MBNEP

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Fowl River Watershed Study

December 2017

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1. Executive Summary

The study on the Fowl River watershed was performed to gain an understanding of the watershed's response during rain events. It was also performed to generate a baseline hydrologic model that can be used for determining discharges for the design of future restoration projects and their impact on the watershed. The information obtained can be used for future stormwater planning and management. The study was accomplished by looking at the basin as a whole and identifying areas were detention may or may not be beneficial. The method of analysis used for the study employed the use of the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) system. The two-dimensional overland flow model was calibrated to historic events for use in predicting watershed reaction to various land use changes.

Results of the findings for the Fowl River watershed indicate that discharges from storm events equal to or less than a 5-year recurrence interval are more in line with a rural watershed instead of an urban watershed. There is a significant amount of storage in various capacities throughout the entire watershed. In the headwaters large man-made ponds provide benefit. In the middle and southern part of the watershed there are wide, flat floodplains and wetlands which provide retention. Significant storage occurs between I-10 and Half Mile Road. It is postulated that the existing Louisville and Nashville Railroad crossing acts as a constriction that reduces and attenuates peak discharges.

The study finds that the addition of a regional pond on Fowl River in the upper part of the watershed can offset headwater development without impacting downstream discharges. Regional ponds located on lateral branches of the watershed can reduce local discharges, however changes in timing of the peak cause a negative impact once the flow reaches the confluence with Fowl River.

For rain events (5-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 within the watershed.

2. Introduction

2.1. Description

Fowl River is a coastal river located in southwest Mobile County, AL (Figure 2-1). The Fowl River Watershed (HUC 031602050206) drains much of southern Mobile County, and is a direct contributor to Mobile Bay. Its headwaters are located near the Mobile suburb of Theodore, AL and it splits just south of Bellingrath Gardens into East Fowl River, which flows northeasterly into Mobile Bay, and West Fowl River, which flows south into Mississippi Sound (http://www.mobilebaynep.com/the_watersheds/fowl_river_watershed/the_landscape). The drainage area of Fowl River is approximately 52.7 square miles.

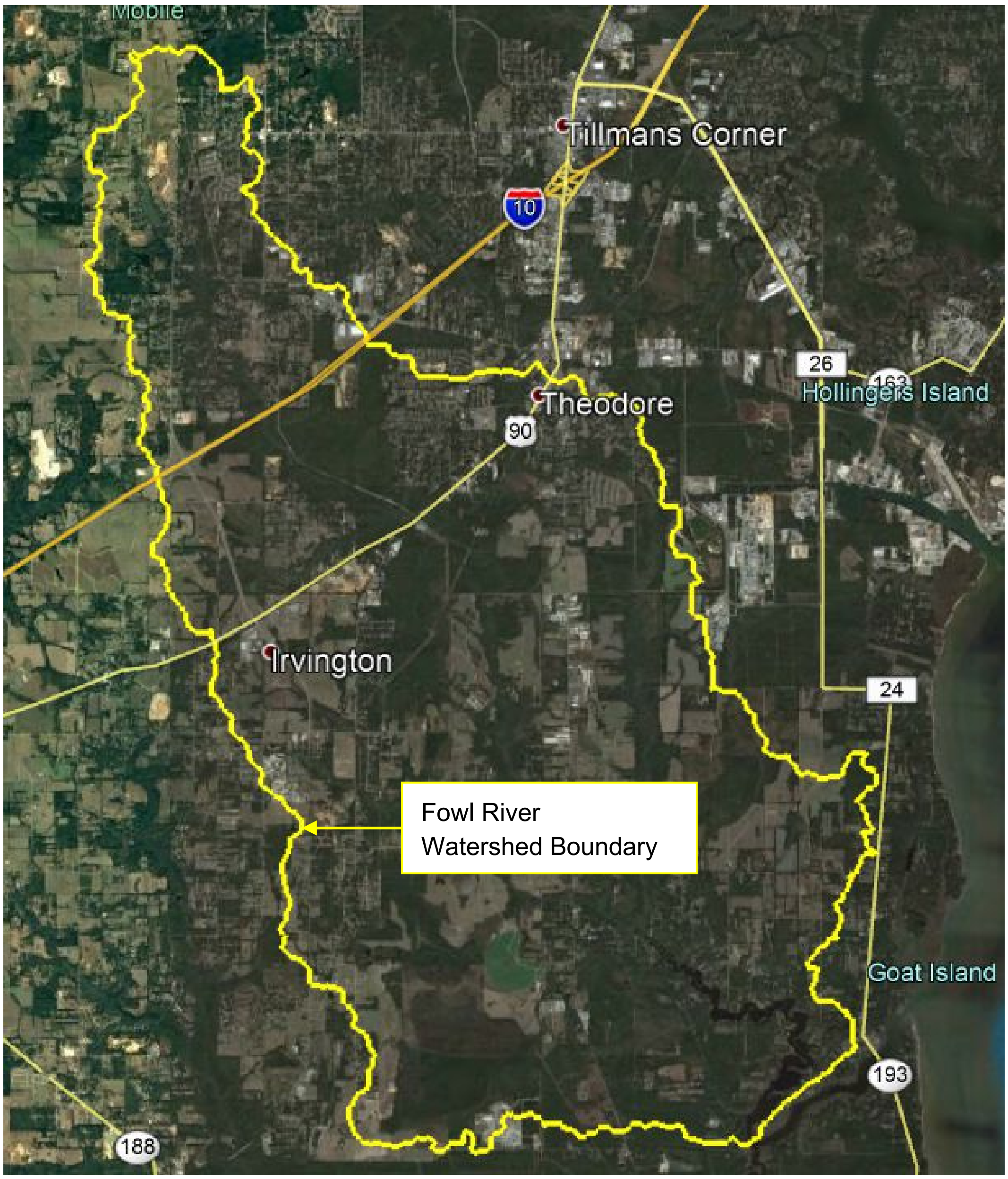
Fowl River has only two named tributaries, both of which are located in the central portion of the watershed. Muddy Creek originates east of Bellingrath Road, approximately two miles north of Laurendine Road (CR 24), and flows south for 4.5 miles to its confluence with Fowl River near Fowl River Road (CR 20). Dykes Creek originates less than a mile east of Muddy Creek, south of CR 24, and flows south for 2.5 miles to its confluence with Fowl River just south of CR 20. Due to its close proximity to Mobile Bay and the Gulf of Mexico, the lower portions of the watershed are tidally influenced.

2.2. Climate

According to the *Fowl River Watershed Management Plan* prepared by 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 Mobile WSO Airport, Alabama (weather station 015478). Precipitation within the Fowl River Watershed 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.

Average annual precipitation at the Mobile WSO 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 and Watershed Boundary



2.3. Physiography

The *Fowl River Watershed Management Plan* states, “The Watershed lies within parts of two physiographic districts: the Southern Pine Hills and the Coastal Lowlands. The Southern Pine Hills is an upland area (Sapp and Emplaincourt, 1975). The Coastal Lowlands is a flat to very gently undulating area that is locally swampy. Many streams are tidally influenced. The landward edge of the Coastal Lowlands, the boundary with the Southern Pine Hills, is defined by the Pamlico marine scarp at an elevation of approximately 25-30 feet (Sapp and Emplaincourt, 1975).

There are five major soil associations present in the Fowl River Watershed. Soils developed from the Citronelle Formation include the Troup-Heidel-Bama and Notcher-Saucier-Malbis soil associations. These soils are nearly level to undulating, well drained, with loamy subsoils. Soils present in the Watershed that developed from the coastal deposits and alluvium include the Dorovan-Johnston Levy, Bayou-Escambia-Harleston, and Axis-Lafitte soil associations. The Dorovan-Johnston- Levy soils are nearly level, very poorly drained, and mucky and loamy and contain thick deposits of organic residues and alluvial sediments on bottomlands. The Bayou-Escambia-Harleston soils are nearly level to gently undulating, poorly to moderately well drained, with loamy subsoils. The Axis Lafitte soils are nearly level, very poorly drained formed from loamy marine sediments and the organic debris from decayed plants in the coastal marshes. Each soil association contains multiple soil types. Soil types are described in detail in the Soil Survey of Mobile County, Alabama publication (USDA, 1980).”

2.4. Land Use

The majority of the Fowl River watershed is covered in undeveloped areas consisting of forested and herbaceous uplands as well as wetlands. Table 3.9 in the *Fowl River Watershed Management Plan* provides a detailed breakdown of the land use throughout the watershed. It can be seen that urban development and barren land make up roughly 14.4% of the watershed. The publication also states, "Infrastructure can create major changes to how land is developed within a watershed. Much of the small communities around the Fowl River Watershed were developed around roadways or railroads that have been around for over 100 years. As infrastructure drove a rise in development within and around the Watershed, the land use and land cover was changed. Over the course of 34 years, ranging from 1974 to 2008, urbanization in the Fowl River Watershed increased by 58.8 percent." The majority of this development is located north of I-10, the eastern edge of the watershed around Theodore, and the western edge of the watershed around Irvington.

The forested and herbaceous uplands make up around 54.6%, while woody and non-woody wetlands make up 29.7%. The remainder is classified as water mostly in the form of freshwater ponds. The significant amount of wetlands throughout the watershed promotes its overall health. Not only does it provide storage of stormwater, but also provides a filter for pollutants generated from the impervious areas.

3. Model

3.1. General

The hydrologic model used to evaluate the Fowl River 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.

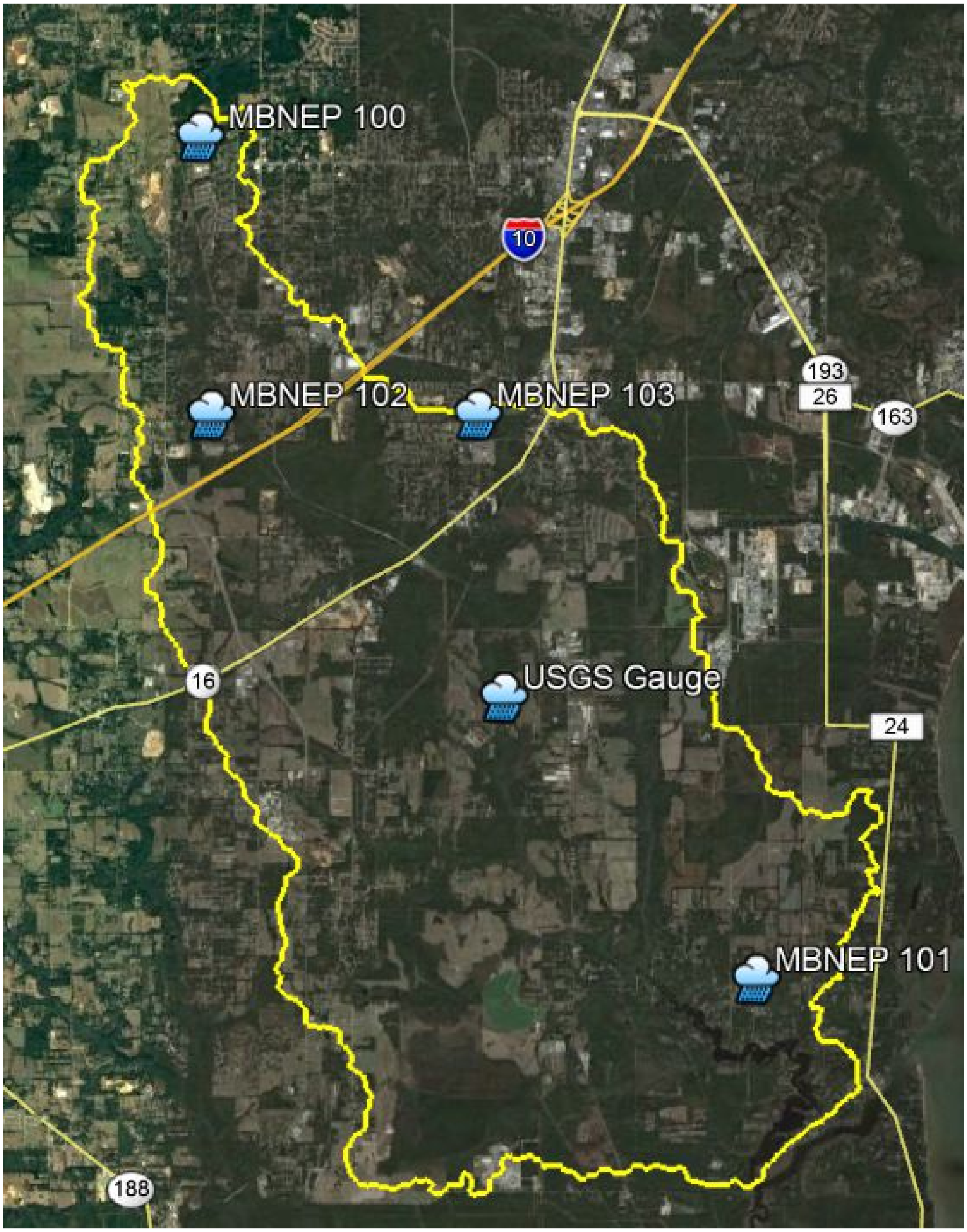
3.2. Rainfall Data

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 (HES) obtained storm data from two different monitoring sources.

The first source for gathering rainfall data is from weather stations that HES deployed throughout the watershed (Figure 3-1). On June 14 and 15, 2017, two weather stations were installed. The first weather station (MBNEP 100) was installed at Meadowlake Elementary School in the upper part of the watershed. The second weather station (MBNEP 101) was installed at the Fowl River Volunteer Fire Department in the lower part of the watershed.

After coordinating with other entities and getting the required permission, two more gauges were installed within the watershed (Figure 3-1). On July 3, 2017, one station (MBNEP 102) was installed at Pearl Haskew Elementary School and a second station (MBNEP 103) was installed at Theodore High School.

Figure 3-1
Fowl River Watershed with Rainfall Gauge 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. Weatherlink software was used for data retrieval for each station. After a storm event, data would be retrieved and then processed.

The second source of rainfall data was obtained from USGS gauge 02471078 located on Half Mile Road near Laurendine, AL (Figure 3-1). Rainfall is provided by the Hydrometeorological Automated Data System (HADS) which is a real-time data acquisition and data distribution system operated by the National Weather Service Office of Dissemination. The site ID for data acquisition is NESDIS ID DE243418. Only the last 7 days of data are kept within the system. The link to the website is https://hads.ncep.noaa.gov/.

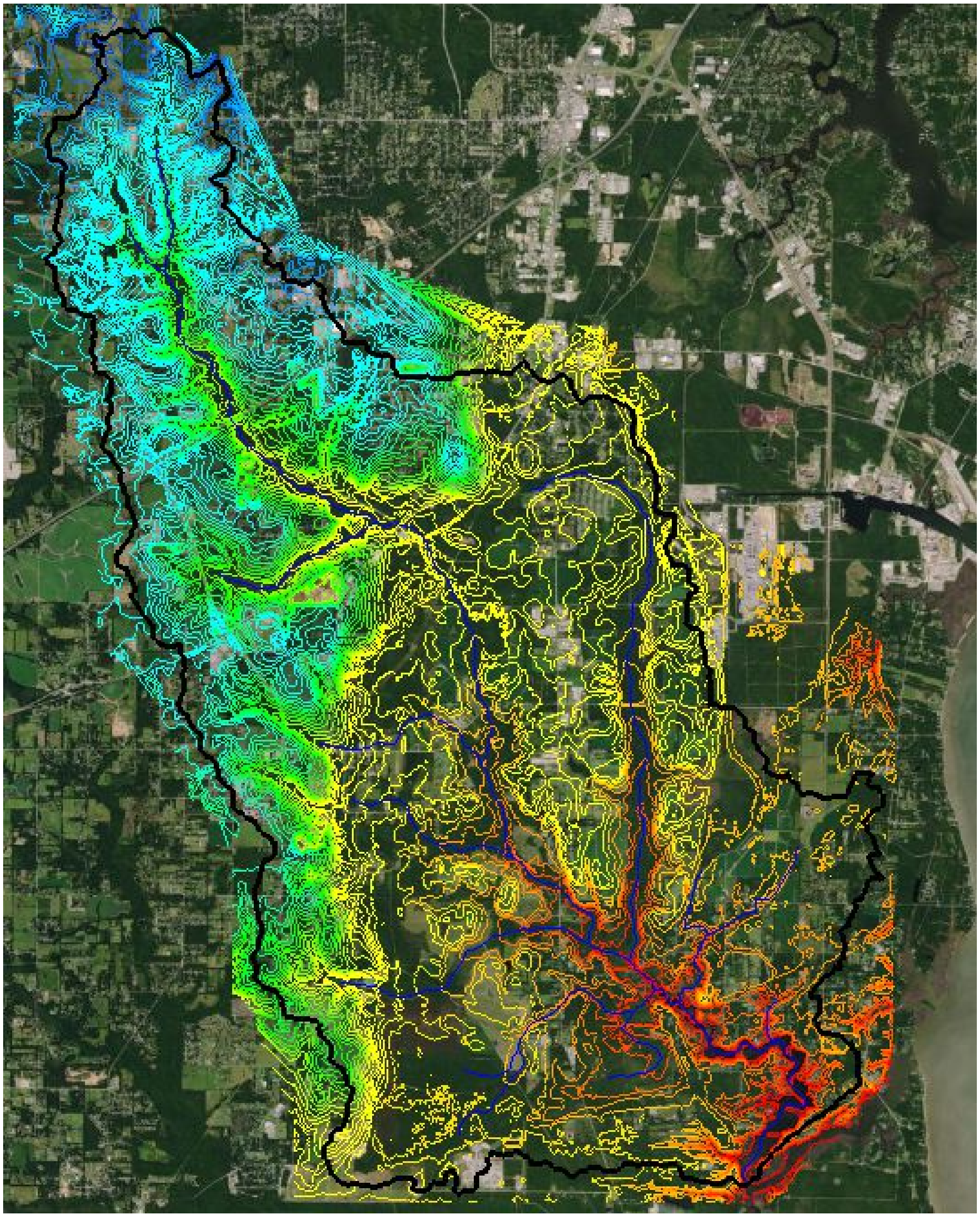
3.3. Digital Terrain Data

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 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 3-2
Fowl River Watershed with Topographic Data



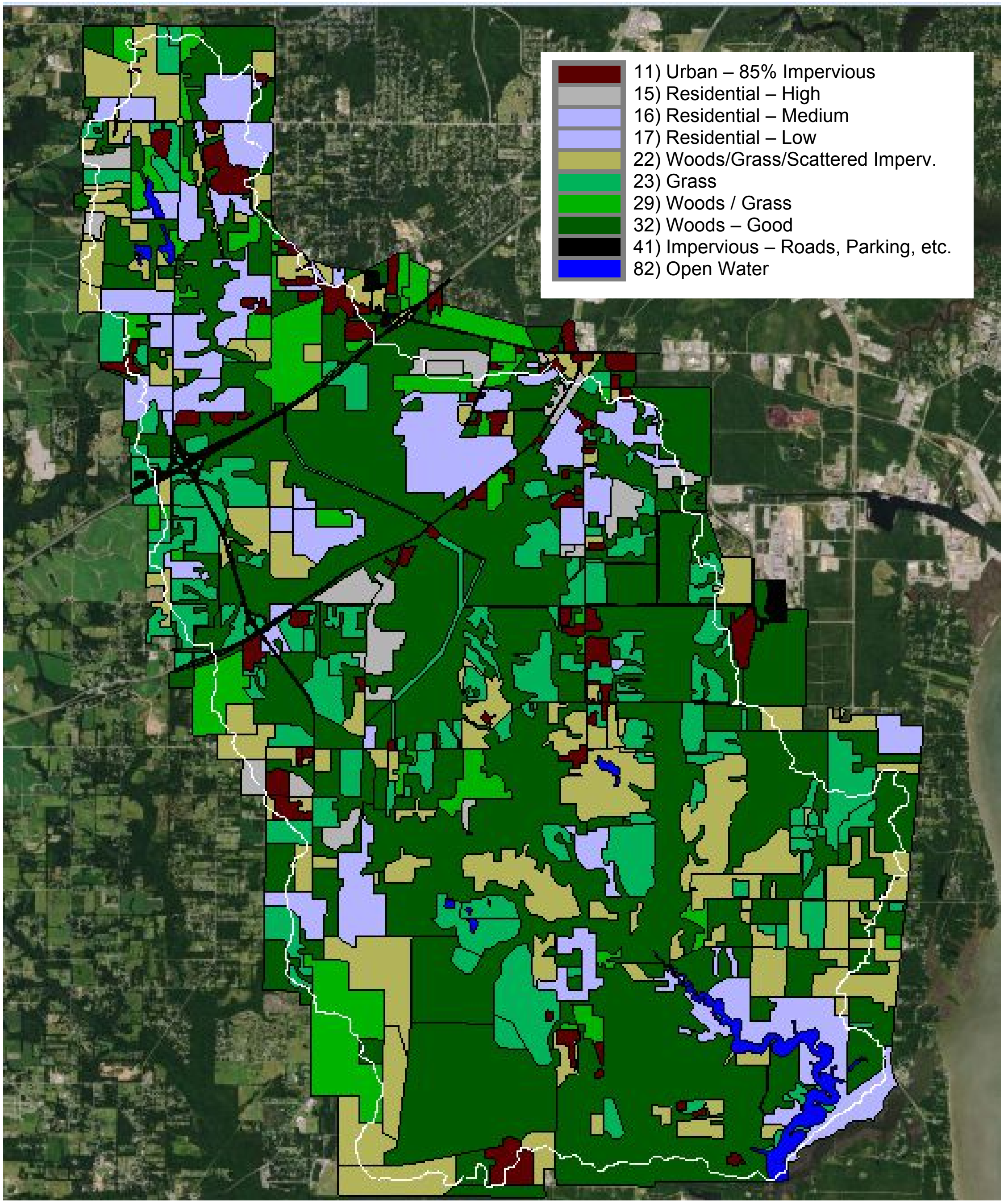
3.4. Land Use

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 photography. The GSSHA 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 3-5 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
15	Residential - High	0.05
16	Residential - Medium	0.08
17	Residential - Low	0.12
22	Woods / Grass / Scattered Impervious	0.20
23	Grass	0.22
29	Woods / Grass	0.25
32	Woods – Good	0.28
41	Impervious – Roads, Parking, etc	0.011
82	Open Water	0.04

Figure 3-3
Fowl River Watershed with Digitized Land Use



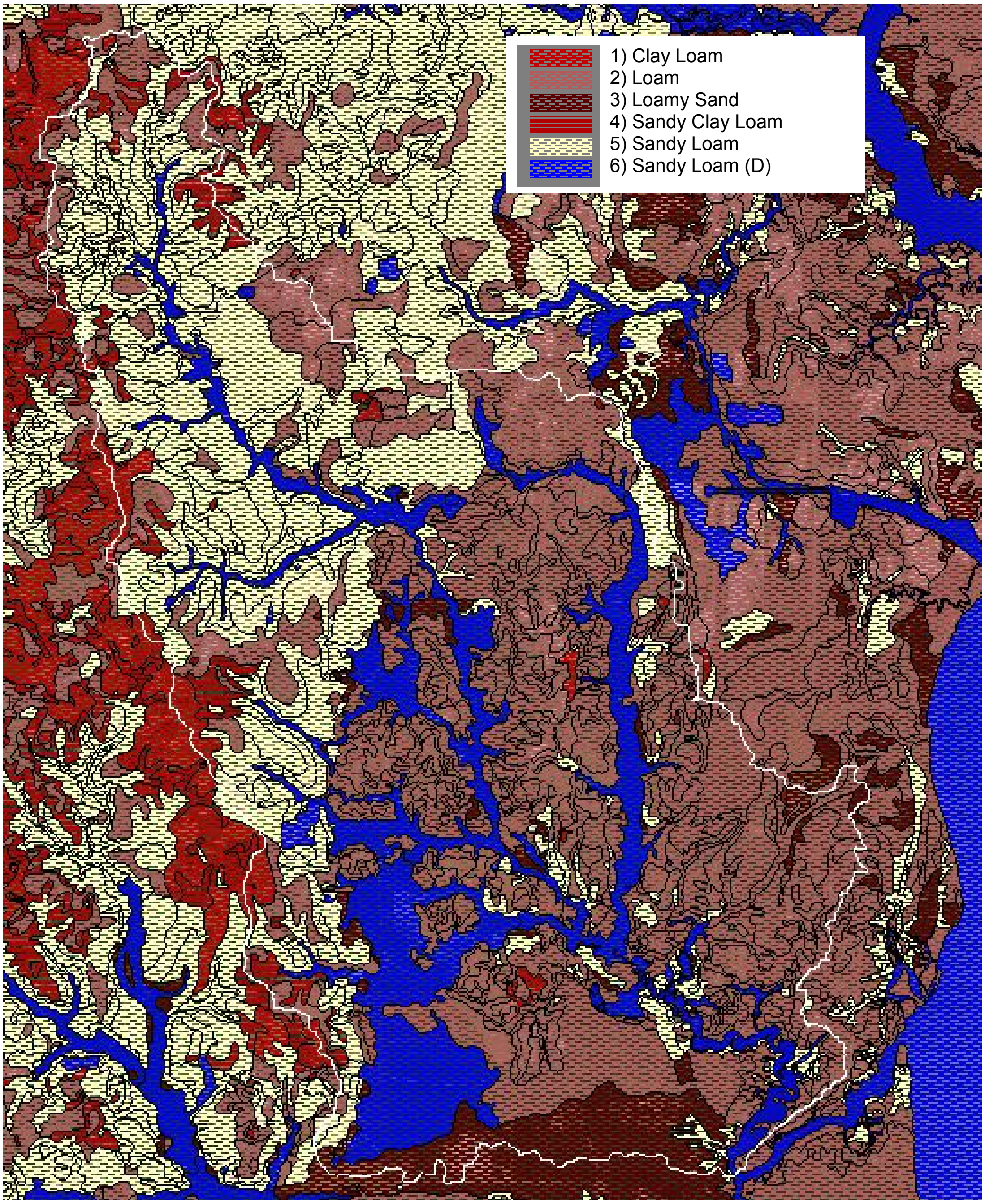
3.5. Soils

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. 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 runoff in determining the peak discharge and volume of storm events. Soils data shapefiles were obtained from the Web Soil Survey (WSS). The WSS is operated by the USDA National Resources Conservation Service (NRCS). Figure 3-4 indicates the soil data that has been incorporated into the GSSHA model. Infiltration can be defined through the soils coverage or through a combined land use/soils data coverage.

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 a model to the real world.

Figure 3-4
Fowl River Watershed with Digitized 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 Fowl River model a 60 meter x 60 meter (197 feet x 197 feet) grid size was utilized (Figure 3-5). As mentioned previously, the settings for GSSHA require the units to be in the International System of Units (SI). The total drainage area to the confluence with East Fowl River is approximately 52.7 square miles. Over the entire watershed this generates approximately 37,900 grid cells. Figures 3-5 to 3-8 indicate the gridded elevation, land use, soils data, and combined layer.

Figure 3-5
Fowl River Watershed with Gridded Elevation Data

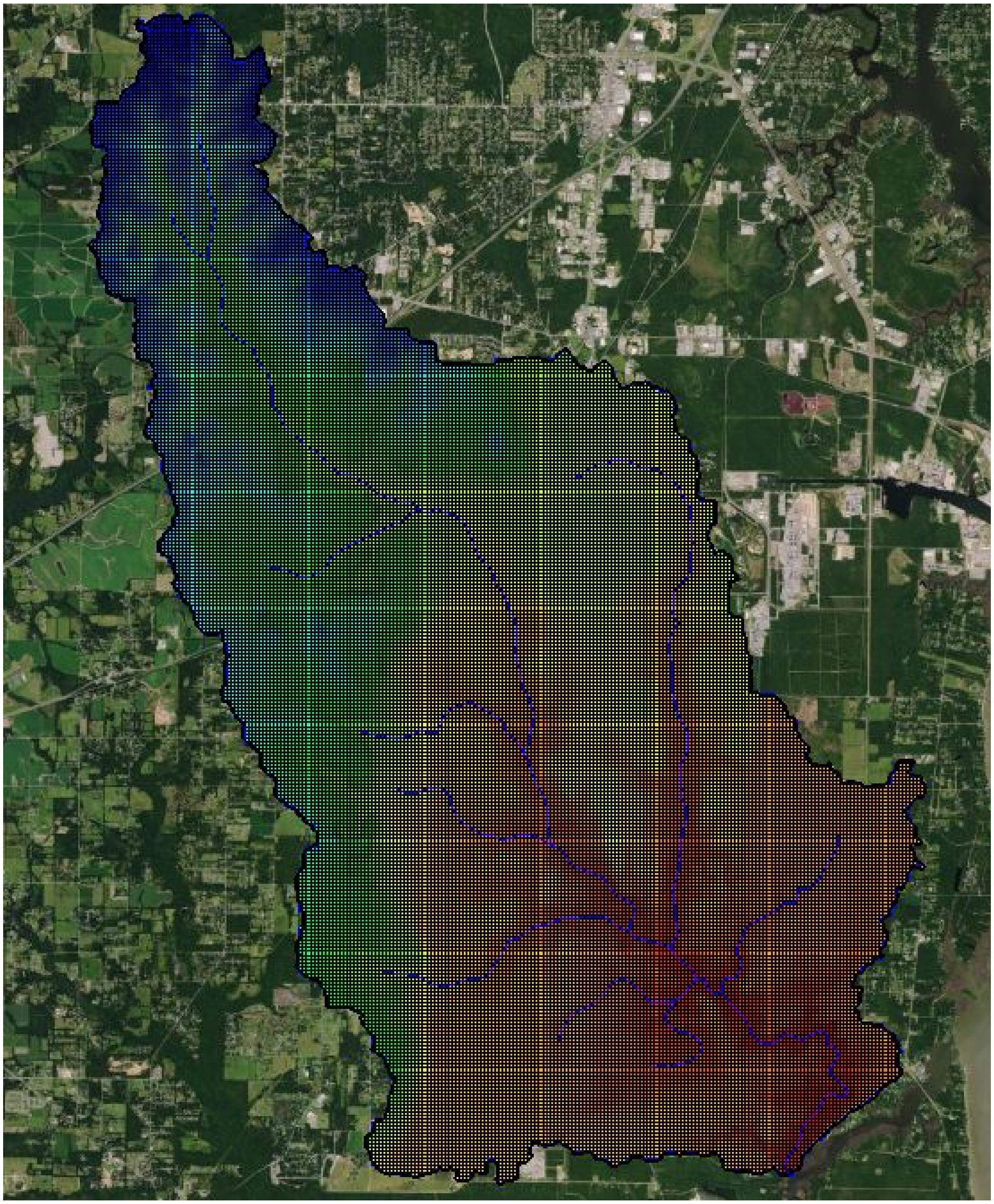


Figure 3-6
Fowl River Watershed with Gridded Land Use Data

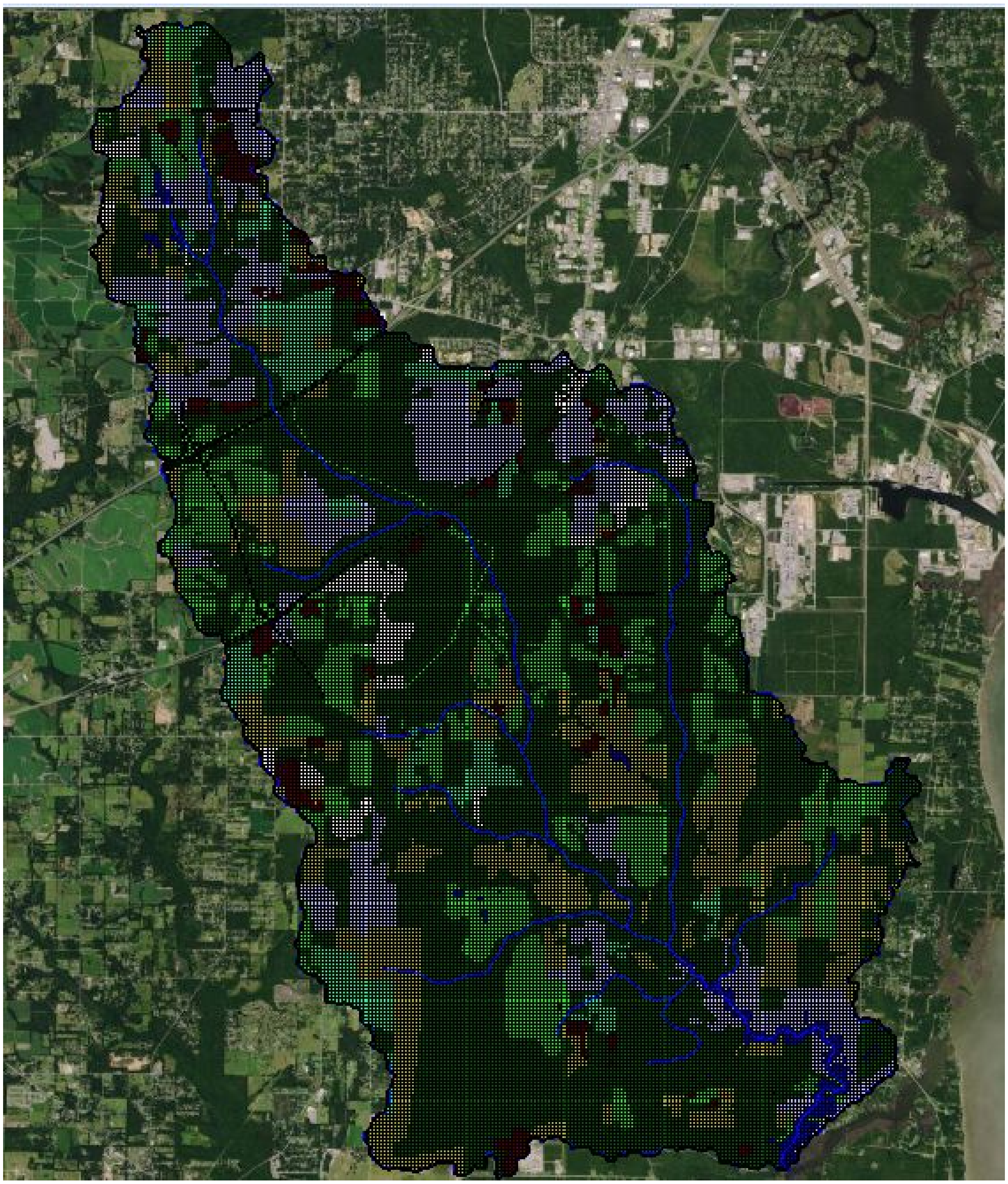


Figure 3-7
Fowl River Watershed with Gridded Soils Data

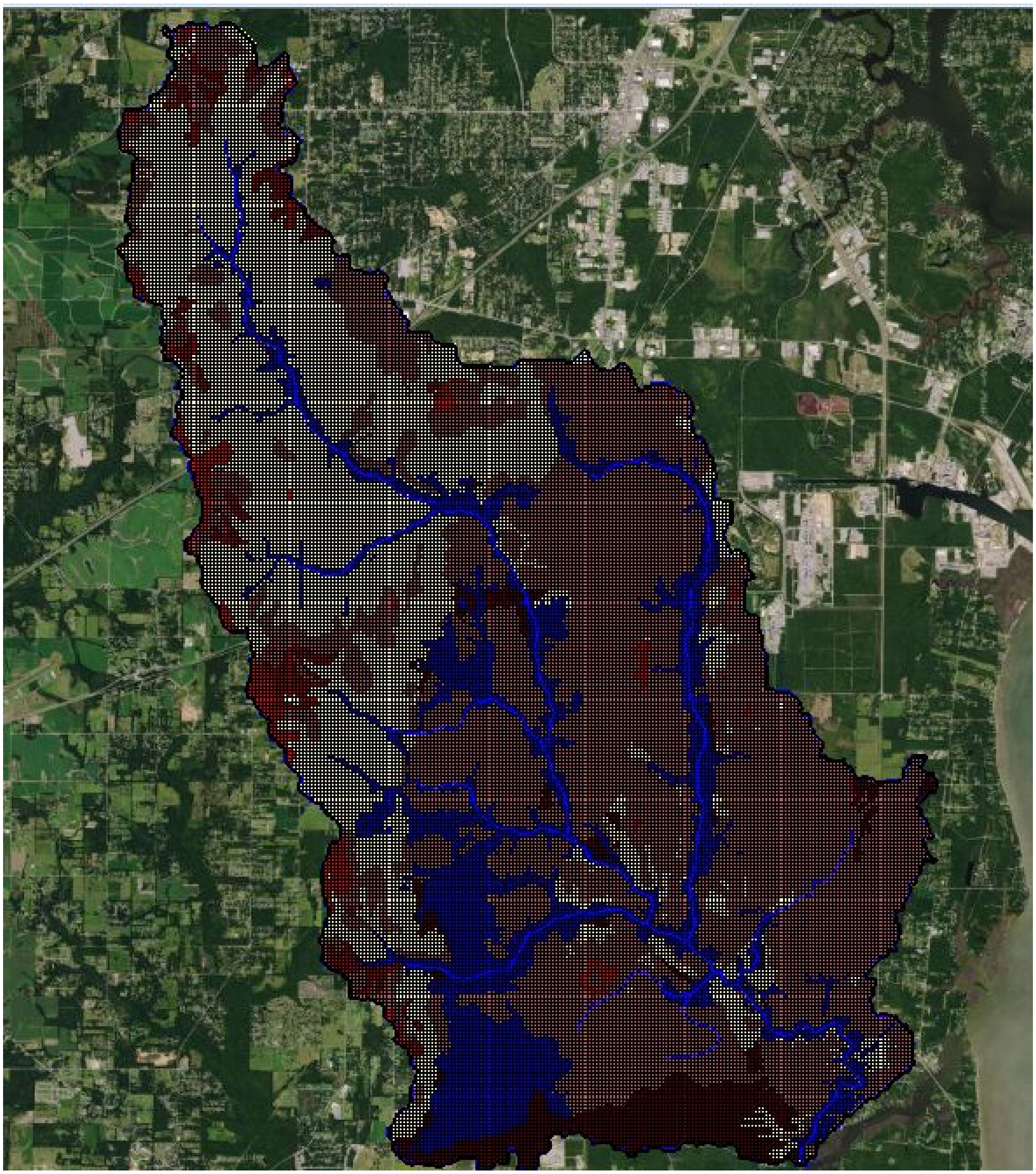
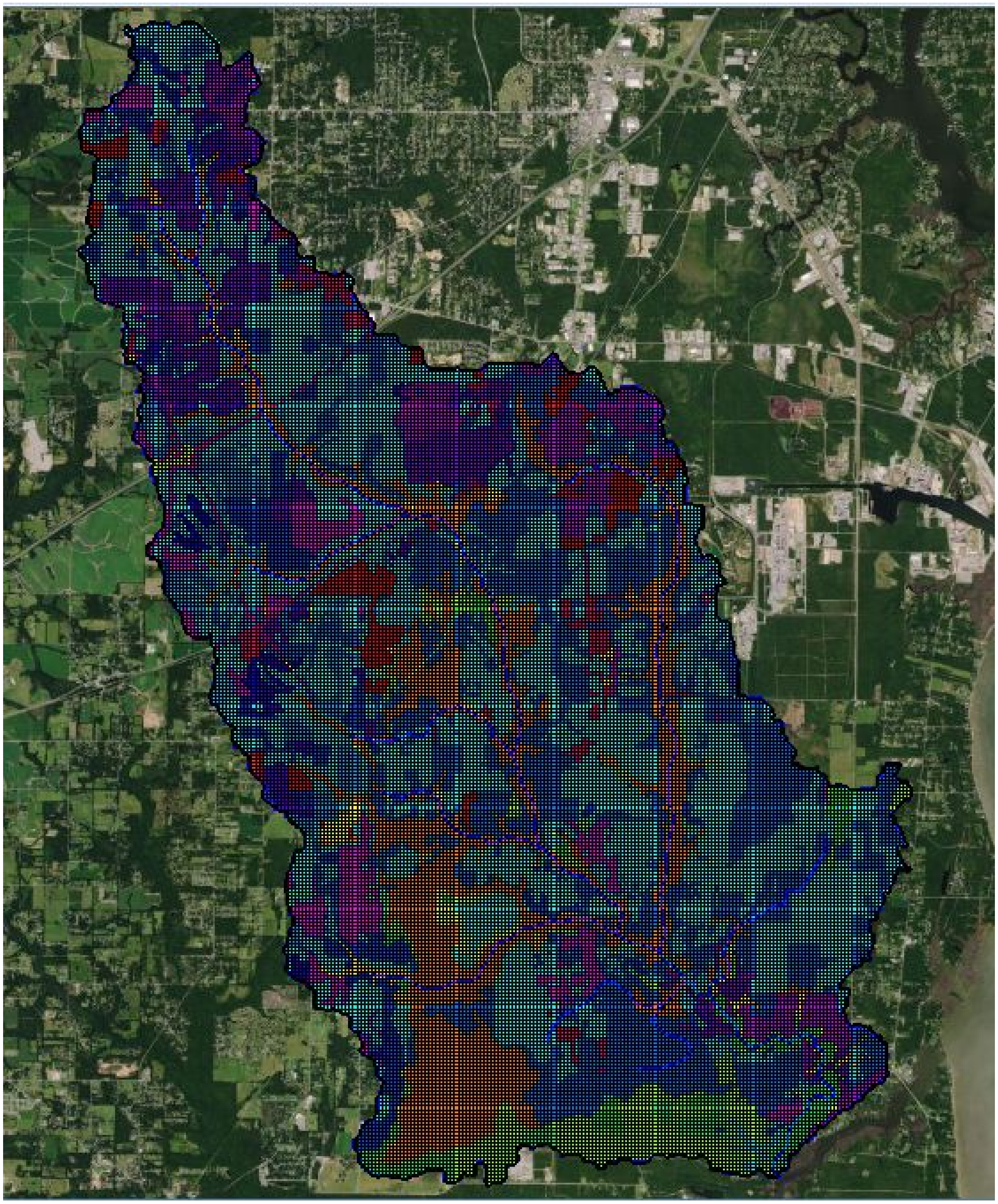


Figure 3-8
Fowl River Watershed with Gridded Combined Data

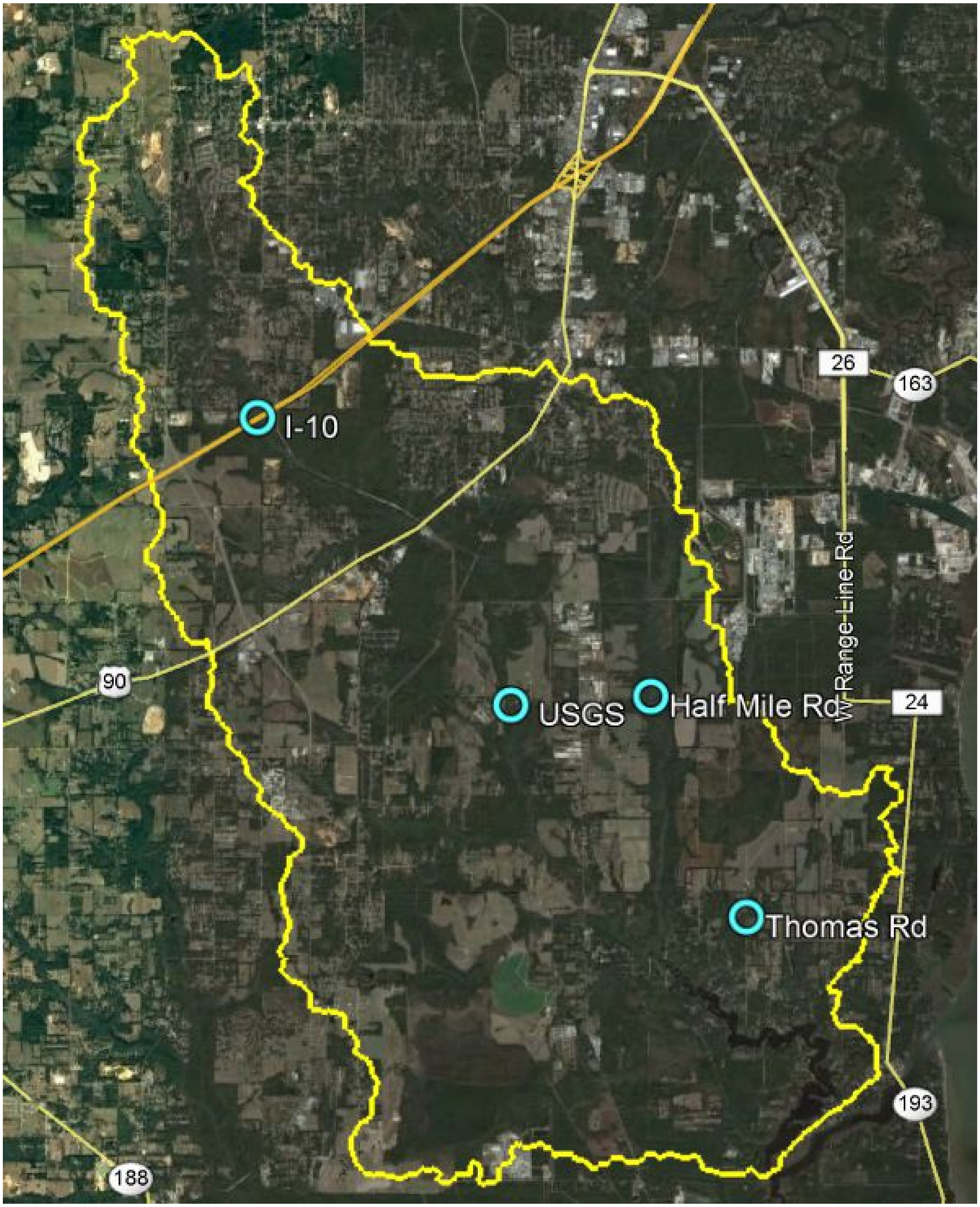


3.8. Calibration

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 rain gauges, 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. The USGS currently has an operating gauge at Half Mile Road (USGS 02471078). Available parameters for this site are discharge and gage height.

There were three locations within the watershed that were deemed useful for monitoring (Figure 3-9). These locations were located near existing drainage structures. The first gauge was installed on Fowl River upstream of the I-10 culvert. The second gauge was installed on Muddy Creek. This gauge is located upstream of the Half Mile Rd (Laurendine Rd) culvert crossing. The final gauge was installed on Dykes Creek. This gauge is located just upstream of the Thomas Road culvert crossing. 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 three gauges were installed and started recording data on June 5, 2017.

Figure 3-9
Fowl River Watershed with Stream Gauge Locations



During the June to October time period there were a couple of storm events that were possible candidates for calibration and validation. From the levelogger data and the USGS gauge data it was determined that a fairly adequate rainfall event occurred on June 20 and 21, 2017 (Figures 3-10 and 3-11). This event produced approximately 6" of rain throughout the watershed in approximately 24 hours. Using NOAA Atlas 14 (Figure 3-12) for this rain depth and time period, it was determined that this rain event is equivalent to a 2-year storm. Typically calibrations are not performed using such low storm events as the model variables usually do not translate to larger flooding events (25+ yr). This event was used however in order to get an initial understanding of how the watershed reacts. Three gauges were used to obtain rainfall data: MBNEP 100, MBNEP 101, and the USGS Gauge (Figure 3-1). An initial calibration of the model was performed and compared to the stream gauge data.

In order to compare stages monitored by the stream gauge, it was necessary to obtain field survey data of the drainage structure opening where the gauge was installed. The survey data was taken just upstream of the structure, and this data was entered into the model as a cross-section. Additional model cross-sections 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, soil moisture depth, top layer depth, 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. Figures 3-13 through 3-16 indicate real-time rainfall, gauge data, and calibrated model output for the June 20, 2017 rain event.

Figure 3-10
June 20-21 – Rainfall Distribution

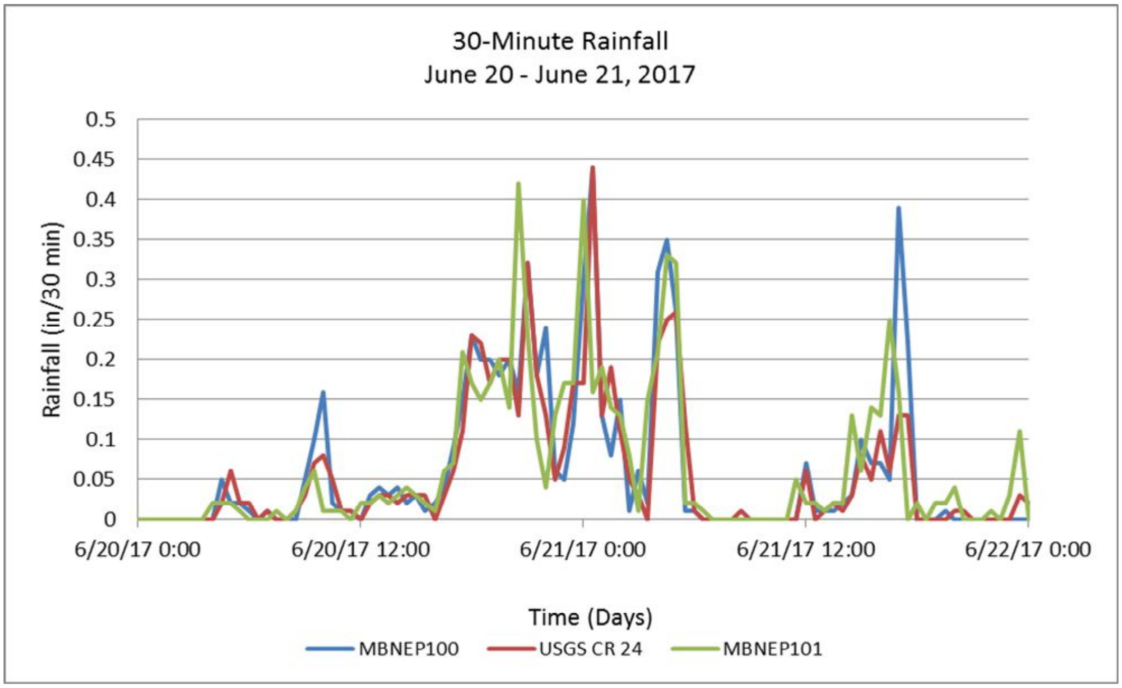


Figure 3-11
June 20-21 – Cumulative Rainfall

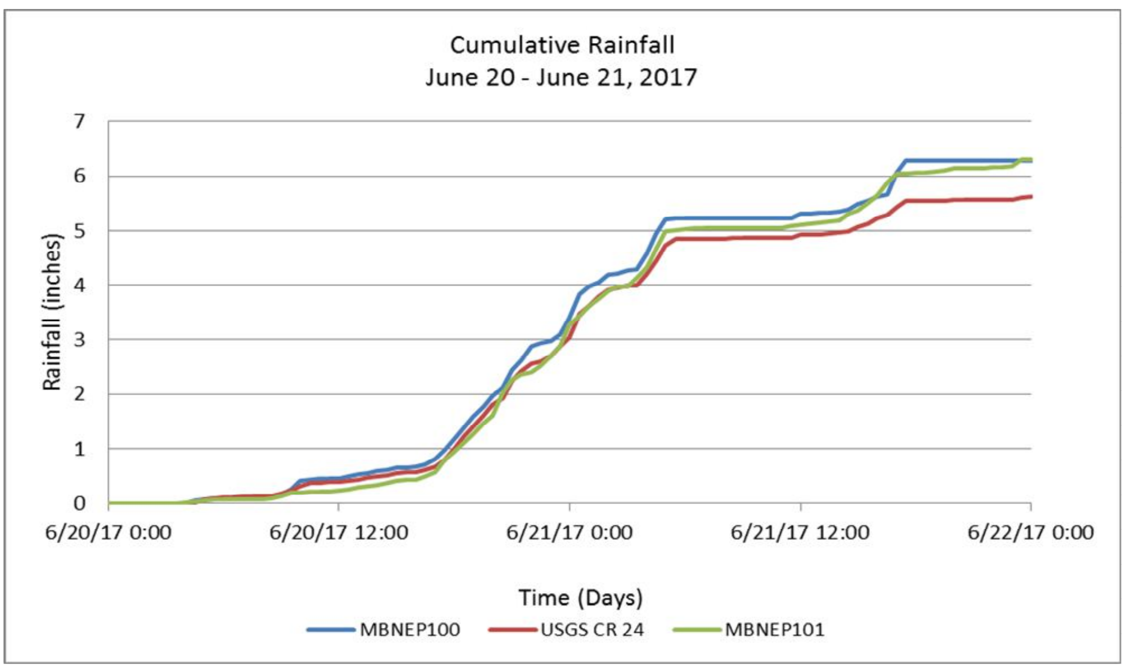


Figure 3-12
Point Precipitation Frequency Estimates

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	1000
5-min	**0.617** (0.502-0.758)	**0.702** (0.571-0.863)	**0.842** (0.682-1.04)	**0.959** (0.772-1.18)	**1.12** (0.873-1.42)	**1.25** (0.949-1.59)	**1.37** (1.01-1.79)	**1.50** (1.06-2.00)	**1.67** (1.14-2.27)	**1.80** (1.19-2.48)
10-min	**0.904** (0.736-1.11)	**1.03** (0.836-1.26)	**1.23** (0.999-1.52)	**1.40** (1.13-1.73)	**1.64** (1.28-2.07)	**1.82** (1.39-2.33)	**2.01** (1.48-2.62)	**2.20** (1.55-2.92)	**2.45** (1.66-3.33)	**2.64** (1.75-3.64)
15-min	**1.10** (0.897-1.35)	**1.25** (1.02-1.54)	**1.50** (1.22-1.85)	**1.71** (1.38-2.12)	**2.00** (1.56-2.53)	**2.23** (1.69-2.84)	**2.45** (1.80-3.19)	**2.68** (1.89-3.56)	**2.99** (2.03-4.06)	**3.22** (2.13-4.43)
30-min	**1.59** (1.30-1.95)	**1.82** (1.48-2.24)	**2.20** (1.78-2.71)	**2.51** (2.02-3.10)	**2.94** (2.29-3.72)	**3.28** (2.49-4.19)	**3.61** (2.66-4.70)	**3.95** (2.79-5.25)	**4.40** (2.99-5.98)	**4.74** (3.14-6.53)
60-min	**2.14** (1.74-2.63)	**2.43** (1.97-2.98)	**2.92** (2.36-3.59)	**3.34** (2.69-4.12)	**3.94** (3.08-5.00)	**4.42** (3.37-5.66)	**4.91** (3.62-6.42)	**5.43** (3.84-7.24)	**6.14** (4.18-8.37)	**6.70** (4.43-9.22)
2-hr	**2.69** (2.20-3.28)	**3.03** (2.48-3.70)	**3.63** (2.96-4.44)	**4.16** (3.37-5.10)	**4.93** (3.88-6.24)	**5.56** (4.27-7.09)	**6.21** (4.61-8.08)	**6.91** (4.93-9.18)	**7.88** (5.40-10.7)	**8.65** (5.76-11.8)
3-hr	**3.06** (2.51-3.71)	**3.44** (2.82-4.18)	**4.12** (3.37-5.02)	**4.74** (3.85-5.79)	**5.66** (4.49-7.16)	**6.43** (4.97-8.20)	**7.25** (5.42-9.43)	**8.14** (5.83-10.8)	**9.39** (6.47-12.7)	**10.4** (6.96-14.2)
6-hr	**3.68** (3.04-4.43)	**4.18** (3.45-5.05)	**5.10** (4.19-6.17)	**5.94** (4.86-7.21)	**7.23** (5.78-9.13)	**8.32** (6.48-10.6)	**9.50** (7.15-12.3)	**10.8** (7.79-14.2)	**12.6** (8.76-17.0)	**14.1** (9.50-19.1)
12-hr	**4.28** (3.55-5.12)	**4.99** (4.14-5.98)	**6.27** (5.18-7.53)	**7.44** (6.12-8.97)	**9.23** (7.42-11.6)	**10.7** (8.41-13.6)	**12.4** (9.35-15.9)	**14.1** (10.3-18.5)	**16.6** (11.6-22.3)	**18.7** (12.6-25.1)
24-hr	**4.94** (4.13-5.88)	**5.83** (4.87-6.94)	**7.44** (6.19-8.87)	**8.92** (7.38-10.7)	**11.2** (9.06-14.0)	**13.1** (10.3-16.5)	**15.2** (11.6-19.4)	**17.4** (12.7-22.7)	**20.6** (14.5-27.5)	**23.3** (15.9-31.1)
2-day	**5.74** (4.83-6.78)	**6.71** (5.63-7.92)	**8.49** (7.11-10.1)	**10.2** (8.46-12.1)	**12.8** (10.4-15.9)	**15.0** (11.9-18.7)	**17.4** (13.4-22.1)	**20.1** (14.8-26.0)	**23.9** (16.9-31.6)	**27.0** (18.5-35.8)
3-day	**6.25** (5.27-7.35)	**7.28** (6.14-8.56)	**9.18** (7.71-10.8)	**11.0** (9.15-13.0)	**13.7** (11.2-16.9)	**16.0** (12.8-19.9)	**18.6** (14.3-23.5)	**21.4** (15.8-27.6)	**25.4** (18.1-33.5)	**28.7** (19.8-37.9)
4-day	**6.68** (5.65-7.82)	**7.75** (6.54-9.08)	**9.70** (8.17-11.4)	**11.5** (9.65-13.6)	**14.3** (11.8-17.6)	**16.7** (13.4-20.7)	**19.3** (14.9-24.4)	**22.2** (16.4-28.5)	**26.3** (18.7-34.5)	**29.6** (20.4-39.0)

* This chart was generated from the lat/long point of 30.5188, -88.1873

Figure 3-13
June 20-21 – I-10 Calibration

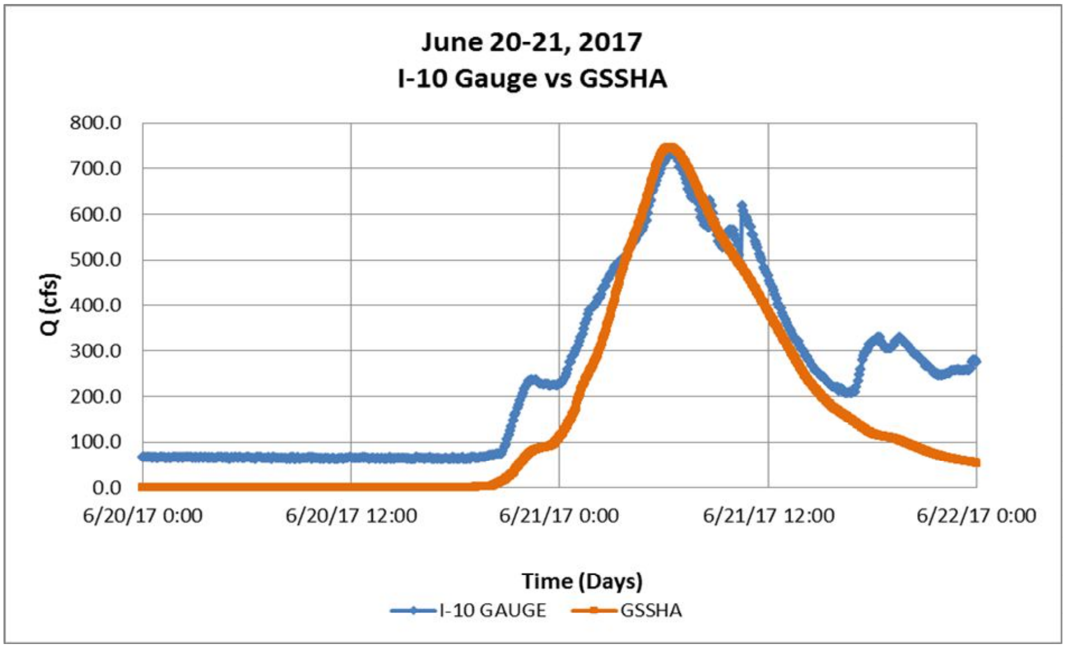


Figure 3-14
June 20-21 – Half Mile Rd Calibration

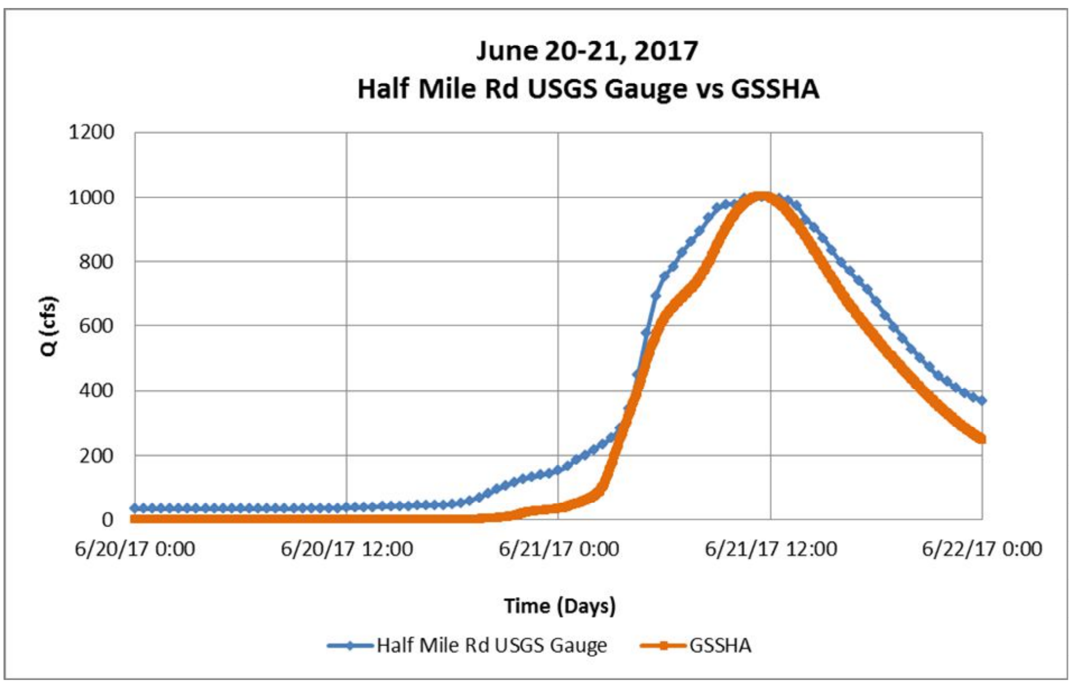


Figure 3-15
June 20-21 – Half Mile Rd (Muddy Cr) Calibration

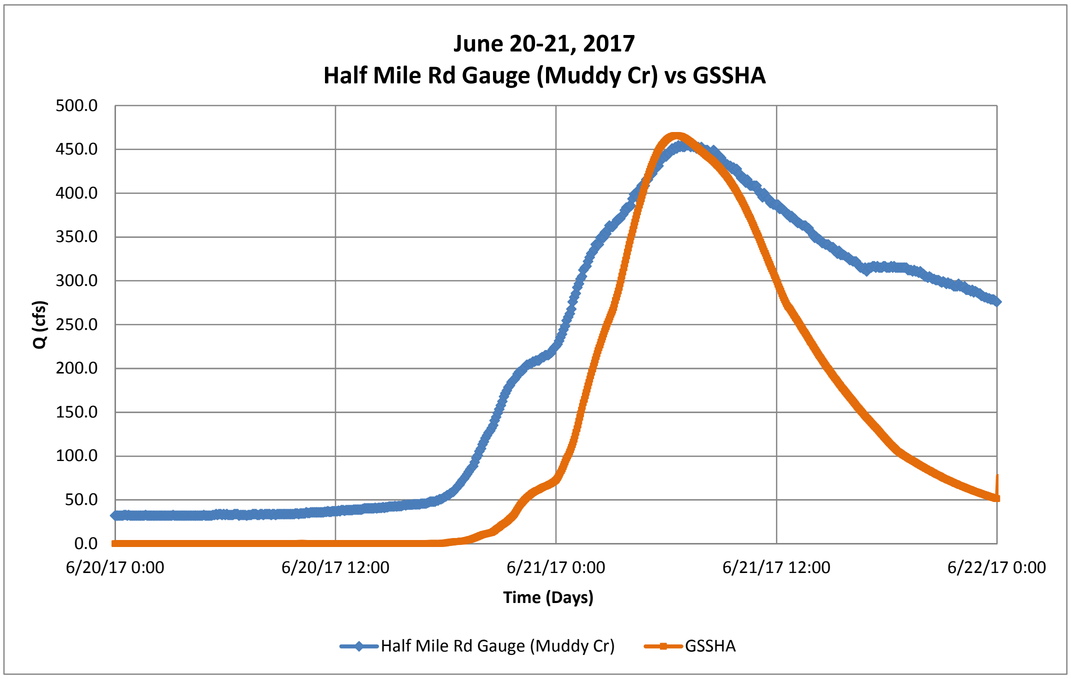
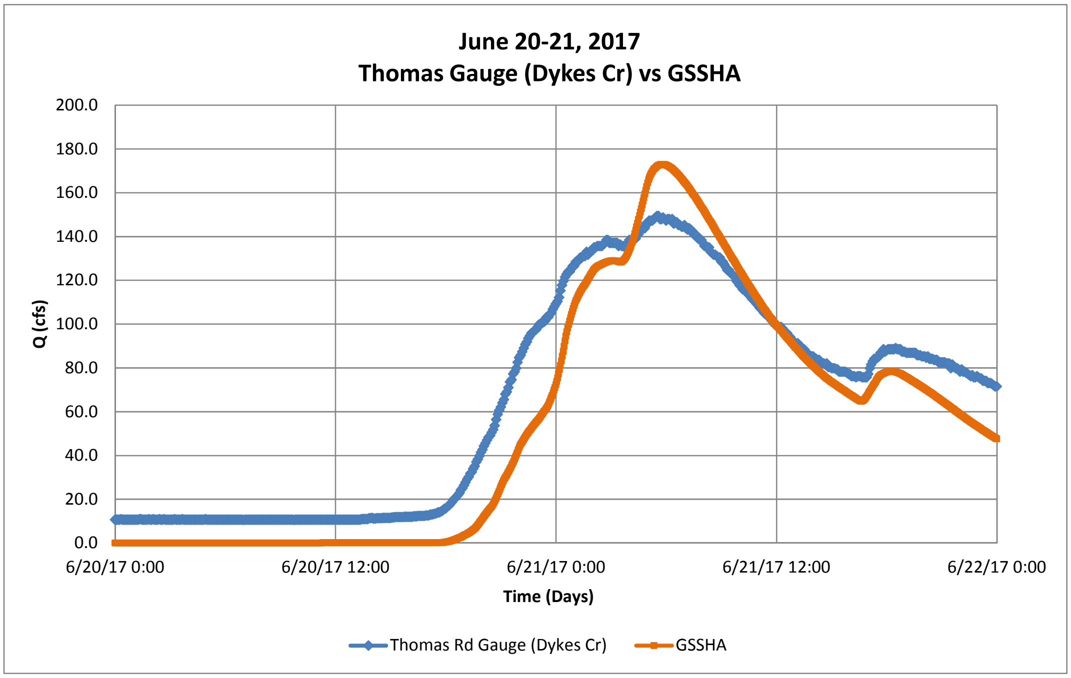


Figure 3-16
June 20-21 – Thomas Road Calibration



At the end of August, the watershed experienced a rainfall event due to Hurricane Harvey. Hurricane Harvey produced record rainfall totals upwards of 40-50” in the Houston, Texas area over a 5-day period. The system stalled in Texas and then made its way northeast. Outer bands of the hurricane produced 7 to 8” of rain across the Fowl River watershed on August 29 and 30, 2017 (Figures 3-17 and 3-18). Utilizing NOAA Atlas 14 precipitation depths it was determined that this system produced a 5-year 24-hour rain event.

This rain event was determined to be a candidate for a validation event or for a new calibration event. During the time period between the June and August rain events, two more weather stations (MBNEP 102 and MBNEP 103) were installed within the watershed (Figure 3-1). The variables used from the calibrated June 20 event were applied to the August 29-30 event. Using the Palmer Drought Index maps, it was determined that the soil moisture conditions during the August event were wetter than that in June. The initial soil moisture in the model was adjusted to compensate for the wetter soil conditions. The results of the validation are found in Figures 3-19, 3-20, 3-21, and 3-22.

Figure 3-17
August 29-30 Rainfall Distribution

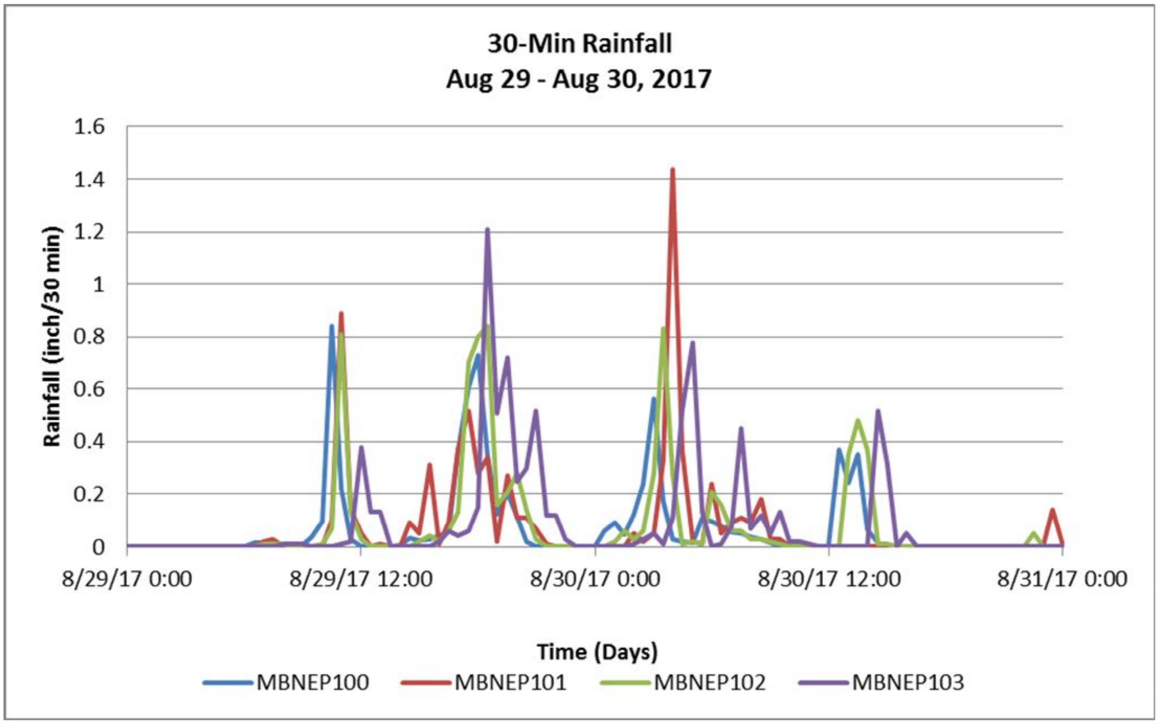


Figure 3-18
August 29-30 Cumulative Rainfall

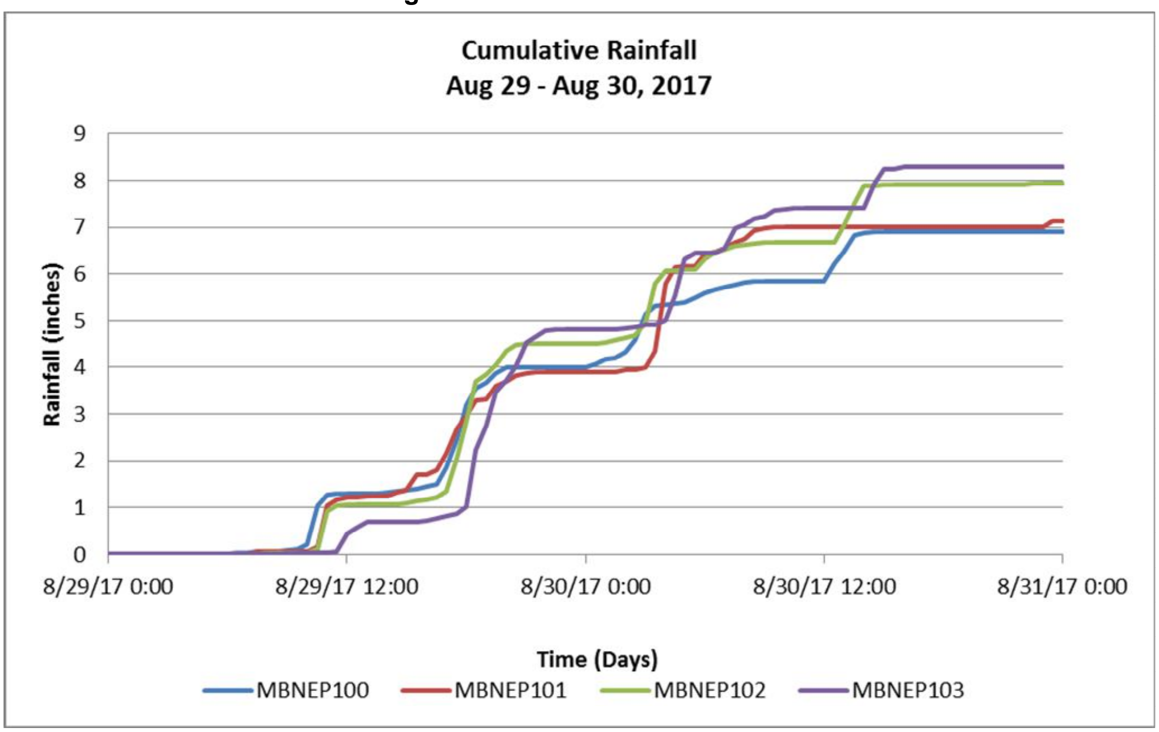


Figure 3-19
August 29-30 - I-10 Calibration

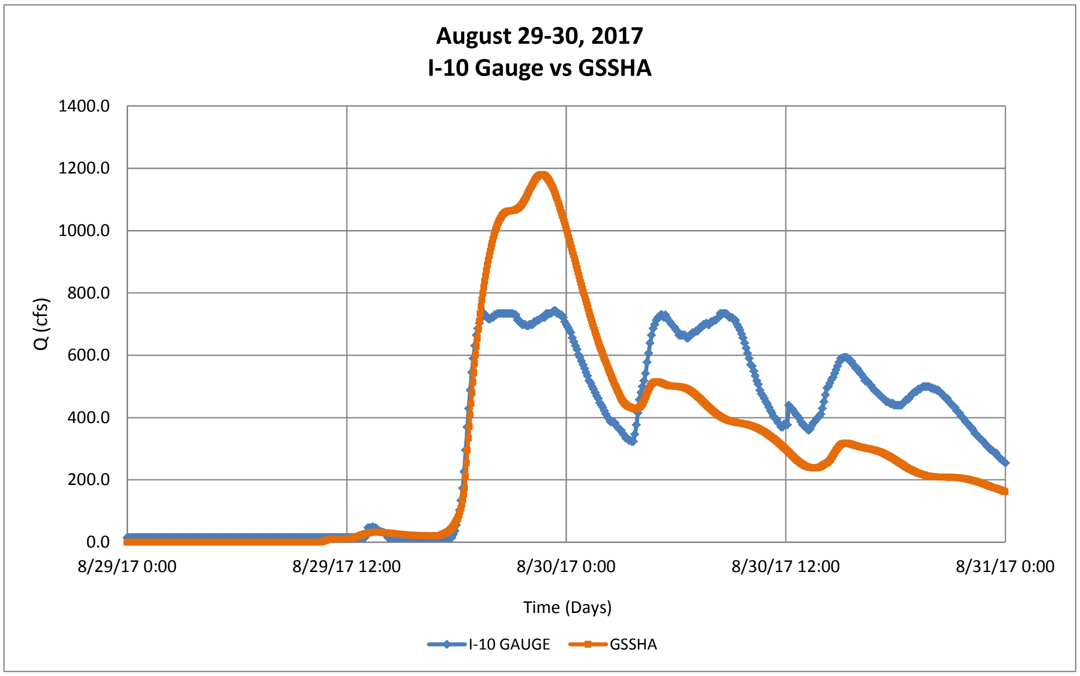


Figure 3-20
August 29-30 – Half Mile Road Calibration

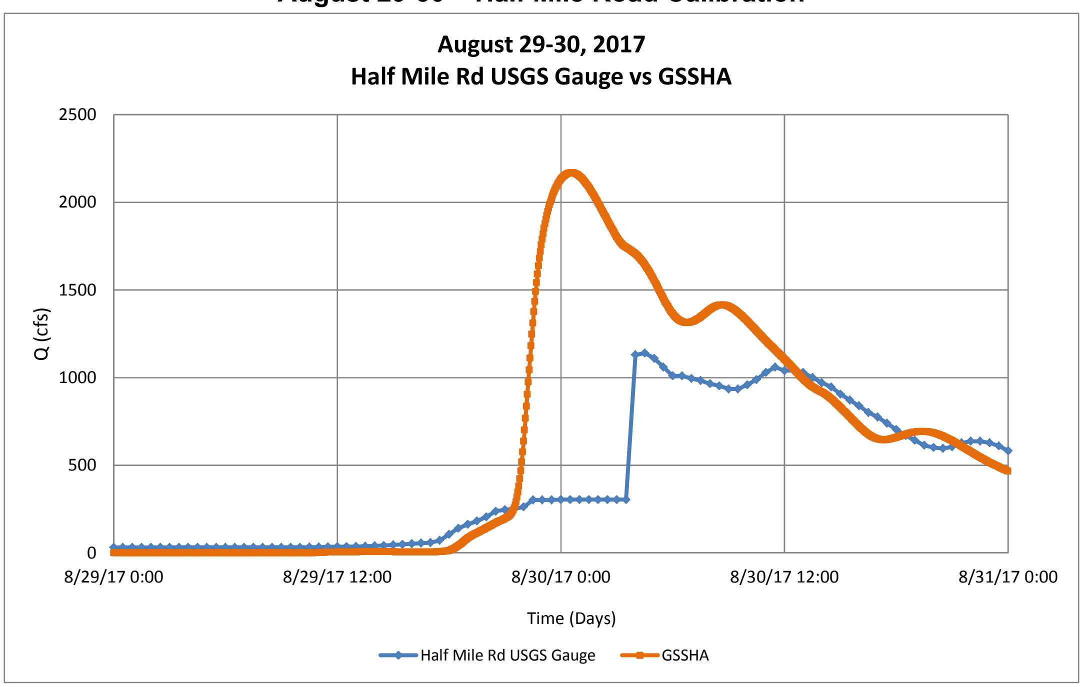


Figure 3-21
August 29-30 – Half Mile Road (Muddy) Calibration

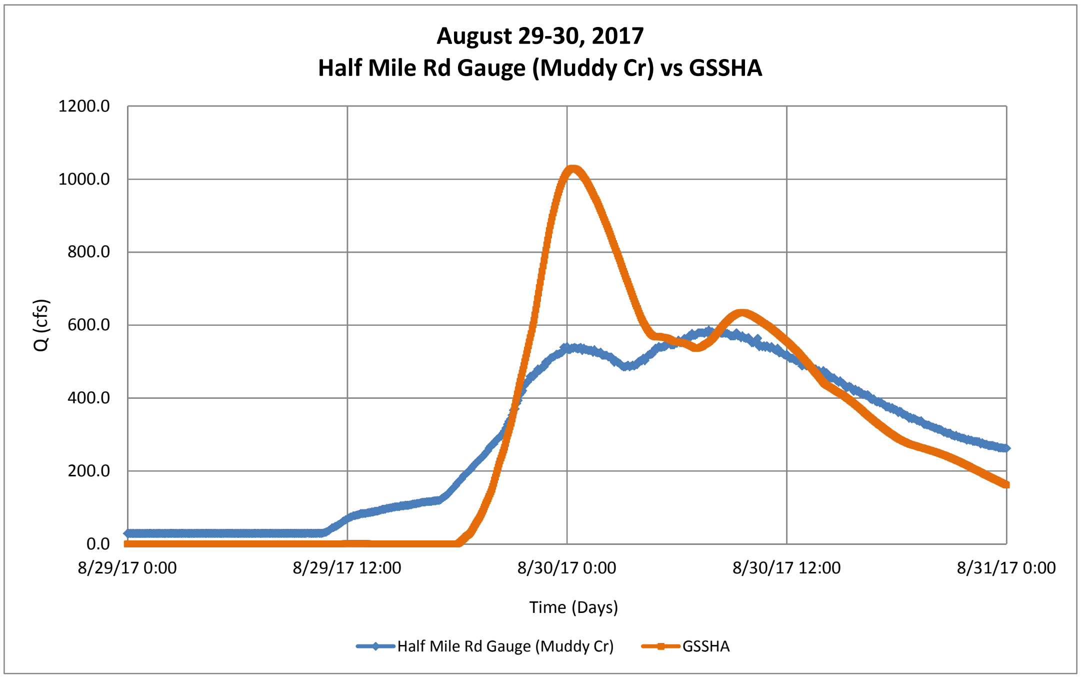
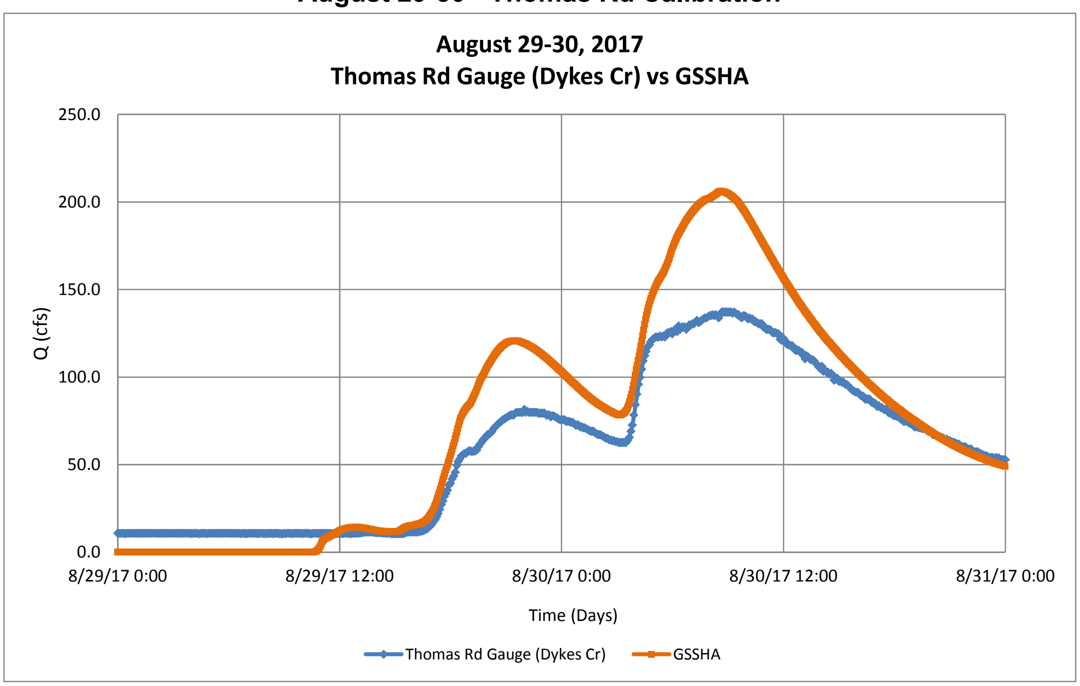


Figure 3-22
August 29-30 - Thomas Rd Calibration



Looking at the results from the August event, it was determined that the variables from the initial calibrated June 20 event cannot be applied to larger rain events. The upper part of the model above I-10 seems to have produced results that agree reasonably well with timing, however the peak discharge does not align well with the measured data (Figure 3-19). Further downstream at the USGS gauge on Half Mile Road the modeled peak discharge is almost twice that recorded at the gauge (Figure 3-20). The same is true for the peak discharge comparison at the Muddy Creek gauge on CR 24 (Figure 3-21). The Thomas Road gauge produced fairly reasonable results with peak discharge and timing (Figure 3-22).

A recalibration of the model was deemed necessary using the August 29-30 rain event. Several iterations and adjustments to the Manning's overland 'n' value, channel 'n' values, hydraulic conductivity, and initial soil moisture were performed. Each adjustment made some improvement, however the peak discharges at the Half Mile Road gauges were still outside the range of a reasonable comparison. It was determined that there was storage within the watershed that needed to be accounted for. In order to account for the extra storage, retention was added throughout the model. The results from the added retention are found below in Figures 3-23, 3-24, 3-25, and 3-26.

Figure 3-23
August 29-30 - I-10 Calibration with Retention

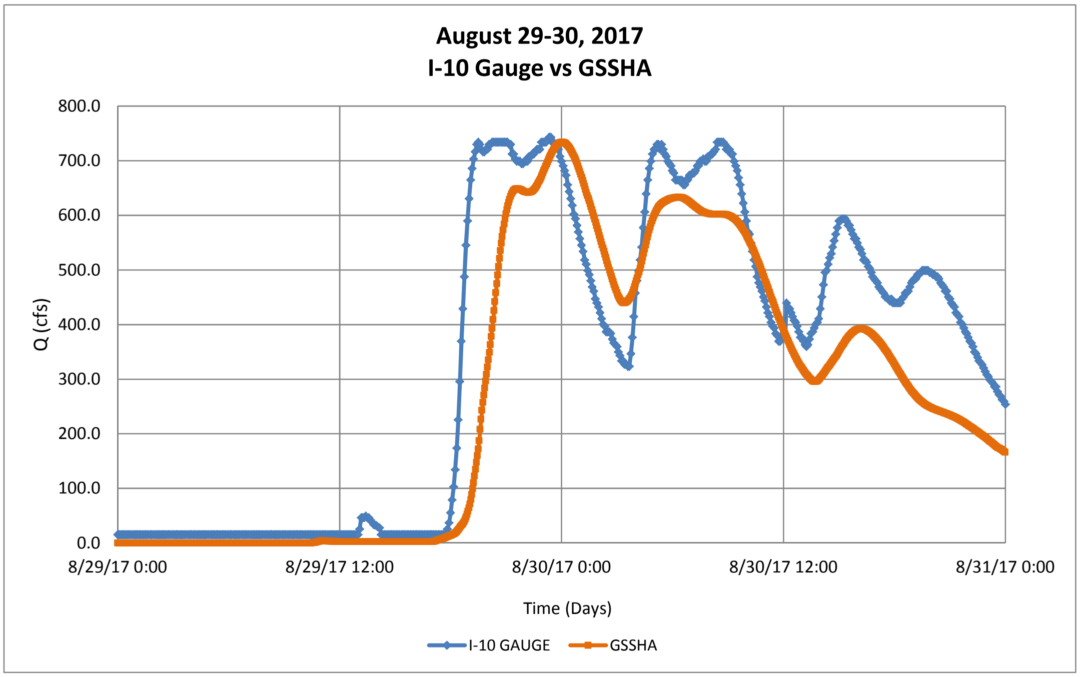


Figure 3-24
August 29-30 - USGS Half Mile Road Calibration with Retention

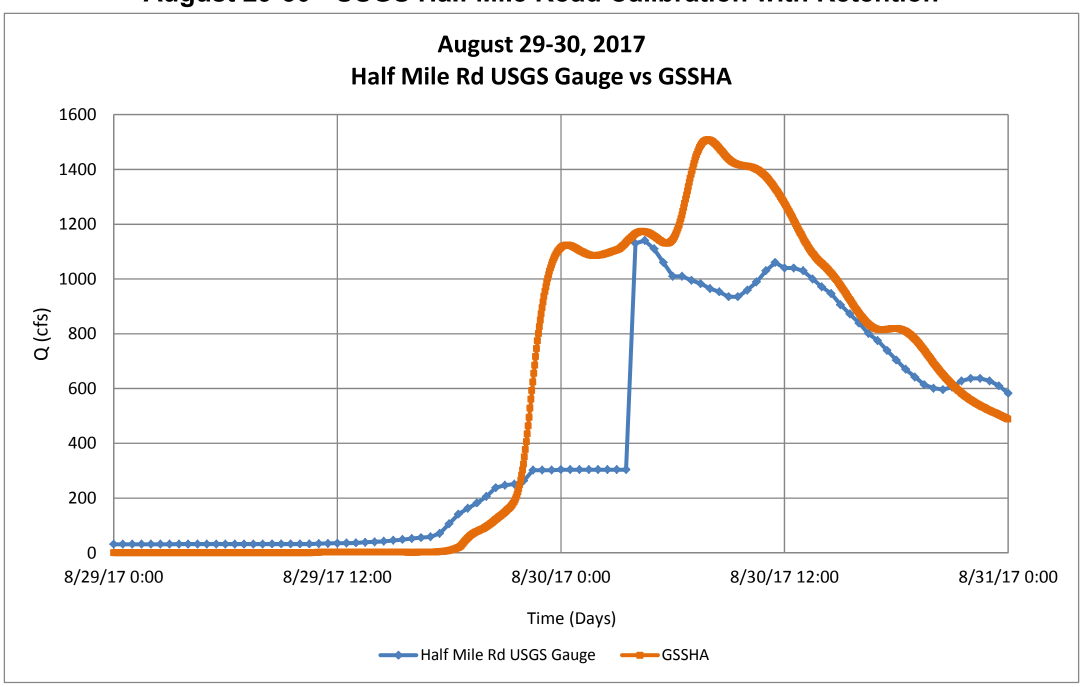


Figure 3-25
August 29-30 - Half Mile Road (Muddy) Calibration with Retention

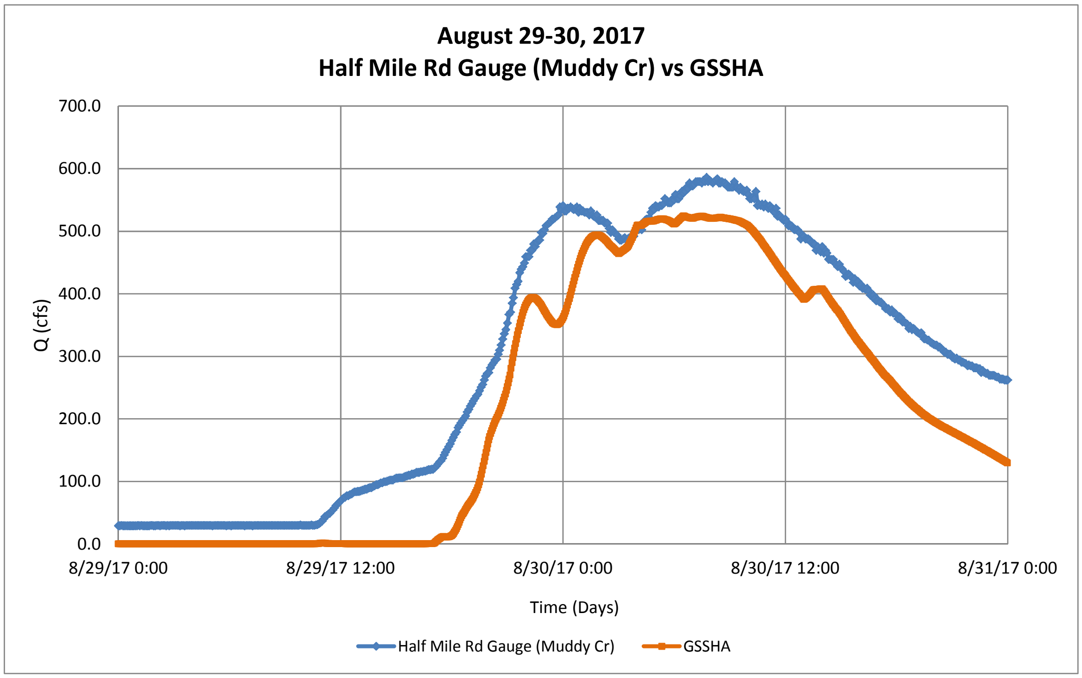
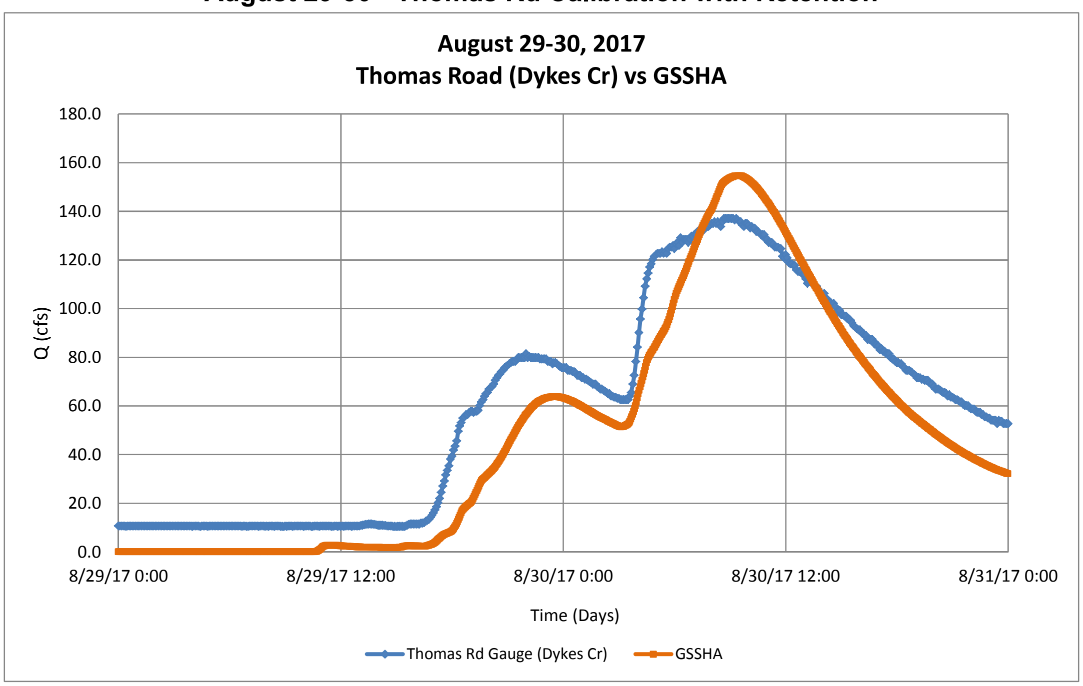


Figure 3-26
August 29-30 - Thomas Rd Calibration with Retention



The addition of retention throughout the watershed helped reduce the high peak discharges found in the model run using the June 20 variables. There is a better fit of data for all four monitoring locations. For the USGS gauge location, the model still shows a peak discharge higher than that was measured. Looking at Figure 3-24, it appears the gauge experienced a period of time between August 29 22:00 and August 30 03:30 where the flow was not being properly recorded. There is a possibility that the gauge did not display the proper peak discharge. Another event was necessary in order to see if the newly calibrated model variables would apply to future events.

On October 7 and 8, 2017 the watershed experienced rainfall resulting from Tropical Storm Nate (Figure 3-27). The watershed received 4.5 to 5.5 inches of rain (Figures 3-28 and 3-29) in approximately 12 hours. Utilizing NOAA Atlas 14 precipitation depths, it was determined that this system produced a 2-year 12-hour rain event. The newly calibrated model with retention was applied to this storm and the results can be found in Figures 3-30 to 3-32.

Figure 3-27
Tropical Storm Nate Cumulative Rainfall

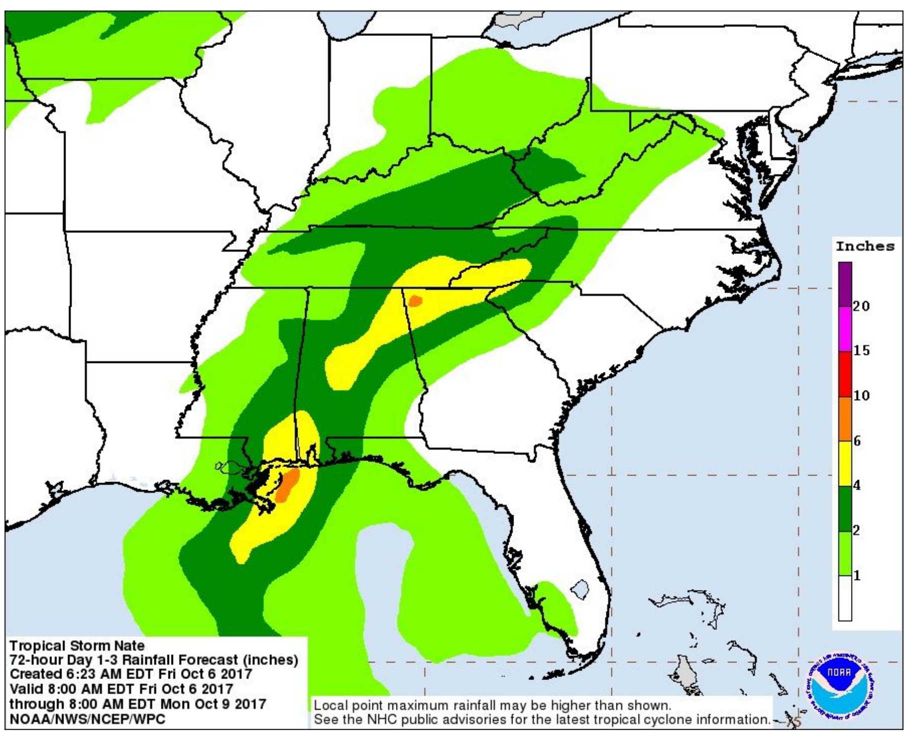


Figure 3-28
October 7-8 Rainfall Distribution

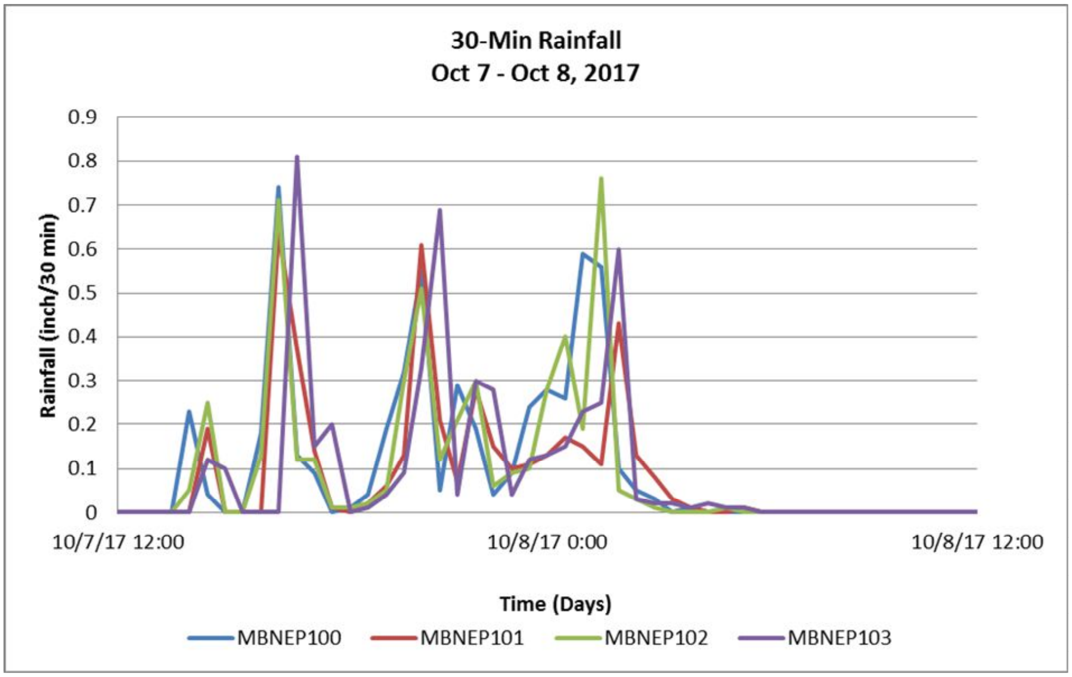


Figure 3-29
October 7-8 Cumulative Rainfall

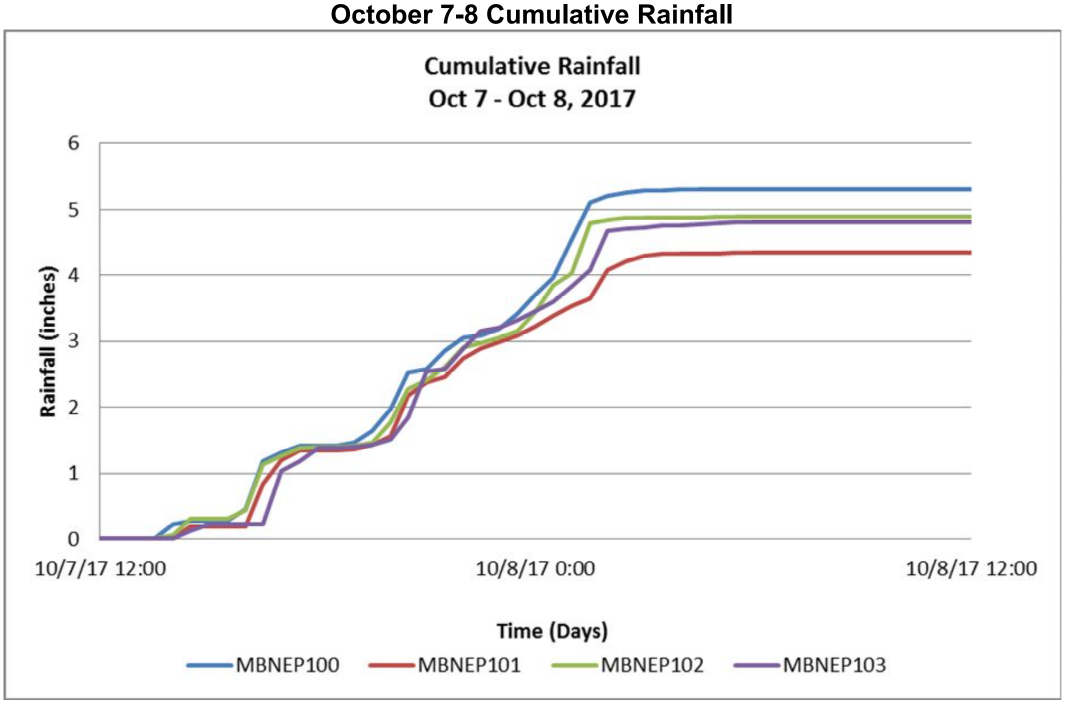


Figure 3-30
October 7-8 - I-10 Calibration with Retention

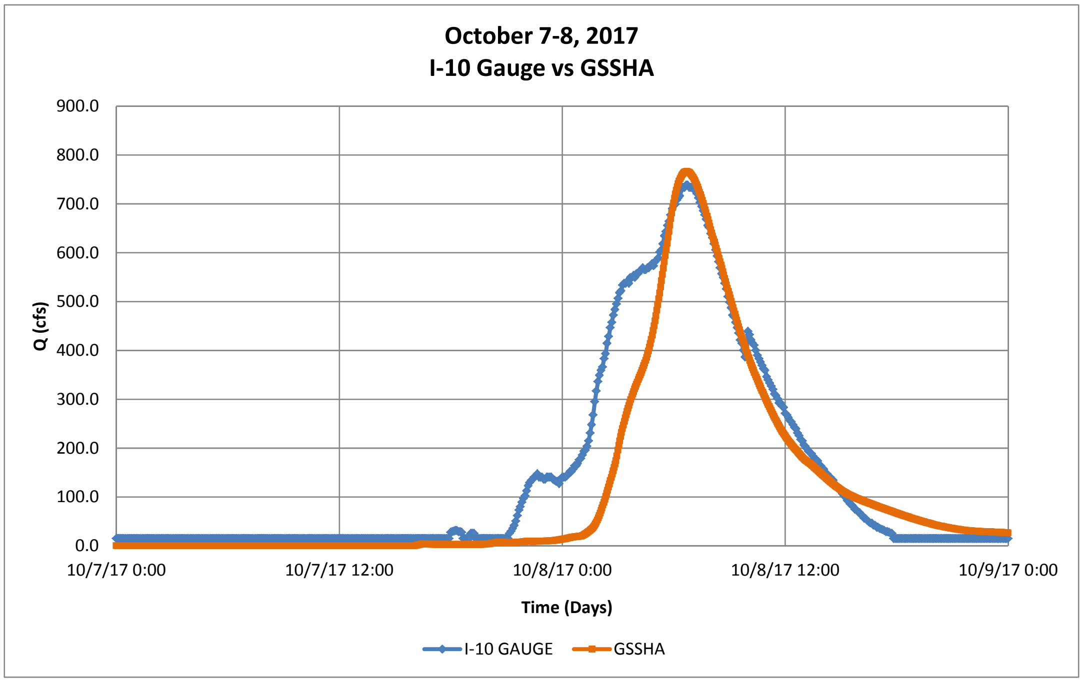


Figure 3-31
October 7-8 - USGS Half Mile Road Calibration with Retention

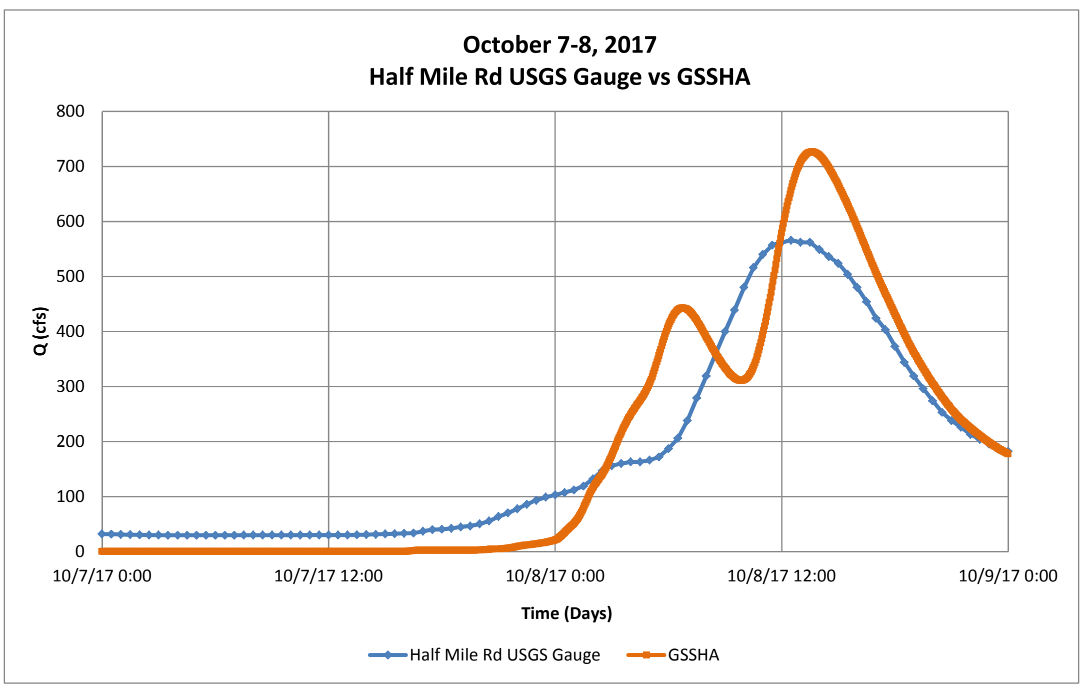
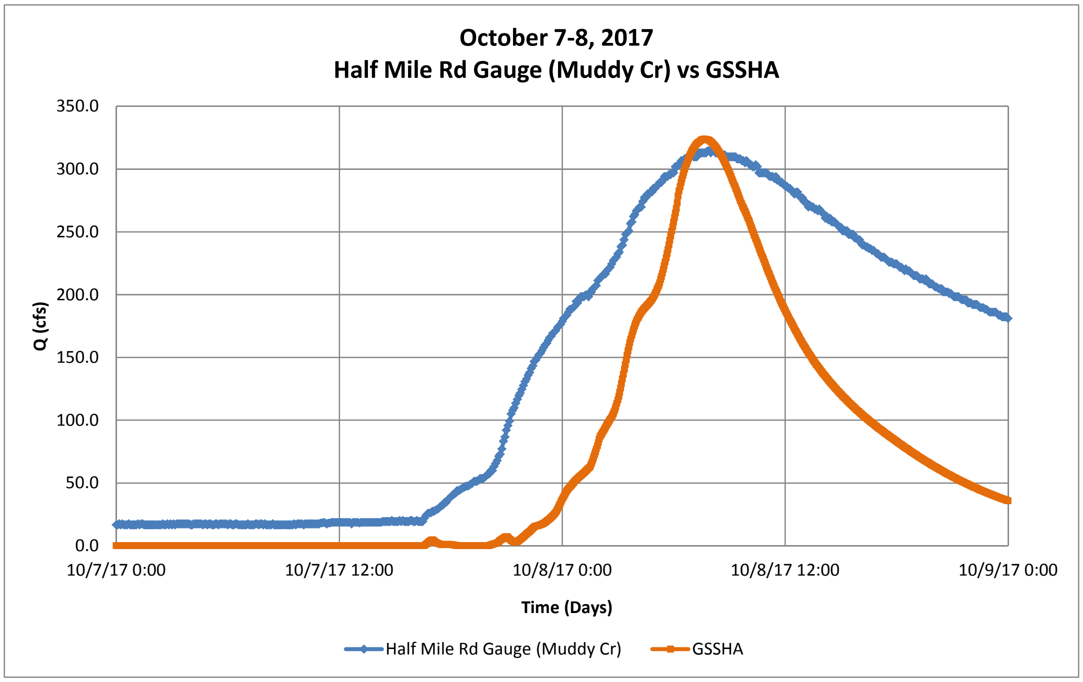


Figure 3-32
October 7-8 - Half Mile Road (Muddy) Calibration with Retention



Peak discharge and timing results from the run seem reasonable. Adjustments made to the model include reducing the initial soil moisture and increasing the retention depth for the sandy loam in order to account for the drier conditions. The Palmer drought maps for the August and October rain events indicating the condition of drought can be found in Figures 3-33 and 3-34.

It should be noted that near the end of September the Thomas Road gauge was vandalized. Readings for the October 7th event were unavailable for comparison. Based on the previous events, however, it was determined that the calibrated variables in the Dykes Creek basin were acceptable and did not need to be modified.

At the end of October on the 22nd and 23rd, there was a small but fairly intense rain event. The storm produced 5-6 inches of rain in the top 1/3 of the watershed in approximately 6 hours (Figures 3-35 and 3-36). Utilizing NOAA Atlas 14 precipitation depths, it was determined that this system produced a 5-year 6-hour rain event. The original variables from the August calibration were used for modeling this event. The results can be found in Figures 3-37 and 3-39.

Figure 3-33
Palmer Drought Map (through Aug 26)

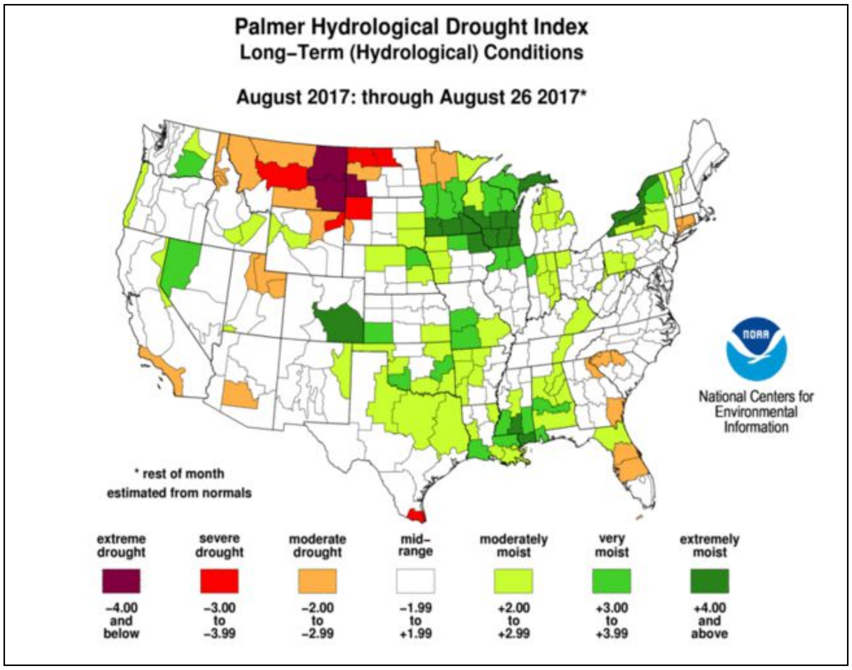


Figure 3-34
Palmer Drought Map (through Oct 7)

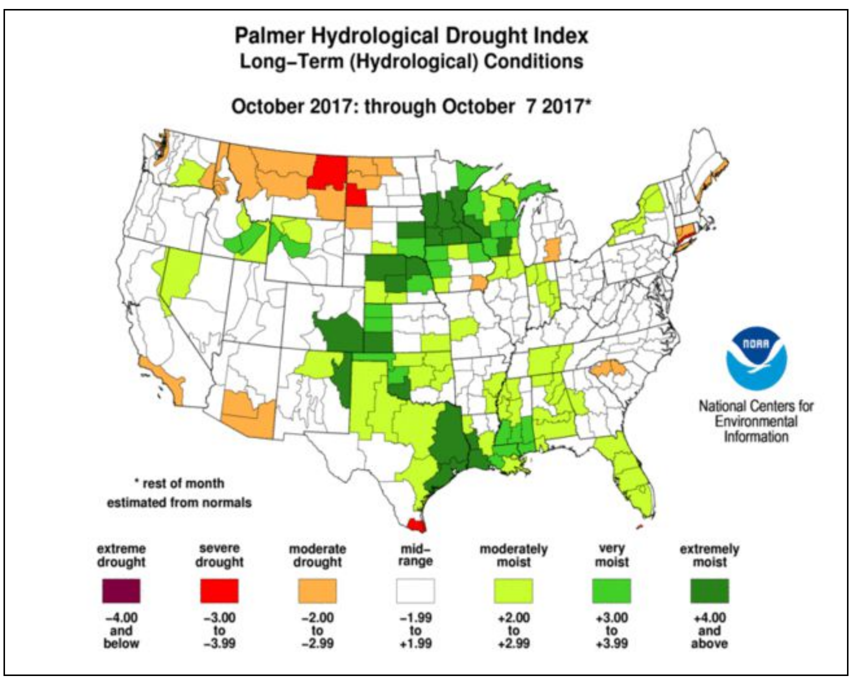


Figure 3-35
October 22-23 Rainfall Distribution

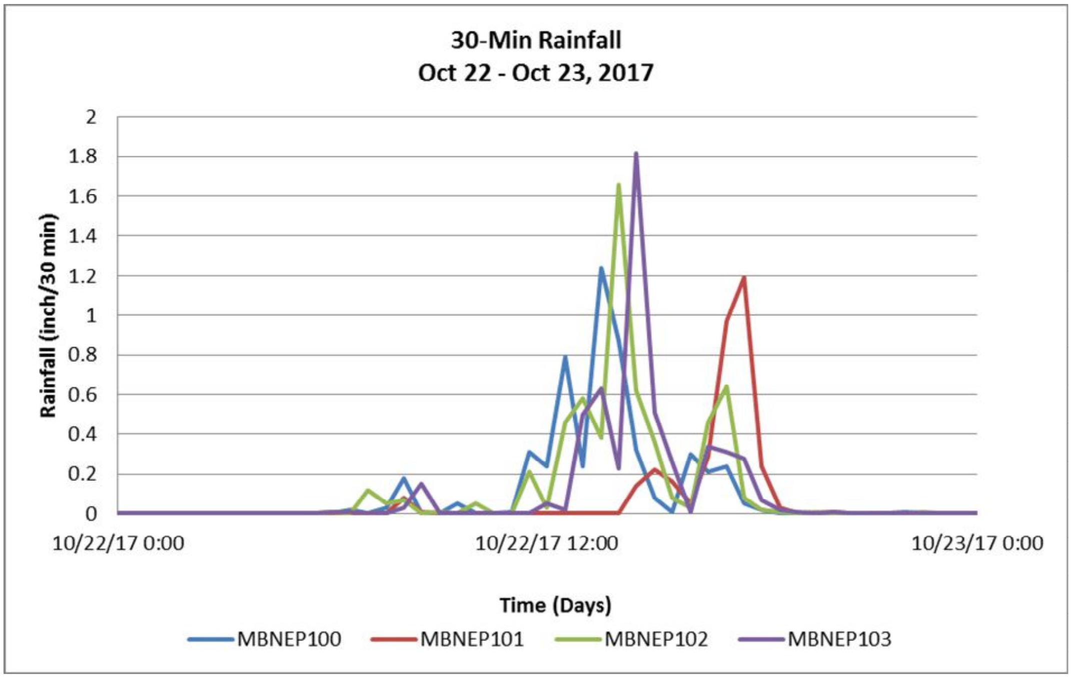


Figure 3-36
October 22-23 Cumulative Rainfall

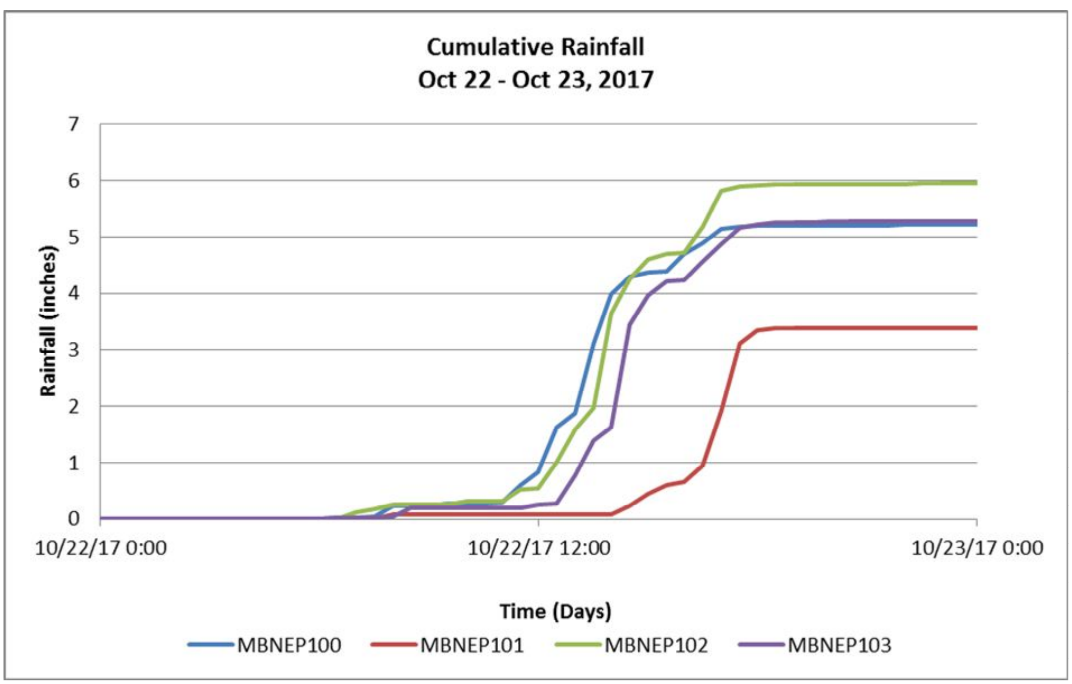


Figure 3-37
October 22-23 - I-10 Calibration with Retention

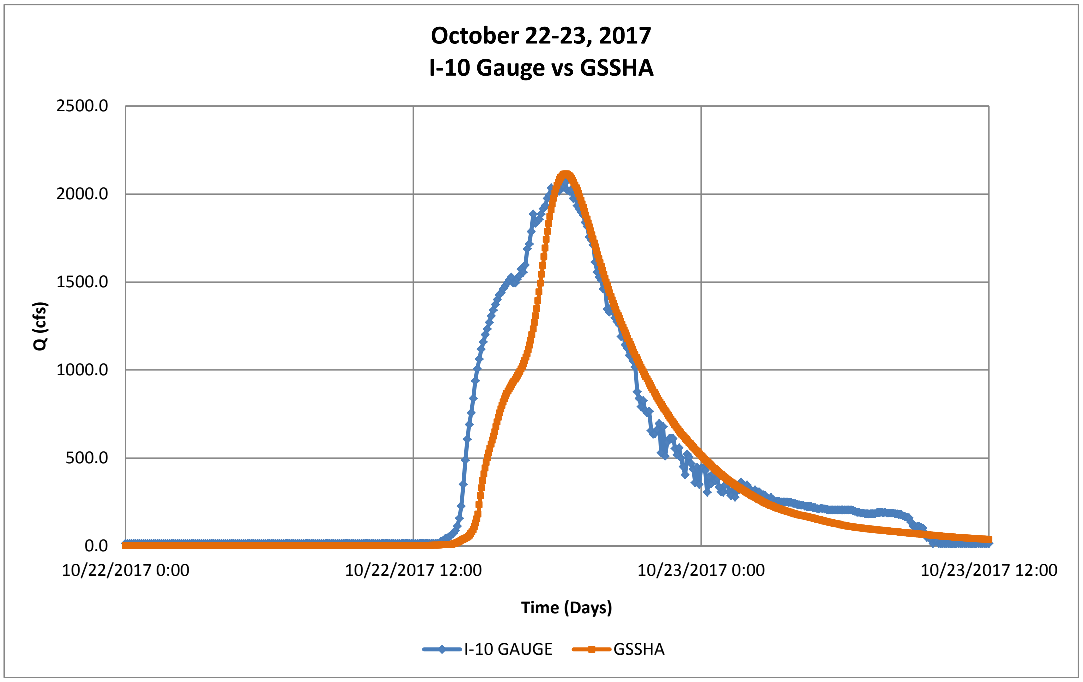


Figure 3-38
October 22-23 - USGS Half Mile Road Calibration with Retention

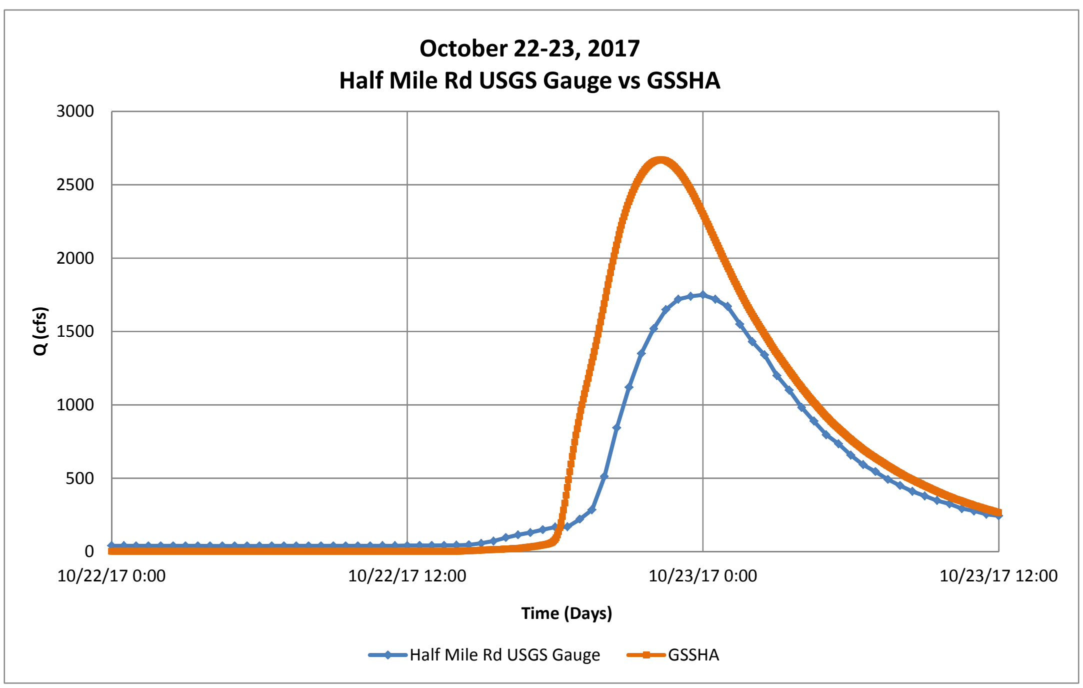
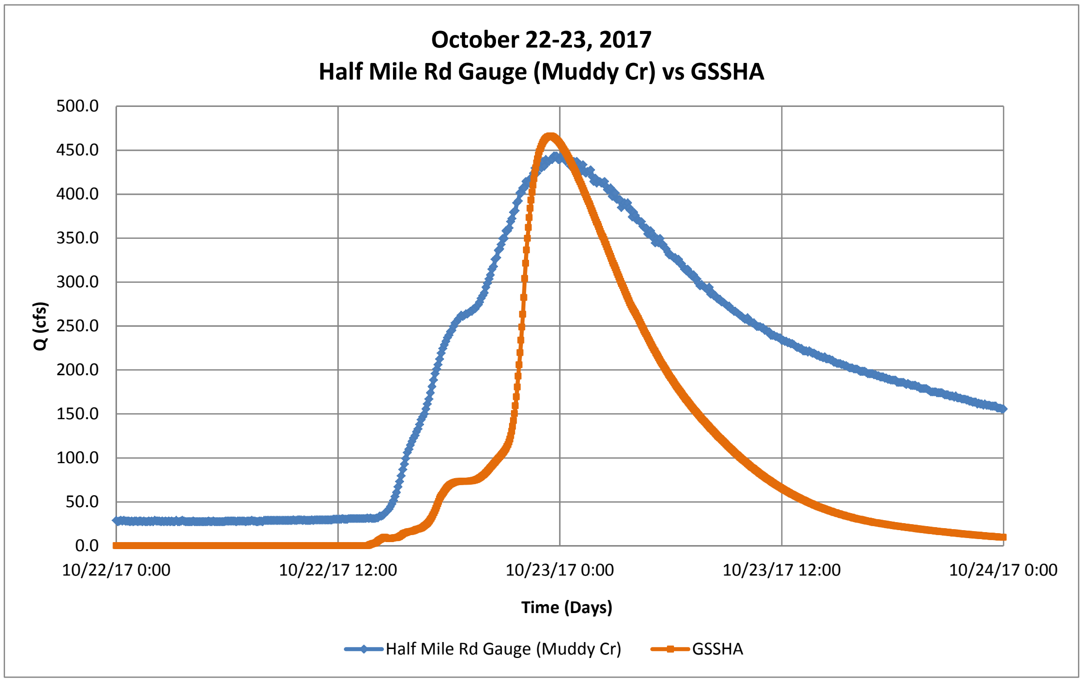


Figure 3-39
October 22-23 - Half Mile Road (Muddy) Calibration with Retention



Using the initial August variables, slight adjustments were made to the model. These include adjusting the initial soil moisture and increasing the retention depth for the loam. The Palmer drought map for the October rain event, indicating the soil moisture condition, can be found below in Figure 3-40. The overall results seem reasonable except at the USGS gauge. The peak discharge from the model is approximately 1.5 times higher and occurs about 2 hours sooner that the measure discharge.

It was determined that there is a significant amount of storage occurring between the I-10 culvert and the USGS gauge on Half Mile Road that cannot be accounted for with retention. A closer look at the model indicates a large amount of tree cover, wetlands, and flatter slopes between I-10 and Half Mile Road. There are also two river crossings between the I-10 and Half Mile Road (Figure 3-41). The first crossing is on Government Blvd and the second is a railroad crossing about 1500' downstream. The FEMA floodplain map indicates that the railroad bridge is a constriction point (Figure 3-41). An aerial image obtained using Bing Bird's Eye view can be found in (Figure 3-42). It appears that there is a significant number of piles and cross bracing which could catch debris that could increase stages and storage.

Figure 3-40
Palmer Drought Map (through Oct 21)

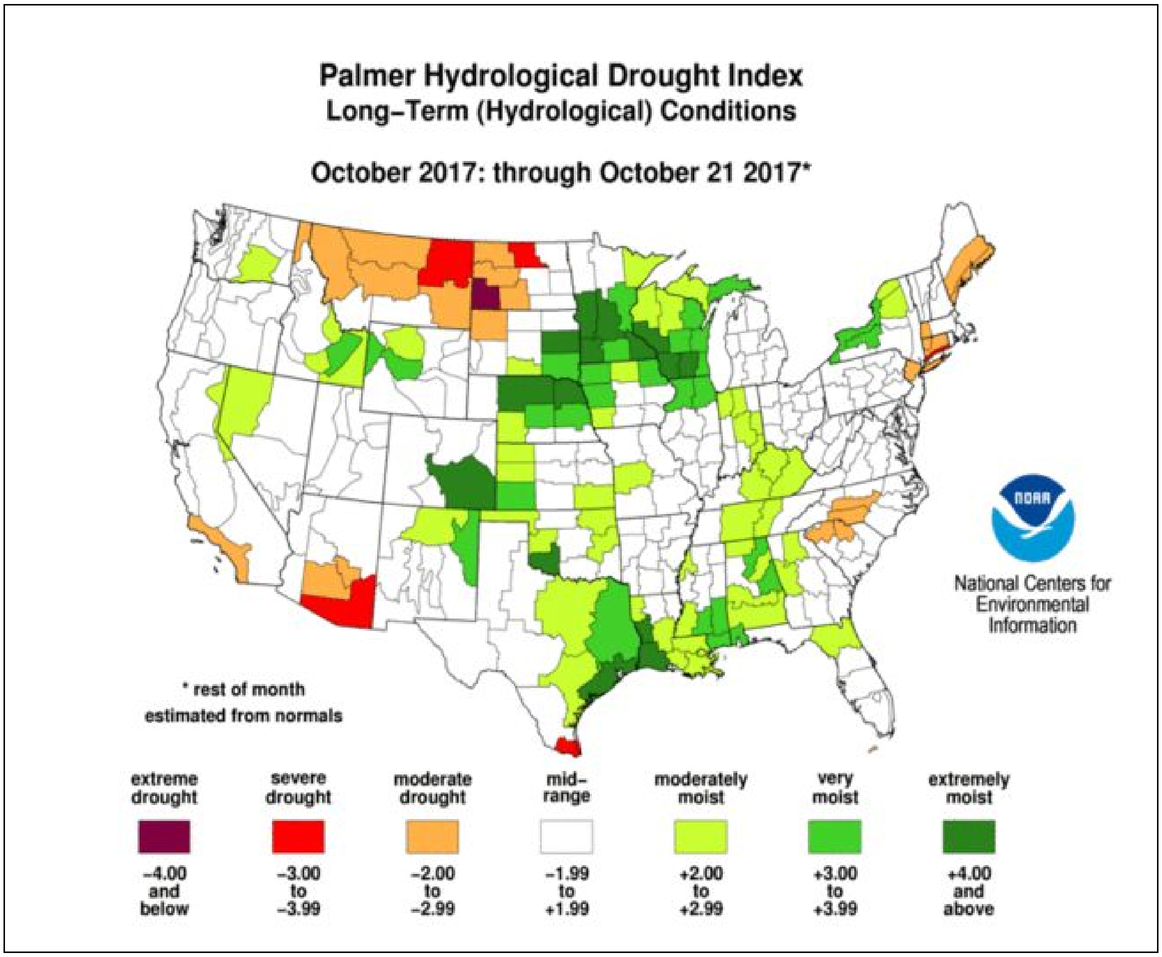


Figure 3-41
FEMA Flood map

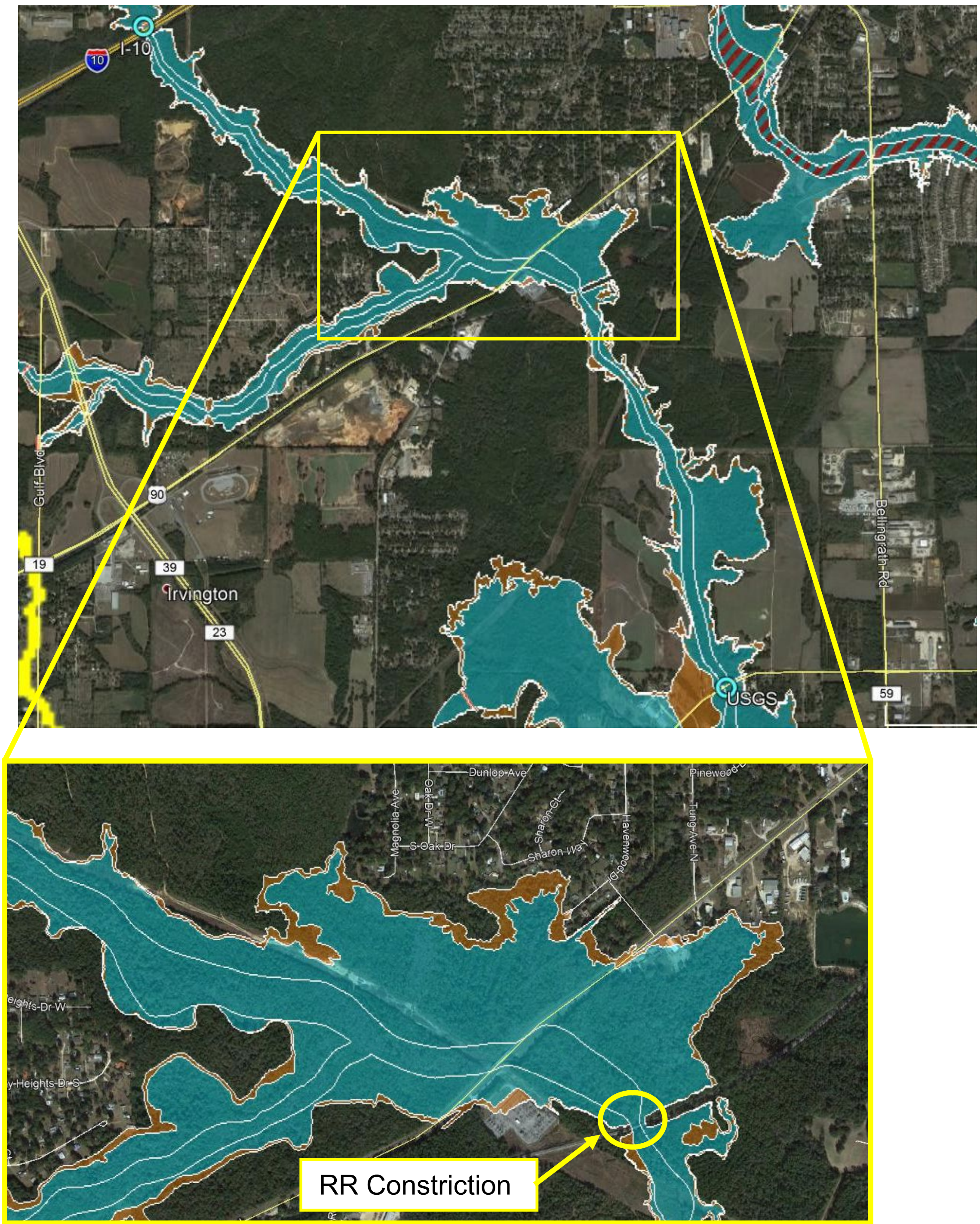
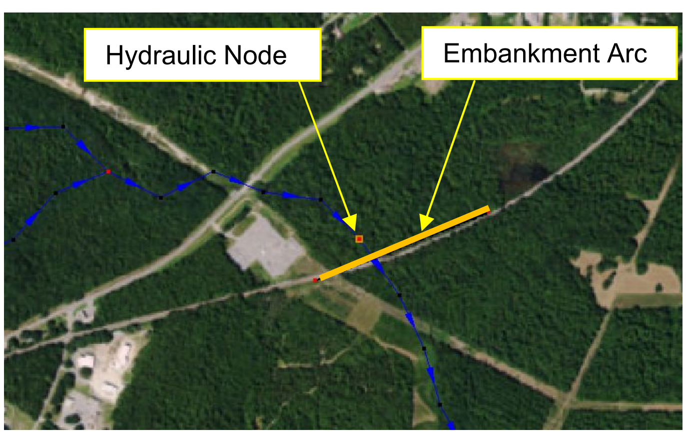


Figure 3-42
Bing Bird's Eye View of Railroad Bridge

The GSSHA model was modified by adding a hydraulic structure that would replicate the storage routing. This was accomplished by adding an embankment arc at the location of the railroad (Figure 3-43). Just upstream of the embankment arc a node was added. Hydraulic structures or rating curves can be added to the node. The model uses the elevation data behind the embankment for the storage volume. Due to the possibility of random debris that could be caught in the piers and cross-bracing of the railroad bridge, an estimate of an equivalent opening was made in order to model the variable head loss. In order to minimize model complexity, a box culvert was used to approximate the hydraulic opening. Various geometries were tested until results were comparable to the measured data.

Figure 3-43
Hydraulic Structure added to GSSHA Model



The newly added structure by itself was not able to provide the sufficient storage routing. An additional modification to the model was made by adding another infiltration grid cell unit (Figure 3-44). This unit was applied to the woodland/ wetland area between I-10 and Half Mile Road in order to represent wetland storage. A large hydraulic conductivity of 25 cm/hr was added to these cells in order to infiltrate more runoff. The results of the updated model can be found in Figures 3-45, 3-46, and 3-47.

Figure 3-44
New Infiltration Cell Unit

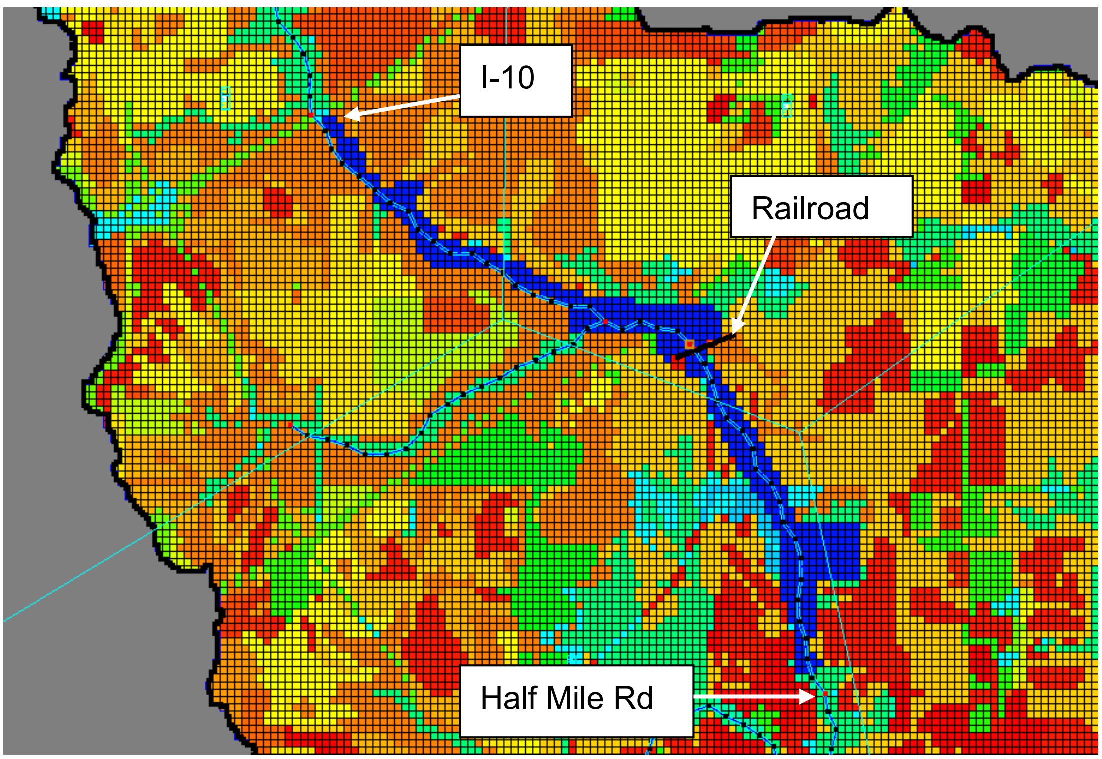


Figure 3-45
October 22-23 - USGS Half Mile Road Retention and Detention

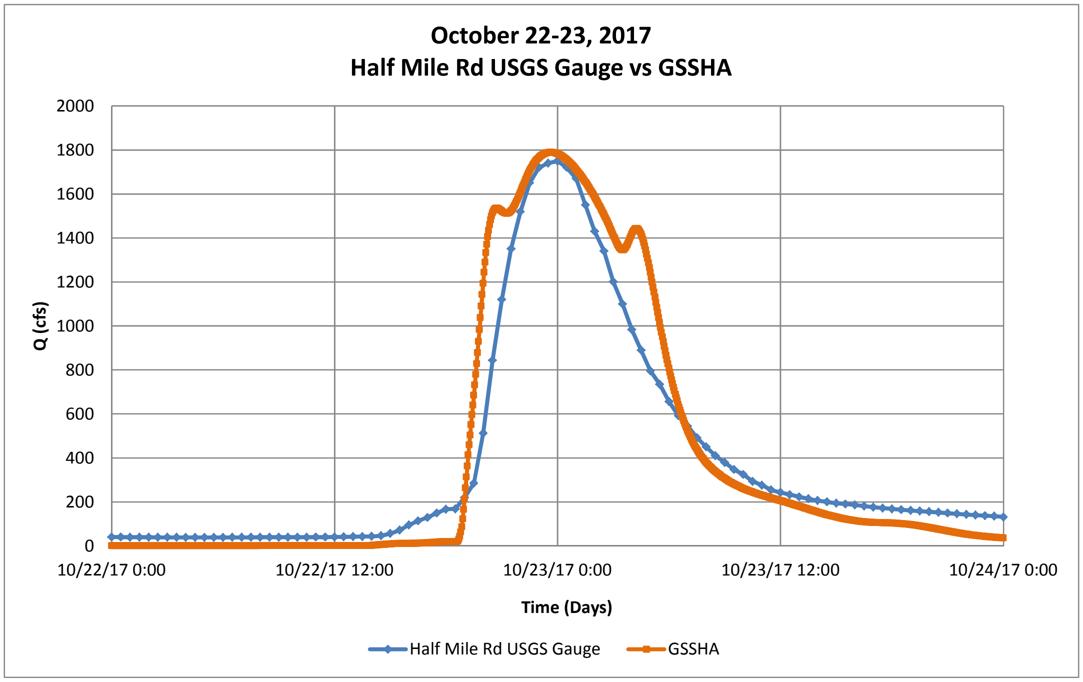


Figure 3-46
October 7-8 - USGS Half Mile Road Retention and Detention

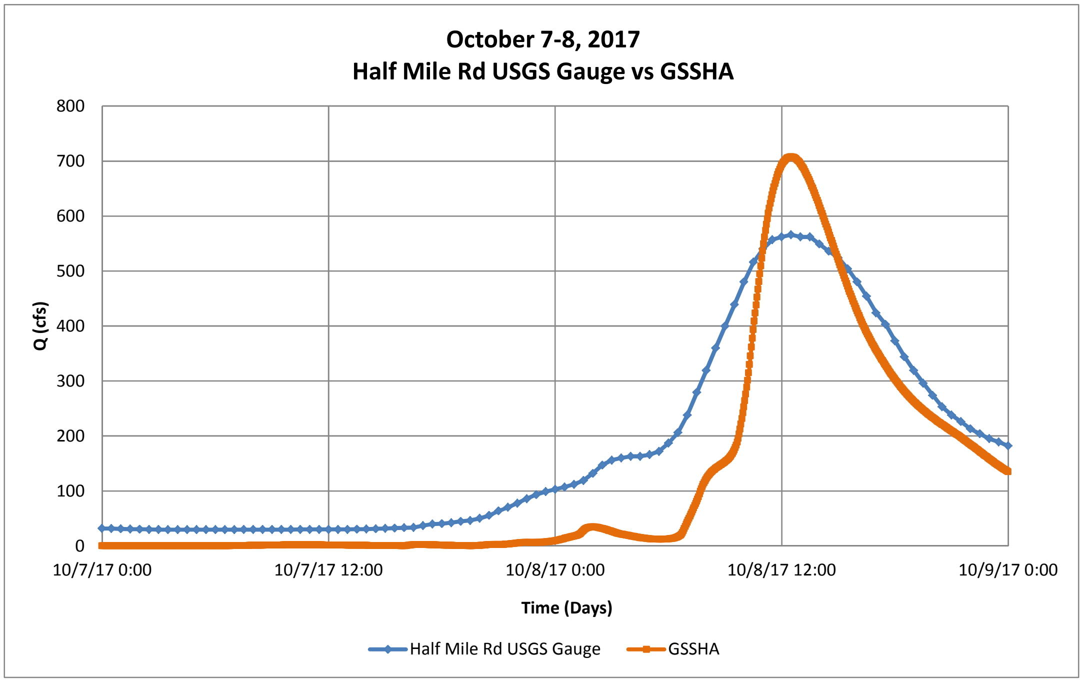
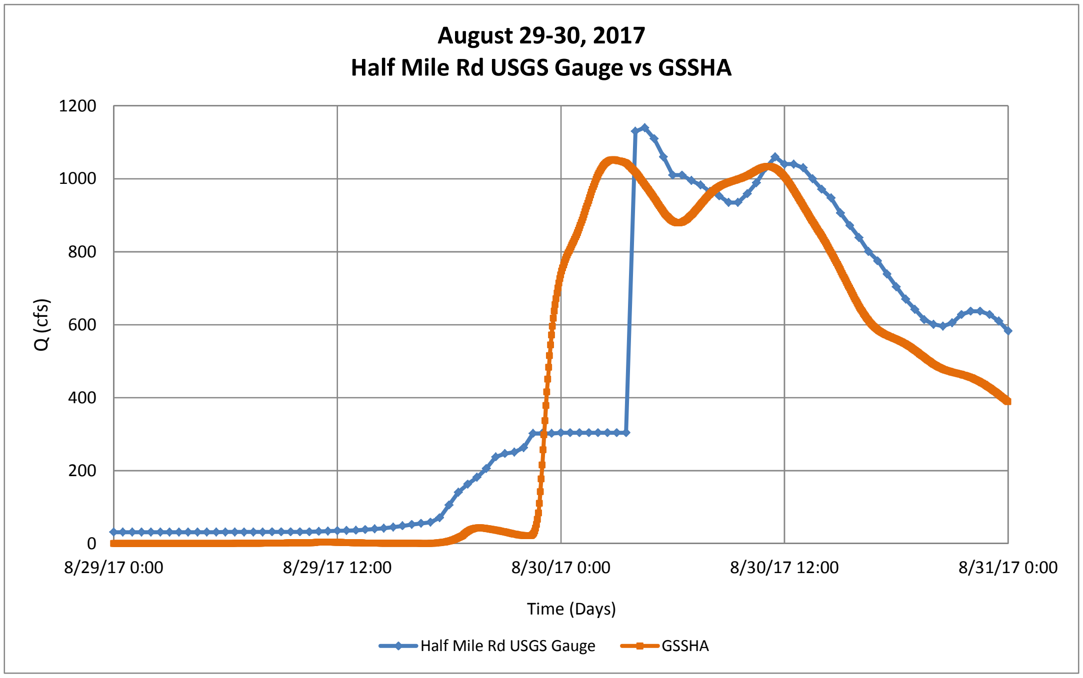


Figure 3-47
August 29-30 - USGS Half Mile Road Retention and Detention

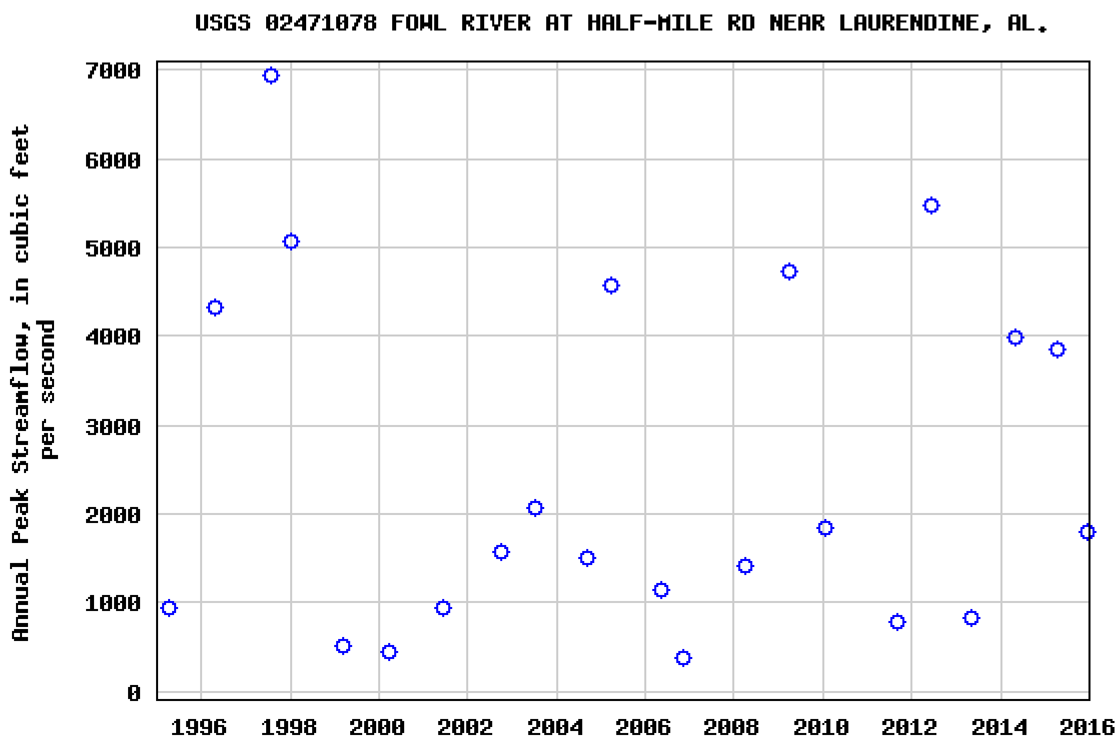


4.1. Fowl River Analysis

After the model was calibrated, the precipitation and rainfall distribution were changed in order to analyze a 5-yr 24-hour storm event. The 5-year 24-hour rainfall amount for the drainage basin was taken from the *NOAA Atlas 14 Point Precipitation Frequency Estimates* website. It was determined the average rainfall amount over the watershed is 7.4 inches or 188 millimeters. The rainfall distribution employed was the SCS Type III distribution.

The annual peak streamflow obtained from https://nwis.waterdata.usgs.gov can be found in Figure 4-1. Using the Region 4 rural regression equations from Magnitude and Frequency of Floods in Alabama, 2003, it was determined that for 16.5 square miles the 5-year discharge is 1,920 cfs.

Figure 4-1
Gauged Discharges on Fowl River at Half Mile Road



After verifying the calibrated model with the 5-year discharges, different scenarios were analyzed to see how the watershed reacted to various land use changes within the basin. Three areas were selected for adding proposed development. These areas were chosen for their location in the watershed as well as their proximity to already developed areas or major arterials that may see future development.

The first scenario consisted of adding development in the very northern headwaters of the watershed. Most of the basin north of Three Notch Kroner Road was converted to residential development (Figure 4-2). This equates to about 0.5 square miles of new development. The second scenario consisted of adding development south of Theodore adjacent to current development (Figure 4-3). Approximately 1 square mile of residential development was added along Muddy Creek. The third scenario was to extend residential development along McDonald Road between I-10 and Government Boulevard. Approximately 0.75 square miles of development (Figure 4-4) were added along the western headwaters of the watershed.

The next set of objectives was to analyze the impacts regional detention may have on reducing increased stormwater generated from the developed land use. These ponds were located downstream of the developments along the main stream to which the developments drain. Fowl River contains many areas of flat, wide floodplains which are ideal for storing water. Routing was performed using LiDAR contour data to determine the storage volumes. Hydrographs were taken from the GSSHA model and entered into HydroCAD for performing storage routing. The routed hydrograph was then entered into a modified GSSHA model and simulated.

Figure 4-2
Residential Development in the Headwaters

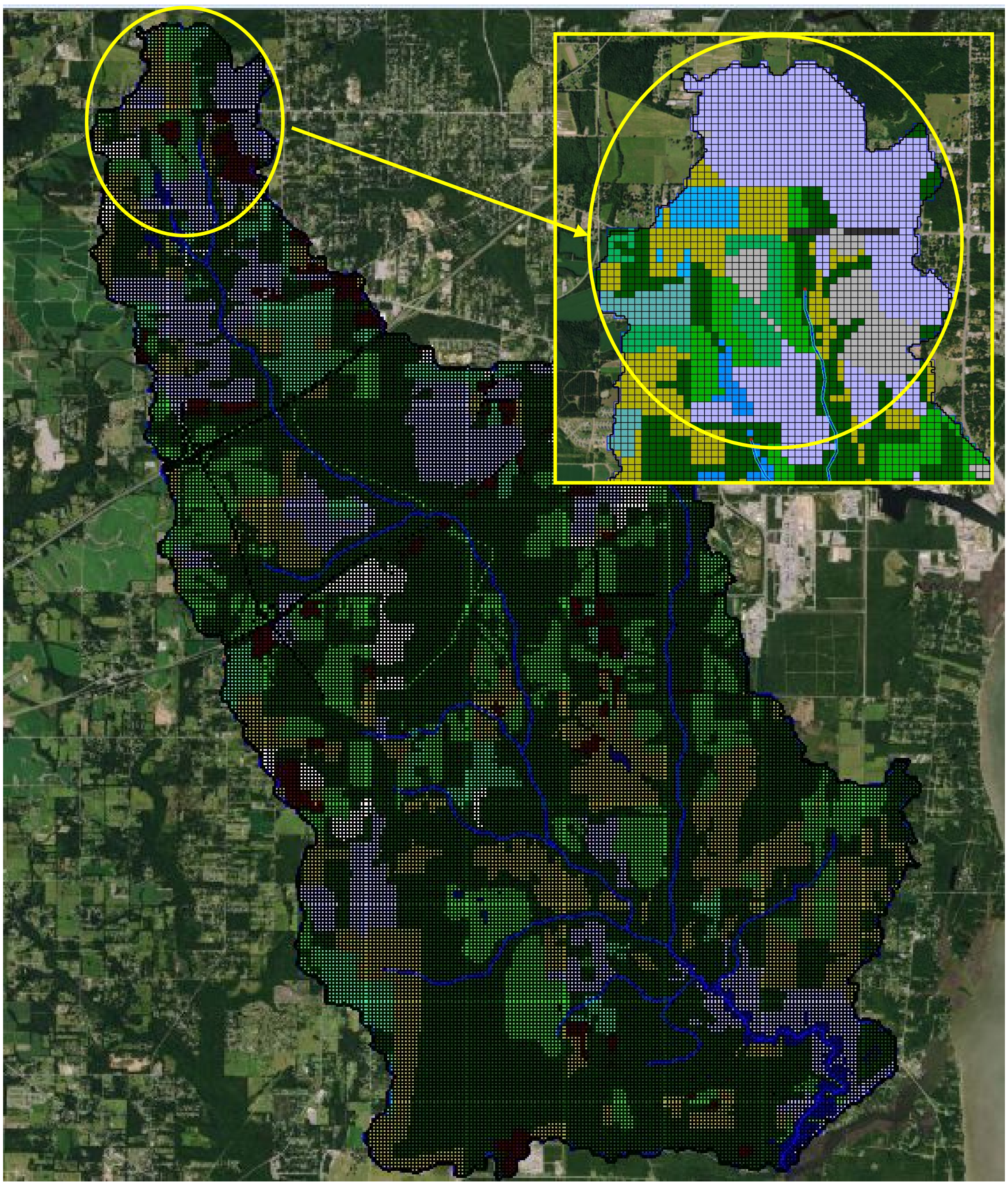


Figure 4-3
Residential Development along Muddy Creek

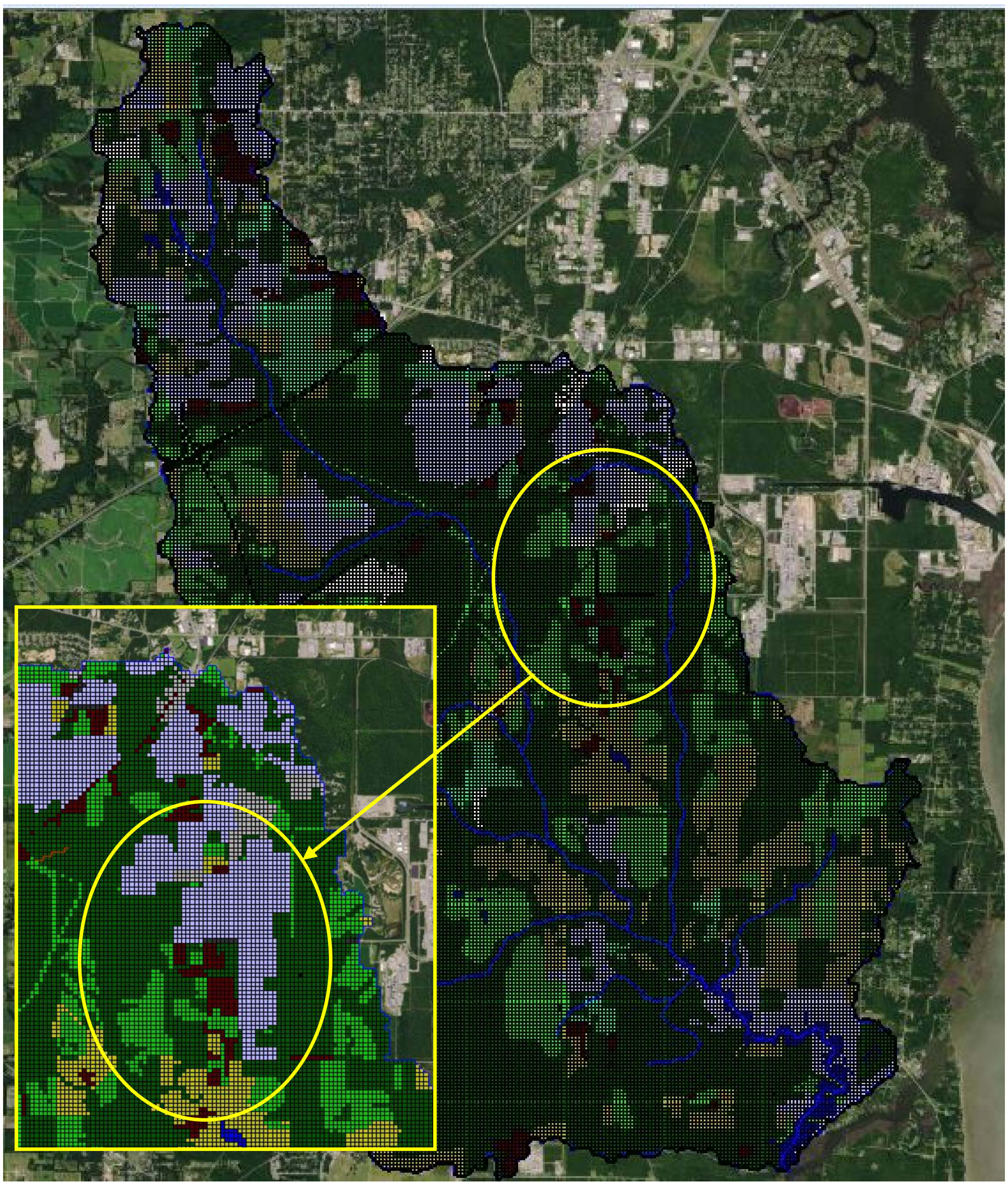


Figure 4-4
Residential Development near Irvington

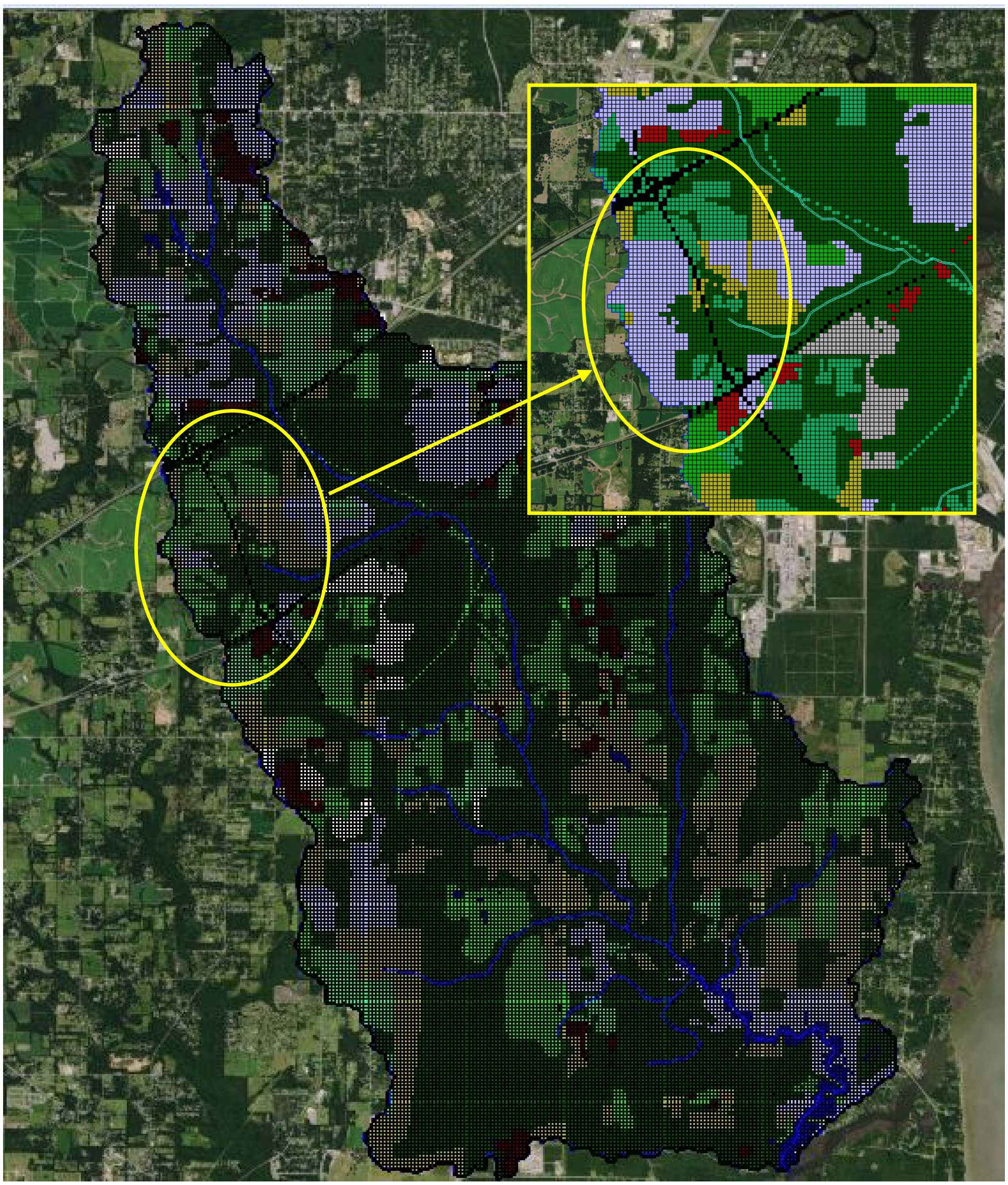


Figure 4-5
Figure indicating location of regional ponds

5. Results and Conclusions

5.1. Results

Results from the multiple analyses indicate that the impact to Fowl River due to increased stormwater from the proposed developments is dependent on the location within the watershed to which the development occurs (Figures 5-1 to 5-19). Results from the multiple analyses of the regional detention ponds indicate that the most effective regional pond placement occurs in the upper part of the watershed on Fowl River. The addition of this pond will attenuate and delay the occurrence of the peak discharge. This change in hydrograph timing can be beneficial in maintaining existing discharges along the reach of Fowl River downstream of the pond. The effect of the pond will diminish downstream due to the addition of drainage area.

The Irvington Pond and the Muddy Creek Pond have both positive and negative impacts. While these ponds are able to offset the increases associated with land use changes, the benefit is only applicable to the local stream on which they are built. When the flow reaches the confluence with Fowl River, the results indicate a slight increase in peak discharge. This is due to the change in timing of the hydrograph. With the addition of ponds, the timing of the peak discharge is delayed, causing it to occur closer to the peak discharge along Fowl River. The cumulative effect is a higher total peak discharge once the two hydrographs merge. Looking at the results of the scenario where all three areas have been developed, it can be seen that there is an increase at the outlet for both the developed condition and the developed condition with ponds included.

If regional ponds are not to be implemented, further considerations should be given to the local streams downstream of any future undetained developments. Although the discharges on Fowl River will not have a negative impact, there will be increased discharge along the local streams. These increased discharges may lead to accelerated in-stream erosion. Stormwater control measures would need to be implemented to arrest any potential erosion issues. Traditional local detention ponds can be utilized to control the smaller more frequent bank forming events. These ponds can help guard against possible stream degradation that would occur with increased runoff.

Figure 5-1
Headwater Development Discharges at Pond Outlet

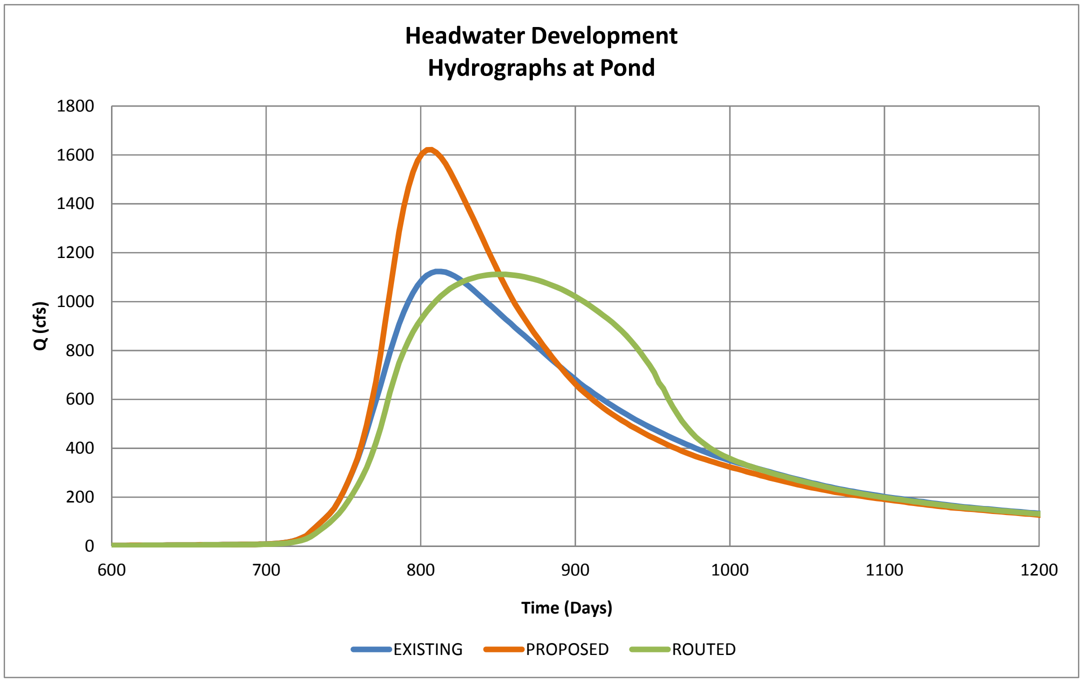


Figure 5-2
Headwater Development Discharges at I-10

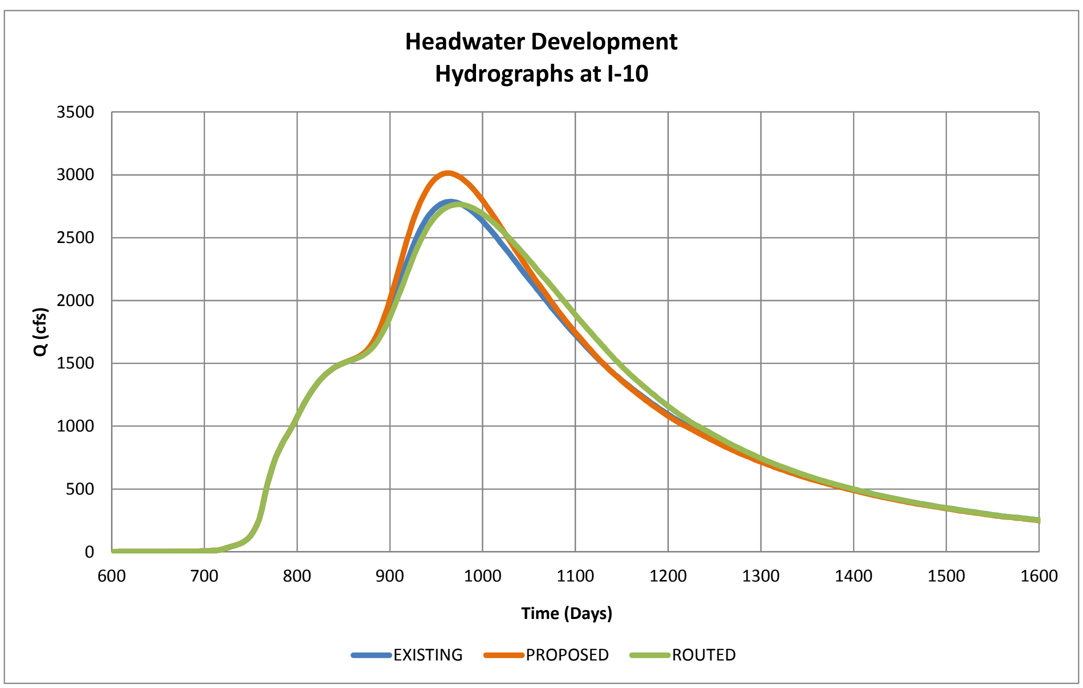


Figure 5-3
Headwater Development Discharges at Half Mile Road

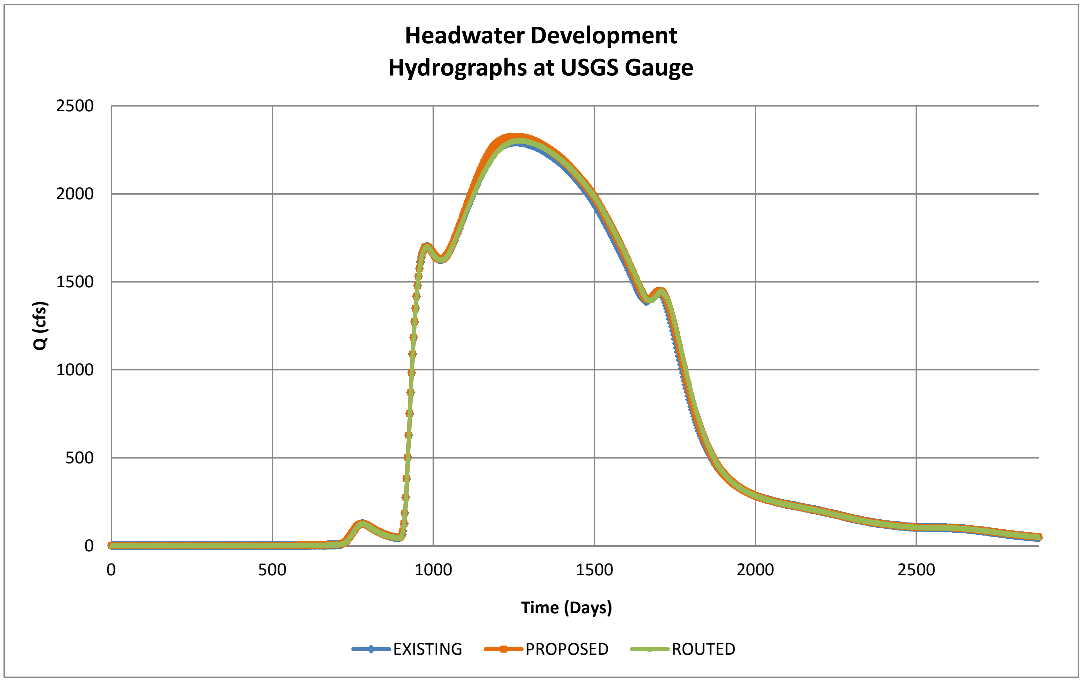


Figure 5-4
Headwater Development Discharges at Half Mile Road (Zoom)

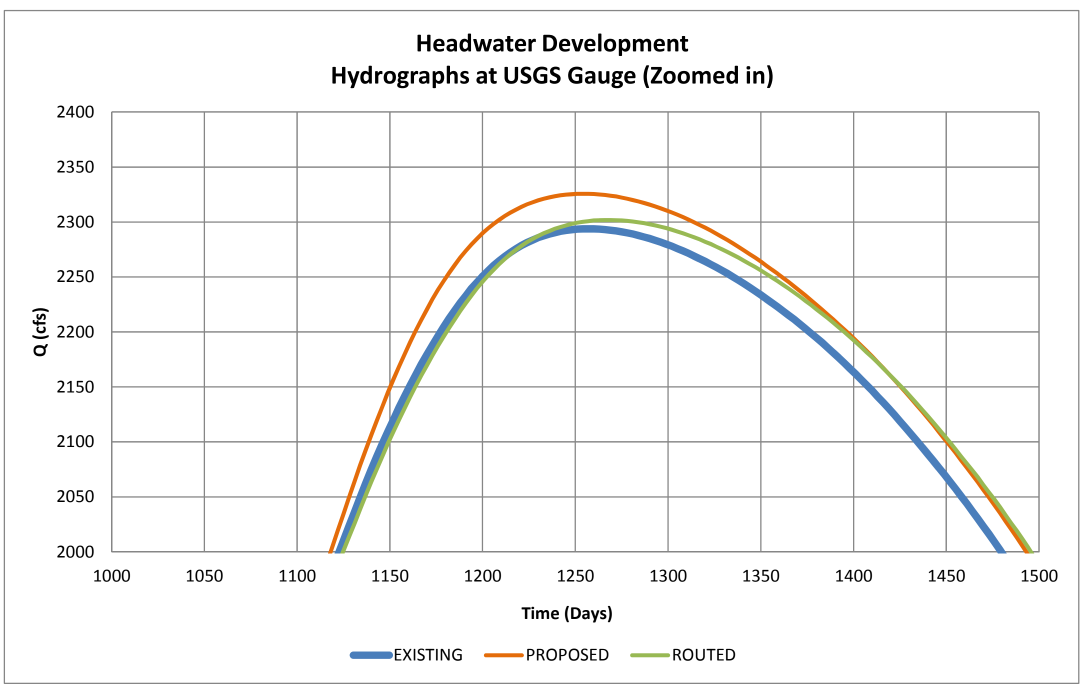


Figure 5-5
Headwater Development Discharges at Watershed Outlet

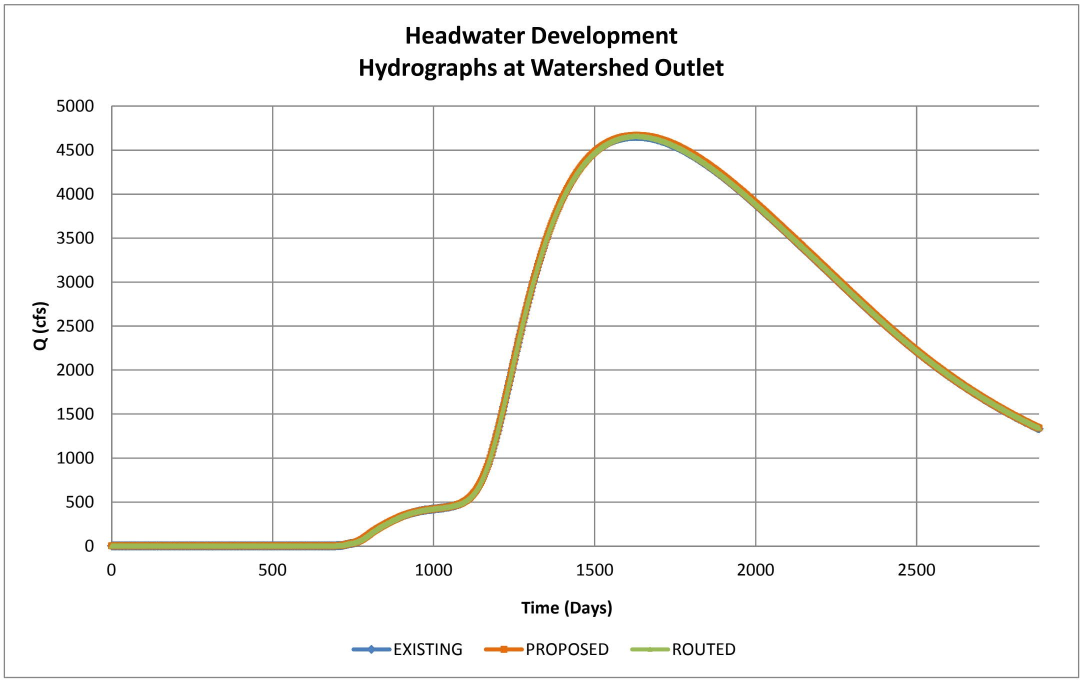


Figure 5-6
Headwater Development Discharges at Watershed Outlet (Zoom)

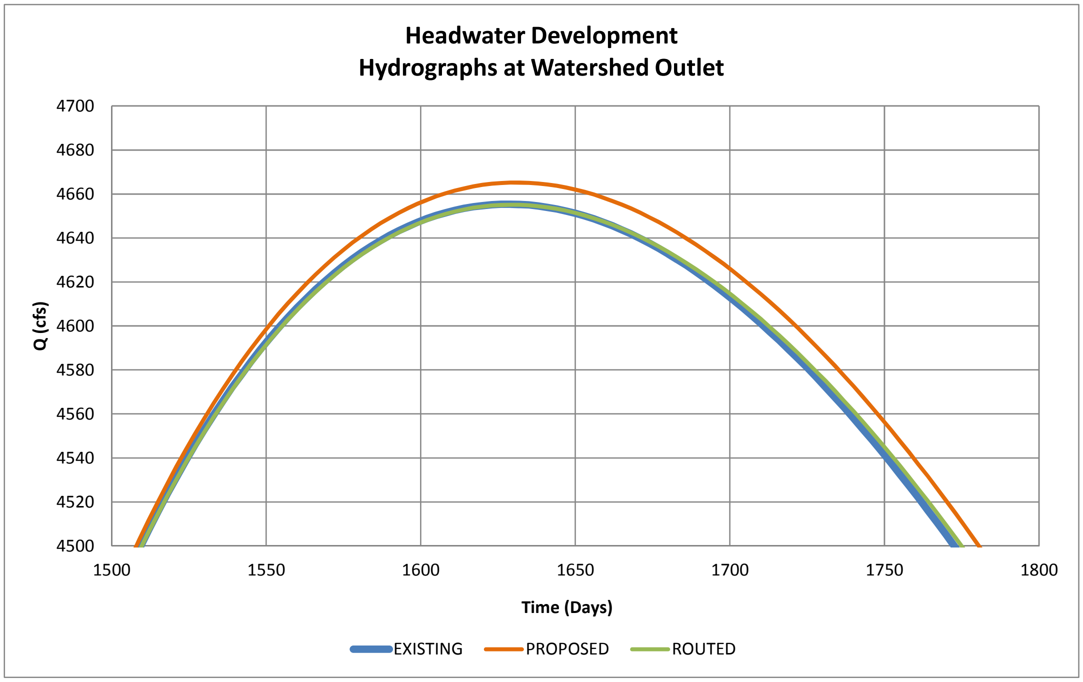


Figure 5-7
Irvington Development Discharges at Pond Outlet

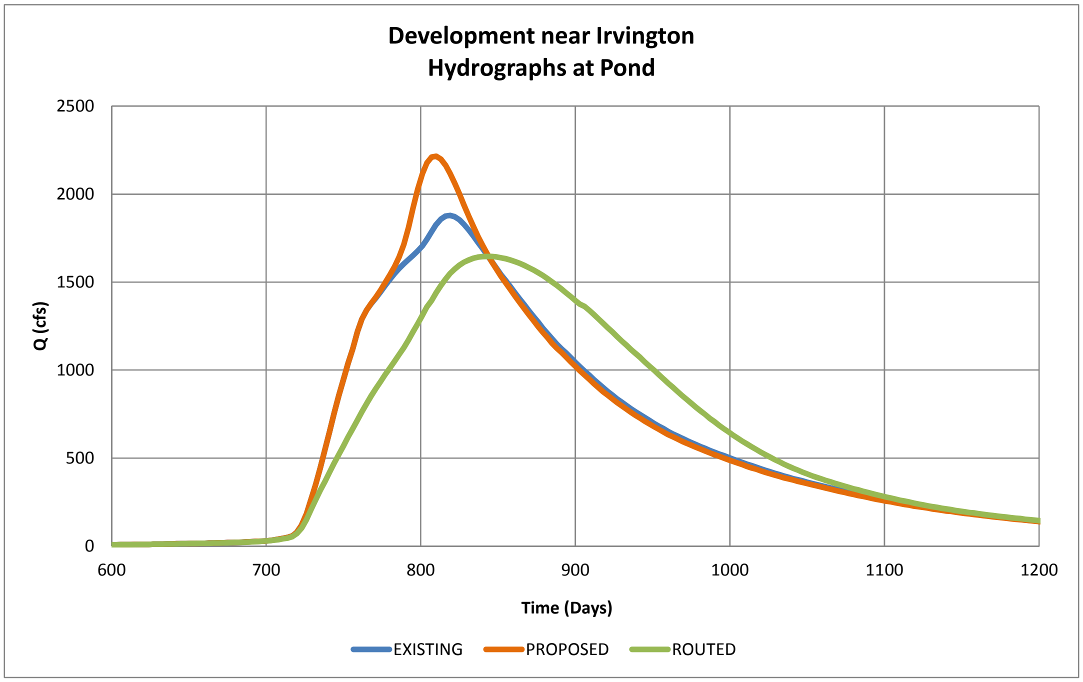


Figure 5-8
Irvington Development Discharges at Half Mile Road

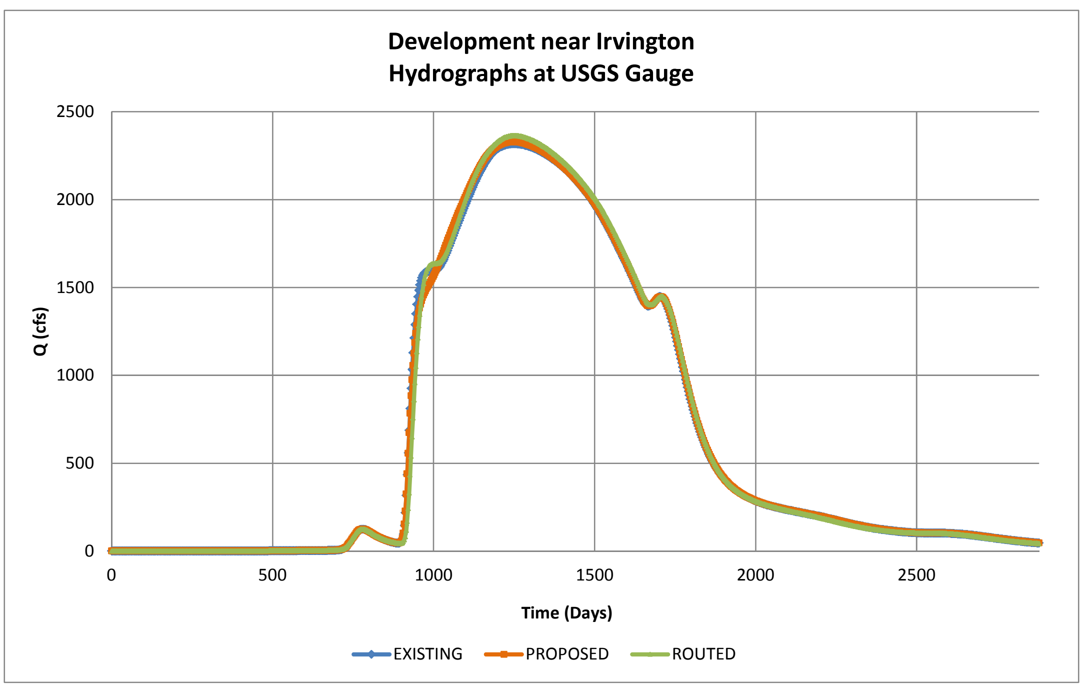


Figure 5-9
Irvington Development Discharges at Half Mile Road (Zoom)

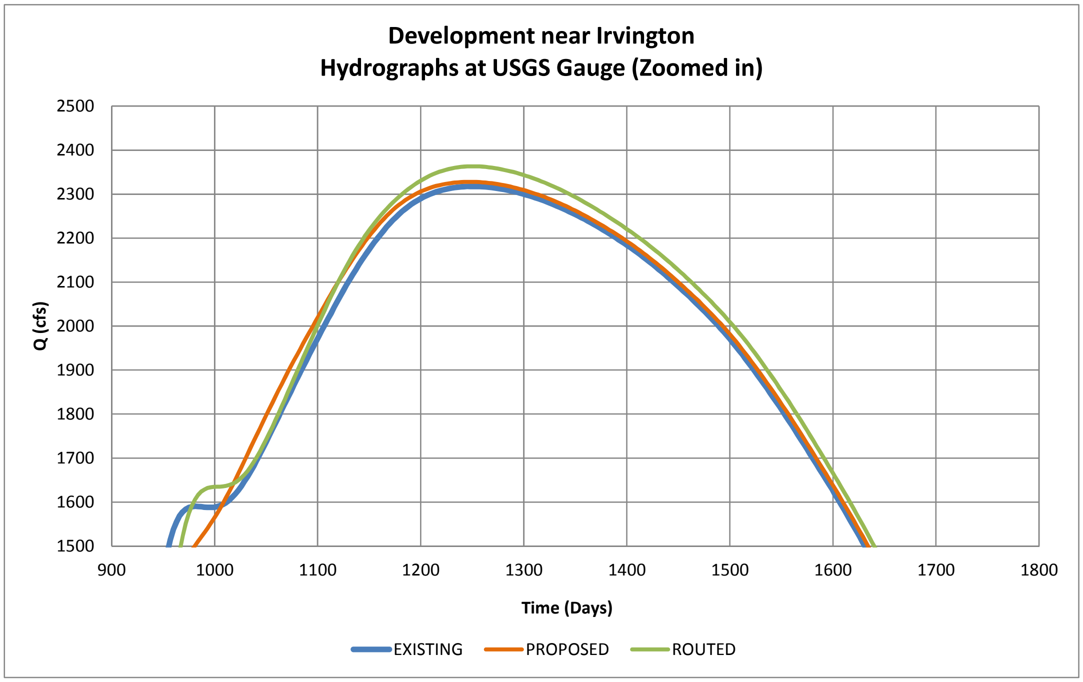


Figure 5-10
Irvington Development Discharges at Watershed Outlet

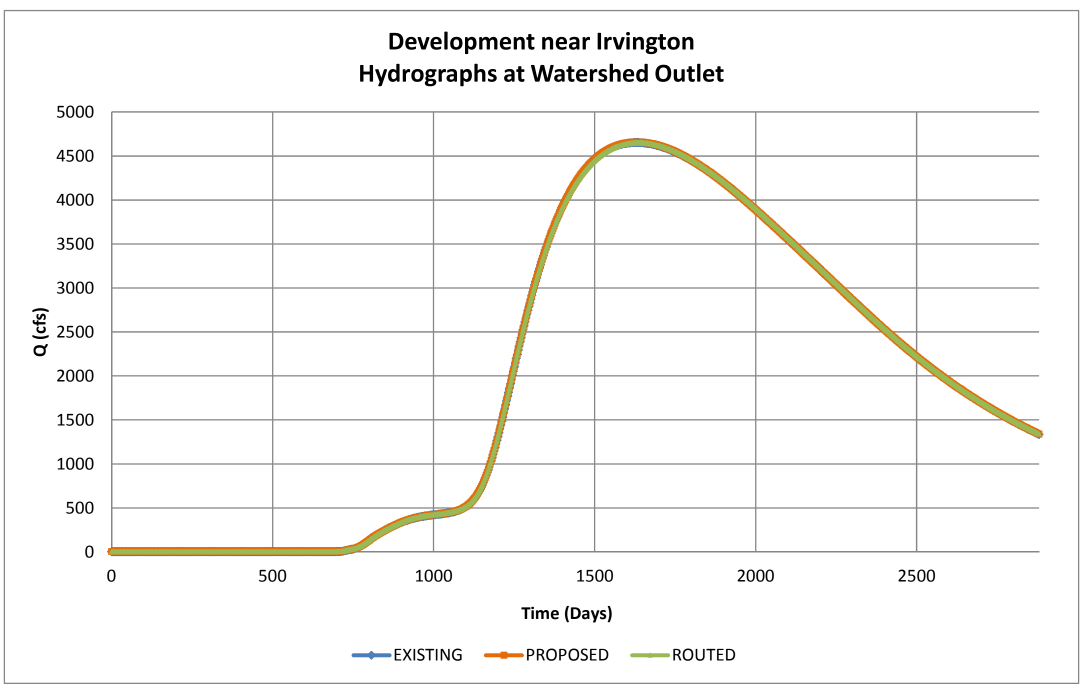


Figure 5-11
Irvington Development Discharges at Watershed Outlet (Zoom)

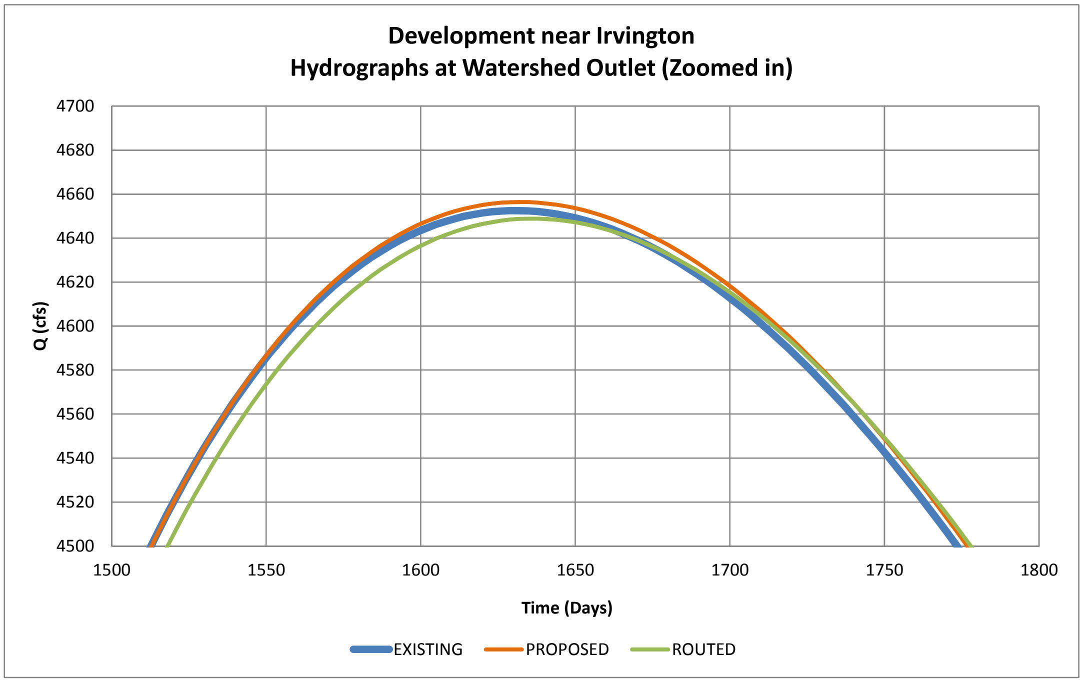


Figure 5-12
Muddy Cr. Development Discharges at Pond Outlet

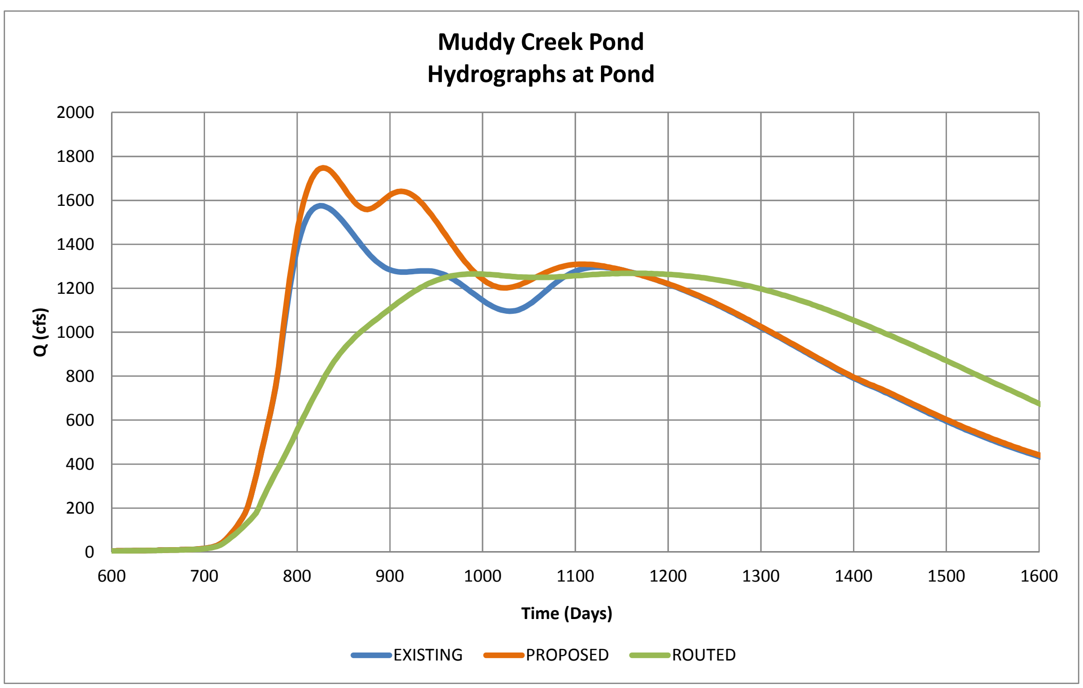


Figure 5-13
Muddy Cr. Development Discharges at Watershed Outlet

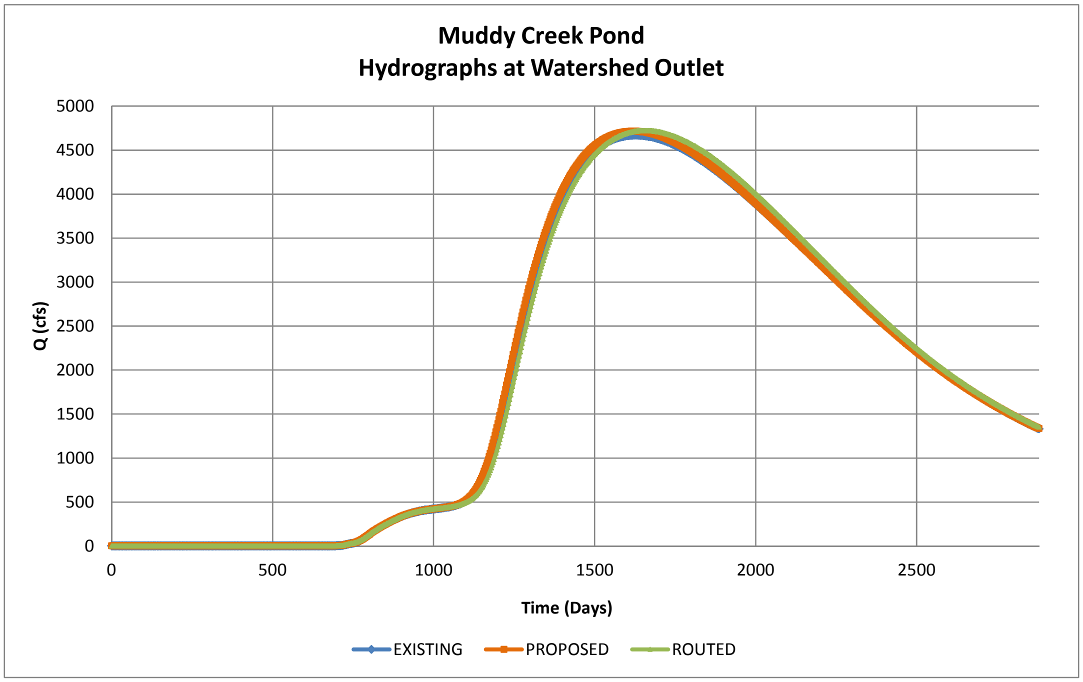


Figure 5-14
Muddy Cr. Development Discharges at Watershed Outlet (Zoom)

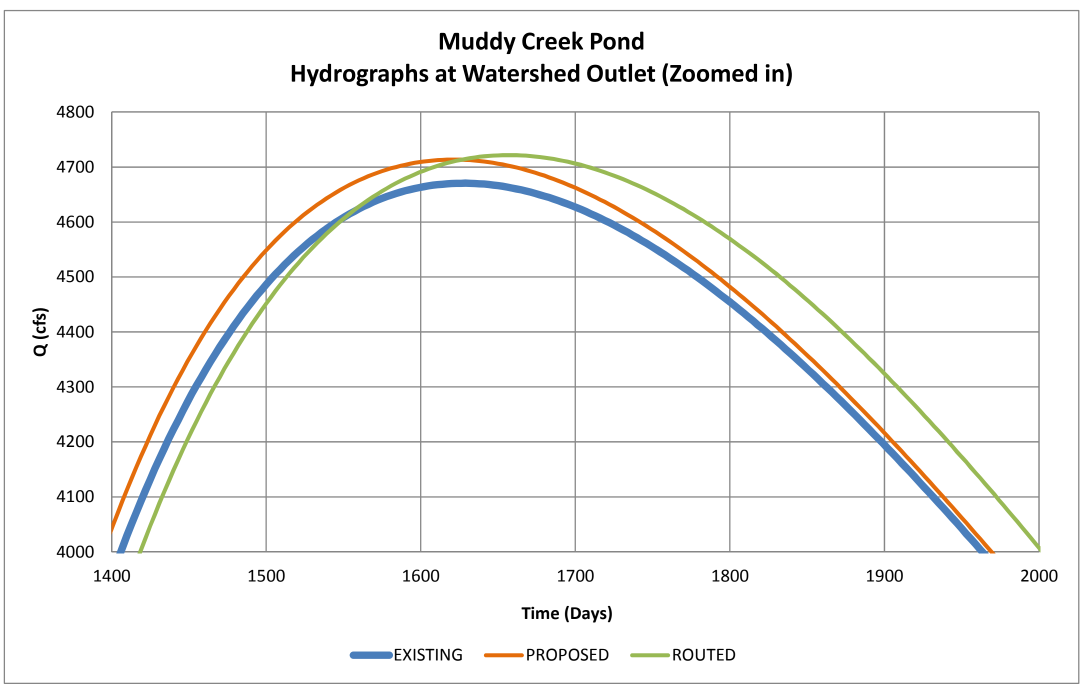


Figure 5-15
All Development Discharges at I-10

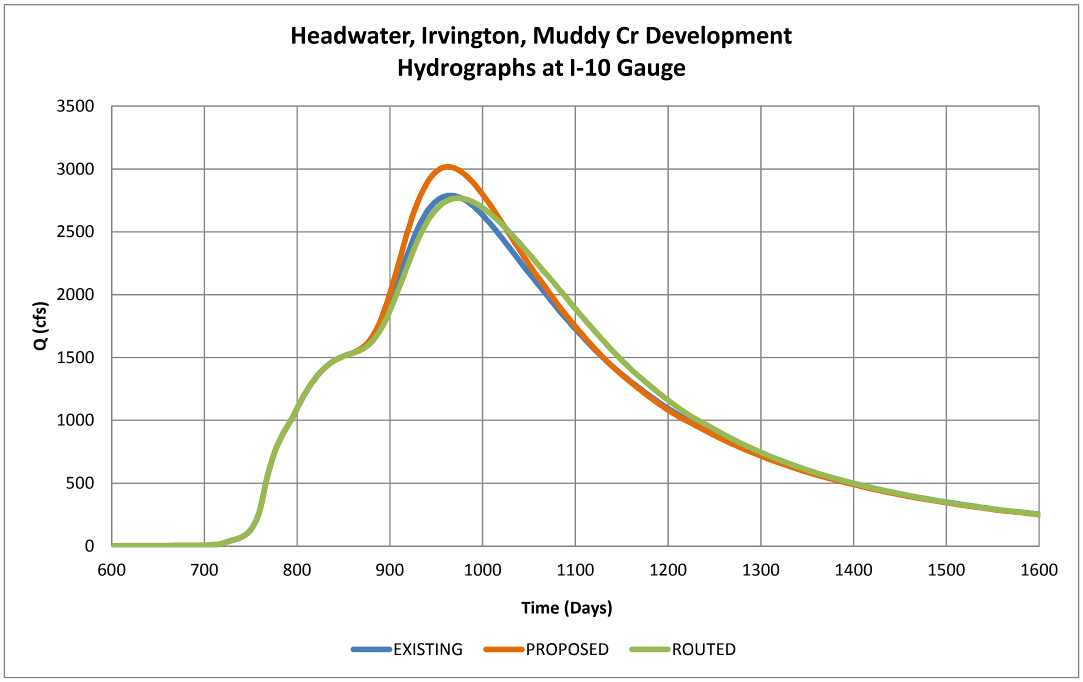


Figure 5-16
All Development Discharges at Half Mile Road

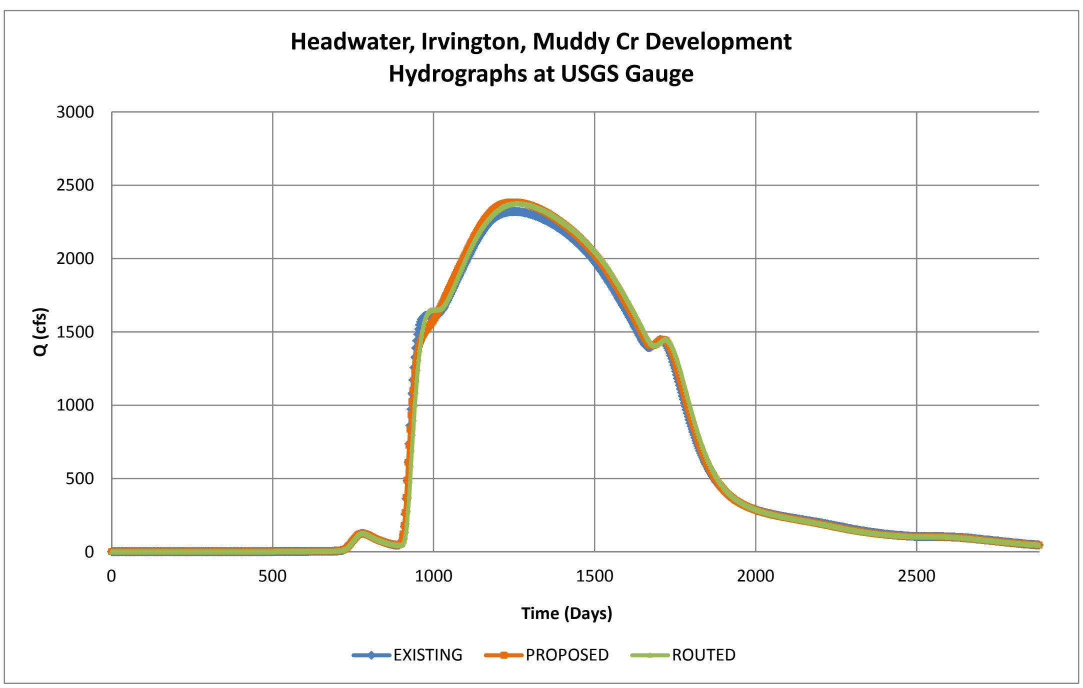


Figure 5-17
All Development Discharges at Half Mile Road (Zoom)

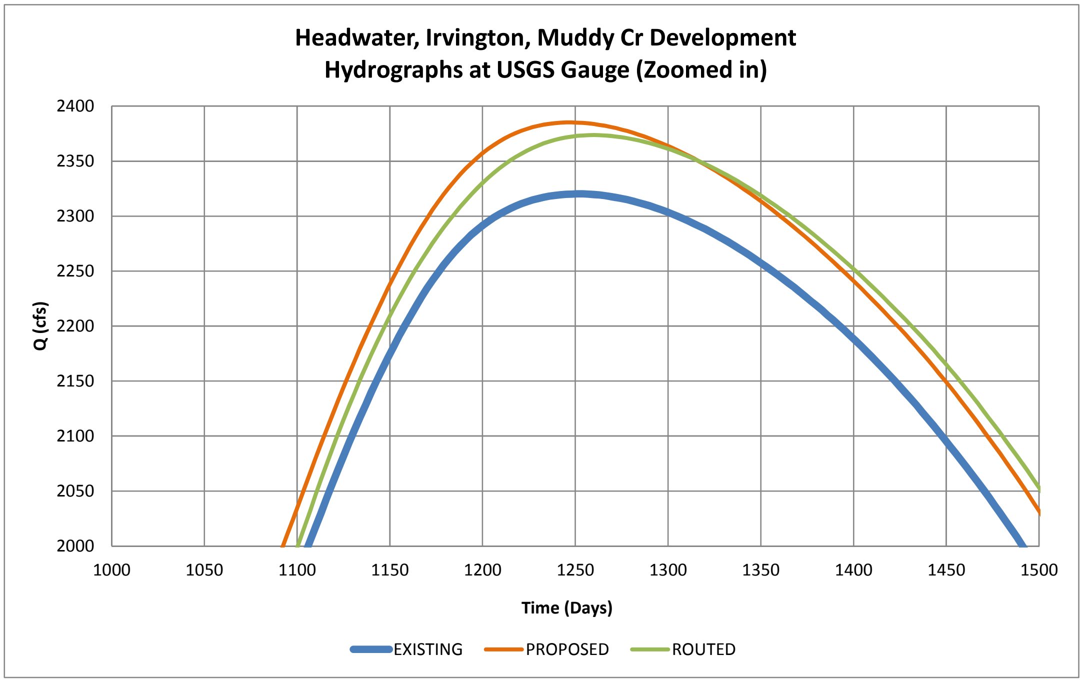


Figure 5-18
All Development Discharges at Watershed Outlet

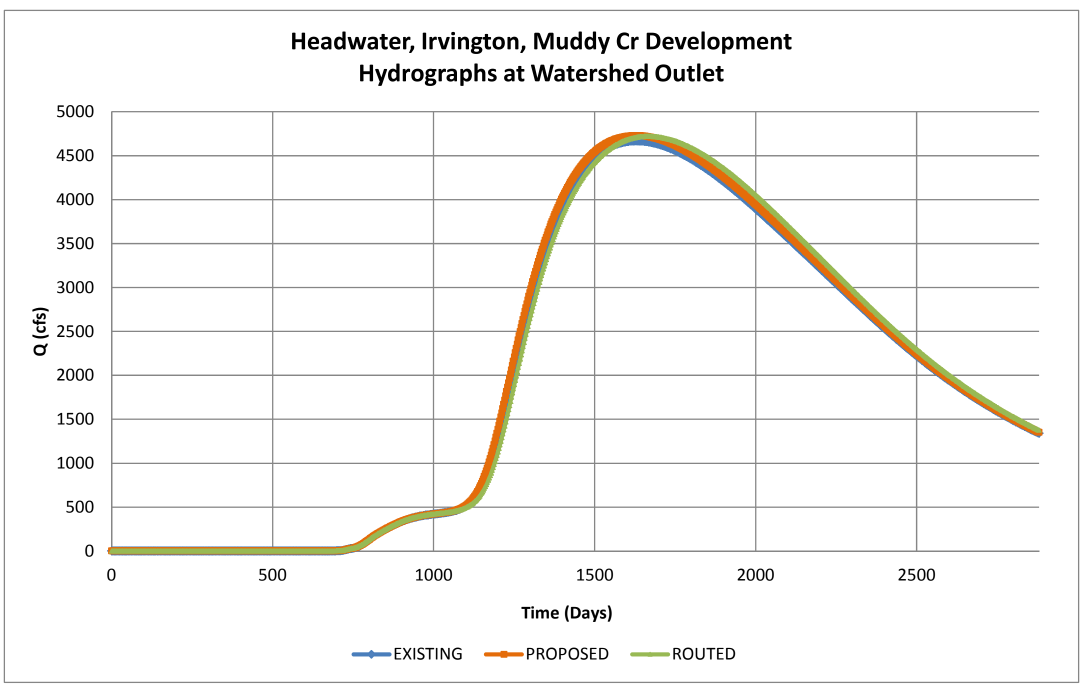


Figure 5-19
All Development Discharges at Watershed Outlet (Zoom)

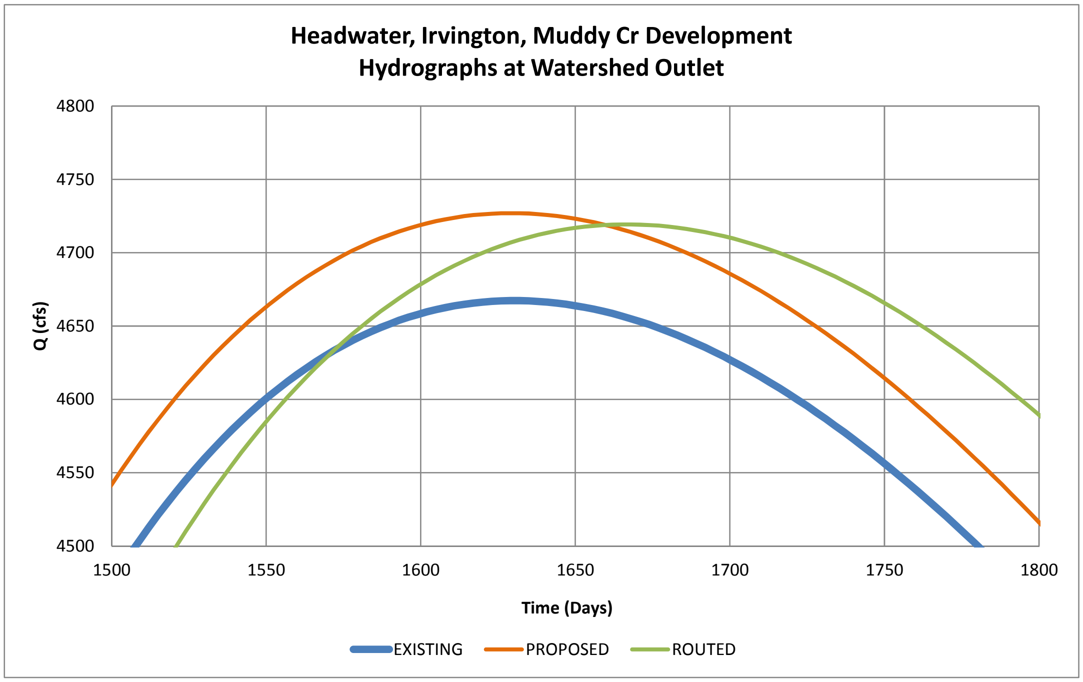


Table 5-1
Fowl River Watershed Summary of Discharges

SCENARIO		I-10	Half Mile Road	Outlet
Existing Conditions		2,790	2,320	4,660
Headwater Developed		3,010	2,330	4,670
Headwater Developed with Pond		2,760	2,300	4,660
Irvington Developed		*	2,330	4,660
Irvington Developed with Pond		*	2,360	4,650
Muddy Cr. Developed		*	*	4,710
Muddy Cr. Developed with Pond		*	*	4,720
All Developed		3,010	2,390	4,730
All Developed with Ponds		2,760	2,380	4,720

* Location upstream of development. Discharges not affected by development.

5.2. Conclusions

After analysis of the four rainfall events that occurred between June and October, it has been determined that there is enough storage area within the watershed to compensate for the current development in the watershed. Storage occurs in the headwater of the basin in the form of manmade ponds located near the intersection of McDonald Road and Belmont Park Drive. South of Government Boulevard the topography starts to flatten and forested areas and wetlands begin to be more prominent. The railroad bridge just south of Government Boulevard appears to act as a control structure allowing for detention-like routing to occur.

For rainfall events up to a 5-year recurrence interval, the discharges in the basin at the three monitoring points are more comparable to rural discharges than urban. Table 5.2 lists the urban and rural discharges for the drainage areas at I-10, Half Mile Road, and at the outlet. Comparing these to the calculated discharges listed in Table 5.3, it can be seen that for the most part, a 2-year or 5-year rain event will produce a 2-year or 5-year discharge for a rural basin.

There is a significant amount of storage occurring between I-10 and Half Mile Road. Looking at Table 5.1, the discharges at Half Mile Road are less than the discharges at I-10 during the two October rainfall events. For the other two events, there is only a 15 – 35% increase in discharge even though the drainage area at Half Mile Road is more than double than that at I-10. The current ponds in the headwaters coupled with wetland storage keeps the discharges at I-10 closer to rural discharges than urban.

It should be noted that these conclusions are based upon rainfall events that have not exceeded a 5-year recurrence interval. It is possible that during larger storm events (25- to 100-year) storage through retention and local ponds could be significantly reduced and the discharges will be more in line with the urban regression equations. It is also unknown how the railroad bridge will behave in regard to routing during a much larger rainfall event.

Table 5-2
Fowl River Watershed Summary of Discharges

I-10				Half Mile Road (Half Mile Rd)				Outlet*	
Year	Urban Q	Rural Q		Year	Urban Q	Rural Q		Year	Rural Q
	PD=36%	Region 4			PD=27%	Region 4			Region 4
2	1480	660		2	2160	1010		2	2120
5	2480	1180		5	3810	1810		5	3810
10	3140	1600		10	4870	2450		10	5140
25	3900	2200		25	6070	3370		25	7010
50	4470	2710		50	6950	4120		50	8540
100	5050	3260		100	7840	4960		100	10250

* PD=16% at the outlet. The minimum PD required for using the urban equations is 20%.

Table 5-3
Fowl River Watershed Summary of Discharges

Rain Event (Date)	Rain (inches)	Duration (hour)	Recurrence Interval (year)	I-10 Q (cfs)	CR24 Q (cfs)	Outlet Q (cfs)
June 20-21	6	24	2	730	1000	1740
Aug 29-30	7-8	24	5	980	1140	3090
Oct 7-8	5	12	2	960	570	950
Oct 22-23	5-6	6	5-10	2060	1750	1610

Results also indicate that the most effective area for a regional pond is along Fowl River itself. Since there are existing ponds within the watershed near the headwaters, these ponds could possibly be retrofit to provide additional storage if future development occurs within the headwaters of the watershed.

The ponds located on the edges of the watershed help with local discharge increases, but cause a slight negative impact on Fowl River itself. The discharge differences along Fowl River from utilizing regional ponds versus undetained flow are less than 1% for the small storm events analyzed. Further analysis would need to be performed locally to determine if any undetained property would cause increased flooding on adjacent properties, or cause other impacts such as stream erosion and degradation. In such cases it may be necessary to install local detention to safeguard property and streams.

For smaller rain events (< 5-yr), 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 smaller local sub-basin level analysis, hydrographs can be developed from outside modeling software and reintroduced back into the GSSHA model to determine possible impacts.

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 storage capacity during larger events. Gauges have been left in the watershed to gather larger events that may occur in 2018.

6. References

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