MBNEP

118 N Royal St Suite 601
Mobile, AL 36602

Tensaw West Watersheds Study

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Prepared By:

HYDRO ENGINEERING SOLUTIONS
A DIVISION OF HYDRO, LLC

2124 Moore’s Mill Road ♦ Suite 120 ♦ Auburn, Alabama 36830

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1. Executive Summary

The study on the Tensaw West watersheds was performed to gain an understanding of the watersheds' response during rain events. Five individual watershed models located between Turnerville and Saraland were developed. These baseline hydrologic models can be used for determining discharges for the design of future restoration projects and their impact on the watershed. The models can also be utilized for future stormwater planning and management. The method of analysis used for the study employed the use of the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model. This two-dimensional overland flow model was calibrated to available rain events from September 2018 to June 2020.

During the evaluation period, the Tensaw West watersheds only experienced two events greater than a 1-year storm. The first event occurred on October 30-31, 2019 when approximately 5 inches of rain fell in 6 hours. This was determined to be greater than a 5-year recurrence interval, however only partially impacted Basins 1, 2, and 3. With only a portion of these basins experiencing this rainfall, the overall average of the total rainfall equated to a 2-year storm event. The second event occurred during Tropical Storm Cristobal when there was 4.4" of rain in 6 hours. This was classified as being a 2-year storm as well. The remainder of the events during the evaluation period was determined to be less than a 1-year recurrence interval. Results of the findings for the Tensaw West watersheds indicate that storm events less than or equal to a 2-year recurrence interval produce discharges that are in line with its determined recurrence interval for a rural basin.

For rain events (2-yr or less), the currently calibrated GSSHA model can be used as a management tool for determining bank forming discharges throughout the watershed. Future restoration projects may be able to utilize these discharges for bankfull analysis. For larger flood events, recalibration will most likely be necessary to account for changes in storage capacity and timing within the watershed.

2. Introduction

2.1. Description

For this study, the Tensaw West watersheds consist of 5 separate basins located mostly above I-65 around and near the communities of Saraland, Satsuma, Creola, and Turnerville (Figure 2-1). The drainage basins range in size from 4.4 square miles to 23.8 square miles. The outlet of each basin is located either at US Hwy 43 or upstream of US Hwy 43 at the next nearest road crossing. Each basin eventually drains into the Mobile-Tensaw River Delta.

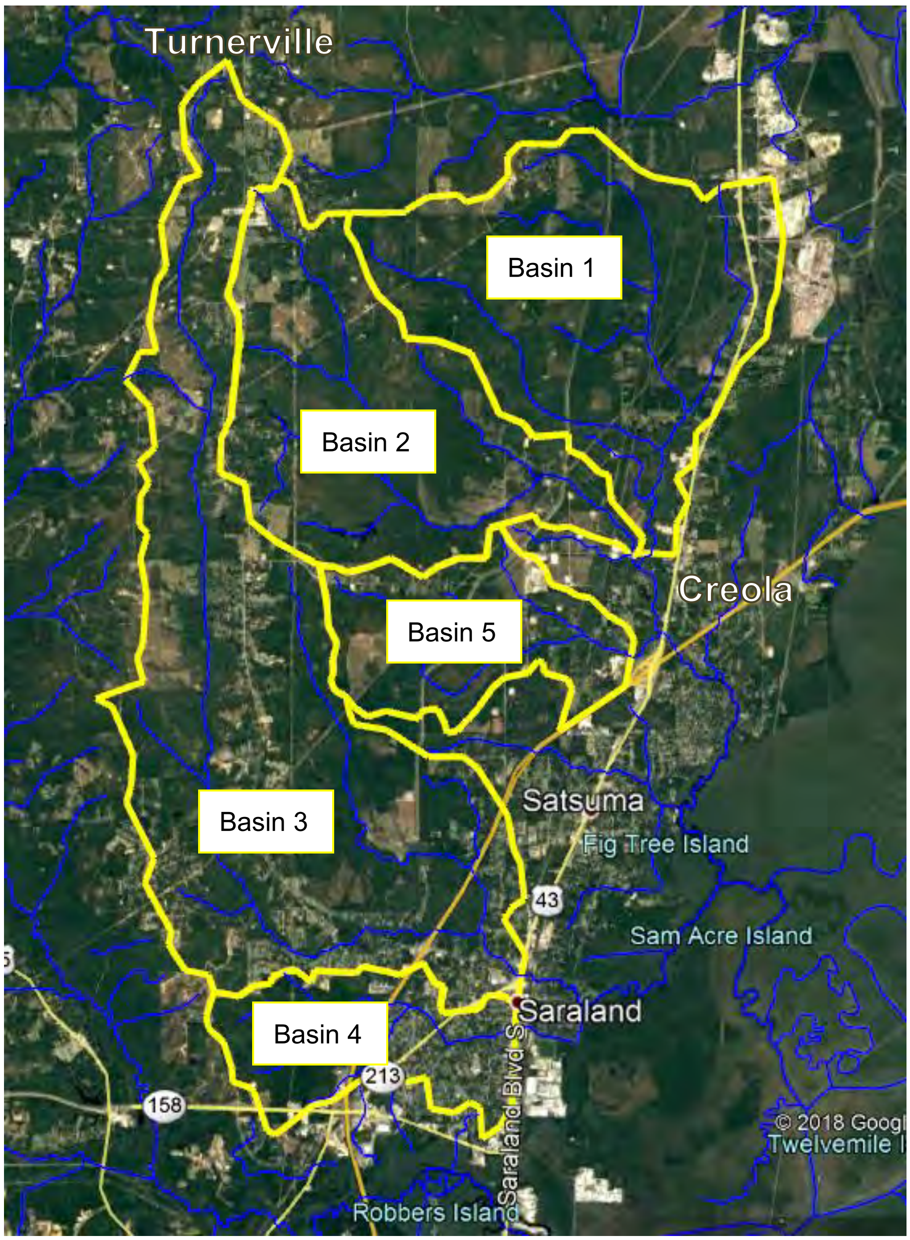
Basin 1 is located just above Creola and to the west of Axis. The two main streams for the watershed are Seymore Branch and Turtle Branch. The outlet point of the basin is at Radcliff Road. Basin 2 is located southwest of Basin 1 and also has the outlet at Radcliff Road. The main streams for the basin are Sawmill Creek and Gunnison Creek. Basin 3 is the westernmost basin and has its outlet point at US Hwy 43. The two main streams for Basin 3 are Bayou Sara and Hells Swamp Branch. Basin 4 is the southernmost basin and has its outlet point at US 43 also. Basin 5 is situated between Satsuma and Creola to the west. The main stream for this basin is Hall Branch with the outlet point being at Hall Branch Road.

2.2. Climate

According to Goodwyn Mills & Cawood (2014), "Mobile County has a hot, subtropical climate with abundant rainfall. Rainfall and climate data from March 1900 through April 2012 are available from the Southeast Regional Climate Center database for the Weather Forecast Office (WFO) located at the Mobile Regional Airport, Weather Station 015478. Precipitation is usually in the form of showers with long periods of continuous rain being rare. Exceptions occur during tropical storms and hurricanes, when rainfall may be long and intense. Thunderstorms may occur at any time of the year.

Goodwyn Mills & Cawood (2016) states, "Average annual precipitation at the Mobile Airport is 65.29 inches. Of that, snow accounts for less than half an inch. Average monthly precipitation ranges from 2.93 inches in October to 7.53 inches in July. Rainfall is only slightly seasonally distributed. October and November are the only months when rainfall averages less than 5 inches. The months of March and July through September all average greater than 6 inches of rainfall per month. Monthly mean maximum temperatures range from 91 degrees Fahrenheit (°F) in July to 60.9 °F in January. Monthly mean minimum temperatures range from 72.9 °F in July to 40.8 °F in January. The lowest temperature recorded was 3 °F on January 21, 1985. The highest temperature recorded was 104 °F on July 25, 1952."

Figure 2-1
Location Map with Tensaw West Watershed Boundaries



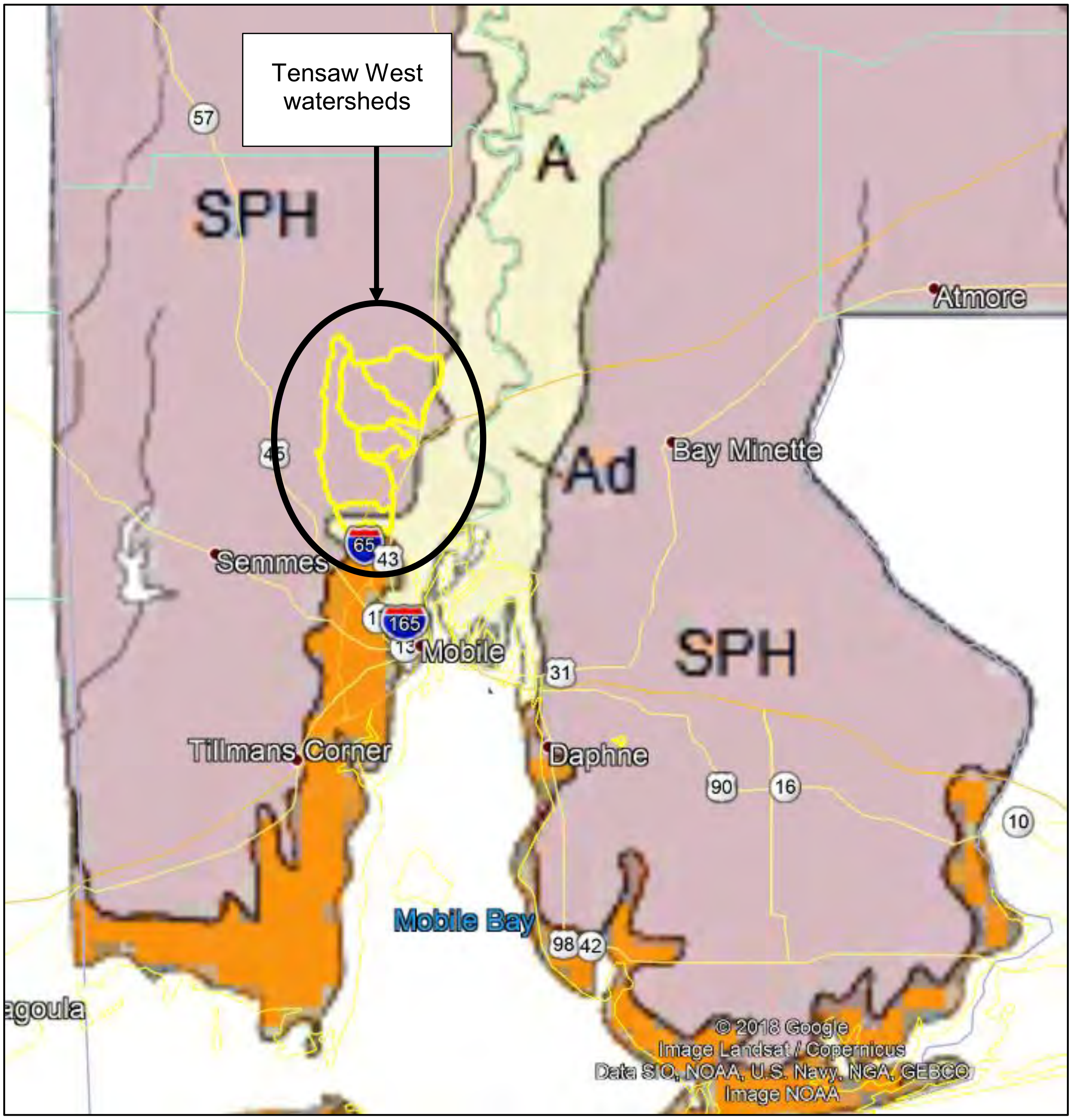
2.3. Physiography

The majority of the Tensaw West watersheds are located within the Southern Pine Hills physiographic section with a portion of Basin 4 being located in the Alluvial-deltaic Plain (Figure 2-2). The Southern Pine Hills is described with the following characteristics: Southward-sloping, dissected irregular plains, some open low hills, mostly broad gently sloping ridgetops with steeper side slopes near drainages; low to moderate gradient sand and clay bottomed streams; some sinkholes in eastern area (Griffith 2001). The area located within the Alluvial-deltaic Plain is described as having the following: Major river floodplains and associated low terraces; low gradient streams with sandy and silty substrates, oxbow lakes, ponds, swamps (Griffith 2001).

Descriptions regarding the different soil types for the watersheds were found from the Web Soil Survey. According to the website, “Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available online for more than 95 percent of the nation’s counties and anticipates having 100 percent in the near future. The site is updated and maintained online as the single authoritative source of soil survey information.”

Information from the website indicates that almost half of the soils in these basins are fluviomarine deposits derived from sedimentary rock. The major soils types for this rating include, Rattlesnake Forks fine sand, Benndale fine sandy loam, Johnston, Bibb, and Smithton soils, and Heidel fine sandy loam. The Wadley soils which are comprised of sandy and loamy marine deposits make up almost a quarter of the soils. These include Wadley loamy fine sand, Wadley-Heidel complex, and the Wadley-Urban land complex. Another large soil component for the watersheds consists of loamy alluvium derived from sedimentary rock. Some of the soil types are Smithton fine sandy loam, Smithton, Dalevile and Bethera soils, and Harleston fine sandy loam, and Cortelyou fine sandy loam.

Figure 2-2
Physiographic Map with Tensaw West Watershed Boundaries



Map taken from Dept of Geography, College of Arts and Sciences, The University of Alabama

2.4. Land Use

The land use of the Tensaw West watersheds consists mostly of undeveloped areas. On average the land use is approximately 73% woodlands, 9% grasslands, 16% residential/urban, and 2% open areas. Most of the residential areas are found in Basins 3 and 4 with 32% and 40% of the basins being residential, respectively. Figures 2-3 through 2-6 contain Google Earth images indicating the changes in land use from 1998 to 2017.

Figure 2-3
Basins 1 and 2 with 1998 and 2017 Google Earth Aerials

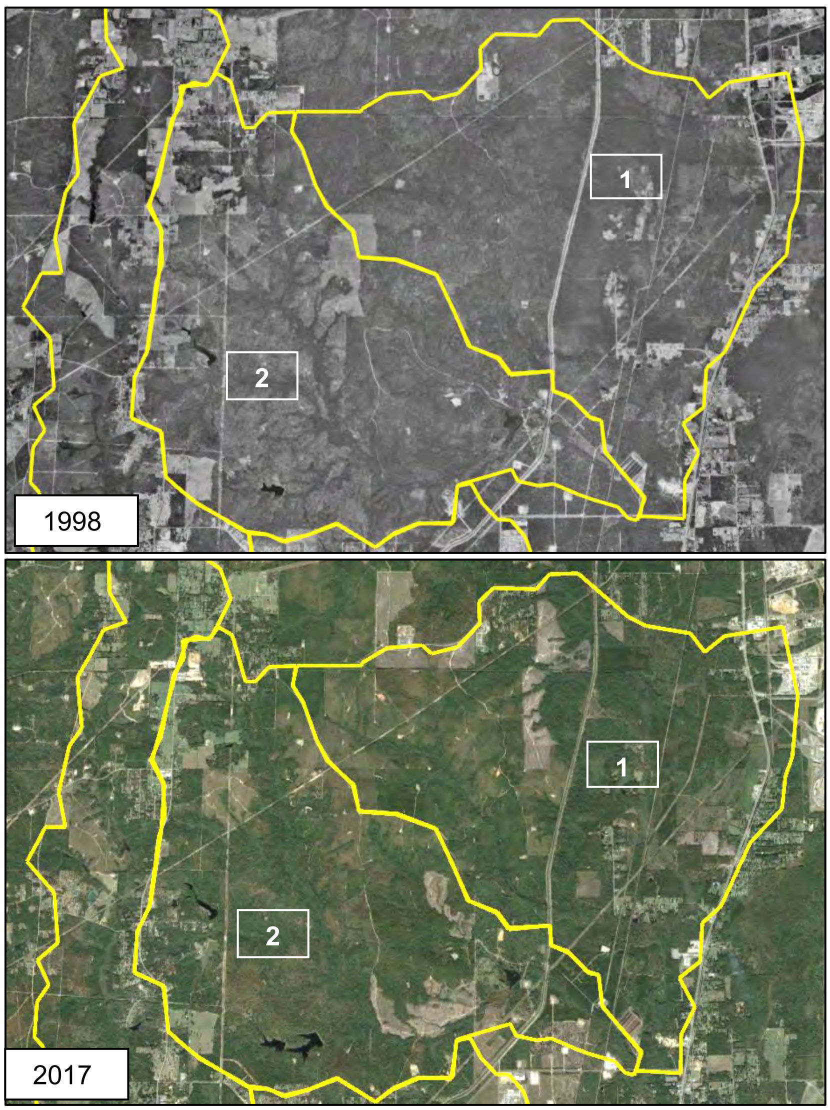


Figure 2-4
Basin 3 with 1998 and 2017 Google Earth Aerials

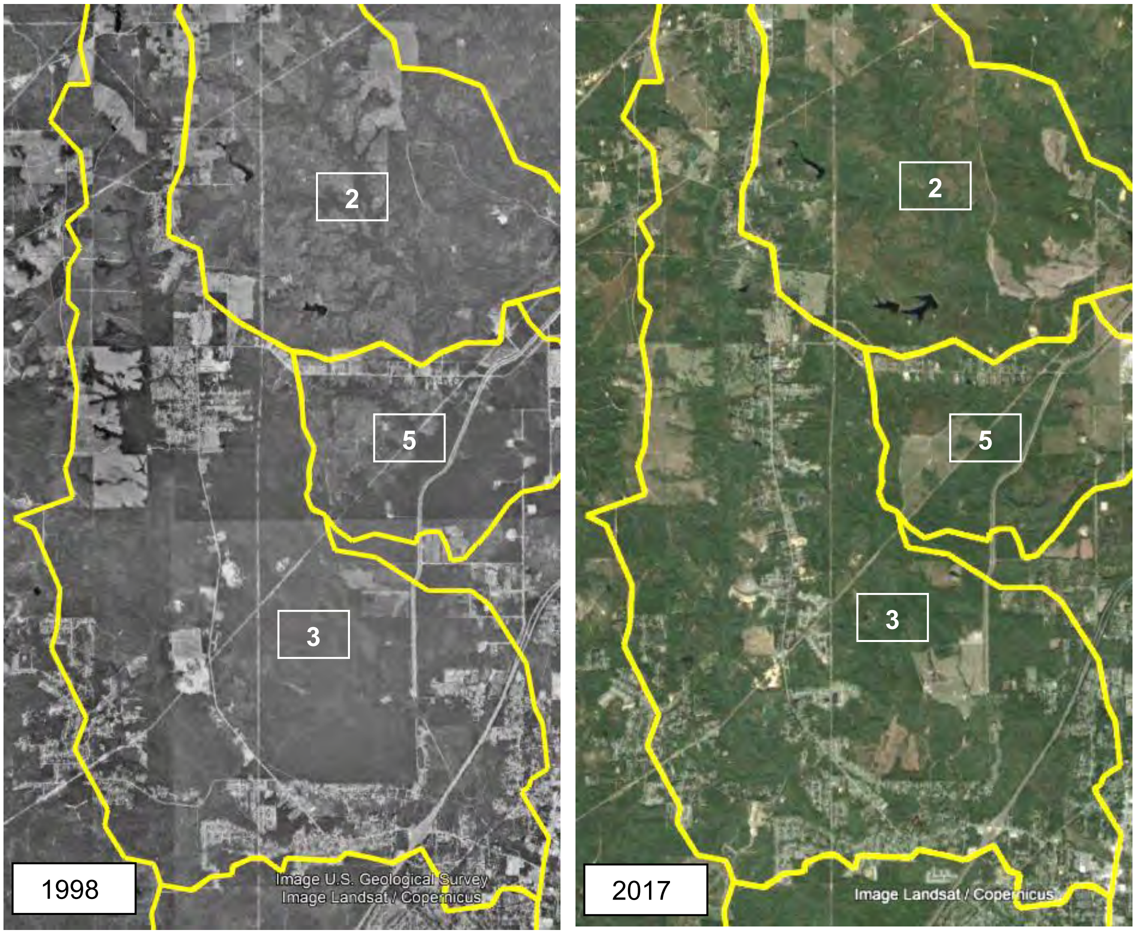
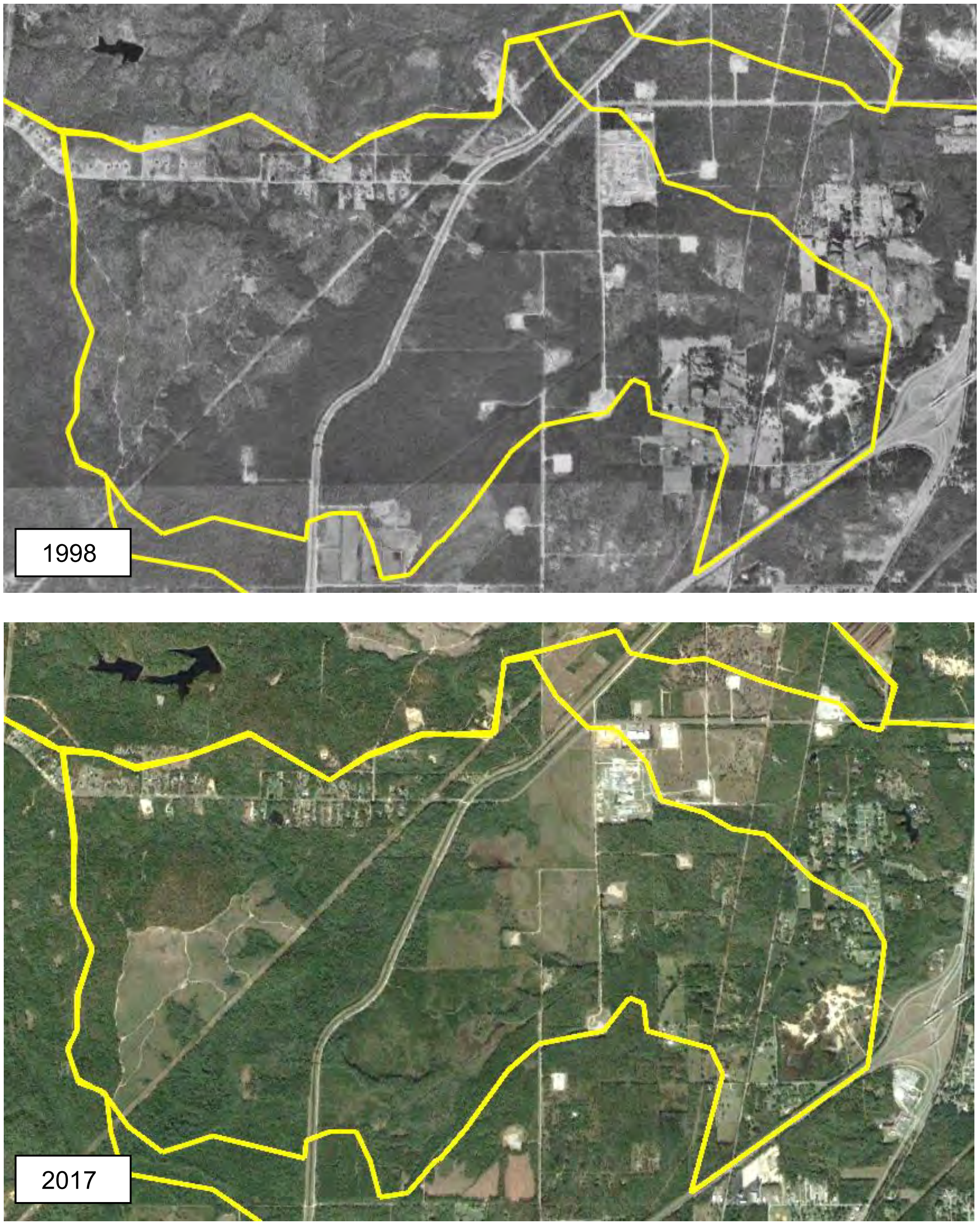


Figure 2-5
Basin 4 with 1998 and 2017 Google Earth Aerials

Figure 2-6
Basin 5 with 1998 and 2017 Google Earth Aerials



3. Hydrologic Model

3.1. General

The hydrologic model used to evaluate the Tensaw West watersheds 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. The interface used for building the model was the Watershed Modeling System (WMS) developed by Aquaveo.

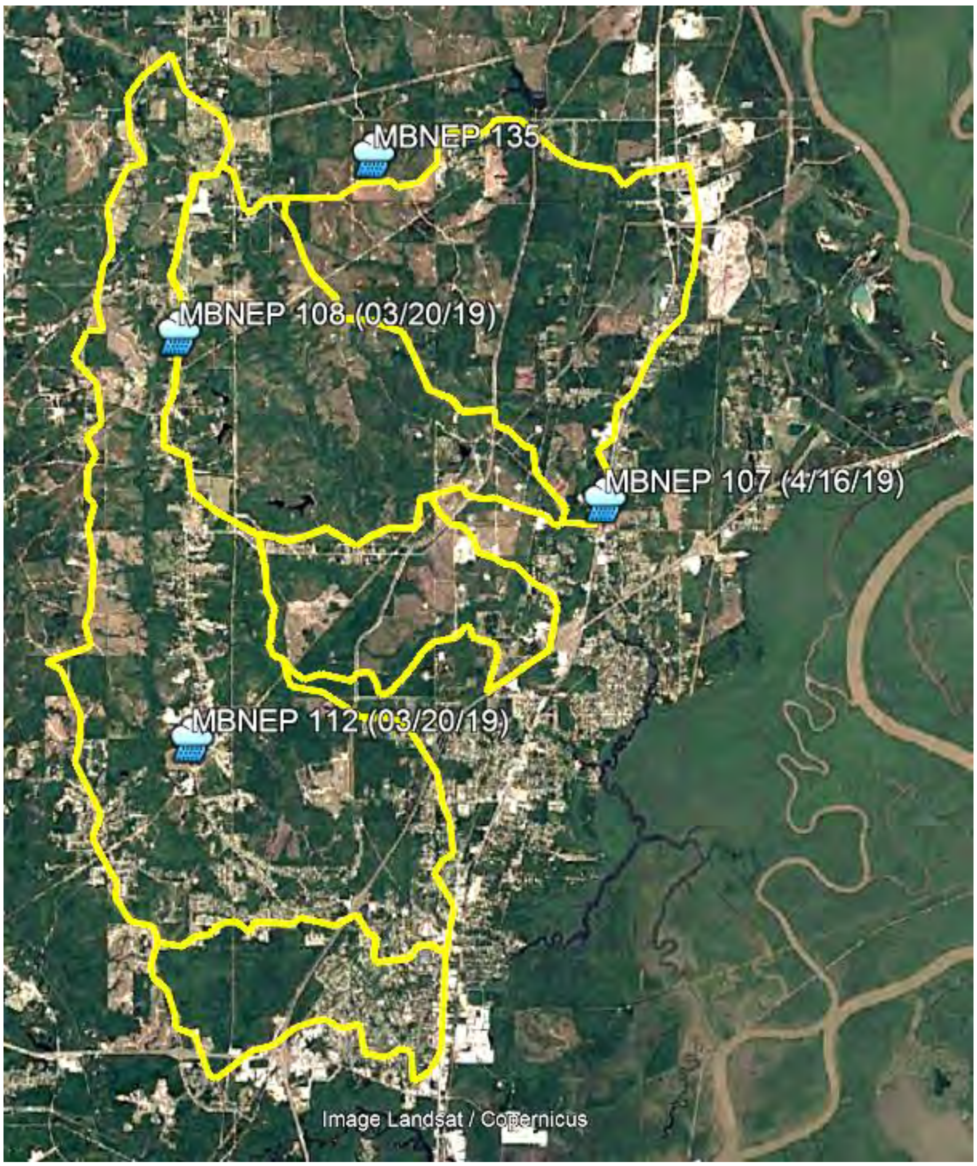
3.2. Rainfall Data

One of the strengths of the GSSHA model is the ability to perform long-term simulations utilizing rainfall distributions longer than just a 24-hour storm. 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 data sources.

The first source for gathering rainfall data is from four weather stations that Hydro deployed throughout the watershed (Figure 3-1). On December 13, 2018, one weather station (MBNEP 135) was installed at the North Mobile County Middle School. This weather station is located at the northern end of all of the watersheds. After coordination and approval with other entities, three more weather stations were installed throughout the watershed area.

The next two were installed on March 20, 2019. MBNEP 108, located between Basins 2 and 3, was installed at the Turnerville Community Center Fire and Rescue. MBNEP 112, located at the lower end of Basin 3, was installed at the Saraland Fire Department Station Number 3. On April 16, 2019 the final weather station (MBNEP 107) was installed at Creola City Hall.

Figure 3-1
Tensaw West Watersheds with Hydro Weather Station Locations



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. Data can be transferred using a wireless console connected to a nearby computer with internet or via Davis' Vantage Connect®. According to the website, Vantage Connect® is a "cellular-based, solar-powered unit that sends remote weather station data to the internet." Weatherlink software was used for data retrieval for each station. After a storm event, data would be retrieved and then processed for use in the GSSHA model.

The second source of data was obtained from Gridded Binary (GRIB2) rainfall data provided by the National Weather Service. GRIB2 is the second version of the World Meteorological Organization's (WMO) standard for distributing gridded data. The major advantages of the GRIB files are that they are typically 1/2 to 1/3 the size of normal binary files (floats), the fields are self-describing, and GRIB is an open, international standard. A decoder is required to view or use the information. Once decoded, the GRIB2 data is in 2-minute increments which provide a good rainfall distribution for calibrating the timing aspect of the model. When there is a lack of information between the installed Hydro weather stations or any Wundermap gauges, GRIB2 data was utilized to get storm distributions. Oftentimes the total rainfall accumulation is low and needs to have a correction factor applied to it. Rainfall totals from other sources (e.g. Hydro Weather Stations, Weather Underground, NWS maps, etc) are used to correct the rainfall amounts when needed. Figure 3-2 indicates the selected locations for the GRIB rainfall points.

The third source of rainfall data 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 available parameter in which to sort the gauges are temperature/wind, temperature, dew point/humidity, and precipitation. Figure 3-2 indicates the number of available precipitation gauges that can be used for analyzing the watershed.

Figure 3-2
NOAA GRIB2 and Wundermap Gauge Locations

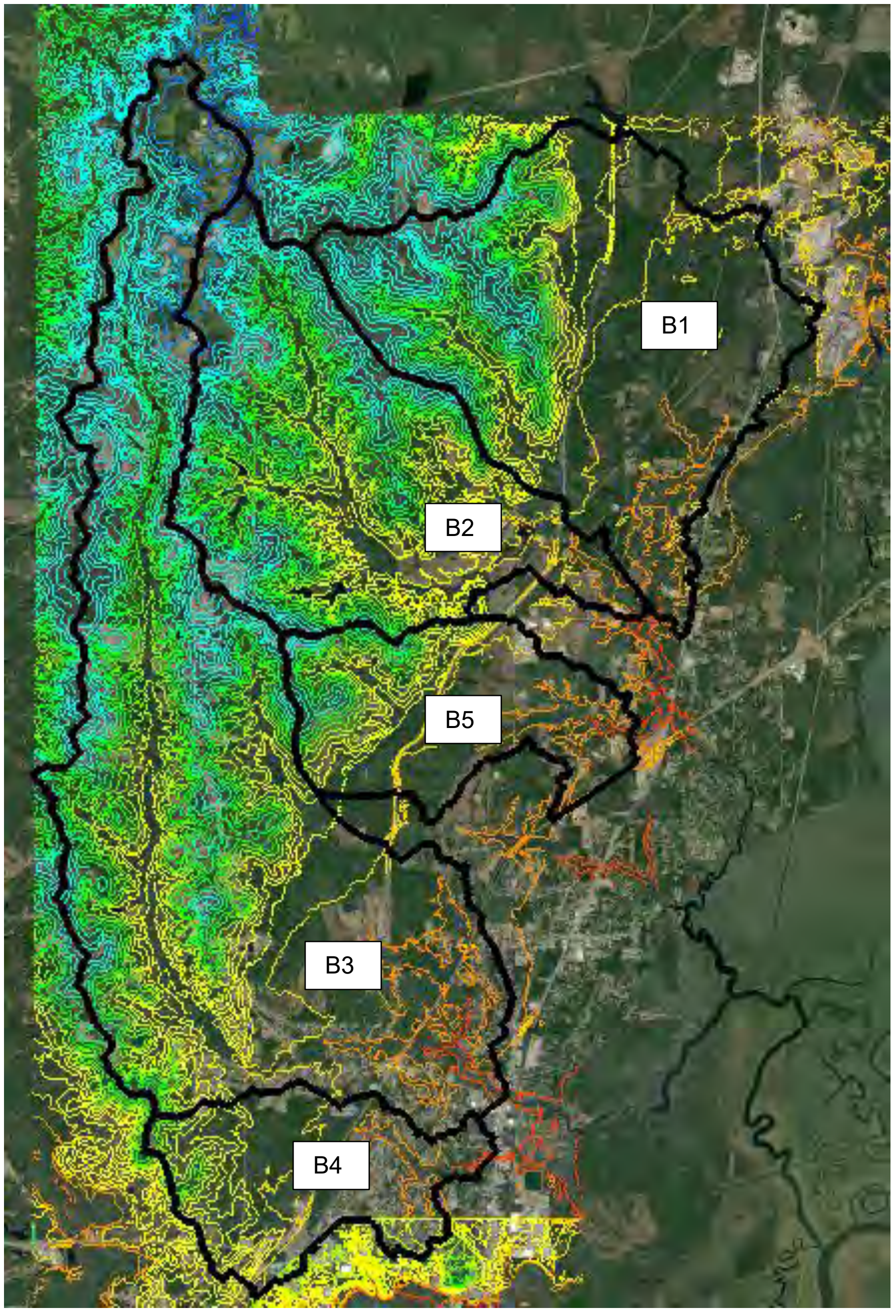
3.3. Digital Terrain Data

The GSSHA model uses digital terrain data to incorporate topography into the hydrologic model. For the model, Light Detection and Ranging (LiDAR) data was obtained from the 2014 Mobile County Lidar DEM (AL) dataset. This information is warehoused by the Office of Coastal Management of the National Oceanic and Atmospheric Administration (NOAA). The raster data is saved as a .tif file, with each file encompassing around 1.29 square miles (6000' x 6000'). The coordinate system for the raster data is set to State Plane AL-W and the units are in feet. The information can be found at the following web address: https://coast.noaa.gov/htdata/raster2/elevation/Mobile_DEM_2014_5169/.

In order to get digital elevation data for basin delineation, each .tif was converted individually to a DEM. Each conversion utilized a 40-foot point spacing. For easier data manipulation, the individual DEM was converted to a .dwg. Once all of the individual DEM files were converted to a .dwg, they were merged into one file using Microstation. The complete basin .dwg was then imported back into WMS for a conversion back to a single DEM.

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. Figure 3-3 shows the topographic data that was used in each model.

Figure 3-3
Tensaw West Watersheds with Topographic Data



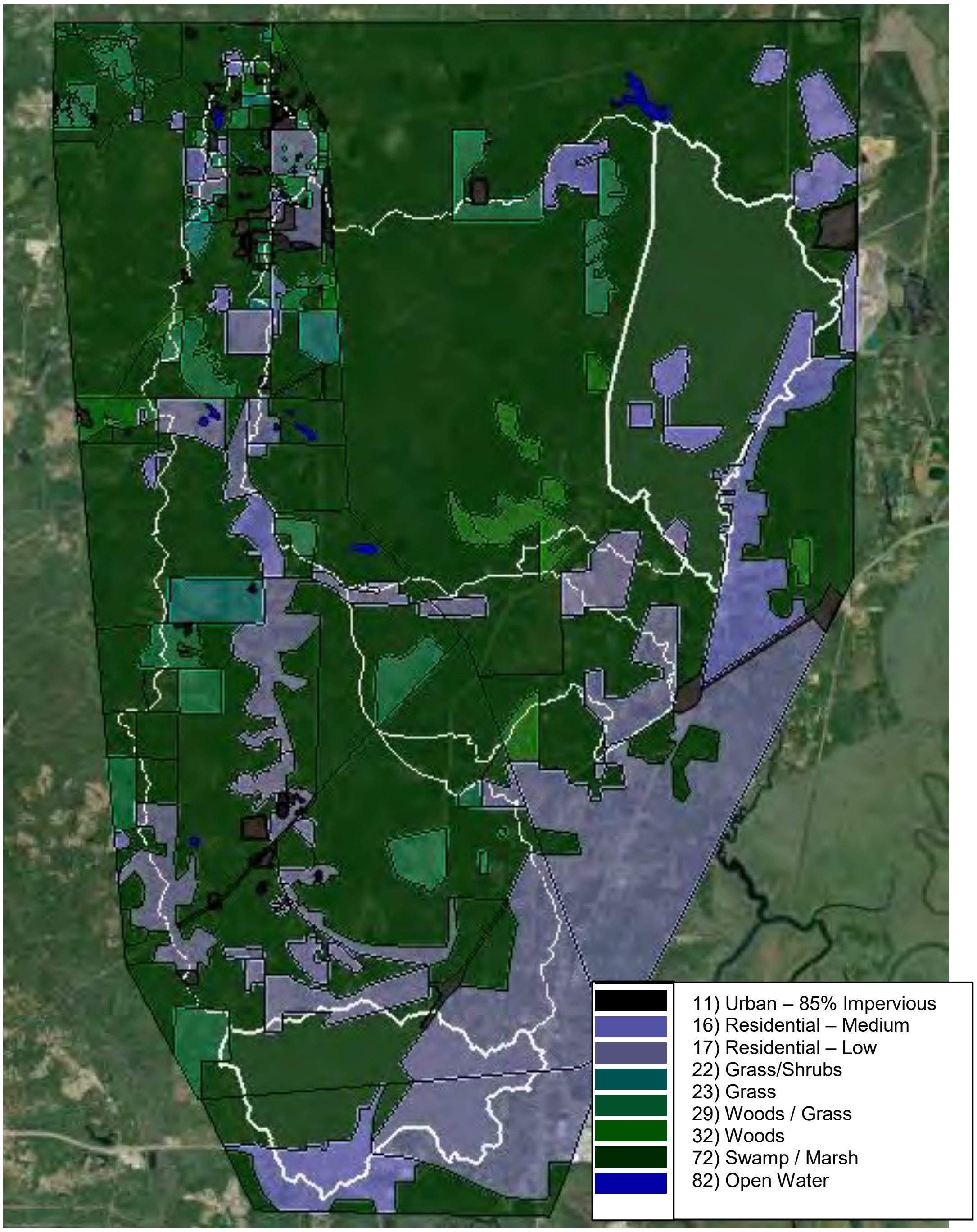
3.4. Land Use

The land use component of the model is necessary to define the various overland flow types throughout the basin. Land use was delineated using geo-referenced aerial imagery. WMS was used to automatically import the latest version of Esri's World Imagery map. (more information can be found at http://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer) The GSSHA model utilizes the land use coverage by assigning a value to describe the overland roughness. The roughness of each land use type is described by an overland Manning's 'n' value. Table 3-1 lists the land use types and the respective 'n' values assigned to them. Figure 3-4 indicates the land use assignments.

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

GSSHA ID	Land Use	Manning's 'n'
11	Urban – 85% Impervious	0.011
16	Residential - Medium	0.08
17	Residential - Low	0.10
22	Grass / Shrubs	0.15
23	Grass	0.15
29	Woods / Grass	0.20
32	Woods	0.25
72	Swamp / Marsh	0.25
82	Open Water	0.011

Figure 3-4
Tensaw West Watersheds with Digitized Land Use



3.5. Soils

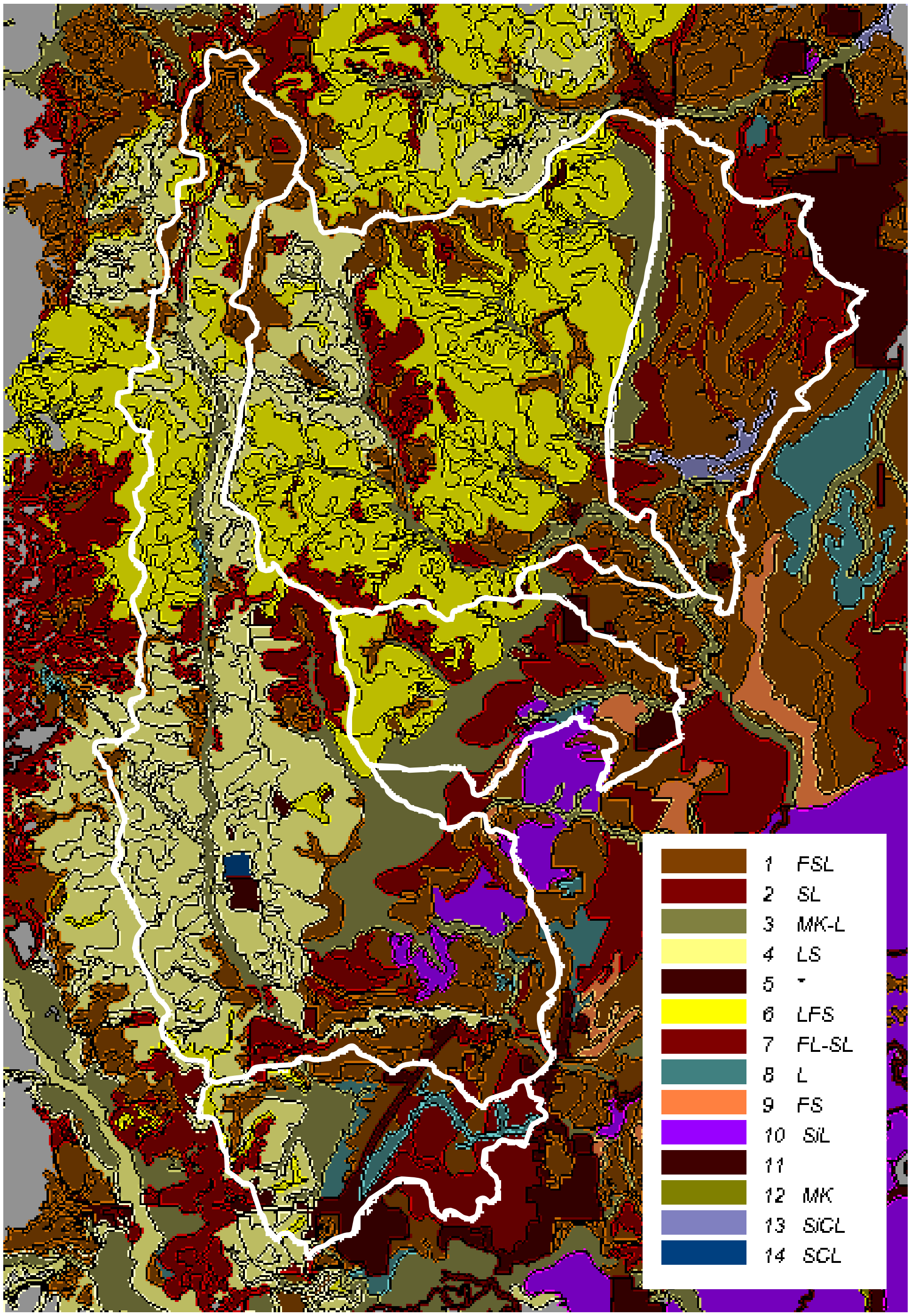
Similarly to the land use, the GSSHA model has the capability to incorporate specific characteristics of the soils located within a drainage basin. The soils coverage can be used for defining infiltration into the soil or setting the initial soil moisture. Table 3-2 indicates the different soil assignments for each sub-basin within the Tensaw West watershed study area. Green and Ampt (G&A) with soil moisture redistribution was used for determining the infiltration of rainfall throughout the basin. Soil parameters used by the G&A method include hydraulic conductivity, porosity, capillary head, pore distribution index, residual saturation, and field capacity. These infiltration values allow the GSSHA model to evaluate the soil's ability to infiltrate stormwater for calculating peak discharge and volume of storm events.

Soils data shapefiles were provided by the Mobile Bay National Estuary Program (MBNEP). According to the metadata provided with the shapefiles, this soil survey is an update to the 1980 soil survey of Mobile County. According to the metadata, "The Soil Survey information was updated using the latest advanced geospatial software ArcGIS 10.3 ArcInfo…. The U.S. Department of Agriculture, Natural Resources Conservation Service, should be acknowledged as the data source in products derived from these data." Figure 3-5 indicates the soil data that has been incorporated into the GSSHA model. Infiltration can be defined through the soils alone or through a combined land use/soils data coverage.

Table 3-2
Tensaw West Watersheds – Basin Soil Types

Basin No.	Soil Types in Basin
1	Loamy Sand, Loamy Fine Sand, Muck/Loam, Fine Sandy Loam, Sandy Loam, Pits, Silty Clay Loam
2	Loamy Sand, Loamy Fine Sand, Muck/Loam, Fine Sandy Loam, Sandy Loam, Pits
3	Loamy Sand, Loamy Fine Sandy, Fine Sandy Loam, Pits, Sandy Loam, Loam, Muck/Loam, Silty Loam, Fine Sand, Sandy Clay Loam
4	Fine Sandy Loam, Muck/Loam, Sandy Loam, Loam, Loamy Fine Sand, Clay Loam
5	Loamy Sand, Fine Sandy Loam, Sandy Loam, Fine Sand, Muck/Loam, Silty Loam, Loam, Pits

Figure 3-5
Tensaw West Watersheds with Digitized Soil Type



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 timing and infiltration 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 models into individual grid cells. As mentioned previously, the settings for GSSHA require the units to be in the International System of Units (SI). Table 3-3 lists the basin number, grid cell size, drainage area, and number of grid cells for each of the five Tensaw West basins. Figures 3-6, 3-10, 3-14, 3-18, 3-22 indicate the gridded elevation data. Figures 3-7, 3-11, 3-15, 3-19, 3-23 indicate the gridded land use. Figures 3-8, 3-12, 3-16, 3-20, 3-24 indicate the gridded soil types. Figures 3-9, 3-13, 3-17, 3-21, 3-25 indicate the combined land use / soil type data.

Table 3-3
Basins with Grid Cell Size, Drainage Area, and Number of Cells

Basin	Grid Cell Size (Meter)	Grid Cell Size (Feet)	Drainage Area (Sq Miles)	Number of Grid Cells
1	38	125	13.13	23555
2	40	131	11.19	18120
3	55	180	23.77	20355
4	24	79	4.44	19950
5	25	82	5.31	22005

Figure 3-6
Basin 1 – Gridded Contours

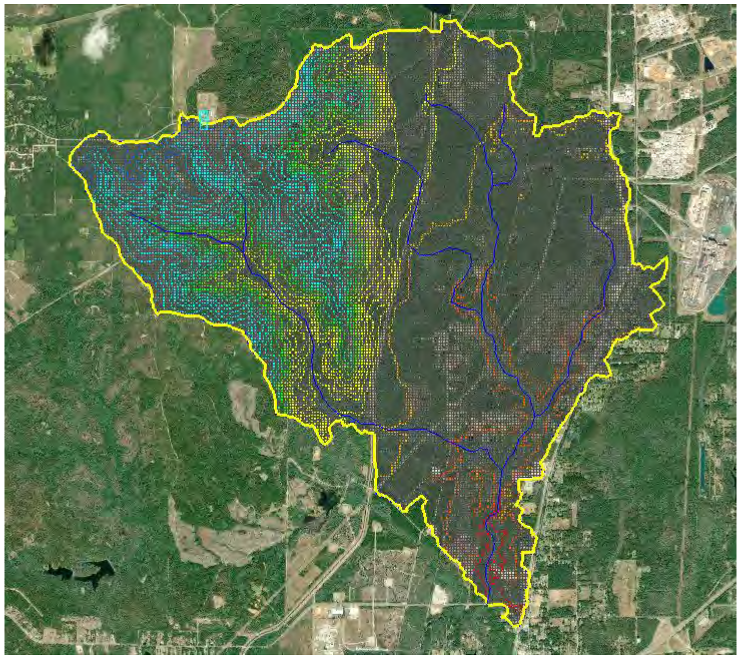


Figure 3-7
Basin 1 – Gridded Land Use

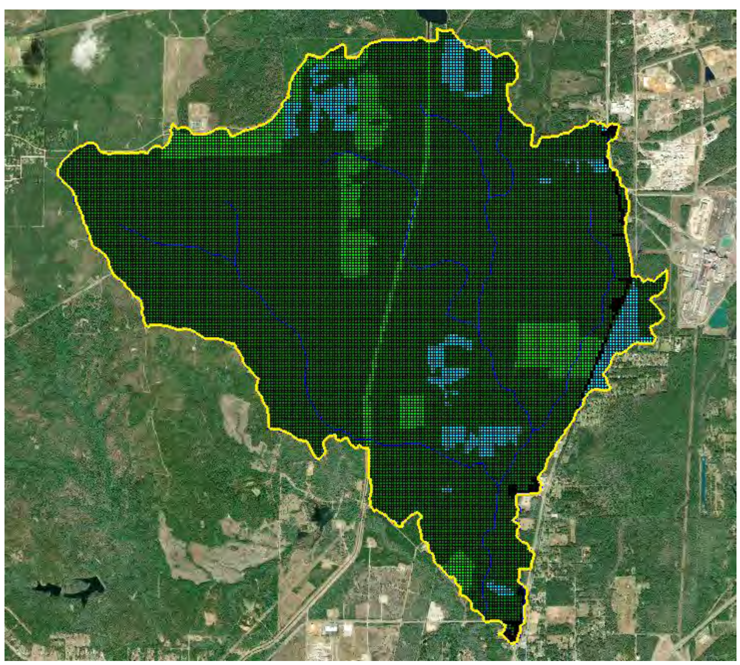


Figure 3-8
Basin 1 – Gridded Soils Data

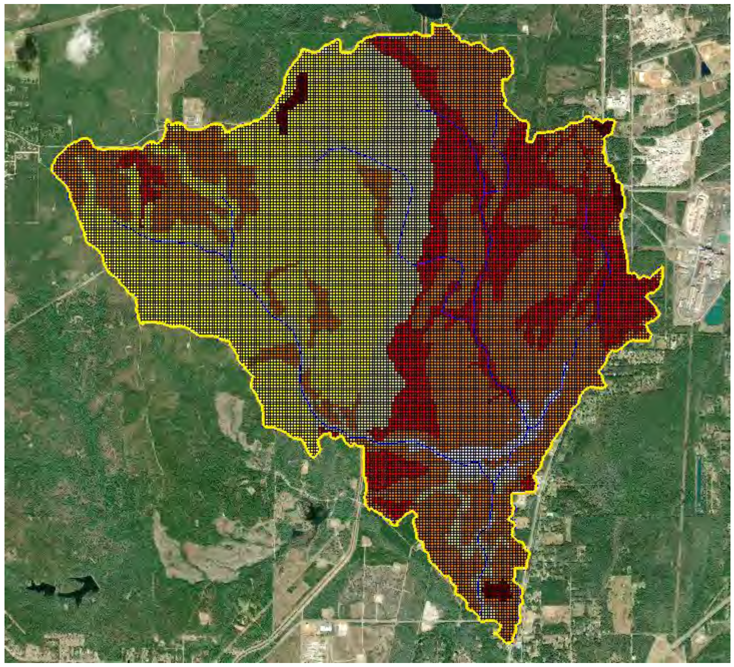


Figure 3-9
Basin 1 – Gridded Combined Land Use and Soil Type

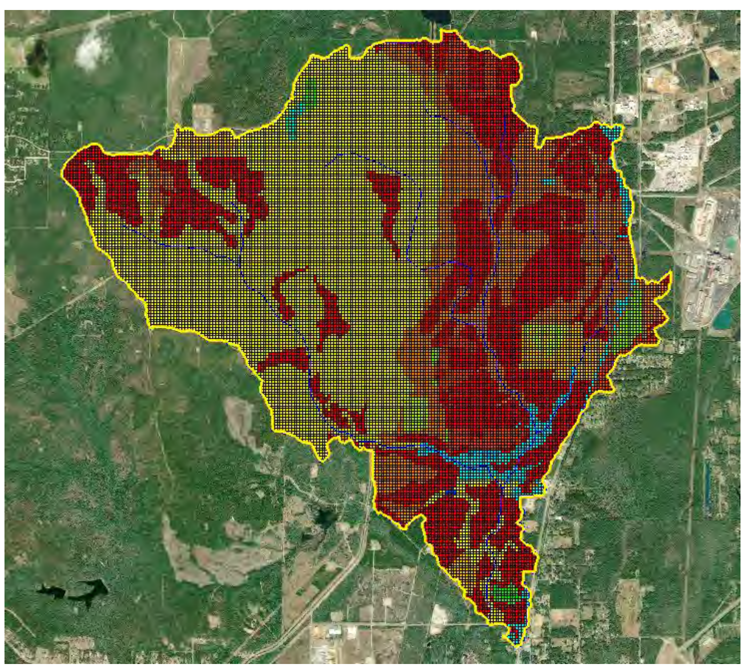


Figure 3-10
Basin 2 – Gridded Contours

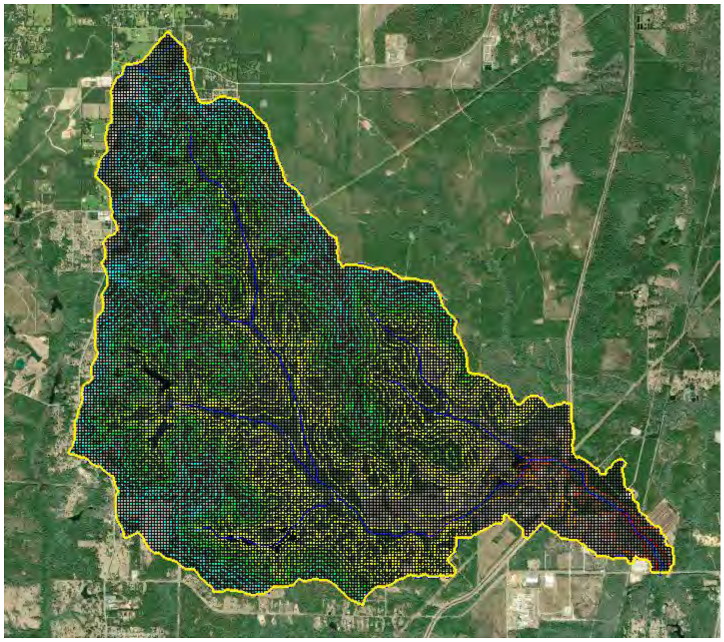


Figure 3-11
Basin 2 – Gridded Land Use

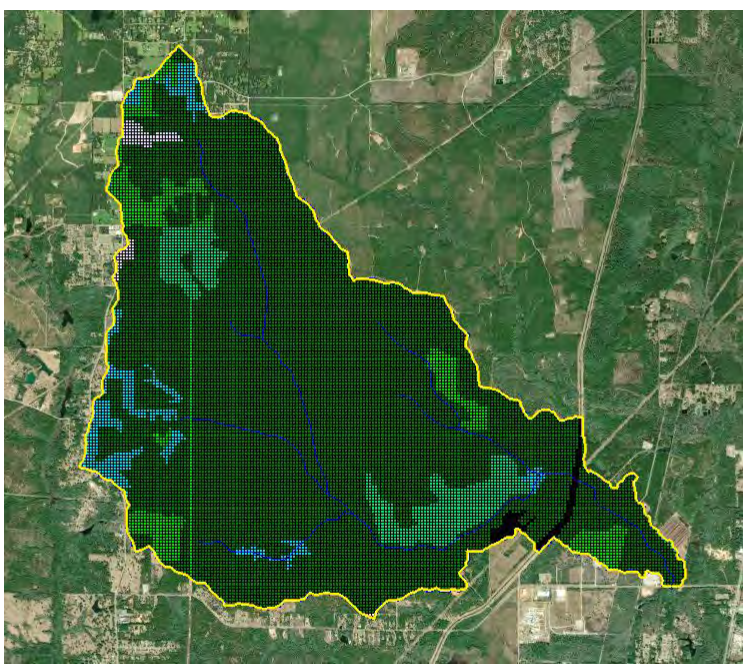


Figure 3-12
Basin 2 – Gridded Soil Type

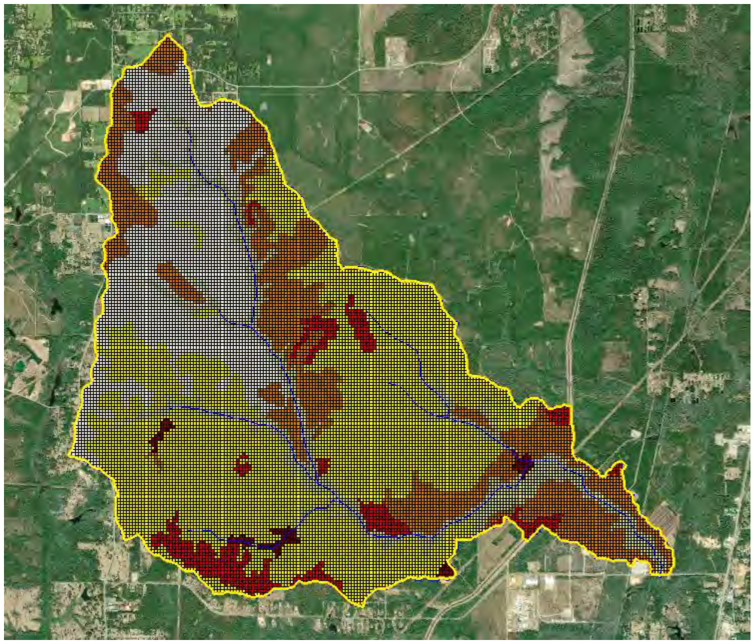


Figure 3-13
Basin 2 – Gridded Combined Land Use and Soil Type

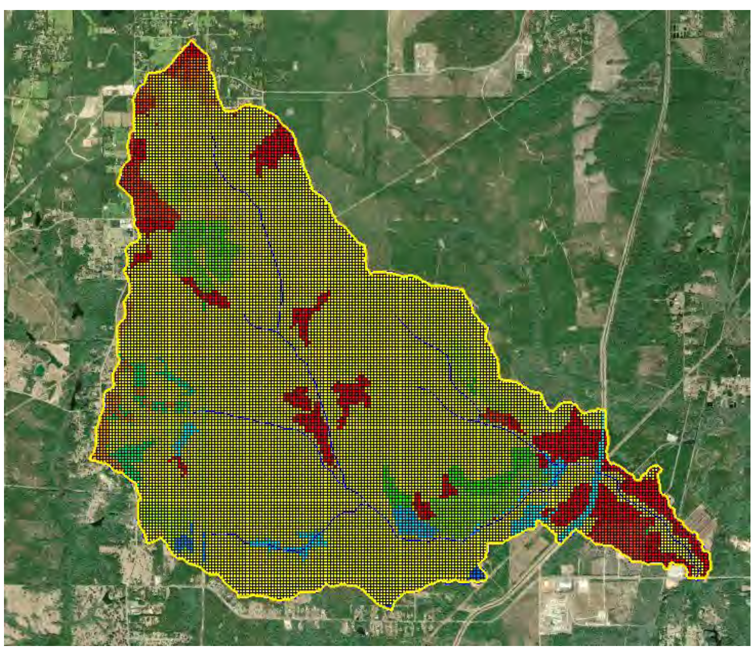


Figure 3-14
Basin 3 – Gridded Contours

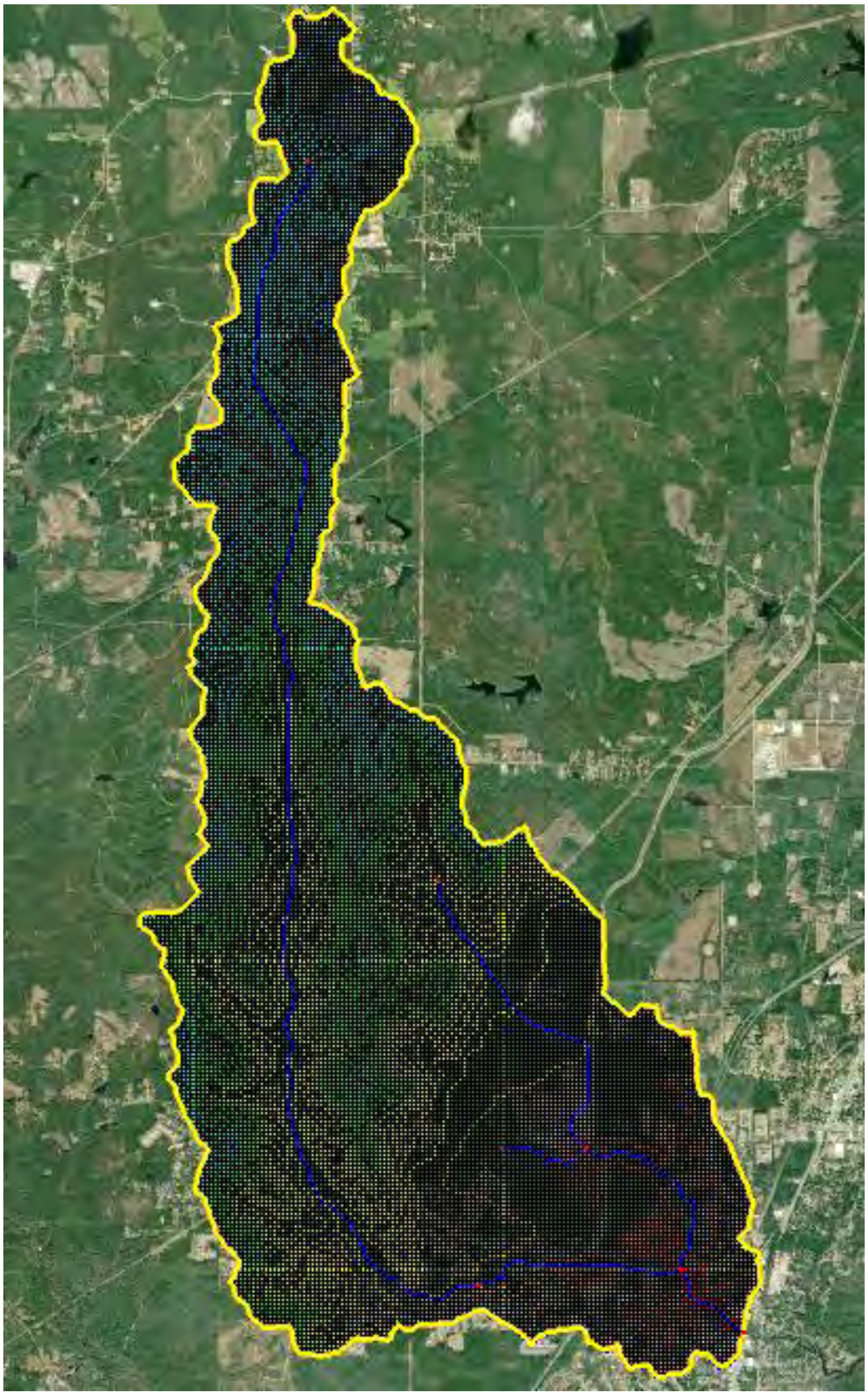


Figure 3-15
Basin 3 – Gridded Land Use

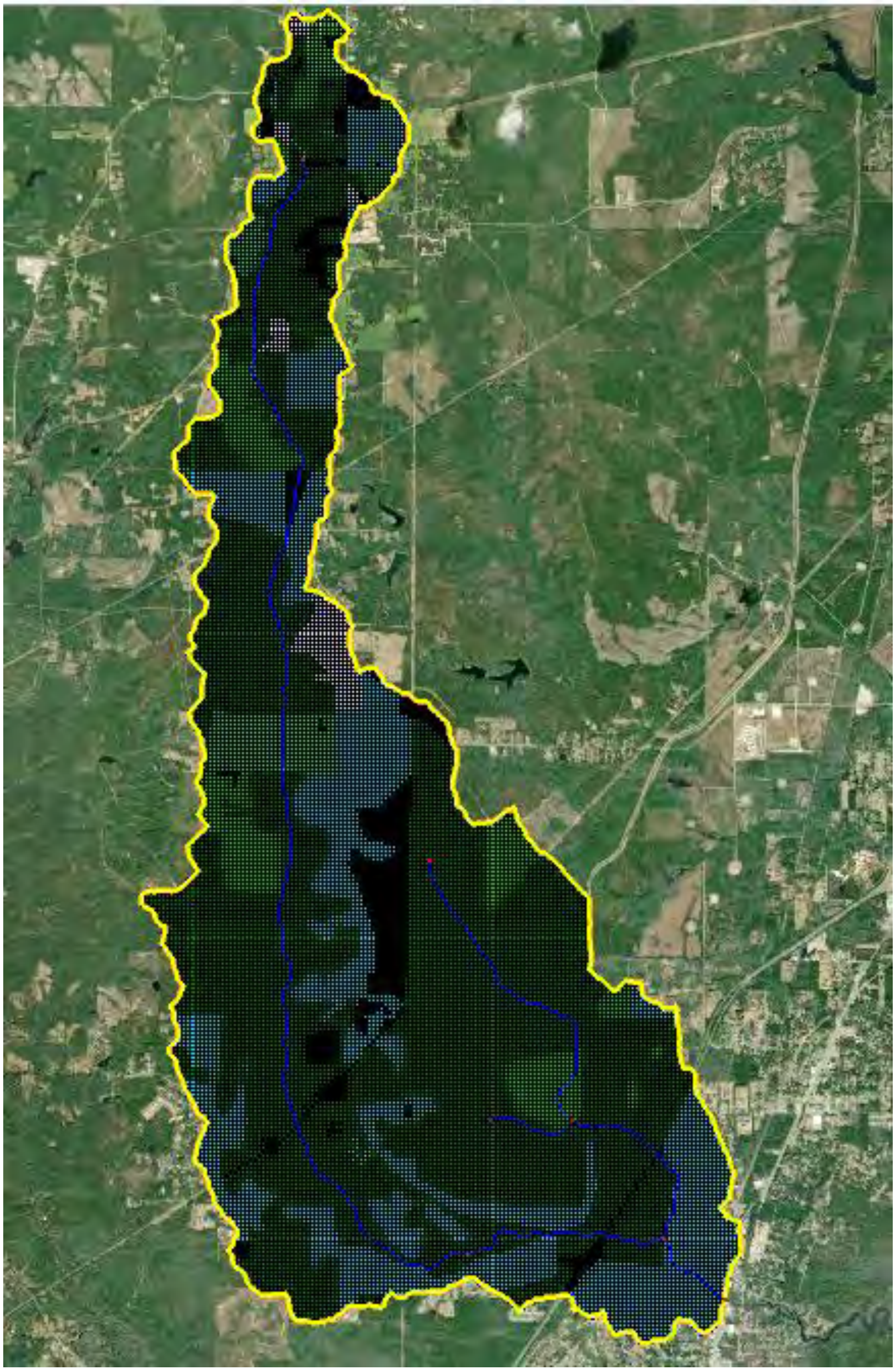


Figure 3-16
Basin 3 – Gridded Soil Type

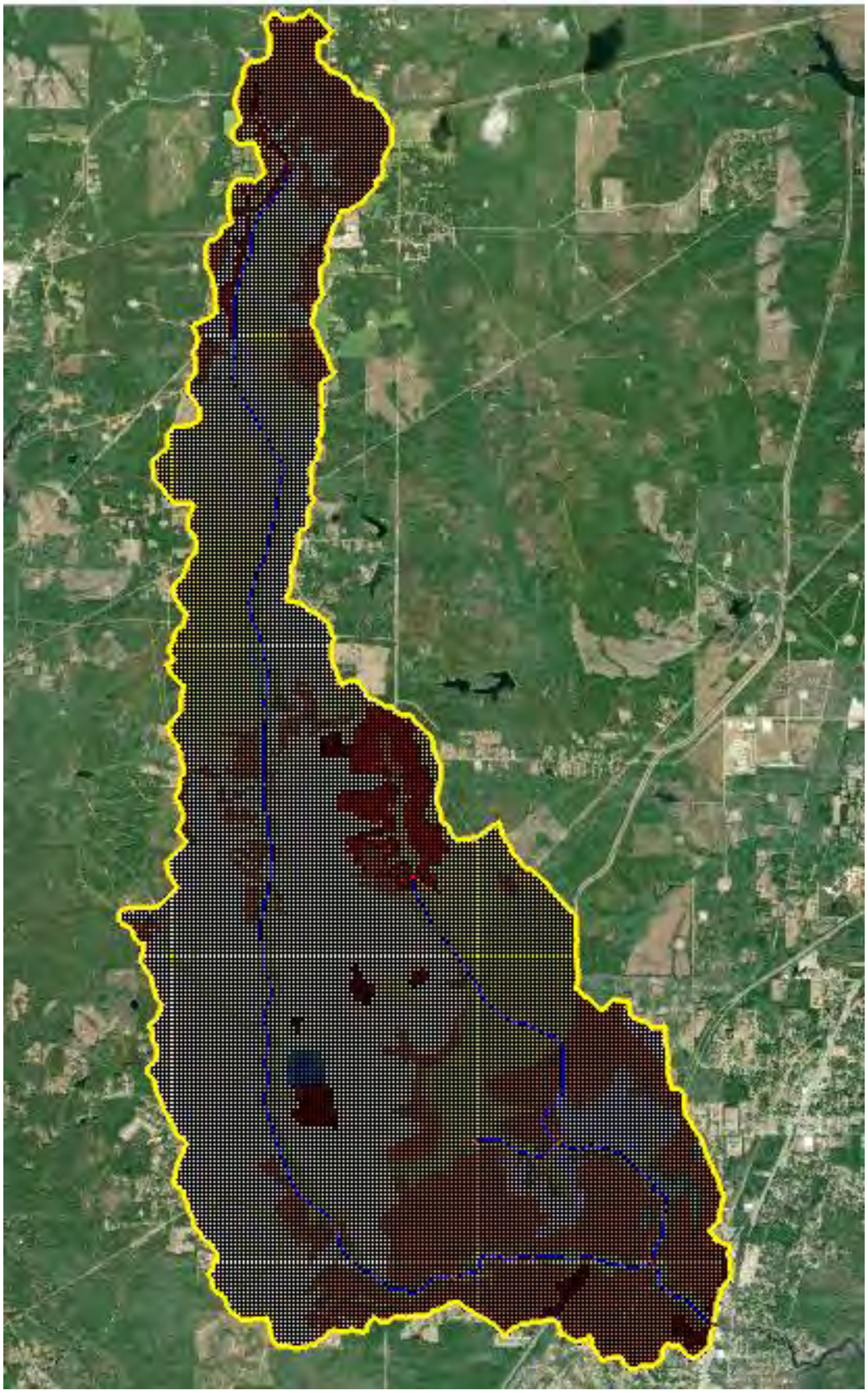


Figure 3-17
Basin 3 – Gridded Combined Land Use and Soil Type

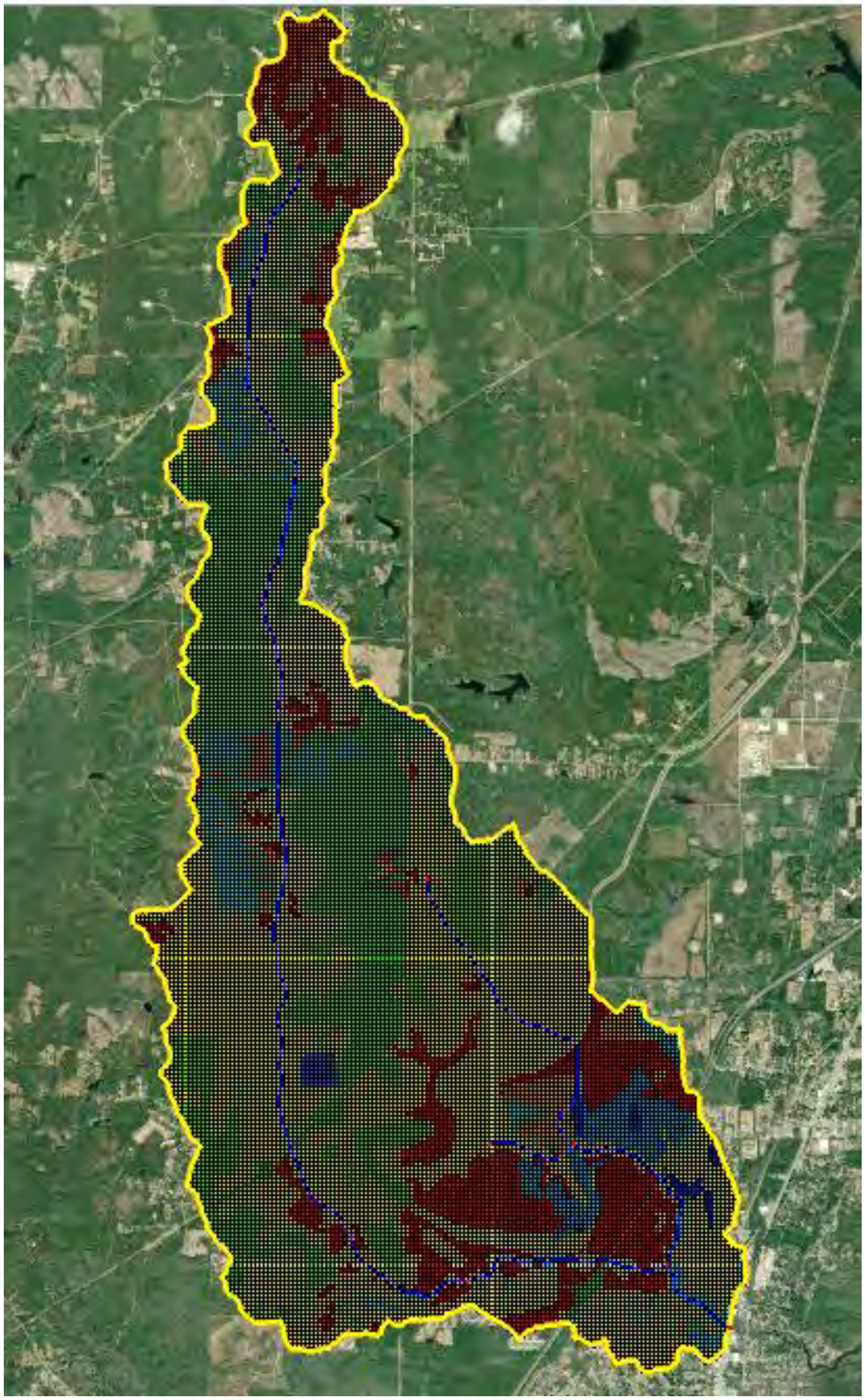


Figure 3-18
Basin 4 – Gridded Contours

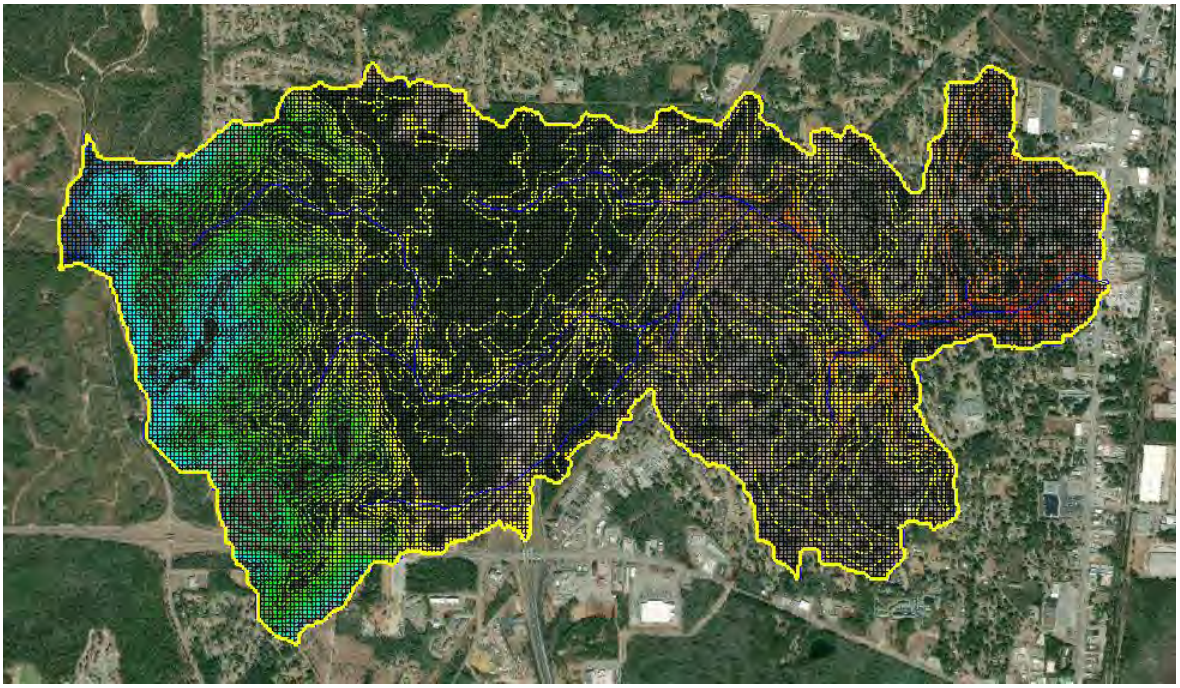


Figure 3-19
Basin 4 – Gridded Land Use

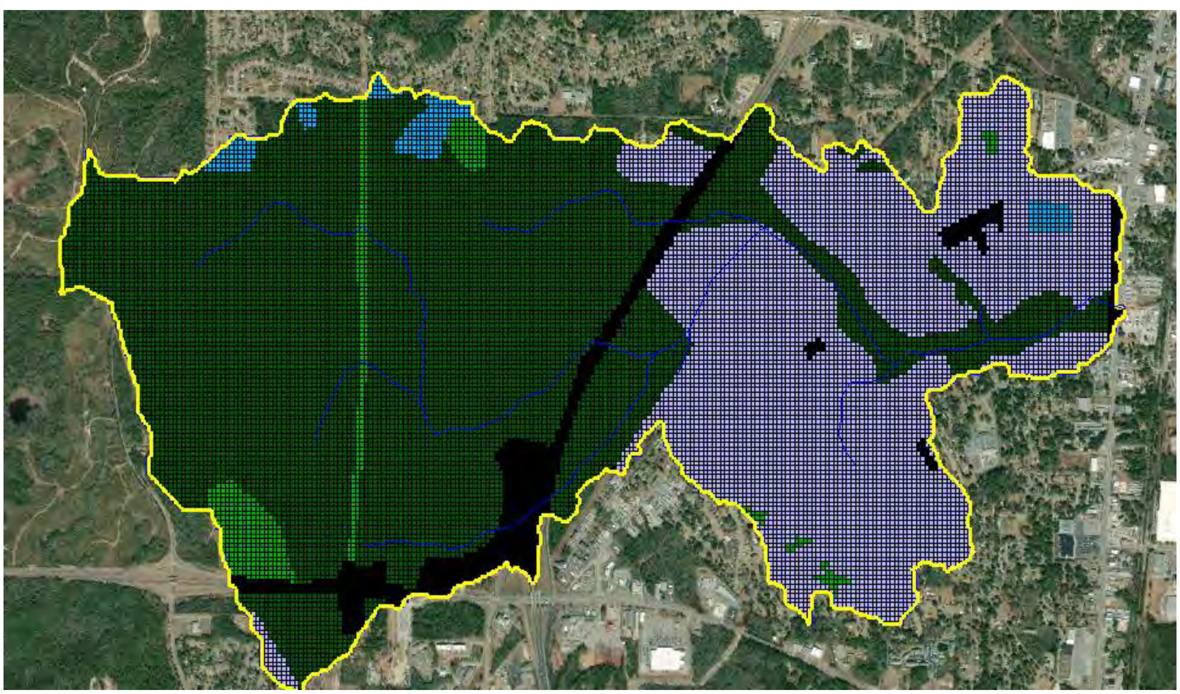


Figure 3-20
Basin 4 – Gridded Soil Type

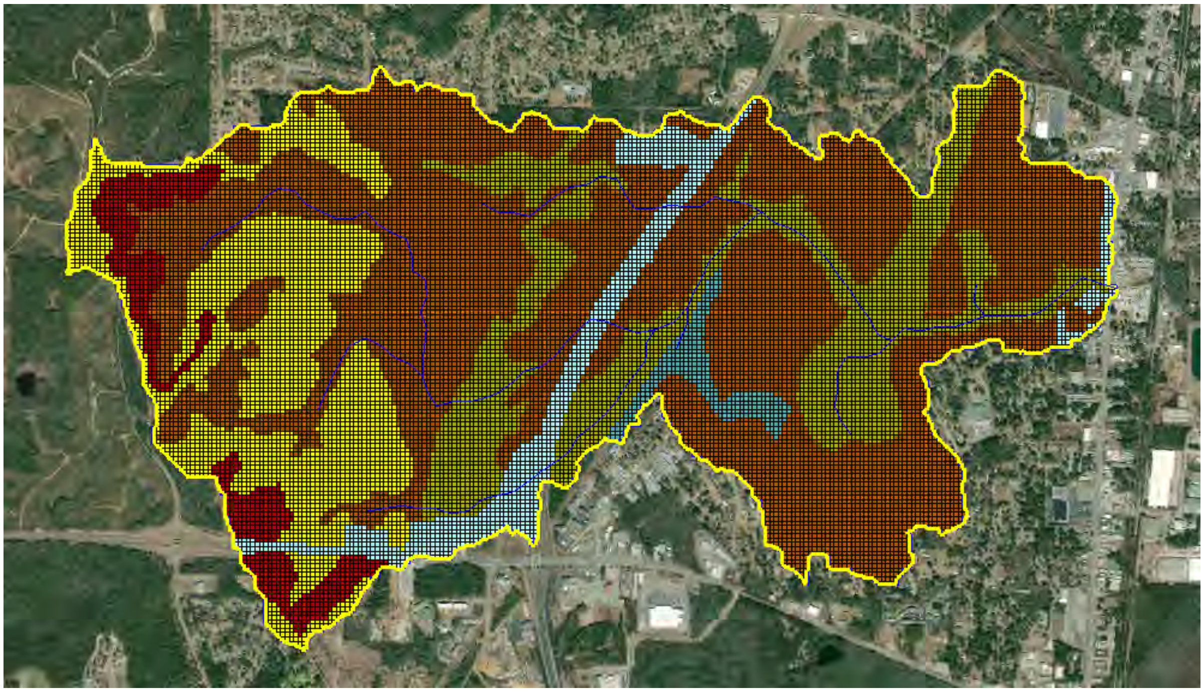


Figure 3-21
Basin 4 – Gridded Combined Land Use and Soil Type

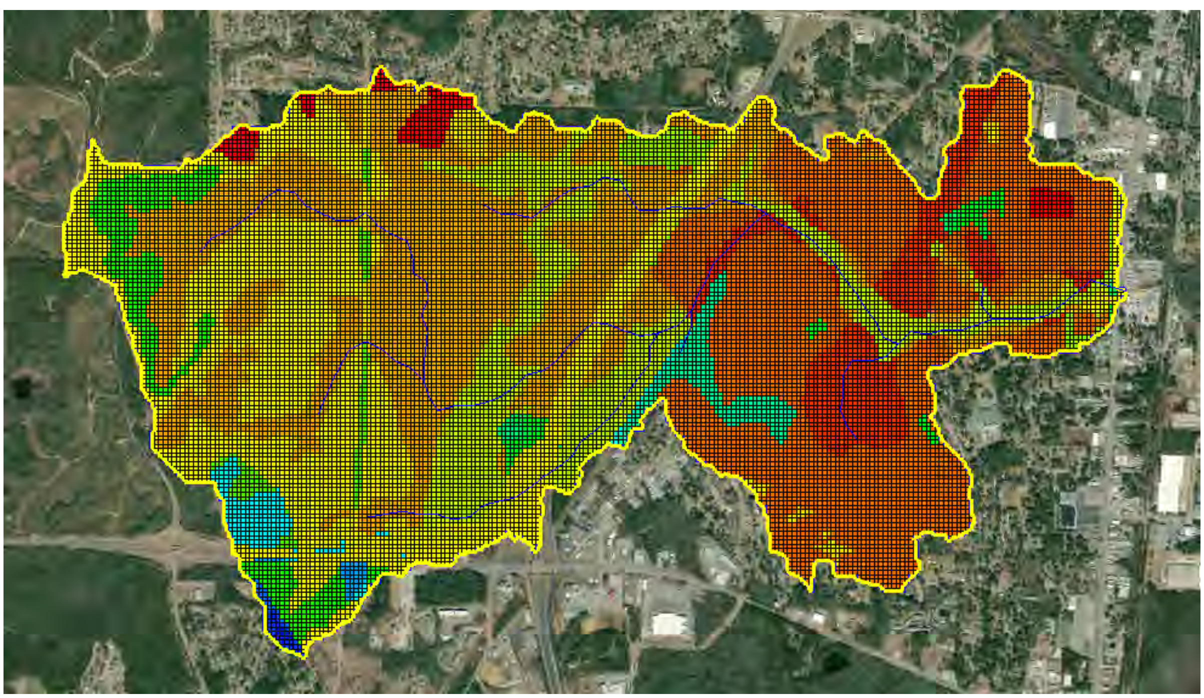


Figure 3-22
Basin 5 – Gridded Contours

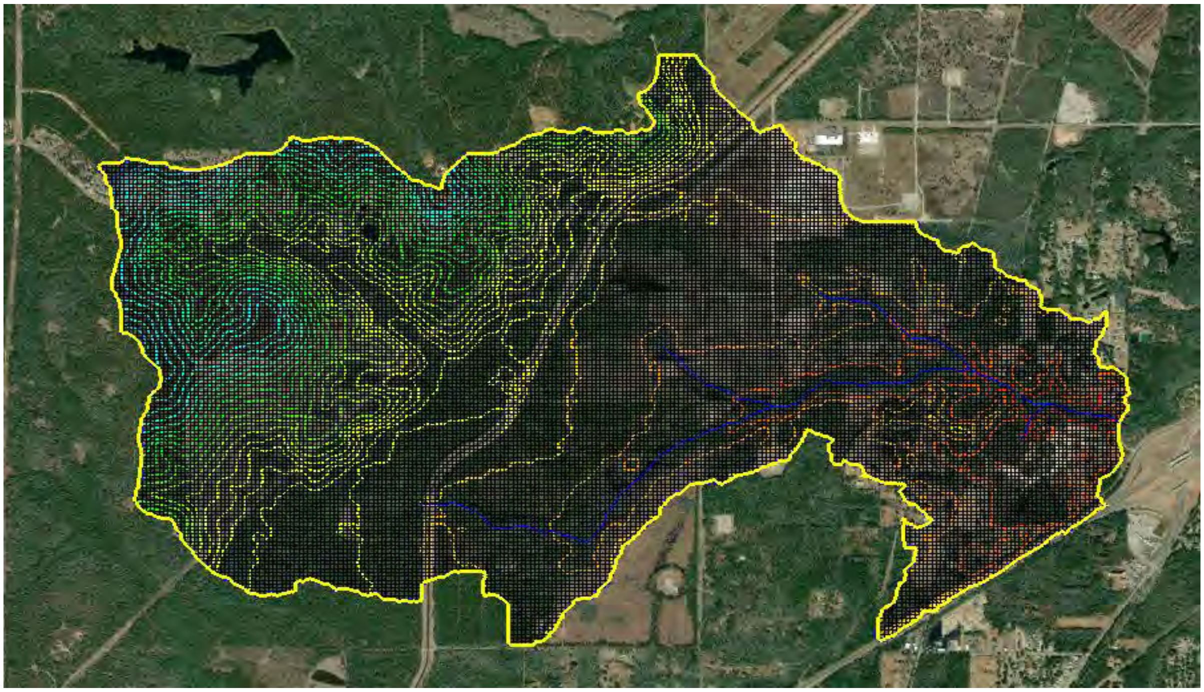


Figure 3-23
Basin 5 – Gridded Land Use

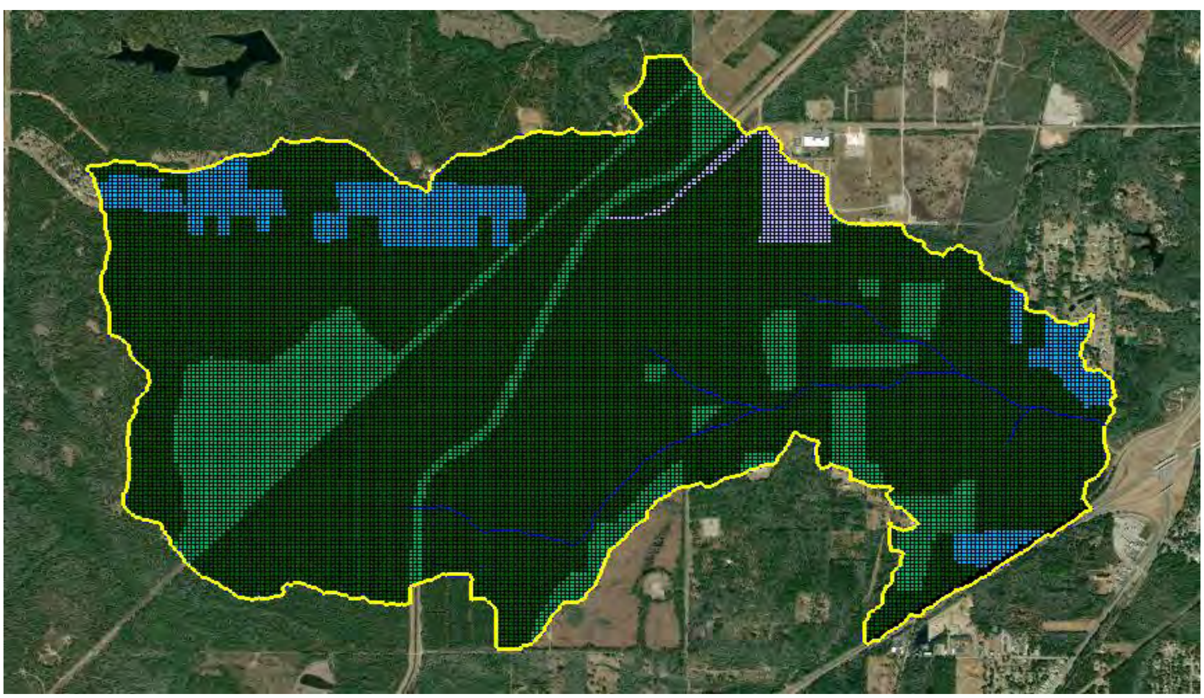


Figure 3-24
Basin 5 – Gridded Soil Type

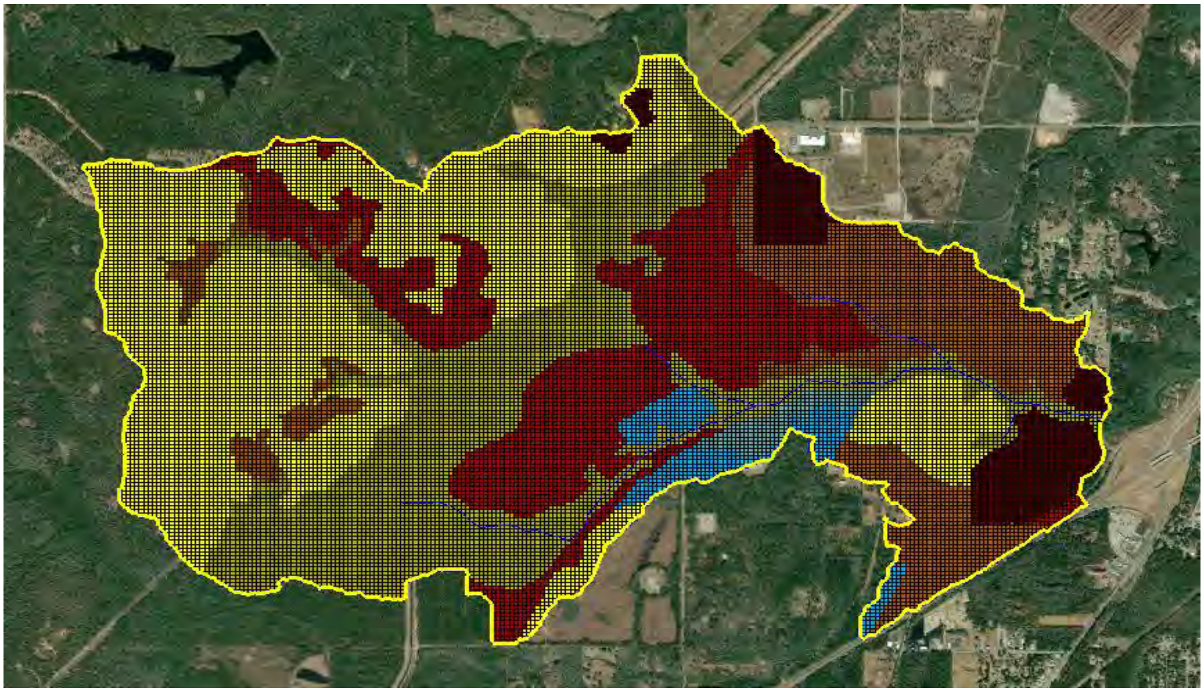
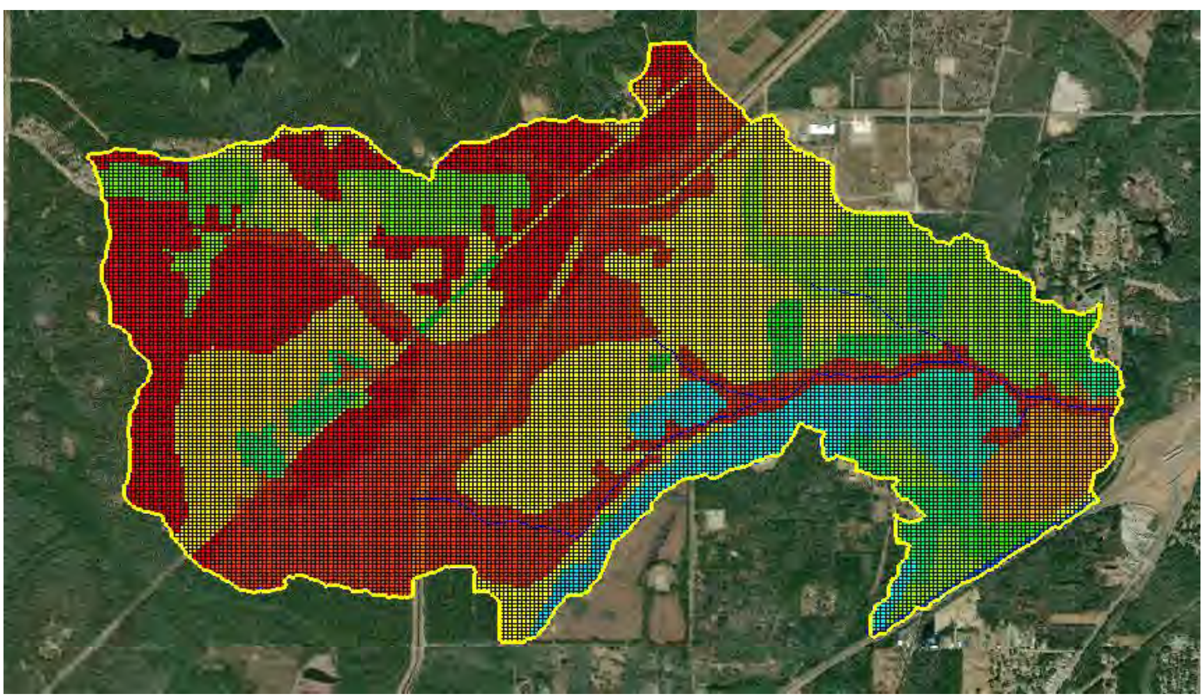


Figure 3-25
Basin 5 – Gridded Combined Land Use and Soil Type



4. Calibration

4.1. Tensaw West Calibration

For a model to be used for forecasting it is best to calibrate to real world storm events. Calibration requires both historic rainfall data distribution and river water surface elevations or discharge measurements during the rain event. With the rainfall distribution being obtained from the installed weather stations, it was necessary to find or install gauges in the watershed to determine stream stages. Telog RU-33 gauges with level logger sensors were used for measuring stream data. These gauges contain 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.

A site visit was performed in order to determine the best location for installing the monitoring gauges. In addition to the RU-33 gauges, crest stage gages were also installed either upstream or downstream in order to record another highwater mark. These simple gages were 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.

There were four locations within the watershed that were deemed useful for monitoring (Figure 4-1). These locations were located near existing drainage structures to help with ease of access. Variables that come into consideration for a gauge location are dependent on location in the watershed, backwater effects, and the possibility of the gauge being vandalized. The four gauges were installed and started recording data on May 31, 2018. A list of gauges and locations can be found in Table 4-1. MBNEP 13 was relocated in January 2019 due to the lack of peak discharge information being recorded at the previous location.

Figure 4-1
Tensaw West Watersheds with Stream Gauge Locations

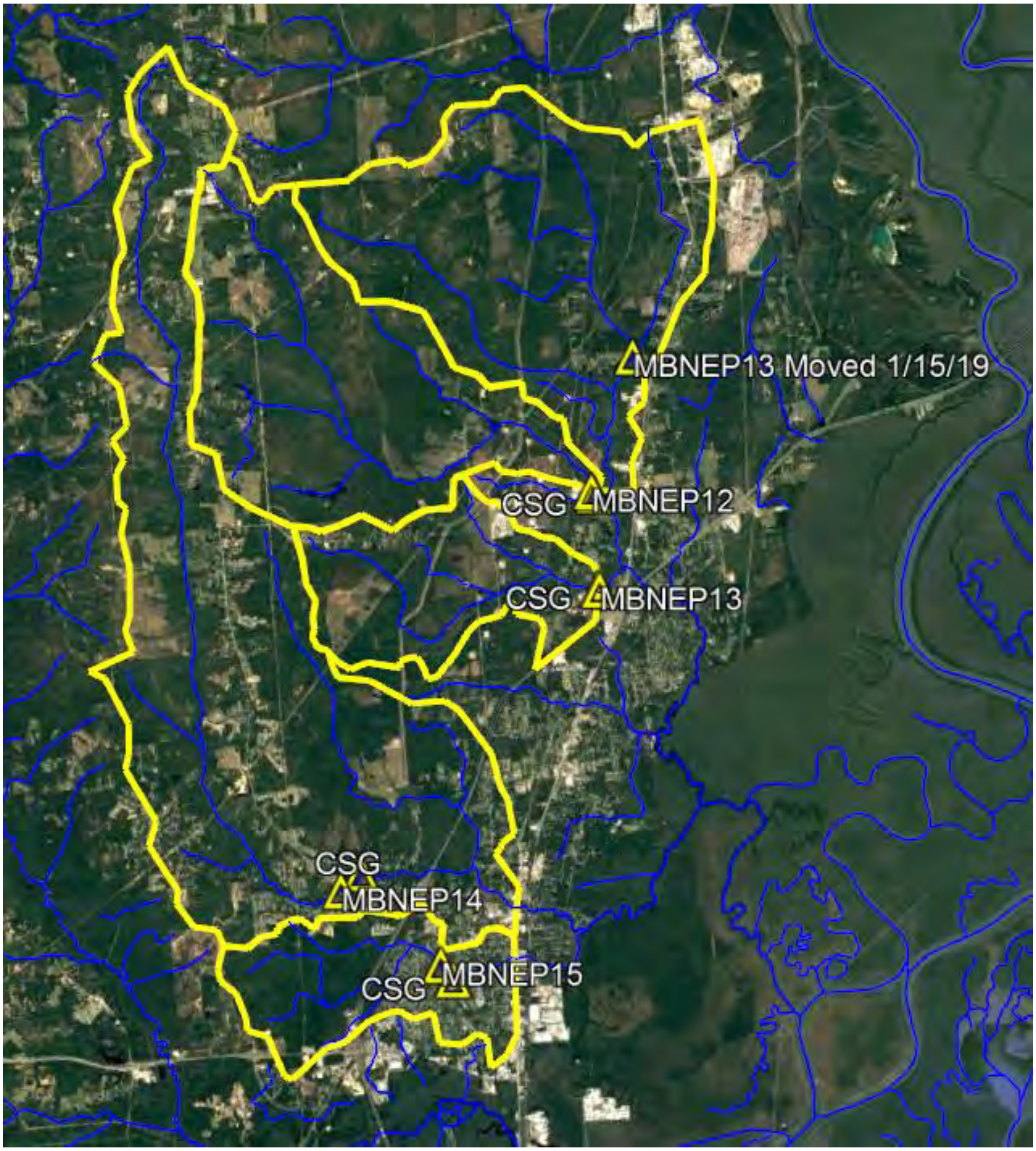


Table 4-1
Stream Gauges and Locations

Gauge Name	Stream	Location
MBNEP 12	Gunnison Creek	50’ d.s of Radcliff Rd CL
Cork Gauge 12	Gunnison Creek	275’ d.s. of MBNEP 12
MBNEP 13	Hall Branch	45’ d.s of Hall Branch Rd CL
Cork Gauge 13	Hall Branch	75’ u.s. of Hall Branch Rd CL
MBNEP 13 Moved	Turtle Branch	55’ d.s of Creax Rd CL
Cork Gauge 13	Turtle Branch	50’ u.s. of Creax Rd CL
MBNEP 14	Bayou Sara	65’ d.s. of Celeste Rd CL
Cork Gauge 14	Bayou Sara	35’ u.s. of Forest Ave CL
MBNEP 15	Norton Branch	50’ d.s of Shelton Beach Rd CL
Cork Gauge 15	Norton Branch	1220’ d.s. of MBNEP 15

During the June 2018 to June 2020 time period there were a couple of storm events that were possible candidates for calibration and validation. From the Telog RU-33 stream gauge data (Figures 4-2 to 4-5), it was determined that there were many equally sized rain events; however, there were no prominent events evident. The two largest events occurred on October 30, 2019, and June 7, 2020. Using NOAA Atlas 14 (Figure 4-6) for the rain depths and time periods for each event, it was determined that these two rain events were equal to a 2-year storm. The next largest events chosen for the calibration occurred on December 8, 2018, January 23, 2019, April 25, 2019, May 11, 2019, and July 13, 2019. Using NOAA Atlas 14 (Figure 4-6) for the rain depths and time periods for each event, it was determined that all of the rain events were less than a 1-year storm event. Calibrations of the models were performed and compared to the stream gauge data.

In order to compare discharges from the hydrologic model to the discharges in the field, it was necessary to build a hydraulic model of the stream in the location of the stream gauge. Information required for the hydraulic model includes a field surveyed cross-section at the location of the RU-33 gauge, Manning's 'n' values for the channel and floodplain, discharges, and a stream slope. The stream slope was determined from the difference in elevation of the peak stage at the RU-33 gauge and at the crest stage gage divided by the distance between them. A range of discharges were entered into the hydraulic model along with the stream slope in order to develop a rating curve. This curve was plotted in excel against the discharge output from the hydrologic model. If any additional model cross-sections were necessary for enhancing the hydraulic model, they were cut using the LiDAR data obtained from NOAA.

Calibration of the model requires adjustment of the key parameters that affect infiltration, overland flow, and channel routing. The variables that are usually examined are hydraulic conductivity, overland roughness, and channel roughness. These values were adjusted until the model output best fit the observed data. Other factors that were considered are interception and retention.

Figure 4-2
MBNEP 12 Gauge Height Readings – June 2018-June 2020

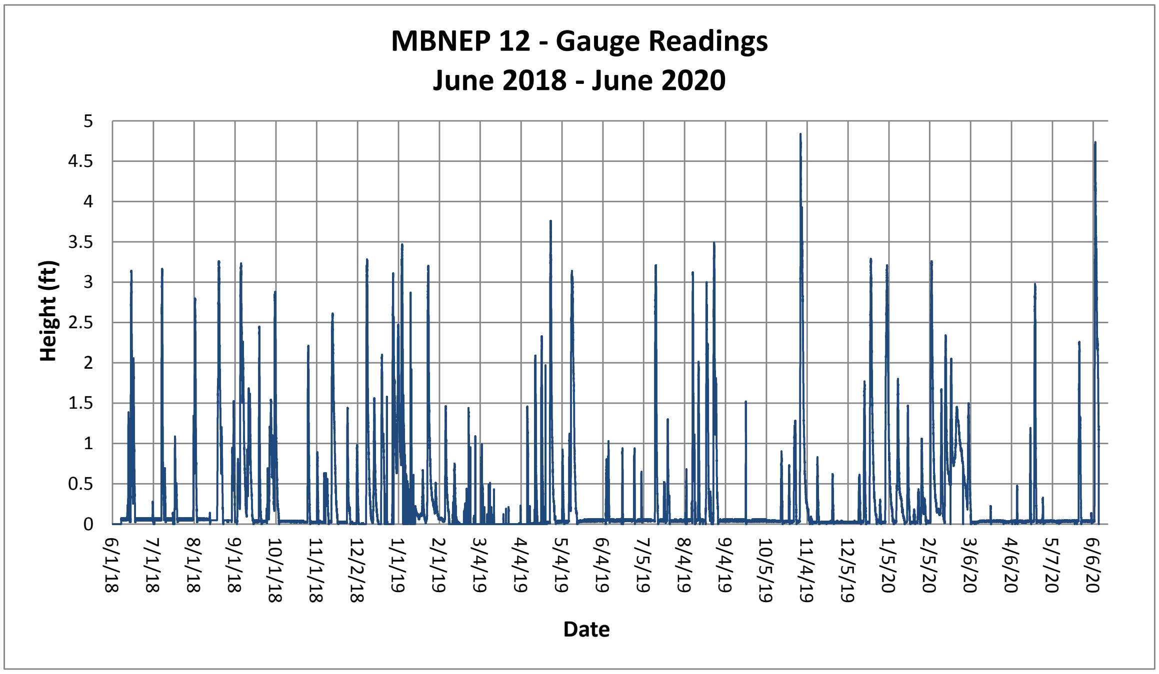


Figure 4-3
MBNEP 13 Gauge Height Readings – June 2018-June 2020

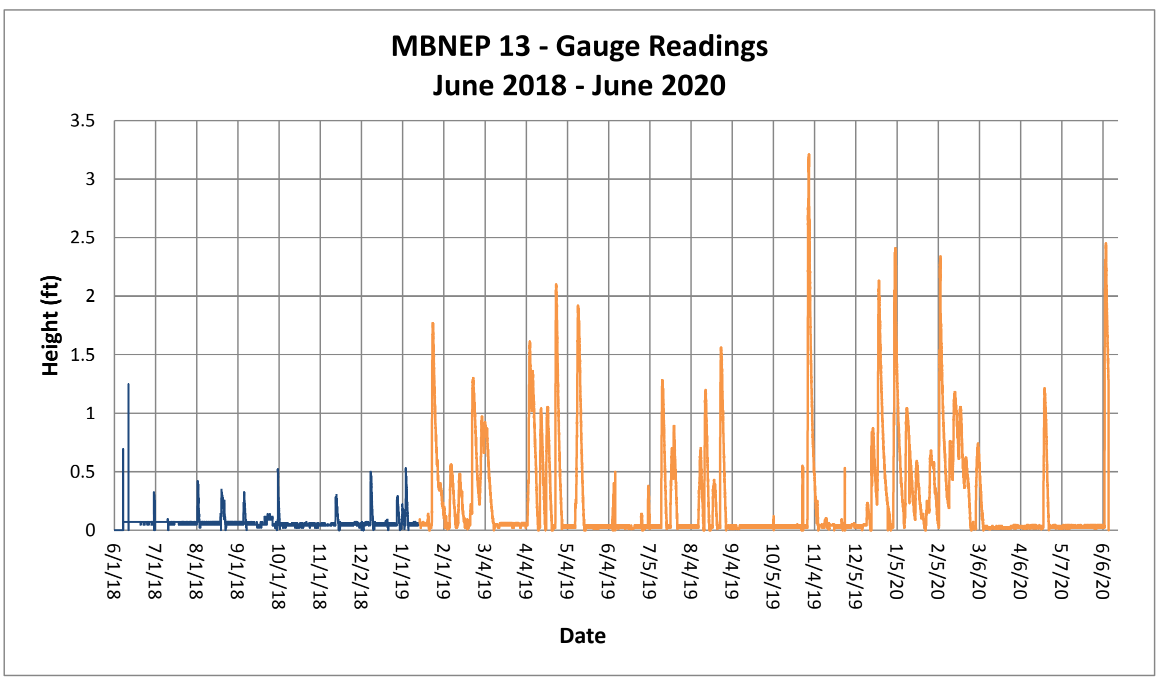


Figure 4-4
MBNEP 14 Gauge Height Readings – June 2018-June 2020

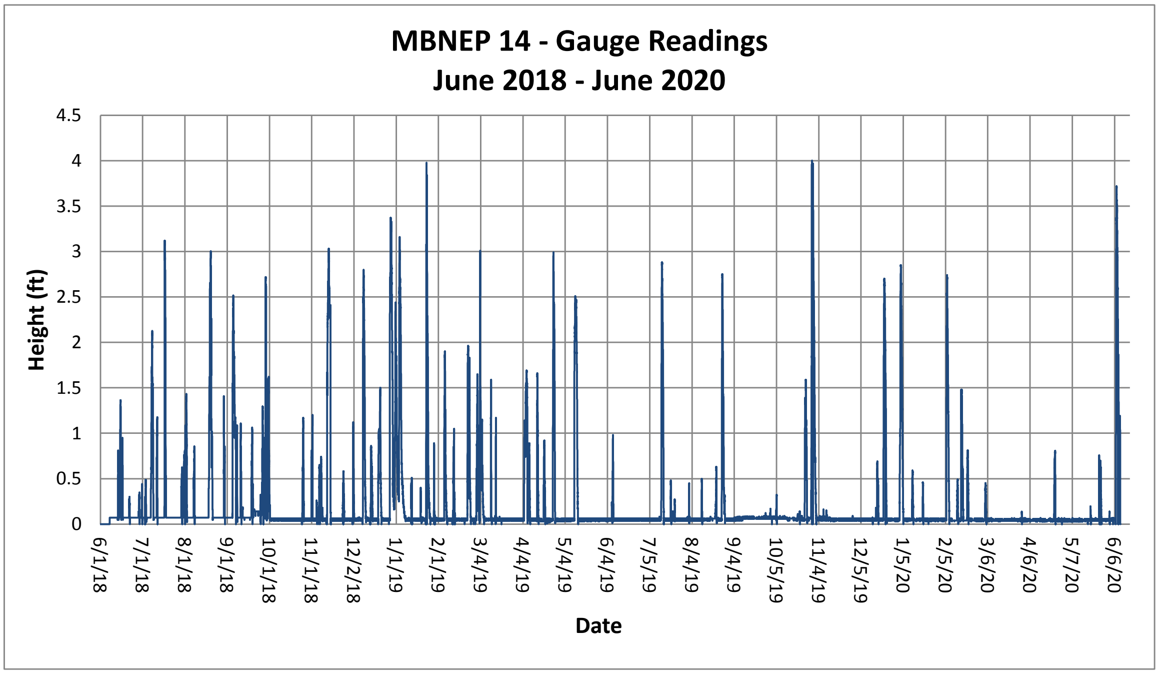


Figure 4-5
MBNEP 15 Gauge Height Readings – June 2018-Oct 2019

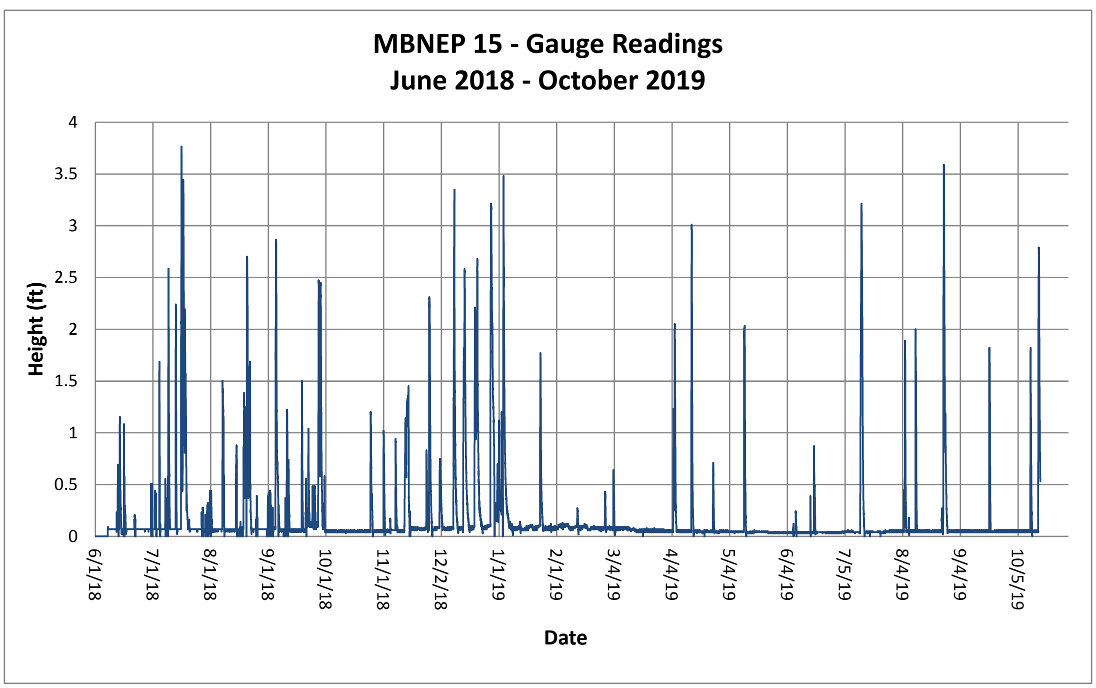


Figure 4-6
Point Precipitation Frequency Estimates

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 9, Version 2

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

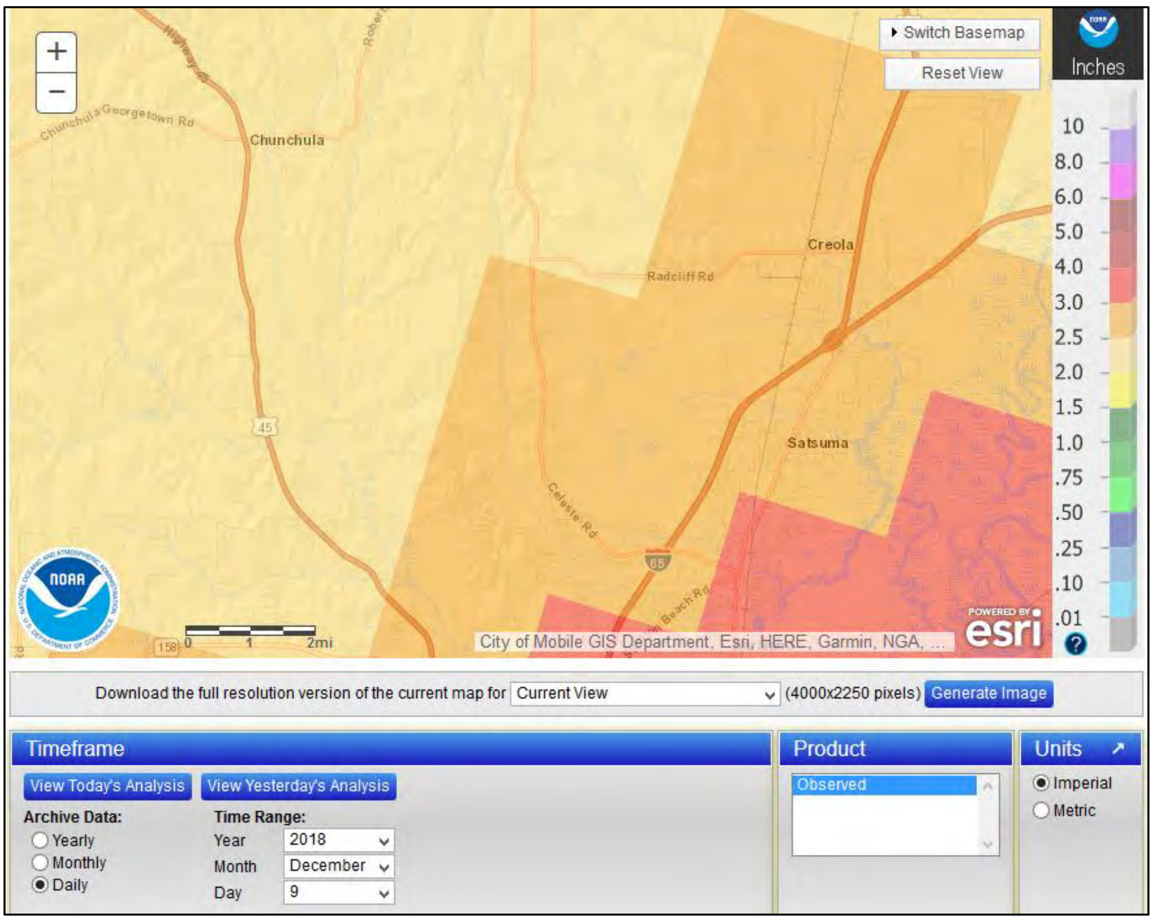
Duration	Average recurrence interval (years)								
	1	2	5	10	25	50	100	200	500
5-min	**0.597** (0.488-0.738)	**0.677** (0.552-0.837)	**0.810** (0.658-1.00)	**0.921** (0.744-1.15)	**1.08** (0.843-1.37)	**1.20** (0.918-1.55)	**1.33** (0.980-1.74)	**1.46** (1.03-1.95)	**1.63** (1.11-2.24)
10-min	**0.875** (0.714-1.08)	**0.992** (0.808-1.23)	**1.19** (0.963-1.47)	**1.35** (1.09-1.68)	**1.58** (1.24-2.01)	**1.76** (1.35-2.27)	**1.94** (1.44-2.55)	**2.13** (1.51-2.86)	**2.38** (1.63-3.27)
15-min	**1.07** (0.871-1.32)	**1.21** (0.986-1.49)	**1.45** (1.18-1.79)	**1.65** (1.33-2.04)	**1.93** (1.51-2.45)	**2.15** (1.64-2.76)	**2.37** (1.75-3.11)	**2.60** (1.84-3.49)	**2.91** (1.98-3.99)
30-min	**1.55** (1.26-1.91)	**1.76** (1.44-2.18)	**2.12** (1.73-2.63)	**2.42** (1.96-3.01)	**2.85** (2.23-3.63)	**3.18** (2.43-4.09)	**3.51** (2.59-4.60)	**3.85** (2.73-5.16)	**4.30** (2.93-5.90)
60-min	**2.05** (1.68-2.54)	**2.34** (1.91-2.89)	**2.82** (2.29-3.50)	**3.25** (2.62-4.03)	**3.86** (3.03-4.95)	**4.36** (3.34-5.64)	**4.87** (3.61-6.43)	**5.42** (3.85-7.30)	**6.18** (4.22-8.50)
2-hr	**2.56** (2.10-3.14)	**2.91** (2.39-3.57)	**3.52** (2.88-4.33)	**4.07** (3.31-5.02)	**4.87** (3.86-6.22)	**5.54** (4.27-7.13)	**6.24** (4.66-8.20)	**6.99** (5.01-9.38)	**8.05** (5.54-11.0)
3-hr	**2.89** (2.38-3.53)	**3.28** (2.70-4.01)	**3.99** (3.27-4.88)	**4.63** (3.77-5.69)	**5.61** (4.47-7.16)	**6.43** (4.99-8.28)	**7.32** (5.49-9.60)	**8.28** (5.96-11.1)	**9.66** (6.68-13.2)
6-hr	**3.49** (2.89-4.23)	**3.98** (3.29-4.83)	**4.88** (4.03-5.93)	**5.73** (4.70-6.99)	**7.05** (5.67-8.98)	**8.18** (6.40-10.5)	**9.41** (7.11-12.3)	**10.8** (7.81-14.4)	**12.7** (8.87-17.3)
12-hr	**4.14** (3.45-4.98)	**4.76** (3.97-5.74)	**5.93** (4.92-7.15)	**7.02** (5.80-8.51)	**8.73** (7.06-11.1)	**10.2** (8.02-13.0)	**11.8** (8.96-15.3)	**13.5** (9.88-18.0)	**16.1** (11.3-21.7)
24-hr	**4.82** (4.04-5.76)	**5.60** (4.69-6.70)	**7.05** (5.88-8.44)	**8.40** (6.97-10.1)	**10.5** (8.54-13.2)	**12.3** (9.73-15.6)	**14.2** (10.9-18.4)	**16.4** (12.0-21.6)	**19.5** (13.8-26.2)
2-day	**5.56** (4.69-6.59)	**6.48** (5.45-7.69)	**8.16** (6.85-9.71)	**9.74** (8.13-11.6)	**12.2** (9.98-15.2)	**14.3** (11.4-17.9)	**16.5** (12.7-21.2)	**19.0** (14.1-24.9)	**22.6** (16.1-30.2)
3-day	**6.06** (5.12-7.15)	**7.04** (5.95-8.31)	**8.83** (7.44-10.5)	**10.5** (8.80-12.5)	**13.1** (10.8-16.3)	**15.3** (12.2-19.1)	**17.7** (13.7-22.6)	**20.3** (15.1-26.4)	**24.1** (17.2-32.0)
4-day	**6.49** (5.50-7.64)	**7.49** (6.34-8.82)	**9.32** (7.87-11.0)	**11.0** (9.26-13.1)	**13.7** (11.2-16.9)	**15.9** (12.7-19.8)	**18.3** (14.2-23.3)	**21.0** (15.6-27.3)	**24.8** (17.8-32.9)
7-day	**7.63** (6.50-8.93)	**8.59** (7.32-10.1)	**10.4** (8.81-12.2)	**12.1** (10.2-14.2)	**14.7** (12.2-18.1)	**16.9** (13.6-21.0)	**19.4** (15.1-24.5)	**22.1** (16.5-28.5)	**26.0** (18.7-34.3)

* This chart was generated from the lat/long point of 30.8907, -88.1028

Source: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=al

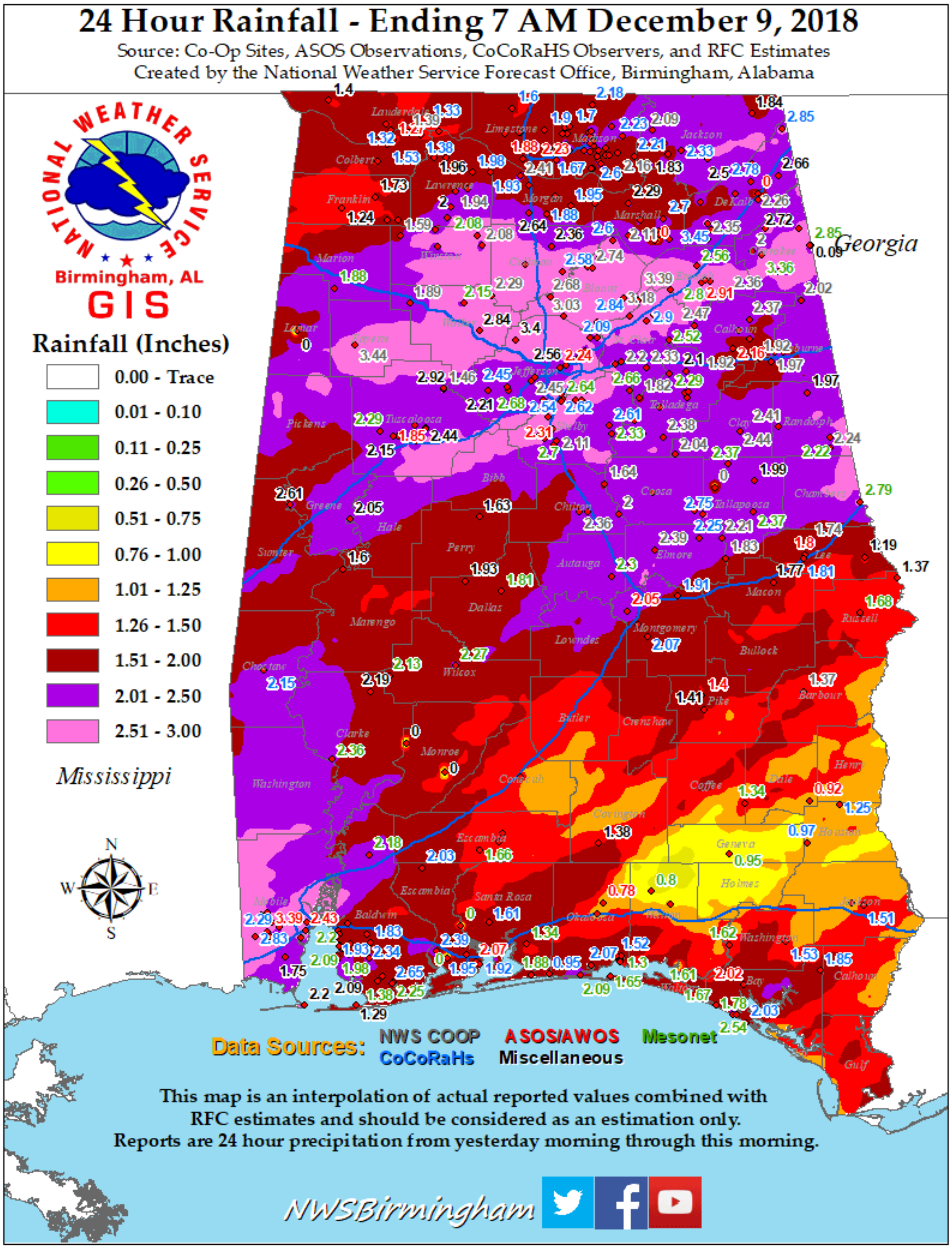
Figures 4-7 and 4-8 indicate the total rainfall maps for the December 8, 2018 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-9, 4-11, and 4-13 indicate the total rainfall distribution for Basins 2, 3, and 4. Figures 4-10, 4-12, and 4-14 indicate the calibrated model output for Basins 2, 3, and 4.

Figure 4-7
December 8-9, 2018 – AHPS Total Rainfall Map



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

Figure 4-8
December 8-9, 2018 – Total Rainfall Map



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

Figure 4-9
December 8, 2018 – Total Rainfall Basin 2

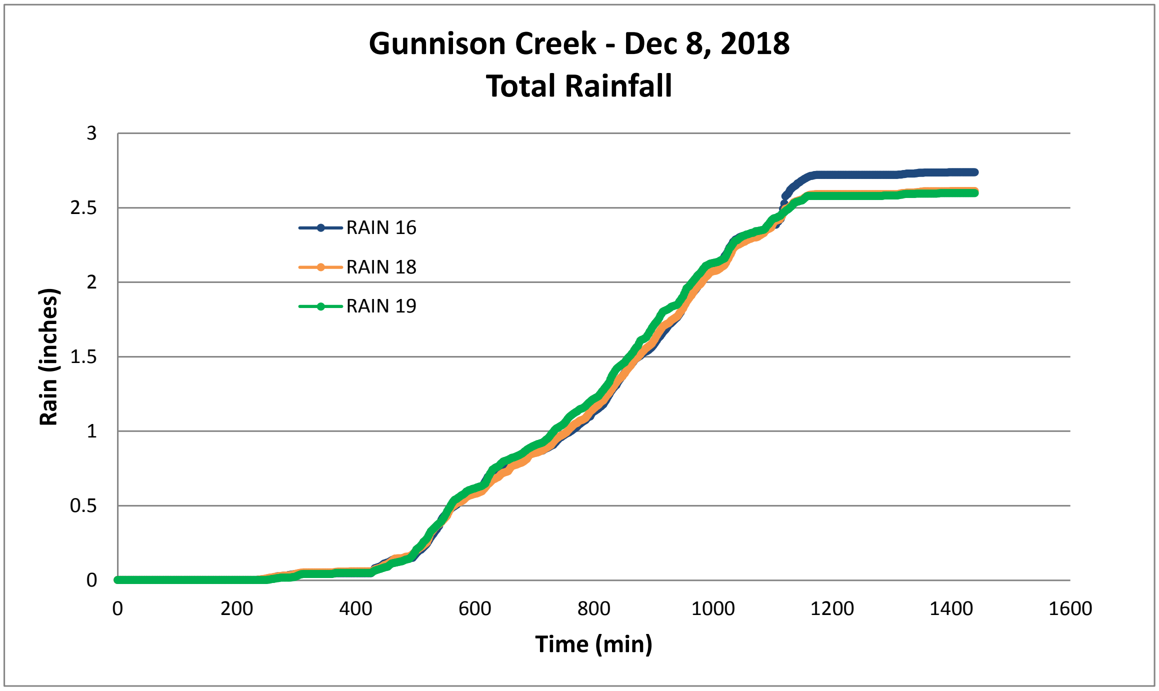


Figure 4-10
December 8-10, 2018 – Gunnison Creek Calibration (B2)

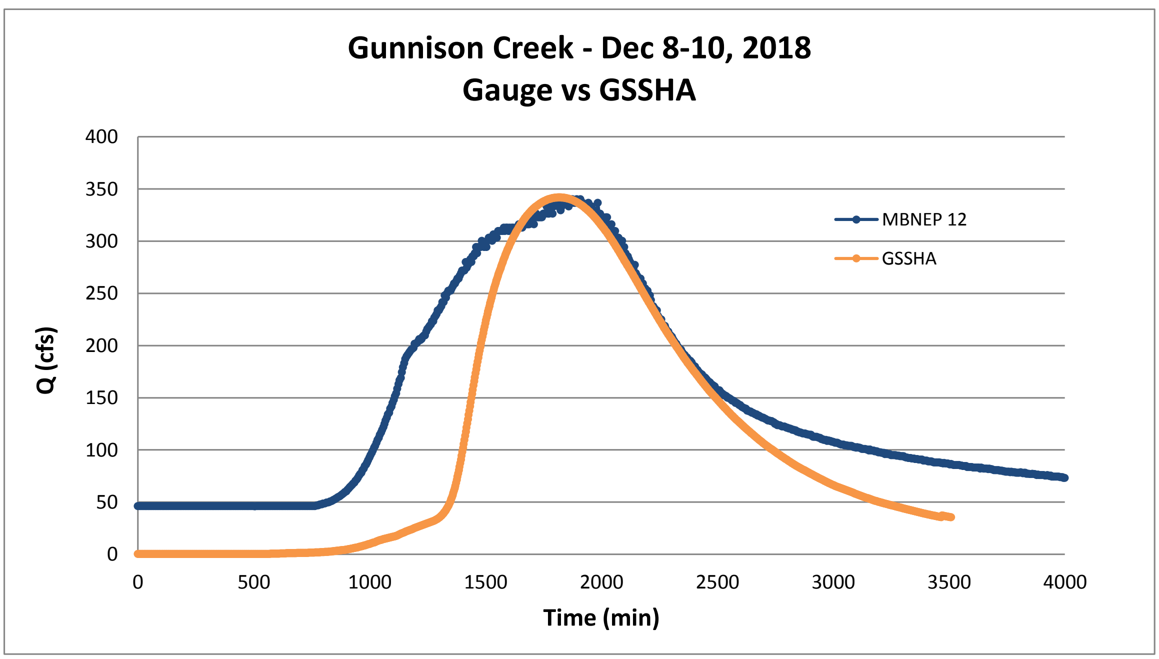


Figure 4-11
December 8, 2018 – Total Rainfall Basin 3

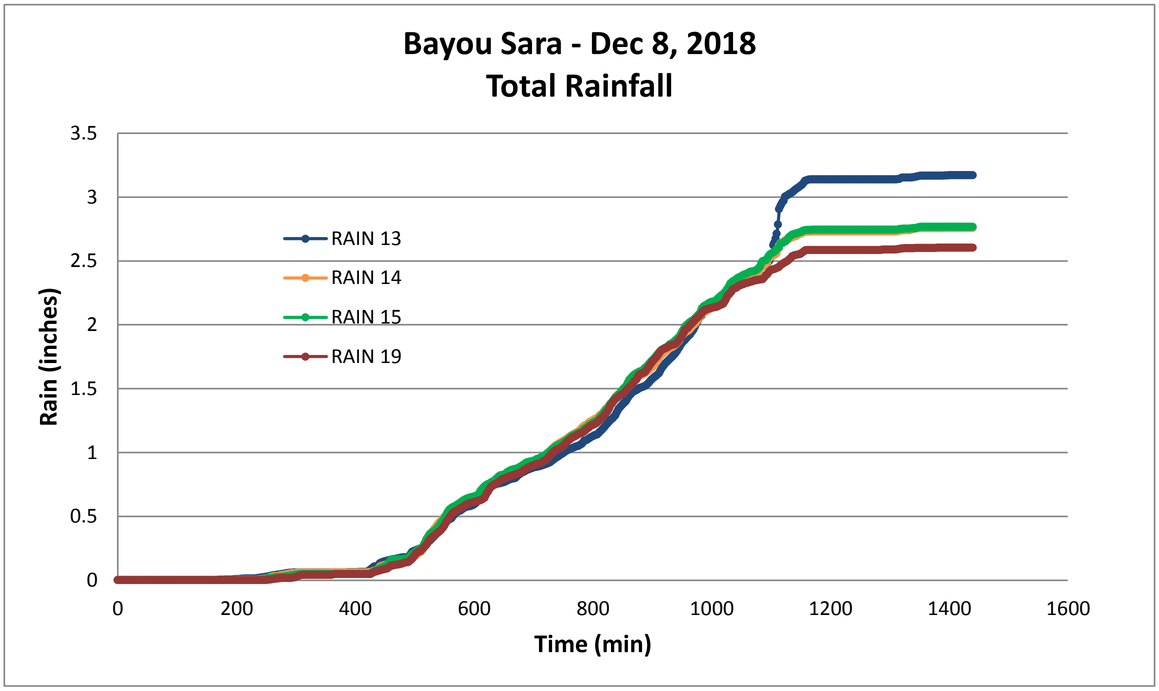


Figure 4-12
December 8-10, 2018 – Bayou Sara Calibration (B3)

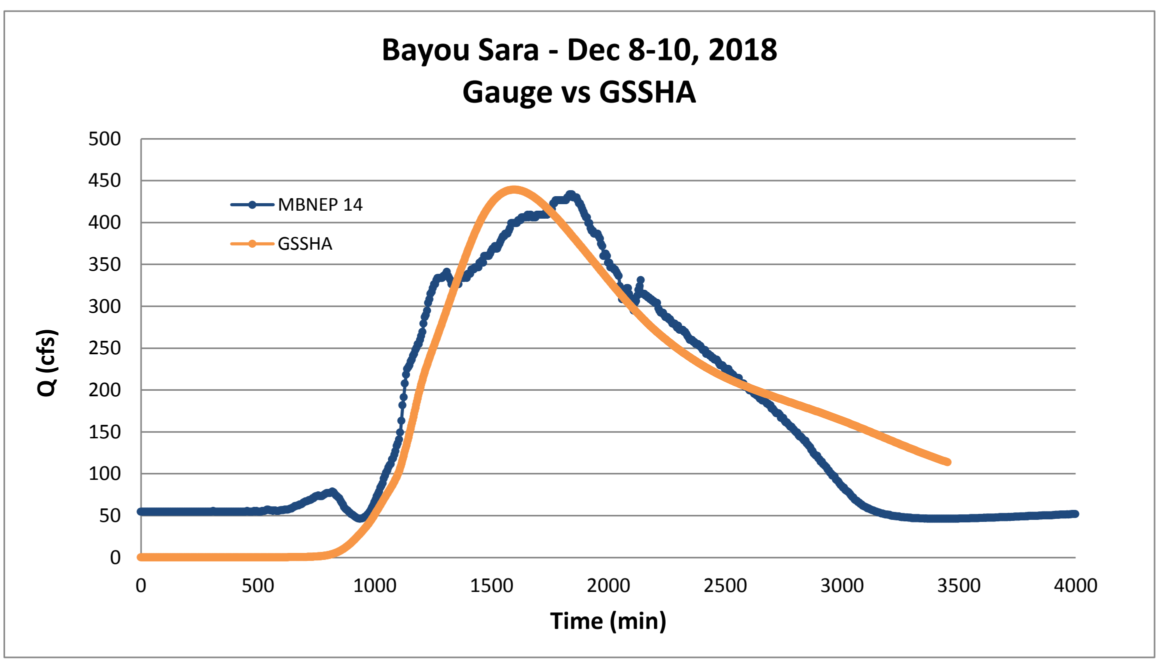


Figure 4-13
December 8, 2018 – Total Rainfall Basin 4

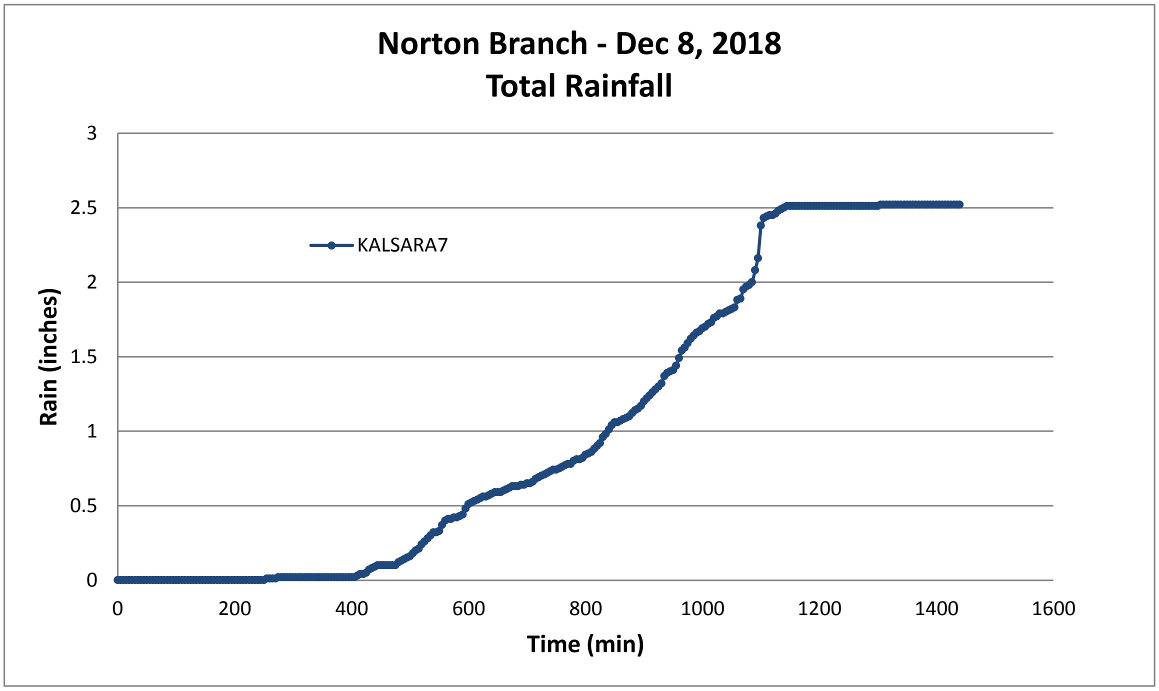
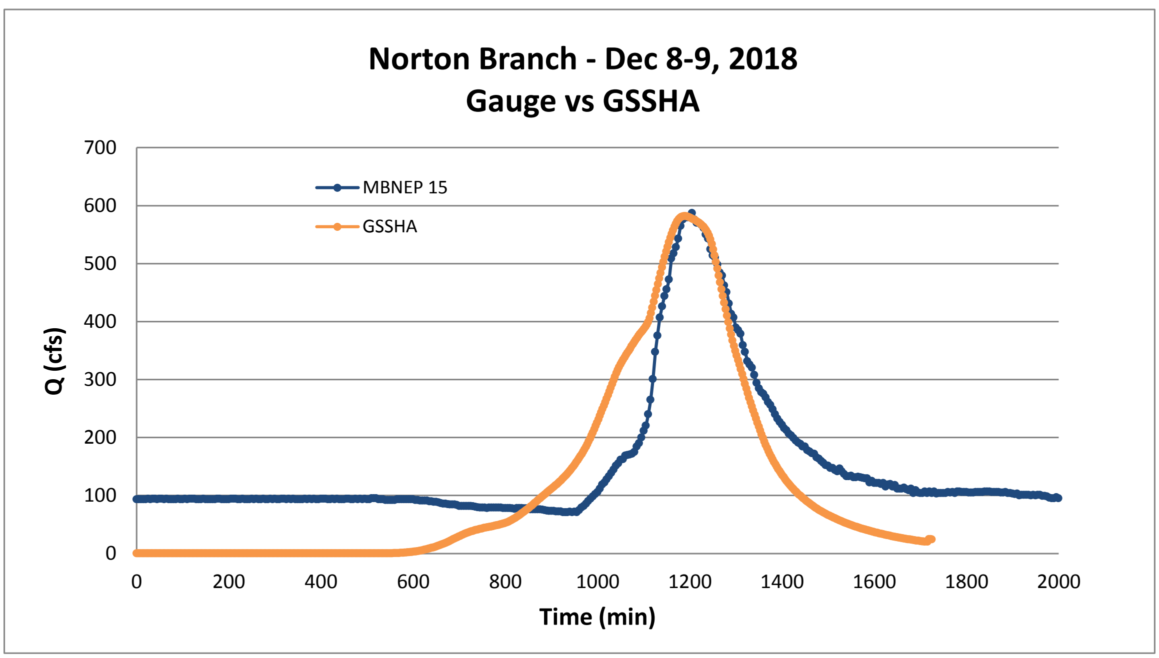


Figure 4-14
December 8-9, 2018 – Norton Branch Calibration (B4)



Figures 4-15 and 4-16 indicate the total rainfall maps for the January 23, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-17 and 4-18 indicate the total rainfall distribution and the calibrated model output.

Figure 4-15
January 23-24, 2019 – AHPS Total Rainfall Map

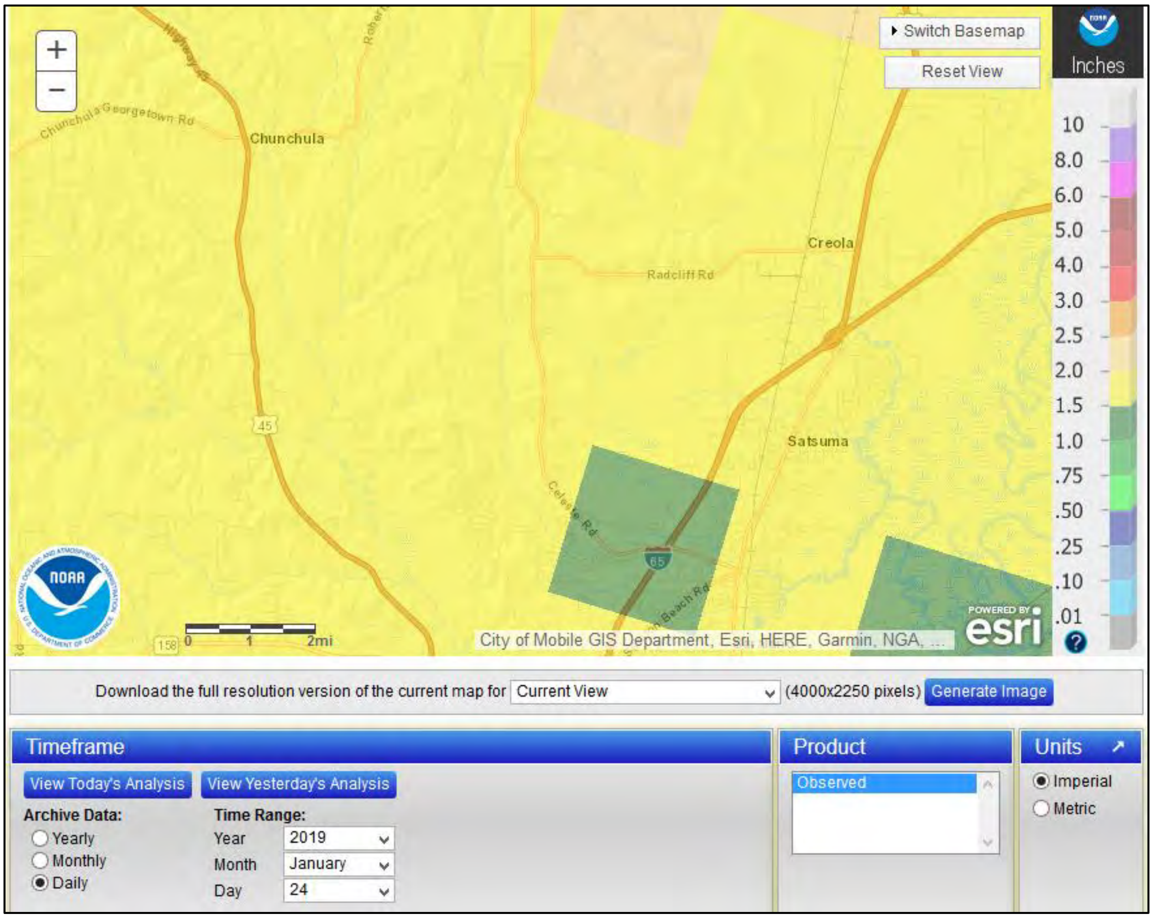


Figure 4-16
January 23-24, 2019 – Total Rainfall Map

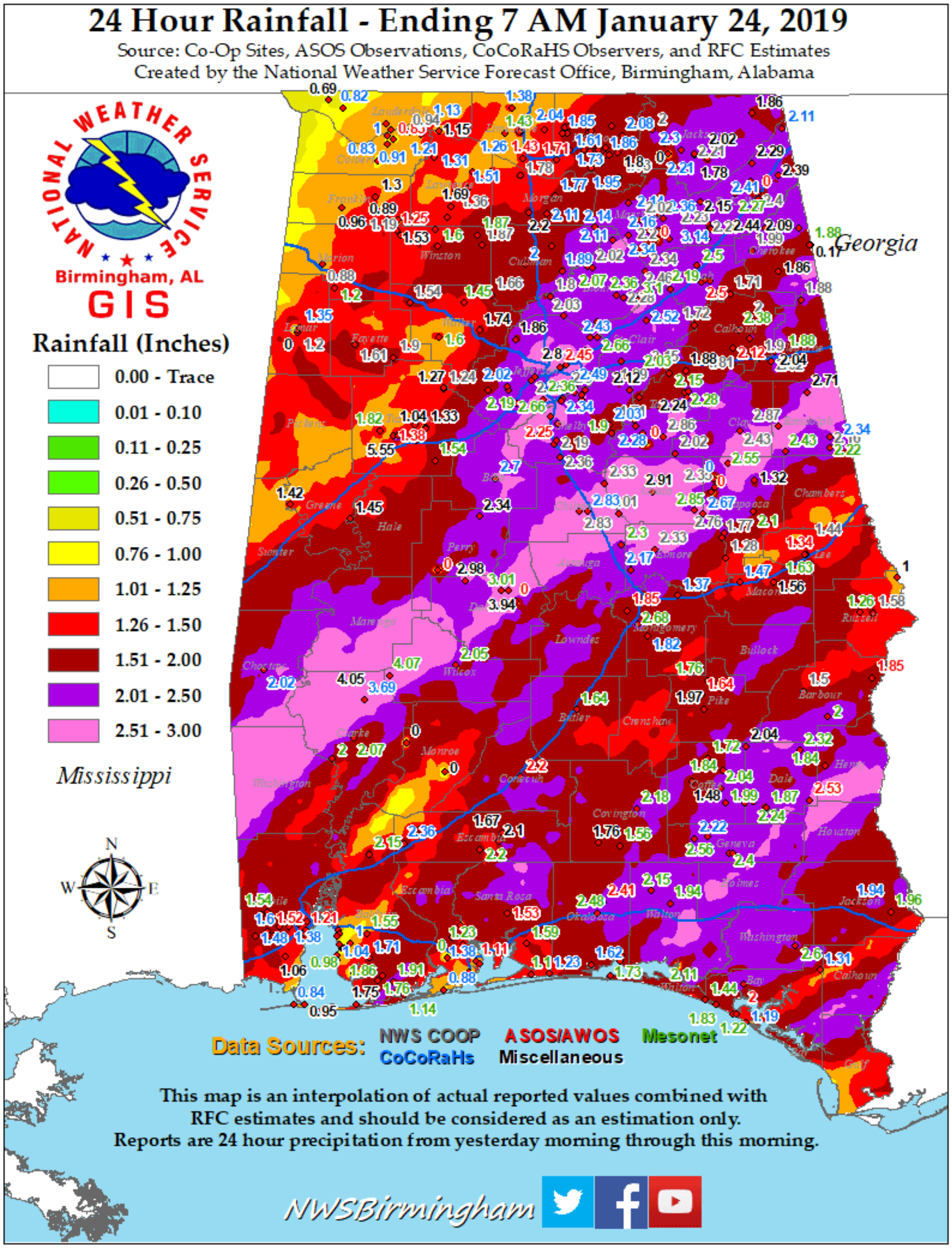


Figure 4-17
January 23, 2019 – Total Rainfall Basin 4

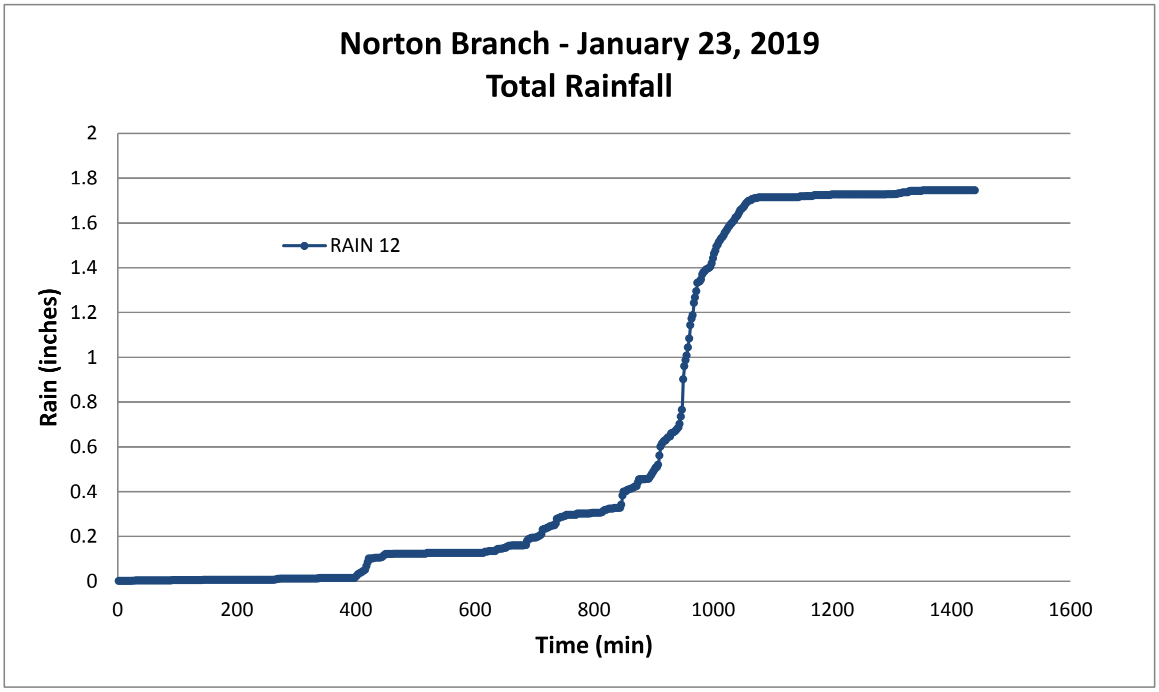
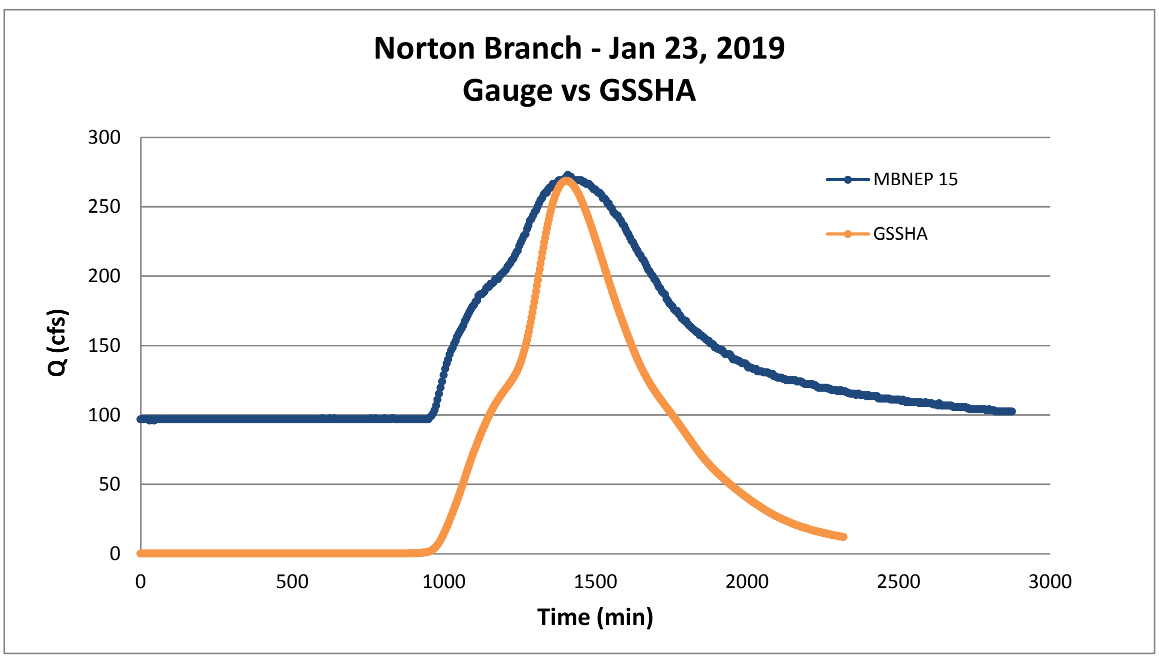


Figure 4-18
January 23, 2019 – Norton Branch Calibration (B4)



Figures 4-19 and 4-20 indicate the total rainfall maps for the April 25, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-21 and 4-22 indicate the total rainfall distribution and the calibrated model output.

Figure 4-19
April 25-26, 2019 – AHPS Total Rainfall Map

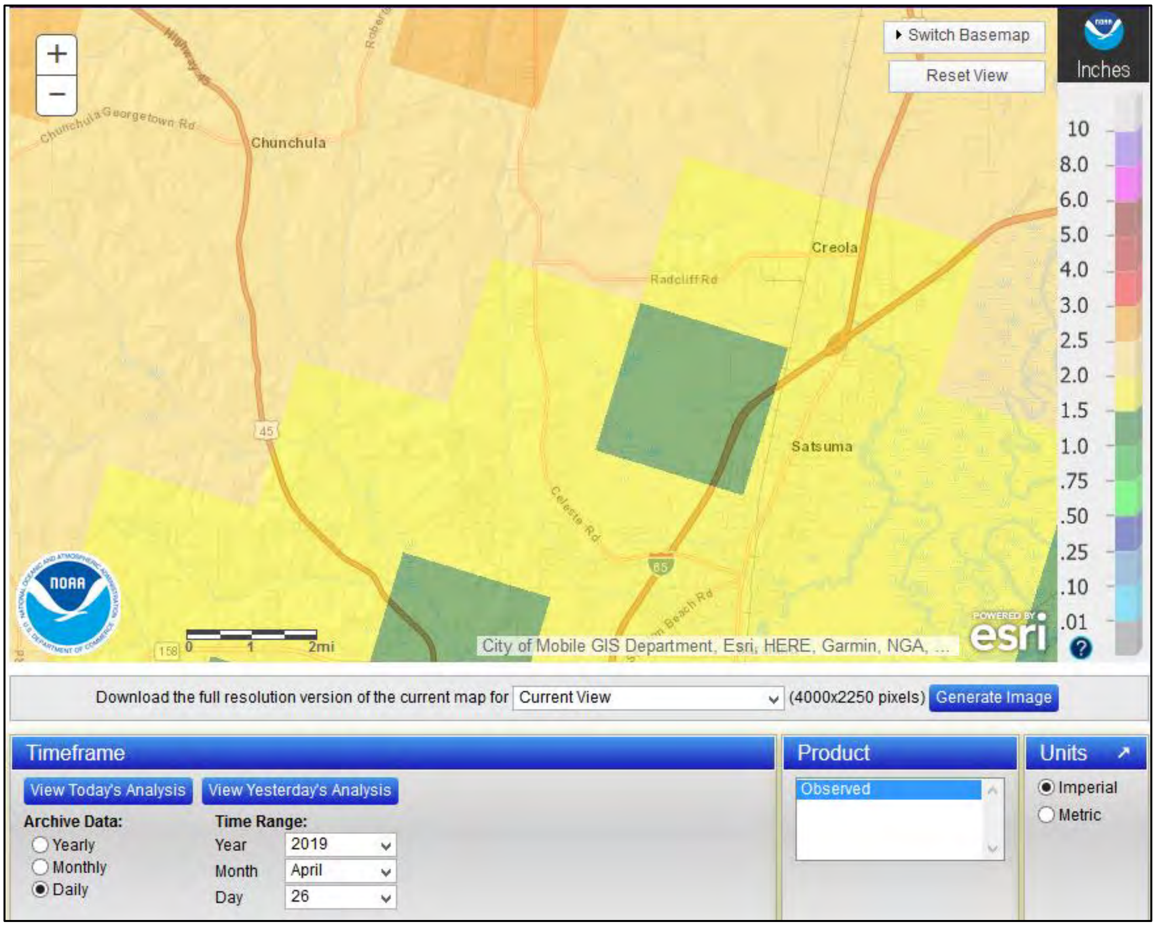


Figure 4-20
April 25-26, 2019 – Total Rainfall Map

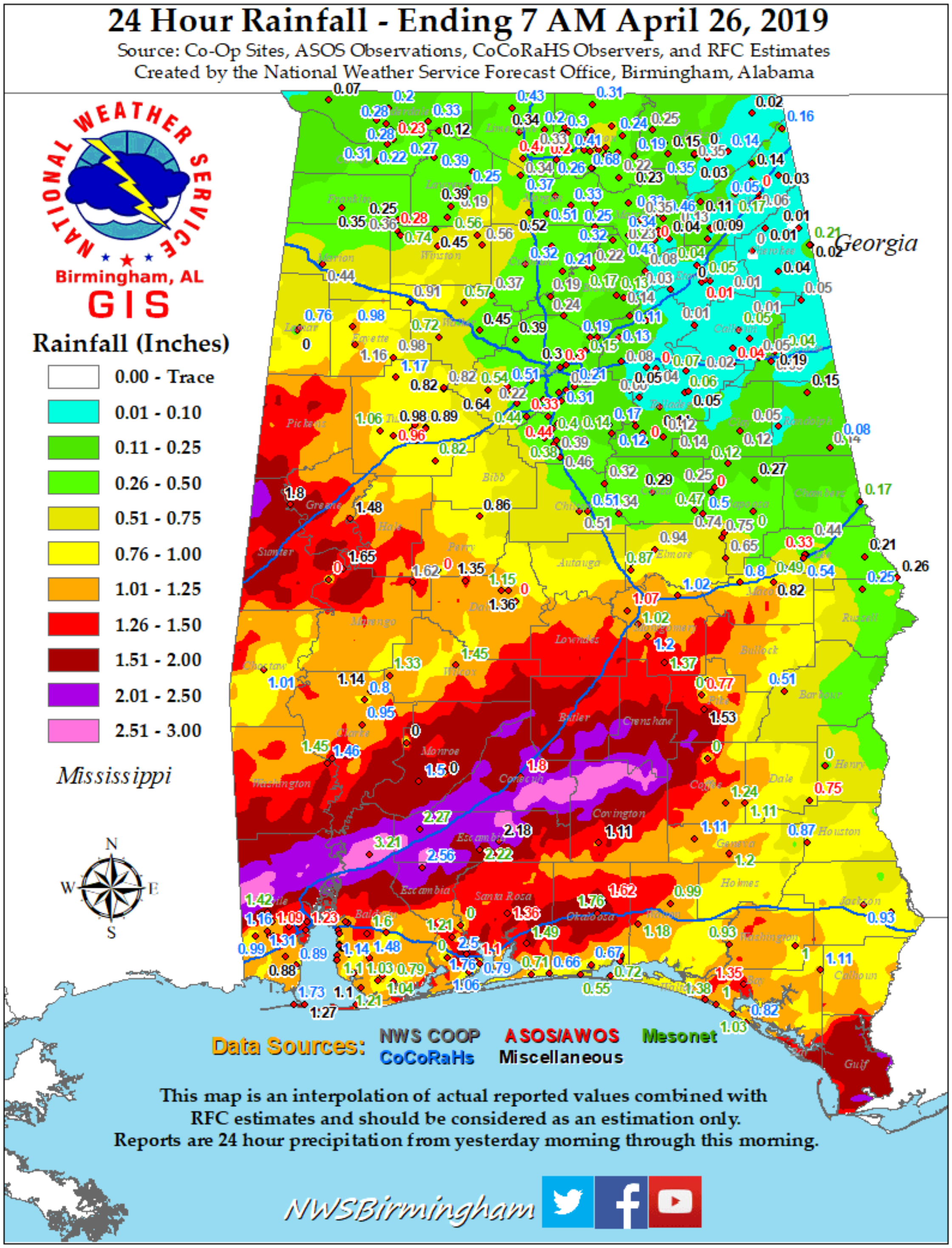


Figure 4-21
April 25, 2019 – Total Rainfall Basin 1

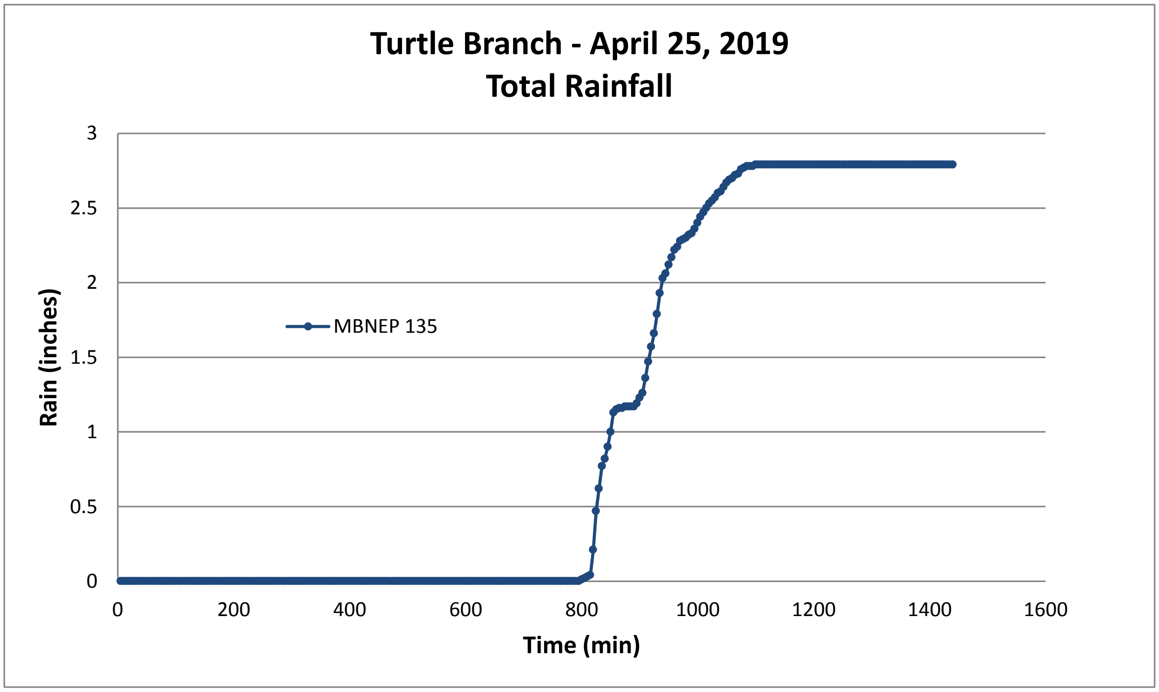
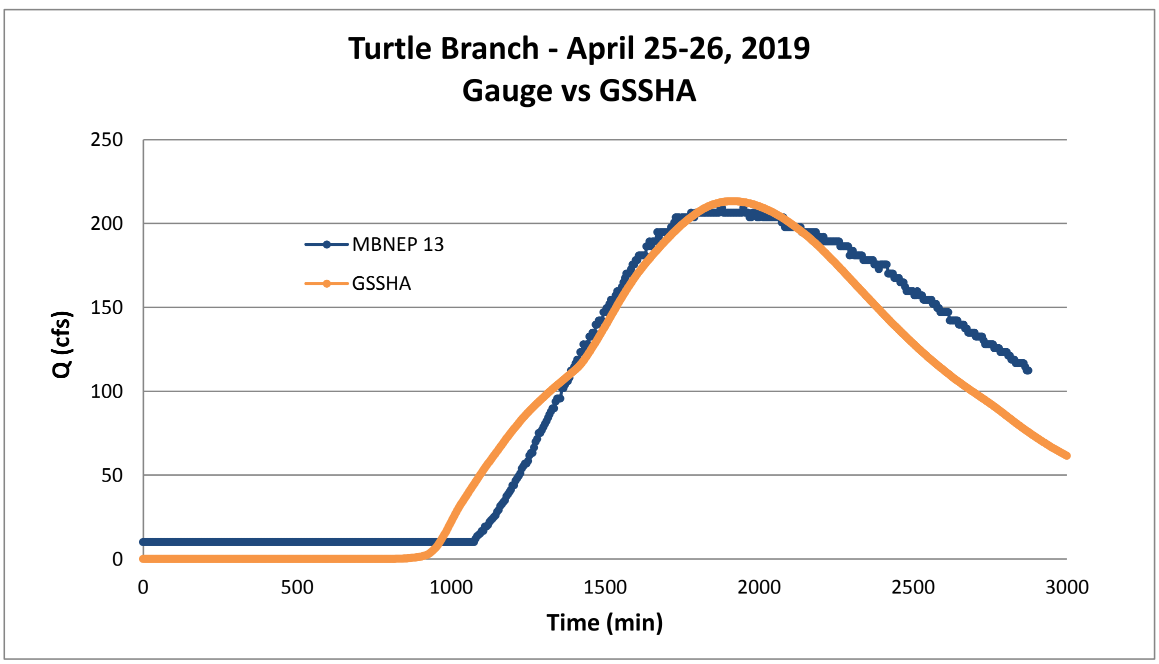


Figure 4-22
April 25-26, 2019 – Turtle Branch Calibration (B1)



Figures 4-23 and 4-24 indicate the total rainfall maps for the May 11, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-25 and 4-26 indicate the total rainfall distribution and the calibrated model output.

Figure 4-23
May 11-12, 2019 – AHPS Total Rainfall Map

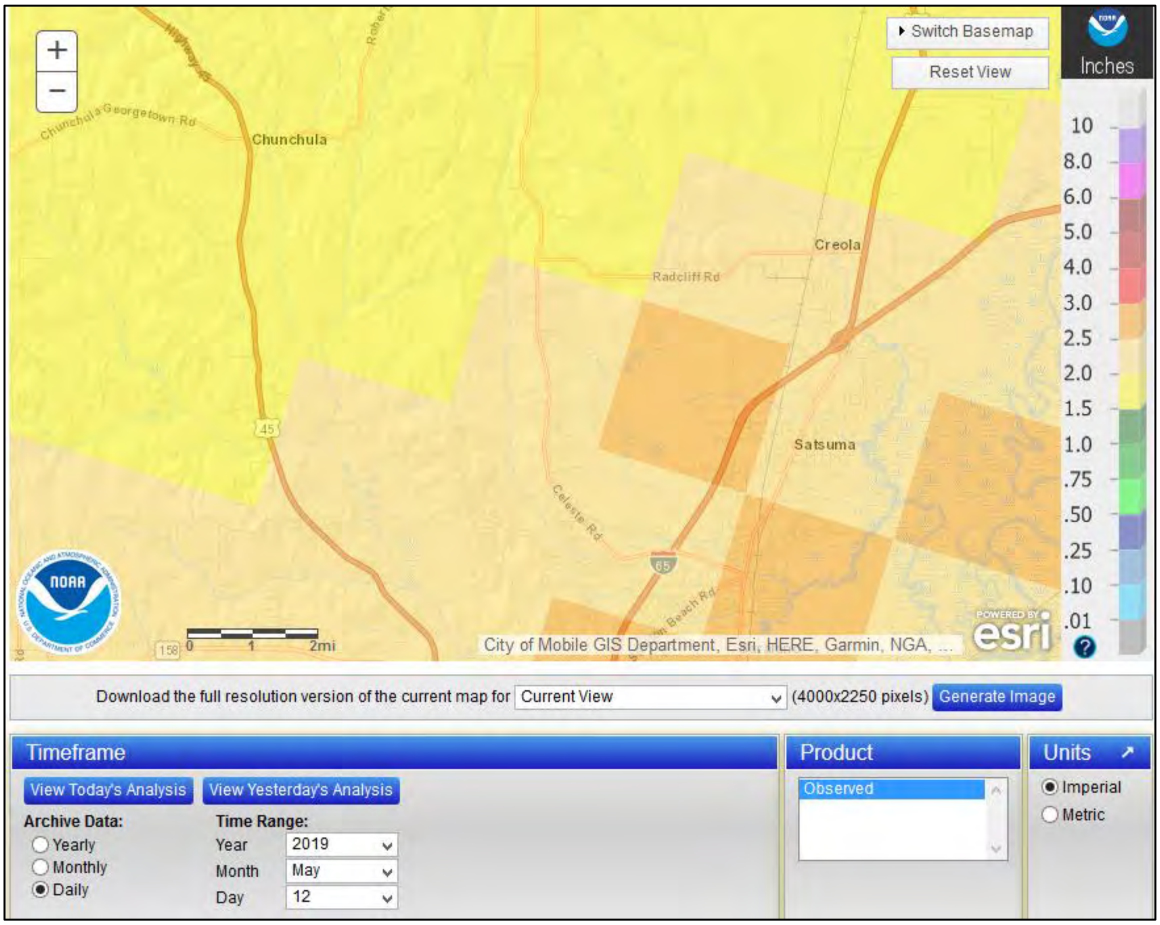


Figure 4-24
May 11-12, 2019 – Total Rainfall Map

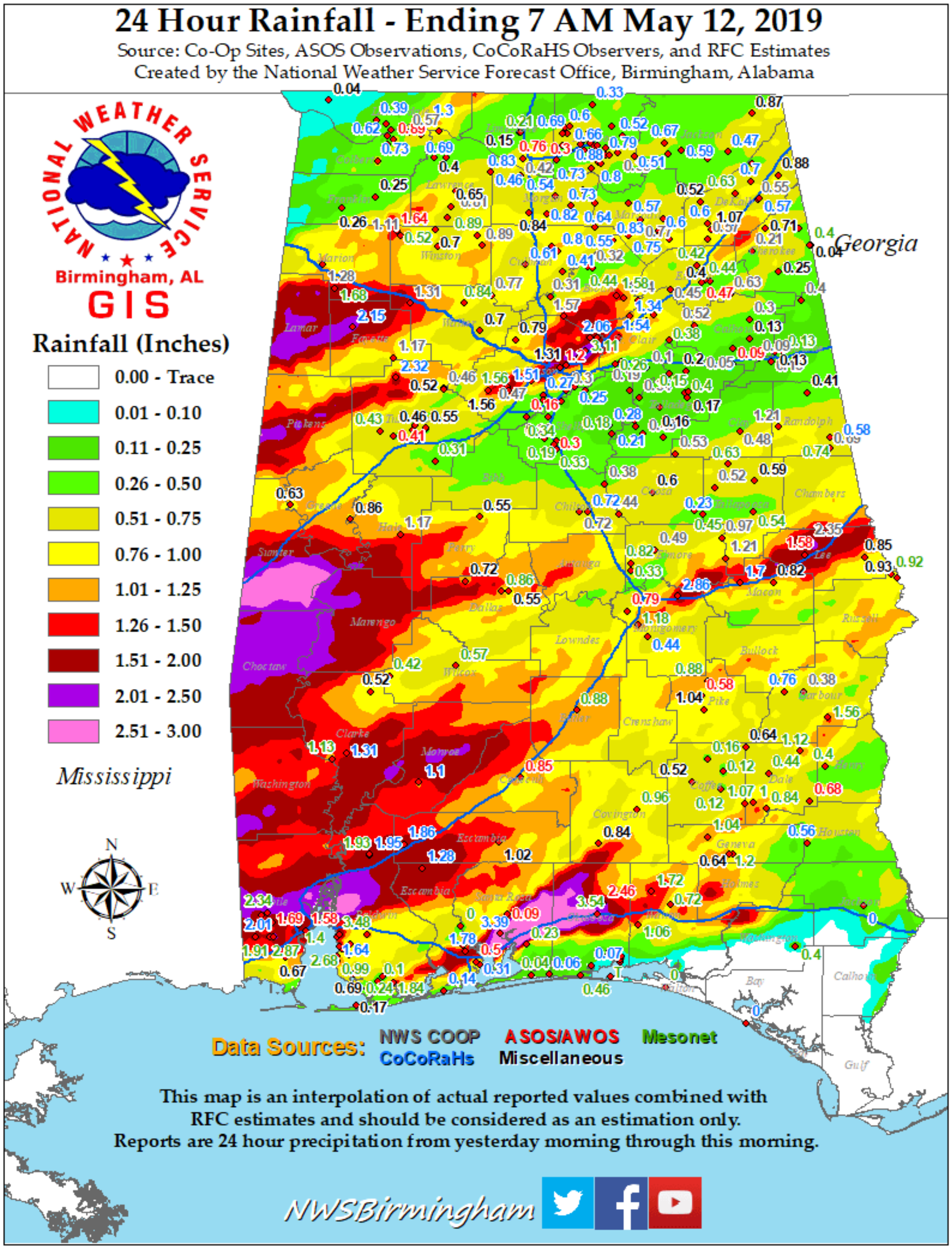


Figure 4-25
May 11-12, 2019 – Total Rainfall Basin 1

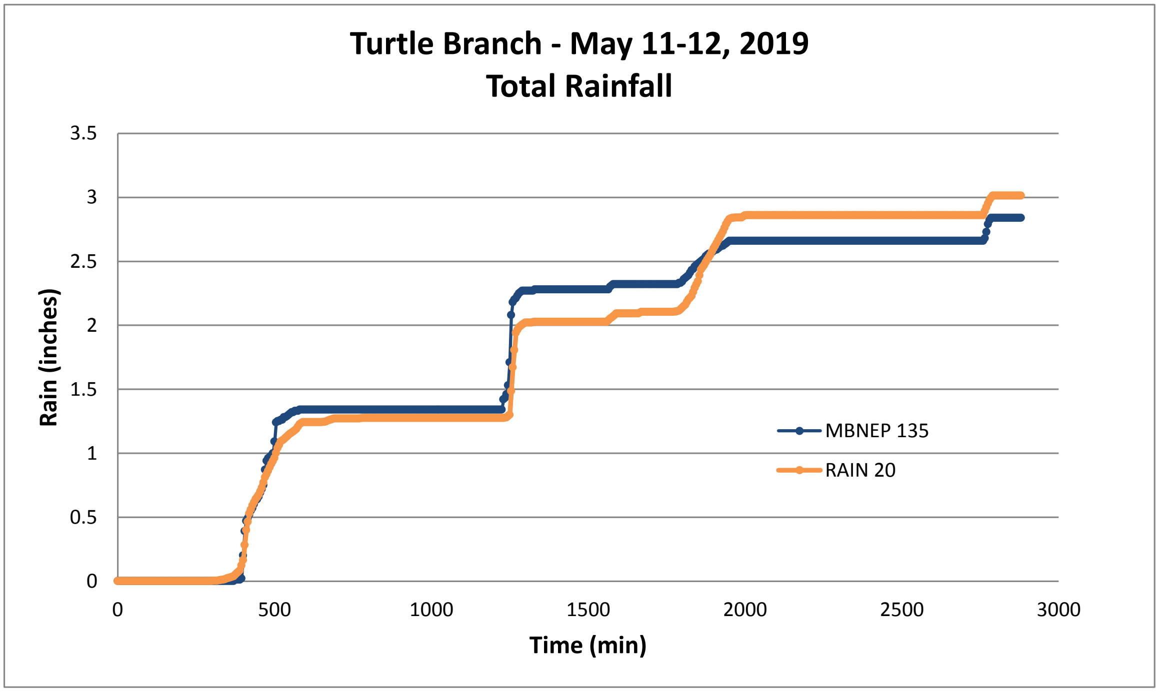
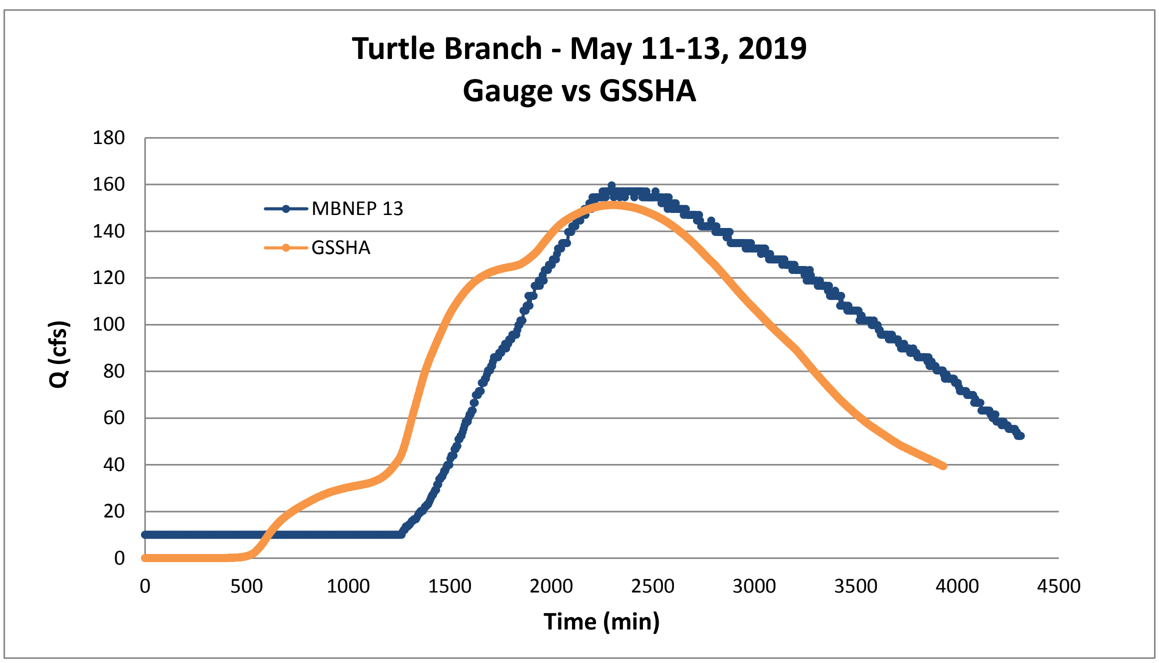


Figure 4-26
May 11-13, 2019 – Turtle Branch Calibration (B1)



Figures 4-27 and 4-28 indicate the total rainfall maps for the July 13, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-29 and 4-31 indicate the total rainfall distribution Basins 2 and 3. Figures 4-30 and 4-32 indicate the calibrated model output for Basins 2 and 3.

Figure 4-27
July 13-14, 2019 – AHPS Total Rainfall Map

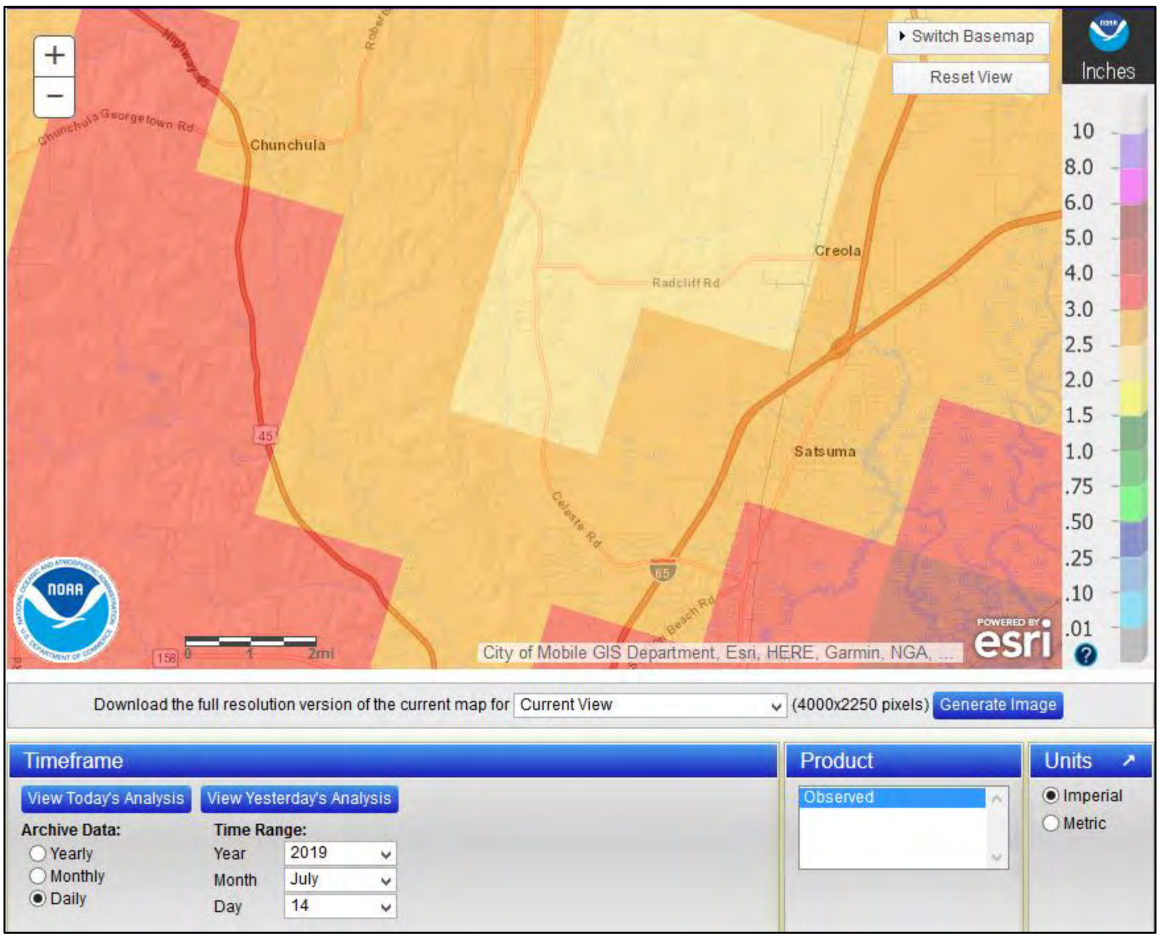


Figure 4-28
July 13-14, 2019 – Total Rainfall Map

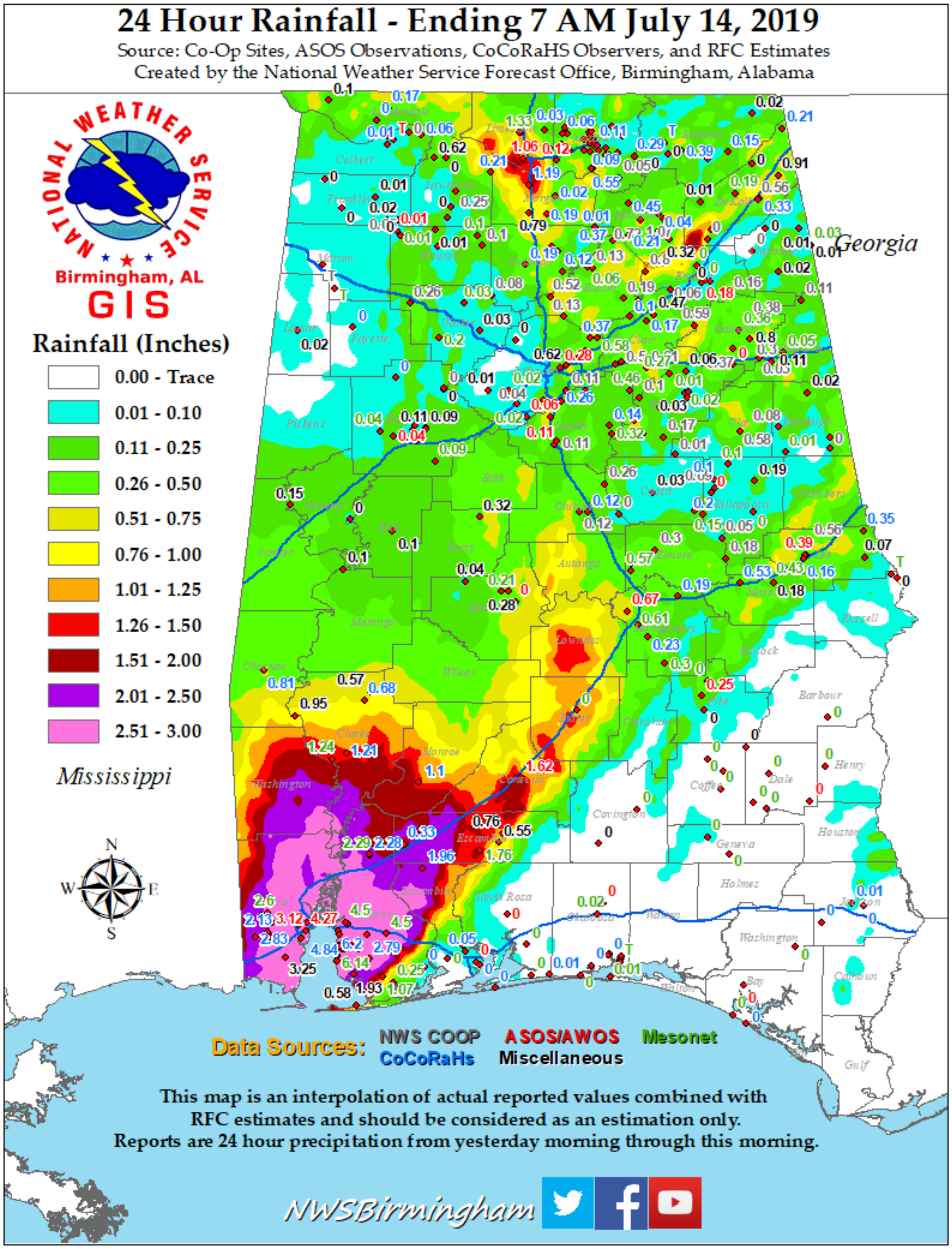


Figure 4-29
July 13, 2019 – Total Rainfall Basin 2

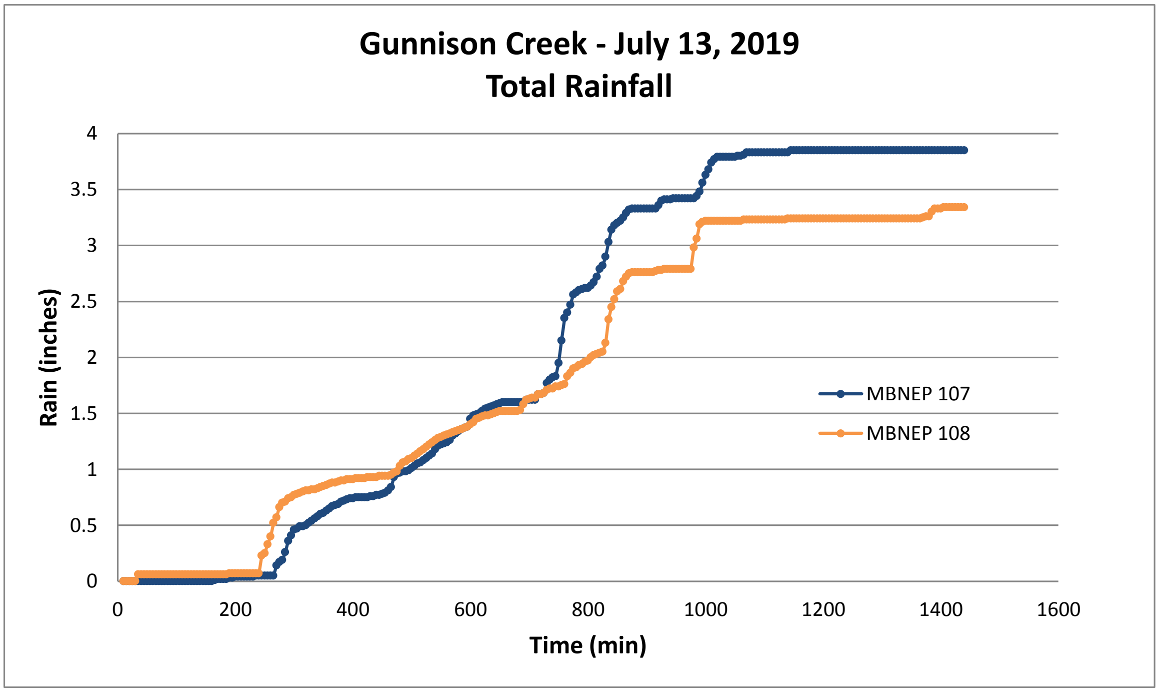


Figure 4-30
July 13-14, 2019 – Gunnison Creek Calibration (B2)

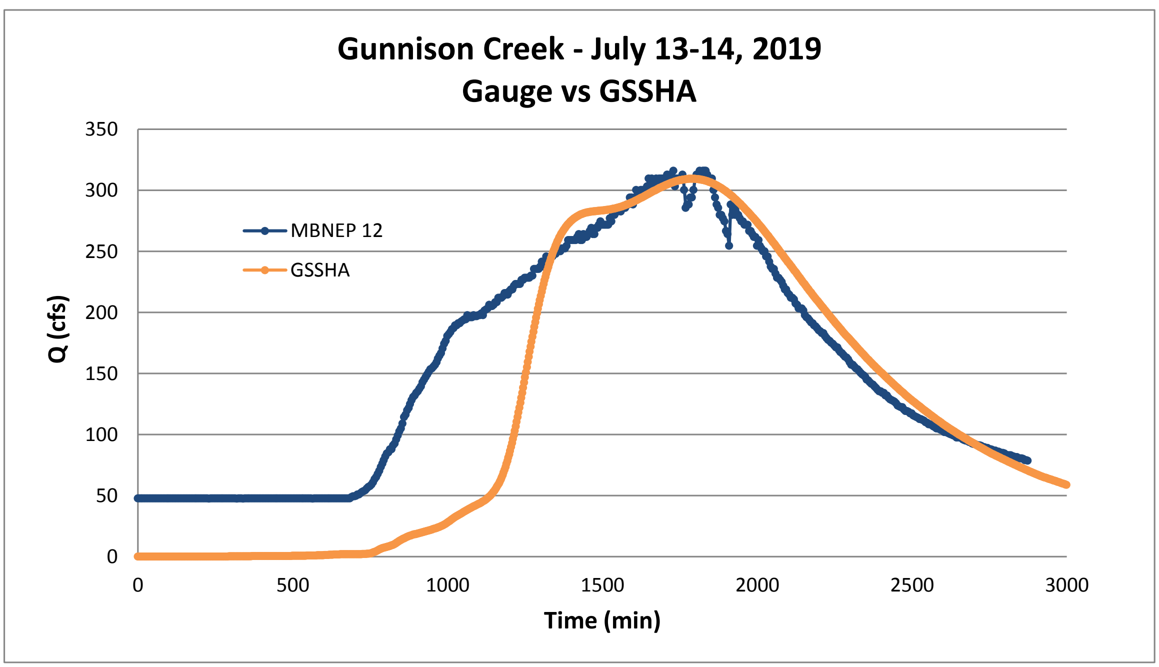


Figure 4-31
July 13, 2019 – Total Rainfall Basin 3

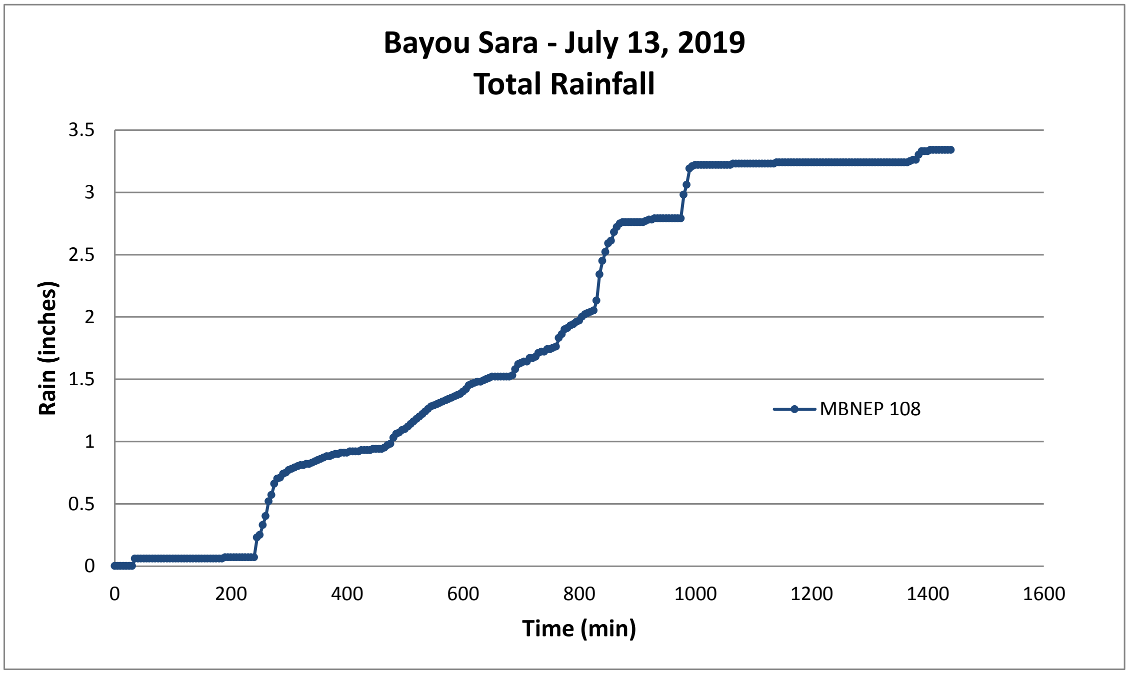
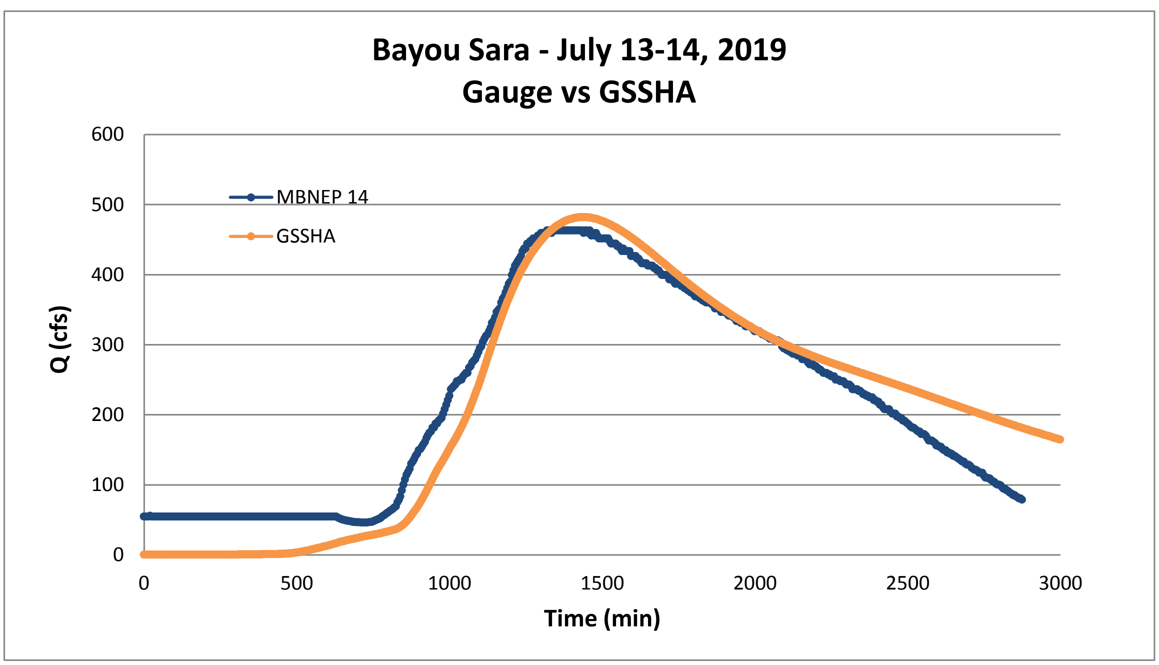


Figure 4-32
July 13-14, 2019 – Bayou Sara Calibration (B3)



Figures 4-33 and 4-34 indicate the total rainfall maps for the October 30, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figure 4-35 indicates the total rainfall distribution throughout the study area. Figures 4-36, 4-37, and 4-38 indicate the calibrated model output for Basins 1, 2, and 3.

Figure 4-33
October 30-31, 2019 – AHPS Total Rainfall Map

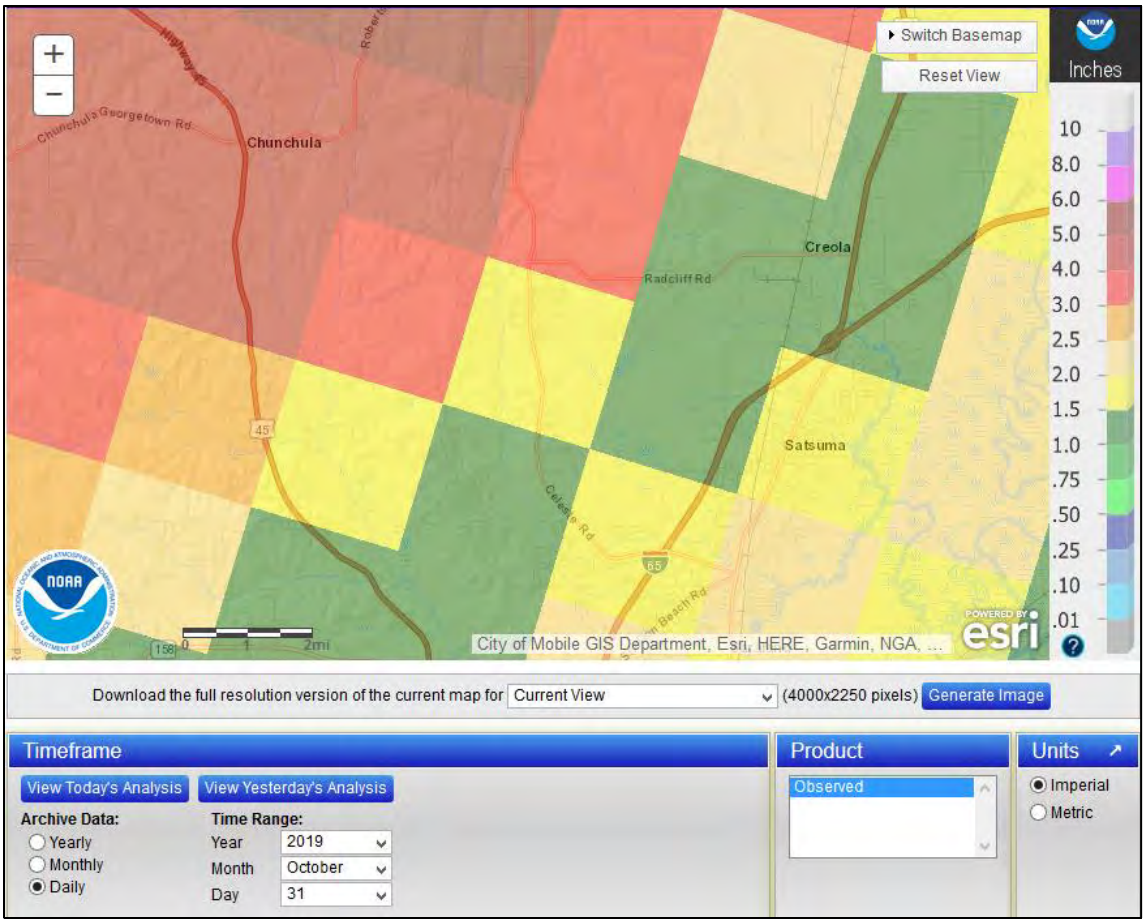


Figure 4-34
October 30-31, 2019 – Total Rainfall Map

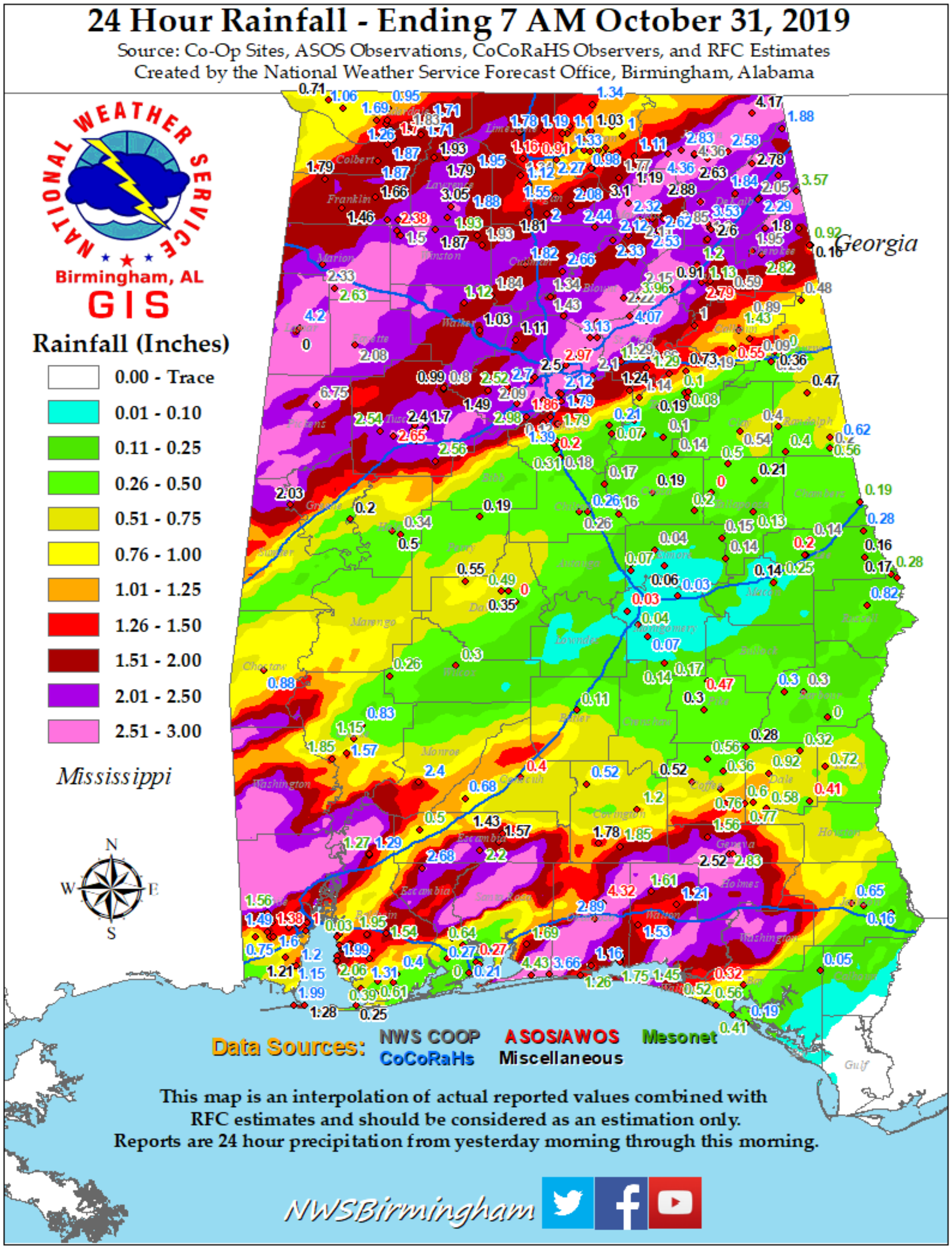


Figure 4-35
October 30, 2019 – Total Rainfall Basins 1, 2, 3

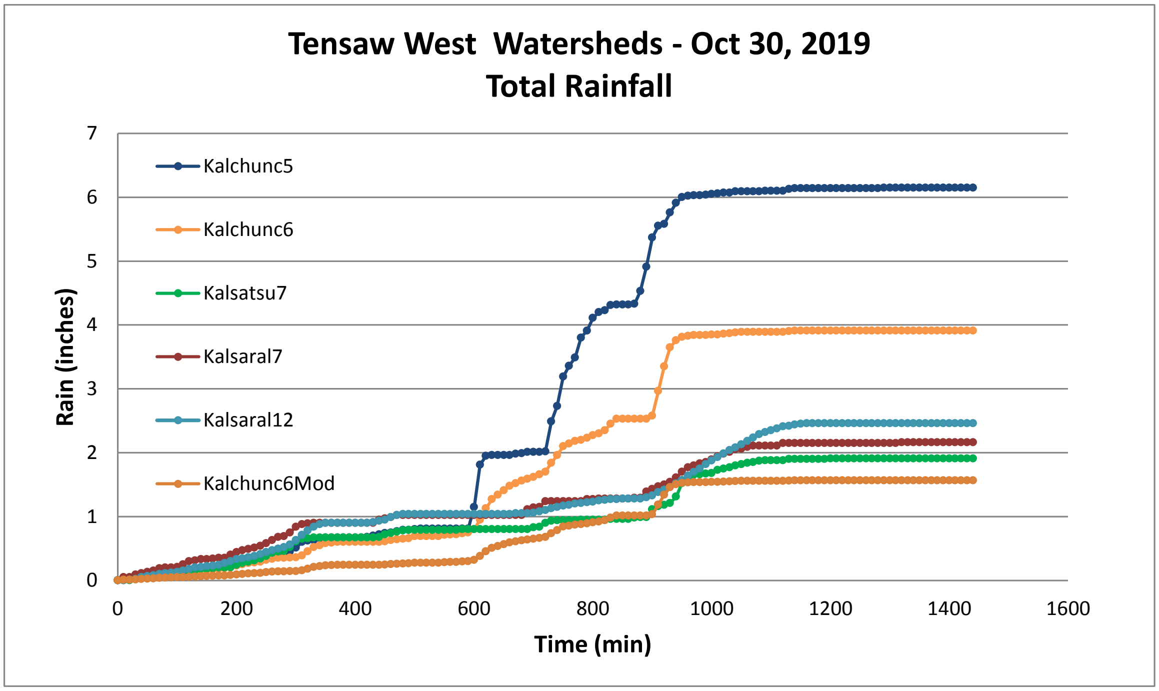


Figure 4-36
October 30-31, 2019 – Turtle Branch Calibration (B1)

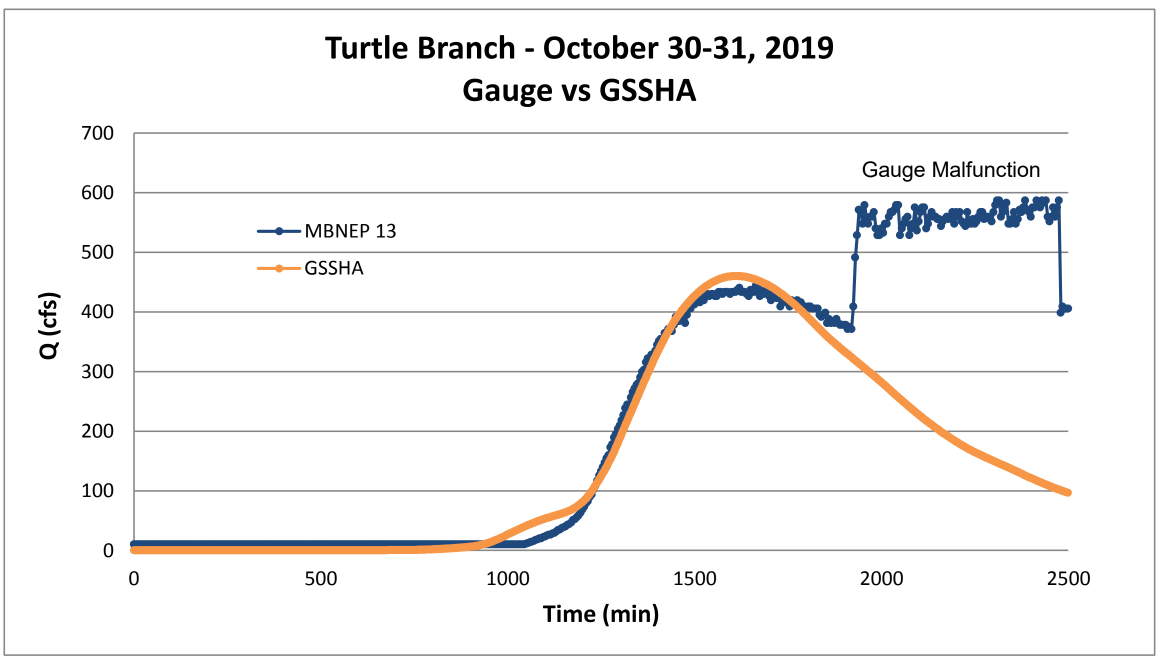


Figure 4-37
October 30-31, 2019 – Gunnison Creek Calibration (B2)

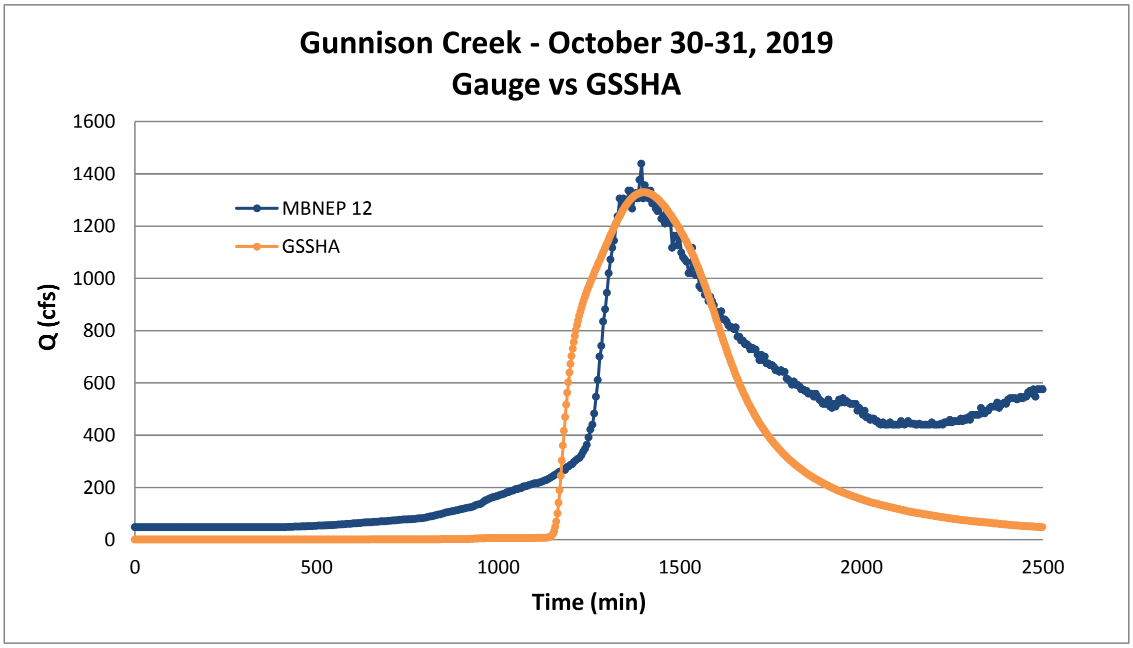
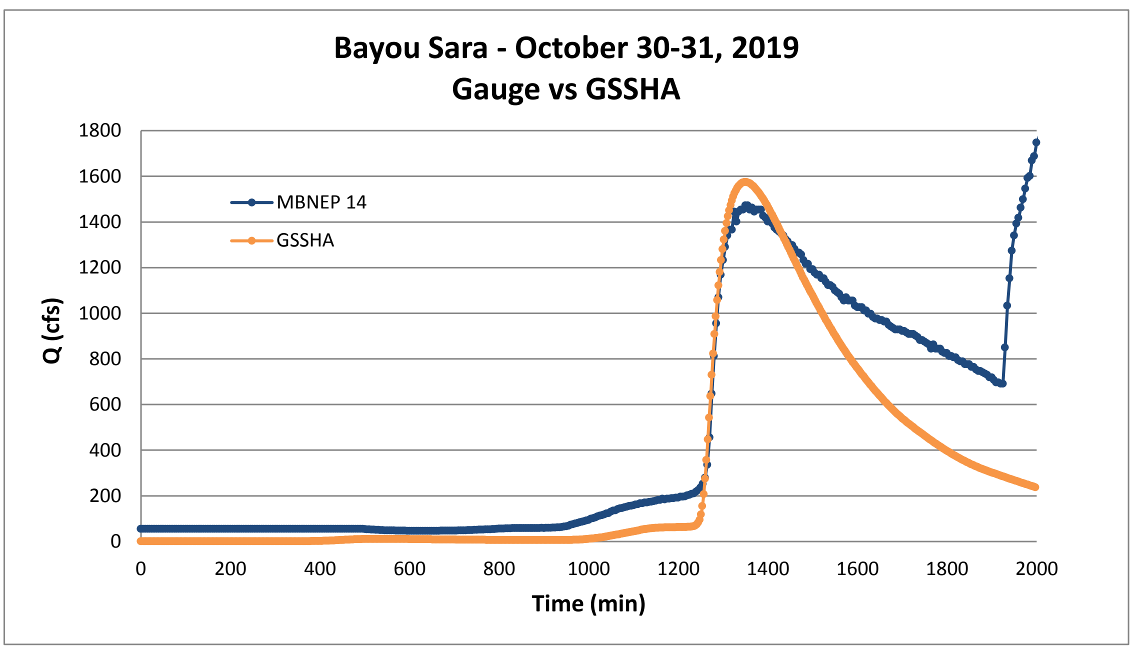


Figure 4-38
October 30-31, 2019 – Bayou Sara Calibration (B3)



Figures 4-39 and 4-40 indicate the total rainfall maps for the June 7, 2020 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figure 4-41 indicates the total rainfall distribution throughout the study area. Figures 4-42, 4-43, and 4-44 indicate the calibrated model output for Basins 1, 2, and 3.

Figure 4-39
June 7-8, 2020 – AHPS Total Rainfall Map

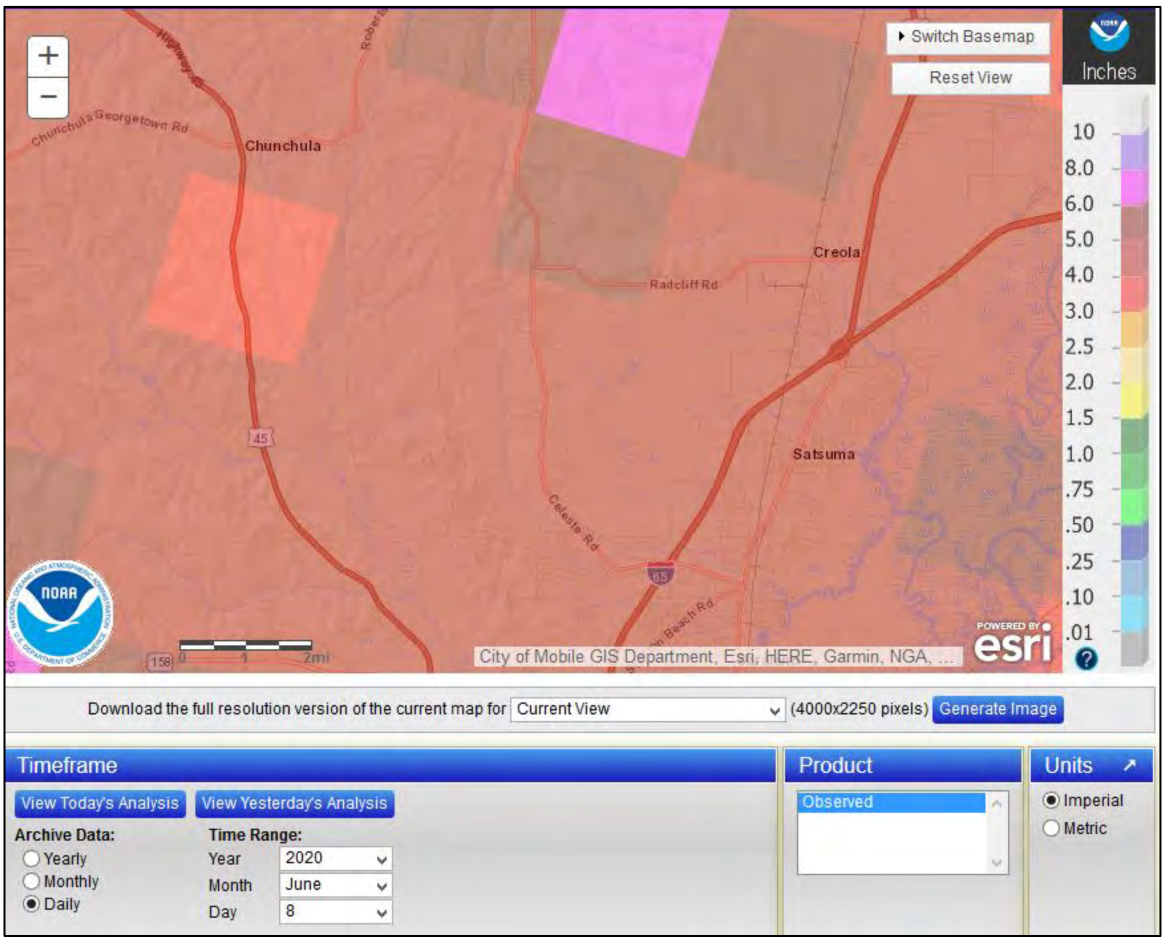


Figure 4-40
June 7-8, 2020 – Total Rainfall Map

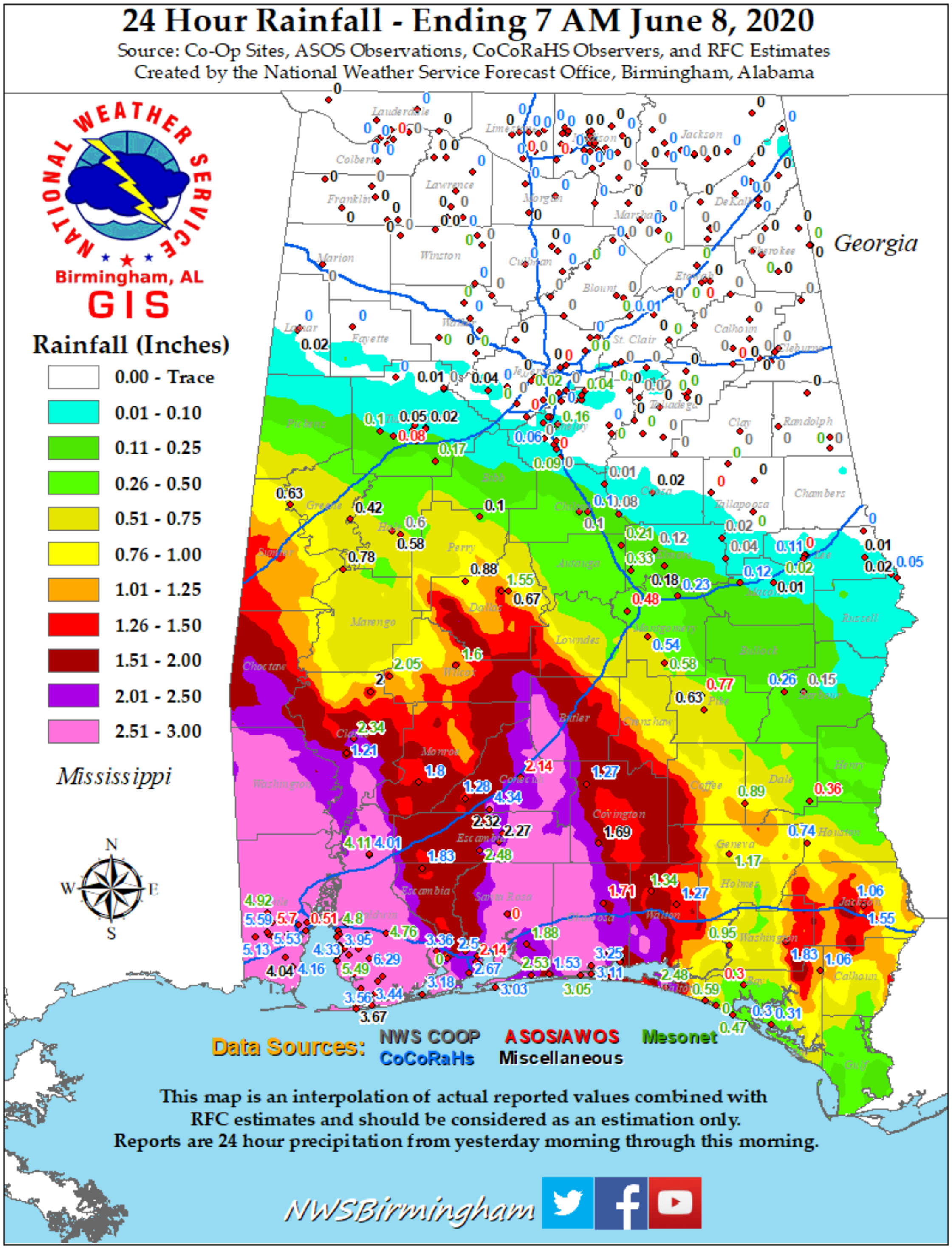


Figure 4-41
June 7-8, 2020 – Total Rainfall Basins 1, 2, 3

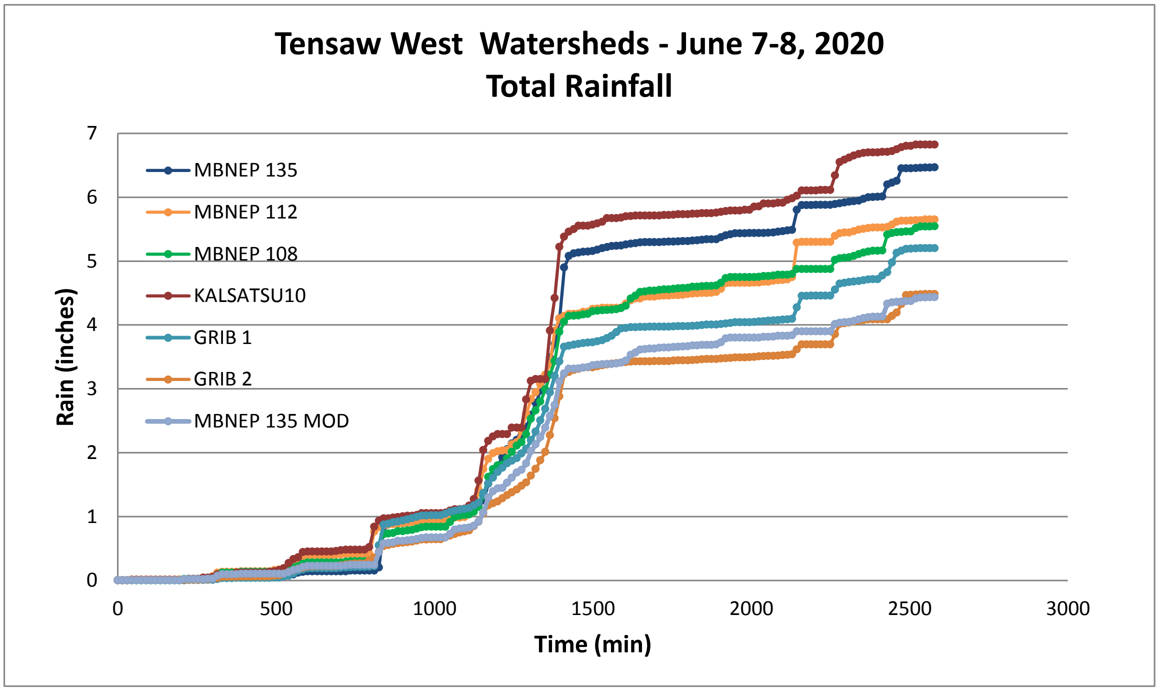


Figure 4-42
June 7-8, 2020 – Turtle Branch Calibration (B1)

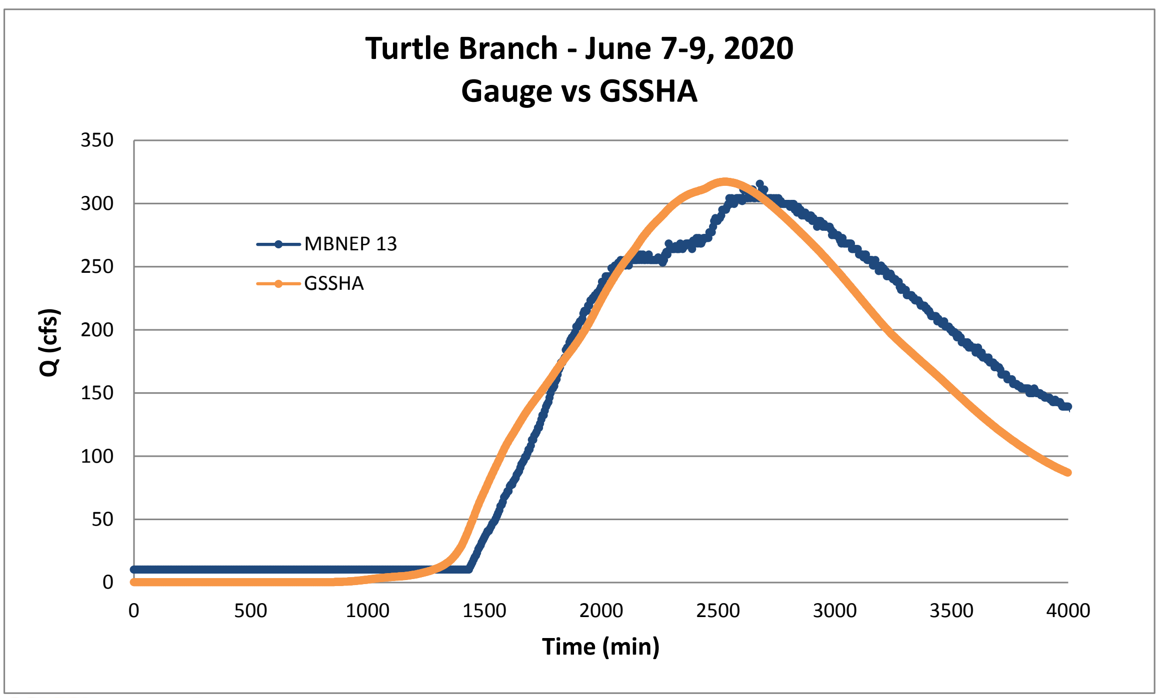


Figure 4-43
June 7-8, 2020 – Gunnison Creek Calibration (B2)

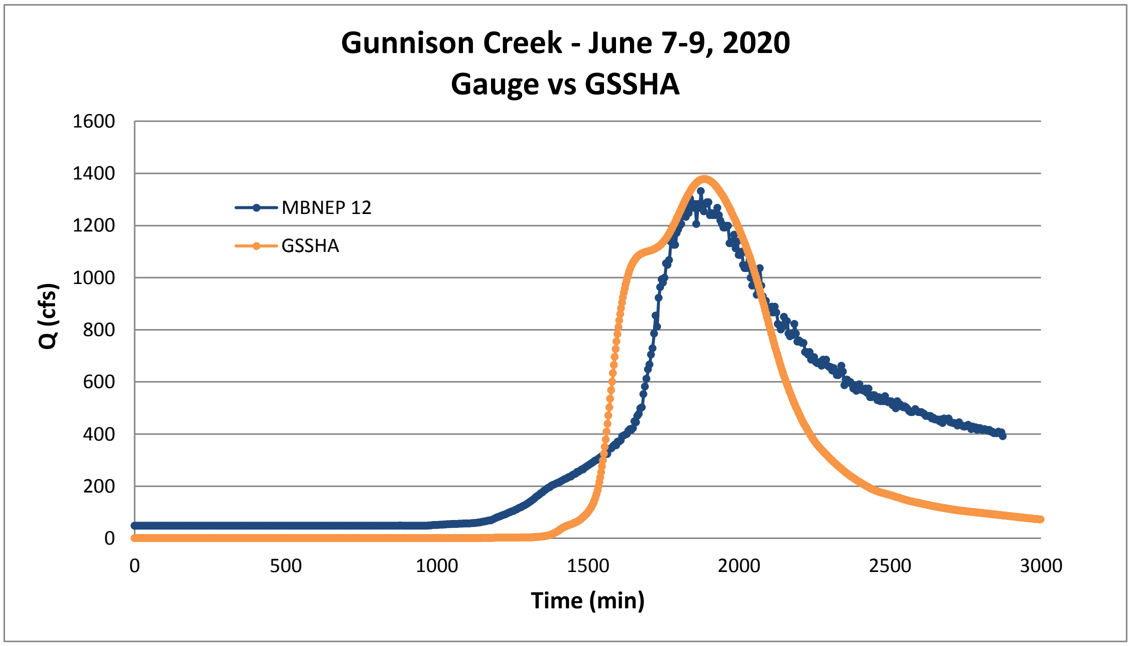
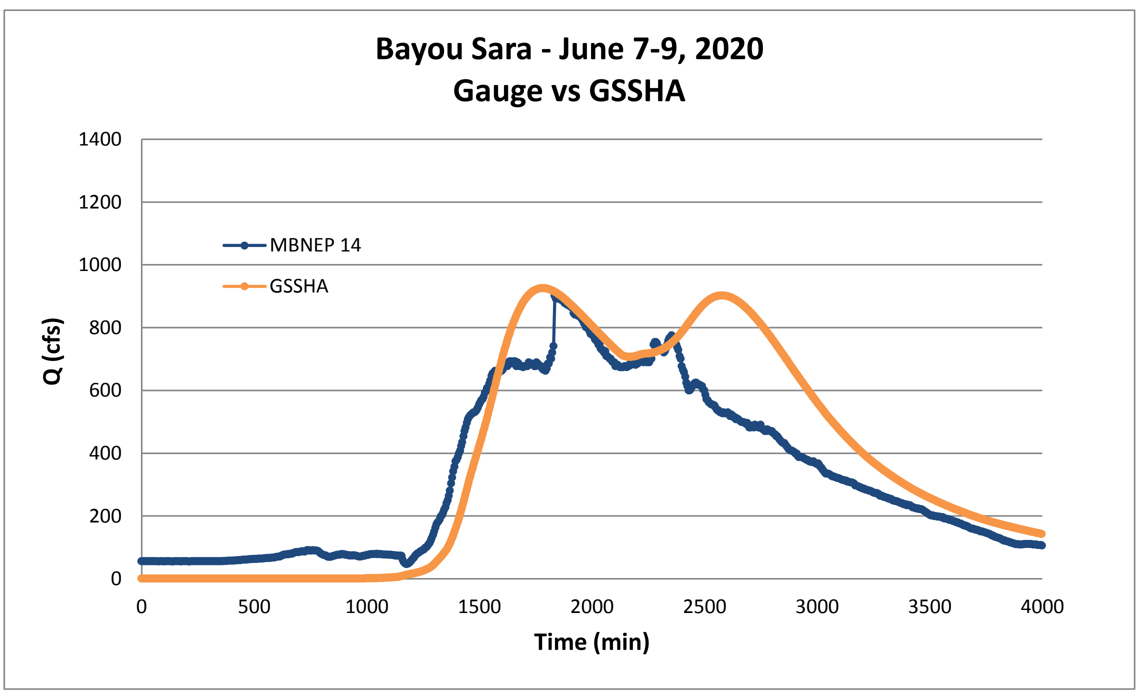


Figure 4-44
June 7-8, 2020 – Bayou Sara Calibration (B3)



5. Results and Conclusions

5.1. Results

During the evaluation period between the middle of June 2018 and June 2020 the West Tensaw watersheds experienced multiple small rain storms. These rain storms typically produced less than 2 or 3 inches per event. Using the stream gauge plots found in Figures 4-2, 4-3, 4-4, and 4-5 the largest events were chosen for model calibration.

During this study, the two largest events occurred on October 30-31, 2019 and June 7-8, 2020. The October rainfall event produced approximately 5 inches of rain in 6 hours. Using Figure 4-6, it was determined that this is greater than a 5-year recurrence interval. This 5-year rainfall, however, fell only within a 3 mile radius of Turnerville. These heavier rains only impacted the upper half of Basin 3 and just the uppermost headwaters of Basins 1 and 2. The lower half of Basins 1-3 during this event experienced rainfall totals between 1.5 and 3 inches. On average Basins 1, 2, and 3 experienced a 2-year rain event. The June rain event produced approximately 5 inches of rain in 12 hours. This too was classified as a 2-year storm event.

All of the other rain events that occurred during the evaluation period were deemed to be less than a 1-year event. The maximum rainfall accumulation occurred during the July 13, 2019 event where 3.5 to 4 inches fell within 12 hours. The remainder of the rain events used for calibration averaged rain totals between 2.5 and 3 inches.

5.2. Conclusions

After analysis of the discharges and rainfall events that occurred between June 2018 and June 2020, it has been determined that a 1-year or 2-year rainfall event produces discharges equal to that of their equivalent recurrence interval for a rural basin. Excluding Basin 3 and the lower portion of Basin 4, there is very little development within the watersheds. The majority of the watersheds are covered with evergreen forest and woody wetlands. This contributes to interception of the rainfall as well as reducing travel time of the stormwater runoff.

Aside from Basin 2, at least half of each watershed contains very mild slopes that create opportunities for storage routing that can hold and attenuate the flow. While this is evident for the smaller rainfall events, it is uncertain what the extent of the storage routing will be during larger flooding events. Comparing the calibrated discharges to the discharges determined from the rural regression equations, it can be seen that a 1-2 year storm event produces discharges equivalent to those calculated from the regression equations for a 1-2 year event.

For smaller rain events (< 2-year), the currently calibrated GSSHA model can be used as a management tool for determining bank forming discharges throughout the watershed. Future restoration projects may be able to utilize these discharges for bankfull analysis. For larger discharge events, the model will need to be reevaluated to determine if further calibration is required. This is due to the uncertainty of the amount of impact the storage within the watershed will have on timing and peak discharges.

6. References

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