DRAFT

Basin 6A

Waccasassa Watershed Case Study

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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.

The effort discussed herein focuses on the application of our developed screening tool to assess risk in Springs Coastal watershed located in central west 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 watershed. Such knowledge permits local agencies to develop means to address high risk properties.

1.0 Introduction

Waccasassa is located in north central Florida (see Figure 1), and is home to the City of Newberry, Trenton, Alachua, Cedar Key, and over 20 smaller communities. It covers most of Levy County, along with smaller portions of Alachua, Marion, and Gilchrist Counties. It is part of the larger Suwannee watershed, which ranges from the bottom of Waccasassa to the border with Georgia in the north. The 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 63,000 people who live in the watershed. The Suwannee River Water Management District maintains most of the watershed, while the Southwest Florida Water Management District maintains a small portion along the southeast edge of the watershed. The watershed is adjacent to the Gulf of Mexico.

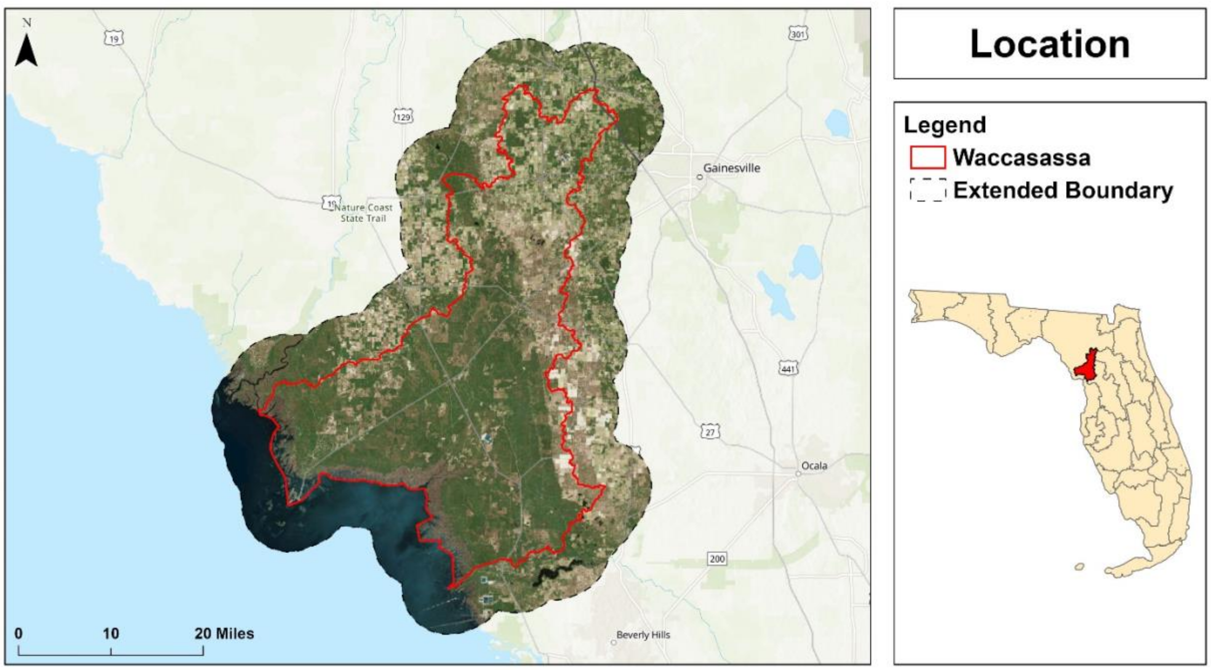

Figure 1 Location of the Waccasassa watershed in Florida.

2.0 Summary of Watershed

2.1 General Description of Watershed

The jurisdictional area of the District is 7,640 square miles and includes all or part of 15 counties in north-central Florida. The District includes all of Columbia, Dixie, Gilchrist, Hamilton, Lafayette, Madison, Suwannee, Taylor, and Union counties, and parts of Alachua, Baker, Bradford, Jefferson, Levy, and Putnam counties. The District contains over 300 documented springs, including the highest concentration of both freshwater springs in the state and first magnitude freshwater springs in the United States.

2.1.1 Climate/Ecology

The historical character of northern 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 and is most common from May to October. The climate is humid subtropical, with summer temperatures averaging from a minimum of upper 70s to a maximum of lower 90s. Winter temperatures average from a minimum of upper 40s to a maximum of lower 70s.

2.1.2 Topography and Soils

The two major physiographic provinces in the District include the Northern Highlands and Gulf Coastal Lowlands (White, 1970; Ceryak et al., 1983). 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. The Gulf Coastal Lowlands are characterized by elevations ranging from sea level to approximately 100 feet above mean sea level. The Gulf Coastal Lowlands feature a low relief, karstic topography, and shallow sandy soils with muck in many wetland areas. Karst landforms are widespread in the lowlands, with abundant sinkholes, sinking streams and springs, and a high degree of interconnection between surface water and groundwater systems. The Gulf

Coastal Lowlands therefore have high rates of recharge to the limestone aquifer and extensive karst development, resulting in a groundwater-dominated (subsurface) drainage pattern throughout much of this region.

A significant geologic feature separating the two major physiographic provinces is the Cody Escarpment or Cody Scarp, which generally separates the Northern Highlands Physiographic Province and the Gulf Coastal Lowlands Physiographic Province. 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). During average and lower flows, with the exception of the Suwannee River, all rivers and streams, including the Santa Fe and Alapaha Rivers, are completely captured by sinkholes as they cross the Cody Scarp. Some subsequently re-emerge downgradient as river rises.

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.

2.1.3 Boundaries/Surface Waters

The key elements of the watershed include coastal swamps, rivers systems, lakes, springs, and the rainfall over the area. Major water features include the Suwannee River, Waccasassa River, Waccasassa Flats, Suwannee River Estuary, Manatee Spring, Fanning Springs, and Waccasassa Bay("Learn About Your Watershed," 2014).

2.1.4 Hydrogeological Considerations

The aquifer system contains a sequence of limestone rock and dolomite mineral and can be divided into an upper and lower aquifer by the amount of permeability. The District has three primary hydrostratigraphic units which are, in descending order, the unconfined surficial aquifer system, the intermediate aquifer system/intermediate confining unit (located in the northeastern and eastern portions of the District), and the UFA.

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, whereas, to the south and west in the Gulf Coastal Lowlands, these clay layers are generally absent and the UFA is generally unconfined. The UFA in the Gulf Coastal Lowlands region experiences very high rates of recharge by way of sinking streams, sinkholes, and diffuse recharge through the land surface. Therefore, in this area, maintenance of groundwater levels is critically important to maintaining spring flow and baseflow in rivers (e.g., the Lower Santa Fe and Ichetucknee Rivers).

The presence or absence of the Hawthorn Group determines whether the UFA is confined/semi-confined 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 major features for the watershed are the ocean and the swamp areas on the west. Due to the limited human settlements and structures, most of the watershed is largely controlled naturally, with few portions completely managed by people.

2.2 Socio-economic Conditions of the Watershed

2.2.1 Demographics

As of the 2018 United States Census, the Waccasassa watershed had 62,589 people, 24,544 households, and 15,769 families. Of the 24,544 households in the watershed, the average household size was 2.51 and the average family size was 3.24. In the watershed, the population was spread out with 6.2% under the age of 5, 15.4% from 5 to 17, 4.4% from 18 to 21, 8.1% from 22 to 29, 11.9% from 30 to 39, 12.0% from 40 to 49, 22.1% from 50 to 64, 11.9% from 65 to 74, 5.8% from 75 to 84, and 2.1% who were 85 years of age or older. The median age was 45 years. For every 100 females, there were 98.87 males. The racial makeup of the watershed was 87.86% White (7.87% Hispanic or Latino), 8.51% Black or African American, 0.87% Asian, 2.19% from two or more races, 0.33% Native American, 0.01% Pacific Islander, and 0.24% from some other race. As of the 2018 United States Census, the median income for a household in the watershed was $47,217, the median income for a family was $57,837, and 18.0% of the population was below the poverty line ("United States Census," n.d.).

2.2.2 Property

The community is primarily agricultural and rural, with few large concentrations of residential activities near the interior and coastline.

2.2.3 Economic Activity/Industry

Employment indicates the watershed area is a minor component of the state GDP which includes farming, conservation, forestry, and tourism. There is ample agriculture in the watershed, with most available property not developed.

3.0 Watershed Analysis

3.1 Data Sets

3.1.1 Topography

Figure 2 shows the results of the LiDAR 3-meter DEM processed conducted for the watershed. Along the western and southern areas, the elevation is low, ranging from 0 feet (sea level) to 20 feet. Further inland the elevation is higher and more varied, ranging from 40 to over 100 feet, with a maximum elevation of approximately 241 feet. Figure 3 contains the impervious areas, primarily roads and structures. These are areas where water cannot seep into the soil, and as a result may travel on the surface. Figure 4 contains the areas that contain either water (ex. rivers, lakes, canals, etc.) or land in the Waccasassa watershed.

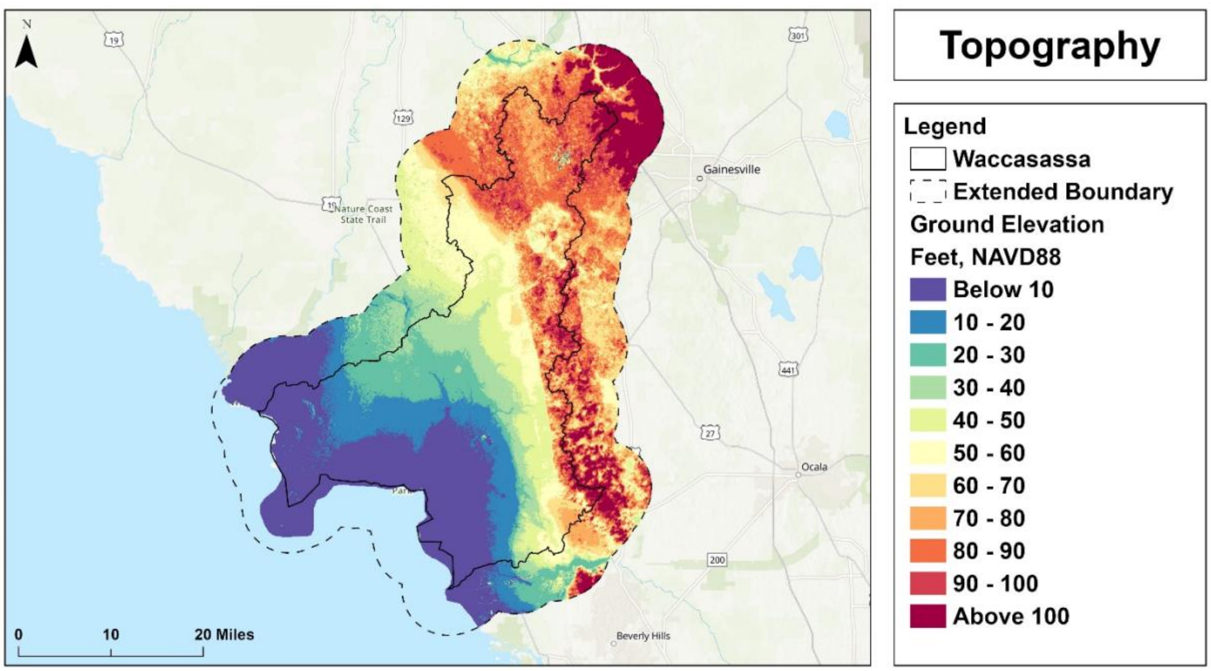

Figure 2 Topography of the Waccasassa watershed based on LiDAR DEM.

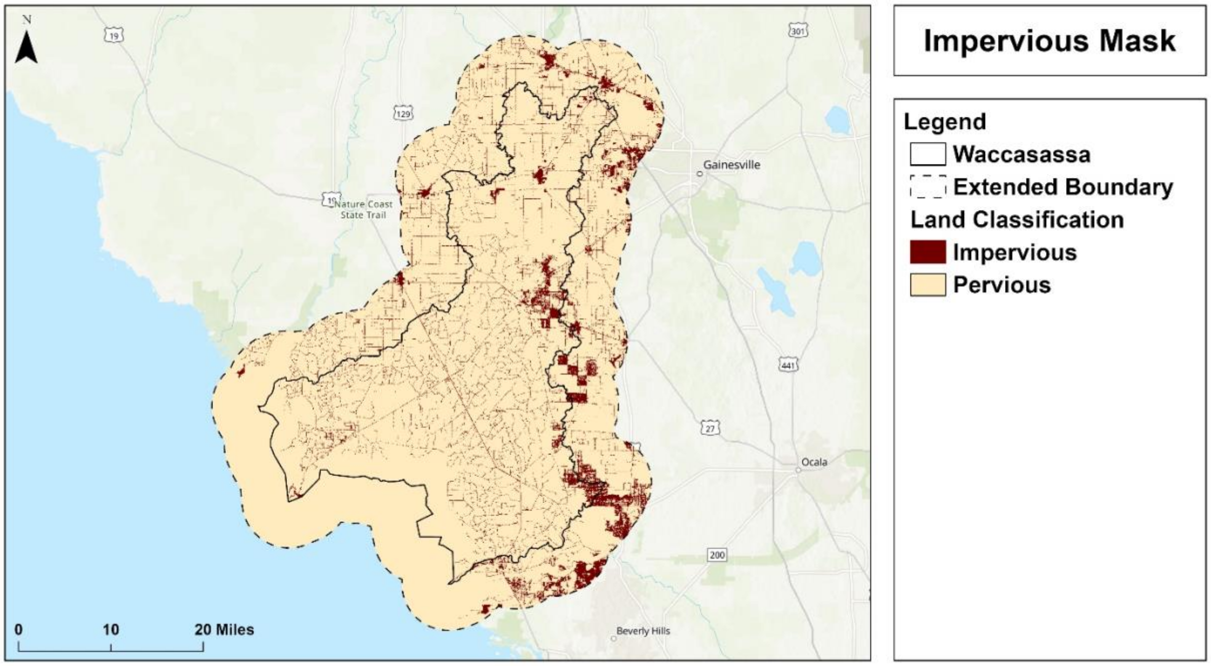

Figure 3 Impervious areas in the Waccasassa watershed.

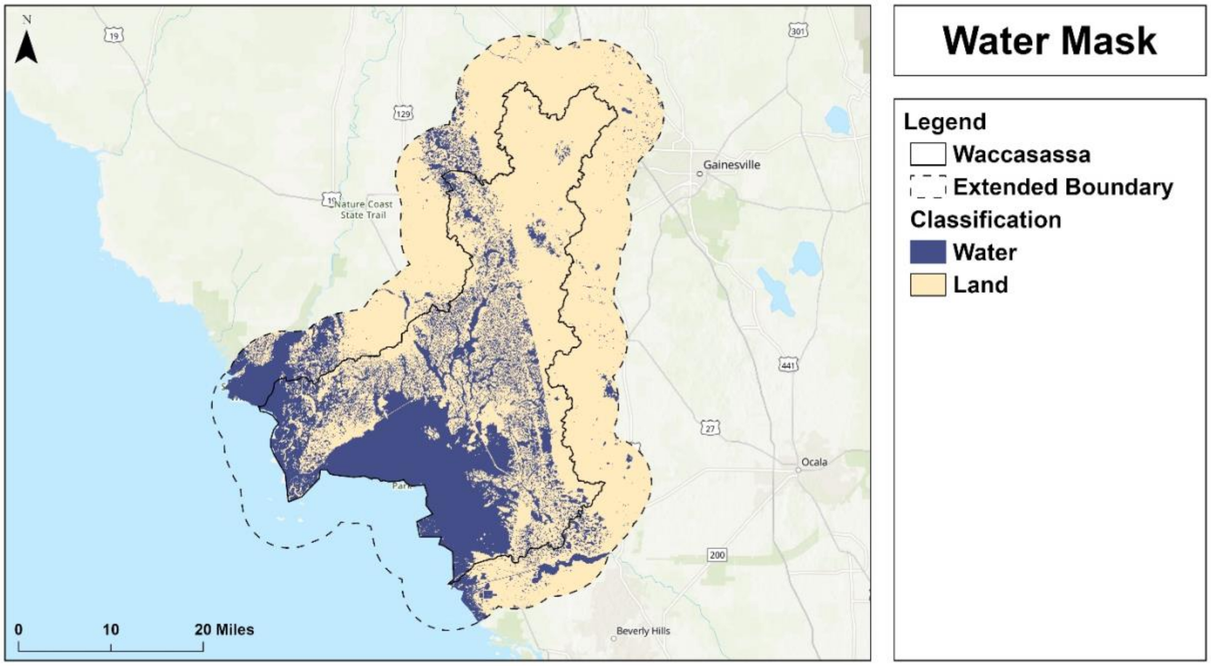

Figure 4 Water bodies in the Waccasassa watershed.

3.1.2 Groundwater

The groundwater table was determined by using the kriging approach that was used in Zhang et al. (2020) as there were limited wells within this watershed. The locations of the wells, surface water, and tidal gauge stations are displayed in Figure 5.The combination of the known water table readings from groundwater stations, surface water stations, and a tidal gauge were used to create the water table for the watershed as seen in Figure 6. This represents the surface level where the ground soil is permanently saturated with water. The lowest water table elevations are found near the coast, from 0 feet (sea level) to 20 feet, while the higher water table elevations are found more inland, ranging from 40 feet to above 70 feet, with a maximum water table elevation of approximately 75 feet.

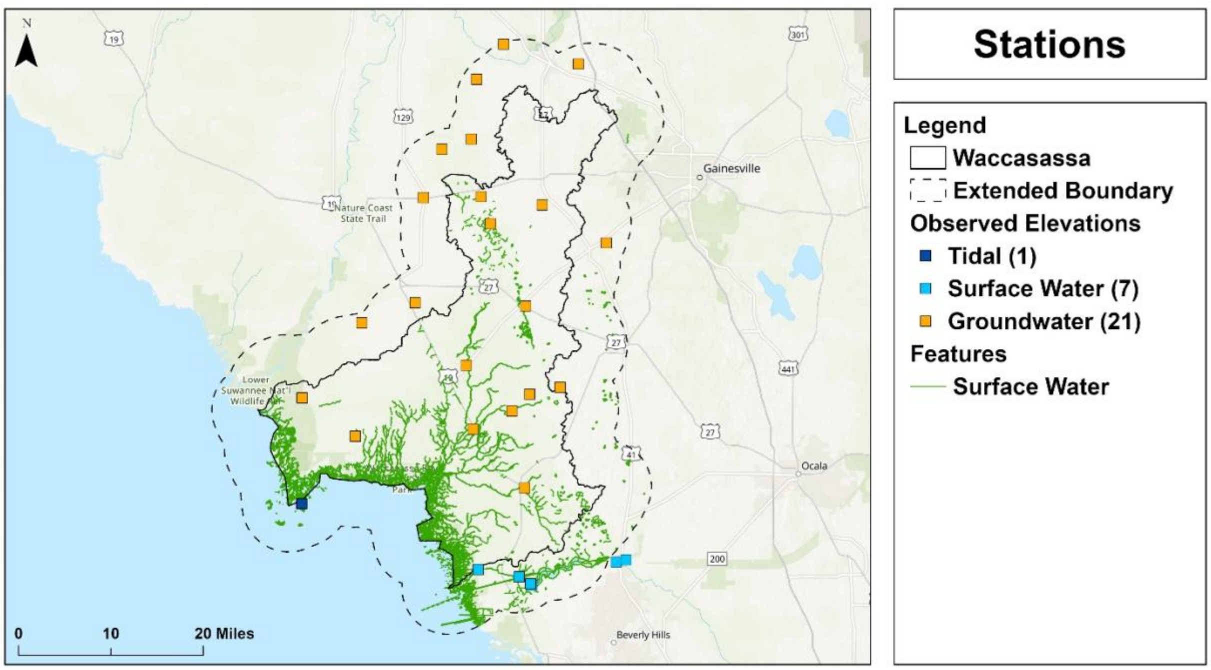

Figure 5 Locations of groundwater wells, surface water wells, and tidal gauge station in the Waccasassa watershed.

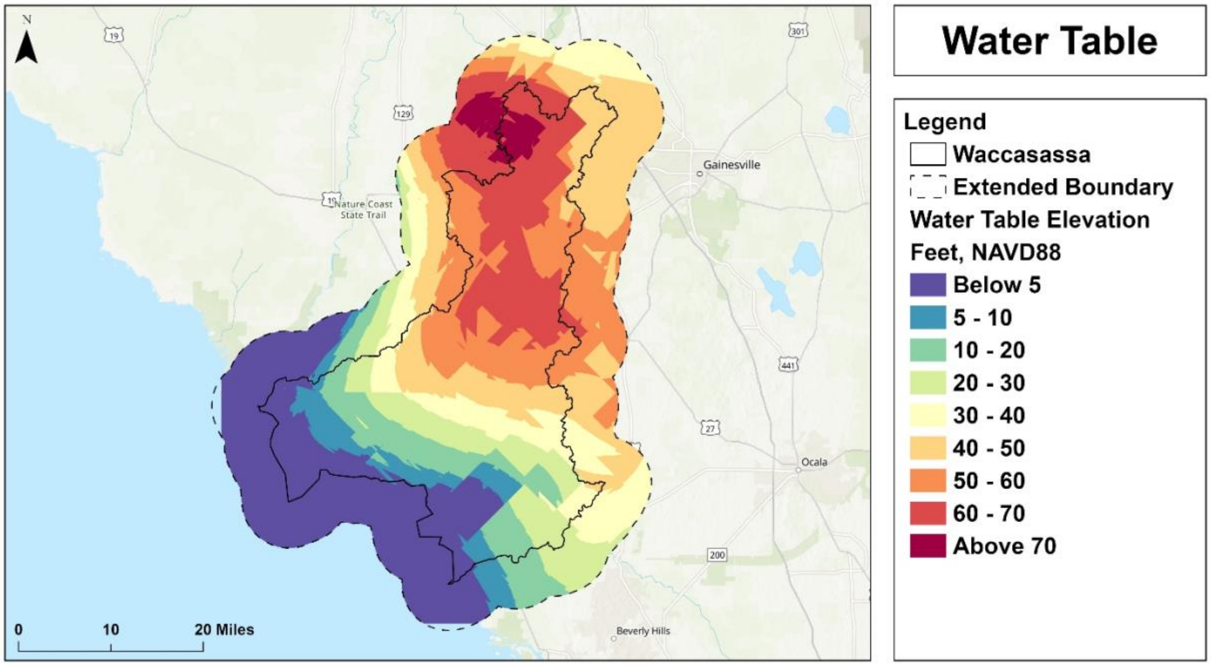

Figure 6 Groundwater layer in the Waccasassa watershed.

3.1.3 Surface Waters

Figure 6 includes a map of the surface waters in the Waccasassa watershed, along with the locations of the 21 groundwater stations, 7 surface water stations and 1 tidal gauge. Groundwater stations were adequately found throughout the entire watershed, while surface water stations were only found in the bottom of the watershed. These were chosen based on the date 08/04/2018, which contained the highest recorded water levels of the active stations and reduced influence of unusually large storm events on the watershed.

3.1.4 Open Space

The open space map (Figure 7) is from the USGS NLCD 2016 land cover dataset and the open lands are displayed in the map.

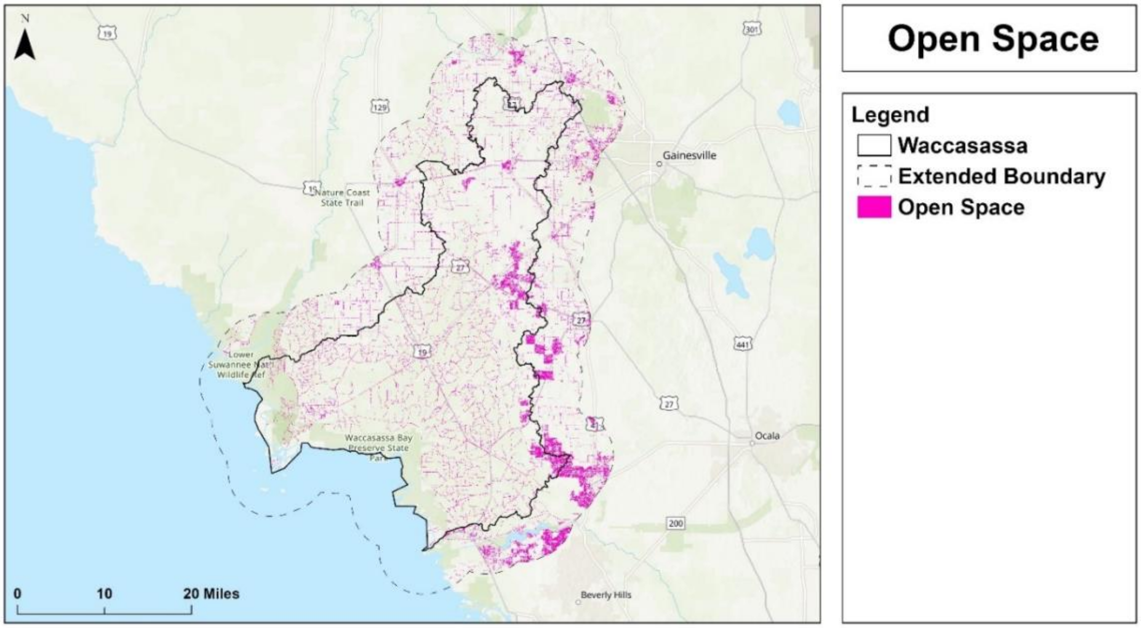

Figure 7 Open space in the Waccasassa watershed.

3.1.5 *Soil Capacity*

Figure 8 shows the soil capacity in the Waccasassa watershed. Much of the coastal areas, which includes impervious land and water, have no or very little water holding capacity. Areas found more inland have a higher soil capacity ranging from 0.10 to 1.00.

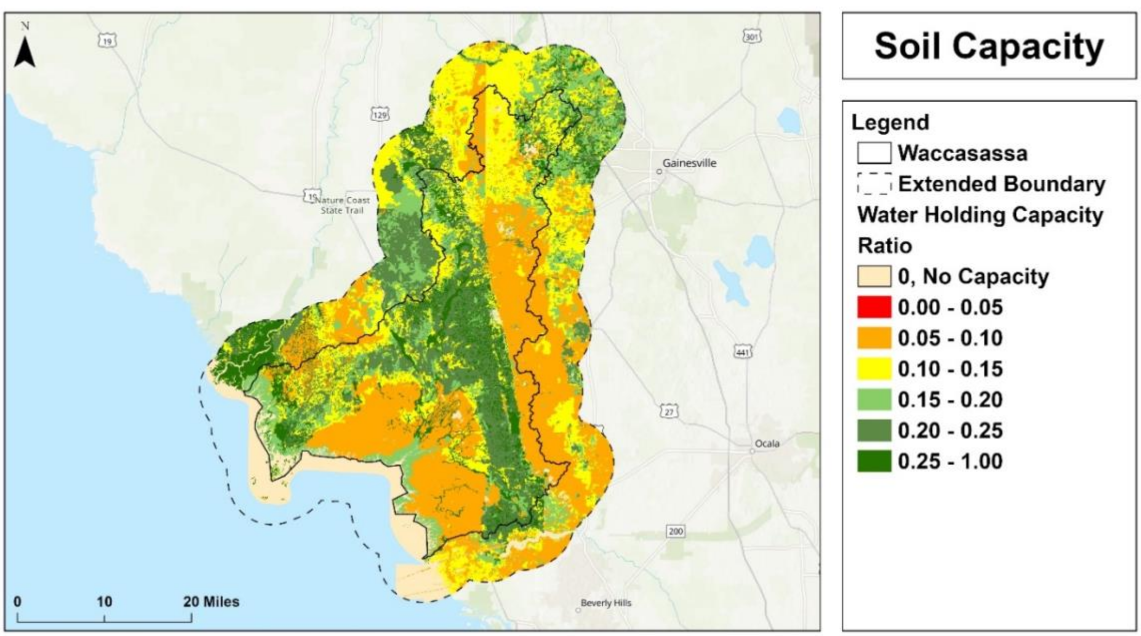

Figure 8 Soil capacity in the Waccasassa watershed.

3.1.6 Rainfall

Figure 9 contains the average rainfall for the watershed, based on a 25-year, 3-day rainfall average. There was a lower recorded rainfall average further inland at under 13 inches, while near the coast the average rainfall amount increased to over 18 inches.

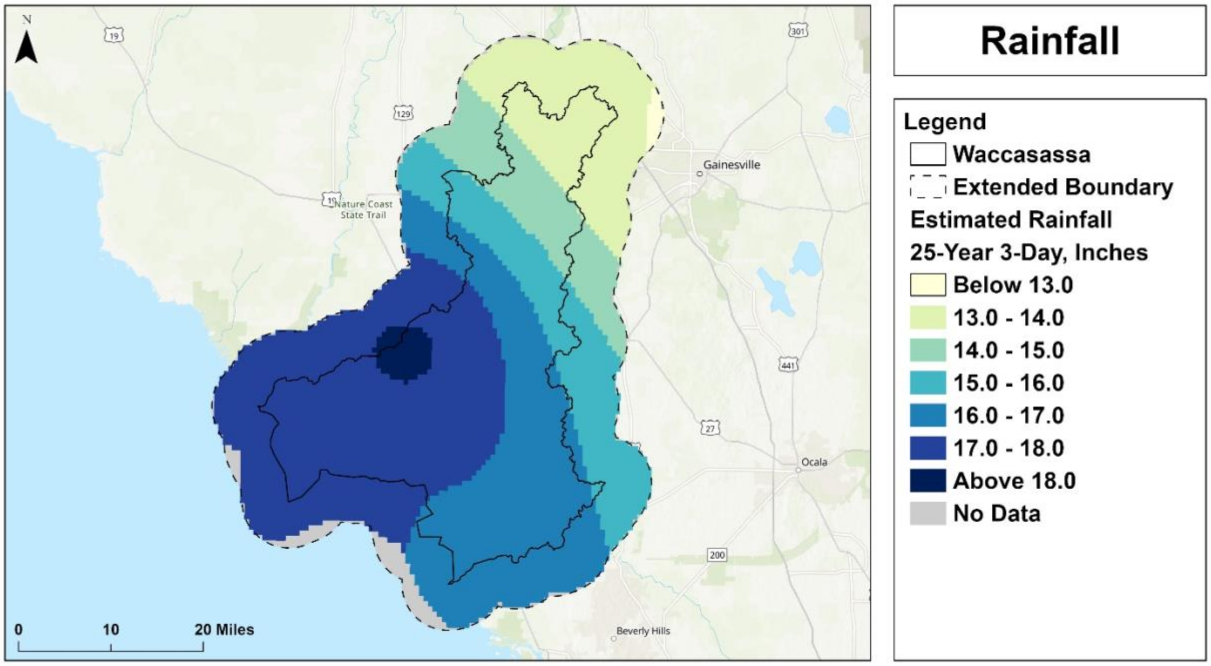

Figure 9 Average rainfall in the Waccasassa watershed.

3.2 Modeling Protocol

The modelling of the watershed was done using ArcGIS, ArcHydro, and Cascade software. The 3-meter DEM (Figure 2), impervious mask (Figure 3), water mask (Figure 4), open space (Figure 7), and rainfall (Figure 9) were created by clipping the obtained layers to the 5-mile buffer of the watershed. A 5-mile buffer was used instead of the original boundary, as to remove any inconsistencies or abnormalities that could occur near the edges of the watershed. The exception to this was the station data (Figure 6) as some stations could be found outside of the 5-mile buffer. The soil capacity (Figure 8) was created by multiplying the water mask, impervious mask, and a soil ratio dataset. The groundwater layer (Figure 5) was created by using the kriging method in ArcGIS software, which utilized the water levels that were found by the groundwater stations, surface water stations, and tidal gauges.

Figure 10 shows the quantity of the soil storage that was computed in preparation for the final flooding data. This was created by using the expression *DEM - groundwater layer * 12 * soil storage capacity*. The areas with the lowest storage were found along the coast and in the middle, which correspond low elevation and the presence of water (ex. rivers, swamps). The areas with the highest amount of soil storage over 8 inches were found in drier parts of the inland, along with areas in higher elevation.

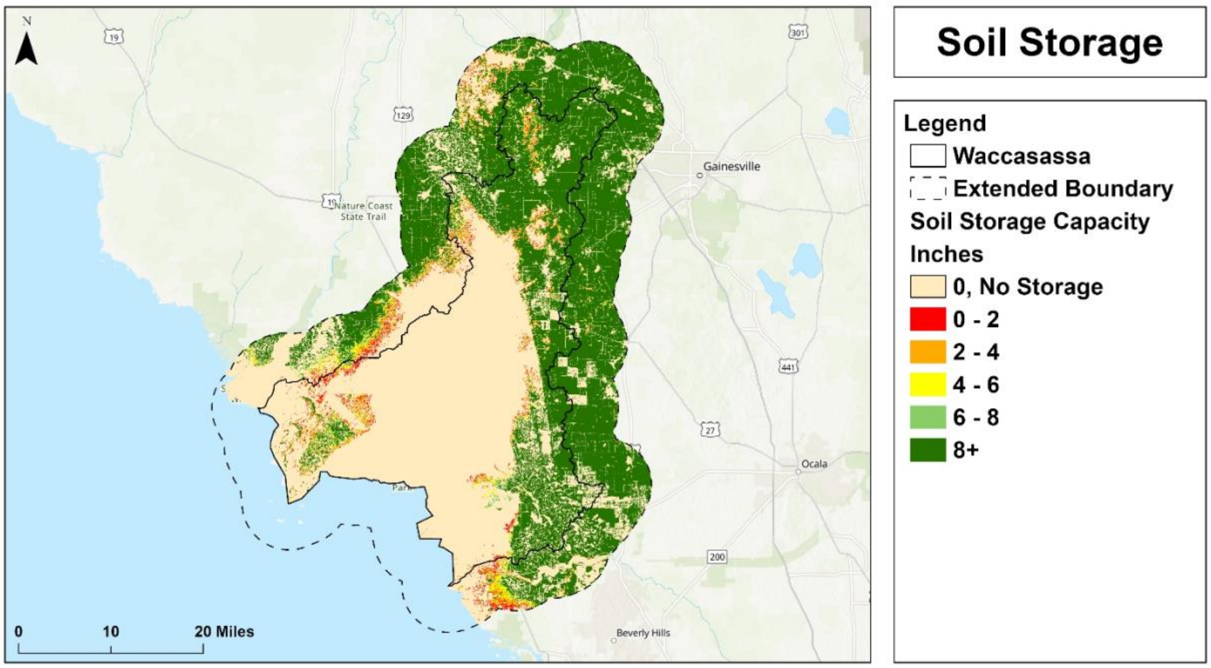

Figure 10 Soil storage in inches in the Waccasassa watershed

ArcHydro was then used to generate the catchments within the watershed, which also included the drainage lines and drainage points for each of the catchments. This was done to determine the direction and the longest drainage path for the catchments to understand where water would flow from areas of higher elevation to areas of lower elevation. The average rainfall, average soil storage, initial drainage elevation, maximum ground elevation, and area in acres was then calculated for each catchment for use in Cascade software in order to calculate the maximum headwater height for each catchment in preparation for the flood inundation. Once the headwater height was obtained from each catchment, the expression *(Headwater Height – DEM Elevation) +/- 0.46)* was used to calculate the Z-score for the entire watershed, which was assigned a probability of flood inundation for the entire watershed.

3.3 Modeling Results

3.3.1 Watershed pathways

The catchments and waterway flow paths that were produced from ArcHydro as shown for the Waccasassa watershed can be found in Figure 11.

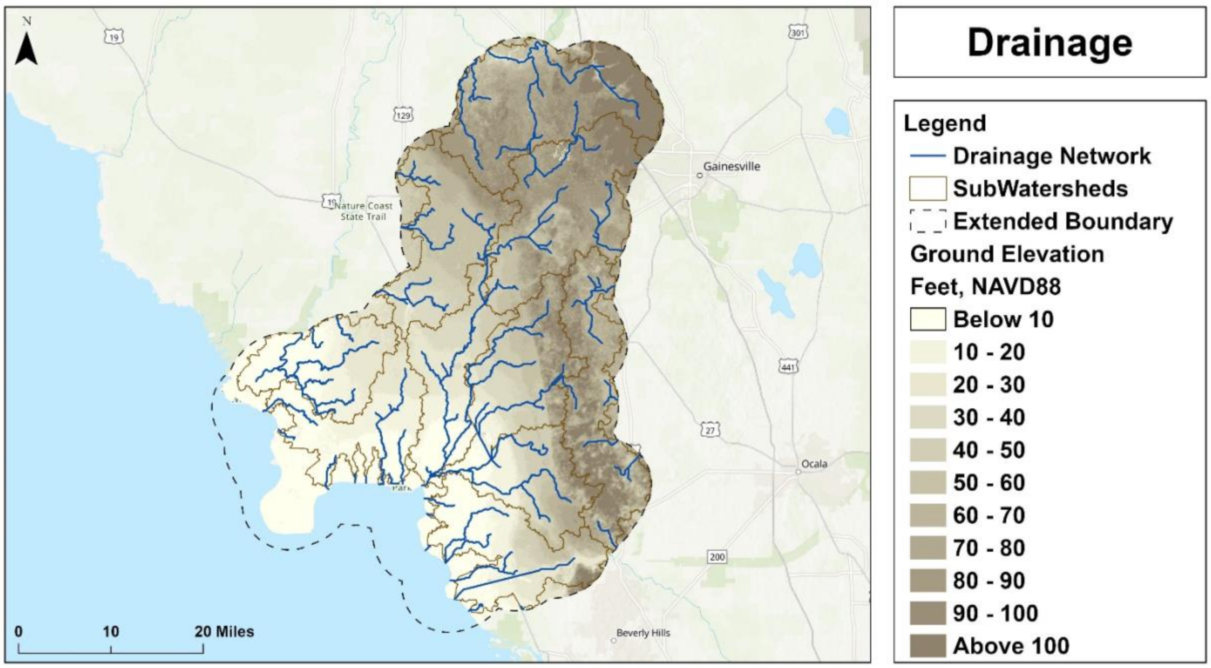

Figure 11 Catchments and flow paths in the Waccasassa watershed.

3.3.2 Cascade Results

The final results from Cascade can be seen in Table 1, which displays the predicted headwater height for each of the catchments, along with the area in acres, mean rain, mean soil storage capacity, initial stage, and the maximum elevation from ArcGIS and ArcHydro.

Table 2: Cascade Results

Catchment	Area (Acres)	Mean Rain	Mean Soil Storage	Initial Stage	Max DEM	Headwater Height
1	144,154.05	13.70	59.09	43.66	235.98	43.75
2	132,503.53	14.36	43.51	61.35	203.73	62.13
3	98,201.95	16.29	10.96	11.64	121.72	18.91
4	75,546.43	17.77	3.98	-7.53	49.50	-1.32
5	77,498.10	17.71	0.94	0.25	50.51	11.56
6	79,357.70	17.50	0.00	5.08	69.82	14.52
7	88,337.76	16.50	9.58	44.50	141.50	51.62
8	102,754.60	15.43	37.04	52.35	176.14	53.82
9	73,076.97	16.57	25.15	8.61	160.16	8.61
10	93,853.96	16.61	10.68	1.71	177.62	13.92

3.3.3 Vulnerability to Flooding

Figure 12 contains the predicted likelihood of flooding in the Waccasassa watershed. The probability of inundation was determined based on the Z-score for each of the pixels within the watershed, which was used to represent the confidence interval. Z-score values that were below 0 were considered having less than of 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. In addition, known bodies of water (ex. lakes, canals, rivers, etc.) were also displayed so to only show land-based flooding.

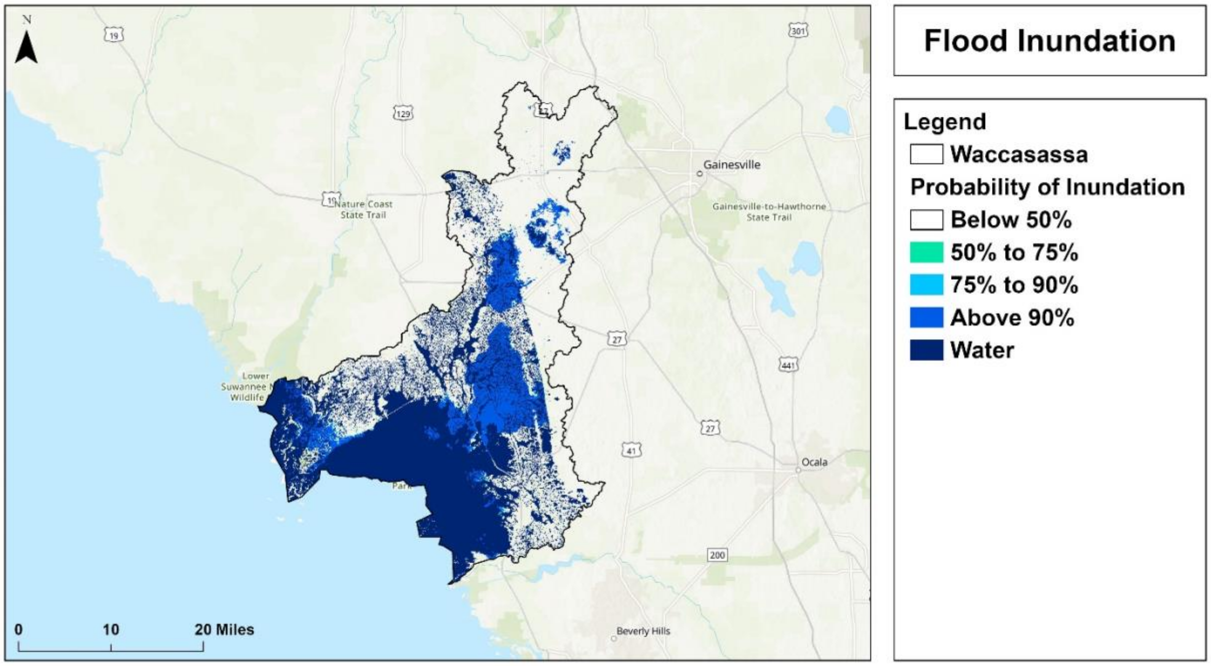

Figure 12 Predicted flooding in the Waccasassa watershed

3.3.4 FEMA Flood map comparison

Figure 13 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.).

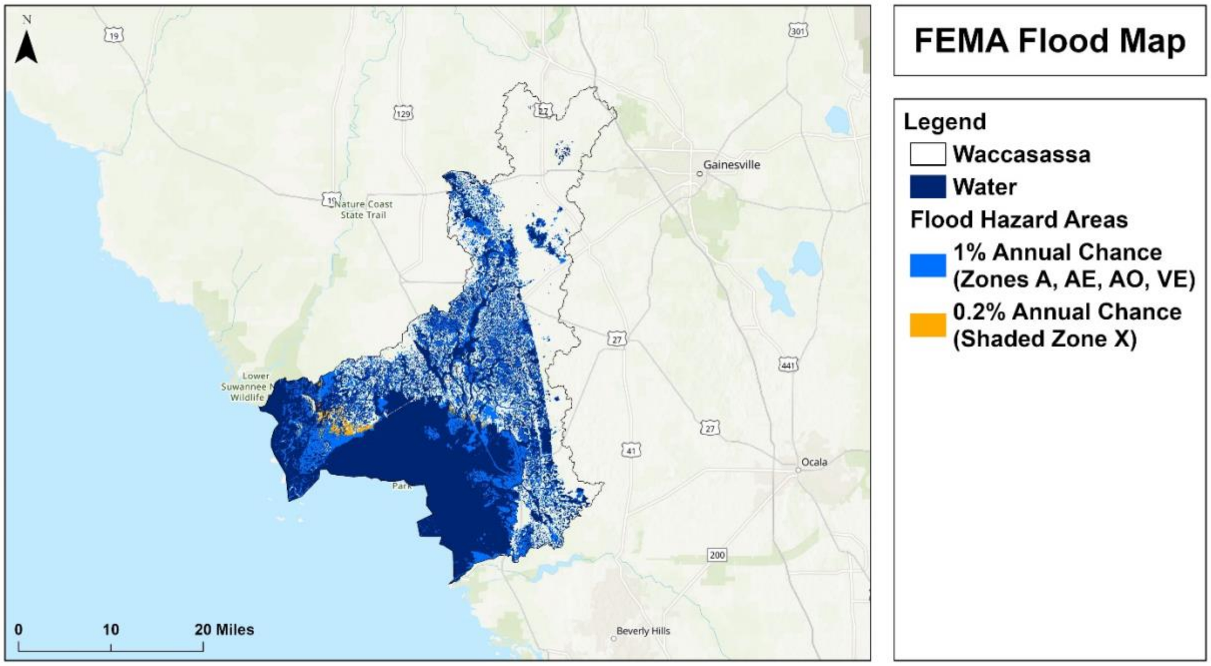

Figure 13 Designated FEMA flood hazard area comparison in the Waccasassa watershed.

3.3.5 Repetitive Loss

Figure 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.

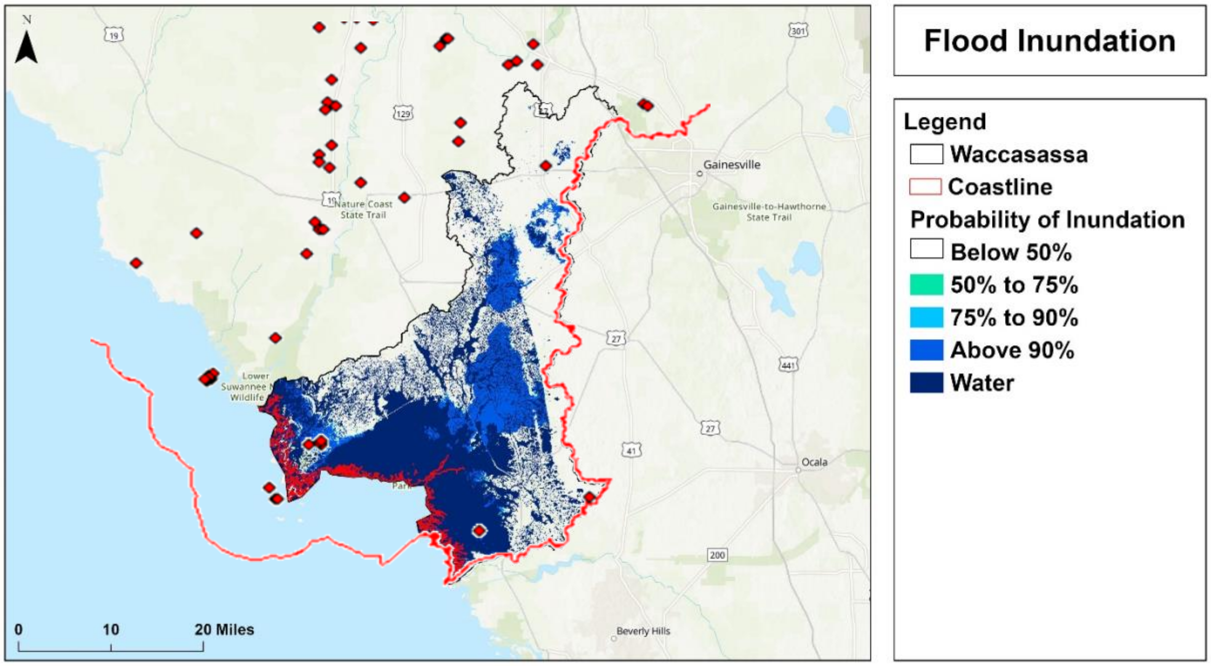

Figure 14 Repetitive loss areas from 2004 -2014 superimposed on the flood risk map created by FAU.

3.4 Drill down in Developed Areas Loss

Figure 15 shows the areas of the basin that are developed and flooded so further drill down could be conducted. The drilldown to the higher risk/ vulnerability maps to highlight critical areas in this watershed included1) Newberry; 2) Bronson, and 3) Yankeetown. The location of these three drilldown areas is displayed in Figure 13. These are urban areas that are particularly vulnerable to flooding and are subject to further study through a scaled-down modeling approach.

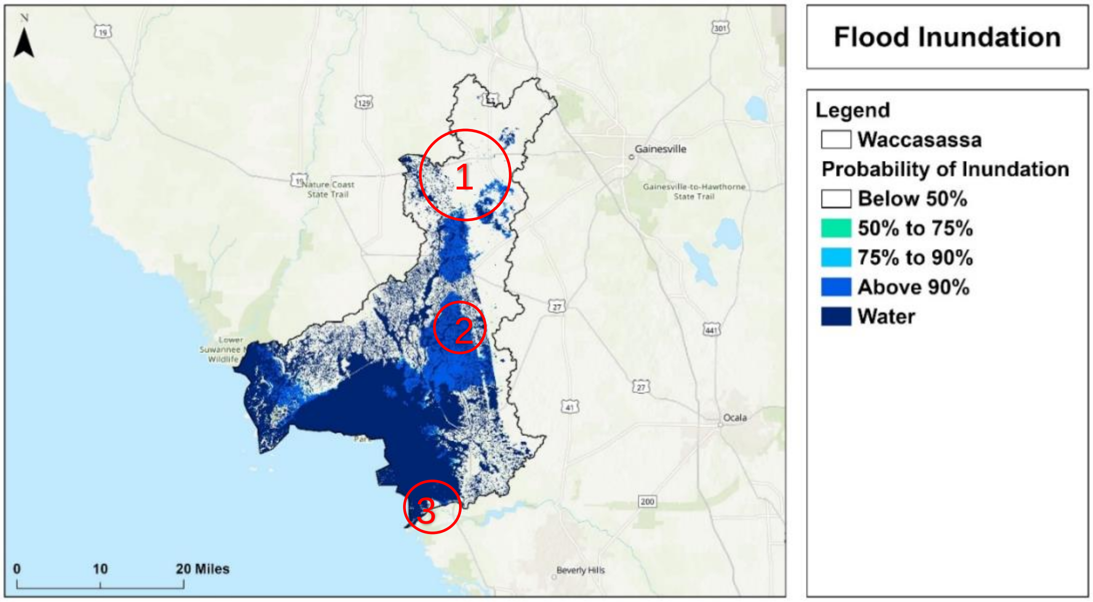

Figure 1 Location of three drilldown areas for further flood mapping: 1) Newberry; 2) Bronson, and 3) Yankeetown.

1) Newberry

Newberry is located in the north part of this watershed. As of the 2018 census estimate, the population was 5,789 over this city and has a total area of 53.6 square miles (138.8 km2). Newberry is not bordered by major water bodies, though it is surrounded by small lakes and ponds. The vulnerability map for this area is displayed in Figure 16.

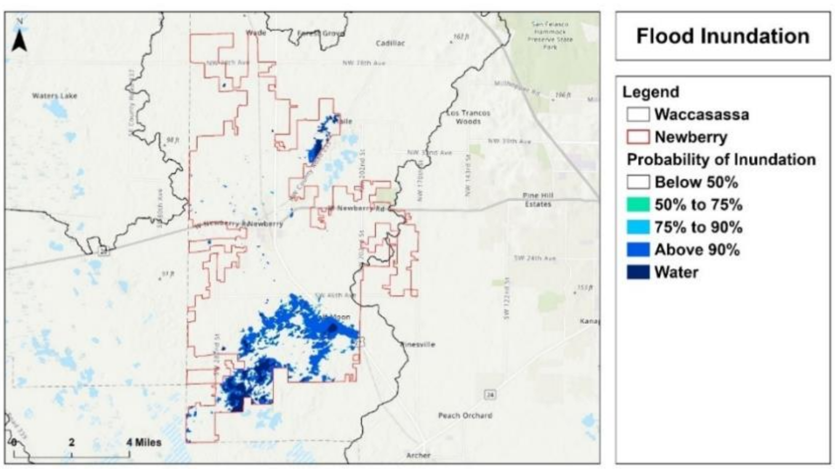

Figure 2 Flooding vulnerability of Newberry in the north of the watershed.

2) Bronson

Bronson is located in the north part of this watershed. As of the 2018 census estimate, the population was 913 over this town and has a total area of 4.2 square miles (10.9 km^2). Bronson is not bordered by major water bodies, though it is surrounded by small lakes and ponds. The vulnerability map for this area is displayed in Figure 17.

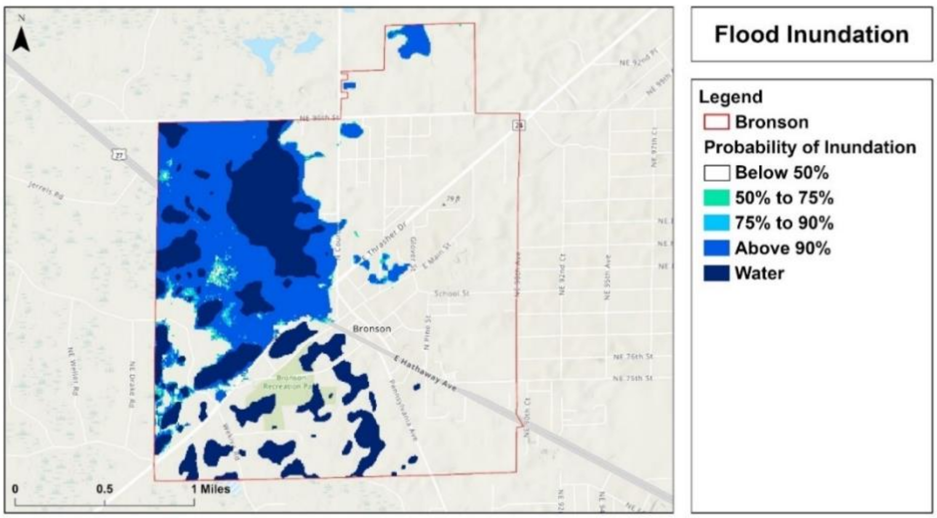

Figure 3 Flooding vulnerability of Bronson in the middle of the watershed.

3) Yankeetown

Yankeetown is located in the south part of this watershed is also selected for drilldown. As of the 2018 census estimate, the population was 585 over this town and has a total area of 7.6 square miles (19.7 km^2). Yankeetown is bordered by the Withlacoochee River and Withlacoochee Bay. The vulnerability map for this area is displayed in Figure 18.

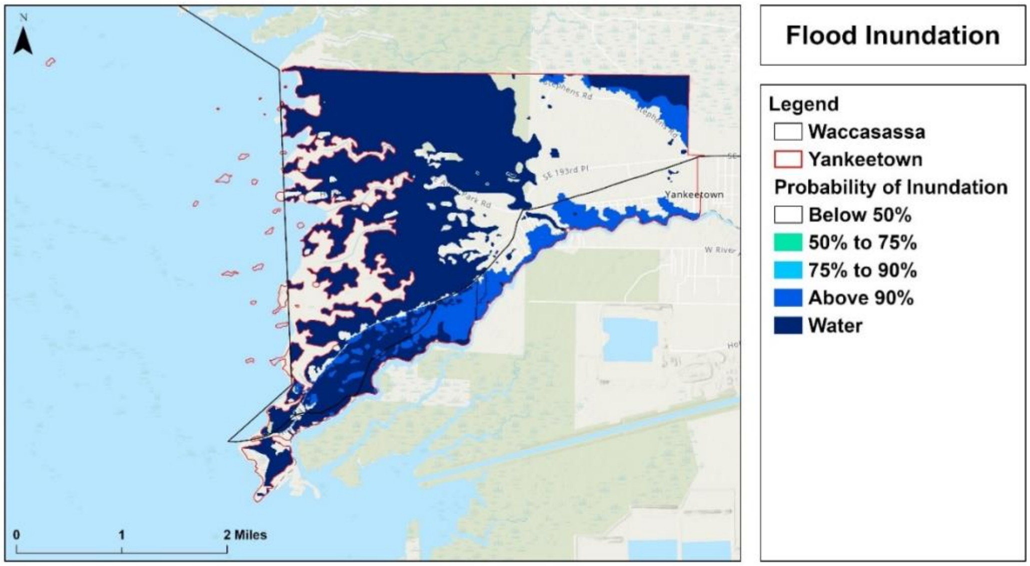

Figure 4 Flooding vulnerability of Yankeetown in the south of the watershed.

4.0 Conclusions

FDEM contracted with FAU to develop a screening tool of flood risk areas for 29 watershed basins. The effort discussed herein focusses on the development procedures for a screening tool to assess risk in the Waccasassa Basin (#6) basin, a watershed located in Southwest Florida that combines readily available data on topography, ground, and surface water elevations, tidal information for coastal communities, soils, open space and rainfall to permit an assessment of the risk of inundation of property. The basin shows widespread flooding due to low elevation proximity to the Gulf of Mexico coast and extensive sensitive areas that currently received extensive environmental protection. A drilldown to the local communities indicates that the major developments are flood prone. Solutions to improve flood resiliency in this basin will yield long term benefits. The developed kriging approach produced a reasonable groundwater table pattern for this watershed, which is critical for further Cascade modeling. Application of the developed protocol for inundation mapping works well for this watershed.

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