DRAFT

Ocklawaha Watershed

BASIN 13

FLORIDA ATLANTIC UNIVERSITY

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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 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.

This report focusses on the application of the screening tool to assess risk in Ocklawaha River Watershed, 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

Ocklawaha River watershed is in central Florida (see Figure 1), and spans 6 counties, including Orange, Lake, Polk, Marion, Putnam, and Alachua. This watershed is an inland portion of the Florida Peninsula, and consists of 2,769 square miles. Hydraulic and sociopolitical factors have resulted in the Department of Environmental Protection dividing the watershed into Upper Ocklawaha River, Lower Ocklawaha River, and Orange Creek sub basins (Learn About Your Watershed, 2014). Major communities in the basin include Gainesville, Apopka and Ocala, along with Clermont, Lady Lake, Leesburg and Haines City.

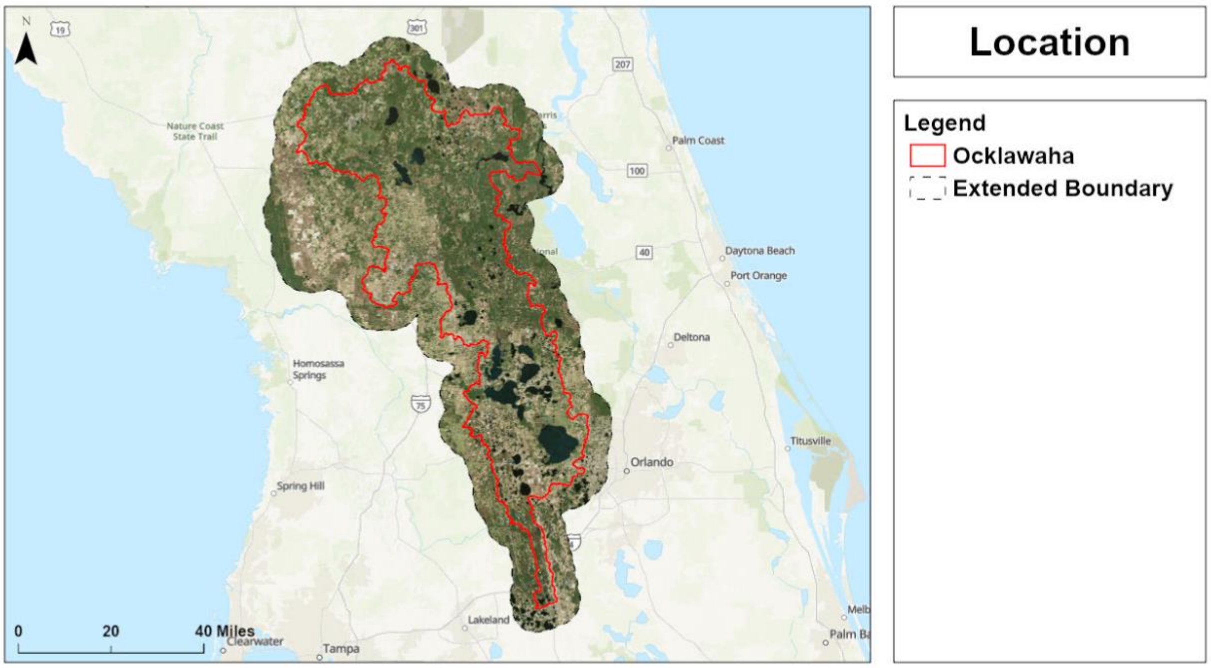

Figure 1 Location of Ocklawaha TMDL, Florida.

2.0 Summary of Watershed

2.1 General Description of Watershed

2.1.1 Climate/Ecology

The Ocklawaha River watershed is characterized by its humid subtropical climate with two seasons, a hot and wet season from May to October, and a mild and dry season from November through April. Rainfall averages 47 inches per year and the average temperature is 72 degrees Fahrenheit.

2.1.2 Topography and Soils

Elevation of the Ocklawaha River Basin ranges from 0 to 308 feet. Areas of high elevation are condensed mostly in the north and south of the basin, and areas of low elevation are located near St. Johns River. On the western edge of the basin is a significant geologic feature - the Cody Escarpment or Cody Scarp. The Cody Scarp is an erosional geomorphologic feature which represents the break between the surface-water dominated hydrology of the Northern Highlands, and the groundwater dominated hydrology of the Coastal Lowlands. The Cody Scarp region is characterized by active sinkholes, springs, sinking streams, and river rises (Ceryak et al., 1983).

Other characteristics of the Northern Highlands include gently rolling topography, generally from 100 - 200 feet above mean sea level. Soils typically range from sand to clayey sand. The presence of relatively low permeability clayey sediments, at or near the surface, limits the infiltration of rainfall. Therefore, local rainfall drainage in the Northern Highlands (i.e., the Upper Suwannee and Santa Fe River basins) is characterized by surface water features.

Florida has one of the largest concentrations of freshwater springs on Earth, with more than 700 springs within its boundaries. There are 148 known springs within the St. Johns River Water Management District. Of those, 96 springs have been documented and are described in this section of the district's website. Some springs are made up of several spring vents, such as the 30 that make up Silver Springs, and are not described separately. As water levels rise and fall over time, new springs are discovered and reported to the district, however details have not yet been completed for publishing, which accounts for the number of known springs and those described here.

Springs provide natural, recreational and economic benefits for Florida's residents and visitors. The crystal-clear water from springs supplies the base flow for many rivers and streams and the habitat for wildlife. Springs provide a "window" into the aquifer, allowing for a measure of the health of the Floridan aquifer system. Springs are the setting for numerous recreational activities, and Florida's springs and attractions are a multi-million-dollar industry in Florida.

2.1.3 Boundaries/Surface Waters

This watershed is characterized by chains of large connected lakes and wetlands. Lake County, located in the southern portion of the Basin, accounts for a large majority of these water features, with lakes, swamps, and marshes comprising roughly 32 percent of the county (Knochenmus and Hughes, 1976). In addition to the numerous lakes and surface water, St John's river, Florida's largest river, is in the northeast. Orlando is located at the southern tip.

2.1.4 Hydrogeological Considerations

The Ocklawaha River Watershed is underlain by the Floridan aquifer system, an Eocene to Oligocene carbonate sequence with high primary porosity and development of secondary porosity. This vertically continuous sequence of carbonate rocks is highly permeable and hydraulically connected in varying degrees (Sutton, Screaton, and Martin 2015). One issue with this limestone is that is it friable, meaning that can collapse when water is removed, creating sinkholes.

The UFA is highly productive and represents the primary source of water supply and provides the baseflow to rivers and springs in the watershed. Most of the UFA system in the watershed is located near or at the surface, with some smaller areas being buried deep underground. Much of the Floridian aquifer in the watershed is unconfined, though there are small pockets of the aquifer that are thinly confined further inland.

In the Northern Highlands region, which includes the Upper Suwannee and Santa Fe River basins, the UFA is overlain by a thick confining layer of clay, which retards recharge into the UFA. The presence or absence of the Hawthorn Group determines whether the UFA is confined/semiconfined or unconfined (Scott, 1988, 1992), respectively. Table 1 shows the aquifer layers in the basin.

Table 1 Summary of Aquifers in the Basin.

Geologic Unit	Hydrostratigraphic Unit
Undifferentiated Sand	Surficial Aquifer System
Hawthorn Group	Intermediate Aquifer System and Intermediate Confining Unit
St. Marks Formation	
Suwannee Limestone	Floridan aquifer system (Upper Floridan aquifer where Middle Confining Unit is absent)
Ocala Limestone	
Avon Park Formation	
Oldsmar Formation	

For planning purposes, fresh groundwater is recognized as the only traditional water supply source, with all other water sources considered to be nontraditional (i.e., alternative water supplies; 373.019(1) F.S.). This WSA was conducted to determine whether fresh groundwater supplies in the District will be adequate to satisfy water supply demands for the 2015-2035 planning period while protecting natural systems. Existing use and future water demand projections were examined as required by Rule 62-40, Florida Administrative Code (F.A.C.). Total water demand in the District is projected to grow from 229 million gallons per day (mgd) to 300 mgd, with fresh groundwater from the FAS supplying over 90% of this demand. Agricultural Self-supply remains the largest use category in the District and represents the largest projected water demand growth through 2035.

2.1.5 Special Features

The Ocklawaha River watershed is comprised of two hydrologically distinct parts. The eastern and northern portion of the watershed contains the Ocklawaha River as well as the associated lakes and tributaries, creating a connected surface drainage pattern. The Central eastern portion of the basin is home to the Ocala wildlife management area 430,447 acres a wildlife management area, in which hunting, and fishing activities are managed by the Florida Fish and Wildlife Conservation Commission. This watershed is also located 27 miles to the west Gulf of Mexico and 12 miles to the east of the Atlantic Ocean.

2.2 Socio-economic Conditions of the Basin

2.2.1 Demographics

The demographic data of this watershed is listed in Table 1. These data are from statistical analysis of the census dataset of U.S. Census Bureau 2015 Census Block Groups for the State of Florida with selected fields from the 2014-2018 American Community Survey (ACS).

Table 2 Demographic statistics of Ocklawaha

Attribute	Statistics
Total population	1,129,633
Total households	425,843
Total families	441,079
Total male	869,163
Total female	925,547
Age of under 5	97,131
Age between 5-17	266,118
Age between 75-84	124,532
Age of above 85	40,721
Mean median household income	$46,679
Mean median family income	$55,225

2.2.2 Property

The median value of owner-occupied housing units $135,539 (US Census 2018). The majority of the acreage in the basin is agriculture or natural areas, many of which are preserved. Population density is low except in the municipalities.

2.2.3 Economic Activity/Industry

Major employment includes agriculture and forestry along with smaller amounts of retail trade, health care and social assistance, food services, and construction.

3.0 Watershed Analysis

3.1 Data Sets

3.1.1 Topography

Ground elevation dataset Digital Elevation Model (DEM) for the watershed is displayed in Figure 2. Areas in the North and South have higher elevations than the central basin, especially near St. Johns River. The elevation ranges from 0 ft near the St. Johns River, to 308 ft.

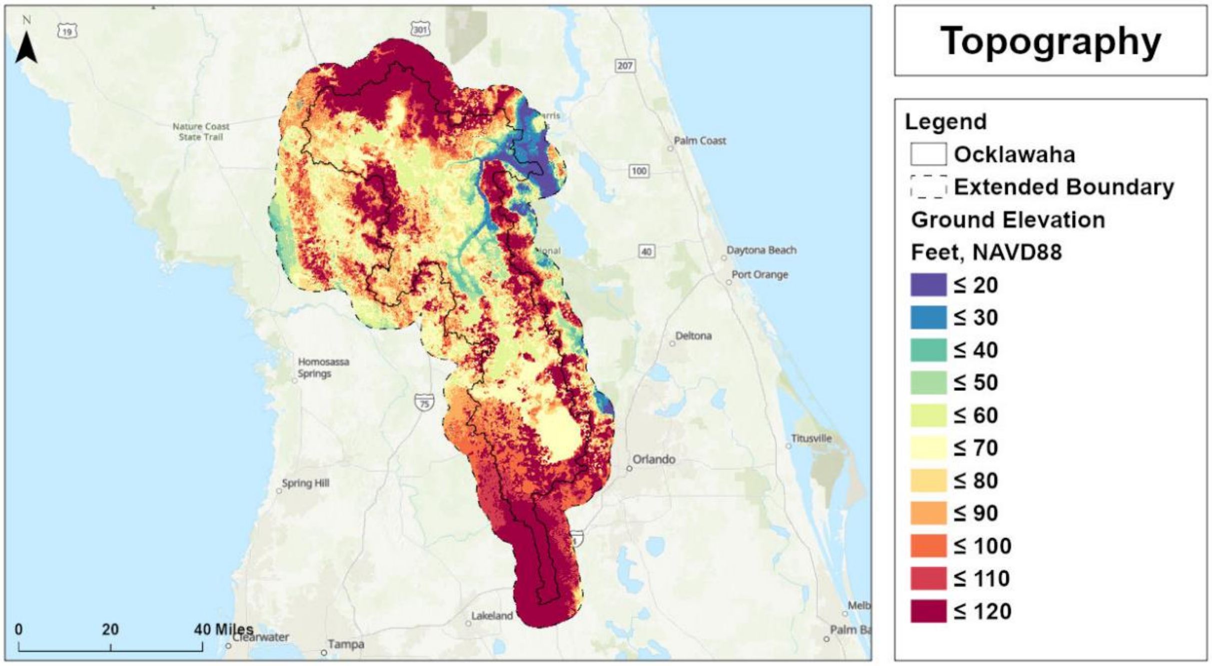

Figure 2 Topography of Ocklawaha River Basin.

3.1.2 Groundwater and Surface water

Water table generation consisted of surface water station and groundwater stations as inputs into ordinary kriging. For this approach, groundwater wells and surface water stations were sorted for maximum groundwater elevations for 8/19/15. There were 189 surface water and groundwater stations available. All datasets were converted into the NAD_1983_UTM_Zone_17N projection, North American Vertical Datum of 1988 (NAVD 88) for the vertical datum for elevation datasets, and the elevation unit was in feet. Well and surface water observation sites are displayed in Figure 3. The groundwater table, as shown in Figure 4, ranges from 0 feet along most of the western perimeter, to over 100 feet in the East and North. Figures 5 and 6 show the water bodies and impervious surface within this basin, respectively.

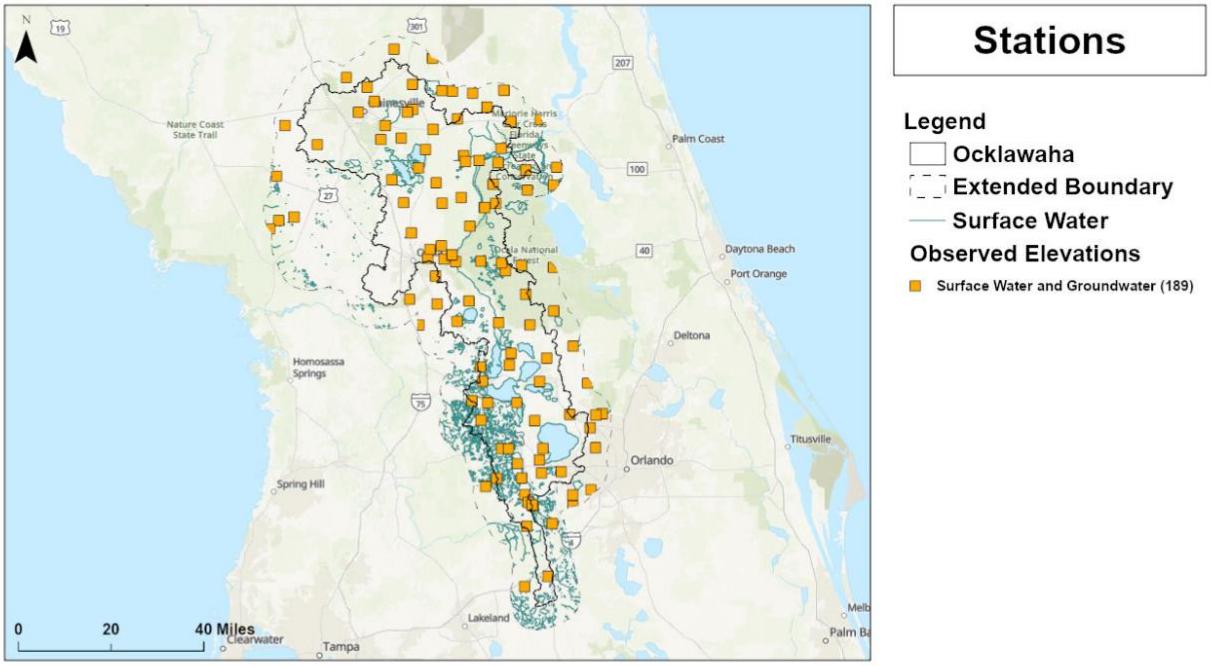

Figure 3 Surface water stations, groundwater wells, and surface water for Ocklawaha River Watershed.

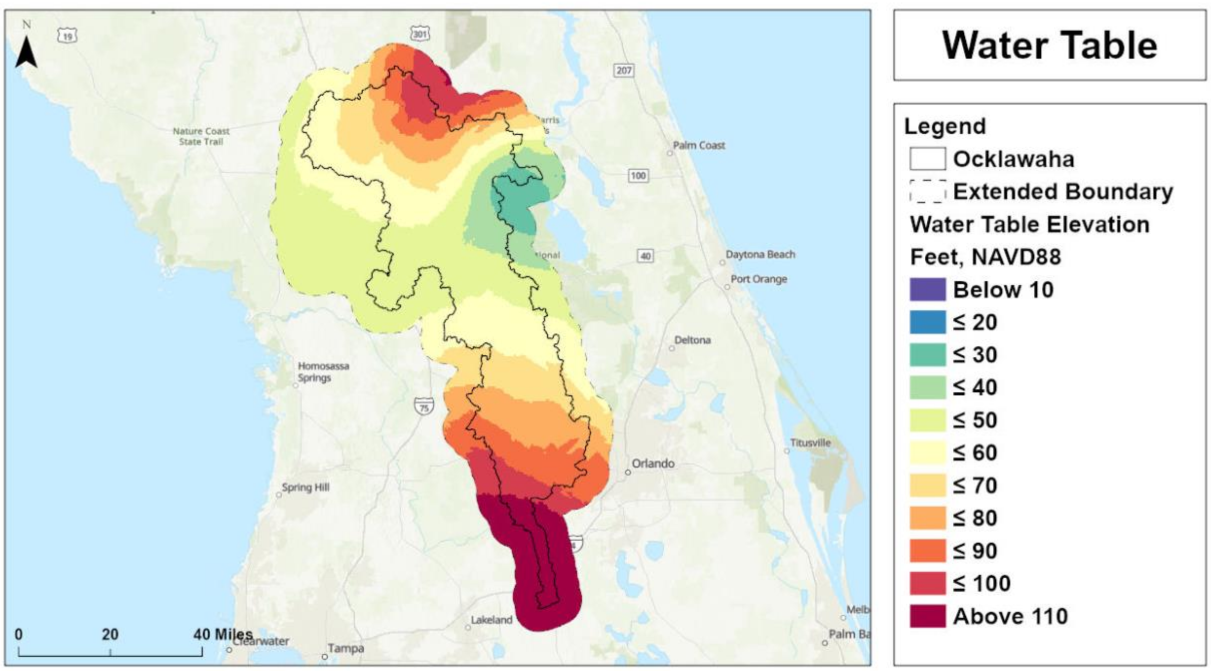

Figure 4 Groundwater Table for Ocklawaha River Watershed.

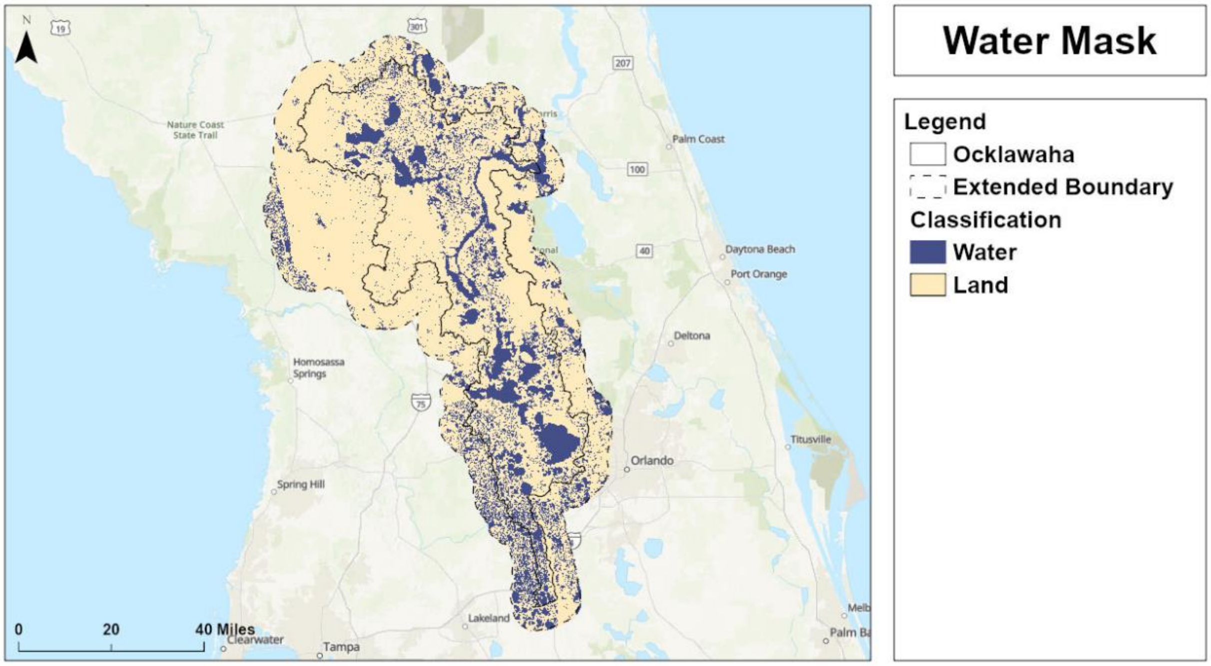

Figure 5 Waterbodies within Ocklawaha watershed.

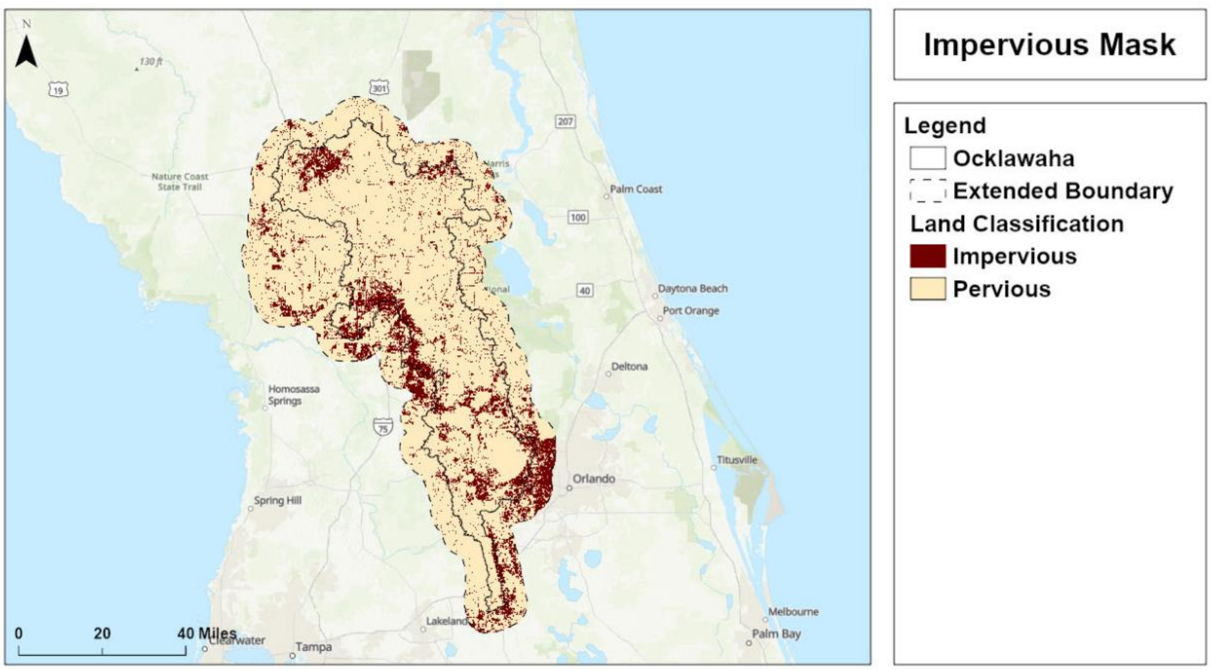

Figure 6 Impervious mask for Ocklawaha River Watershed.

3.1.3 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. The open space map, displayed in Figure 7, shows the open lands classification from the 2014 land use land cover dataset.

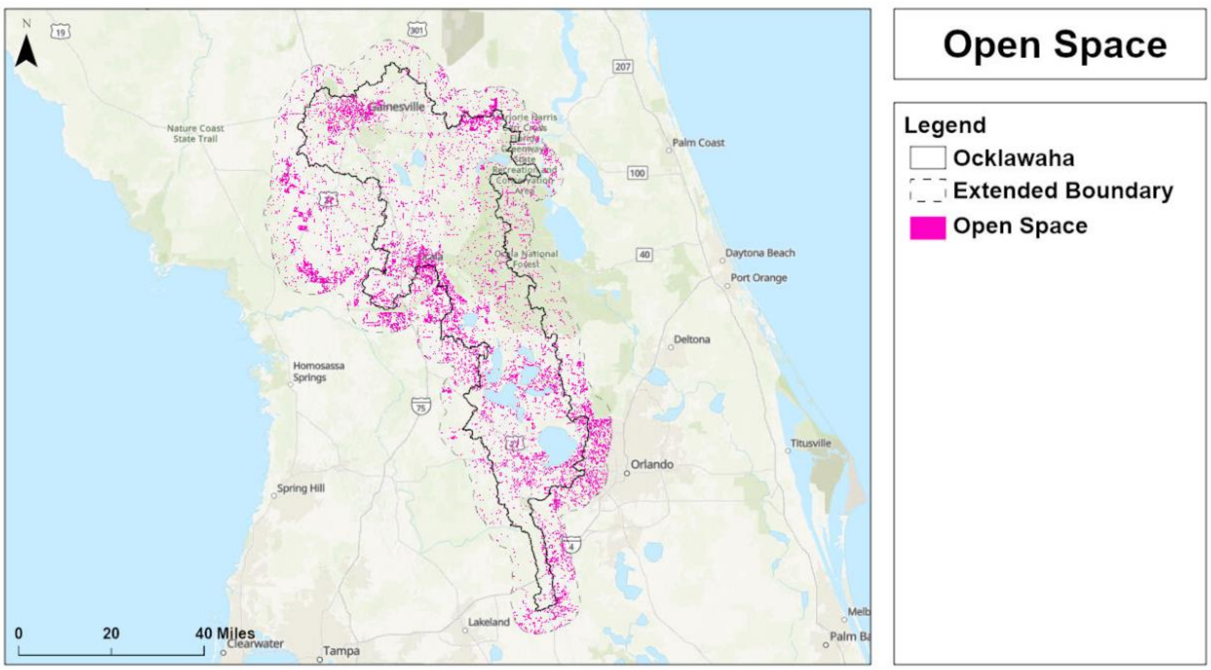

Figure 7 Open space map of the Ocklawaha Watershed.

3.1.4 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. Figure 8 displays the soil storage capacity for this watershed. Soil storage capacity was zero in areas with known waterbodies and impervious surface and was the highest in the Northern portion of the basin.

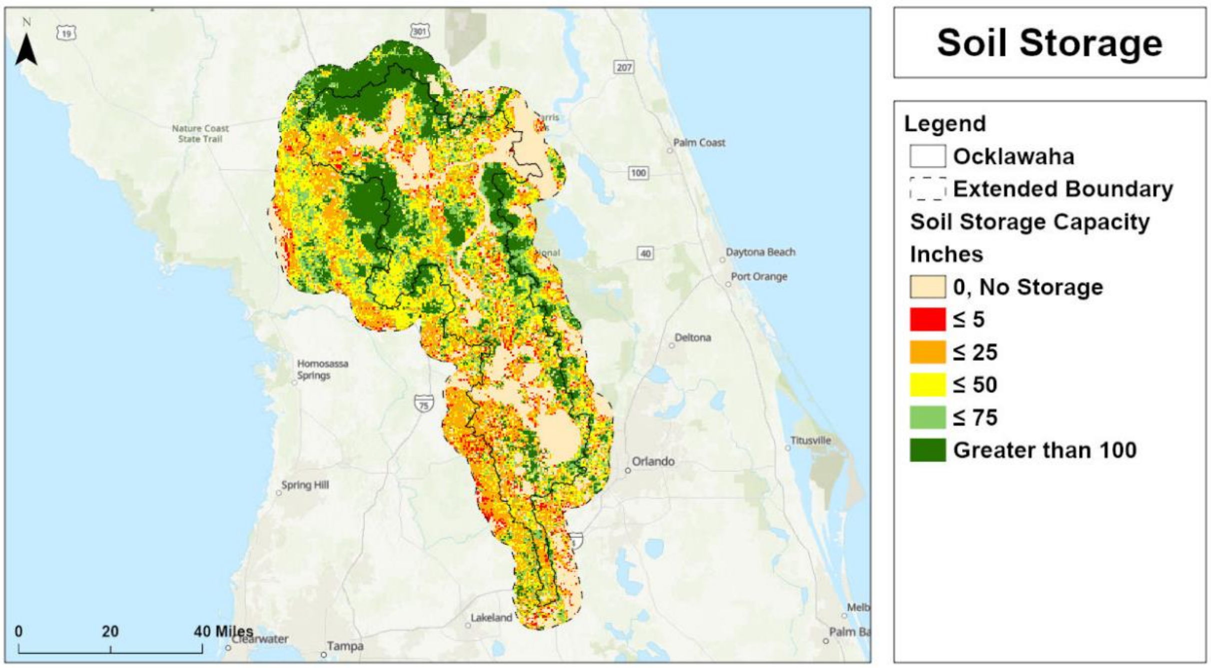

Figure 8 Soil storage for Ocklawaha River Watershed.

3.1.6 Rainfall

The rainfall map is created using the rainfall dataset downloaded from NOAA and processed in this project of 3 days for a 25-year average recurrence interval, as displayed in Figure 9.

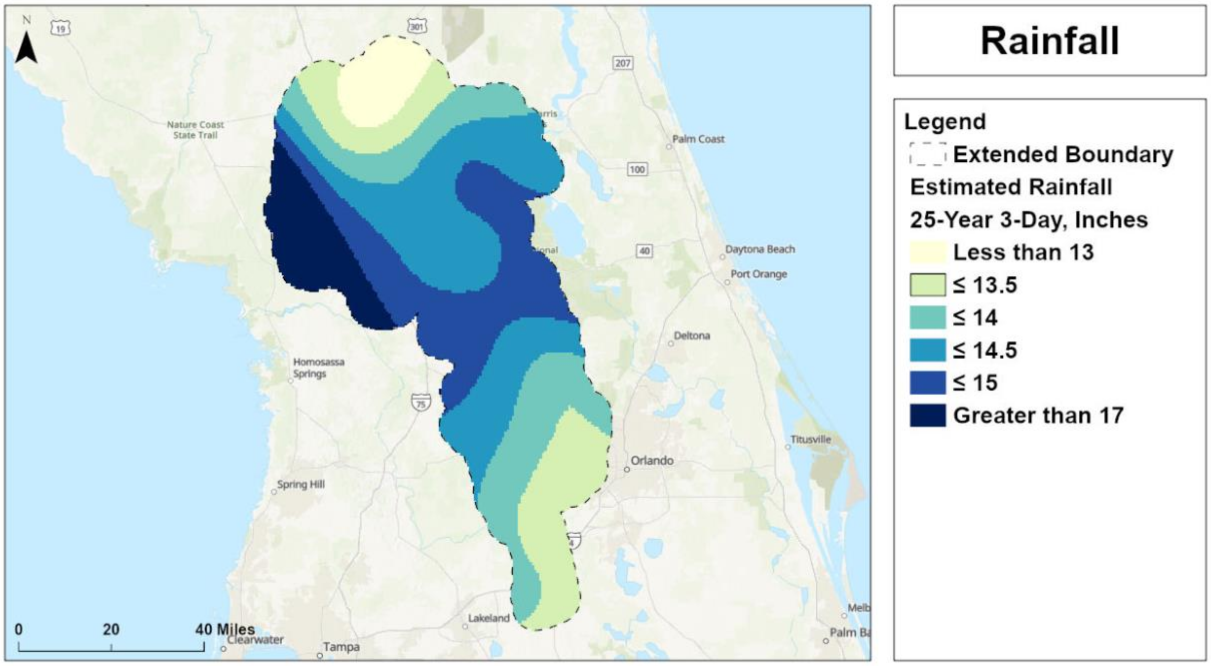

Figure 9 Rainfall data for Ocklawaha River Watershed

3.2 Modeling Protocol

Catchments and drainage points were generated using the ArcHydro tool in ArcGIS 10.7. These catchments were then merged into 10 larger catchments based upon hydraulic characteristics, and one drainage point was selected per catchment to represent the outlet. For inputs into Cascade, area was calculated in acres based off the 10 larger catchments, outlets derived elevation from the water table to represent initial stage, and ground storage and rainfall were calculated using zonal statistics on the groundwater dataset and rainfall dataset. In Cascade, the stage-storage relationship was calculated using a combination of Maximum DEM statistics for each catchment, the initial stage, and average rainfall. The structure for his watershed was not available.

3.3 Modeling Results

3.3.1 Watershed pathways

Watershed pathways of Ocklawaha River basin were derived using ArcHydro using the DEM dataset, as shown in Figure 10.

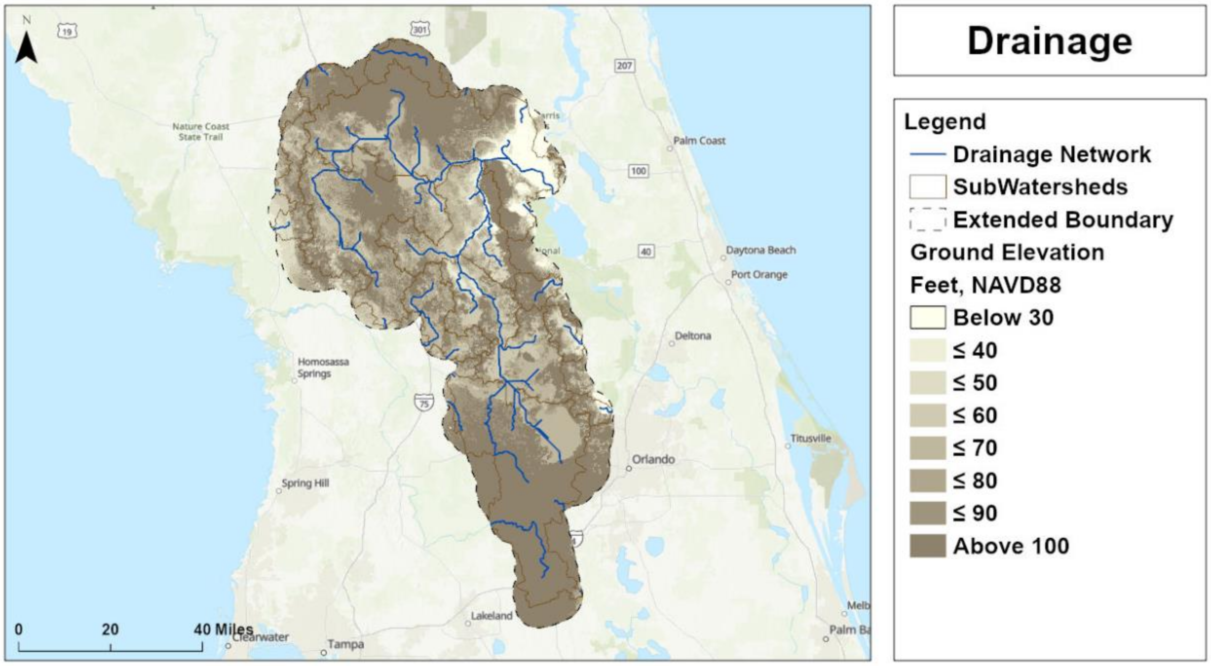

Figure 10 Drainage networks and catchments for Ocklawaha River Watershed.

3.3.2 Cascade Results

To estimate high-water head, zonal statistics for each subbasin were prepared using of DEM, water table, soil storage, and rainfall as inputs into Cascade 2001 software, and the inputs for the Cascade 2001 are displayed in Table 2.

Table 2 Cascade inputs and results

Catchment	Acres	Rainfall	Max DEM	Soil Storage	Initial Stage	HW
1	71037.75	12.86	199.62	87.54	68.11	68.11
2	136729.78	14.62	240.86	63.47	45.21	45.26
3	609830.43	13.76	226.37	37.32	30.58	32.07
4	430071.56	14.68	212.31	62.91	55.99	56.08
5	253430.81	14.46	205.46	44.37	43.07	43.92
6	135953.59	14.52	182.77	19.67	58.80	62.62
7	112960.71	14.61	191.37	31.97	55.04	65.95
8	103090.45	14.25	194.26	30.66	50.72	52.75
9	160077.78	14.15	194.96	15.01	68.44	73.44
10	514746.07	13.72	310.19	11.11	120.20	124.83

3.3.3 Vulnerability to Flooding

The likelihood of flooding in Tampa Bay Tributaries based off the model results is displayed in Figure 11. Using the Z-score for each of the pixels within the watershed to represent the confidence interval, the probability of inundation was calculated (NOAA, 2015). Z-score values below 0 were considered having less than a 50% likelihood of flooding, between 0 and 0.675 having 50% - 75% likelihood of flooding, between 0.675 and 1.282 having 75% - 90% likelihood of flooding, and above 1.282 having over 90% of flooding. Waterbodies are visualized to distinguish areas on land-based flooding.

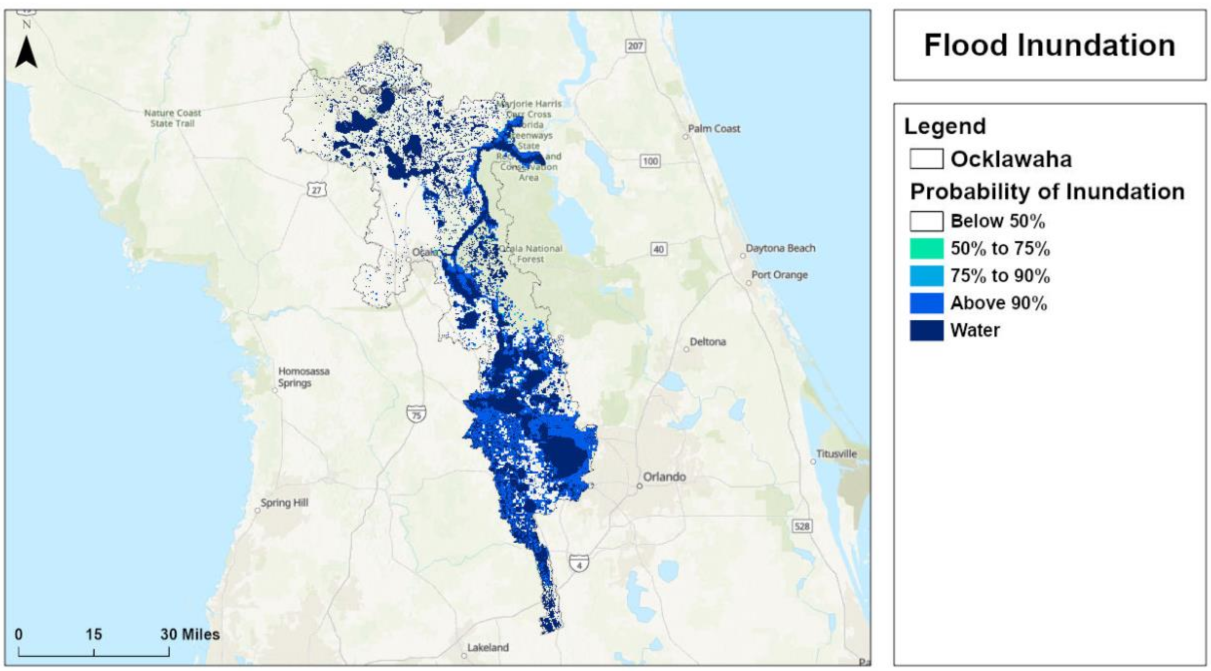

Figure 11 Vulnerability to flooding map for Ocklawaha River Watershed.

3.3.4 FEMA Flood map comparison

Figure 12 displays contains the risk of flooding for the watershed based on FEMA estimations of flood risk. 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) ("Definitions of FEMA Flood Zone Designations," n.d.).

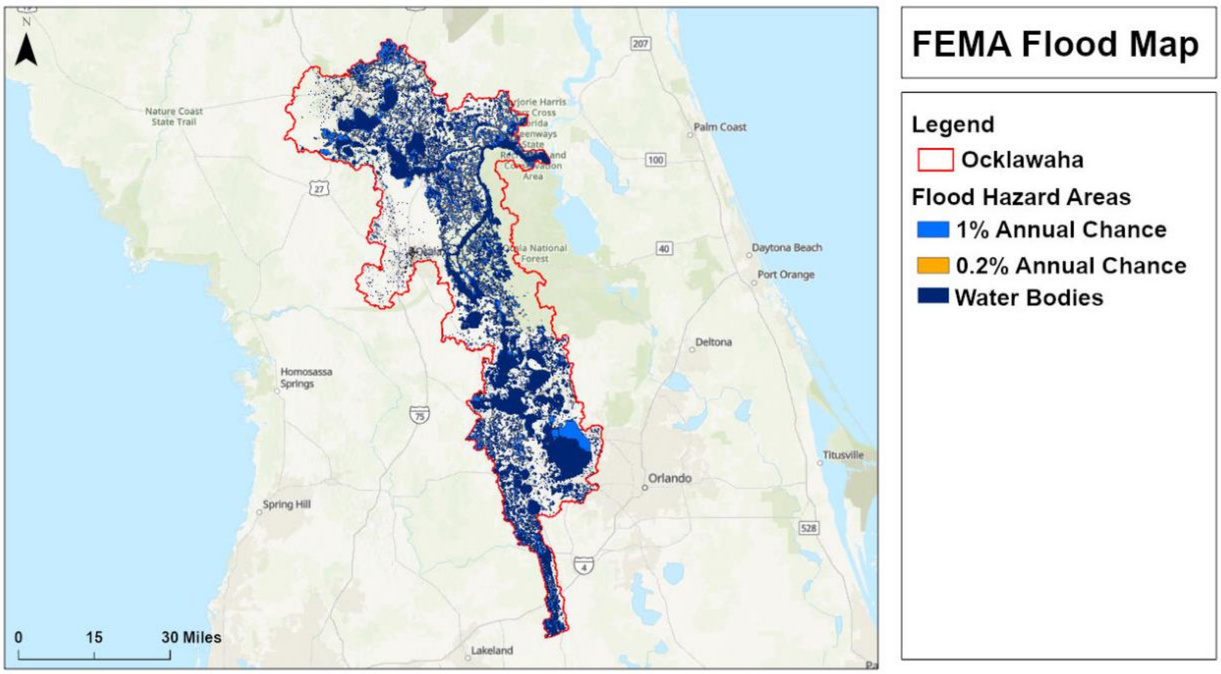

Figure 12 Annual flood risk in Ocklawaha

3.4 Repetitive Loss

Figure 13 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.

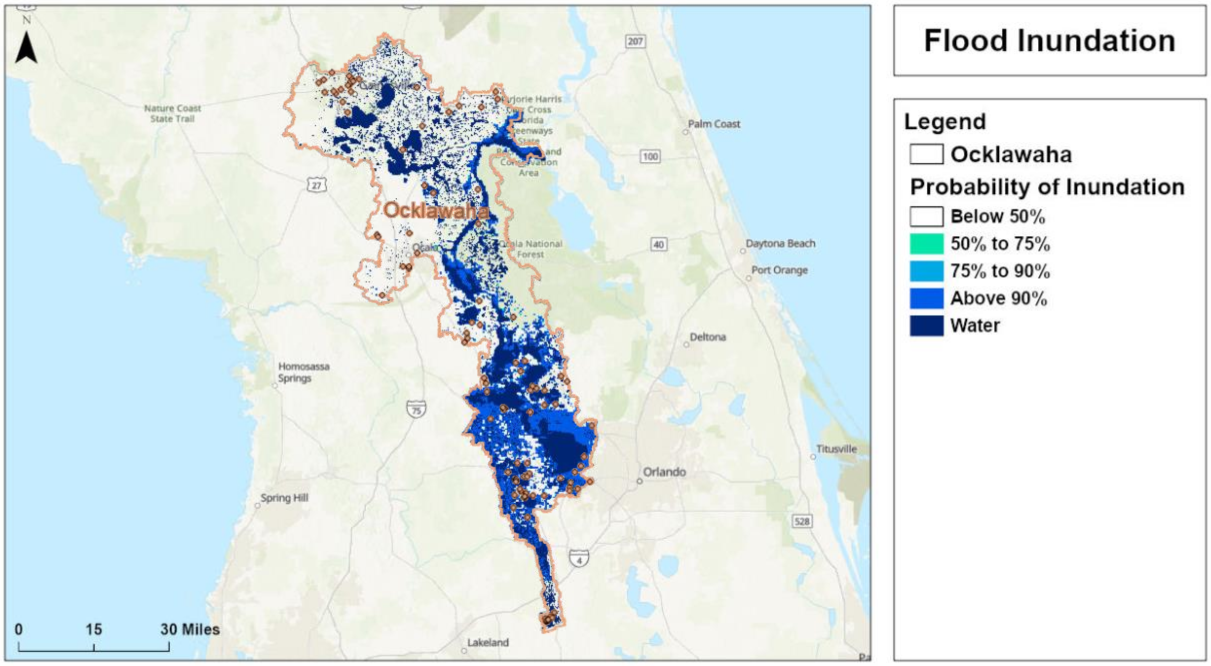

Figure 13 Repetitive loss areas from 2004 -2014 superimposed on the flood risk map created by FAU.

3.5 Drill down in Developed Areas Loss

Figure 14 shows the areas of the basin that are developed and flooded so further drill down could be conducted. From this map, three area of focus were identified:

1) Northwest of City of Tampa, Florida - The drilldown map of northwest of City of Tampa in this watershed is displayed in Figure 15.
2) Riverveiw, Florida - Riverview, Florida is an unincorporated community in this watershed with a population of 71, 050. The drilldown map for this area is displayed in Figure 16.
3) Bradenton, Florida - The drilldown flood map for Bradenton is displayed in Figure 17.

All confirm the FAU findings.

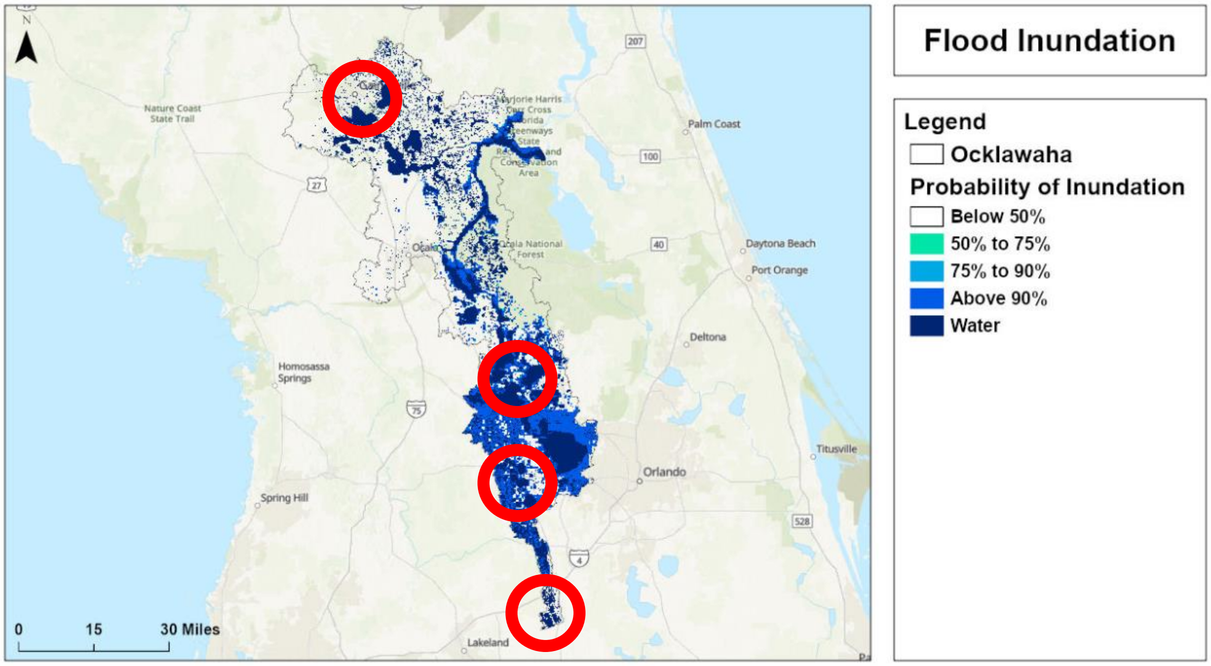

Figure 14 Location of drilldown areas.

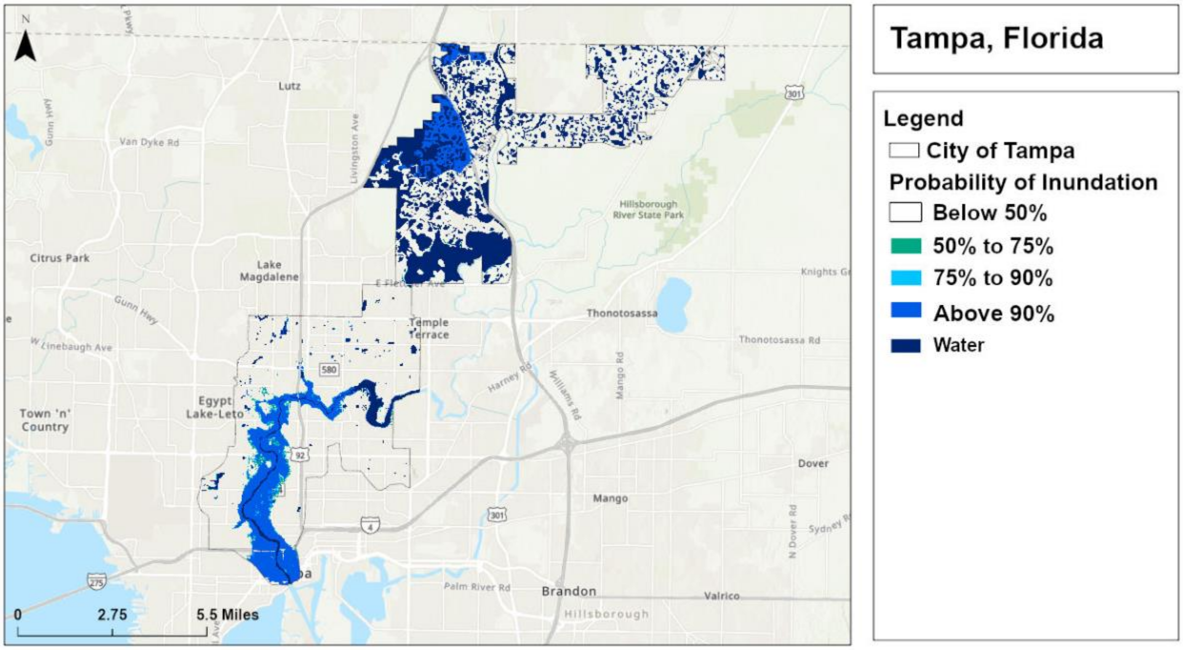

Figure 1 Northwest of City of Tampa, Florida.

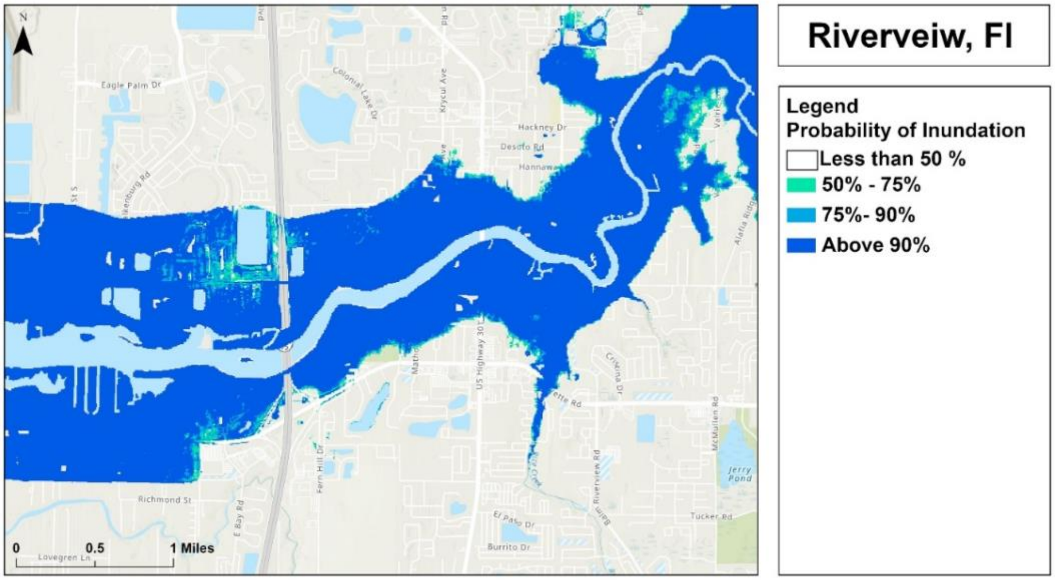

Figure 2 Flood map for Riverview, Florida.

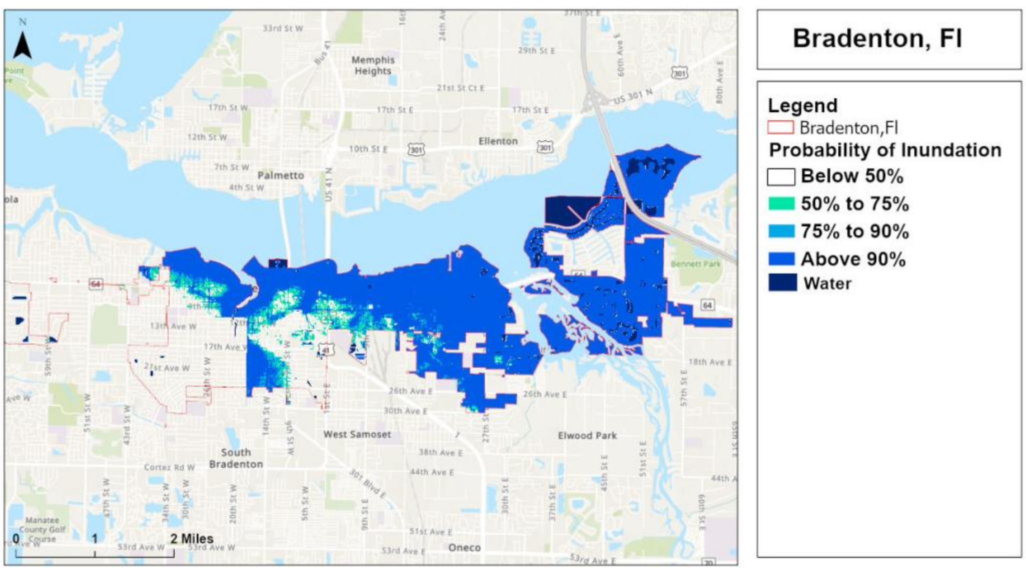

Figure 3 Flood map of Bradenton, Florida

4.0 Conclusions

This report focusses on the application of the screening tool to assess risk in Ocklawaha River Watershed, Florida, a watershed located on the west coast of 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 Modeling 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. It was determined that flooding will primarily occur along this river system and be localized to developed land areas in the watershed's coastal regions and inland cities. 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 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.

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