MBNEP

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Wolf Bay Watershed Study

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1. Executive Summary

This report is a modification to the Wolf Bay Watershed Study report submitted to Baldwin County on September 2013 by Hydro-Engineering Solutions, A Division of Trimble. The 2013 calibrated GSSHA hydrologic model was reexamined with the September 4, 2018 rainfall event from Tropical Storm Gordon to see if the GSSHA model was still applicable.

During the September 4, 2018 rainfall event, the watershed experienced approximately 5” of rain in 10 hours. This equates to a 2-year recurrence interval. It was determined from this rainfall event that the previously calibrated Wolf Bay model from 2013 provided reasonable results for both timing and peak discharge. The model was also run with the updated NOAA Atlas 14 precipitation depths for a 100 year-event and then compared to the updated 100-year rural regression equations found in *Magnitude and frequency of floods in Alabama, 2015:* It has been determined that the previously calibrated 2013 Wolf Bay watershed model produces discharges in line with the updated regression equations and is still an applicable tool for analyzing stormwater impacts based on future developments.

2. Introduction

2.1. Description

Wolf Bay is an estuary located in the southeastern part of Baldwin County, AL (Figure 2-1). Wolf Bay drains through a series of other bays and ultimately drains into the Gulf of Mexico. The portion of the watershed that is being analyzed for this study drains approximately 56 square miles. There are generally 5 sub-basins that make up the drainage area for Wolf Bay being studied (Figure 2-2). The major creeks that make up these sub-basins include Wolf Creek, Sandy Creek, Miflin Creek, Hammock Creek, Owens Bayou, and Graham Bayou. The southern end of the creeks experience daily tidal fluctuations with about 2 feet of change. There are two municipalities found within the study area. The first is Foley, which is located on the northwestern boundary of the Wolf Creek sub-basin. The second is Elberta, which is located in the northern part of the Miflin Creek Sub-basin. The municipalities of Gulf Shores and Orange Beach also drain into Wolf Bay; however, this is below the area of interest.

The ADEM classification for Wolf Bay and all connecting coves and bayous is OAW / S / F&W / SH. The OAW (Outstanding Alabama Water) classification is the highest level of waterbody classifications. It indicates "high quality waters that constitute an outstanding Alabama resource of exceptional recreational and ecological significance." The OAW designation was granted in 2007. The other classifications indicate that the waterbody is also used for swimming (S), fish and wildlife (F&W), and shellfish harvesting (SH).

Figure 2-1
Location Map and Watershed Boundary

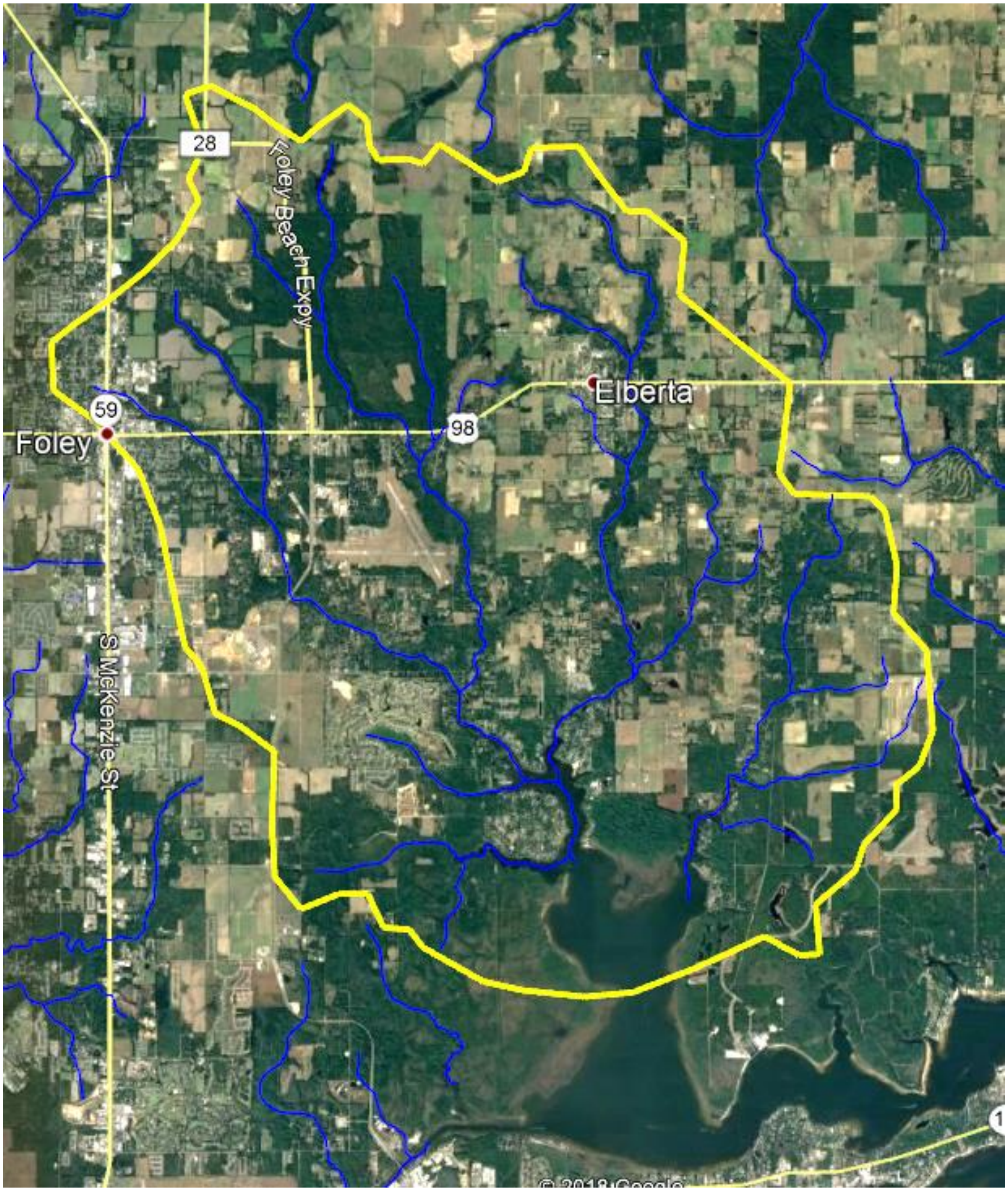
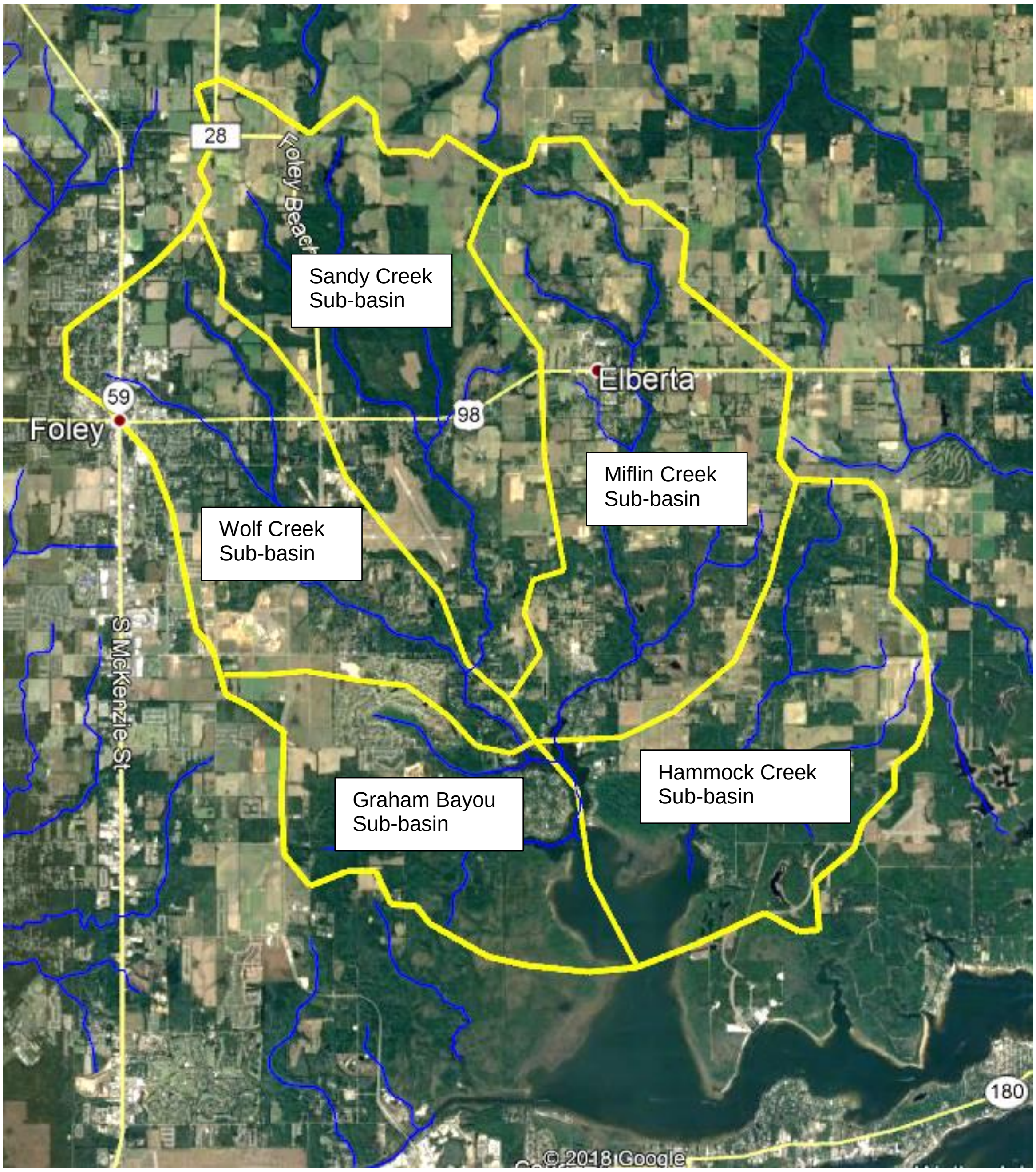


Figure 2-2
Wolf Bay Sub-basins



2.2. Climate

Baldwin County has a mild but humid climate. Data obtained from "weatherdb.com" indicates the average annual rainfall for Baldwin County (Foley and Elberta area) is around 61 inches. The summer months are typically the wettest with the winter typically being the driest months. The average high and low temperatures are 77 degrees and 55 degrees respectively. The warmest month is typically July with the coldest month being January.

Although the yearly rainfall is generally well distributed, significant rain events can be experienced in the watershed due to proximity to the coast and exposure to hurricanes. The hurricane season usually occurs in the late summer to early fall. Table 2-1 lists select hurricanes indicated by the date of occurrence, the hurricane name, and the range of rainfall related to the storm.

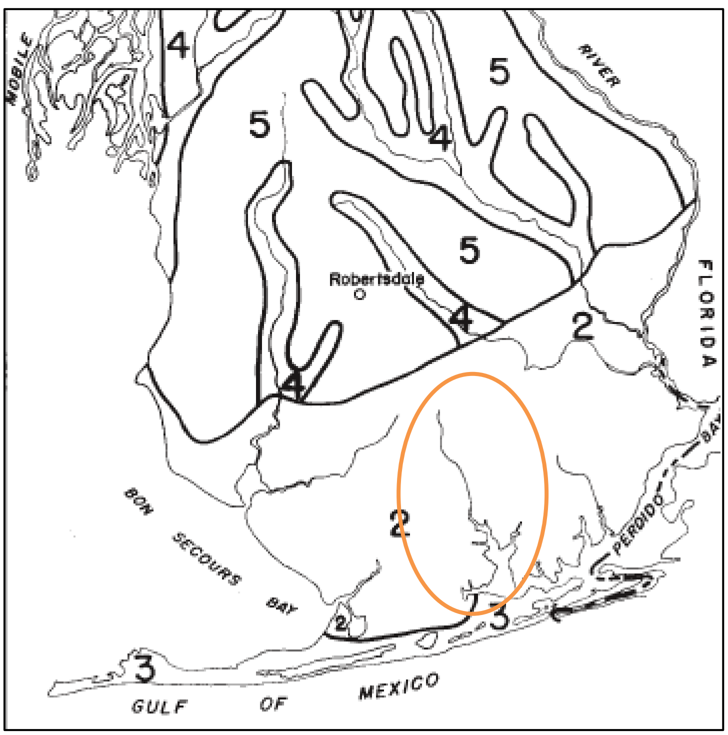
Table 2-1
Hurricane Event and Related Precipitation

Date	Hurricane	Precipitation (inches)
Oct 3-5, 1995	Opal	9-12
July 18-25, 1997	Danny	18-24
Sept 21-Oct 1, 1998	Georges	9-18
Sept 13-26, 2004	Ivan	7-10
July 5-13, 2005	Dennis	3-4
Aug 23-31, 2005	Katrina	2-3
Sept 1-4, 2011	Tropical Storm Lee	7-11

2.3. Physiography

According to the *Soil Survey of Baldwin County*, "Baldwin County is a part of the Gulf Coastal Plain physiographic region known as the Lower Coastal Plain. The county is underlain by five different kinds of deposits or geologic formations…" These are 1) River floodplains and terraces 2) Marine terraces 3) Areas of coastal beaches 4) Areas underlain by Hattiesburg clay and 5) Plateaus and ridgetops underlain by the Citronelle formation. The Wolf Bay watershed falls within area 2. Area 2 is underlain by deposits on marine terraces. This area is nearly level to gently sloping and is at an elevation that ranges from 10 to 100 feet above sea level. Figure 2-3 indicates the physiographic area of the study.

Figure 2-3
Physiographic areas of Wolf Bay Watershed



2.4. Land Use

According to _Baldwin County Profile – An Analysis of the Demographics and Other Characteristics that Constitute Baldwin County_ published by the Planning and Zoning Department of the Baldwin Count Commission May 2008, the majority of Baldwin County is made up of agriculture, upland forested areas, and wetlands. These three land uses make up approximately 83.06% of the land use. Residential land use accounts for about 8.88% and commercial and industrial accounts for about 0.75%.

According to _Citizen Volunteer Water Monitoring on Wolf Bay_ published by the Alabama Water Watch in 2008, the majority of the Wolf Bay Watershed is made up of agriculture, upland forested areas, and urban development. From 2005 data, these three land uses make up approximately 27%, 23%, and 27% of the land use respectively. As compared to 1992, agricultural and forested areas have decreased while urban development has increased. The percentages of land use in 1992 for agriculture, forests, and urban are 46%, 32%, and 4%. Water and wetlands for the area account for approximately 18% of the land use.

3. Model

3.1. General

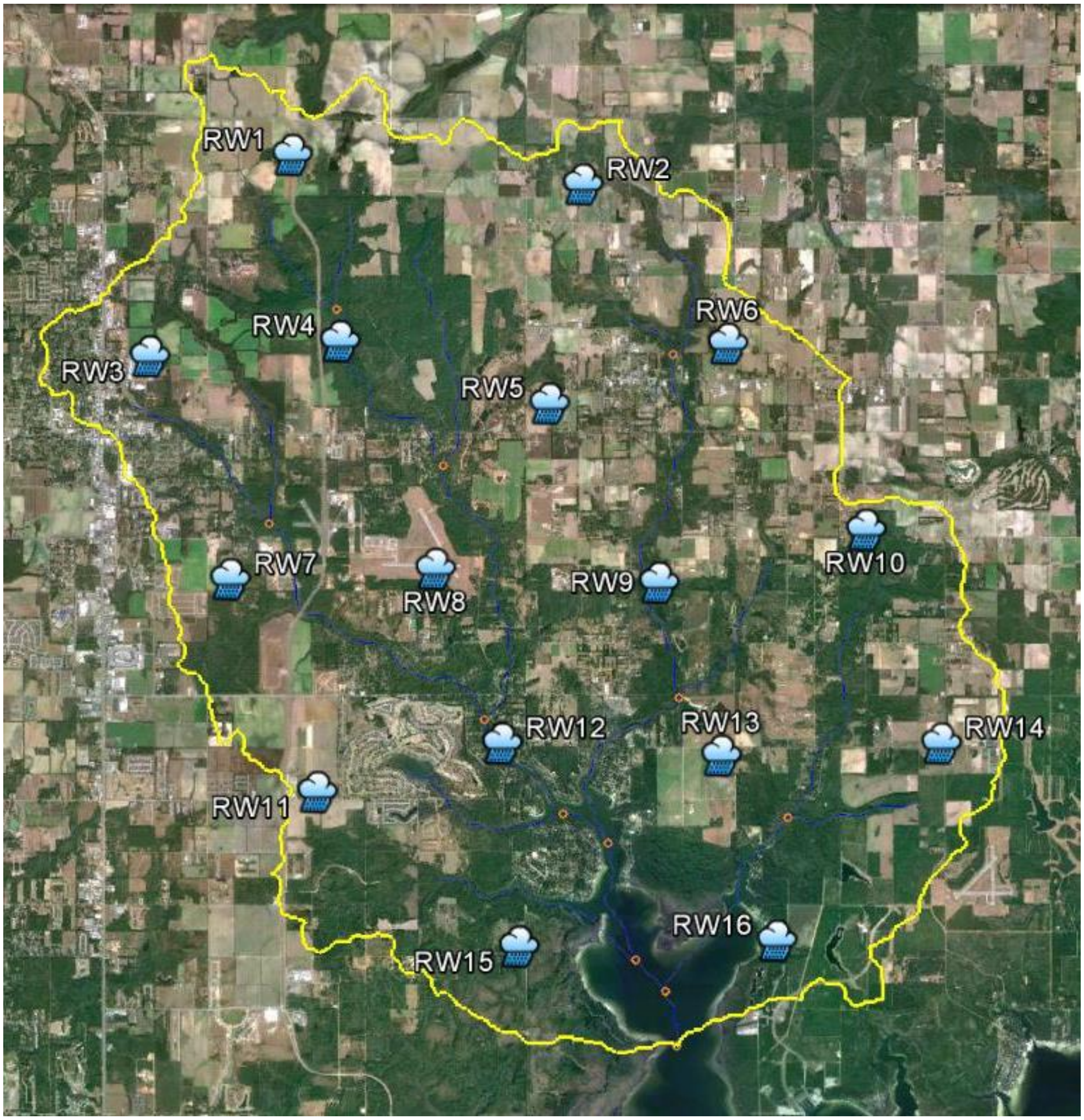
The hydrologic model used to evaluate the Wolf Bay watershed is the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model. GSSHA is developed and maintained by the US Army Engineer Research and Development Center (ERDC) Hydrologic Modeling Branch, in the Coastal and Hydraulics Laboratory. GSSHA is a physically-based, distributed parameter hydrologic model with sediment and constituent fate and transport capabilities. Features include two dimensional (2-D) overland flow, 1-D stream flow, 1-D infiltration, 2-D groundwater, and full coupling between the groundwater, shallow soils, streams, and overland flow. Sediment and constituent fate and transport are simulated in the shallow soils, overland flow plane, and in streams and channels. GSSHA can be used as an episodic or continuous model where soil surface moisture, groundwater levels, stream interactions, and constituent fate are continuously simulated. Parameters used to generate a GSSHA simulation include rainfall data, digital terrain data, land use data, and soils data.

3.2. Rainfall Data

One of the strengths of the GSSHA model is the ability to perform long-term simulations. A key element in forecasting discharges for future storm occurrences depends upon good rainfall data. For the rainfall component used in the simulations, Hydro-Engineering Solutions (Hydro) obtained storm data from three different monitoring sources.

For the rainfall component used in the original simulations, Hydro-Engineering Solutions (Hydro) employed the use of RainWave. RainWave offers precipitation-monitoring services that allow a user to enter a latitude and longitude for a point of interest. Once this point is entered into the system, various rainfall data can be obtained. For the modeling simulations 5-minute rainfall intervals were utilized. This data can then be formatted for a GSSHA long-term simulation. Figure 3-1 indicates the RainWave point locations used for gathering rainfall distribution data. It should be noted that RainWave no longer provides precipitation services.

Figure 3-1
2013 RainWave Point Locations



The second source for gathering rainfall data is from weather stations that Hydro deployed throughout the watershed (Figure 3-2). On June 6, 2018 a weather station (MBNEP 124) was installed at Foley High School just west of the Wolf Bay watershed boundary. The second weather station (MBNEP 136) was installed at a residence in Elberta on May 15, 2019.

The Davis Instruments, Corp.'s Vantage Pro 2 Precision Weather Station was used for data collection. Information collected from this weather station include: rainfall, temperature, humidity, wind speed, and barometric pressure. The data is sent to Weatherlink.com, which is Davis' global weather network. Weatherlink software was used for data retrieval for each station. After a storm event, data would be retrieved and processed for use in the GSSHA model.

The third source of rainfall used was obtained from Weather Underground. Weather Underground is a weather service that provides real-time weather information over the internet. According to their website, "Our brand mission is to make quality weather information available to every person on this planet." The service makes use of "the generous and passionate community of weather enthusiasts that share weather data and content..." The information is obtained from the members who send real-time data from their personal weather stations. The weather stations available are plotted on a map (Wundermap) based on the parameter selected. The parameters available in which to sort the gauges are temperature/wind, temperature, dew point/humidity, and precipitation. Figure 3-3 indicates two of the available precipitation gauges that can also be used for analyzing the watershed. These two gauges are Kalfoley3 at Myrtle Court and Kalelber4 near Bingham Street and Anthony Lane.

Figure 3-2
HES Weather Station Locations

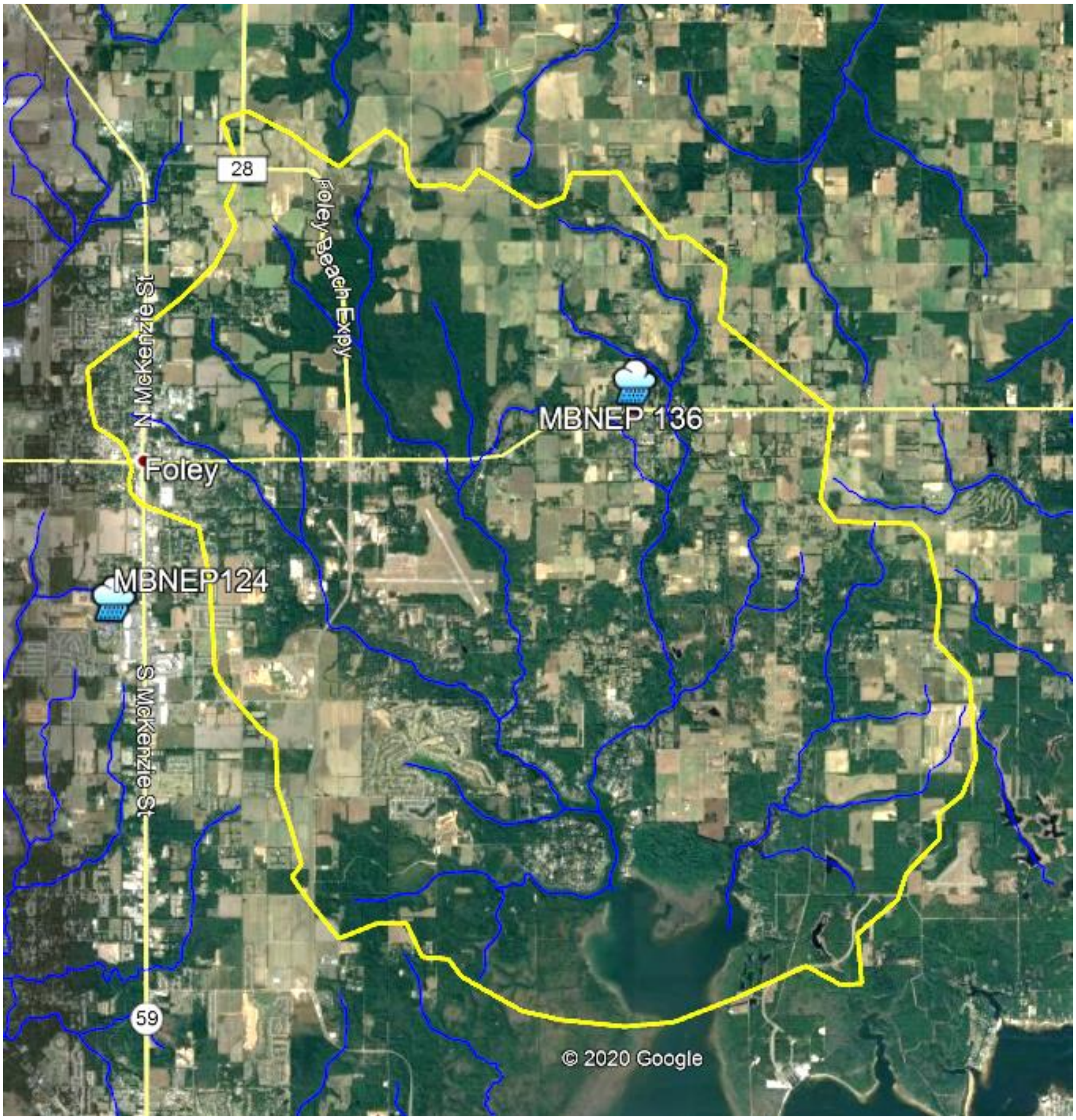
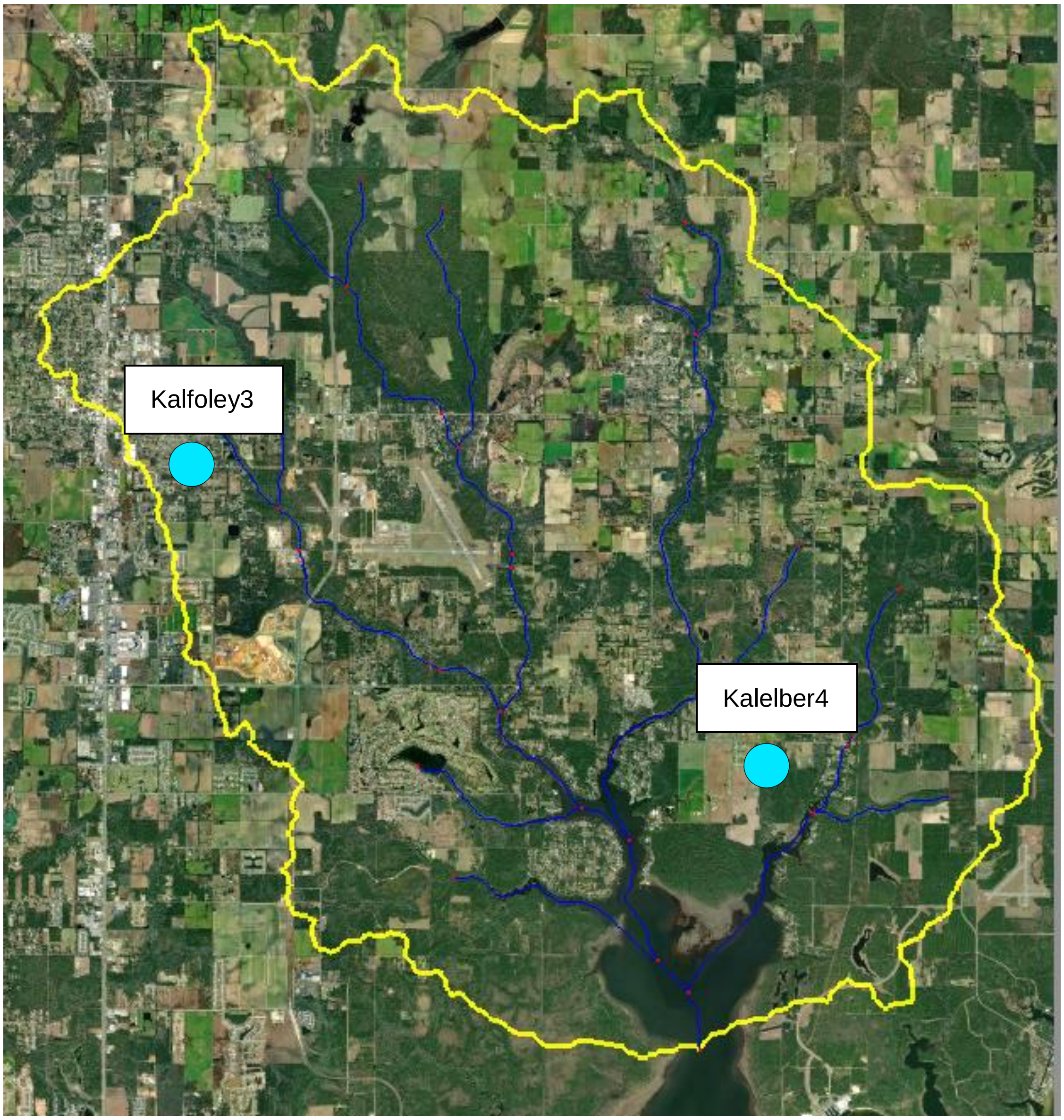


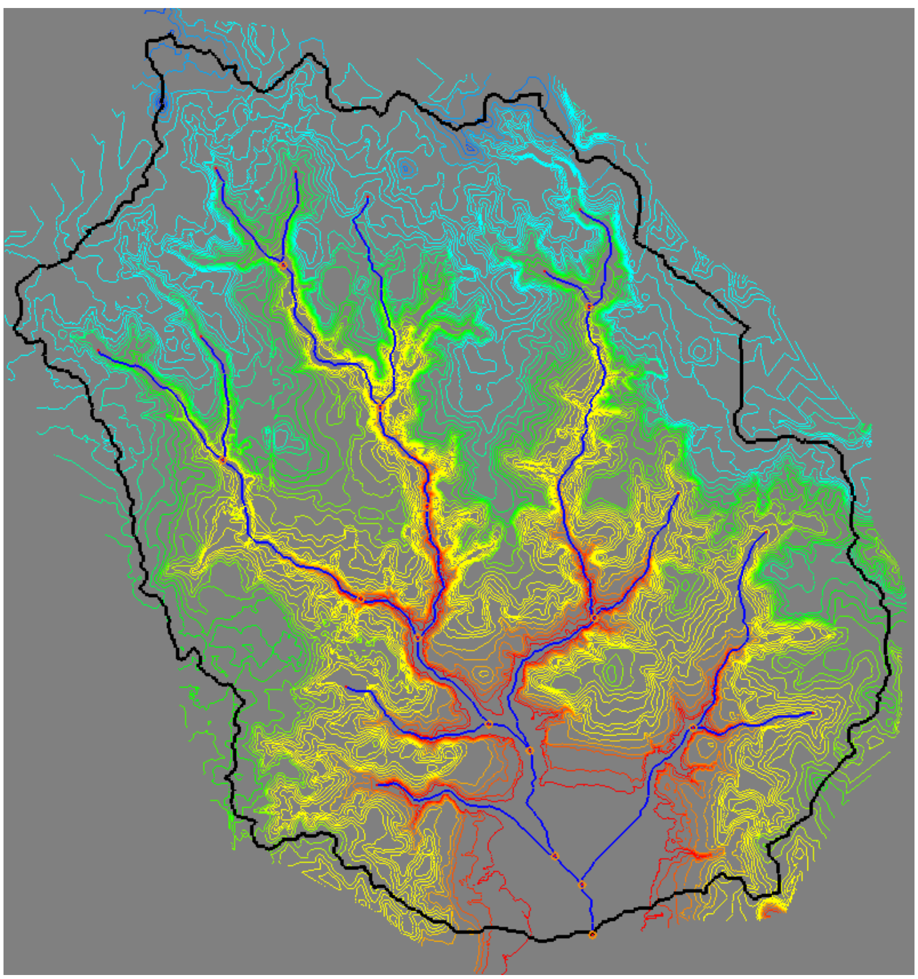
Figure 3-3
Weather Underground Gauge Locations



3.3. Digital Terrain Data

The GSSHA model uses digital terrain data to incorporate topography into the hydrologic model. For the original model, one-foot Light Detection and Ranging (LiDAR) data provided by Baldwin County was used to generate the digital elevation model (DEM). Due to the size of the drainage area, the file size of the LiDAR contours was too large for WMS to process. Contour intervals within the steep sections of the watershed that would not affect creation of the DEM were removed in order to reduce file size. Once the DEM was built, it was used for basin delineation. The DEM data was also used for generating cell elevations for the gridded model. Figure 3-4 indicates the topographic data that was used in the model.

Figure 3-4
Wolf Bay Watershed with Topographic Data



The GSSHA model requires all units to be in the International System of Units. It was therefore necessary to convert the State Plane AL-W data to UTM Zone 16 data. The units were also converted from feet to meters. After proper conversion, the DEM data can be used for automatic delineation of the basin, as well as, for generating cell elevations for the gridded model.

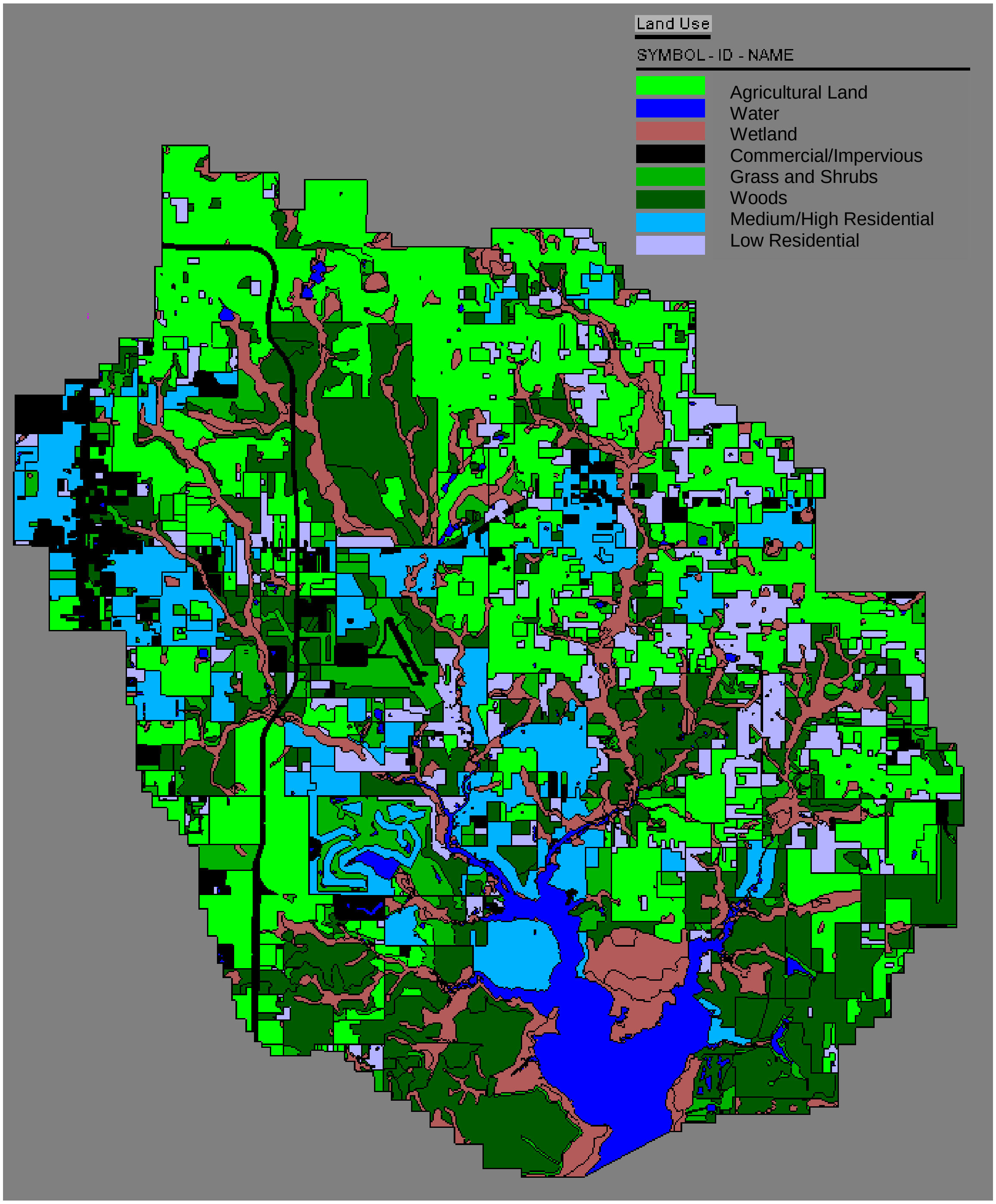
3.4. Land Use

The land use component of the model is necessary to define the various overland flow types throughout the basin. The roughness of each land use type is described by a Manning's 'n' value. A shapefile of the land use was provided by Baldwin County. The shapefile was converted to feature objects to be used in the model. It was necessary to simplify some of the land use descriptions for calibration purposes. Using geo-referenced aerial photography provided by Baldwin County, land use was checked to ensure all areas were properly assigned. Table 3-1 lists the land use types and the respective calibrated 'n' values assigned to them. Figure 3-5 indicates the land use assignments.

Table 3-1
Land Use and Manning's 'n' Values

GSSHA ID	Land Use	Manning's 'n'
2	Agriculture	0.250
5	Water	0.150
6	Wetlands	0.180
12	Commercial	0.011
32	Grass / Brush / Shrubs	0.260
36	Woods – Good	0.320
95	Med Residential	0.090
97	Low Residential	0.110

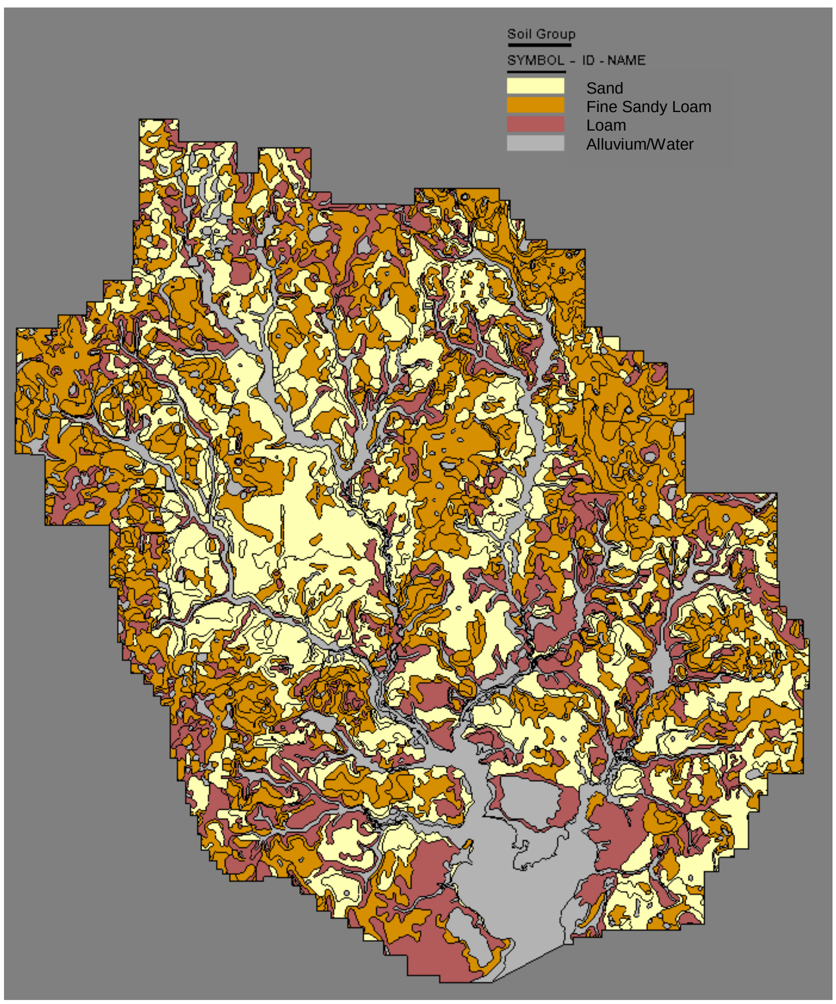
Figure 3-5
Original Digitized Land Use



3.5. Soils

Similarly to the land use, the GSSHA model has the capability to incorporate specific characteristics of the soils located within a drainage basin. The soils coverage is used for defining infiltration into the soil. The infiltration method used is Green and Ampt (G&A) with soil moisture redistribution. Soil parameters used by the G&A method include hydraulic conductivity, porosity, capillary head, pore distribution index, residual saturation, and field capacity. This allows the GSSHA model to evaluate the soil's ability to infiltrate stormwater in determining the peak discharge and volume of storm events. Soils data shapefiles provided by Baldwin County were converted to feature objects to be used in the model. Figure 3-6 indicates the soil data that has been incorporated into the model.

Figure 3-6
Original Digitized Soils Data



3.6. Combined Coverage

A combined land use / soils coverage layer can be generated in order to incorporate a more detailed way to specify infiltration. Instead of defining the infiltration parameters with just soils, it can be defined based on a soil type and specific land use. For example, a sandy loam may have woods described as the land use in one part of the watershed and a parking lot in another. Instead of applying the infiltration values for just a sandy loam, a combined coverage can utilize an infiltration value for the woods and a separate one for the parking lot. This can help better replicate the infiltration and timing related to the ground cover and soil type.

3.7. Gridded Model

Once all of the variables mentioned above have been incorporated into the model, it was necessary to divide the model into individual grid cells. For the Wolf Bay model a 70 meter x 70 meter (230 feet x 230 feet) grid size was utilized (Figure 3-7). The settings for GSSHA require the units to be in the International System of Units (SI). The total drainage area to the designated outlet is approximately 56 square miles. Over the entire watershed this generates approximately 25,900 grid cells. Figures 3-7, 3-8, 3-9, and 3-10 indicate the gridded topographic data, the gridded land use, the gridded soil types, and the gridded combined layer.

Figure 3-7
Gridded Topographic Data

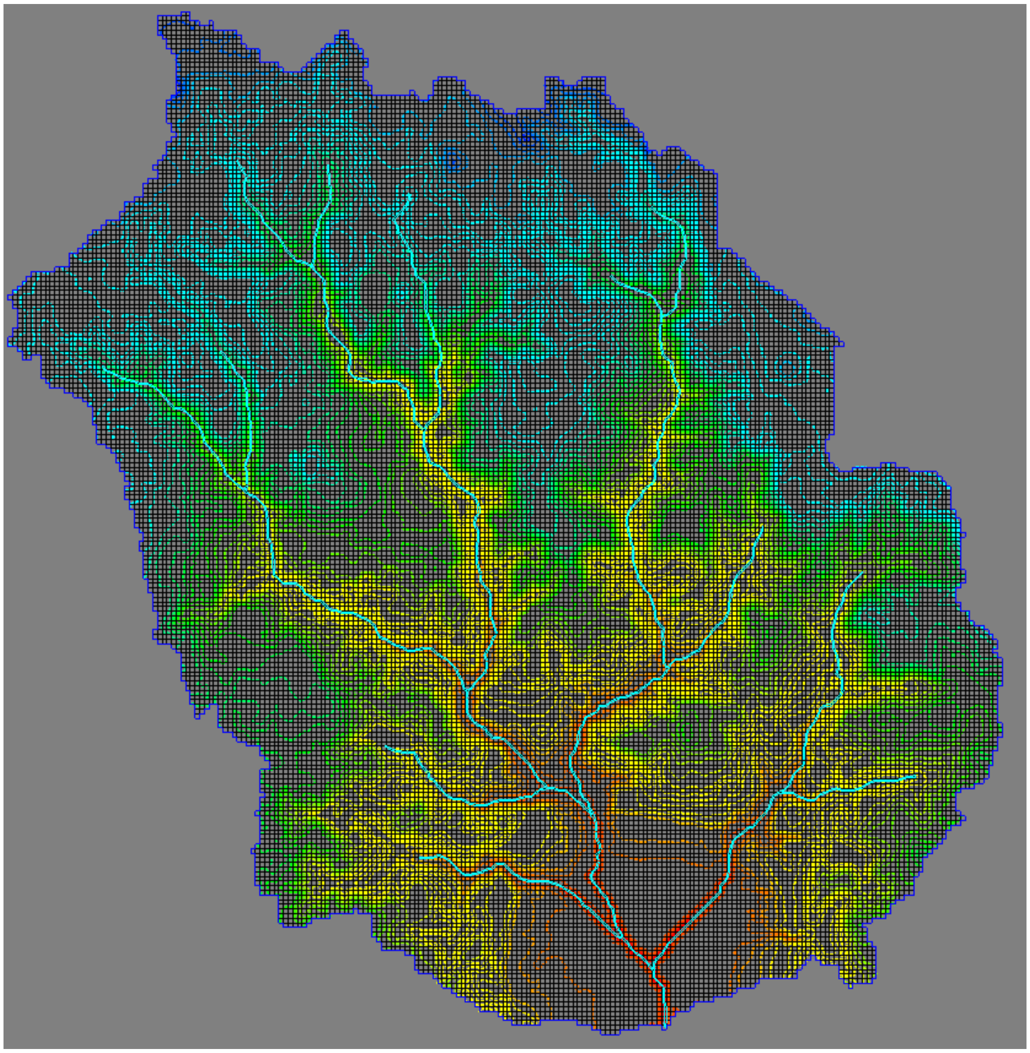


Figure 3-8
Gridded Land Use

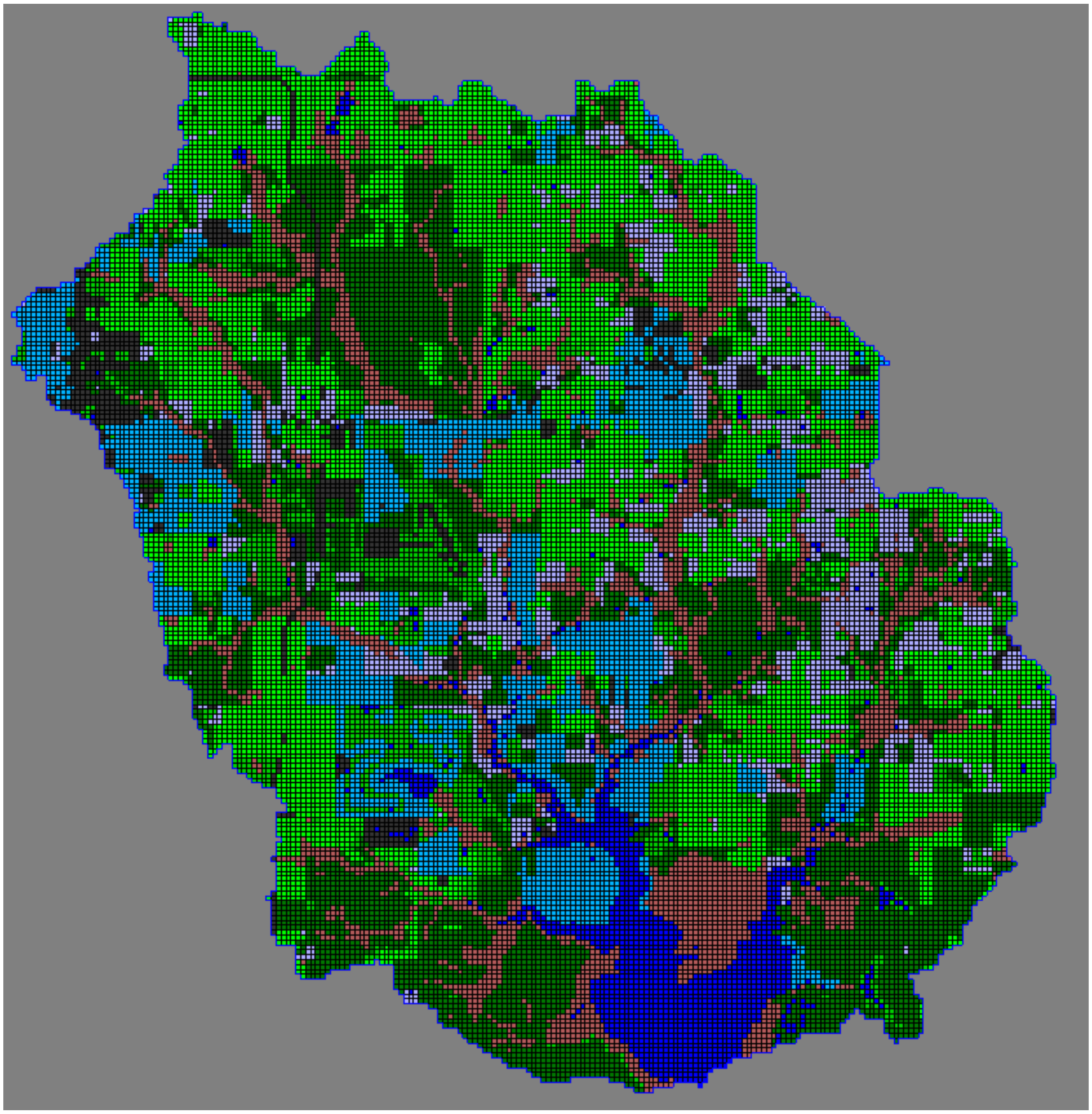


Figure 3-9
Gridded Soil Types

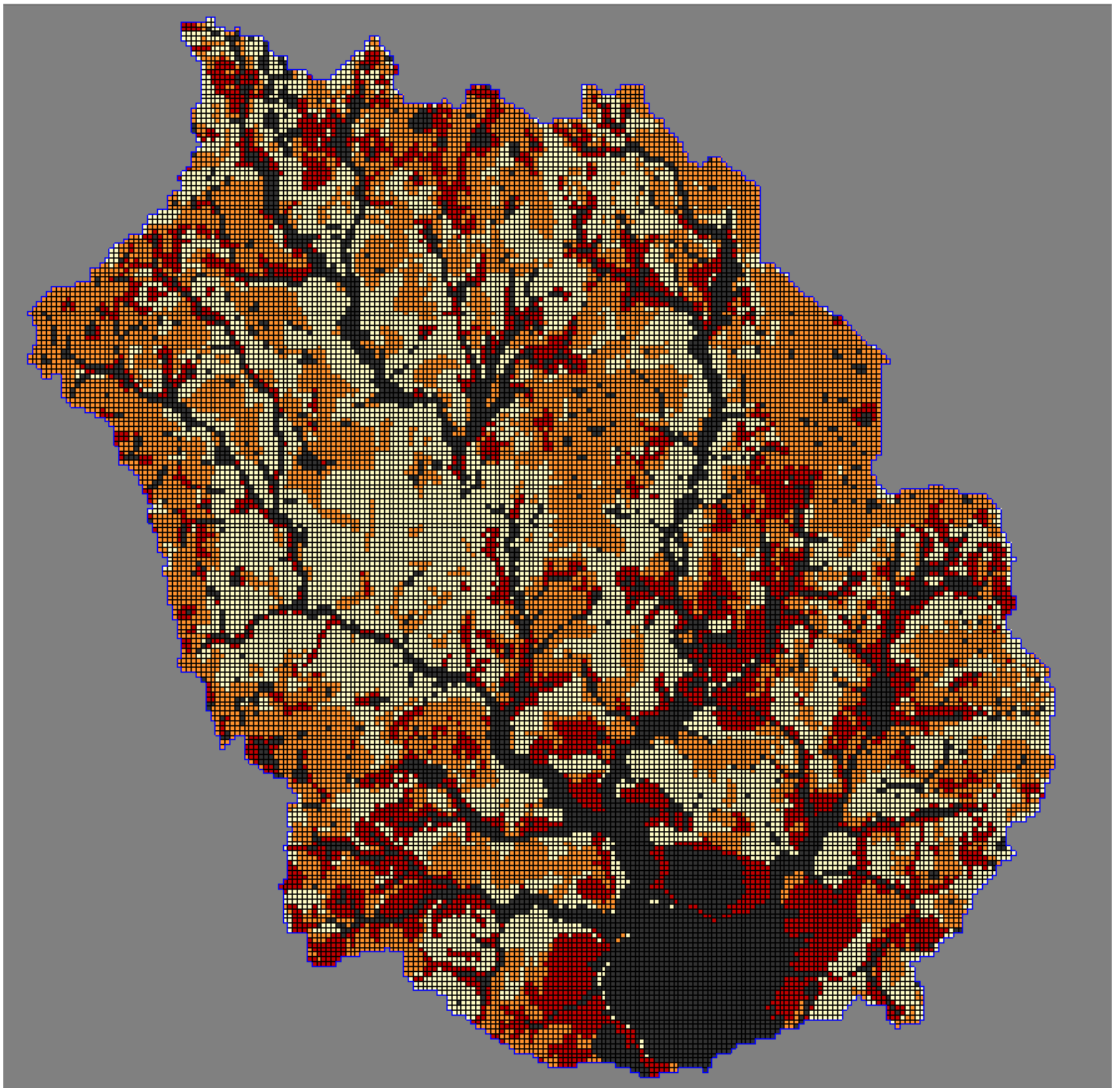
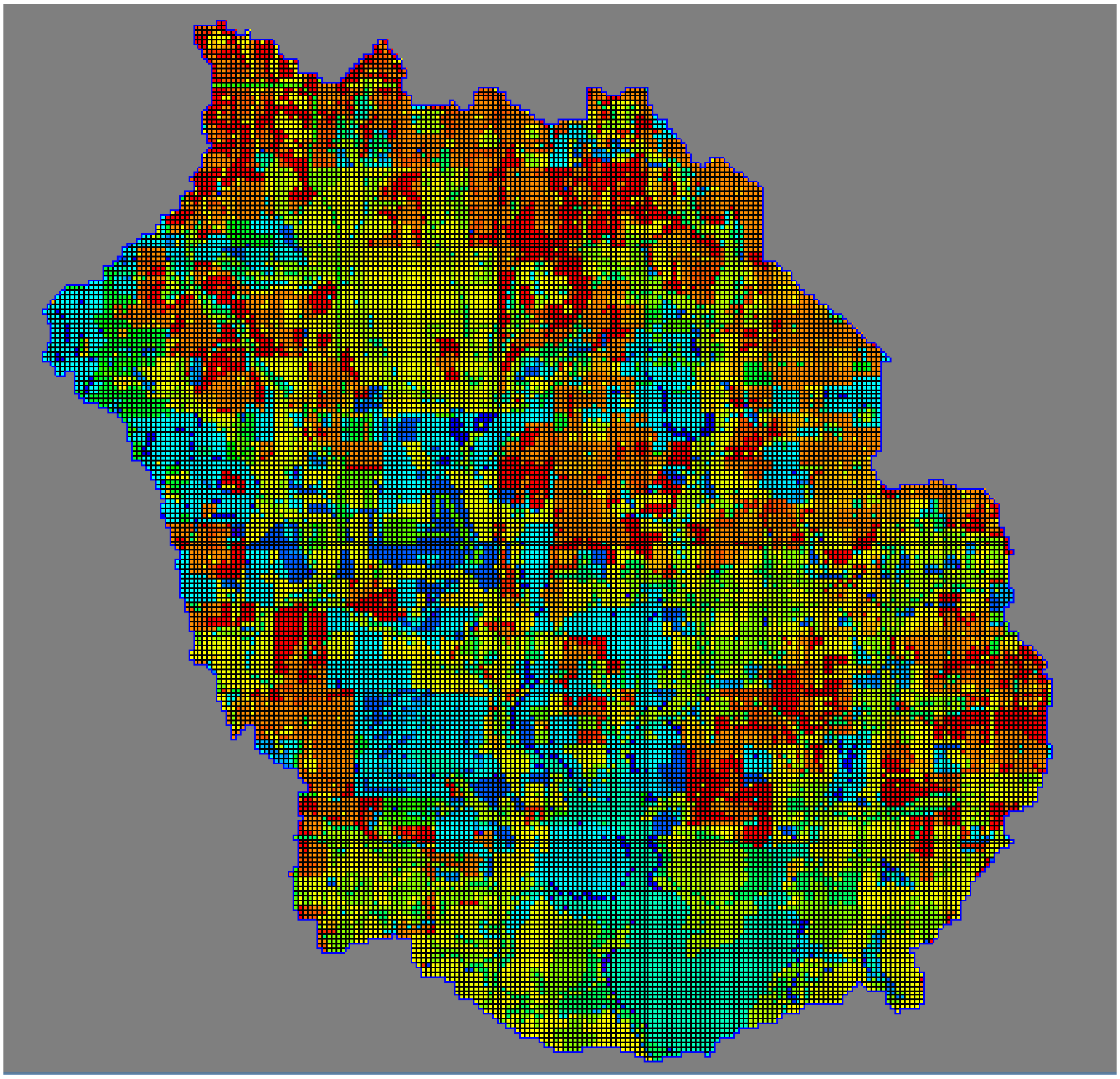


Figure 3-10
Gridded Combined Land Use and Soils Data



4. Calibration

4.1. Calibration (2013)

For a model to be used for forecasting it is best to calibrate to real world storm events. Calibration requires both historic rainfall data and river water surface elevations (stages) or discharges during the rain event. With the rainfall being obtained by RainWave, it was necessary to find or install gauges in the watershed to determine stream stages. A site visit was performed in order to determine the best location for installing the monitoring gauges. The USGS currently has an operating gauge on Doc McDuffie Road over Wolf Creek (USGS 02378170). Available parameters for this site are discharge and gage height. Three Solinst Leveloggers were installed throughout the Wolf Bay Watershed (Figure 4-1). The first gauge was installed on Swift Church Road over Wolf Creek. The second gauge was installed on Sandy Creek located in the property boundary of the Barin Nolf Naval Airfield. The last gauge was installed on CR 20 over Hammock Creek. These locations were chosen in order to maximize the drainage area in which to calibrate, for ease of access, and for limiting the possibility of being tampered with. Due to the very flat topography, these sites experience tidal influence.

The leveloggers were installed on May 28, 2013. After installation, the watershed experienced a large rain event on July 4, 2013. For this storm the maximum average rainfall over a 12-hour period was around 5.7 inches. This occurred between 7:00 p.m. on July 3rd to 7:00 a.m. on July 4th. The maximum rainfall during that time was 6.8 inches which occurred at RainWave gauge point 10. The cumulative rainfall for the July 4th event can be found in Figure 4-2. Figures 4-3, 4-4, 4-5, and 4-6 indicate the differences between the discharges from the field measured data and the modeled GSSHA discharges.

Figure 4-1
USGS Gauge and Levelogger Locations (2013)

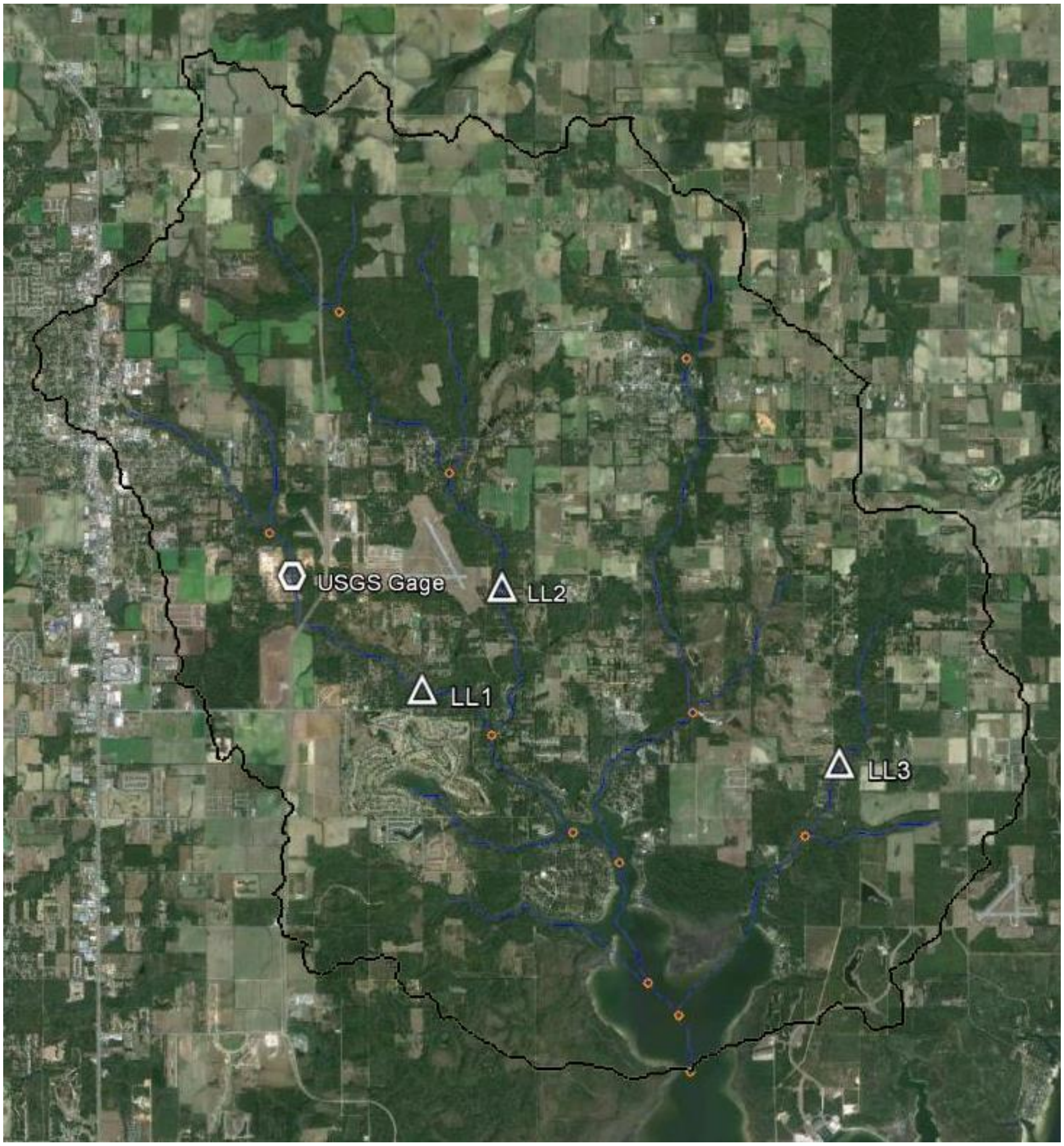


Figure 4-2
July 3-8, 2013 – Total Cumulative Rainfall

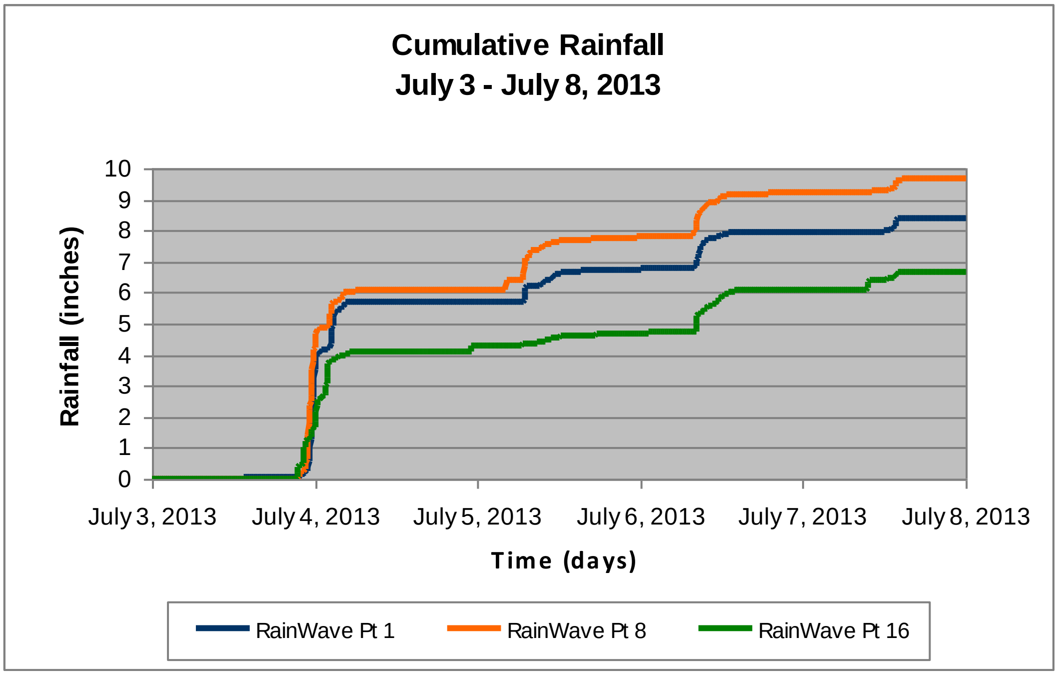


Figure 4-3
Wolf Bay Watershed – Doc McDuffie Road Calibration

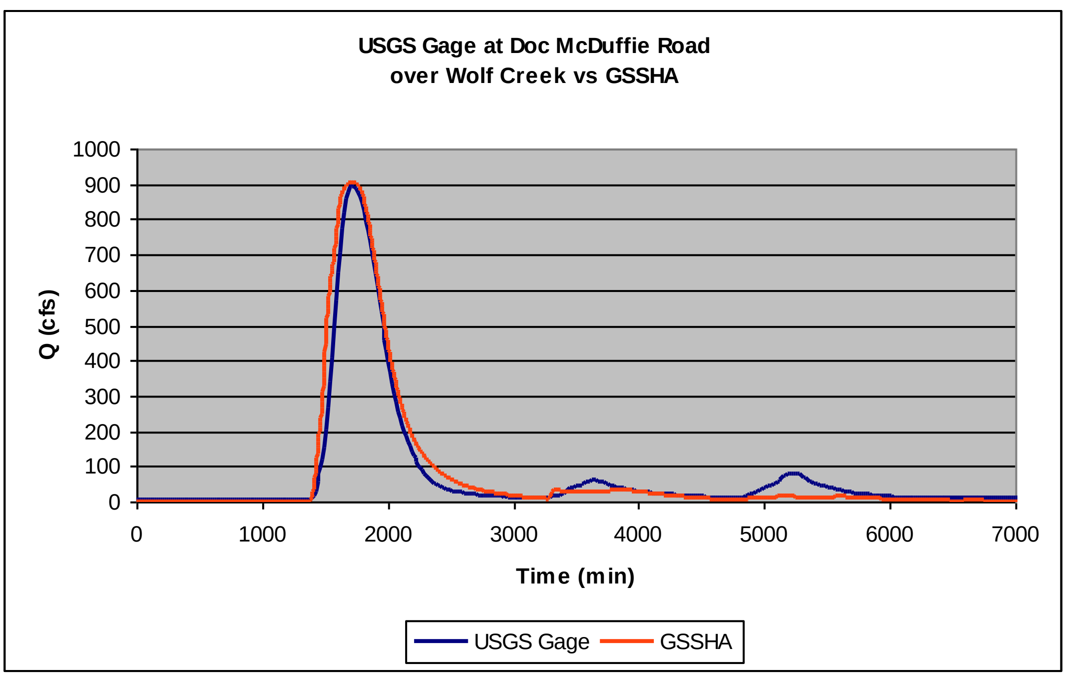


Figure 4-4
Wolf Bay Watershed – Swift Church Road Calibration

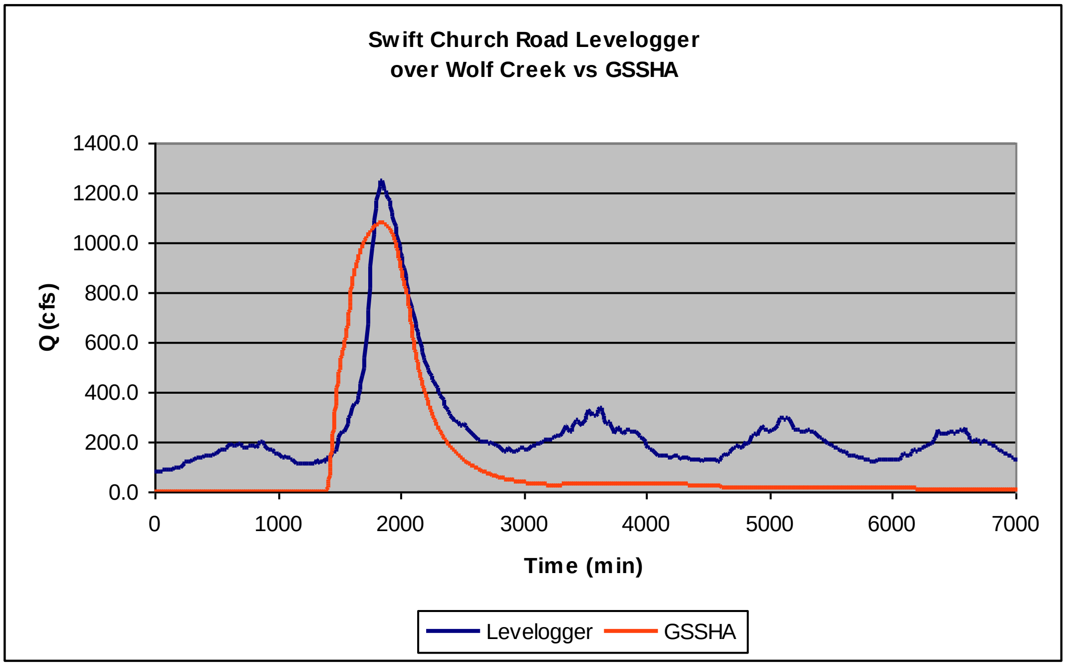


Figure 4-5
Wolf Bay Watershed – Sandy Creek Calibration

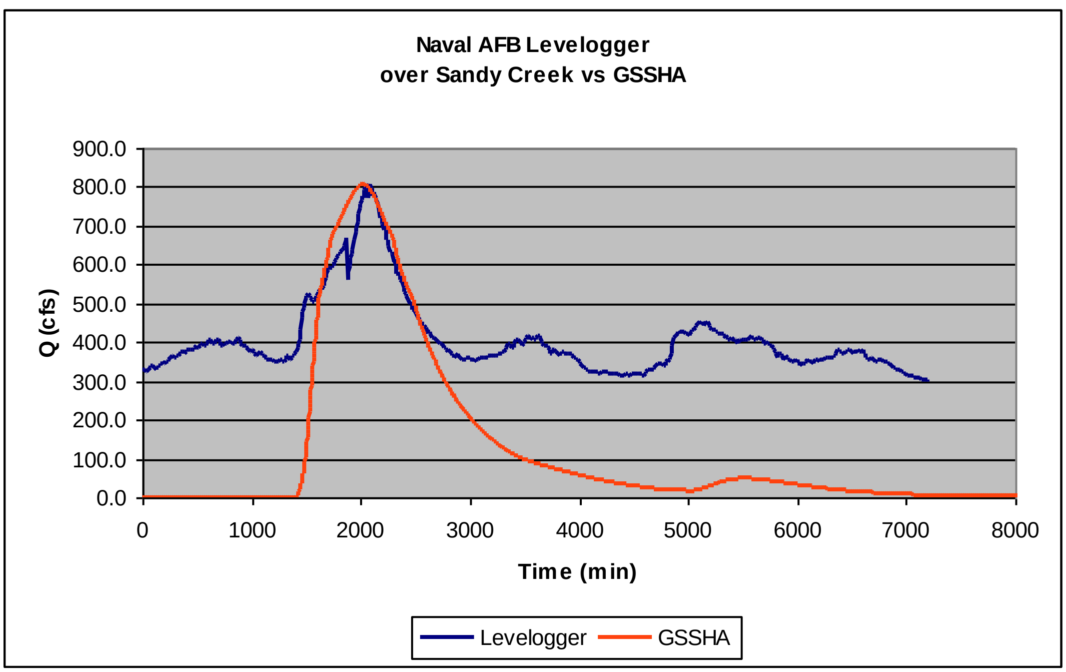
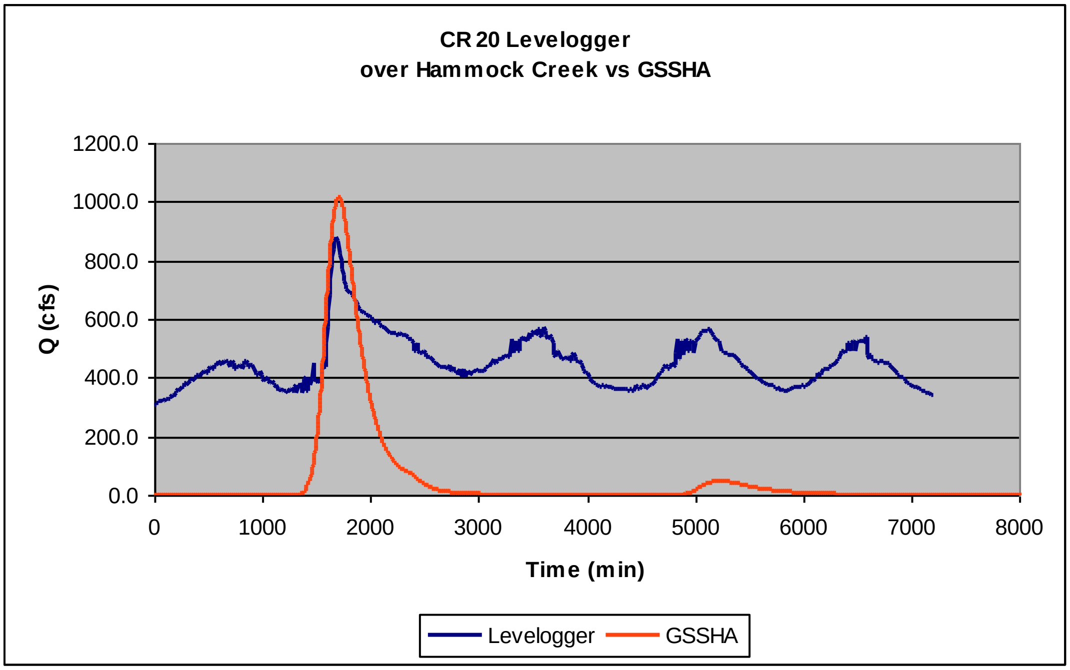


Figure 4-6
Wolf Bay Watershed – Hammock Creek Calibration



4.2. Validation (2019)

For the 2019 analysis, a new stream gauge (MBNEP 23) was installed on Sandy Creek (Figure 4-7). A Telog RU-33 gauge with a level logger sensor was used for measuring stream data. This gauge contains a Recording Telemetry Unit (RTU) which forwards data wirelessly to a host computer which can be accessed through the internet. After a rain event, level data can easily be downloaded from the Telog Enterprise website.

This RU-33 gauge was installed approximately 60' downstream from the centerline of HWY 98. A crest stage gage was also installed approximately 280' downstream of the RU-33 gauge. This simple gage is constructed with PVC pipe, a wooden rod, and some crushed cork. During a flooding event, the cork would rise with the water level and then be deposited on the wooden rod. A measurement of the cork marking can be used to determine maximum stage height during the storm. These cork gauge marks were used in conjunction with the RU-33 highwater readings in order to obtain the water surface slope during the flood event.

The USGS continues to have an operating gage on Doc McDuffie Road over Wolf Creek (USGS 02378170) (Figure 4-7). Available parameters for this USGS gage are discharge and gage height.

Looking at the stage data collected from June 13, 2018 to June 10, 2020 it could be seen that the largest storm event occurred on September 4, 2018 (Figure 4-8). Rainfall from Tropical Storm Gordon produced a total of 5” - 6” of rain throughout the watershed. Figures 4-9 and 4-10 indicate the total rainfall maps for the September 4, 2018 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figure 4-11 indicates the distribution of rainfall for the storm event. The calibrated model output for the Sandy Creek gauge can be found in Figure 4-12 and for the USGS Wolf Creek gauge in Figure 4-13.

Figure 4-7
USGS Gauge and RU-33 Location (2019)

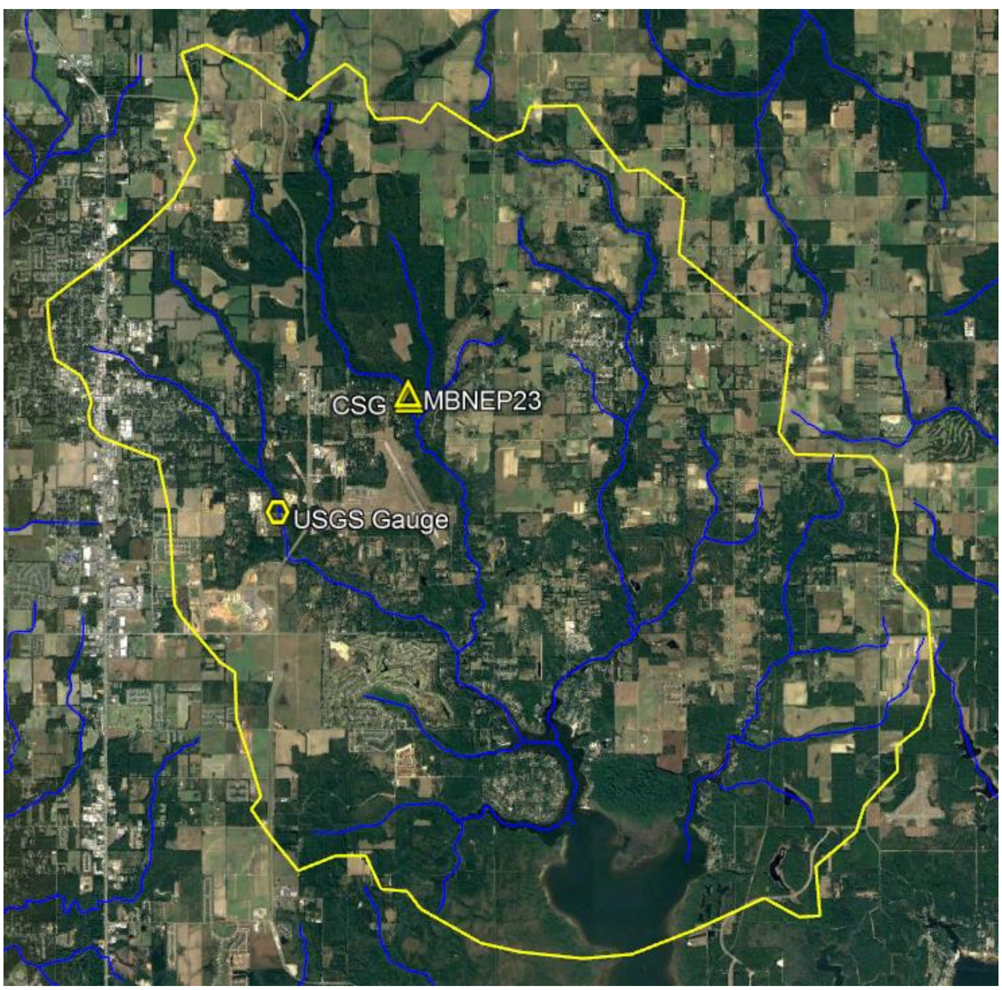


Figure 4-8
MBNEP 23 Gauge Height Readings – June 2018-June 2020

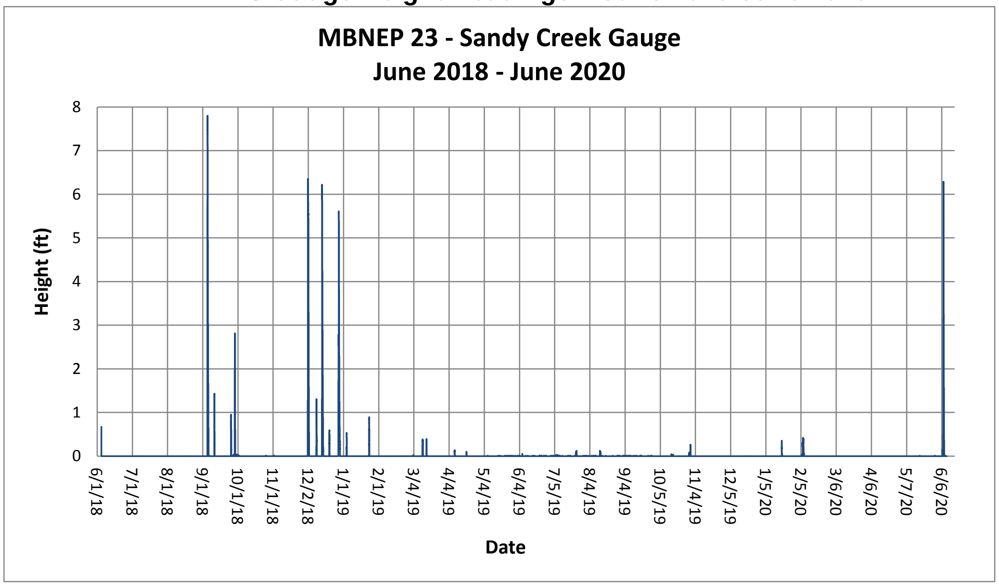
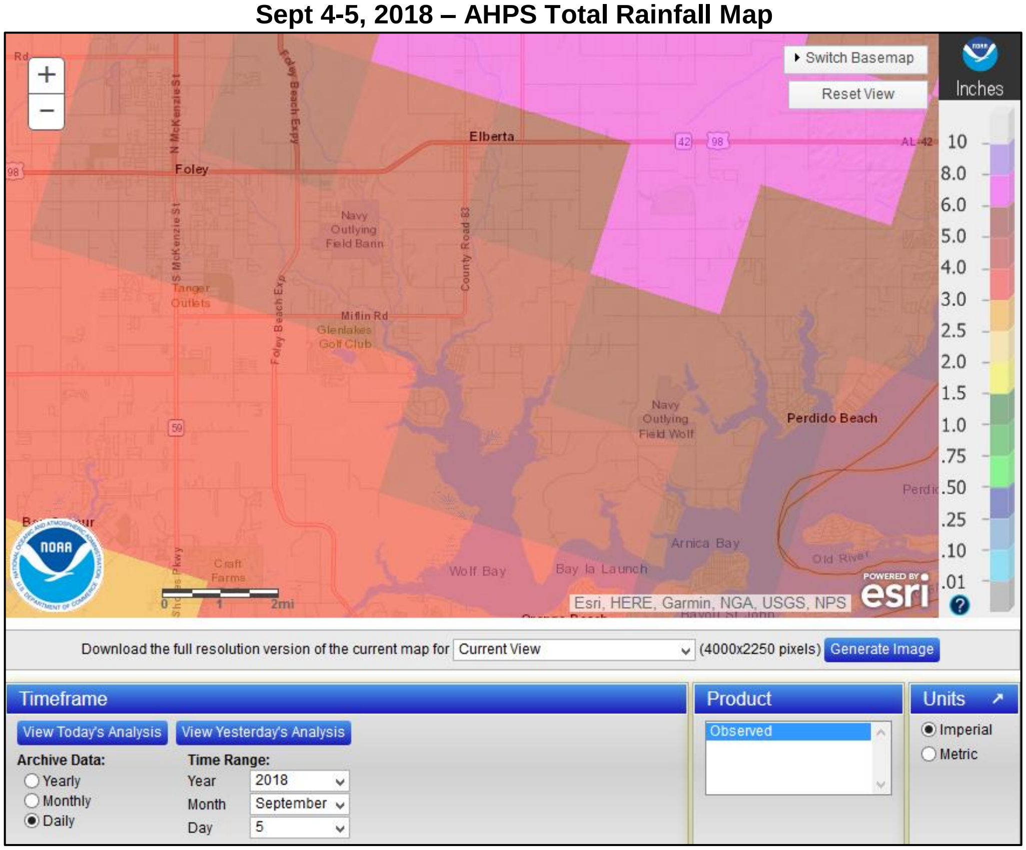
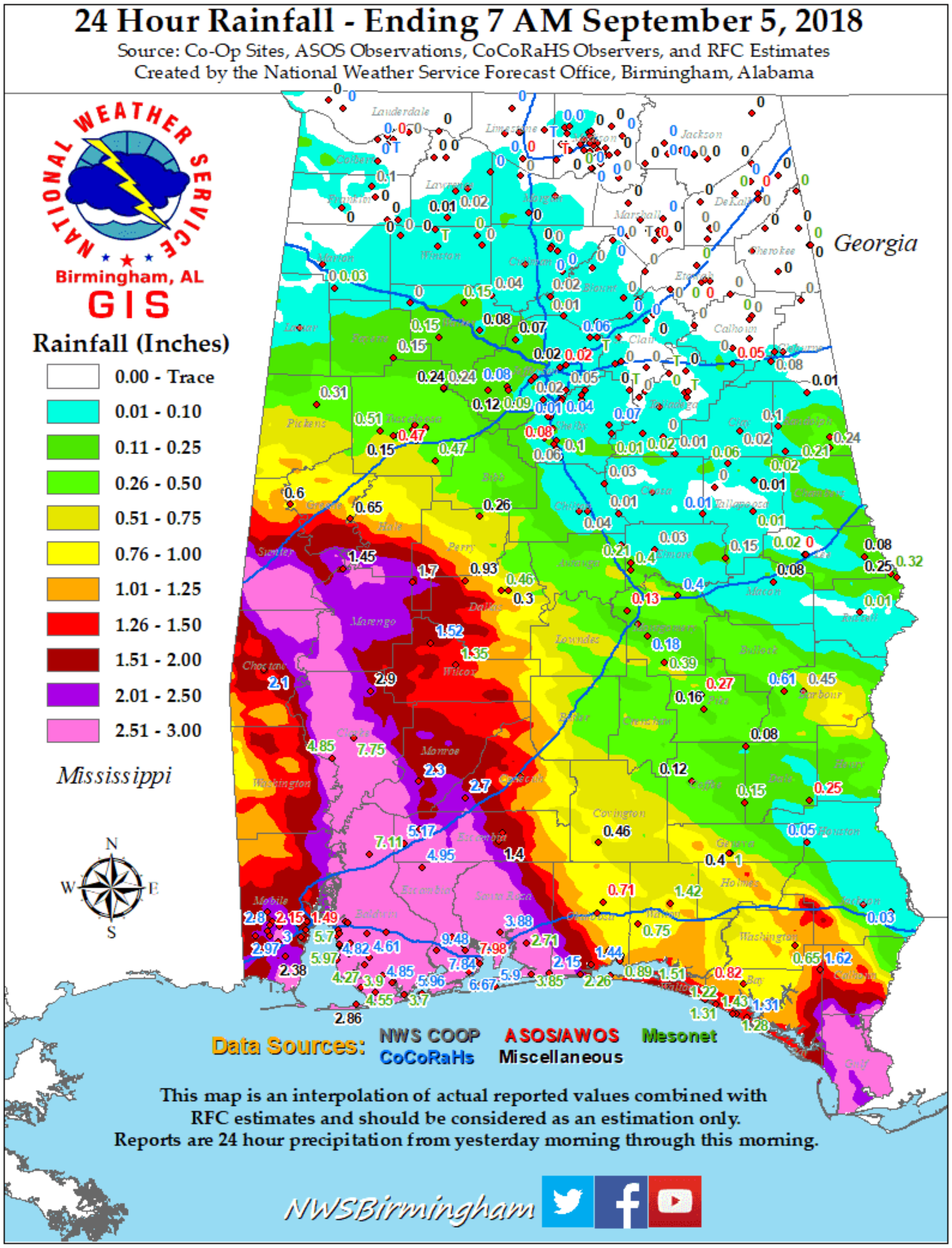


Figure 4-9
Sept 4-5, 2018 – AHPS Total Rainfall Map



Source: https://water.weather.gov/precip/

Figure 4-10
Sept 4-5, 2018 – Total Rainfall Map



Source: https://www.weather.gov/bmx/rainfallplots

Figure 4-11
Sept 4-5, 2018 – Total Rainfall Distribution

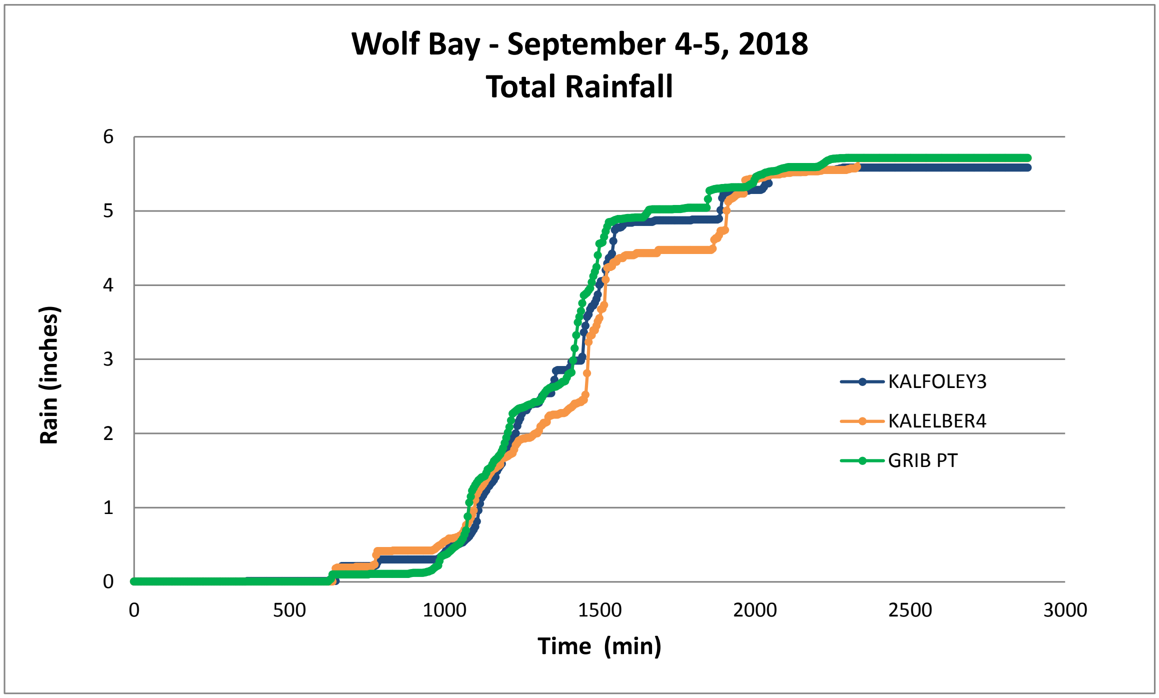


Figure 4-12
Sept 4-5, 2018 – Sandy Creek Calibration

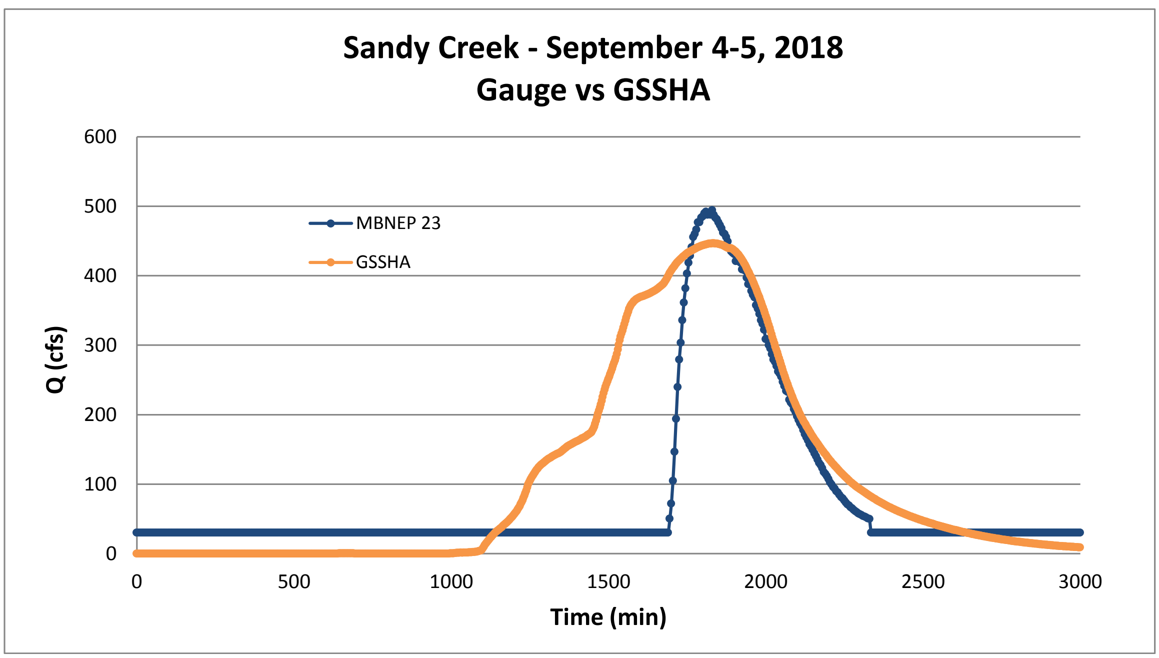
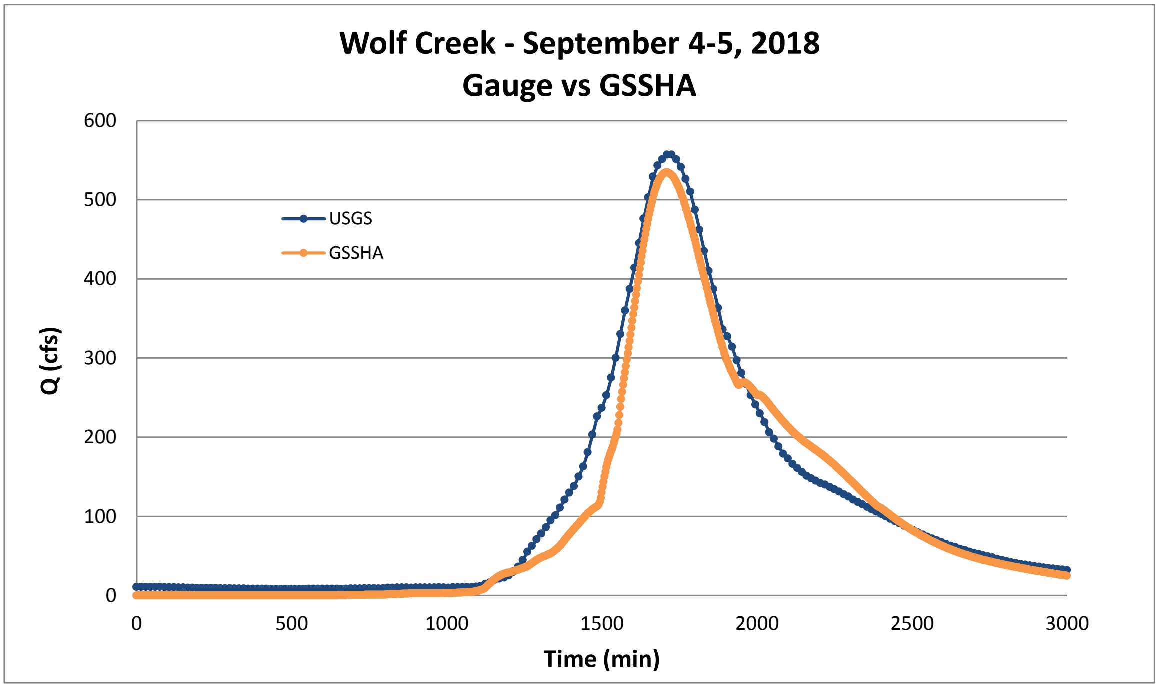


Figure 4-13
Sept 4-5, 2018 – Wolf Creek Calibration



5. Results and Conclusions

5.1. Results and Conclusions

During the evaluation period between the middle of June 2018 and June 2020 the Wolf Bay watershed experienced very few rain storms that produced enough discharge for analyzing. The largest storm occurred on September 4, 2018 when Tropical Storm Gordon generated approximately 5.5" of rain with about 5" occurring in 10 hours. Interpolating from NOAA Atlas 14 for this rainfall depth and time period it was determined that this is equivalent to a 2-year storm. Using the previously calibrated model from 2013, the results translated well to the smaller 2018 storm event.

The model was also run with the updated NOAA atlas precipitation values for a 100 year-event and then compared to the updated 100-year rural regression equations found in the publication, *Anderson, B.T., 2020, Magnitude and frequency of floods in Alabama, 2015: U.S. Geological Survey Scientific Investigations Report 2020-5032, 148p., https://doi.org/10.3133/sir20205032.* It has been determined that the previously calibrated 2013 Wolf Bay watershed model produces discharges in line with the updated regression equations and is still an applicable tool for analyzing stormwater impacts based on future developments.

6. References

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