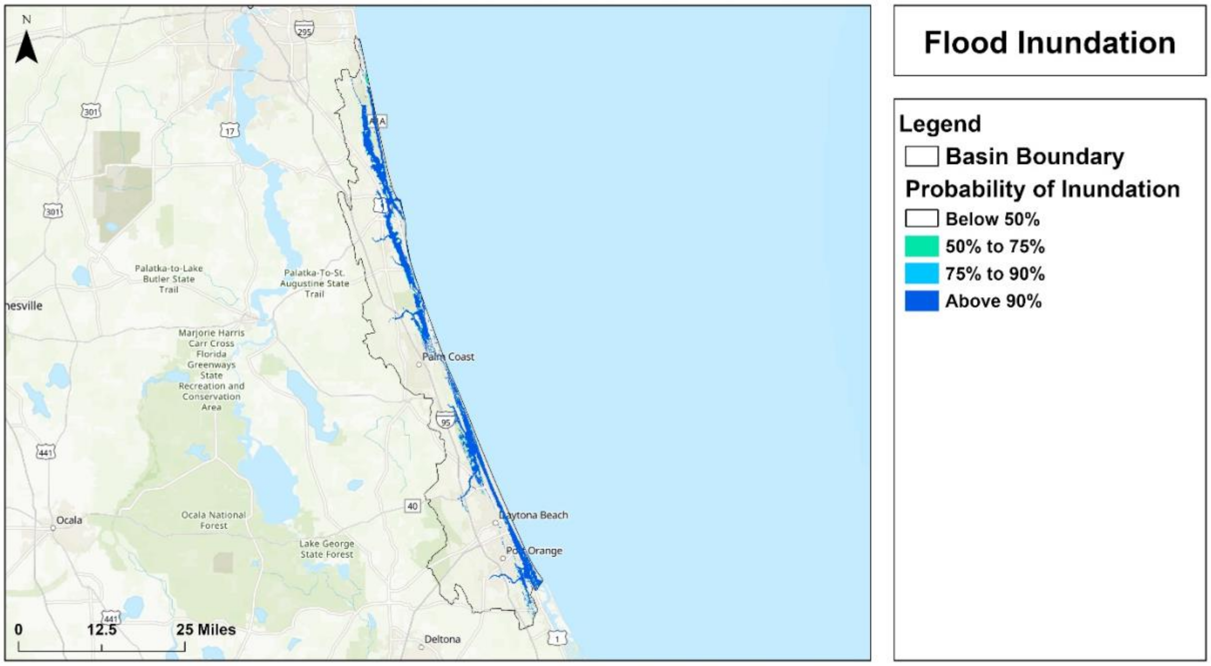


Figure 3.12: Flooding area map

3.3.4 *FEMA Flood map comparison*

The 3-day 25-year design storm was selected by FAU to model the watershed's flood response and generate flood risk maps. The existing Flood Insurance Rate Maps (FIRMs) released by FEMA focus on identifying Special Flood Hazard Areas (SFHAs) and classifying the flood risk associated with SFHAs. However, FEMA utilizes the 100-year flood event where there is a 1% annual chance of flooding and the 500-year flood event where there is a 0.2% annual chance of flooding to generate FIRMs. Despite using different flooding scenarios, it is still useful to make the comparison between FAU's recently developed flood risk maps and FEMA's existing FIRMs. Both maps identify vulnerable areas and classify the risk associated with areas that are prone to flooding.

FEMA publishes Flood Insurance Rate Maps (FIRMs) that show the flood risk within a given area. Areas of high risk are Special Flood Hazard Areas (SFHA). These regions can be identified by the type of flood zone starting with the "A" or "V". The high-risk areas tend to have a 1% annual chance of flooding and a 26% chance of flooding over a 30-year mortgage. Areas of moderate to low risk are identified by “B”, “C”, or “X.” These regions tend to have a 0.2% chance of annual flooding.

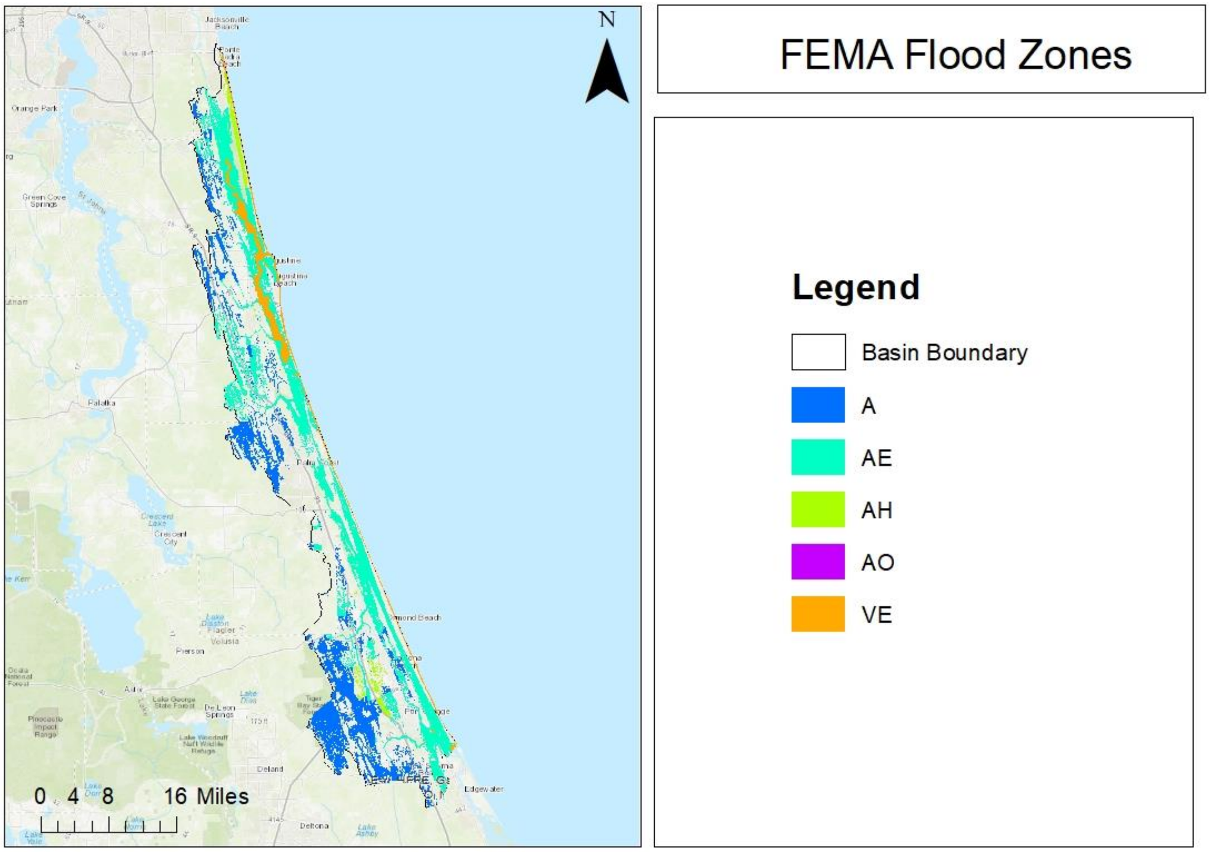


Figure 3.13: FEMA Flood Maps

Despite using different flooding scenarios, it is still useful to make the comparison between FAU’s recently developed flood risk maps and FEMA’s existing FIRMs. Both maps identify vulnerable areas and classify the risk associated with areas that are prone to flooding. The Special Flood Hazard Areas designated by FEMA in the Indian river Lagoon Watershed are shown on the map in Figure 3-14. The areas classified by FAU as having above 90% flood inundation probability correspond to a high risk of flooding during the 3-day 25-year storm event. The areas identified by FEMA as being in the 1-percent-annual-chance flood hazard region correspond to a high risk of flooding during the 100-year flood event. A comparison of these two flood risk maps is provided in Table 3-2 to quantify the percentage of similarity.

Table 3.2: FEMA map comparisons

Description of Calculation	Result
Total area of FEMA’s high-risk region based on the 100-year flood event (1%-annual-chance Flood Hazard Areas)	724 km$_2$
Total area of FAU’s high-risk region based on the 3-day 25-year storm event (classified above 90% probability of inundation)	115.8km$_2$
Total area of overlap between the high-risk regions designated by FAU and FEMA	57.92 km$_2$
Percentage of overlap to FEMA’s high-risk region calculated as = (total area of overlap / total area of FEMA’s high-risk region) * 100%	8%
Percentage of overlap to FAU’s high-risk region calculated as = (total area of overlap / total area of FAU’s high-risk region) * 100%	50%

3.3.5 Repetitive loss comparison

Figure 3.14 shows a comparison of the flood map and repetitive loss property locations for the basin. The loss areas coincide with the areas predicted by the FAU model as being at risk for flooding.

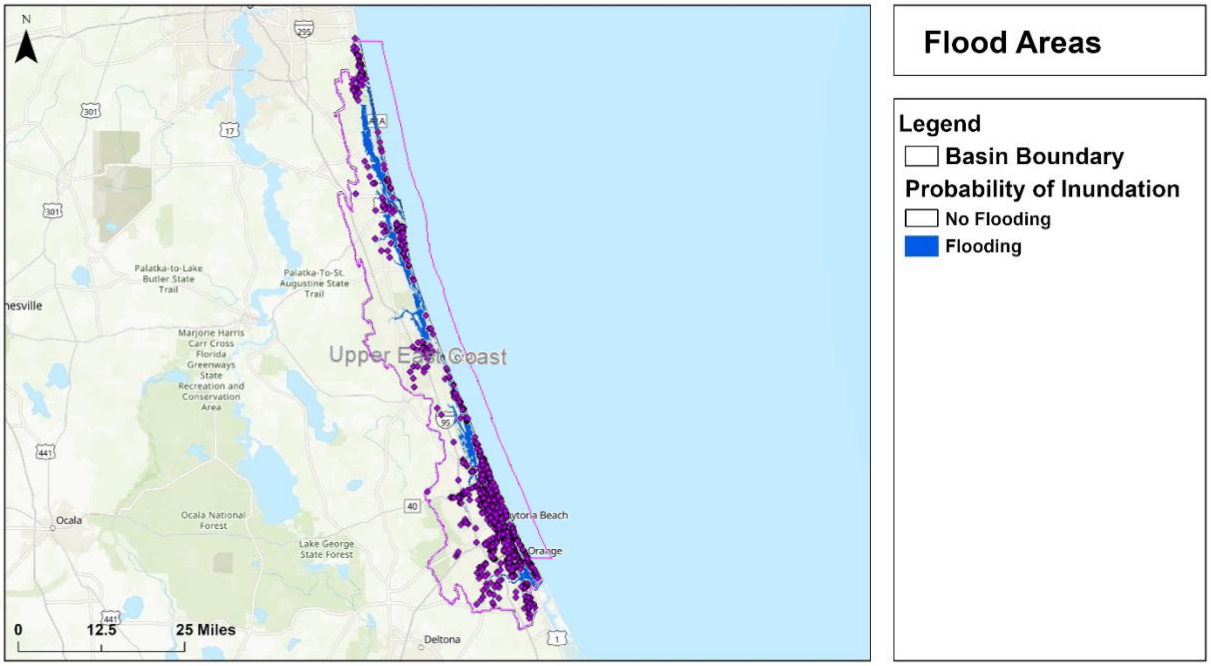


Figure 3.14. Repetitive loss areas from 2004 -2014 superimposed on the flood risk map created by FAU

3.4 Drilldown comparison

Figure 3.15 shows the areas of the basin that are developed and flooded so further drill down could be conducted. The drill down maps show the Volusia and Daytona Beach drill down areas of critical importance.

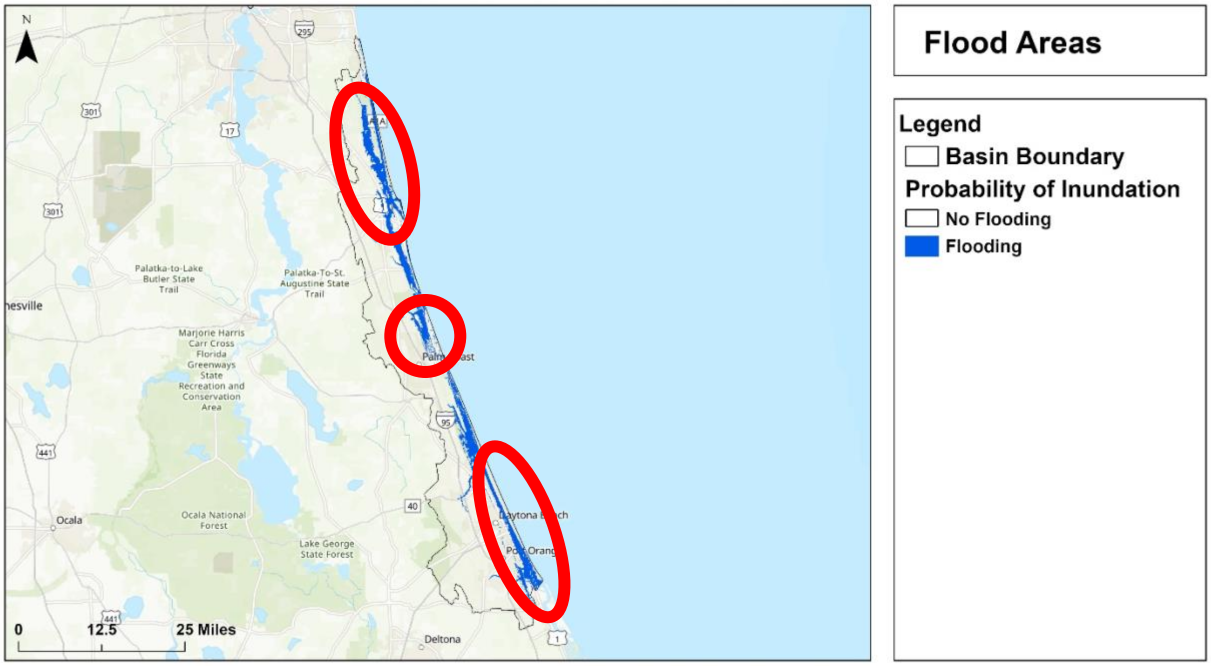


Figure 3.15. Location of drilldown areas in the Upper East Coast Watershed

By modeling the Upper East Coast flood response to a 3-day 25-year storm event and further classifying flood risk as the probability of inundation, it is possible to identify critical target areas within the watershed. The screening tool should first be applied at the watershed level to provide an initial risk assessment focused on the hydrologic response to a rainfall event given the unique characteristics and features of the watershed. For example, characteristics of the Upper east Coast Watershed are incorporated to represent possible driving factors of flooding in the region such as low ground surface elevations, a high groundwater table, low soil storage capacity, and heavy rains. However, to prioritize funding for future mitigation and planning efforts at the local level, it is necessary to identify areas of concern within the watershed that are highly susceptible to flooding. Understanding localized flooding conditions is crucial for developing strategies to protect vulnerable communities and infrastructure. A closer look at the flood risk map created for the Upper East Coast provides additional drill down perspectives of the watershed, increasing the displayed level of detail. Several areas of critical importance in the Indian River Lagoon Watershed have been examined, including Volusia and Daytona Beach shown in Figures 3.16 and 3.17.

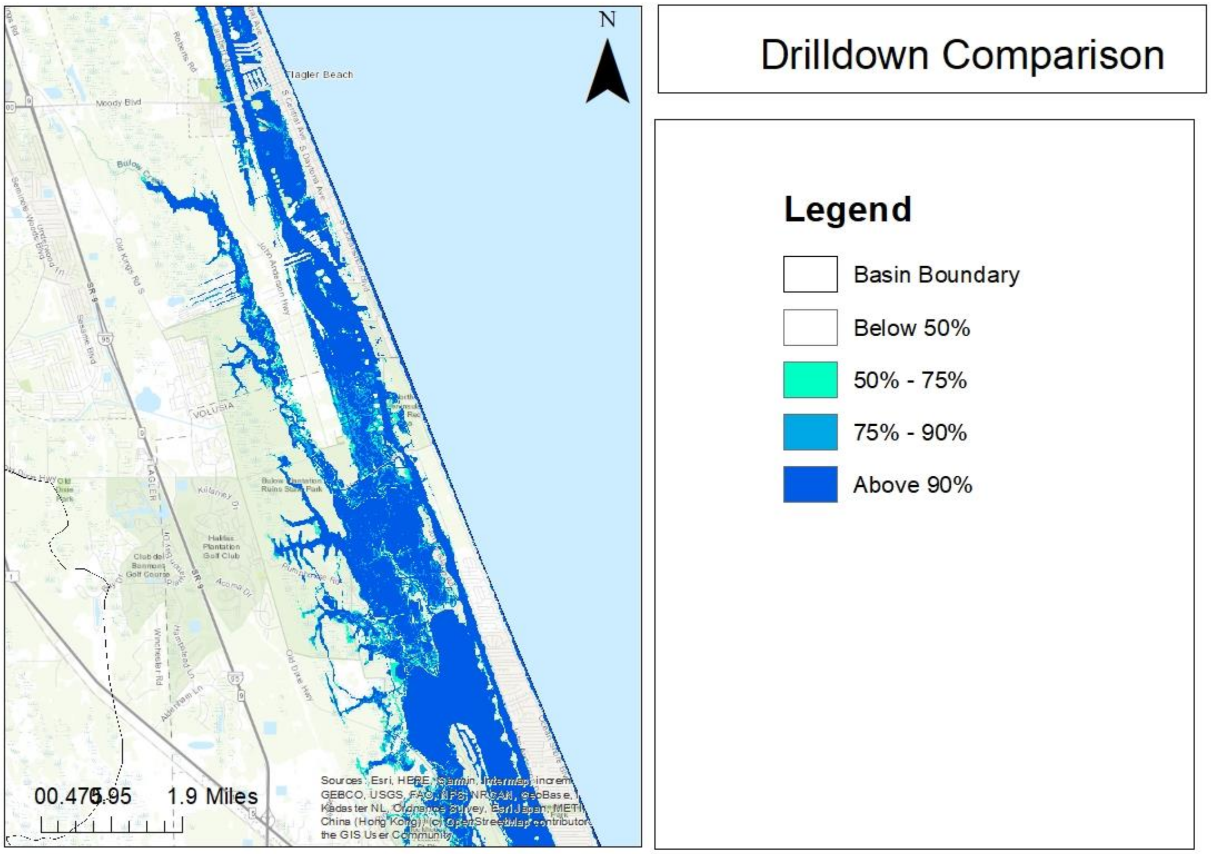
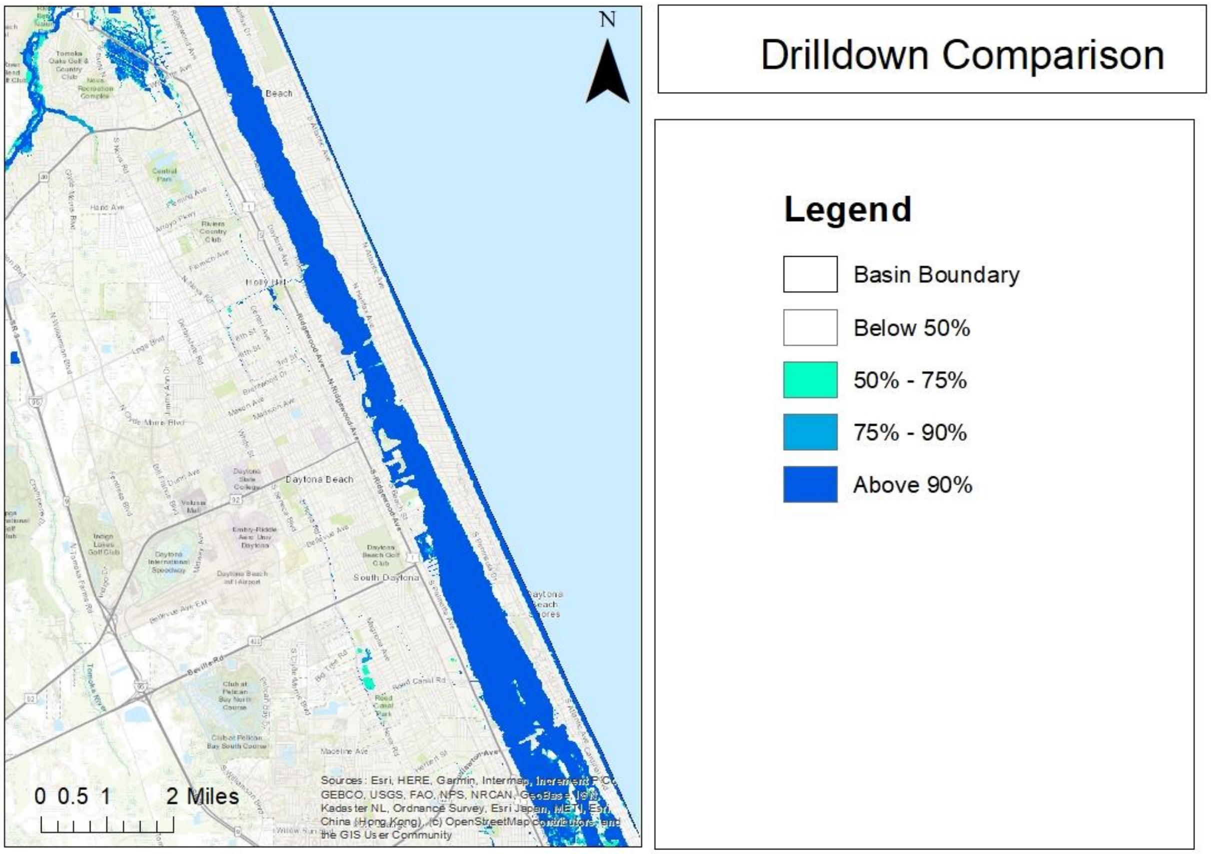


Figure 3.16: Drilldown study of Volusia



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 3.17: Drilldown study of Daytona Beach

4.0 Conclusion

FDEM contracted with FAU to develop a screening tool of flood risk areas for 29 watershed basins. The effort discussed above focusses on the development procedures for a screening tool to assess risk in the Upper east coast, a watershed located in Eastern Florida that combines readily available data on topography, tidal information for coastal communities, soils, open space and rainfall to permit an assessment of the risk of inundation of property. The extent of flooding and its associated risk was assessed by utilizing existing spatial and hydrologic data to follow FAU's modeling protocol and developing a CASCADE 2001 simulation for analysis of the Watershed's flood response to a 3-day 25-year storm. The basin shows widespread flooding due to low elevation proximity to the eastern coast. A drilldown to the local communities indicates that the major developments are flood prone. Comparison of the FEMA flood maps, and repetitive loss properties correlate well visually. It indicates the modeling methodology provides a basin-wide and localized analysis tool useful for future basin planning activities.

The contributing factors of flooding include the low ground surface elevations, high groundwater table, low soil storage capacity, and heavy rains common in this region of Florida. These characteristics and several others were calculated and incorporated into the simulation model to ensure that the true flooding conditions of the watershed are represented in the results. As a result of this effort, critical target areas in the watershed that are particularly vulnerable to flooding can be identified for future studies and scaled-down modeling efforts. Such knowledge permits the development of tools to permit local agencies to develop means to address high risk properties.

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