DRAFT

Basin 29A

Miami-Dade Watershed Case Study

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Principal Investigator: Gerardo Rojas, CEGE MS Student

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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 having 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 developing watershed management plans. There are several steps to address the development of watershed plans including the development of 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 Miami-Dade County, Florida, a watershed located in Southeast Florida that combines readily available data on topography, ground and surface water elevations, tidal data 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 permit local agencies to develop means to address high risk properties.

1.0 Introduction

Miami-Dade County is located in southeast Florida (see Figure 1.1), and is home to the City of Fort Lauderdale, Hollywood, Pompano Beach, Pembroke Pines and nearly 30 smaller communities. The county and watershed is coastal, so flood risks from king tides, rainfall, wet season thunderstorms and tropical storm activity are concerns for local officials and the nearly 2 million people who live in the watershed.

Over 30 miles of beachfront property exists within the county. The western half the County is part of the Water conservation areas maintained by the South Florida water Management District.

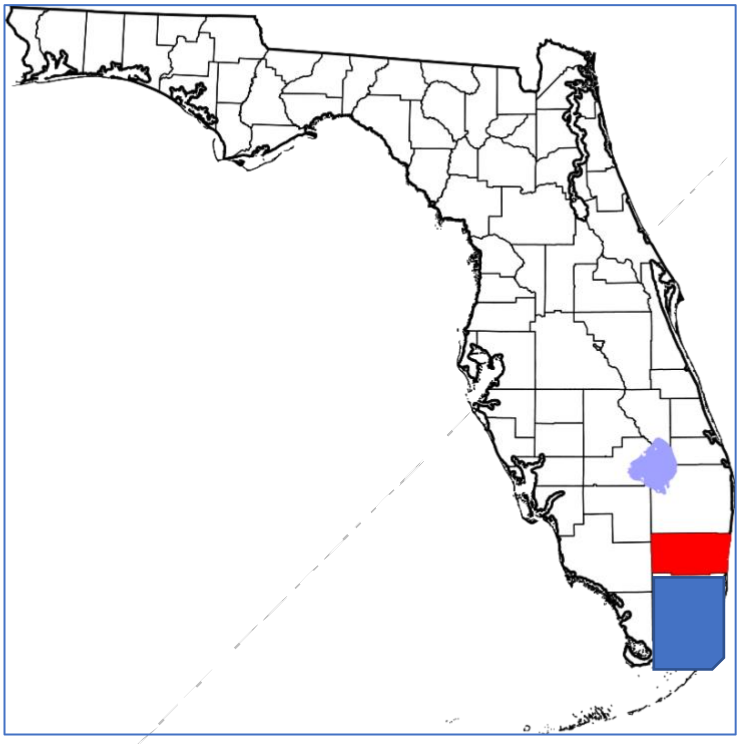
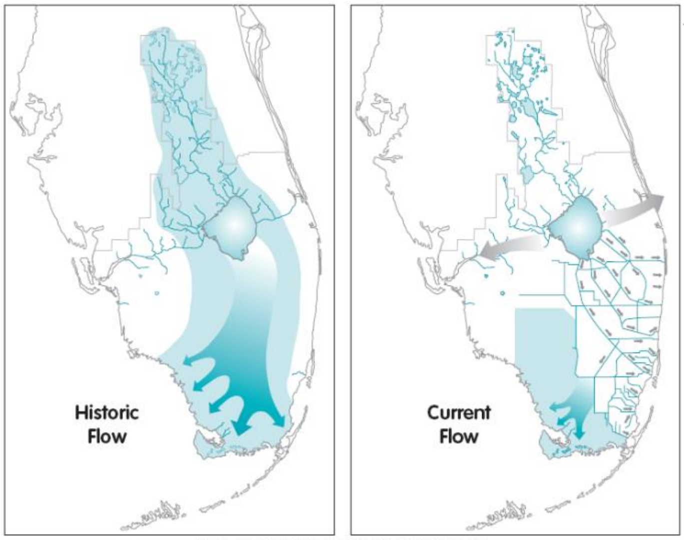


Figure 1.1 Location of Miami-Dade County, FL (blue, the lower half of the basin (red plus blue)

2.0 Summary of Watershed

2.1 General Description of Watershed

In South Florida, water supply, water quality, and health of the Everglades ecosystem are intrinsically linked. When attempting to evaluate the ecological health of Southeast Florida, one must look at the entire southern portion of the peninsula of Florida. Historically there were no barriers or canals to direct or control the path of water except a minor connection created by Native Americans between the Caloosahatchee and Lake Okeechobee for transportation purposes (Figure 1.2).



Source: South Florida Water Management District

Figure 2: Change in natural flow paths in South Florida (SFWMD, 2020)

The next modifications to the South Florida landscape were constructed in the 1880s by Hamilton Disston with the dredging of the Caloosahatchee River and the creation of drainage canals in the Kissimmee Upper Chain of Lakes. The dredging was conducted in order to drain the land to facilitate agricultural production and urban development. The C-44 Canal and the associated locks and structures were constructed between 1916 and 1928. This canal provided a navigable connection between the east and west coasts of Florida. It connects Lake Okeechobee to the south fork of the St. Lucie River and makes the St. Lucie Estuary one of the major outlets for water draining from the Upper Kissimmee and Lake Okeechobee basins.

The first efforts to contain Lake Okeechobee involved construction of a low levee and three drainage canals running south from Lake Okeechobee, the Miami, North New River, and Hillsboro canals between 1913 and 1917. In 1930, during the aftermath of the Storm of 1928, which pushed water out of the shallow lake and drowned thousands of people, the federal government authorized the US Army Corps of Engineers (USACE) to build the Herbert Hoover Dike. Over the next seven years, a series of levees, culverts, and locks were built to contain the lake, including 67 miles of dikes along the southern shore, effectively halting natural waterflows out of the lake to surrounding areas. In 1938, the USACE began to regulate lake levels, and lake inflows and outflows were altered to include structures and channelization to more effectively move water in and out of the lake. Modifications to the outlets on the east and the west sides of the lake made the St. Lucie and Caloosahatchee rivers the primary outlets from the lake.

However, due to a series of back-to-back hurricanes in 1946 and 1947 and resulting significant flooding in South Florida, the need for additional features to manage excess water became evident. In response to these conditions, the State of Florida requested assistance from the federal government. As a result of that request, the Central and Southern Florida Flood Control Project (C&SF Project) was authorized by the U.S. Congress in 1948. Subsequently, the USACE produced a comprehensive water management plan for flood control that became the blueprint for the project to drain the land quickly to tide to allow for urban and agricultural development. It took approximately 20 years to implement the project features, canals, levees, pump stations, and other structures that were built in the 1950s and 1960s. The channelization of the Kissimmee River was completed in 1971.

By 1969, over 1800 miles of primary canals were constructed to reduced groundwater levels along the coast, which enabled the development that exists today. The canals serve as flood protection for low lying areas because the currently drain by gravity to the ocean. Figure 1.3 shows the canals in the SFWMD service area. These areas would be flooded in the summer months without the canals. However, as a result of the canals reducing groundwater levels, combined with lessened historical flows to the Everglades and less water standing in the Everglades during the summer months. In addition, the need to control Lake Okeechobee levels requires discharges through the

St. Lucie River and Caloosahatchee watersheds. The timing of these discharges are historically different than the natural system, creating disruptions in water quality and supply.

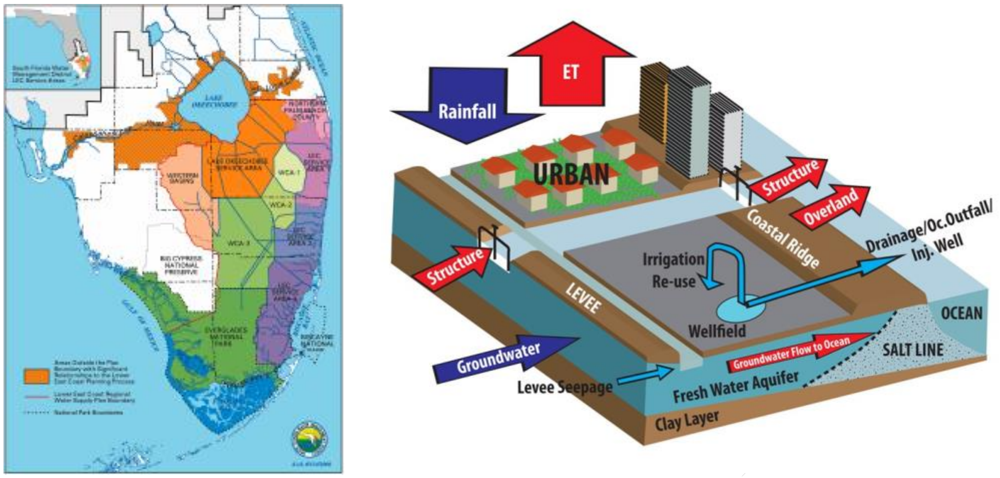


Figure 1.3 South Florida Water Management District LEC service area and drainage pattern after C&SF drainage improvements (SFWMD, 2020 for figure on the left)

As a result, south Florida and the Caloosahatchee watershed landscapes have been dramatically altered by construction of this elaborate system of canals, dikes, levees, flow control structures, pumps, and other water control facilities. These changes also allowed south Florida to be one of the largest metropolitan areas in the United States, and for the Fort Myers area to develop to nearly 1 million people at present.

The watershed also affects local flood management. Currently, rain falls on impermeable land where the water collects in pools or runs off rapidly where development has taken place. Stormwater is collected locally in neighborhoods in swales, ponds, small lakes, ditches and small canals. These are connected through canals and conduits to the secondary system under the jurisdiction of local drainage districts or city or county governments, which in turn connect to the major waterways controlled by SFWMD and USACE. The highly engineered stormwater drainage system and water control structures have effectively enabled management (lowering) of water tables to permit development.

2.1.1 *Climate/Ecology*

The historical character of the south Florida has been shaped in part by how much freshwater is delivered, how fast this water enters the wetlands and estuaries, and the quality of that water. Rainfall averages over 50 inches per year but evapotranspiration and rainfall do not coincide which makes water supply planning difficult (see Figure 1.4).

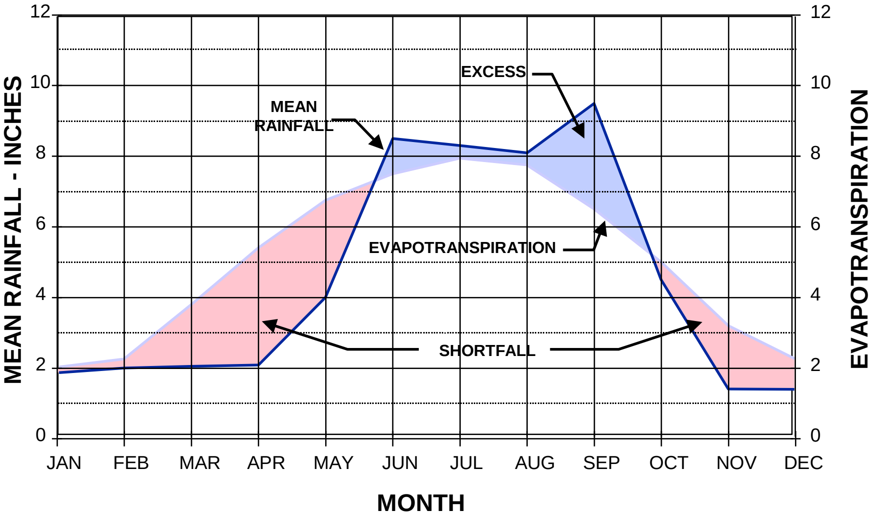


Figure 1.4 Evapotranspiration vs. Rainfall

2.1.2 Topography and Soils

While the native soil and topography create an environment that is highly permeable and capable of absorbing significant percolation of the water into the soil, the change in the land use has resulted in water falling on impermeable land where the water collects in pools or runs off rapidly where development has taken place, in direct contrast to the natural condition. The result of run-off flowing over impermeable regions often results in large-scale flooding because the storm intensity (rate of rainfall) cannot be used to design facilities due to economics.

2.1.3 Boundaries/Surface Waters

The key elements of the watershed include Atlantic Ocean, Lake Okeechobee, the Everglades, the Big Cypress swamp, the canal system and the rainfall over the area.

2.1.4 Hydrogeological Considerations

The entire south Florida plain is underlain by beds of porous limestone that absorb water standing on the land during the wet season (mostly in the Everglades). These limestone formations contain large volumes of fresh water - perhaps more than in any other limestone formations in the eastern United States. Southeast Florida is underlain by a series of interspersed rock formations with varying permeability. The uppermost formation generally encountered along the southeast coast is the Pamlico Sand formation of the Biscayne Aquifer. This surficial, Pleistocene Age deposit occurs throughout most of South Florida and consists predominantly of fine to medium-grained quartz sand, with varying amounts of shell, detrital clays and organic constituents. Thickness of the sand is variable in the area, but averages approximately 40 feet. Under the surficial sand lies a series of fossiliferous, sandy limestones, which are part of the Anastasia or Fort Thompson formation. These also date to the Pleistocene Age and often occur interwoven with each other and the Key Largo Limestone, making distinction difficult. Together with the Pamlico Sand layer these formations compose the wedge-shaped Biscayne Aquifer, which gains thickness as it approaches the coast, where it can be as much as 400 feet deep (but generally less than 200 feet).

The Biscayne Aquifer is one of the most productive aquifers in the world, since its components are all very permeable and full of water. The Biscayne Aquifer often contains two distinct sandy, limestone beds that are generally separated by 40 to 50 feet of sand. The upper bed occurs between 40 and 100 feet below land surface (bls) and the lower bed between 110 and 200 feet bls. The Tamiami Formation of the Pleistocene Age lies beneath the Anastasia/Ft Thompson Formations. The Tamiami Formation consists primarily of fossiliferous, sandy, limestones that have well-developed secondary porosity and are highly permeable.

The water levels in the Biscayne Aquifer fluctuate in response to rainfall, drainage and withdrawal for irrigation and potable use. Since the Biscayne Aquifer is exposed to the surface with little in the way of confinement, the only major recharge in the area is rainfall, most of which occurs between

June and October. During the winter months the aquifer's water level continues to decline without some form of supplemental recharge. The canals operated by the South Florida Water Management District are designed to provide flood protection, but also serve to limit drawdown induced by the canals by delivering water stored in Lake Okeechobee during the dry season. Western Miami-Dade wellfields benefit due to their proximity to the water conservation areas operated by the South Florida Water Management District, but little help is available for eastern wellfields such as the City of Dania Beach's. As a result, the aquifer levels in eastern wellfields steadily decline during the winter months, which subject the Biscayne Aquifer to contamination from saltwater intrusion, as well as surficial activities. Several areas of the Biscayne Aquifer already have saltwater intrusion problems, the most extensive occurring along the coast and the canals connected directly to the coast without salinity barrier/control structures. Generally, the water level in the Biscayne Aquifer averages 1 to 2 feet ngvd, except during extremely wet and dry periods. The Biscayne is the only fresh aquifer system – all the rest contain brackish or salt water.

Beneath the Biscayne Aquifer, is a thick, confining layer known as the Hawthorn Group. The Hawthorn Group dates back to the Miocene Age and contains two formations - the Peace River Formation and the Arcadia Formation. The Hawthorn Group Aquifers are used for water supply in some areas of south Florida, but have low permeability. The Hawthorn Group beneath Miami-Dade County appears to act as a barrier between the saline water of the underlying Floridan Aquifer and the fresh Biscayne Aquifer.

2.1.5 Special Features

The major features for the watershed are the ocean on the east and the water conservation areas on the west. The coastal ridge average 10 ft above sea level – it is located 2 miles off the coast. As a result, most of the watershed is completely managed by people.

2.2 Socio-economic Conditions of the Watershed

2.2.1 Demographics (US Census, 2010)

As of the 2015 5-year ACS, Miami-Dade County had 1,843,152 people, 670,284 households, and 425,680 families. Of the 670,284 households in Miami-Dade County, 26.2% had children under the age of 18 living with them, 43% were married couples living together, 15.6% had a female householder with no husband present, and 36.5% were non-families. 29.6% of all households were made up of individuals and 11.6% had someone living alone who was 65 years of age or older. The average household size was 2.73 and the average family size was 3.43.

In the county, the population was spread out with 21.7% under the age of 18, 8.5% from 18 to 24, 26.9% from 25 to 44, 27.7% from 45 to 64, and 15.0% who were 65 years of age or older. The median age was 40 years. For every 100 females, there were 94.4 males. For every 100 females age 18 and over, there were 98.7 males.

The racial makeup of the county was 62.3% White, 17.1% Hispanic or Latino of any race), 30% Black or African American[, 5.07% Asian, 2.20% from two or more races, 0.66% Native American, 0.16% Pacific Islander, and 0.20% from some other race.

As of the 2015 5-year ACS, the median income for a household in the county was $51,968, and the median income for a family was $61,809. Of full-time workers, males had a median income of $46,372 versus $39,690 for females. The per capita income for the county was $28,381. About 11.2% of families and 14.5% of the population were below the poverty line, including 19.9% of those under the age 18 and 12.6% of those aged 65 or over.

The age distribution is 22.4% under the age of 18, 8.4% from 18 to 24, 27.2% from 25 to 44, 27.7% from 45 to 64, and 14.3% who were 65 years of age or older. The median age was 39.7 years. For every 100 females, there were 93.9 males. For every 100 females age 18 and over, there were 91.0 males.

2.2.2 Property

The community is primarily residential with small concentrations of commercial activities along US 1, the beach and the larger cities.

2.2.3 Economic Activity/Industry

Employment indicates the County is a major component of the state GDP including banking, cruise line and port activity in Por Everglades, tourism, real estate and construction. There is no agriculture to speak of in the County and most available property is developed.

3.0 Watershed Analysis

3.1 Data Sets

3.1.1 Topography

Figure 3.1 shows the results of the LiDAR DEM processed conducted for the County. Based on the data developed by Romah (2012), Wood (2015) and Zhang et al (2020), The LiDAR uses 3 meter tiles with +/- 4inches of accuracy. The highest points are the three landfills that are approximately 100 ft above sea level. The entire County is low – the high spot is in Coral Bales on Biscayne Bay. For reference, Miami is in central Miami-Dade County near the coast. The water conservation areas are the western boundary. They do not receive any water from the developed area o Miami-Dade County

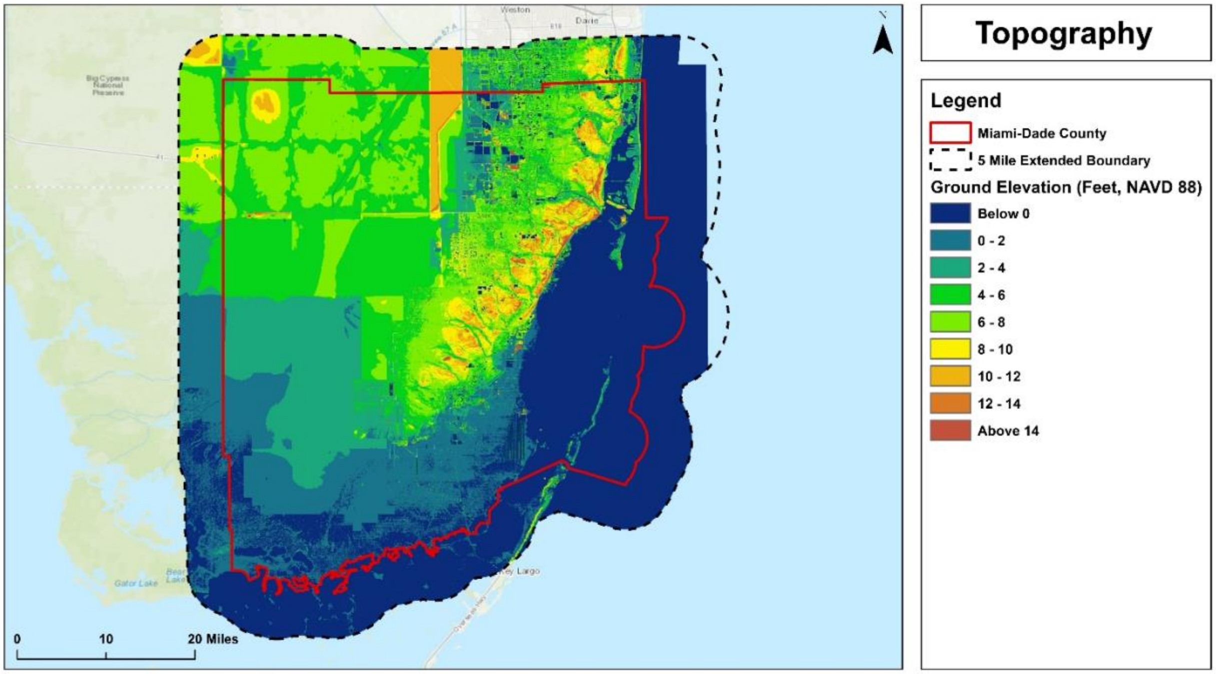


Figure 3.1 Topography of Miami-Dade County based on Lidar DEM

3.1.2 Surface Waters

Figure 3.2 shows the canals and surface waters in Miami-Dade County, along with the location of the structures. The structures are relevant because they alter the groundwater level upstream of the structures, and therefore downstream of the coastal structures are open to tide. As a result, the water fluctuates with the level of the ocean. For Miami-Dade County, the tidal information demonstrated the surface and ground water levels interact as one, there is a need to capture groundwater data. Romah (2011), Bloetscher and Wood (2016) and others have noted that both tides and groundwater are increasing with time (Figure). As a result, the groundwater dataset was developed which date range of 2000 to 2018. Prior work by Romah (2012) showed there was a 1:1 relationship along the coast with the level of the tides and the groundwater. Groundwater was never below the tides unless in a coastal wellfield and even then the difference was minimal

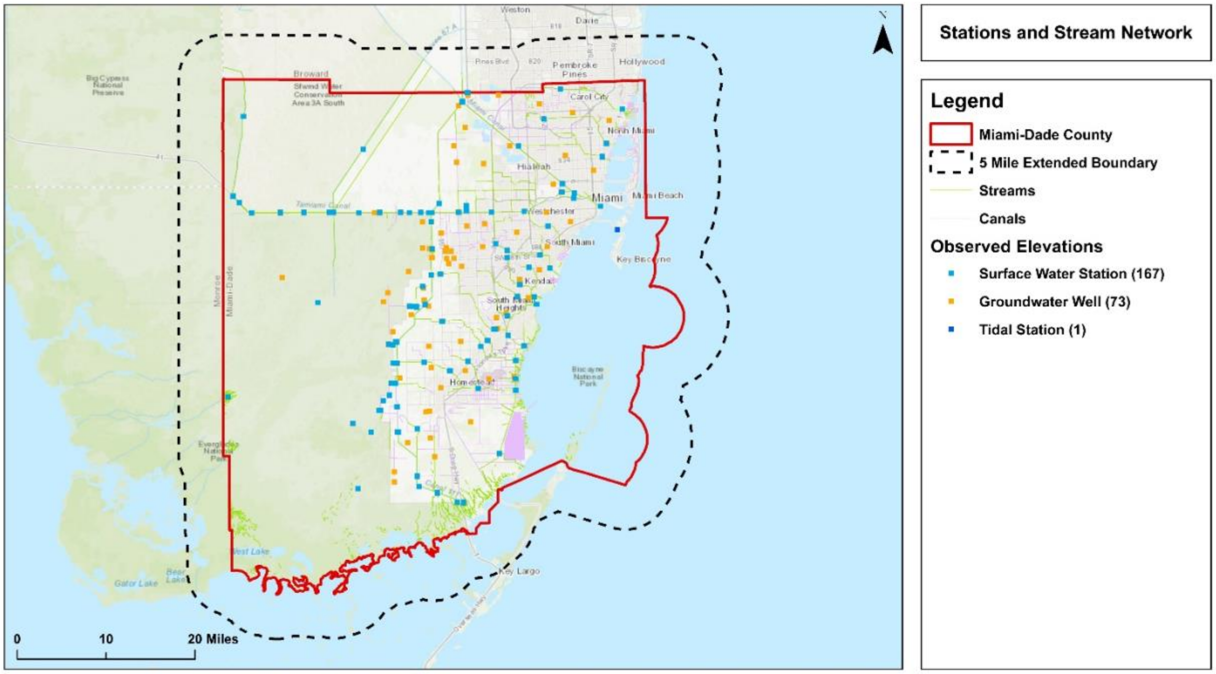


Figure 3.2 Water bodies and canals in Miami-Dade County

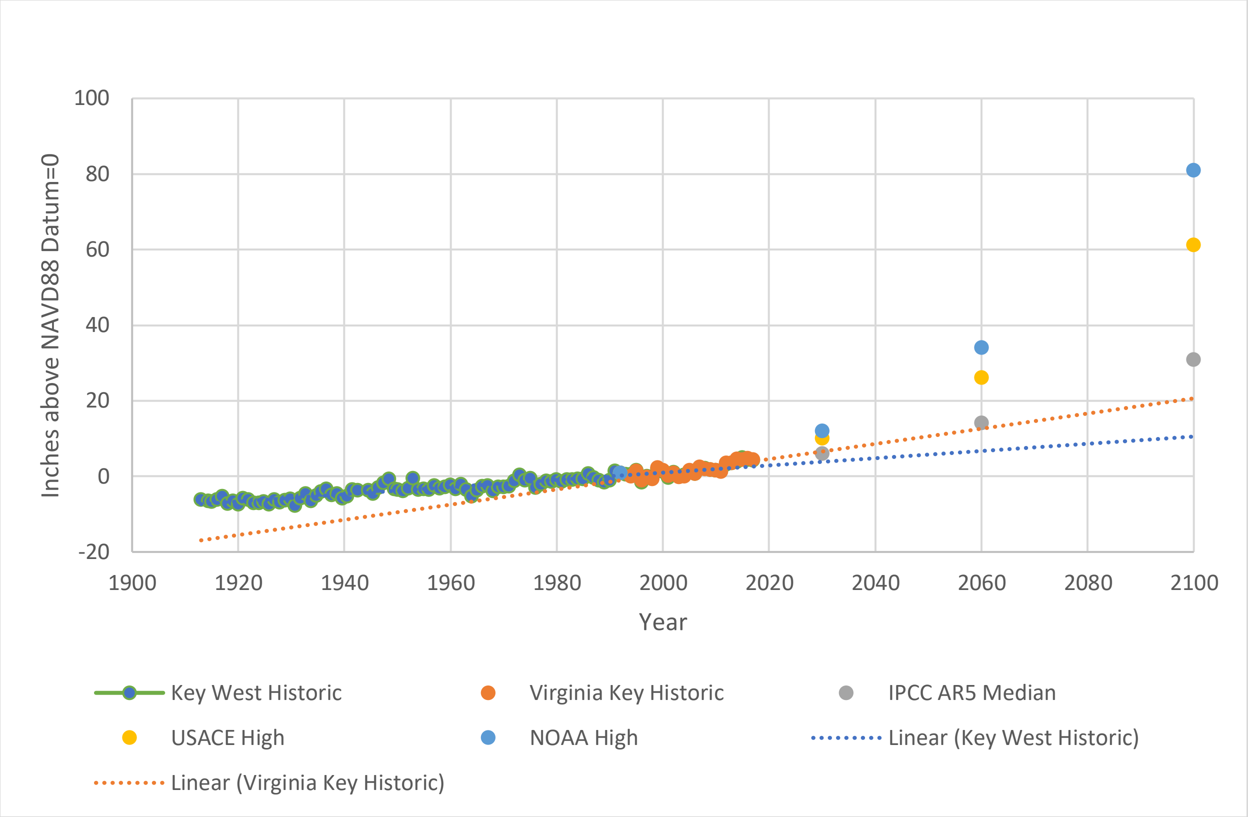


Figure 3-3. Increasing tides and projected future increase – 99th percentile

3.1.3 Groundwater

There are over 50 groundwater wells located in and around Miami-Dade County were used to develop Figure 3.5. The drainage canals installed between 1930 and 1960 control groundwater levels throughout the County. Groundwater is lowest near canals and the coastal ocean and rises with he wet season and king tides. Water shows to be lowest near the coast, as the well indicate. Southeastern Miami-Dade, a place a known concern with respect to aquifer levels, was the most impacted, in part because the closest salinity structure is at US 441 in Dave – 10 miles from the ocean, creating a major potential for both aquifer drainage and saltwater intrusion (experienced0.

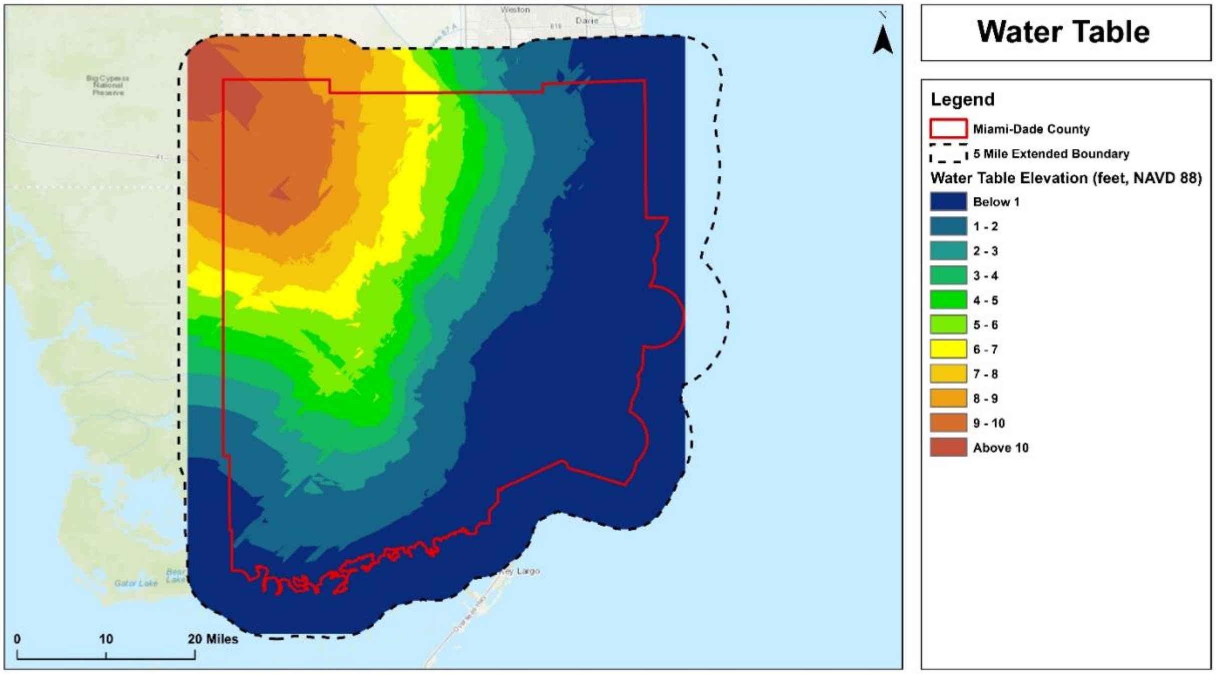


Figure 3-4 Groundwater layer

3.1.4 Unsaturated zone

To find the unsaturated zone, the groundwater layer, as influences by the surficial canals, was subtracted from the topographic layer to show the apparent unsaturated zone. In Miami-Dade County there is much of the County that has minimal difference between the surface and the surficial aquifer levels in the fall, except along the coast l ridge, as shown Figure 3-5. Water can seep into this layer, but is must be adjusted for the actual void space.

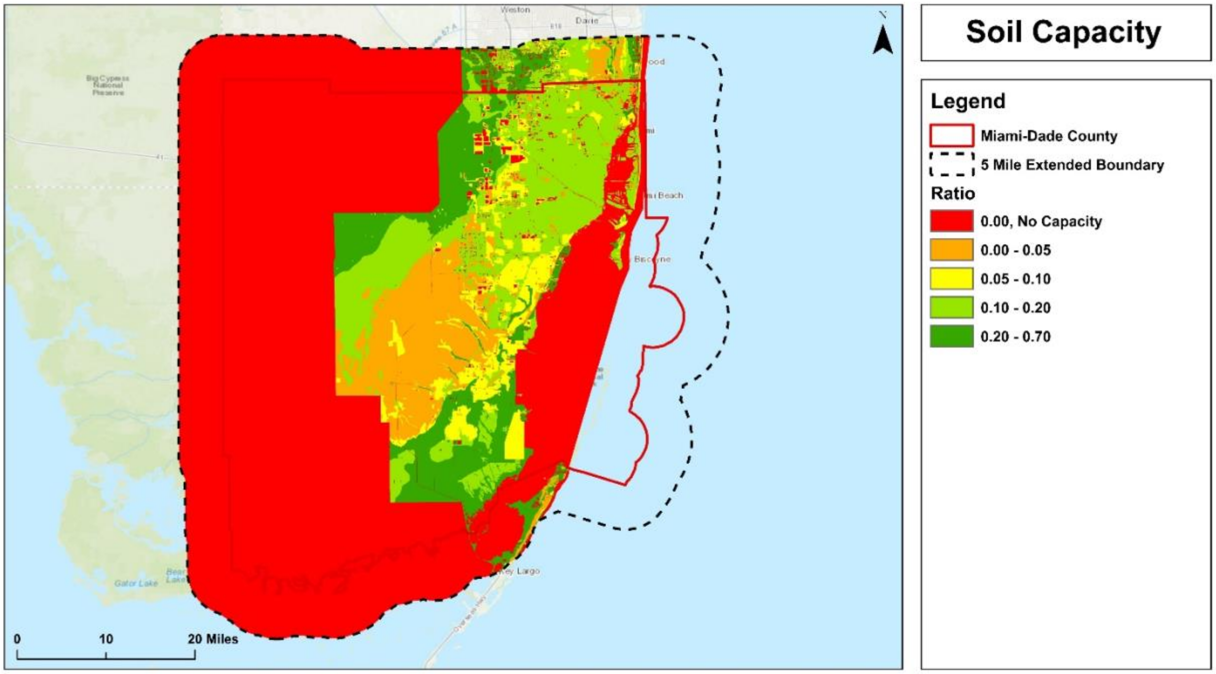


Figure 3-5 Unsaturated zone

3.1.5 Soil Capacity

The void space comes from a state-wide GIS file of soil void capacity noted in the Methodology section. Figure 3-5 is multiplied by the soil void ratio layer to give the actual amount of water that can enter the soil before filling it. As shown Figure 3-6, most of the County has minimal soil storage capability.

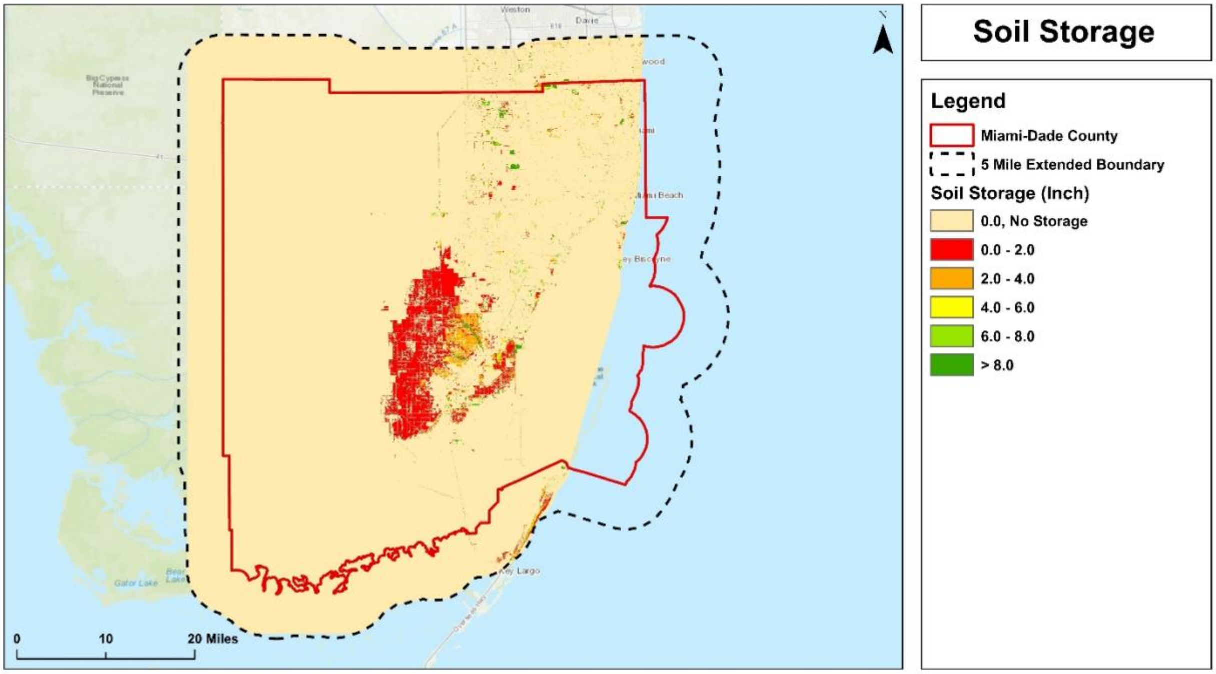


Figure 3-6 – Soil storage capacity

Figure 3-7 is the impervious areas, primarily roads. These are areas where water cannot seep into the soil and as a result seep to unsaturated areas. Impervious areas also include water bodies (Figure 3-8). These layers, along with the soil capacity layer in Figure 3-6, are quired to perform the flood analysis.

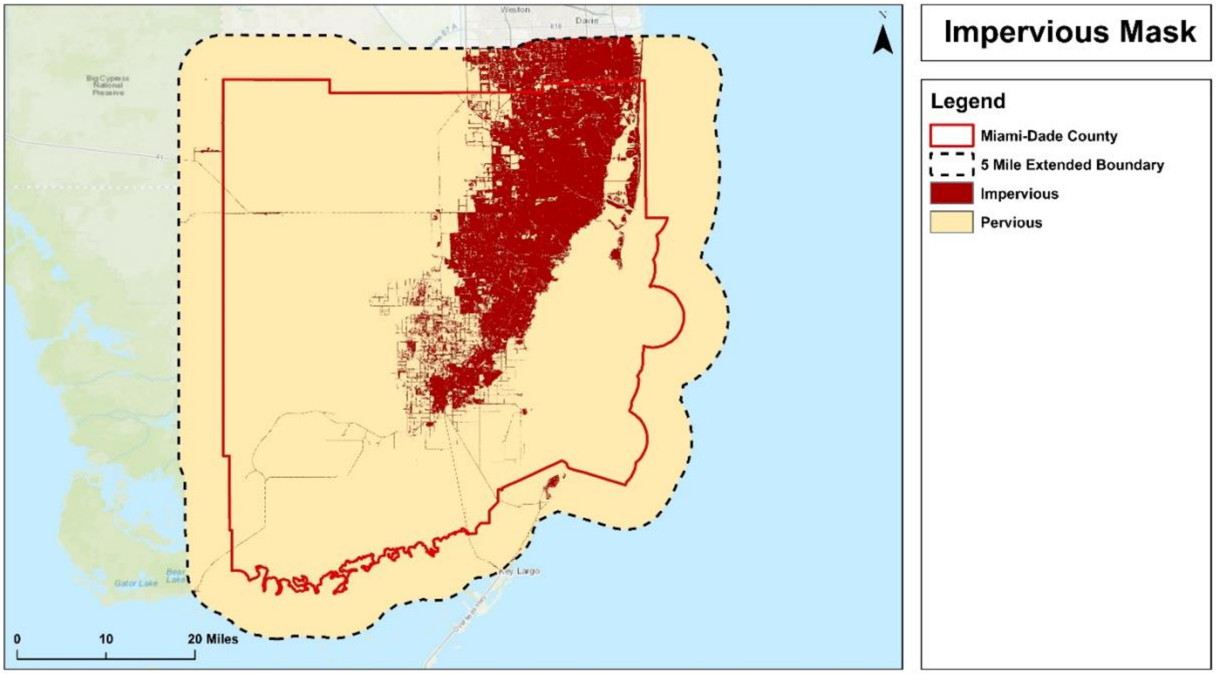


Figure 3-7 Impervious areas in Miami-Dade

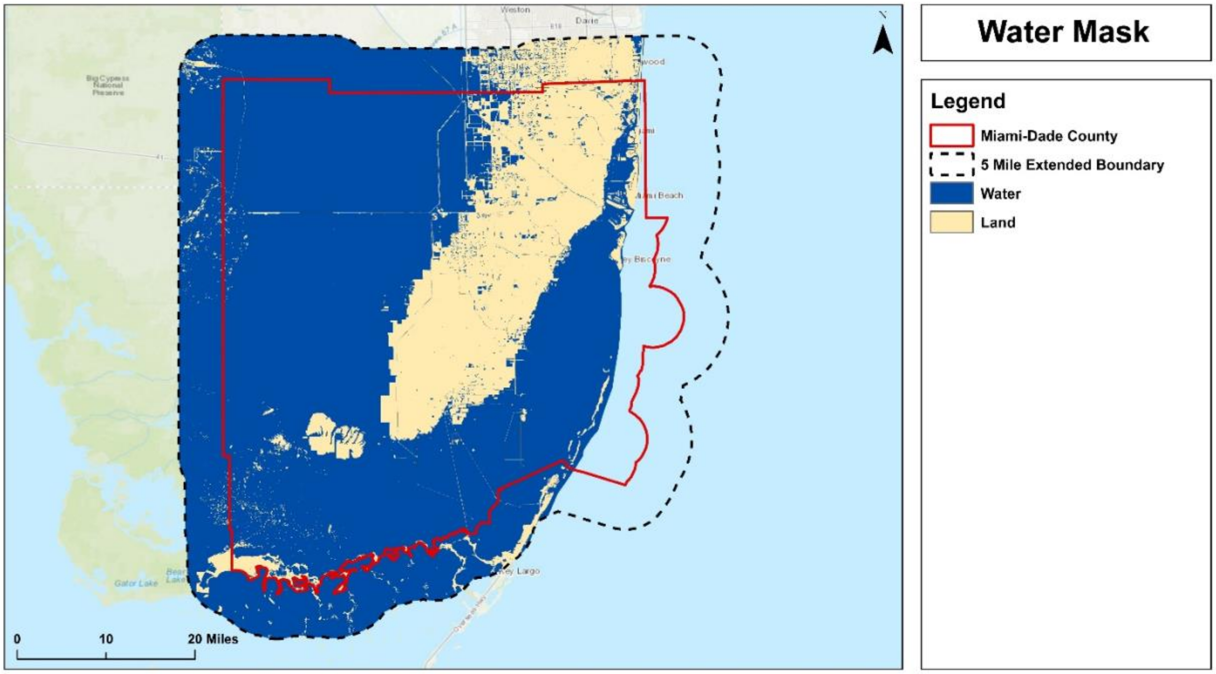


Figure 3-8 Water bodies

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 Caloosahatchee 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.

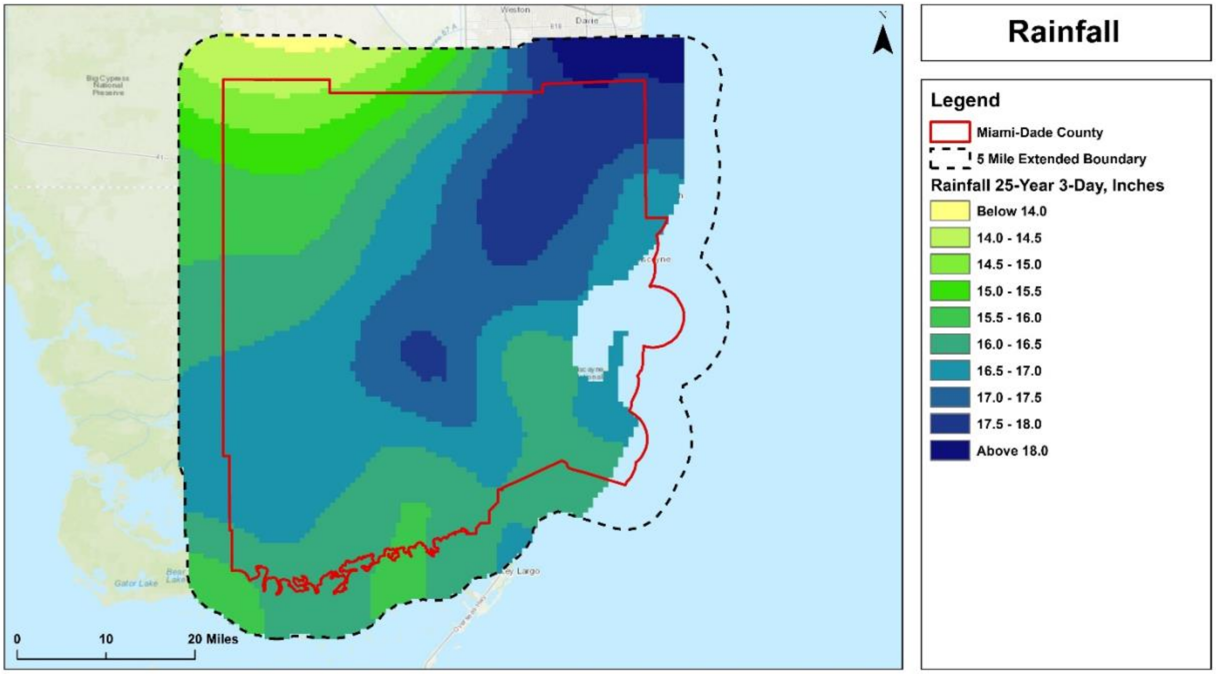


Figure 3.9. Rainfall During a 3-Day 25-Year Storm in the Miami-Dade Watershed

3.2 Modeling Protocol (What was done for this basin)

CASCADE 2001 is a multi-basin hydrologic/hydraulic routing model developed by the South Florida Water Management District (SFWMD). The model develops solutions by basin. A basin is defined as an area where all the water that falls via rainfall stays in an area and travels to an outlet. The areas of the basin and the longest time it takes the runoff to travel to the most distance point to reach the point of discharge must be estimated. Rainfall is also needed. The waterway flow paths from ArcHydro as shown for Miami-Dade County n Figure 3-2.

3.3 Modeling Results

3.3.1 Cascade Results

Based on a 3 day-25 year rainfall, the requirements for stormwater permitting in south Florida, flooding is noted along the coast, but also in many inland areas, especially to the far west.

3.3.2 Vulnerability to Flooding

Figure 3.10 is a probability of flooding per the methodology discussed earlier. Note this is not the storm modeled by FEMA (100 year event) and does not use exactly the same probabilities for flooding that FEMA does. FEMA flood hazard areas identified on the Flood Insurance Rate Map are identified as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a “1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. SFHAs are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, and Zones V1-V30. Moderate flood hazard areas, labeled Zone B or Zone X (shaded) are also shown on the FIRM, and are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood. The areas of minimal flood hazard, which are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded).”

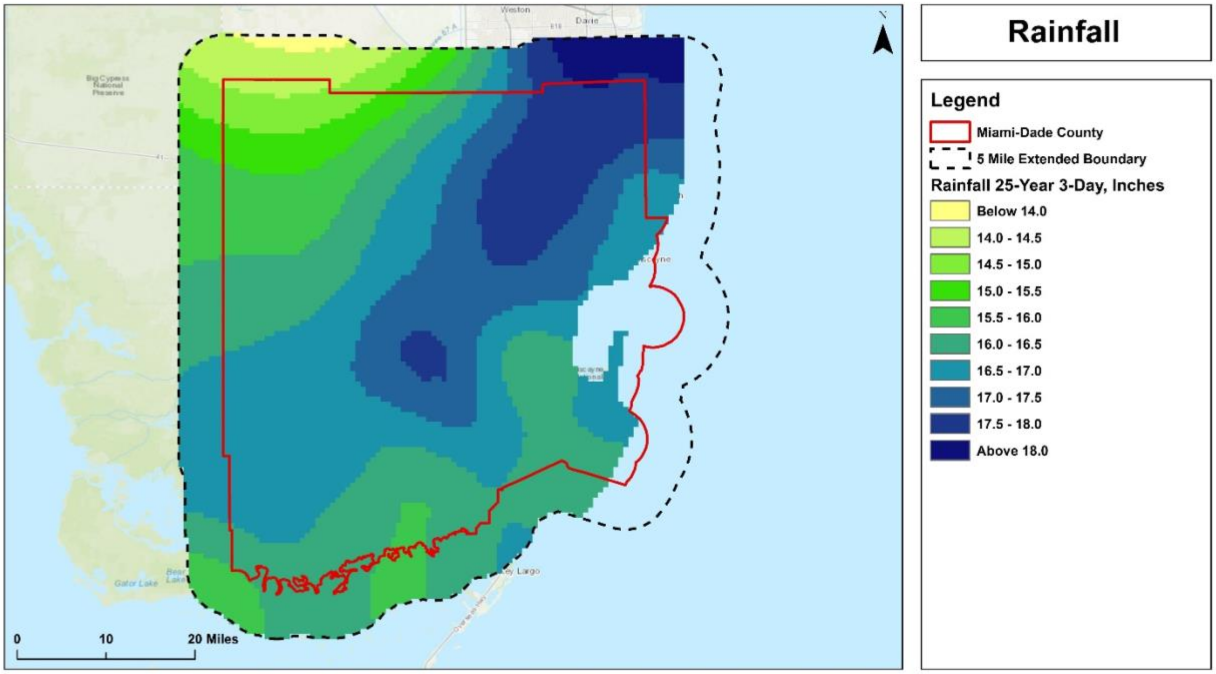


Figure 3-10 Flooding predicted based on the 3 day 25 year storm.

3.3.3 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 (see Figure 3.11). Much of the County floods.

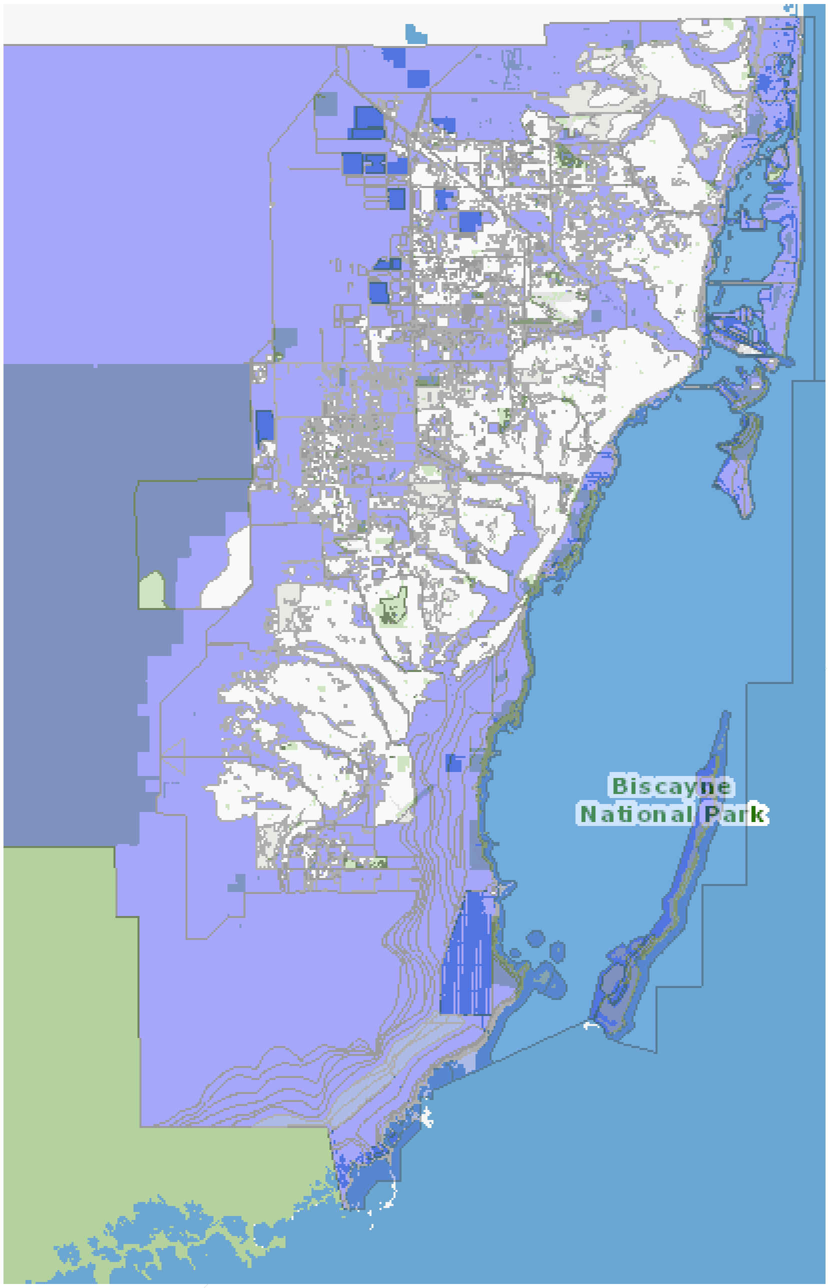


Figure 3.11. Designated FEMA Flood Hazard Areas in the Miami-Dade

3.3.5 *Repetitive Loss Comparison*

Figure 3.12 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. This compares will with the FEMA map despite a different process to predict flooding.

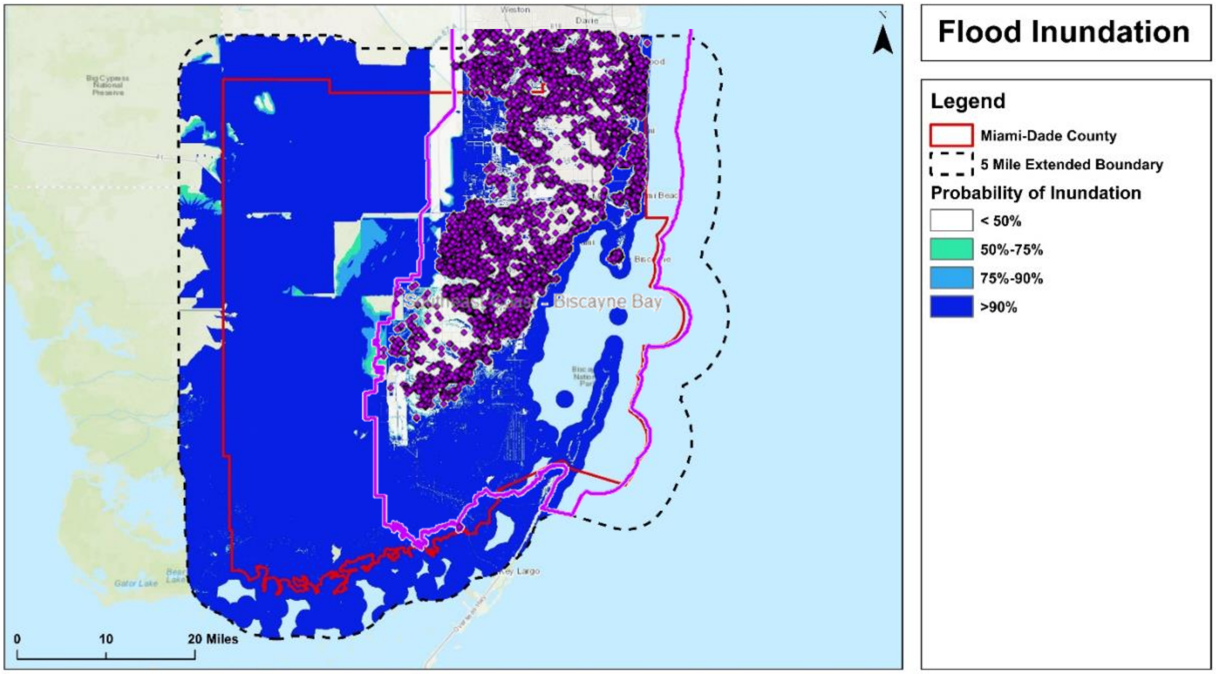


Figure 3.11 Repetitive loss areas from 2004 -2014 superimposed on the flood risk map created by FAU.

4.0 Conclusions

The effort discussed herein focusses on the development procedures for a screening tool to assess risk in Miami-Dade County, Florida, a watershed located in Southeast Florida that combines readily available data on topography, ground and surface water elevations, tidal data 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 permit local agencies to develop means to address high risk properties.

In the modeling considered all aspects of data, which influence the flooding over the region. The terrain surface is the main influencer for flood happenings and groundwater table elevation, soil storage capacity, Land use and Landcover, Water bodies, Rainfall event for 25 years, drainage patterns, catchments of the basin. CASCADE 2001 is a multi-basin hydrologic/hydraulic routing model developed by the South Florida Water Management District (SFWMD). This software helps to simulate the basin more concisely to recreate the earth that users utilize to work on the Florida Watershed Modeling Project. The Output of Hydrologic Modelling shows the results for the headwater height of the basin, using the values to create flood inundation using the topographic surface. A flood happens in the basin, when the headwater height reaches above 19 feet, which will affect the most of the areas near or around the river line because when water increase in the river due to heavy rainfall event or water intrusion happens due to sea level rises from the coastal zone. The places near to the river line are the most probable flood zones and elevation will be very low, so the water gets drains from the higher elevation to lower elevation.

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