DRAFT

Charlotte Harbor Watershed Case Study

Basin 15

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Executive Summary

Flooding is the most common and costly disaster in the United States, where over 98% of counties have experienced a flood and just one inch of water can cause up to $25,000 in damage. Flooding can impact a community's social, cultural, environmental and economic resources; therefore, making sound, science-based, long-term decisions to improve resiliency are critical for future growth and prosperity (FEMA, 2018). The Florida Division of Emergency Management (FDEM) contracted with FAU to develop data that will support local communities seeking to reduce flood insurance costs through flood mitigation and resiliency efforts by developing watershed management plans. There are several steps to address watershed management planning, including the development of support documents to establish community risk associated with common flood events impacting Florida's watersheds.

The effort discussed herein focusses on the development procedures to assess flood risk in the Charlotte Harbor Watershed, specifically the considerations, modeling, and analysis needed to develop a comprehensive management plan. By combining readily available spatial and hydrologic data, FAU developed a modeling protocol to represent possible driving factors of flooding such as low ground surface elevations, a high groundwater table, low soil storage capacity, and heavy rains. By utilizing a well-established flood simulation model, CASCADE 2001, the maximum headwater height of floodwaters during a 3-day 25-year storm was determined based on the unique characteristics of the watershed to identify areas of concern that are particularly vulnerable to flooding. Furthermore, FAU has classified the risk associated with the Charlotte Harbor Watershed's flooded area as the probability of inundation to improve the identification of critical target areas that are subject to further study. Identifying these areas of concern that are highly susceptible to flooding will assist local efforts to prioritize funding for future mitigation and resiliency planning to protect vulnerable communities and infrastructure.

1.0 Introduction

The Charlotte Harbor Watershed, shown in Figure 1-1, covers approximately 886.5 square miles in southwest Florida across three counties, including Charlotte, Lee, and Sarasota Counties. Three major rivers flow into the watershed, including the Myakka, Peace, and Caloosahatchee Rivers. These river systems drain inland areas and outflow through the Charlotte Harbor and Caloosahatchee Estuaries into the Gulf of Mexico. It is expected that flooding will primarily occur adjacent to the major rivers and be localized to developed land areas along the coast. The likely contributing factors to flooding are the low ground surface elevations, high groundwater table, low soil storage capacity, and heavy rains commonly associated with this region of Florida. The extent of flooding will be determined by utilizing existing spatial and hydrologic data to follow a modeling protocol developed by FAU to simulate and analyze the watershed's flood response to a common rainfall event. Then, the risk associated with the flooded area will be classified to identify critical target areas that are vulnerable to flooding.

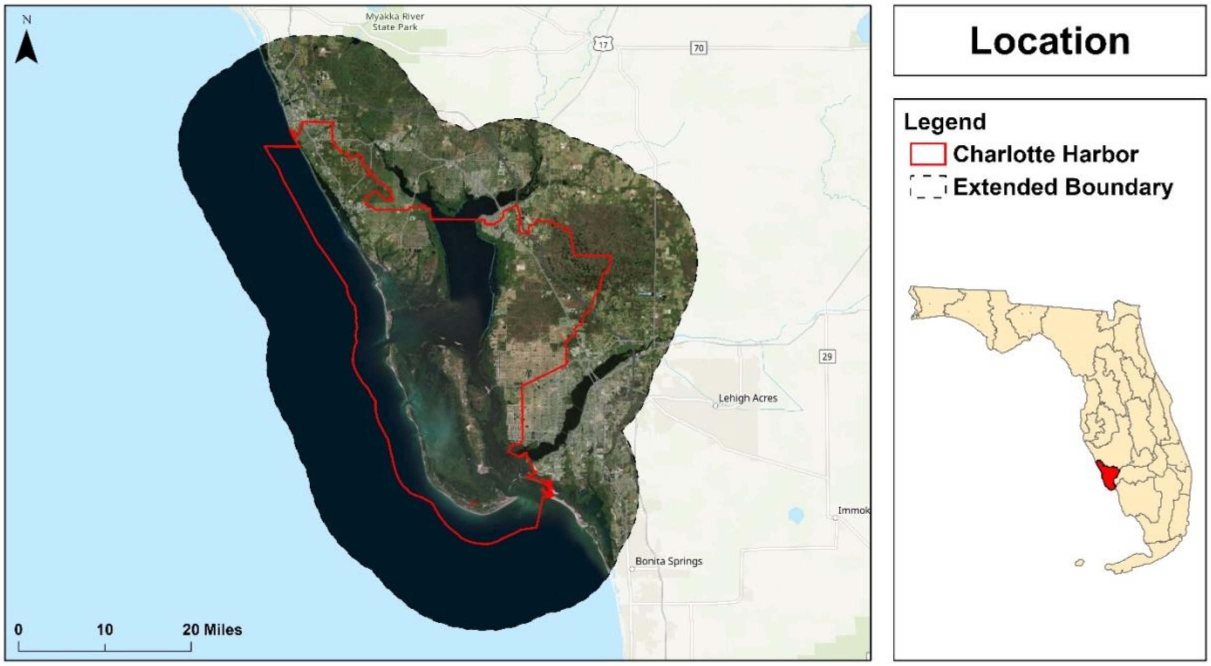


Figure 1-1. Location of the Charlotte Harbor Watershed in Florida

2.0 Summary of Watershed

2.1 General Description of Watershed

2.1.1 Climate/Ecology

The Charlotte Harbor Watershed includes portions of Charlotte, Lee, and Sarasota Counties which are in South Florida. This region has a humid, subtropical climate with both a wet and dry season. The average temperatures range from approximately 60° F to 80° F in the winter and summer, respectively. South Florida typically experiences heavy rains in the summer and fall months, which can be further intensified during hurricane season (Webb, 1999). The selected date to study the Charlotte Harbor Watershed's flood response to heavy rains is September 27th, 2013 to represent a time of elevated flood risk during the region's heavy rainfall season. Additionally, since large urban areas in the watershed's cities contain many impervious surfaces, the increased surface runoff caused by heavy rains must be considered while assessing the watershed's flood response to a rainfall event. These areas are incorporated into the study through the land classification and soils datasets.

2.1.2 Topography and Soils

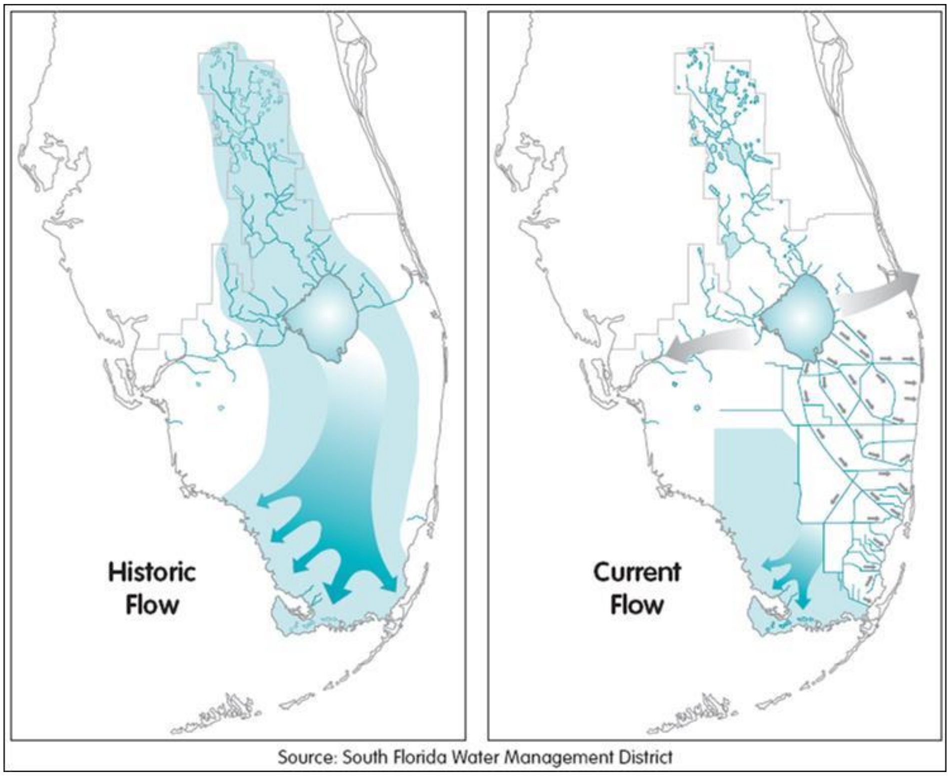
The ground surface elevations in the watershed are lowest along the coast between 5 feet and 15 feet NAVD88. The elevations gradually increase up to 30 feet NAVD88 in the inland areas of the watershed. The low elevations and subtle changes in topography may contribute to flooding as excess rainfall overflows from open surface water bodies, imposing risk on nearby areas. Additionally, high tides move large quantities of water into the estuaries, which can spill over into low-lying coastal areas. In the watershed, there are a variety of sandy soils. This type of soil may improve drainage; however, impervious surfaces in the coastal cities may increase surface runoff by preventing soil infiltration.

2.1.3 Boundaries/Surface Waters

The study area boundary is defined by the total maximum daily load (TMDL) Charlotte Harbor Watershed. All data was gathered for a 10-mile extended boundary to ensure complete coverage of the study area. The primary surface water features of the watershed driving the flow of water are the Myakka, Peace, and Caloosahatchee Rivers. Other features include the Charlotte Harbor Estuary, Caloosahatchee Estuary, and San Carlos Bay.

2.1.4 Hydrogeological Considerations

In South Florida, groundwater and surface water are interconnected due to the shallow water table, low land elevations, and controlled drainage system. Historically, the drainage system of the region was not controlled as there were no canals or structures to direct the flow of water. Today, groundwater flows from the Kissimmee River to Lake Okeechobee where it is then controlled to flow throughout South Florida. Drainage may travel south through the constructed canal system and the Everglades; however, drainage can also be directed west through the C-43 Canal into the Caloosahatchee and Charlotte Harbor Watersheds. The destination of drainage through this flow path is the Gulf of Mexico at San Carlos Bay (SFWMD, 2010). The South Florida Water Management District’s depiction of the historic and current groundwater flow in the region is shown in Figure 2-1.



Source: South Florida Water Management District

Figure 2-1. Historic and Current Groundwater Flow of South Florida

2.1.5 Special Features

The Myakka and Peace Rivers drain water from inland areas out into the Gulf of Mexico. These rivers originate northeast of Charlotte Harbor and have an important role in supplying the region with freshwater. The watershed has a tidal connection where its rivers outflow into the Charlotte Harbor and Caloosahatchee Estuaries. Since open surface water bodies represent a large portion of the watershed, these special features must be taken into consideration when assessing the watershed's flood response to a rainfall event. The low land elevations along the coast and shallow water table driven by the surface waters will likely contribute to flooding, which is expected to occur adjacent to the rivers and coastline. These special considerations were incorporated into the flood simulation model to better represent true flooding conditions under heavy rains (FDEP, 2005).

2.2 Socio-economic Conditions of the Watershed

2.2.1 Demographics

The demographics and housing characteristics have been compiled for each county in the Charlotte Harbor Watershed from the U.S. Census Bureau’s 2018 American Community Survey (ACS) 5-Year Estimates. A summary of the statistics is included in Table 2-1. In total, Charlotte, Lee, and Sarasota Counties have a population of 1,307,777 (U.S. Census Bureau, 2018).

Table 2-1. Demographics and Housing Characteristics of the Charlotte Harbor Watershed by County

County Name Demographic	Charlotte	Lee	Sarasota
Area	680.9 mi^2	783.9 mi^2	555.6 mi^2
Population	176,954	718,679	412,144
No. of Households	76,150	271,861	180,551
Med. Household Income	$49,225	$54,691	$58,644
Median Age	58.6%	48.1%	55.5%
White	90.2%	84.8%	91.2%
Black, African American	5.5%	8.6%	0.5%
American Indian, Native	0.3%	0.2%	0.2%
Asian	1.2%	1.6%	1.7%
Other Race	0.7%	3.0%	0.7%
Two or More Races	2.0%	1.8%	1.6%
Hispanic or Latino (Regardless of Race)	7.0%	20.7%	9.0%

2.2.2 Property

Property values are highest in the major cities of the watershed such as Venice, Punta Gorda and North Port. Unincorporated areas of Port Charlotte and Rotunda are part of the basin. Charlotte County consists of mostly agricultural land and upland forests with urban areas in its cities. Lee County is primarily urban areas along the coast and he Cape Coral portion of this watershed.

Sarasota County is mostly urban areas along the coast of the Gulf of Mexico but contains Myakka River State Park and other large undeveloped, open land areas. According to the U.S. Census Bureau's 2018 American Community Survey, the median housing values in Charlotte, Lee, and Sarasota Counties are $176,500, $207,700, and $234,800, respectively.

2.2.3 Economic Activity/Industry

The major economic activity in the Charlotte Harbor Watershed is recreation and (beach) tourism with a prominent fishing industry. While Charlotte, Lee, and Sarasota Counties attract tourists to their sandy beaches, another strong economic activity of high importance is agriculture, namely citrus and beef cattle. In Charlotte County, Punta Gorda is the only incorporated municipality. In Lee County, there is a metropolitan area comprised of Cape Coral is partially in the basin. In Sarasota County, the incorporated municipalities are North Port, Sarasota, and Venice.

2.3 Watershed Funding

Watershed restoration plans and projects in the region have been funded by the state, SFWMD, and federal government. Historical flood control projects altered the drainage pattern of South Florida to reduce flooding in nearby cities. These restoration plans seek to restore the natural state of Florida's watersheds; for example, the Comprehensive Everglades Restoration Plan (CERP) is a major effort to restore and preserve South Florida. Additionally, local counties have funded stormwater management plans and programs. Many efforts focus on protecting and restoring the natural functions of the watershed.

3.0 Watershed Analysis

3.1 Data Sets

3.1.1 Topography

In a flood risk assessment, the ground surface elevation is an important consideration as low-lying land areas are often highly vulnerable to flooding. FAU gathered elevation datasets with a high spatial and vertical resolution to ensure the integrity of all final flood risk maps, which will inform decision-making efforts for successful watershed management planning. The LiDAR DEM products used in this study have a horizontal resolution of three meters and a vertical accuracy between 22 centimeters and 30 centimeters. This dataset covers nearly all areas in the watershed. However, a small data gap existing near the Charlotte County and Sarasota County border where the Myakka River outflows into the Charlotte Harbor Estuary was filled using LiDAR DEM products with a horizontal resolution of 10 meters and a vertical accuracy of approximately 1.16 meters. Further processing of the data involved mosaicking into a seamless ground elevation surface, projecting into the NAD 1983 UTM Zone 17N coordinate system and converting vertical units from meters to feet. The resulting bare-earth surface elevation of the Charlotte Harbor Watershed is shown on the map in Figure 3-1.

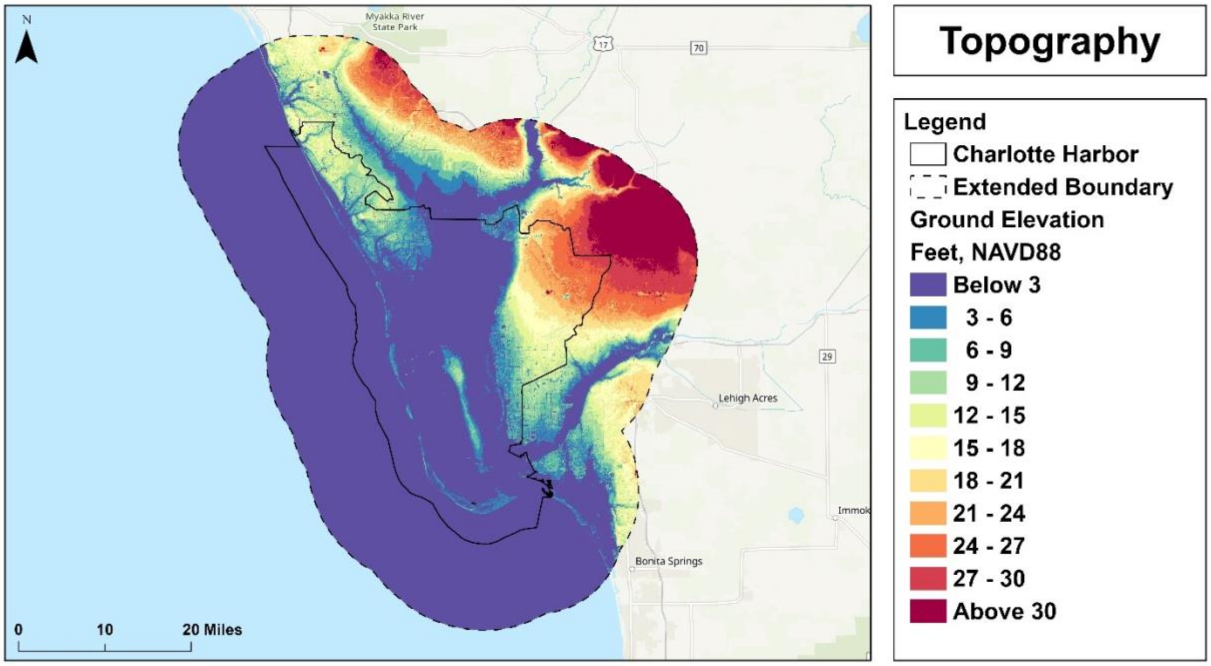


Figure 3-1. Ground Elevation in the Charlotte Harbor Watershed

3.1.2 Groundwater

The high groundwater table commonly associated with this region of Florida contributes to flooding as large portions of the soil layer are typically saturated at the start of rainfall events and cannot store any additional water, which would relieve flooding in many areas. Accurately mapping the groundwater table is possible through spatial interpolation and extrapolation techniques which utilize observed groundwater levels at monitoring stations to generate an elevation surface. The DBHYDRO environmental database was used to gather daily maximum groundwater levels on September 27th, 2013 in the Charlotte Harbor Watershed. The available monitoring stations were further processed to keep only those groundwater wells in the surficial aquifer system, which are interconnected with the surface water and will influence flooding in the region. Nearly all the remaining 16 groundwater monitoring stations are located outside of the Charlotte Harbor Watershed either within the 10-mile extended boundary or the adjacent Caloosahatchee Watershed, as shown on the map in Figure 3-2. For this reason, the same monitoring stations dataset used for the Caloosahatchee Watershed was also used to spatially extrapolate groundwater levels across the Charlotte Harbor Watershed. Since these available stations are not well-distributed throughout the Charlotte Harbor Watershed, a multiple linear regression model was needed to map the groundwater table. This spatial extrapolation method leveraged the interconnectivity of ground and surface waters in South Florida, subtle changes in the groundwater table's elevation across large distances, and proximity of the Charlotte Harbor and Caloosahatchee Watersheds.

3.1.3 Surface Waters

In this region of Florida, there is a direct interaction between groundwater and surface water. In addition to low land elevations and topographic relief, the groundwater and surface water are controlled by the canals, rivers, and tides. Since there is a limited number of groundwater monitoring stations, the strong relationship between groundwater and surface water was leveraged to accurately map the groundwater table elevation. All daily mean surface water level observations on September 27th, 2013 were gathered from monitoring stations in the DBHYDRO database. Nearly all 79 station observations available on this date are located outside of the Charlotte Harbor Watershed either within the 10-mile extended boundary or the adjacent Caloosahatchee Watershed, as shown on the map in Figure 3-2. The same monitoring stations dataset used for the Caloosahatchee Watershed was also used for the Charlotte Harbor Watershed. Open surface water bodies make up a large portion of the study area, namely the tidal connection to the Gulf of Mexico, so the nearby NOAA Fort Myers tidal observation station was used to determine the elevation of tides which greatly influence water levels in the watershed. Additionally, the LiDAR DEM data was used to extract elevation values along open surface water bodies for use as "pseudo-stations" in the multiple linear regression model.

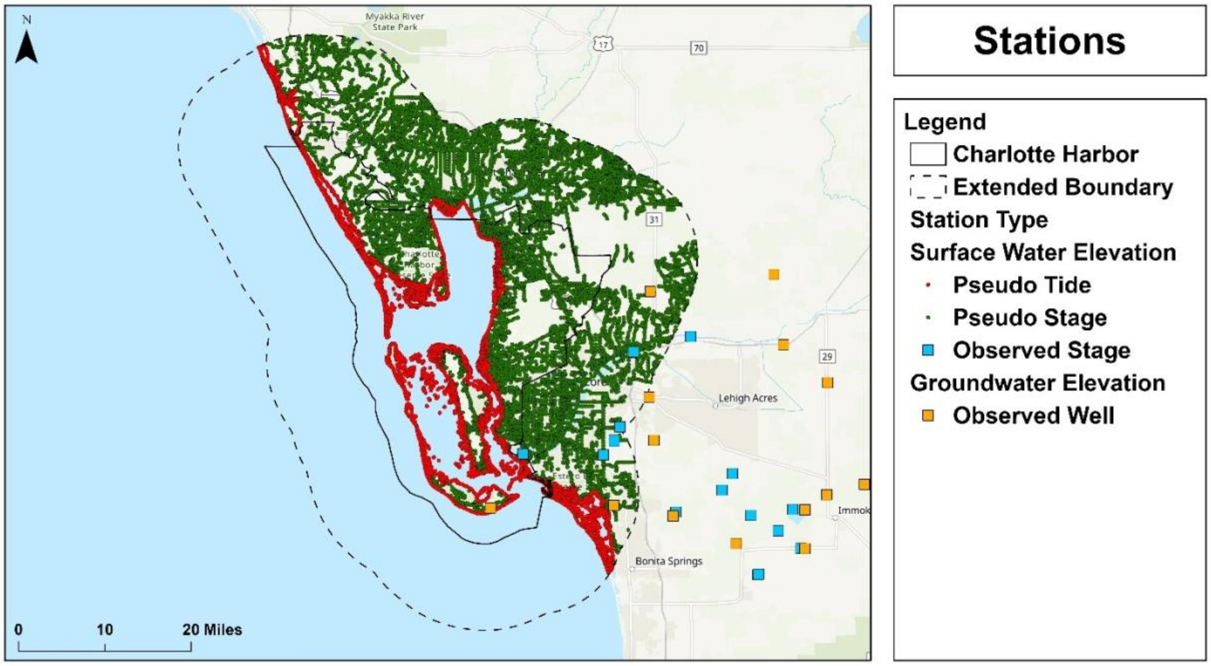


Figure 3-2. Groundwater and Surface Water Monitoring Stations in the Charlotte Harbor Watershed

While low land elevations and high groundwater table elevations influence flooding, the soil storage capacity will also greatly influence the watershed's vulnerability to flooding. Open surface water bodies and frequently inundated land will be unable to store additional water during a rainfall event. Hence, when mapping the soil storage capacity across the watershed, these areas were set to zero storage capacity as there is no capacity for these areas to store additional water. These areas, as shown in Figure 3-3, were delineated from statewide land use land cover datasets and were used in the calculation of soil storage capacity. Flooding is likely to occur near open surface water bodies and areas such as wetlands, swamps, and marshes. These areas were overlaid onto the final risk map to differentiate between flooded land or development and existing surface water bodies.

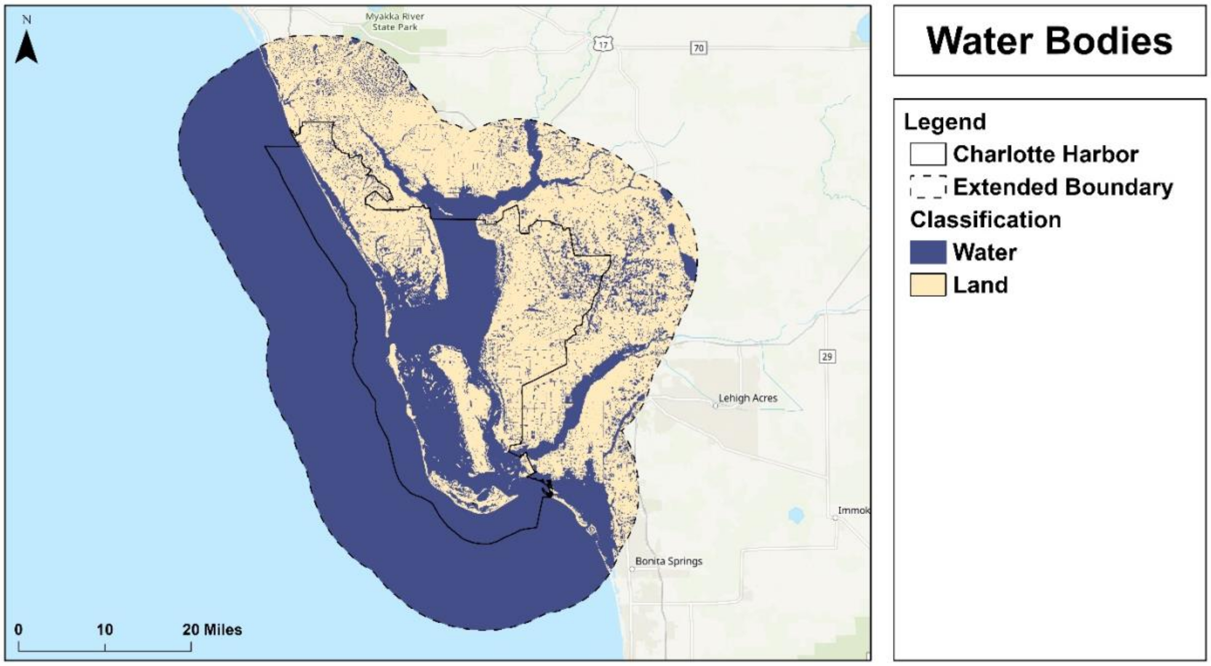


Figure 3-3. Existing Surface Water Bodies in the Charlotte Harbor Watershed

3.1.4 Open Space

Another consideration in calculating the soil storage capacity is the land areas covered by impervious surfaces. While the soil may have the capacity to store water, the type of land cover will either allow or prevent soil infiltration. If an area is covered by impervious surfaces, the rainfall will not infiltrate the soil causing surface runoff and increased flooding. Only those areas classified as open space, or pervious land, will minimize surface runoff, promoting soil infiltration and storage in the unsaturated zone. Therefore, incorporating impervious surfaces into the calculation of soil storage capacity is important. The National Land Cover Database was used to classify land as either pervious or impervious as shown on the map in Figure 3-4. Then, impervious surfaces were assigned a value of zero to designate all impervious areas as having no soil storage capacity since rainfall will simply runoff along the surface without any soil infiltration, preventing storage in the unsaturated zone.

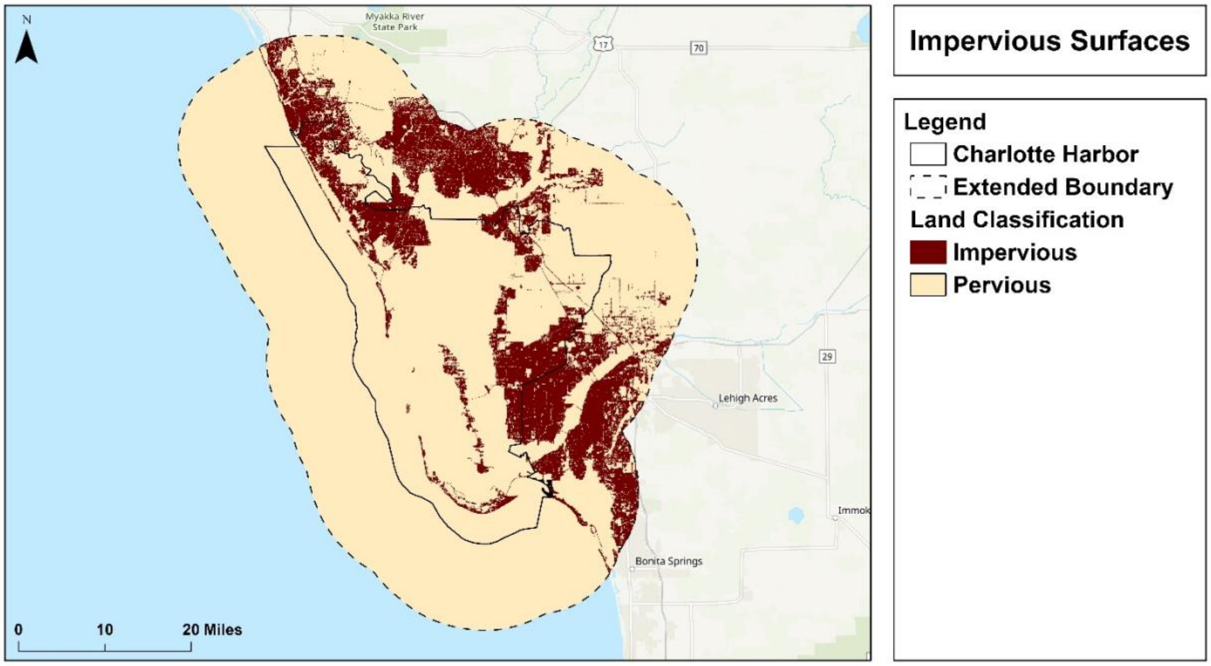


Figure 3-4. Pervious and Impervious Land Classification in the Charlotte Harbor Watershed

3.1.5 Soil Capacity

After determining which land will have the capacity to store excess rainfall in the soil layer, it is necessary to quantify the unsaturated zone’s aptitude for storing water based on the type of soils present within the watershed. Since certain soils can store water given that there is an adequate distance between the land surface and groundwater, it is necessary to determine the relationship between the soils’ characteristics and their capacity to store water. The water holding capacity of the soil was calculated through further processing of data in the USDA’s Gridded SSURGO database. The water holding capacity ratio surface for the Charlotte Harbor Watershed, shown on the map in Figure 3-5, was used to calculate the total amount of water that can be stored in the soil layer during a rainfall event. Poor ground storage conditions will greatly contribute to flooding in the watershed.

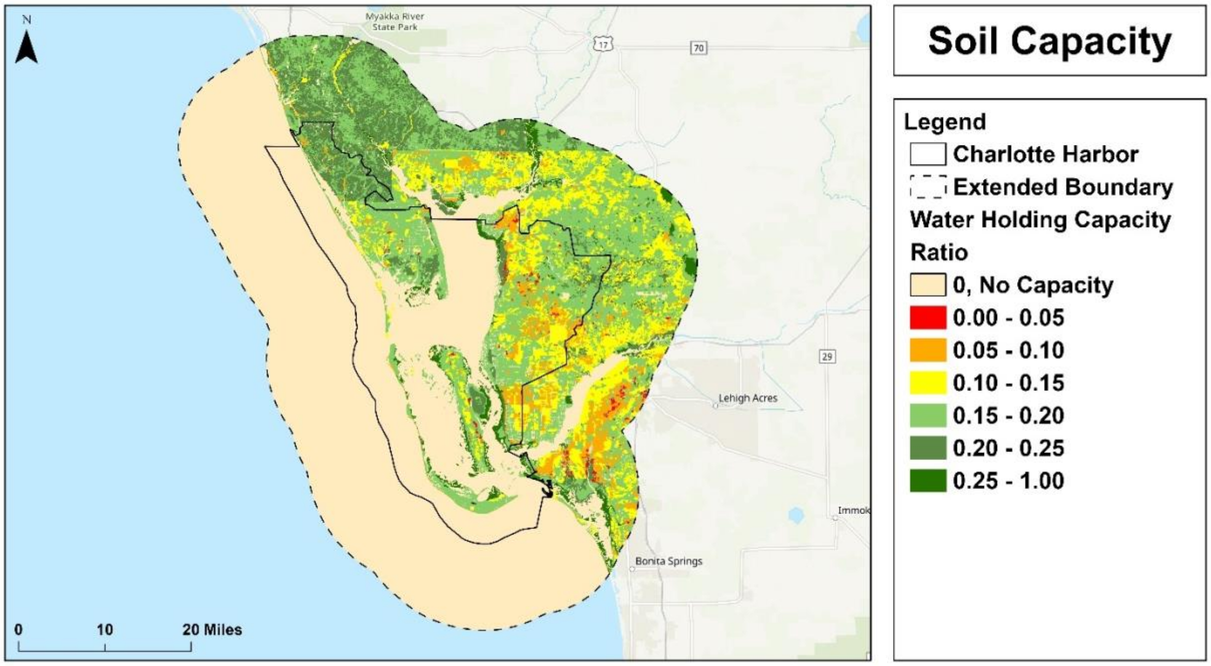


Figure 3-5. Soil Water Holding Capacity in the Charlotte Harbor Watershed

3.1.6 Rainfall

Several datasets are needed to truly represent the unique characteristics of the watershed. By incorporating these characteristics into a flood simulation model, it is possible to determine the extent of flooding. For example, the Charlotte Harbor Watershed has low land elevations, a high groundwater table, and low soil storage capacity which all contribute to flooding. The goal of using a simulation model is to study the watershed's response to flooding under a specified rainfall event. The selected design storm for FAU's flood simulation is based on the 3-day 25-year storm. This standard design storm characterizes a frequently occurring rainfall event that will yield results representing a realistic flooding scenario (SFWMD, 2010). The 3-day 25-year rainfall map based on the NOAA Atlas 14 dataset is shown in Figure 3-6.

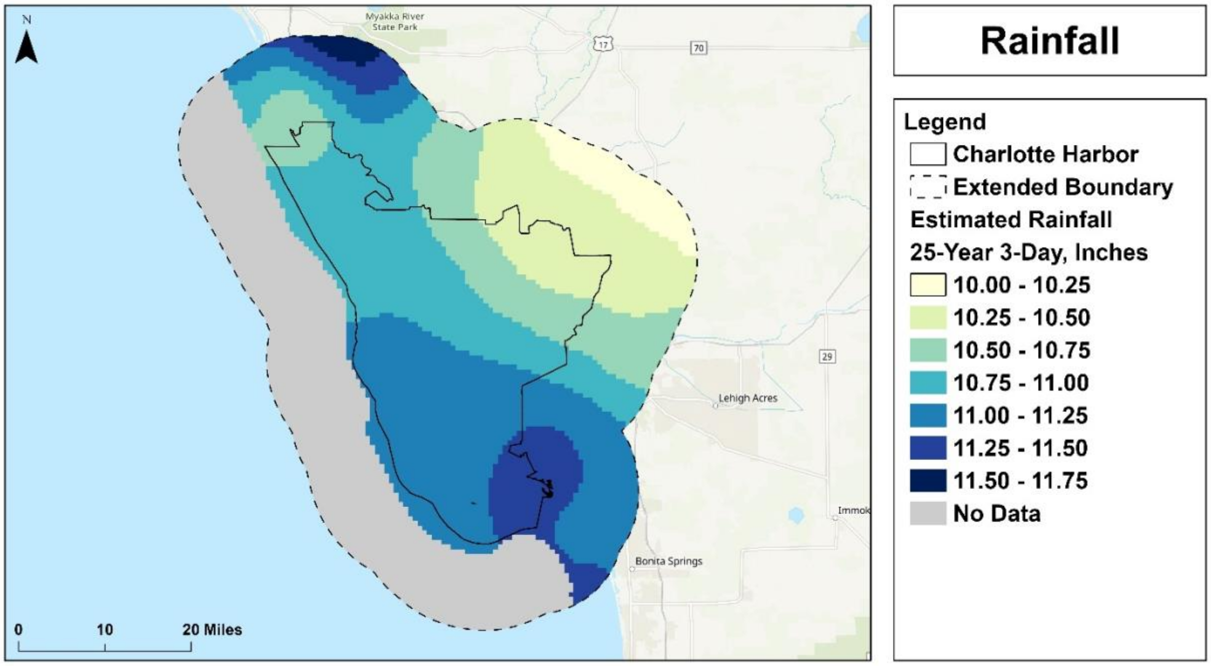


Figure 3-6. Rainfall During a 3-Day 25-Year Storm in the Charlotte Harbor Watershed

3.2 Modeling Protocol

There are many contributing factors to flooding in the Charlotte Harbor 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 Charlotte Harbor 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. The South Florida Water Management District's DBHYDRO database was used to access their station observation data. Nearly all 16 groundwater monitoring stations and 79 surface water monitoring stations available on the selected date are located outside of the Charlotte Harbor Watershed either within the 10-mile extended boundary or the adjacent Caloosahatchee Watershed. For this reason, the same monitoring stations dataset used for the Caloosahatchee Watershed was also used to spatially extrapolate groundwater levels across the Charlotte Harbor Watershed. Additionally, NOAA's Fort Myers tidal station was used to determine the elevation of tides along the coastline. All ground and surface water stations actively observing water levels are shown on the map in Figure 3-2. Given that these available stations are not well-distributed throughout the Charlotte Harbor Watershed, using a multiple linear regression model is necessary to calculate the water table elevations in the watershed. This spatial extrapolation method, requiring several steps to complete, leverages the interconnectivity of ground and surface waters in South Florida, subtle changes in the groundwater table's elevation across large distances, and proximity of the Charlotte Harbor and Caloosahatchee Watersheds.

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 $\text{WTE} = (0.9748 \times \text{MINWTE}) + (0.0363 \times \text{Depth to MINWTE}) + 1.8391$. 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. The predicted water table elevation, shown on the map in Figure 3-7, shares a similar spatial pattern with the land elevation in the DEM; however, the water table sits a few feet below the land surface. This is attributed to the fact that groundwater typically follows topography and the water table is shallow in this region of Florida.

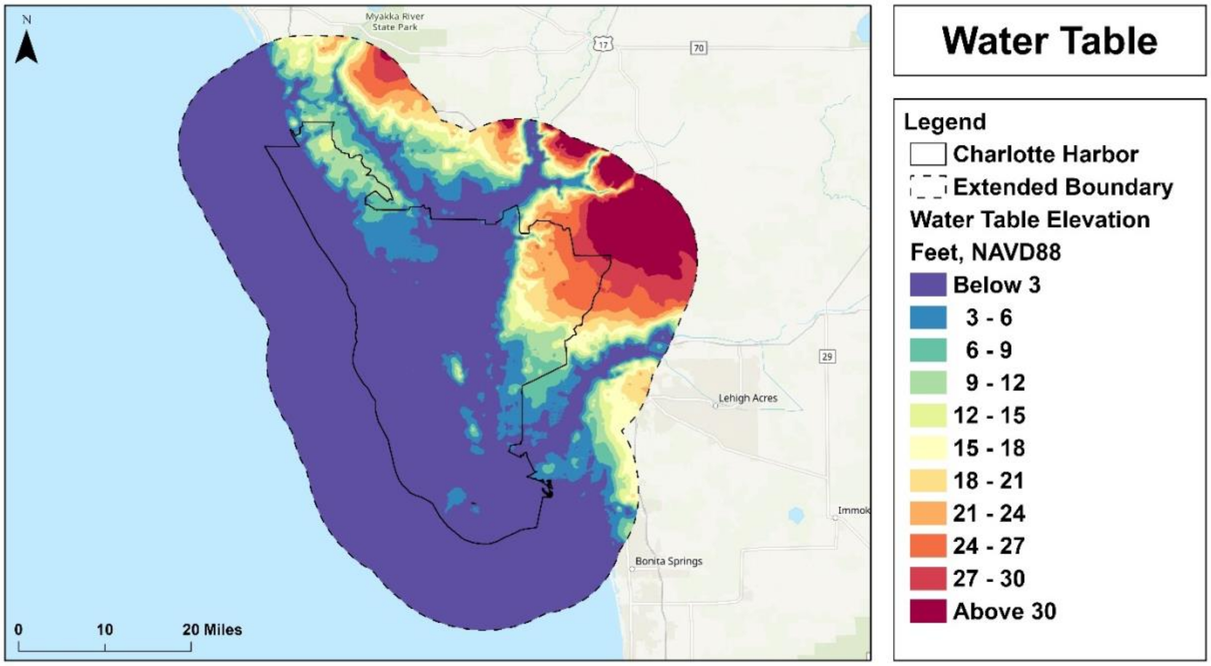


Figure 3-7. Groundwater Table Elevation Generated Using a Multiple Linear Regression Model

After modeling the groundwater table elevations, it is possible to determine the amount of water that can be stored in the soil, or soil storage capacity, which impacts flooding. Given that there is an adequate distance between the bare surface of the earth and the groundwater table, certain types of soil can store quantities of water in the soil layer. The goal is to calculate that distance and therefore the depth of the soil layer known as the unsaturated zone. The unsaturated zone depth in the Charlotte Harbor Watershed, shown on the map in Figure 3-8, was calculated by subtracting the water table elevations from the land elevations.

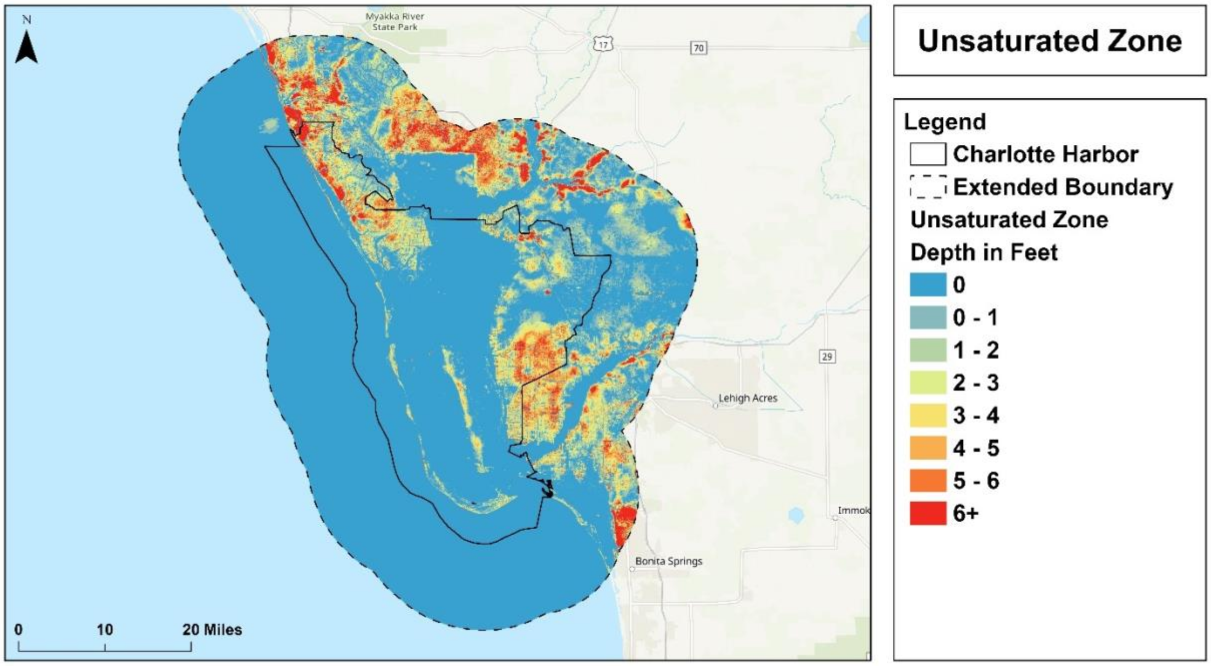


Figure 3-8. Unsaturated Zone Depth in the Charlotte Harbor Watershed

The quantity of water that can be stored in the unsaturated zone during a rainfall event is an important consideration in any flood study. While there may be several feet in distance between the land surface and groundwater table, the true ground storage is dependent upon the water holding capacity of the soil and land classification type. The characteristics of the soil will affect the soil's capacity to store water. The soil storage capacity was calculated by multiplying the unsaturated zone depth surface by the water holding capacity ratio surface on a cell-by-cell basis. This calculation accounts for both the soil layer's total depth and unique characteristics that influence its capacity to store water. However, to better represent true ground storage conditions, the output surface was adjusted based on its land classification type. Land areas representing existing water bodies and impervious surfaces were set to zero storage capacity. Existing water bodies covering land in the watershed cannot store additional water and impervious surfaces prevent soil infiltration, increasing surface runoff (SFWMD, 2010). The final soil storage capacity surface, which was adjusted to represent the soil’s characteristics and land classification type, is shown on the map in Figure 3-9.

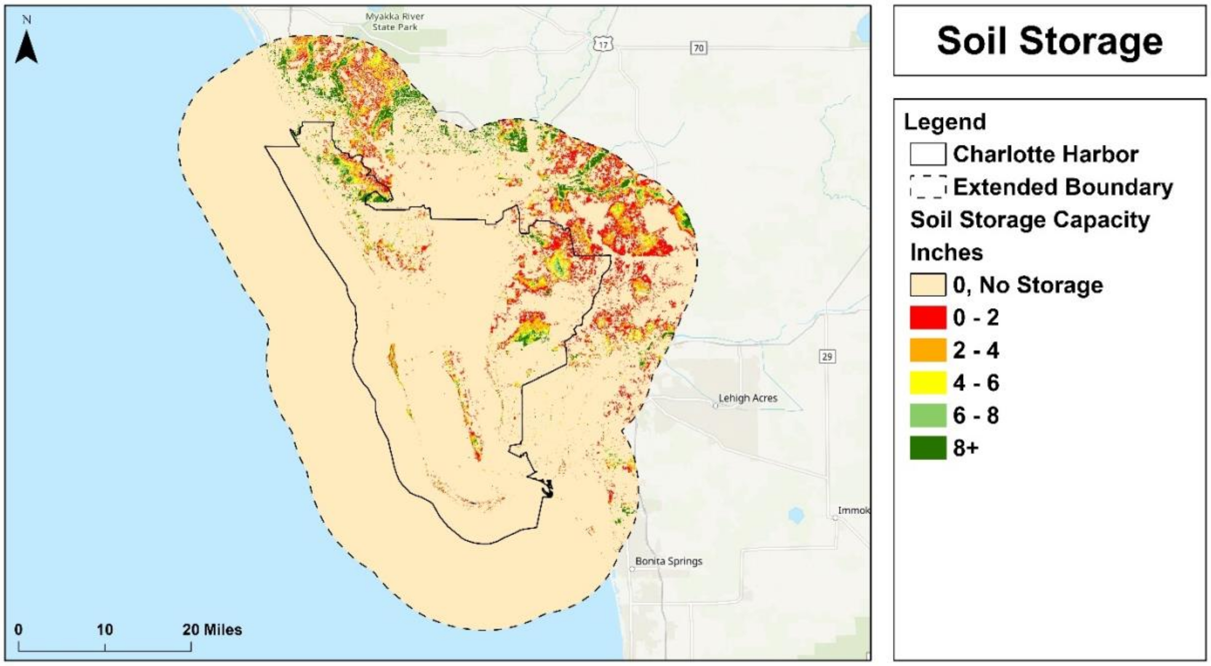


Figure 3-9. Soil Storage Capacity in the Charlotte Harbor Watershed

3.3 Modeling Results

3.3.1 Watershed Pathways

The Myakka, Peace, and Caloosahatchee Rivers move and drain water from inland areas to the Charlotte Harbor and Caloosahatchee Estuaries, which outflow into the Gulf of Mexico. It can be difficult to delineate where drainage is collecting and flowing within the watershed. 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 Charlotte Harbor Watershed will be concentrated during a rainfall event was calculated. The derived drainage network was overlaid onto Florida’s TMDL Planning Unit boundaries, as shown on the map in Figure 3-10. It was not necessary to subdivide the Charlotte Harbor Watershed into smaller units for the CASCADE 2001 simulation since there are no drainage structures controlling the Myakka, Peace, and Caloosahatchee Rivers downstream of the locations that they flow into the watershed. The drainage simply travels through these river systems, collects in the watershed, and then outflows into the Gulf of Mexico.

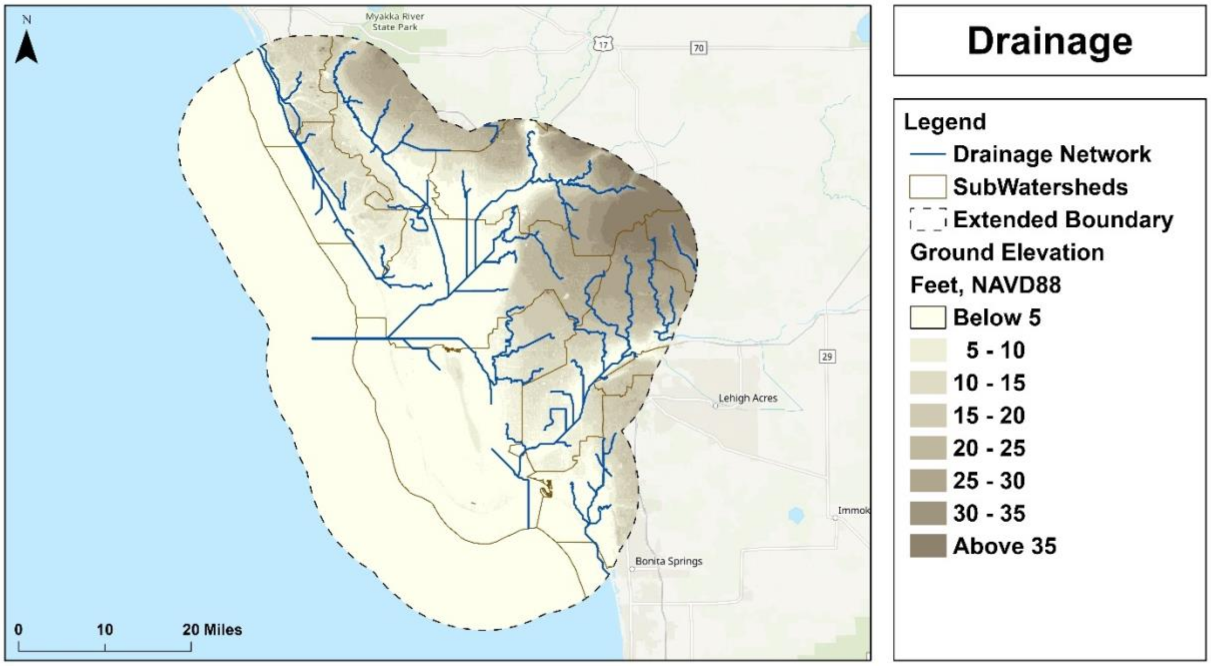


Figure 3-10. Catchment and Drainage Network Delineation in the Charlotte Harbor Watershed

3.3.2 Cascade Results

After following FAU’s modeling protocol, all required input parameters for CASCADE 2001 were calculated. 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 the Charlotte Harbor Watershed. A summary of the watershed input parameters for CASCADE 2001 is provided in Table 3-1.

Table 3-1. CASCADE 2001 Watershed Input Parameters

Watershed Name Input Parameter	Charlotte Harbor
Area (ac)	567,338
Low Elev. (ft)	0.67
High Elev. (ft)	27
Soil Storage (in)	0.47
Concentration (hr)	14.18
Initial Stage (ft)	0.67
Design Storm	3-day 25-year
Rainfall (in)	10.92

Under these constraints, the CASCADE 2001 model simulates the rise of floodwaters during a 3-day 25-year storm. The goal is to obtain the maximum headwater height in the watershed as any land areas below this elevation will be flooded. The identification of flood-prone areas within the Charlotte Harbor Watershed is crucial to inform the decision-making process of prioritizing and allocating funding. In the watershed, it was determined that floodwaters will rise to a maximum headwater height of 7.25 feet NAVD88. The flooded areas during a 3-day 25-year storm in the Charlotte Harbor Watershed are shown on the map in Figure 3-11.

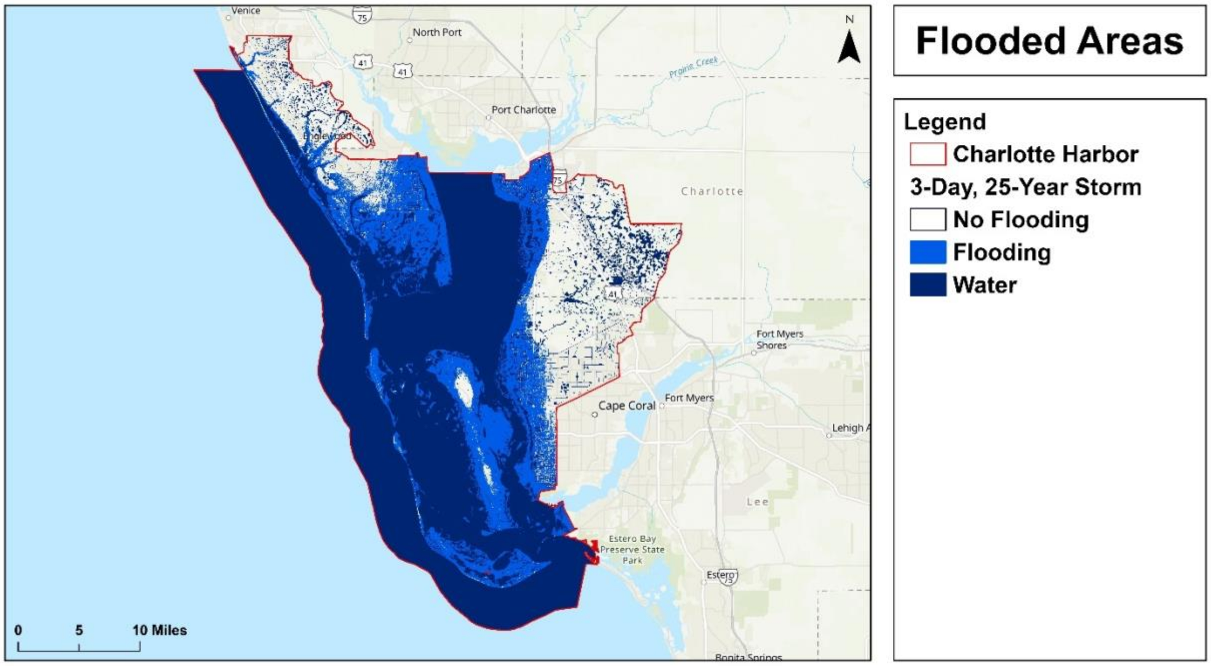


Figure 3-11. Flooded Areas During a 3-Day 25-Year Storm in the Charlotte Harbor Watershed

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 Charlotte Harbor 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 Charlotte Harbor 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. The risk of flooding in the Charlotte Harbor Watershed is shown on the map in Figure 3-12.

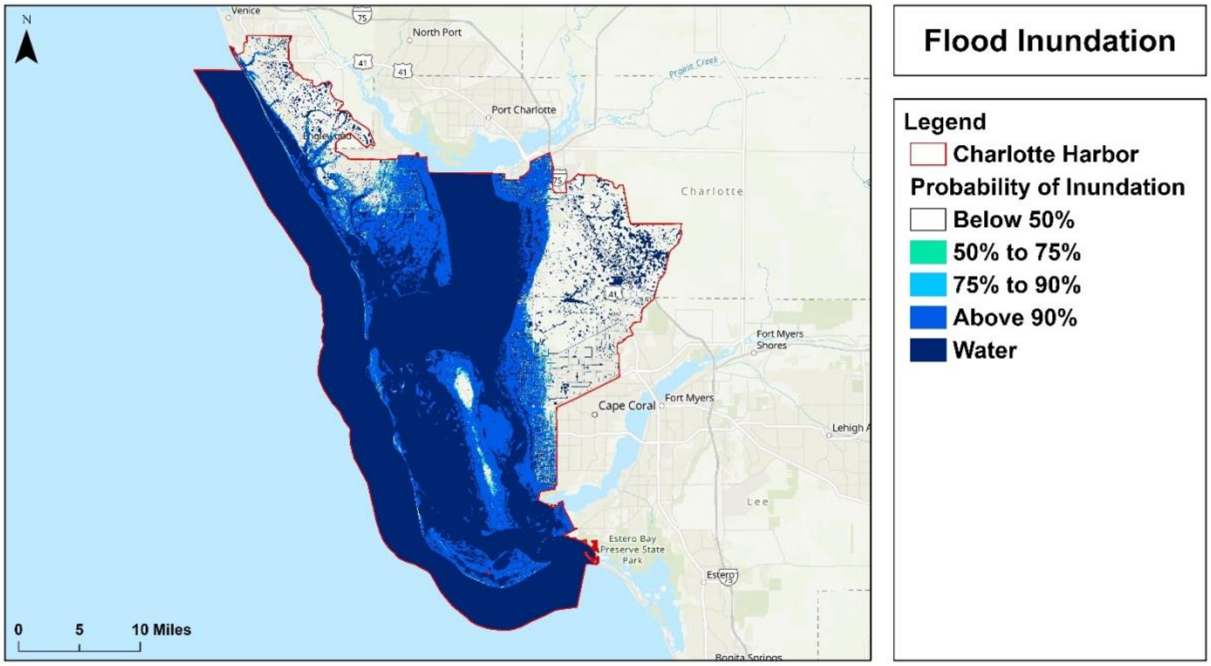


Figure 3-12. Probability of Inundation in the Charlotte Harbor Watershed

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. The Special Flood Hazard Areas designated by FEMA in the Charlotte Harbor Watershed are shown on the map in Figure 3-13. 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.

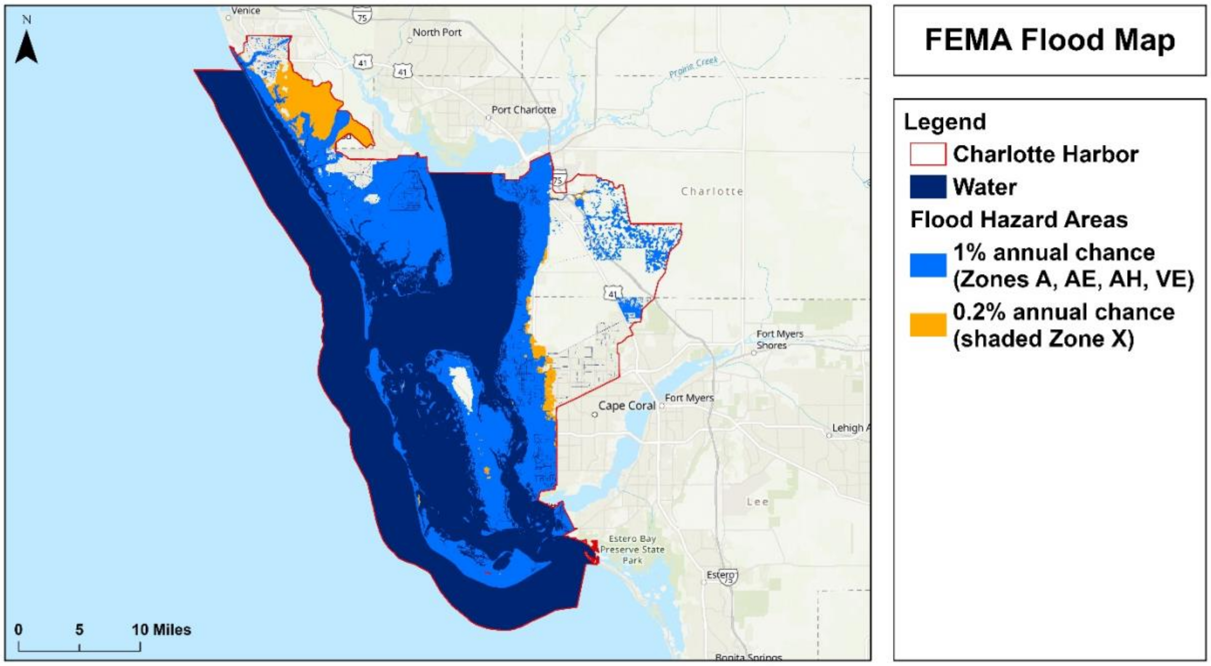


Figure 3-13. Designated FEMA Flood Hazard Areas in the Charlotte Harbor Watershed

Table 3-2. Comparison of FEMA's 1%-annual-chance Flood Hazard Areas and FAU's modeled high-risk region with a flood inundation probability above 90% in the Charlotte Harbor Watershed

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)	467.7 mi_2
Total area of FAU's high-risk region based on the 3-day 25-year storm event (classified above 90% probability of inundation)	161.1 mi_2
Total area of overlap between the high-risk regions designated by FAU and FEMA	158.7 mi_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%	33.9%
Percentage of overlap to FAU's high-risk region calculated as = (total area of overlap / total area of FAU's high-risk region) * 100%	98.5%

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.

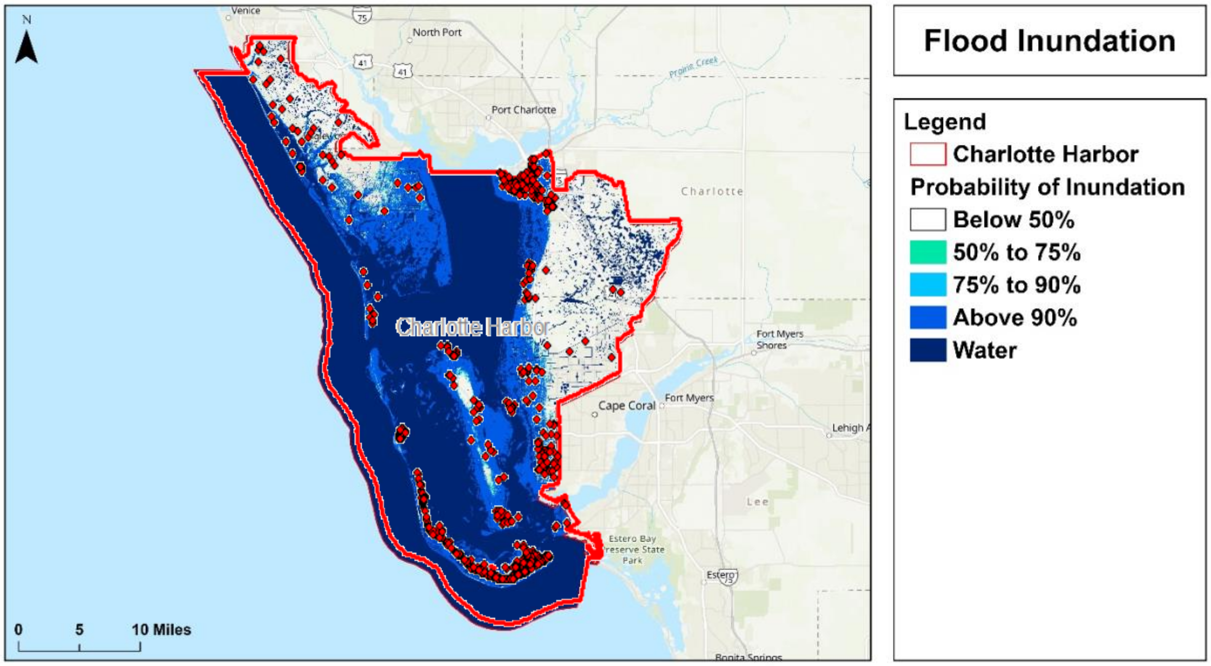


Figure 3-14 Repetitive loss areas from 2004 -2014 superimposed on the flood risk map created by FAU

3.4 Drill down in Developed Areas Loss

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 Cape Coral, Englewood, Punta Gorda, and Sanibel drill down areas of critical importance.

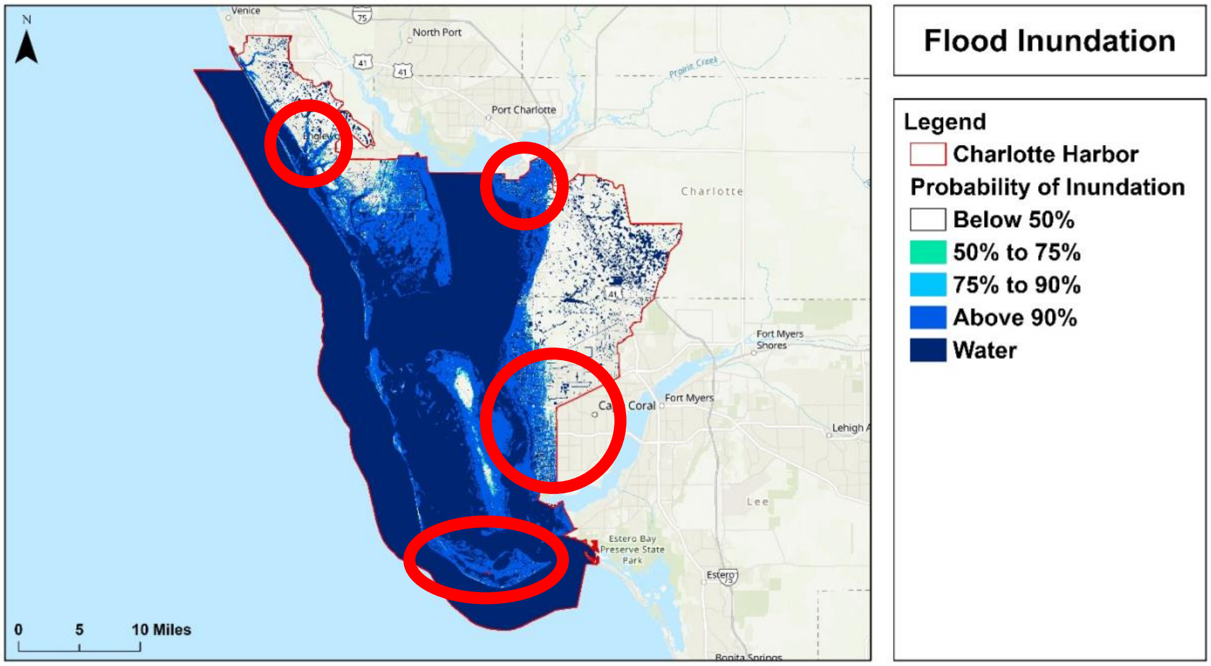


Figure 3-15. Location of drilldown areas.

By modeling the Charlotte Harbor Watershed’s 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. These areas are particularly vulnerable to flooding and are subject to further study through a scaled-down modeling approach. 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 Charlotte Harbor 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. At this scale, flooding generally occurs around large waterbodies, namely the Gulf of Mexico, Myakka River, Peace River, and Caloosahatchee River. 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 Charlotte Harbor Watershed provides additional drill down perspectives of the watershed, increasing the displayed level of detail. Several areas of critical importance in the Charlotte Harbor

Watershed have been examined, including Cape Coral, Englewood, Punta Gorda, and Sanibel in Figures 3-16, 3-17, 3-18, and 3-19, respectively.

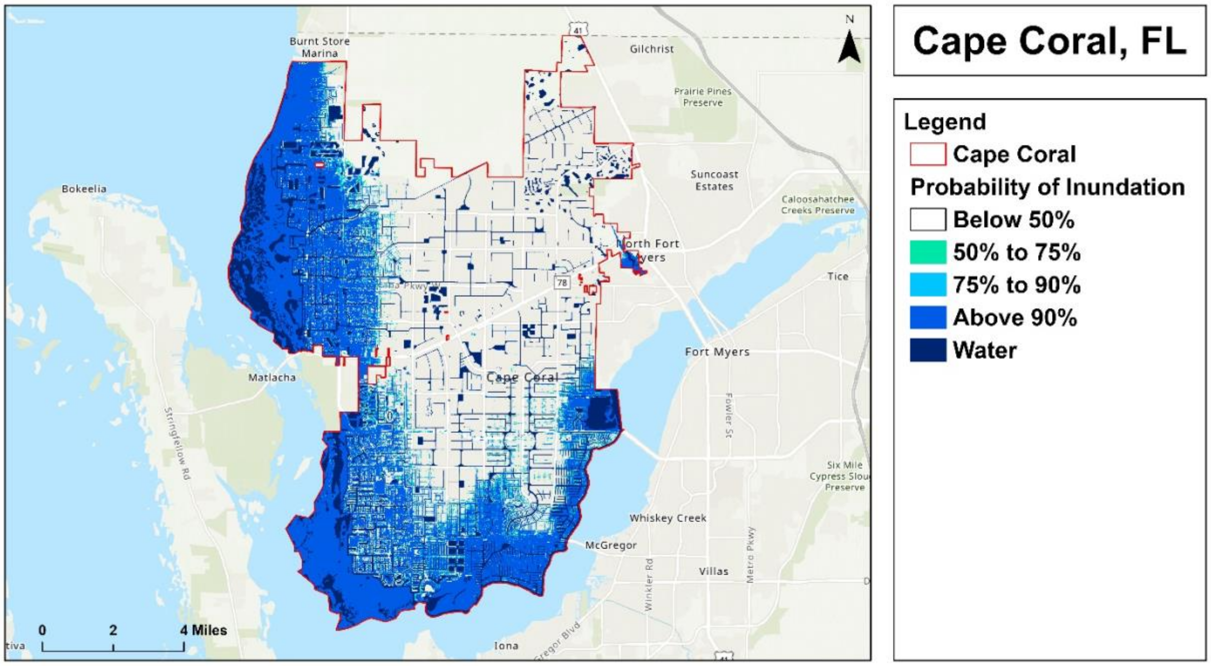


Figure 3-16. Flood risk map for the City of Cape Coral, FL

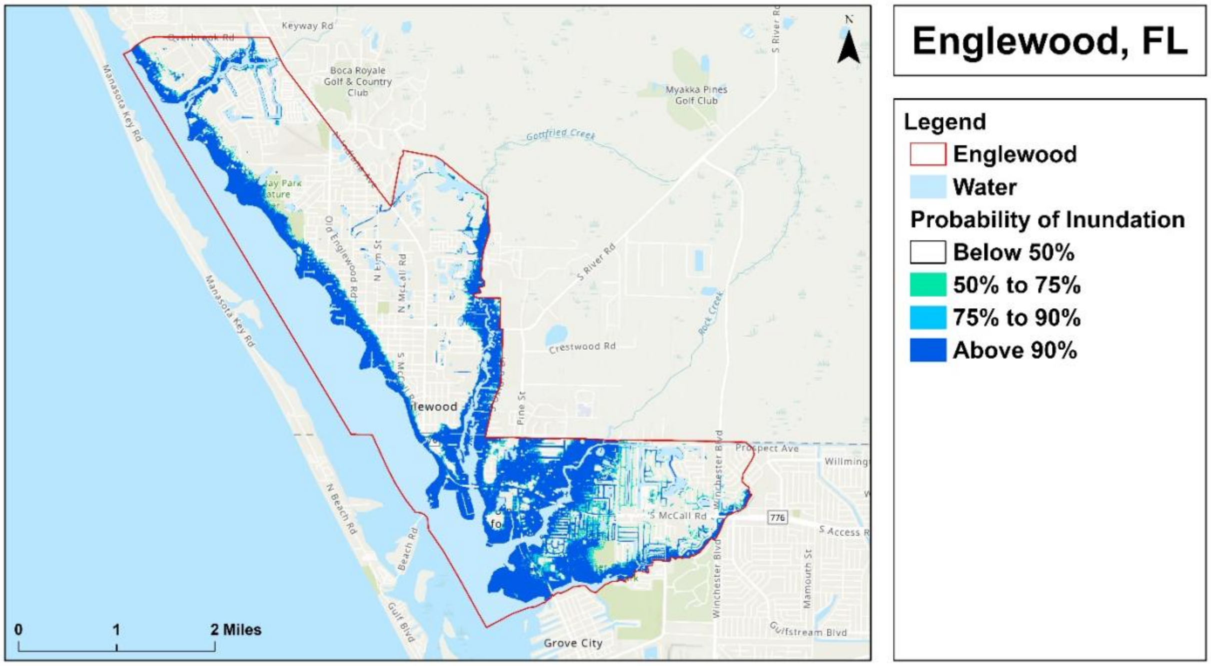


Figure 3-17. Flood risk map for the City of Englewood, FL

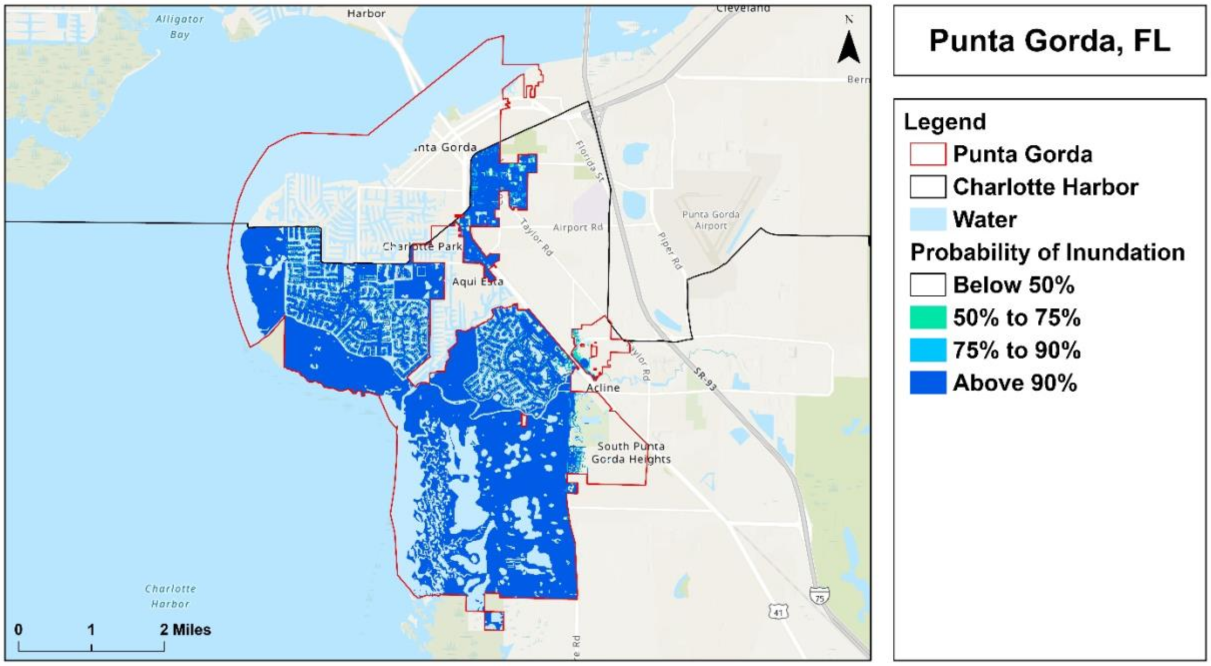


Figure 3-18. Flood risk map for the City of Punta Gorda, FL

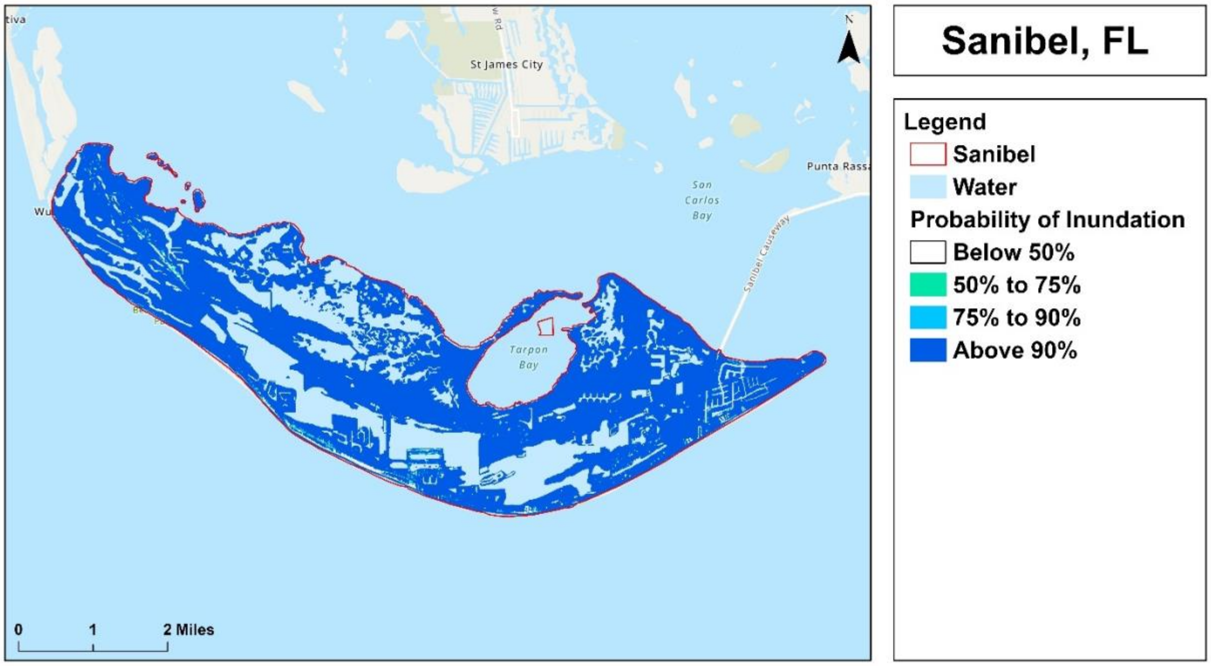


Figure 3-19. Flood risk map for the City of Sanibel, FL

4.0 Conclusion

The Charlotte Harbor Watershed covers approximately 886.5 square miles in southwest Florida across three counties, including Charlotte, Lee, and Sarasota Counties. Three major rivers flow into the watershed, including the Myakka, Peace, and Caloosahatchee Rivers. These river systems drain inland areas and outflow through the Charlotte Harbor and Caloosahatchee Estuaries into the Gulf of Mexico. It was determined that flooding will primarily occur adjacent to the major rivers and be localized to developed land areas along the coast. 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 Charlotte Harbor Watershed’s flood response to a 3-day 25-year storm. 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. The specific considerations, modeling, and analysis of the Charlotte Harbor Watershed were discussed to support the development of a comprehensive watershed management plan. The management plan will inform local efforts to prioritize funding for future mitigation and resiliency planning to protect vulnerable communities and infrastructure.

5.0 References

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