Baldwin County Commission

& Highway Department

322 Courthouse Square
Bay Minette, Alabama 36507

Fish River & Magnolia River Watershed Study

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Prepared By:

HYDRO ENGINEERING SOLUTIONS, LLC

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

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1. Executive Summary

The study on the Fish River and Magnolia River watersheds was performed to gain an understanding of each watershed and determine their sensitivity to land use changes in areas expecting growth in the near future. The information obtained can be used for future stormwater planning and management. The study was accomplished by looking at the basins as a whole and identifying areas were detention may or may not be needed. 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 Fish and Magnolia River watersheds indicate that undetained development in the headwaters of the watershed cause a greater impact to the peak discharges on the river than those in the lower part of the basin. For the Fish River watershed, a regional pond on Corn Branch below Loxley and a pond on Fish River below Turkey Branch provide regional stormwater management benefits. Analysis for the Magnolia River watershed indicates that the regional ponds examined have a minimal impact on reducing existing discharges, and therefore could not be used for allowing future developments to be undetained.

The study finds that with the addition of the two aforesaid ponds in the Fish River watershed, regions around the areas of Fairhope, Belforest, and Silverhill-Robertsdale area can be left undetained and cause no increased impact on Fish River. Local streams experiencing increased discharges from the undetained areas must be examined further to ensure there is no stream degradation or increased flooding of adjacent property owners. For Magnolia River, the proximity of subdivisions and individual property owners near the examined pond locations restrict the ability to construct a regional pond large enough to reduce peak discharges.

Measures presented in this report are a solution to one conservative scenario. For actual future developments, the calibrated GSSHA model can be used as a dynamic management tool in which to analyze the impacts of these developments. Further studies outside of the model can also be performed on a smaller sub-basin level and then reintroduced back into the calibrated model to determine any possible impacts.

2. Introduction

2.1. Description

Fish River and Magnolia River are coastal rivers located in southwest Baldwin County, AL. Both rivers drain into Weeks Bay that ultimately drains into Mobile Bay (Figure 2-1). The southern end of the rivers experience daily tidal fluctuations with about 2 feet of change. The Fish River watershed drains 152 square miles to US HWY 98 just above Weeks Bay. The Magnolia River watershed drains 41 square miles to Weeks Bay. Cities on the outer extents of the Fish River watershed included Stapleton to the north, Robertsdale to the east, and Fairhope to the west. SR 59 acts as the drainage divide for most of the east side of the drainage basin. There are approximately 9 miles of navigable water that lies mostly between CR 32 to the north and US HWY 98 to the south. For the Magnolia River watershed Foley is located at the eastern headwaters with Magnolia Springs being located near the mid-western portion of the basin. Magnolia River has recently been classified as an Outstanding Alabama Water.

2.2. Climate

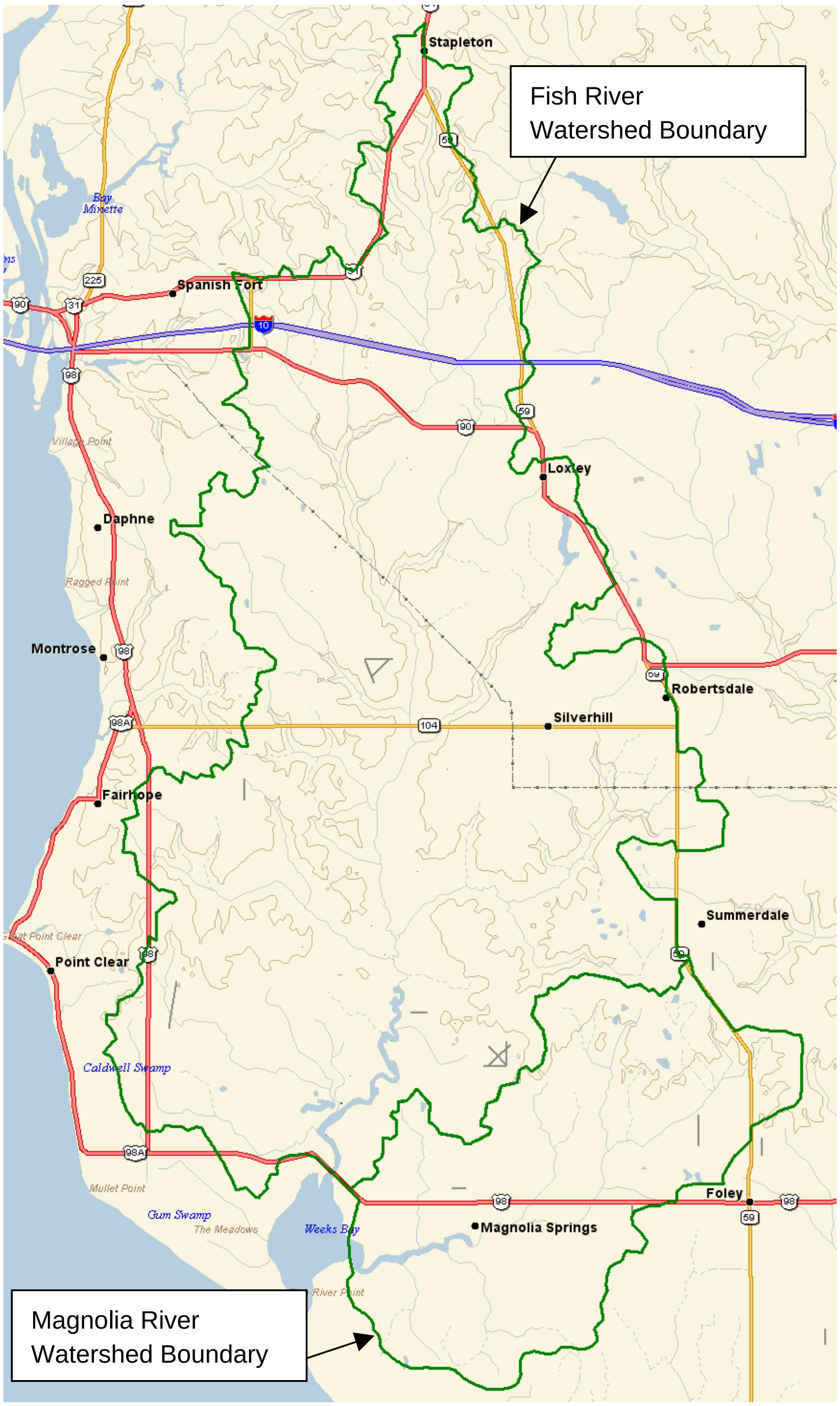
Baldwin County has a mild but humid climate. Data obtained from The Southeast Regional Climate Center indicates the average annual rainfall for Baldwin County (Robertsdale area) is around 68 inches over the past 30 years. July and August are typically the wettest months with October and November typically being the driest months. The average high and low temperatures are 78 degrees and 55.5 degrees respectively. The warmest month is typically July with the coldest month being January.

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

Table 2-1
Hurricane Event and Related Precipitation

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

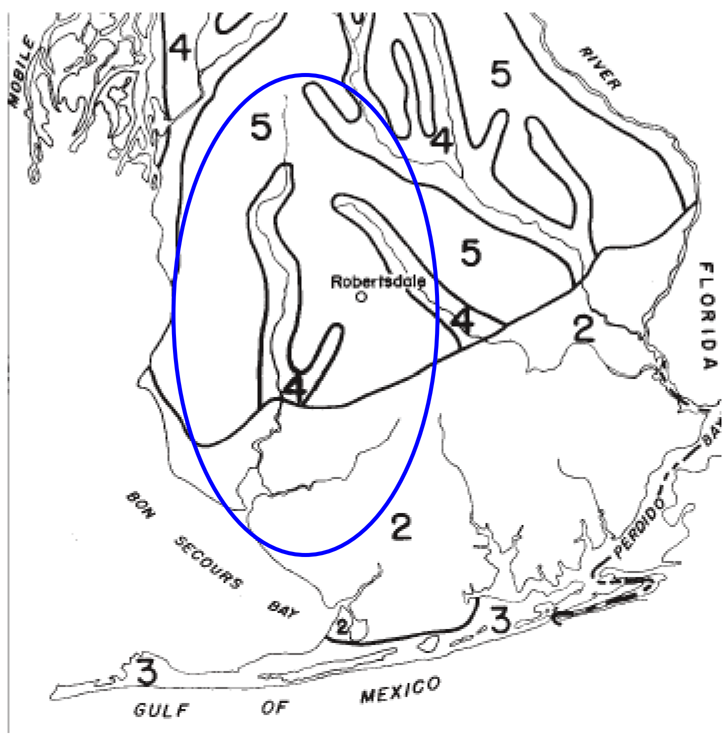
Figure 2-1
Location Map and Watershed Boundary



2.3. Physiography

According to the *Soil Survey of Baldwin County*, “Baldwin County is a part of the Gulf Coastal Plain physiographic region known as the Lower Coastal Plain. The county is underlain by five different kinds of deposits or geologic formations…” These are 1) River floodplains and terraces 2) Marine terraces 3) Areas of coastal beaches 4) Areas underlain by Hattiesburg clay and 5) Plateaus and ridgetops underlain by the Citronelle formation. The Fish River watershed falls within areas 2, 4, and 5. Magnolia River watershed falls within area 2. Area 2 is underlain by deposits on marine terraces. This area is nearly level to gently sloping and is at an elevation that ranges from 10 to 100 feet above sea level. Area 4 is underlain by Hattiesburg clay, which is exposed along the streams in the county. Area 5 is underlain by the Citronelle formation. It is made up of the plateaus and the ridgetops of the county. The material in the Citronelle formation is mostly sandy, but also contains layers of clay. Figure 2-2 indicates the physiographic area of the study.

Figure 2-2
Physiographic areas of Weeks Bay Watershed



2.4. Land Use

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

For both the Fish River and Magnolia River watersheds the land use and vegetative cover is mostly agriculture and forests. The majority of the residential and commercial areas in the Fish River watershed are found around the perimeter of the drainage basin. These areas include the Fairhope area, the Belforest area, the Spanish Fort area, and the area around Silverhill and Robertsdale. Other residential areas are scattered throughout the watershed.

According to the publication entitled *Analysis of Sediment Loading Rates for the Magnolia River Watershed, Baldwin County, Alabama 2009* by the Geological Survey of Alabama, "Commercial development in the Magnolia River watershed is confined to the cities of Foley (in the headwaters on the eastern margin of the watershed) and Magnolia Springs (in the western part of the watershed near the downstream margin of the project area) and minimal development along major roadways. Residential development is characterized by widely spaced single-family homes and small subdivisions."

3. Model

3.1. General

The hydrologic model used to evaluate the Weeks Bay watershed is the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model. GSSHA is a U.S. Army Corps of Engineers (USACE) 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 Weeks Bay watershed was broken up into two separate models, Fish River and Magnolia River.

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) employed the use of RainWave. RainWave is a company that offers precipitation monitoring services that allows a user to enter a latitude and longitude for a point of interest. Once this point is entered into the system, various rainfall data can be obtained. For the modeling simulations 5-minute rainfall intervals were utilized. This data can then be formatted for a GSSHA long term simulation. Figures 3-1 and 3-2 shows RainWave point locations used for gathering rainfall distribution data.

Figure 3-1
Fish River Watershed with RainWave Point Locations

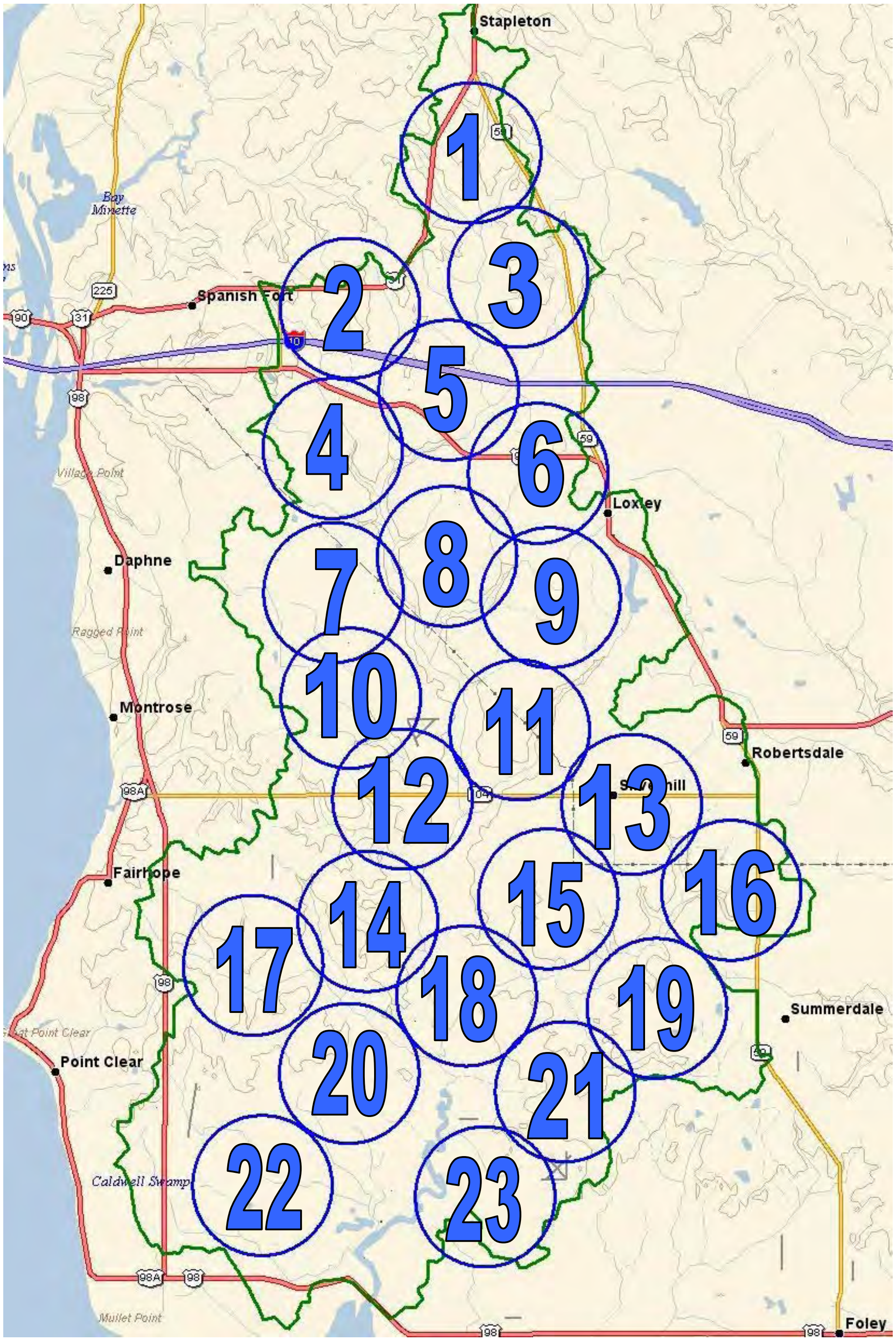
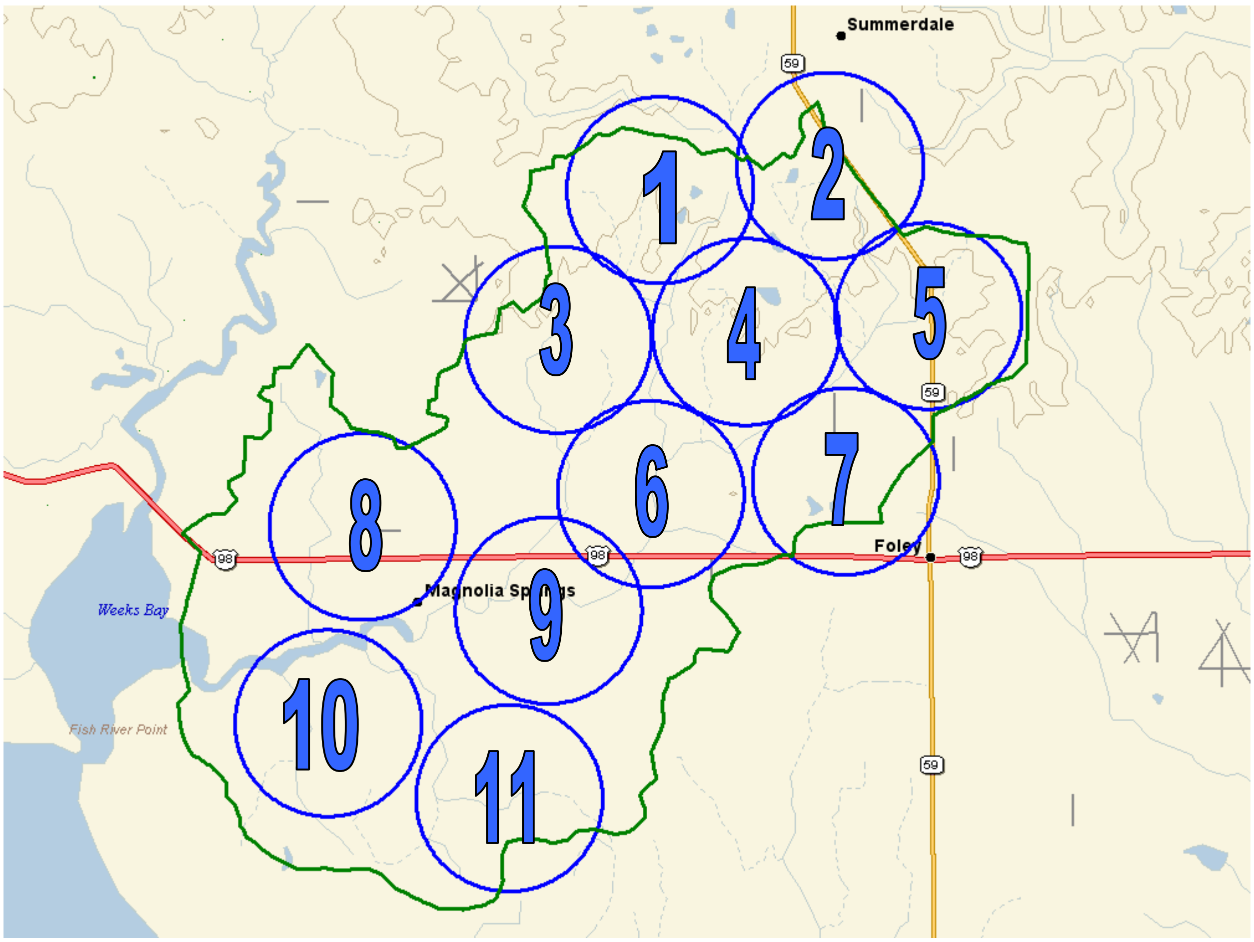


Figure 3-2
Magnolia River Watershed with RainWave Point Locations



3.3. Digital Terrain Data

The GSSHA model uses digital terrain data to incorporate topography into the hydrologic model. For the two models a combination of Light Detection and Ranging (LiDAR) data provided by Baldwin County and the United States Geological Survey (USGS) 10m digital elevation model (DEM) data was used for basin delineation. The combined DEM data was also used for generating cell elevations for the gridded model. Figures 3-3 and 3-4 shows the topographic data that was used in each model.

Figure 3-3
Fish River Watershed with Topographic Data

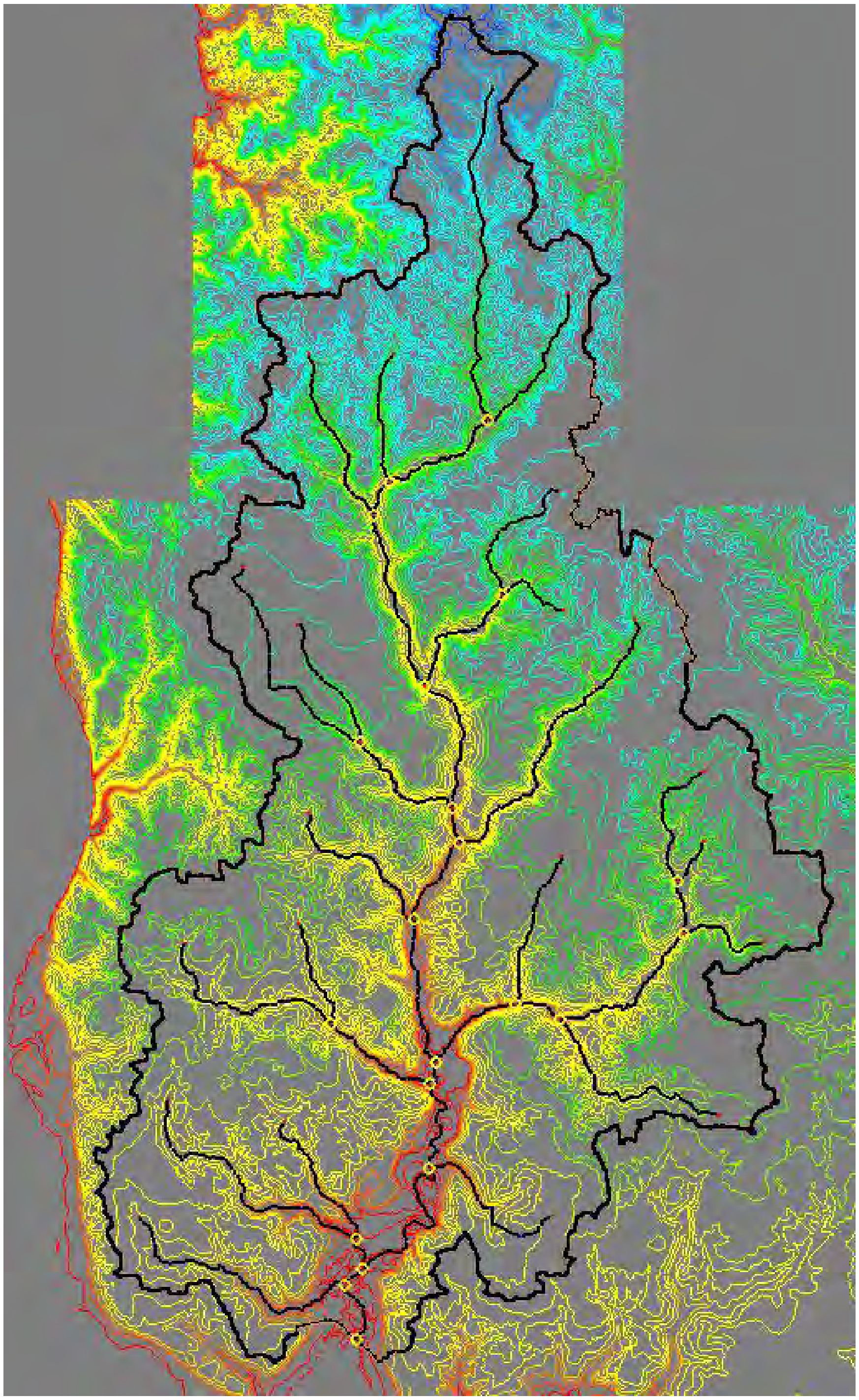
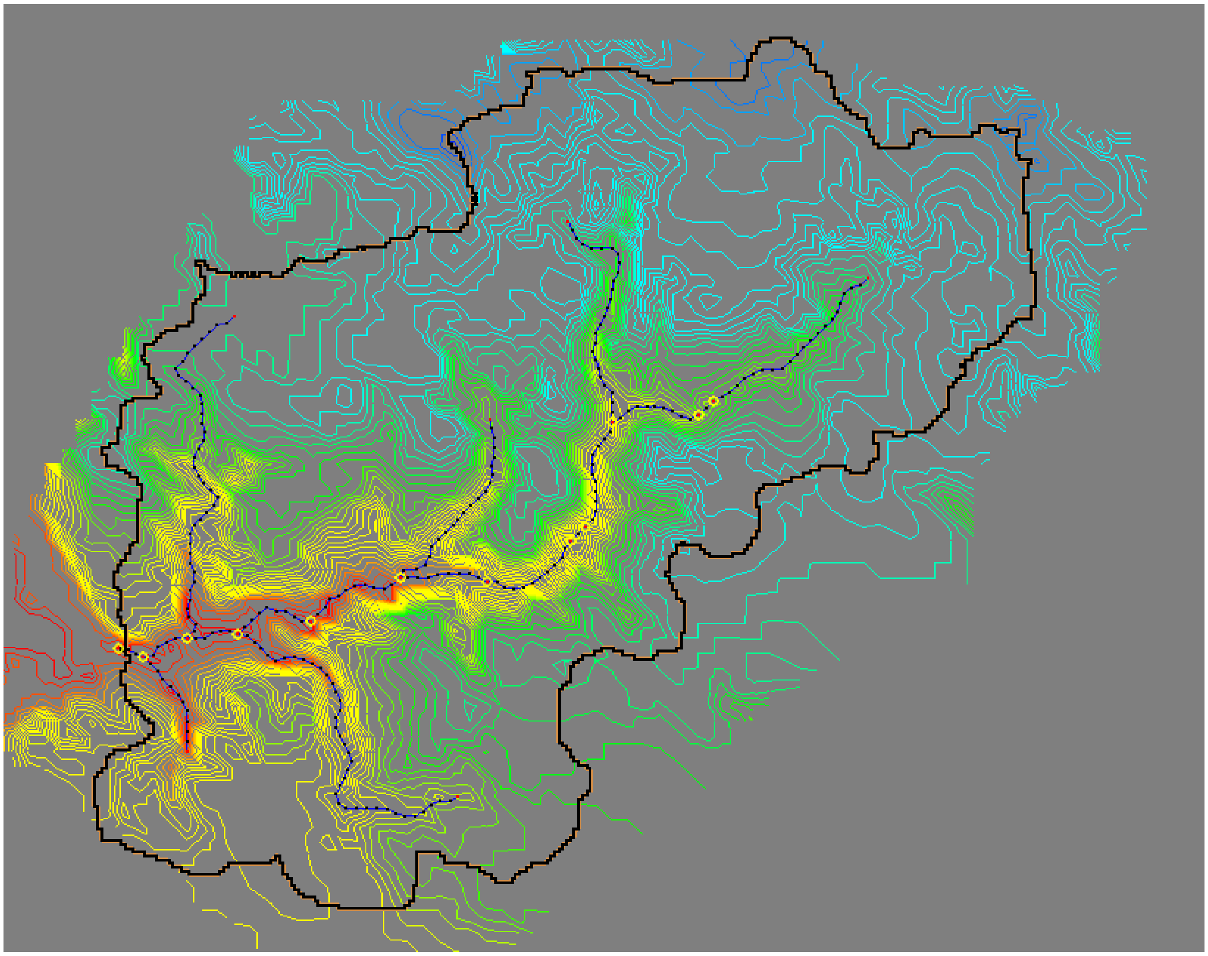


Figure 3-4
Magnolia River Watershed with Topographic Data



3.4. Land Use

The land use component of the model is necessary to define the various overland flow types throughout the basin. The roughness of each land use type is described by a Manning's 'n' value. A shapefile of the land use was provided by Baldwin County. The shapefile was converted to feature objects to be used in the model. It was necessary to simplify some of the land use descriptions for calibration purposes. Using geo-referenced aerial photography provided by Baldwin County, land use was checked to ensure all areas were properly assigned. Table 3-1 lists the land use types and the respective calibrated 'n' values assigned to them. Figures 3-5 and 3-6 indicate land use assignments.

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

GSSHA ID	Land Use	Calibrated Manning's n
12	Impervious, Commercial	0.011
17	Low Residential	0.039
20	Open Land – Fair	0.058
21	Open Land – Good	0.249
31	Woods – Fair	0.270
32	Woods – Good	0.225
81	Med/High Residential	0.015

3.5. Soils

Similarly to the land use, the GSSHA model has the capability to incorporate specific characteristics of the soils located within a drainage basin. The soils coverage is used for defining infiltration into the soil. The infiltration method used is Green and Ampt (G&A) with soil moisture redistribution. Soil parameters used by the G&A method include hydraulic conductivity, porosity, capillary head, pore distribution index, residual saturation, and field capacity. This allows the GSSHA model to evaluate the soil's ability to infiltrate stormwater runoff in determining the peak discharge and volume of storm events. Soils data shapefiles provided by Baldwin County were converted to feature objects to be used in the model. Figures 3-7 and 3-8 indicate the soil data that has been incorporated into the GSSHA model.

Figure 3-5
Fish River Watershed with Digitized Land Use

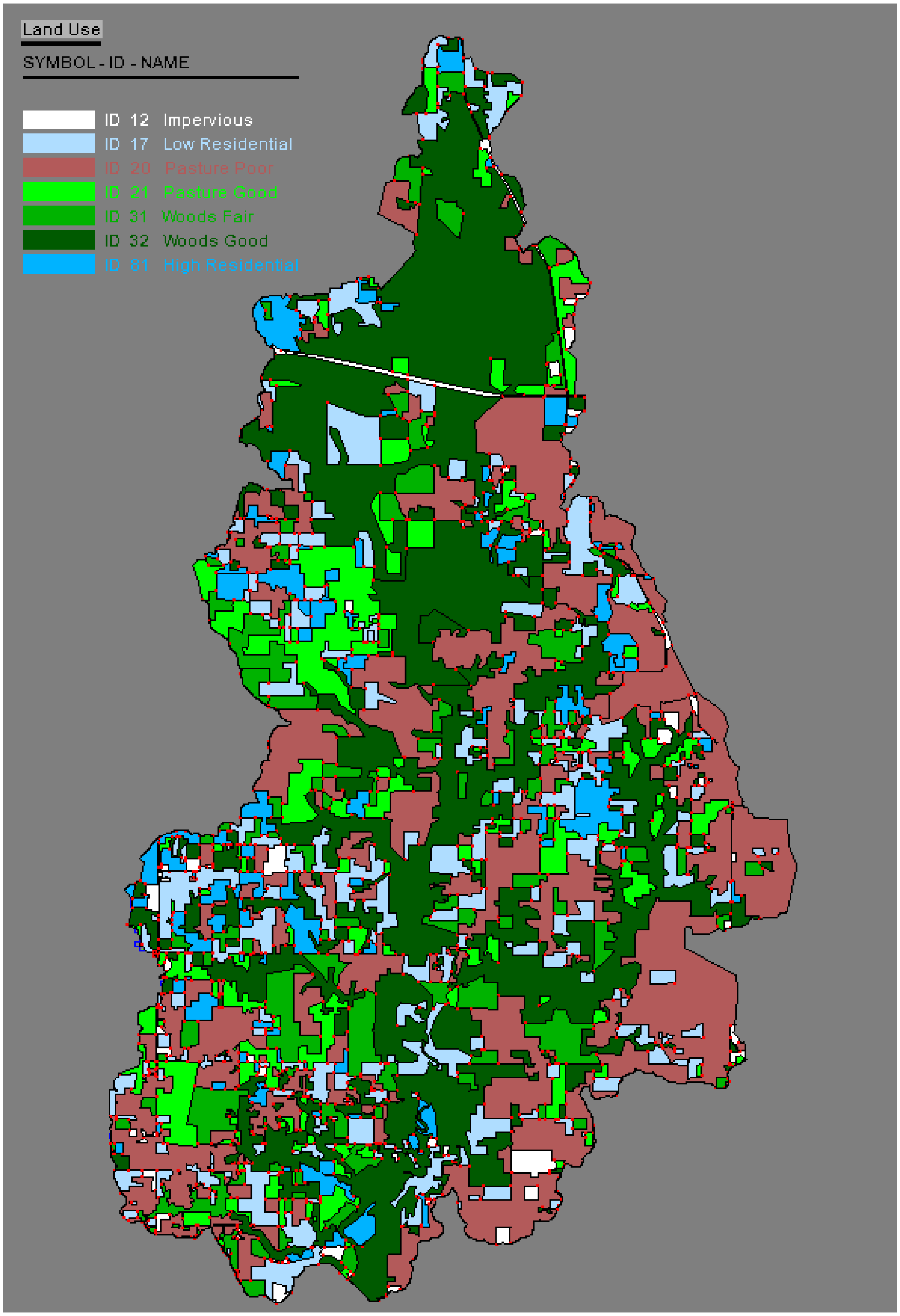


Figure 3-6
Magnolia River Watershed with Digitized Land Use

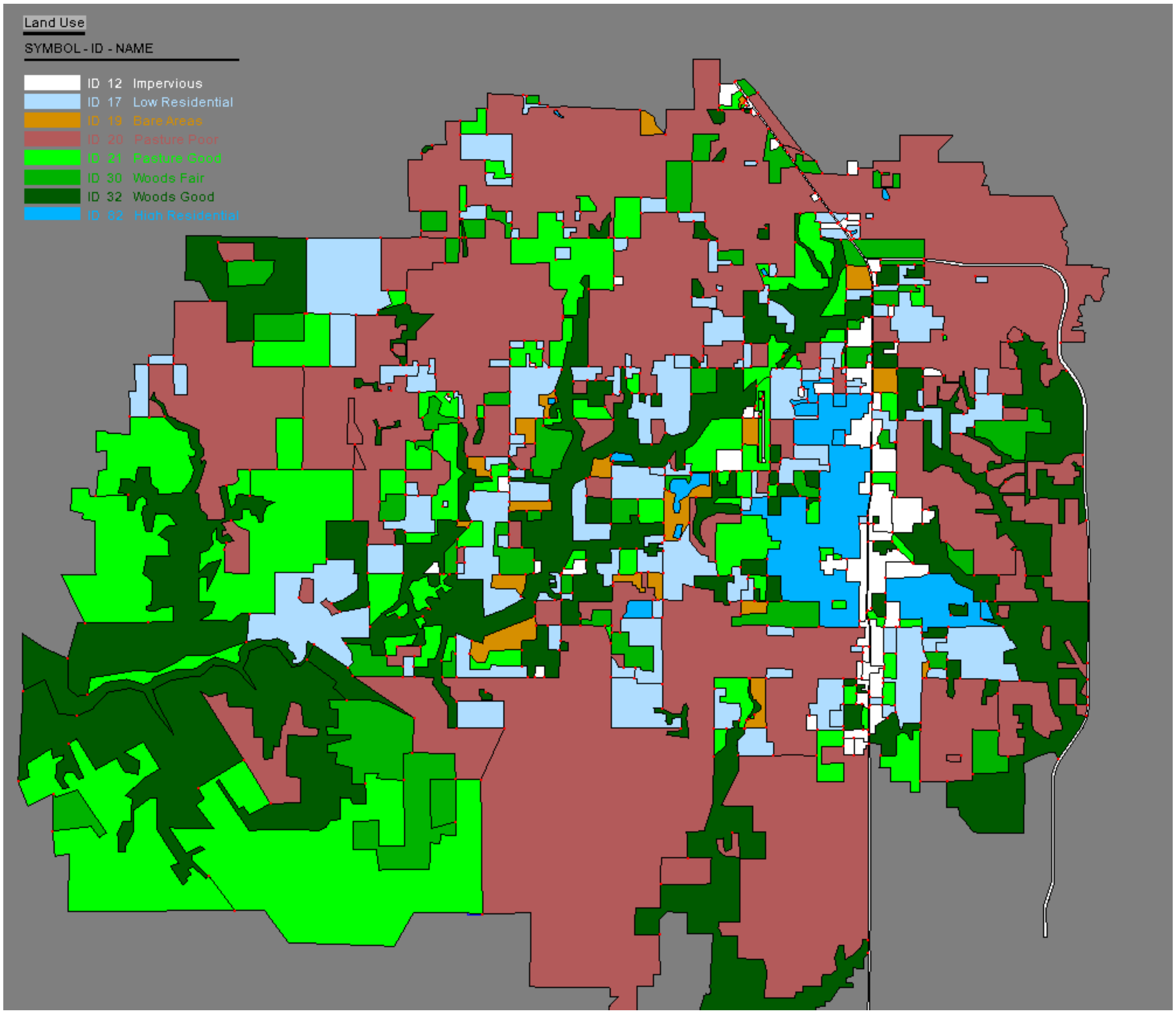


Figure 3-7
Fish River Watershed with Digitized Soil Type

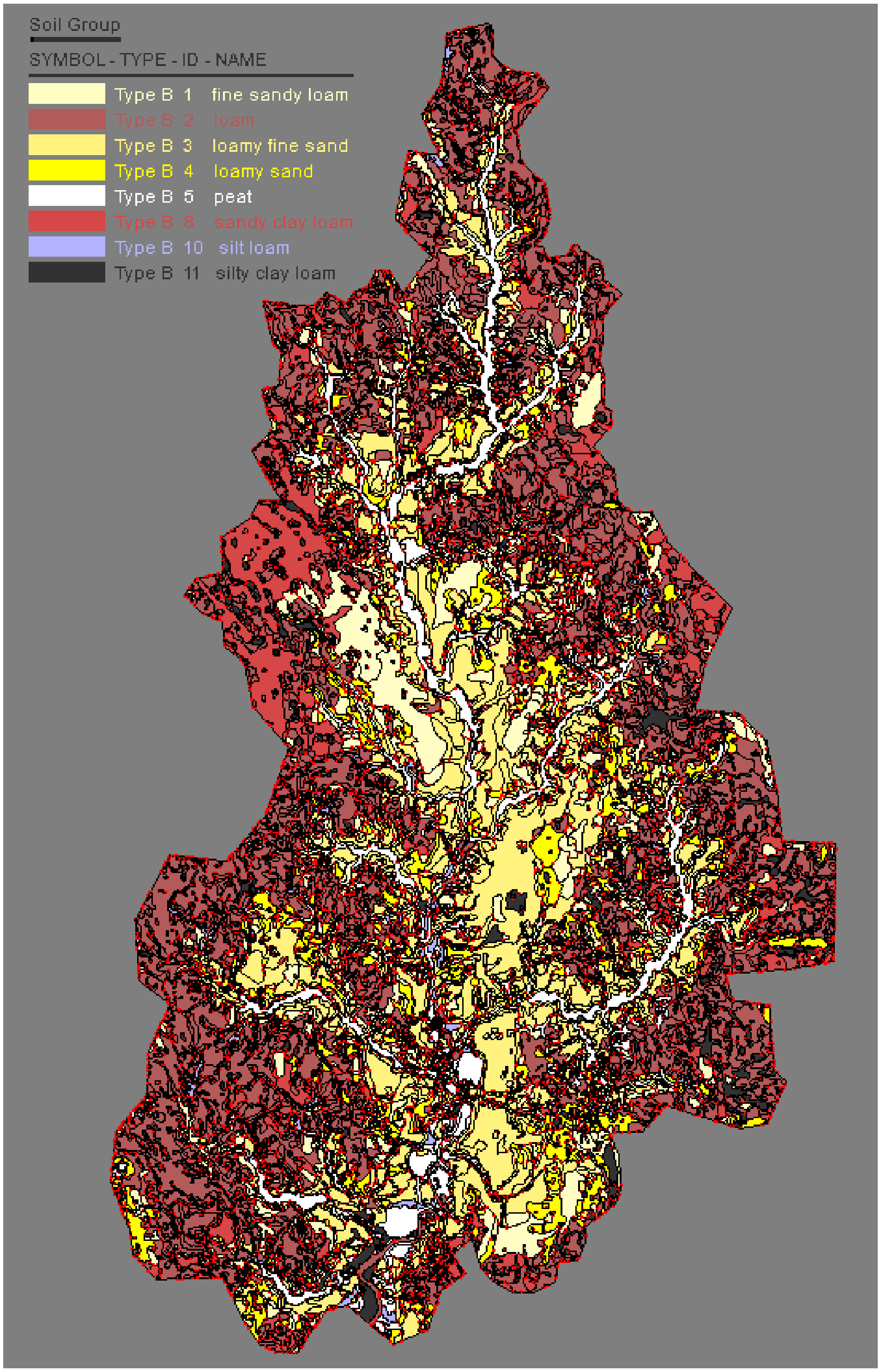
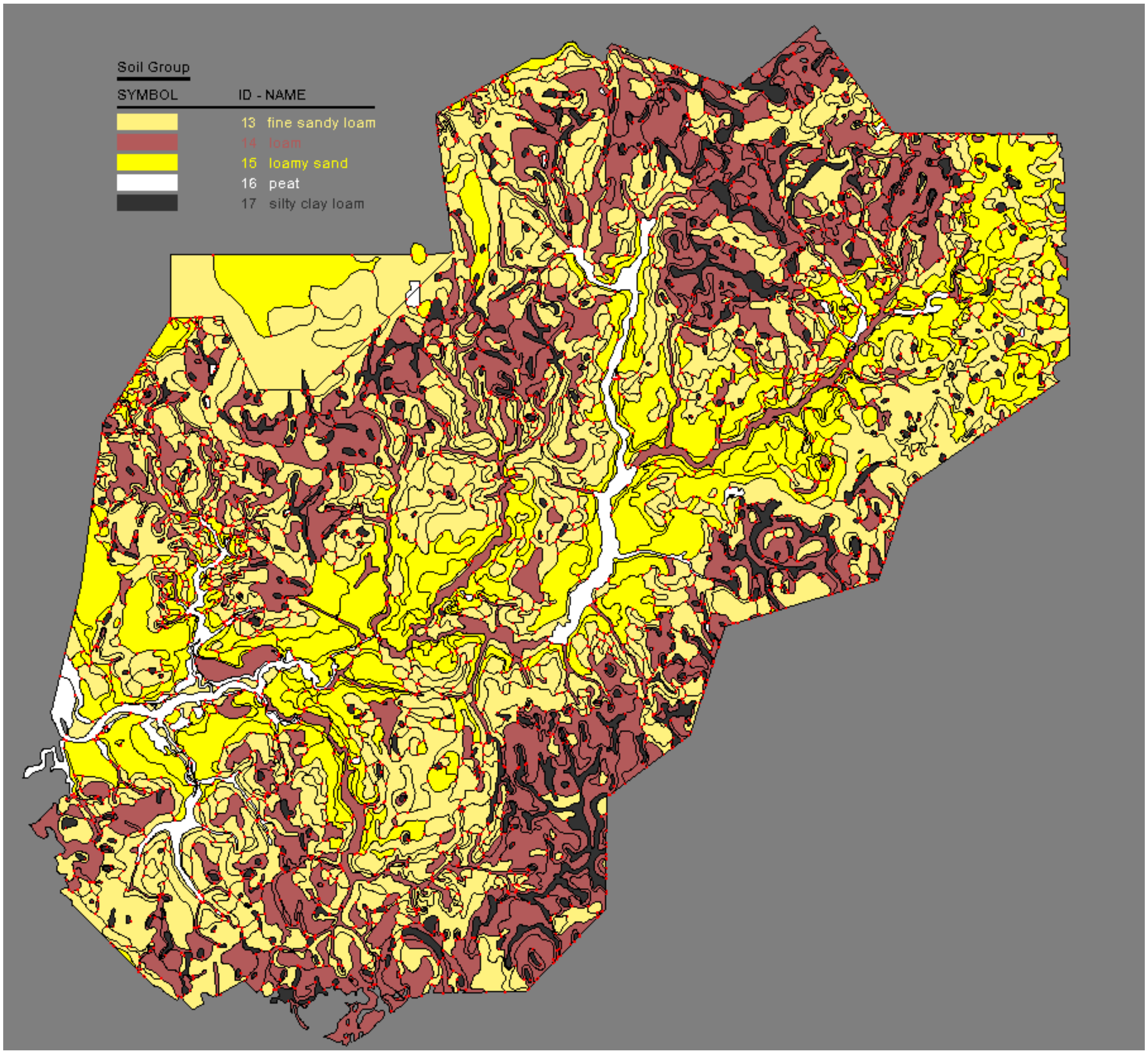


Figure 3-8
Magnolia River Watershed with Digitized Soil Type



3.6. 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 Fish River model a 130 meter x 130 meter (425 feet x 425 feet) grid size was utilized (Figure 3-9). The settings for GSSHA require the units to be in the International System of Units (SI). The total drainage area to HWY 98 is approximately 152 square miles. Over the entire watershed this generates approximately 23,300 grid cells. For the Magnolia River model a 75 meter x 75 meter (245 feet x 245 feet) grid size was utilized (Figure 3-10). The total drainage area to just above the confluence with Weeks Bay is approximately 41 square miles. Over the entire watershed this generates approximately 19,000 grid cells.

3.7. 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 and river water surface elevations (stages) during the rain event. With the rainfall being obtained by RainWave, it was necessary to find or install gauges in the watershed to determine stream stages. A site visit was performed in order to determine the best location for installing a monitoring gauge. The USGS currently has an operating gauge at SR 104 (USGS 02378500). Available parameters for this site are discharge, gage height, and precipitation. A Solinst Levelogger was also installed at the bridge on CR 64 on May 6, 2011. For the Magnolia River watershed, there is a USGS gauge located on HWY 98 (USGS 02378300). After investigating various areas for placement of the levelogger, it was determined that a gauge be installed on the bridge at CR 65. Variables that come into consideration for a gauge location are dependent on location in the watershed, if there are backwater effects, and whether someone could tamper with it. Both leveloggers have continuously recorded water surface elevations from May to October.

During the May to October time period there were a couple of storm events that were possible candidates for calibration. From the levelogger data and the USGS gauge data it was determined that the July 16th event produced the largest discharge event in the Fish River watershed for the duration from May to October. Tropical Storm Lee was also analyzed however it produced smaller discharges than the July 16th event in the Fish River watershed. For the Magnolia River watershed it was determined that the Tropical Storm Lee event generated higher stages and discharges than that of July 16th event during the observed duration. The Tropical Storm Lee event was used as the calibration event for the Magnolia River model.

In order to compare stages monitored by the levelogger it was necessary to obtain field survey data of the bridge opening where the gauge was installed. The survey data was taken just upstream of the bridge and this data was entered into the model as a cross-section. Additional model cross-sections were cut using the 1-foot LiDAR provided by Baldwin County. 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, but did not have as much of an impact as the aforementioned parameters, are interception and retention. Figures 3-11 through 3-18 indicate real-time rainfall, gauge data, and calibrated model output.

Figure 3-9
Fish River Gridded Watershed - 425' x 425' Grid Cell Size

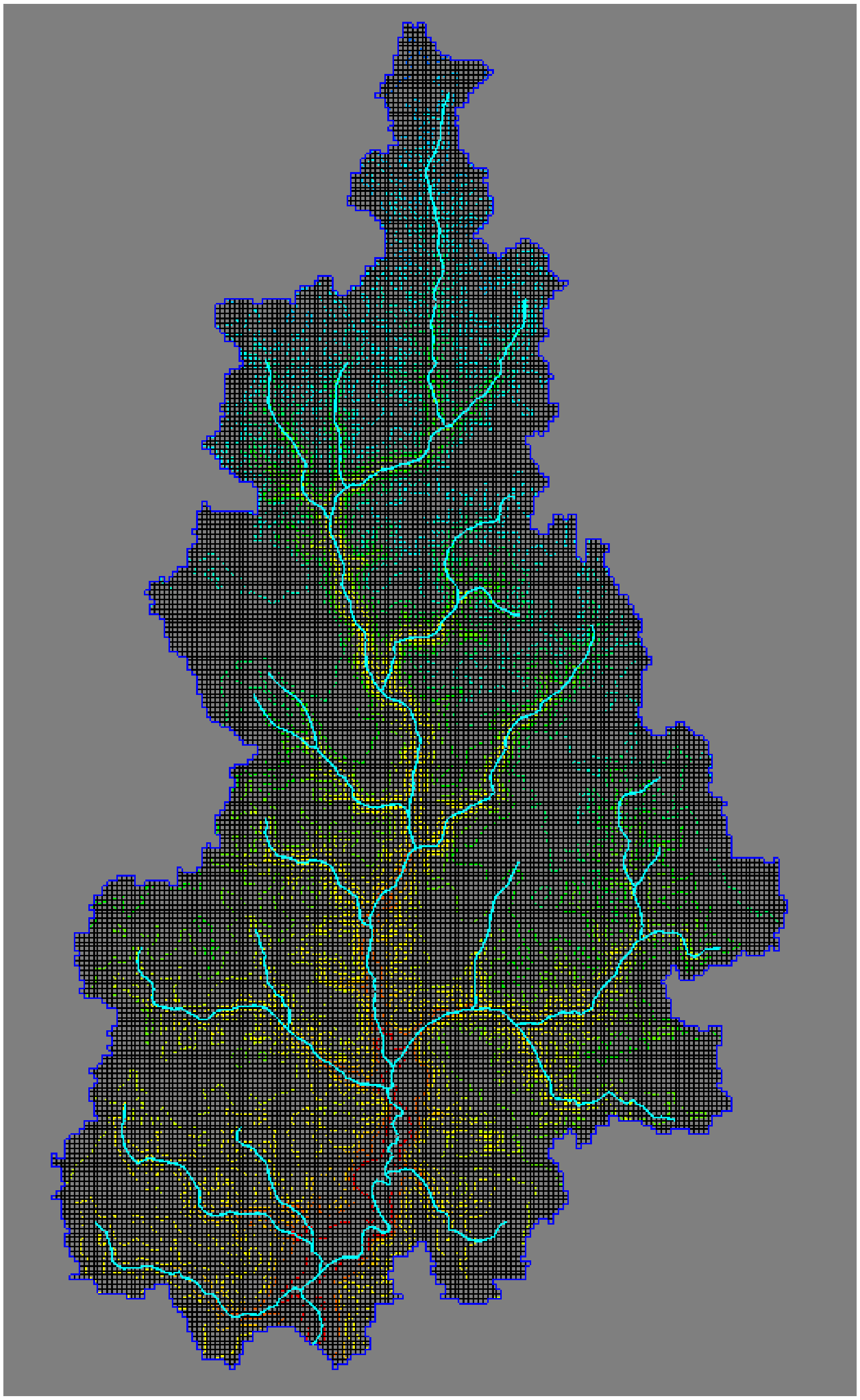


Figure 3-10
Magnolia River Gridded Watershed - 245' x 245' Grid Cell Size

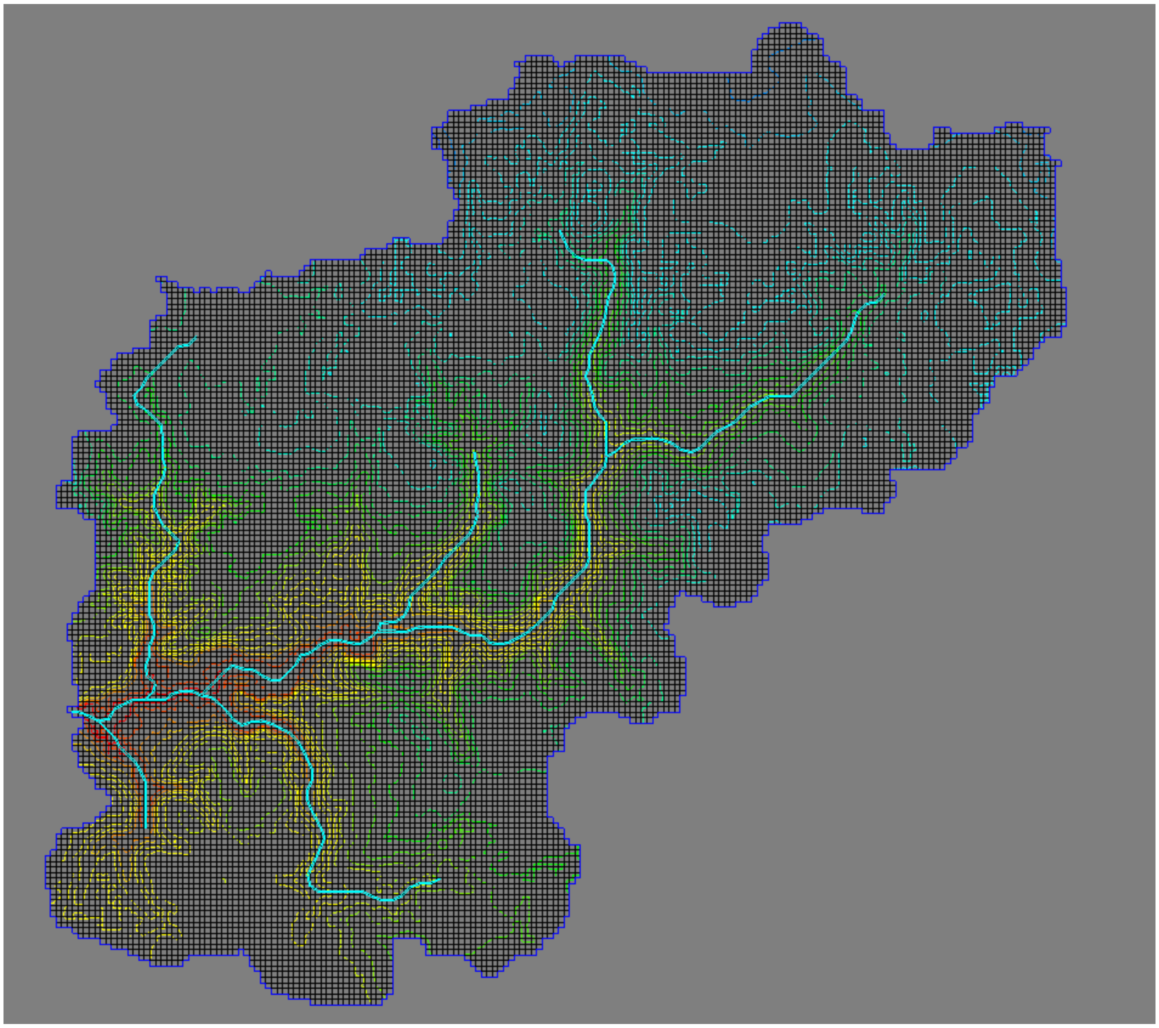


Figure 3-11
Fish River Watershed – Rainfall Distribution

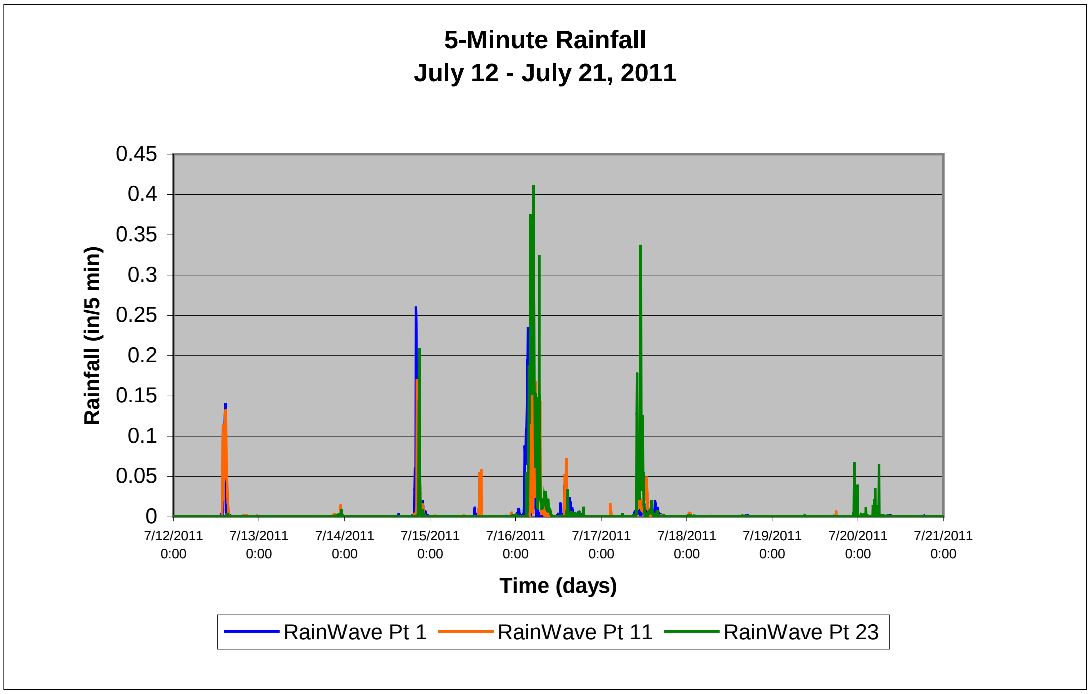


Figure 3-12
Fish River Watershed – Cumulative Rainfall

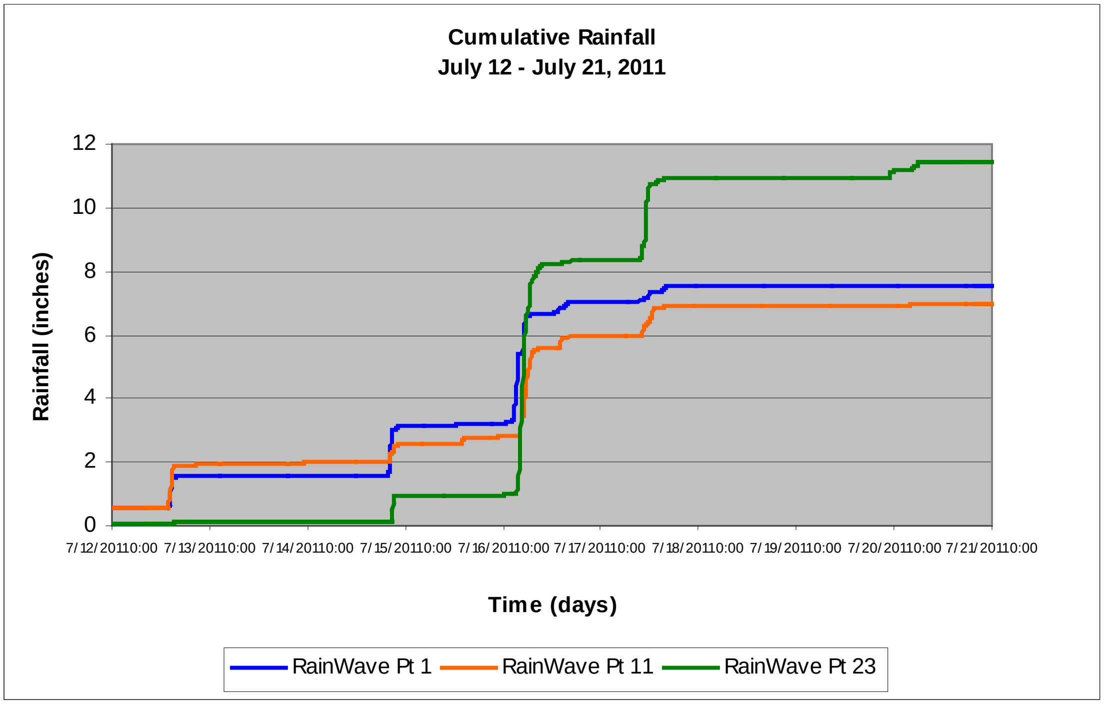


Figure 3-13
Fish River Watershed – SR 104 Calibration

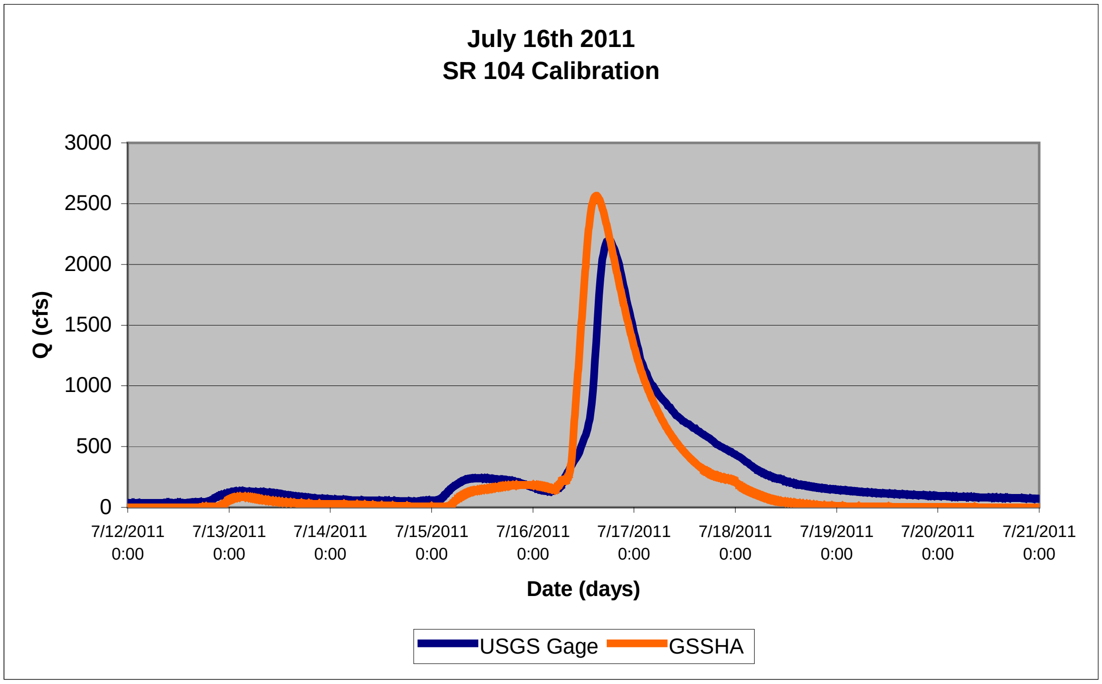


Figure 3-14
Fish River Watershed – CR 64 Calibration

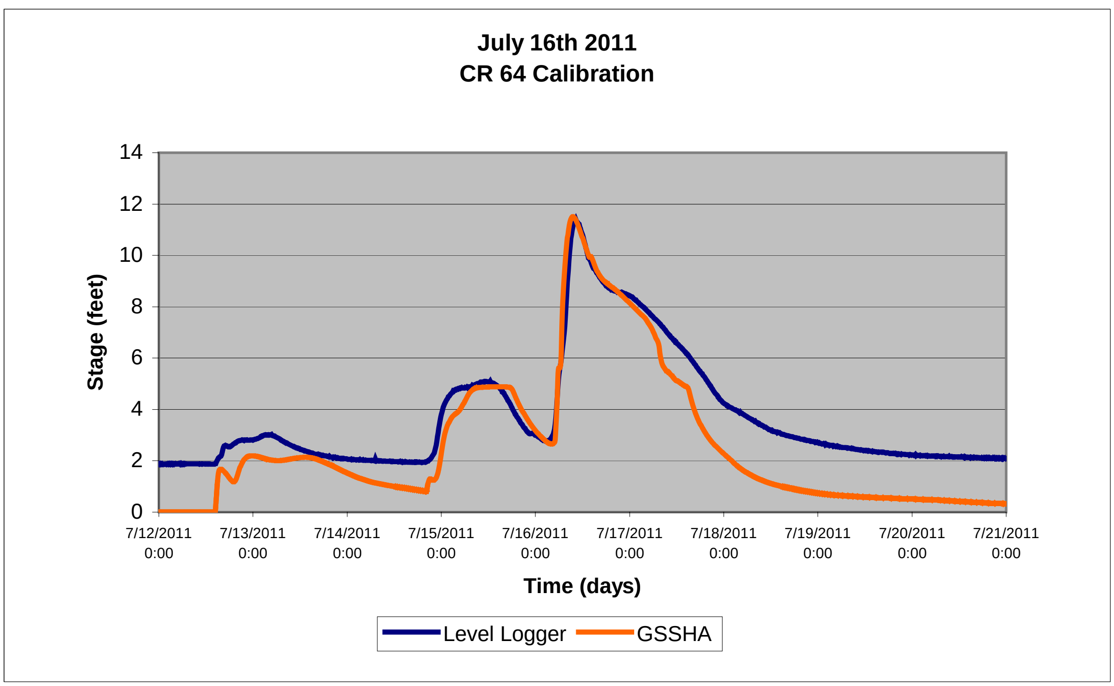


Figure 3-15
Magnolia River Watershed – T.S. Lee Rainfall Distribution

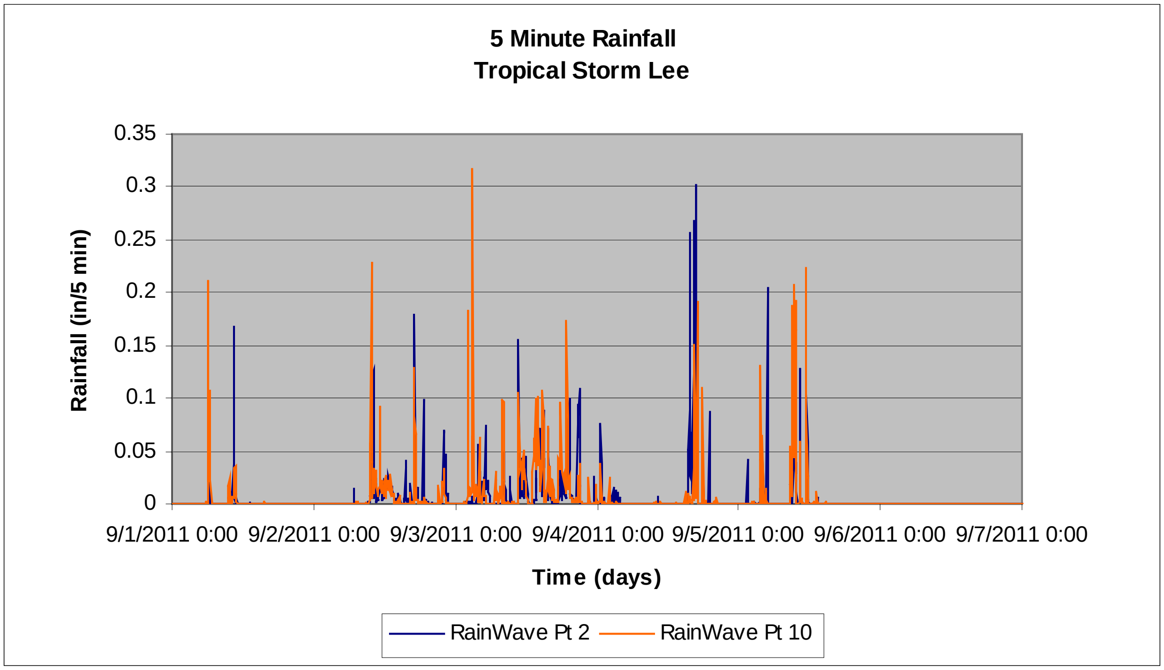


Figure 3-16
Magnolia River Watershed – T.S. Lee Cumulative Rainfall

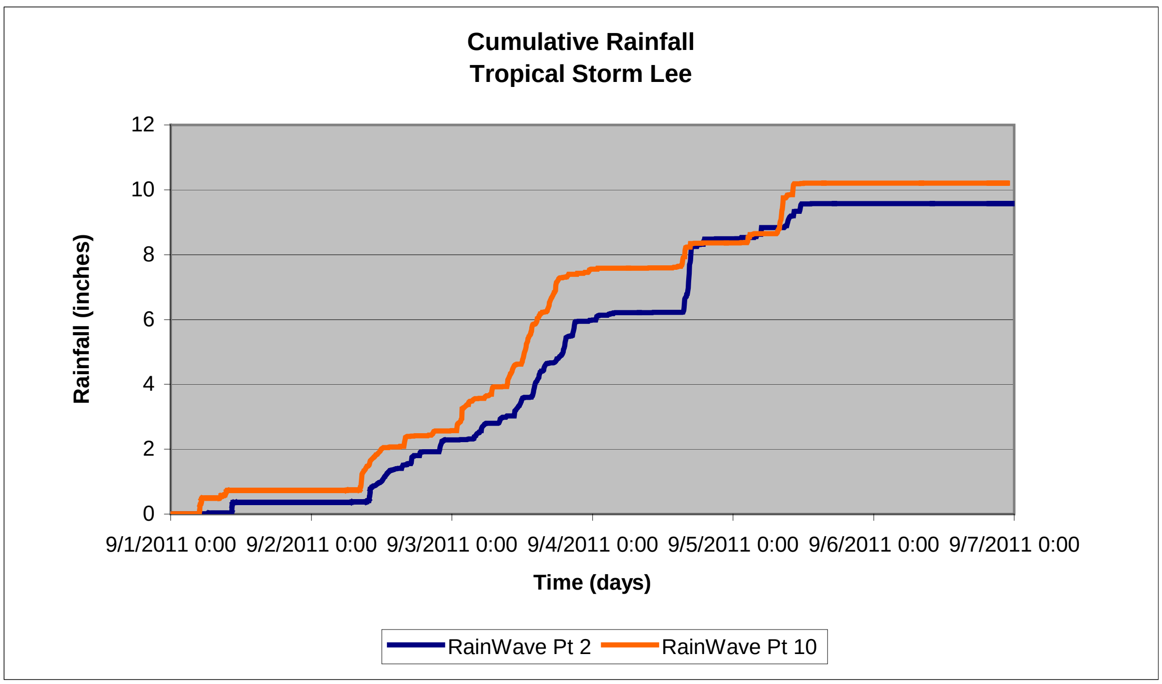


Figure 3-17
Magnolia River Watershed – T.S. Lee Cumulative Rainfall

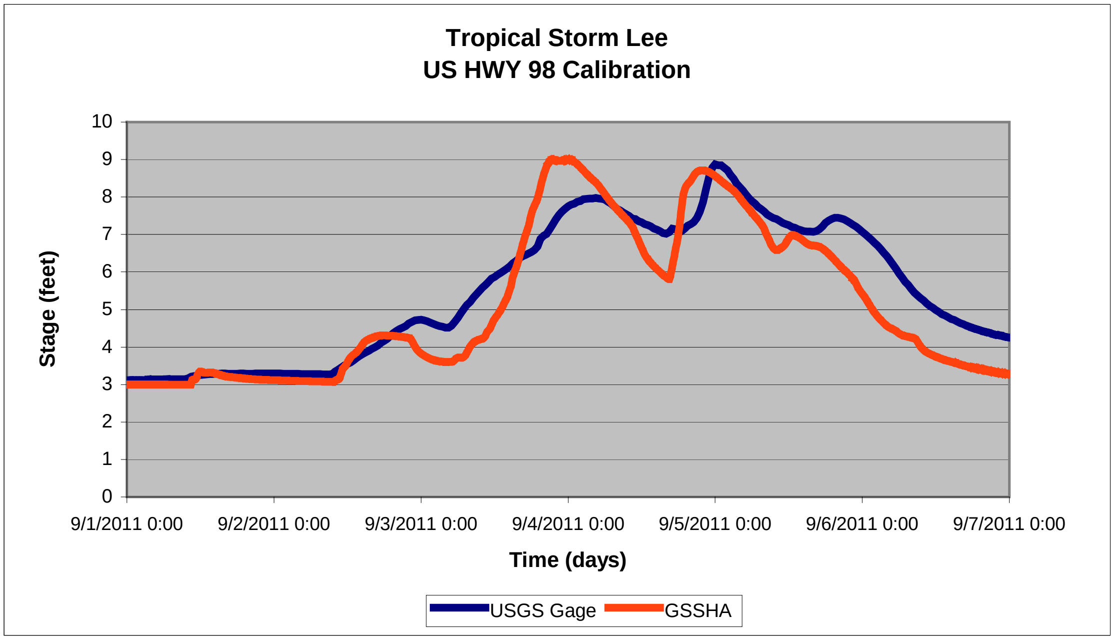
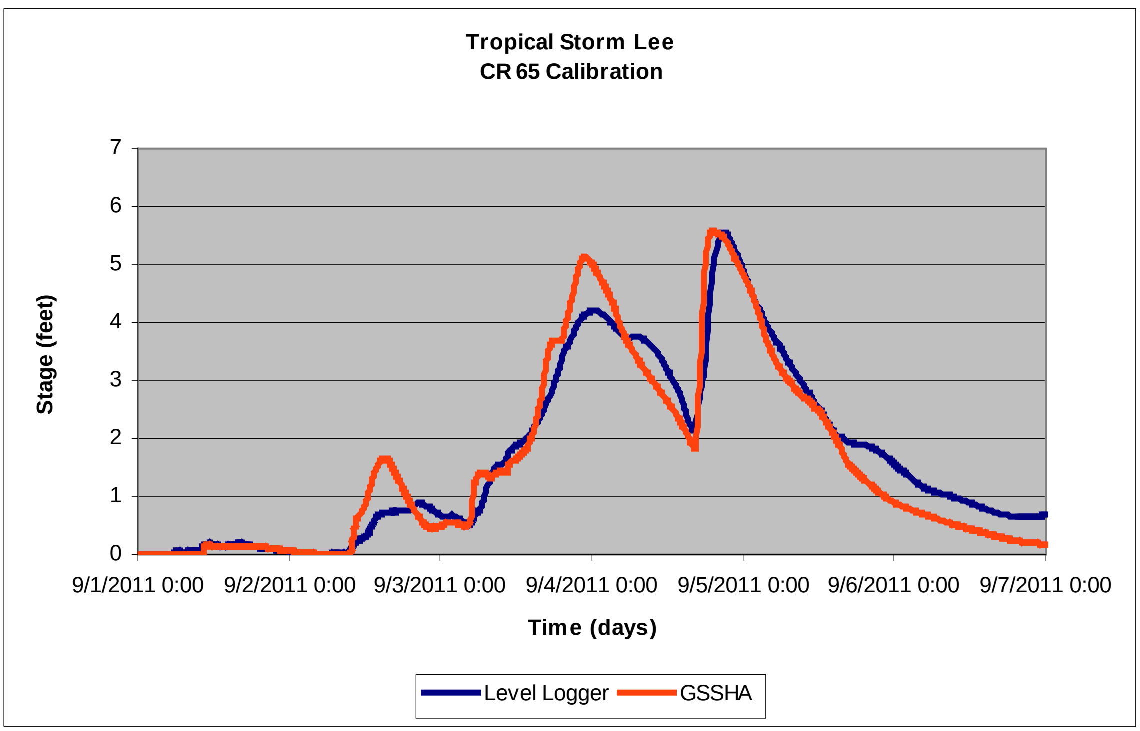


Figure 3-18
Magnolia River Watershed – T.S. Lee Cumulative Rainfall



4. Analysis

4.1. Fish River Analysis

After the model was calibrated, the precipitation and rainfall distribution were changed in order to analyze a 100-yr 24-hour storm event. The 100-year 24-hour rainfall amount for the drainage basin was taken from *Technical Paper No. 40 Rainfall Frequency Atlas of the United States* (TP 40). It was determined the average rainfall amount over the watershed is 13.5 inches or 343 millimeters. The rainfall distribution employed was the SCS Type III distribution. The model was rerun with the previously calibrated parameters and the discharges were examined at SR 104, HWY 98 just above Weeks Bay, and other areas of interest throughout the watershed. From Table 1 in *Magnitude and Frequency of Floods in Alabama, 2003 USGS Scientific Investigations Report 2007–5204*, Figure 4-1, the 100-year log-Pearson Type III discharge is 21,800 cfs and the weighted average or best estimate discharge is 15,700 cfs at SR 104. The calibrated model discharge at the same gauged location is 16,960 cfs. The discharge at HWY 98 for the calibrated model is 28,640 cfs. Comparing gauge-weighted discharges to the regression equations at SR 104 and transferring them downstream to HWY 98 it was determined that a gage-weighted discharge is around 28,200 cfs. The discharge from the model compares favorably with a value of 28,640 cfs.

Figure 4-1

Gauged Discharges on Fish River near Silver Hill

Table 1. Peak discharges for selected recurrence intervals at selected gaging stations in Alabama. — Continued

[no., number; mi^2, square miles; top line for each station entry is the log-Pearson Type III discharge; bottom line is the weighted-average or best-estimate discharge; *, station not used in regional analyses; --, peak discharge not computed;]

Station number	Flood region (fig. 2)	Station name	Drainage area (mi²)	Period of record (years)	Peak discharge, in cubic feet per second, for indicated recurrence interval in years								
					1.5	2	5	10	25	50	100	200	500
02374500	4	Murder Creek near Evergreen	176	67	2,360 2,400	3,440 3,490	7,030 7,130	10,600 10,600	16,700 16,000	22,800 21,000	30,400 27,100	39,800 34,500	56,000 46,800
02374970	4	Sizemore Creek near Robinsonville	79.4	12	3,580 3,110	4,610 3,940	7,220 5,970	9,290 7,520	12,300 9,860	14,900 11,900	17,700 14,200	20,800 16,800	25,500 20,600
02375000	4	Big Escambia Creek at Flomaton	330	37	6,260 6,090	7,180 7,060	13,100 12,600	18,600 17,400	27,800 24,500	36,700 31,000	47,700 38,800	61,000 48,200	83,400 63,100
02377500	4	Styx River near Loxley	92.2	26	2,210 2,210	3,150 3,120	6,470 6,100	9,920 8,670	16,300 12,600	22,900 16,200	31,600 20,800	43,000 26,600	63,500 35,900
02378500	4	Fish River near Silver Hill	55.3	34	1,230 1,270	1,960 1,990	4,550 4,390	7,150 6,440	11,700 9,480	16,200 12,300	21,800 15,700	28,600 19,800	39,900 26,200

After verifying the calibrated model with the 100-year discharges, different scenarios were performed to see how the watershed reacted to various changes within the basin. The initial scenarios consisted of adding development to various locations in the watershed (Figures 4-2 and 4-3). The first scenario was to extend the development of the areas adjacent to larger existing municipalities. This includes the Fairhope, Belforest, Spanish Fort, and Silverhill/Robertsdale areas. Each of these were analyzed independently as well as in conjunction with each other. Next, development just outside of the floodway was analyzed at the lower end of Fish River between CR 32 near Clay City and HWY 98.

Imaging data that indicates the location of impervious areas in the watershed every 4 to 5 years from 1974 to 2008 was provided by Computer Science Corporation through contacts with Ms Roberta Swann of the Mobile Bay National Estuary Program. Figures 4-4 and 4-5 show the data for 1974 and for 2008. This data was used to determine the amount of increase in impervious area throughout the municipalities and the watershed over the 34 year period. Approximate increases of impervious area for the regions around Fairhope, the Belforest area, Spanish Fort, and Silverhill/ Robertsdale are 550%, 1700%, 2500%, and 245% respectively. Taking the amount of development used in the GSSHA model and comparing it to the rate of increase listed above, it was determined that the GSSHA model has an increase rate over the 1974 to 2008 rates providing for a conservative model.

The next set of objectives was to analyze possible areas for regional detention using the condition where all municipalities have been built out. The majority of the focus areas for the ponds were mostly above SR 104. The various individual regional ponds were examined on Picard Branch, Caney Branch, downstream of the confluence of Picard and Caney, Corn Branch, Polecat Creek, Turkey Branch and Fish River (See Figure 4-6). The ponds were initially run in GSSHA using a combination of embankment arcs and the elevation grid, from which storage volumes were determined. This preliminary procedure was used to narrow down the locations that appear to be the most beneficial. After the initial runs, detailed routing was performed using LiDAR contour data to determine more accurate volumes. Hydrographs were taken from the GSSHA model and pond routing was manually performed using the storage-indicator routing technique. The routed hydrograph was then entered into a modified GSSHA model and simulated.

Figure 4-2
Fish River Watershed – Initial Developed Areas

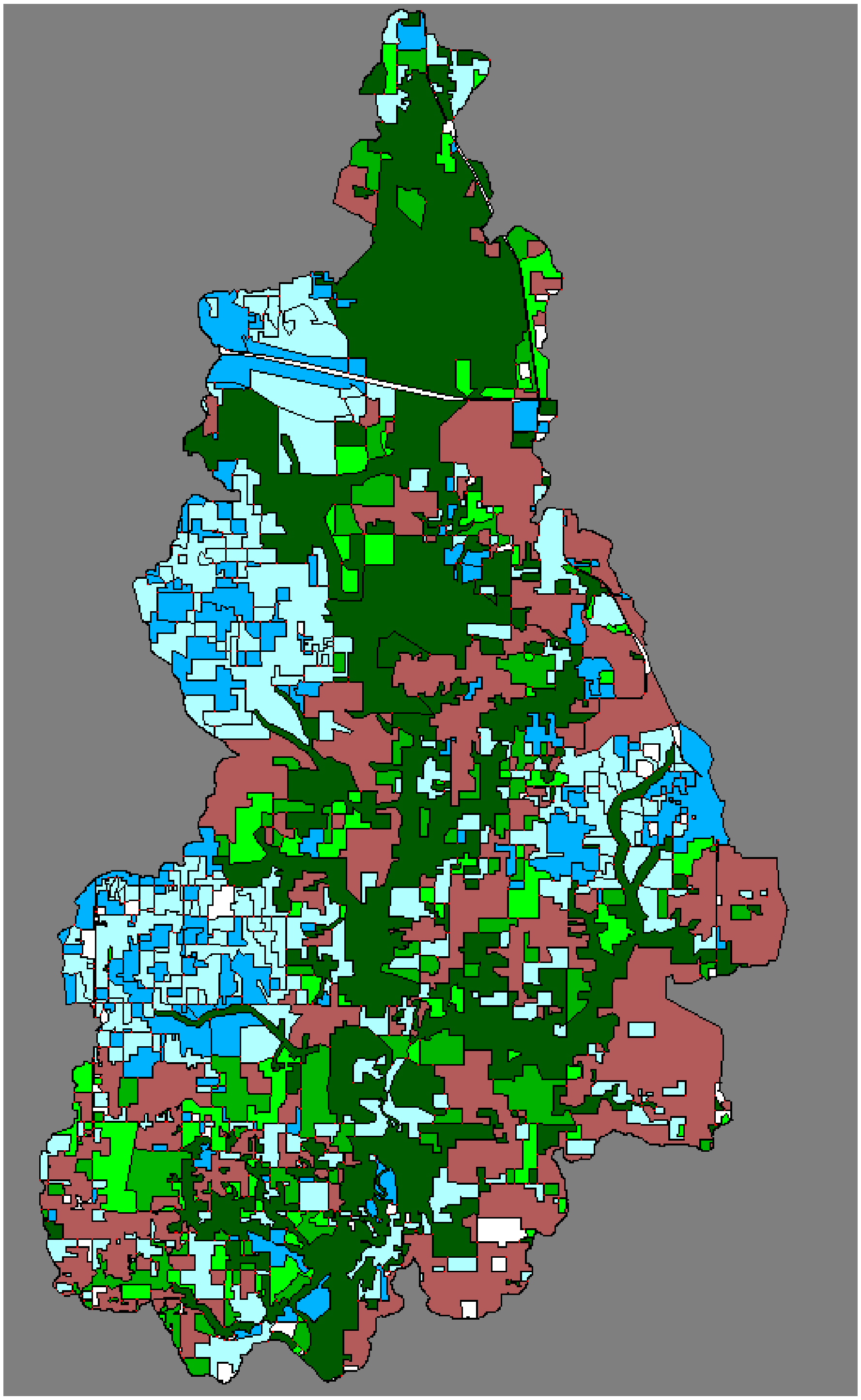


Figure 4-3
Fish River Watershed – Modified Developed Areas

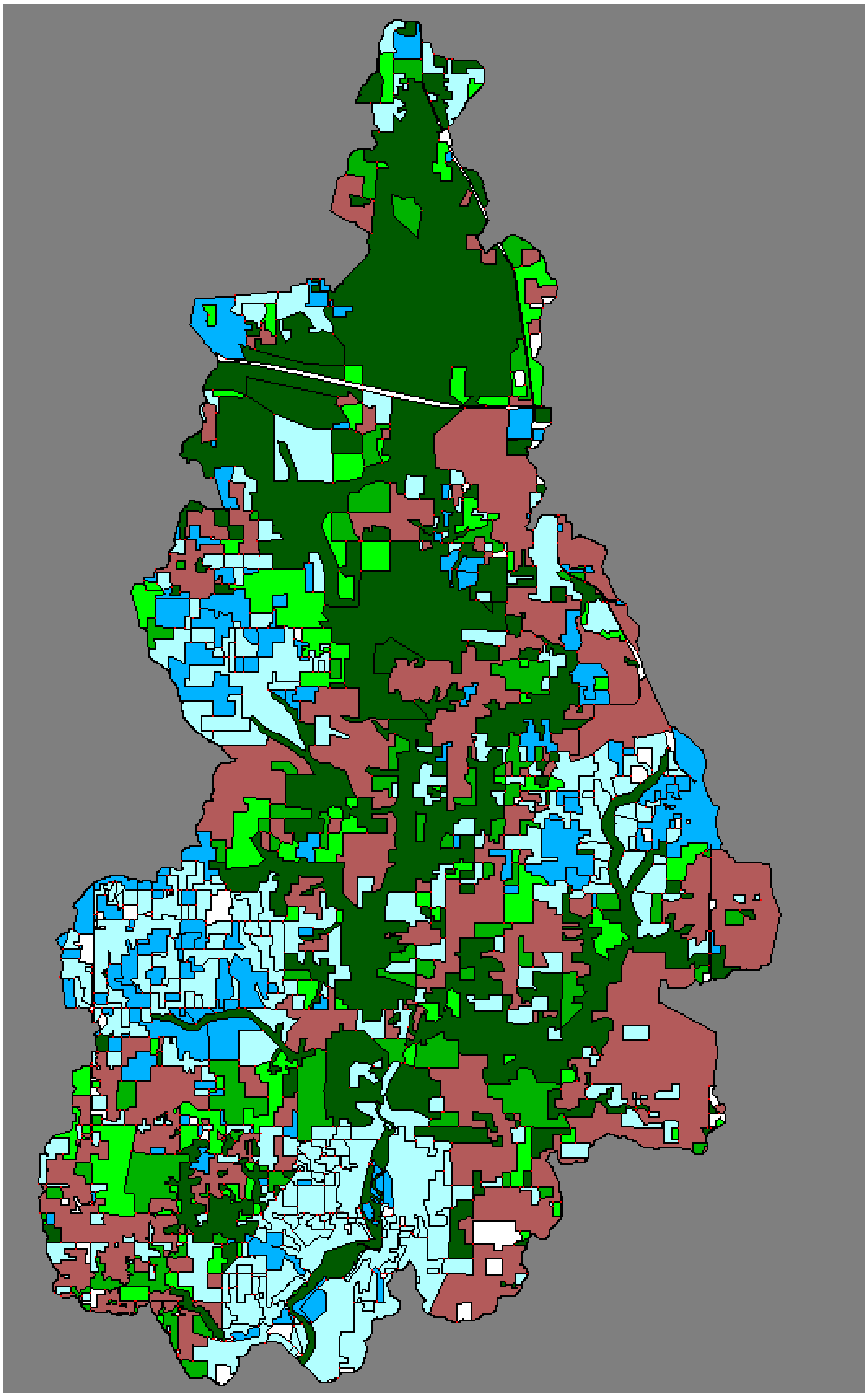


Figure 4-4
1974 Multispectral Scanner Data

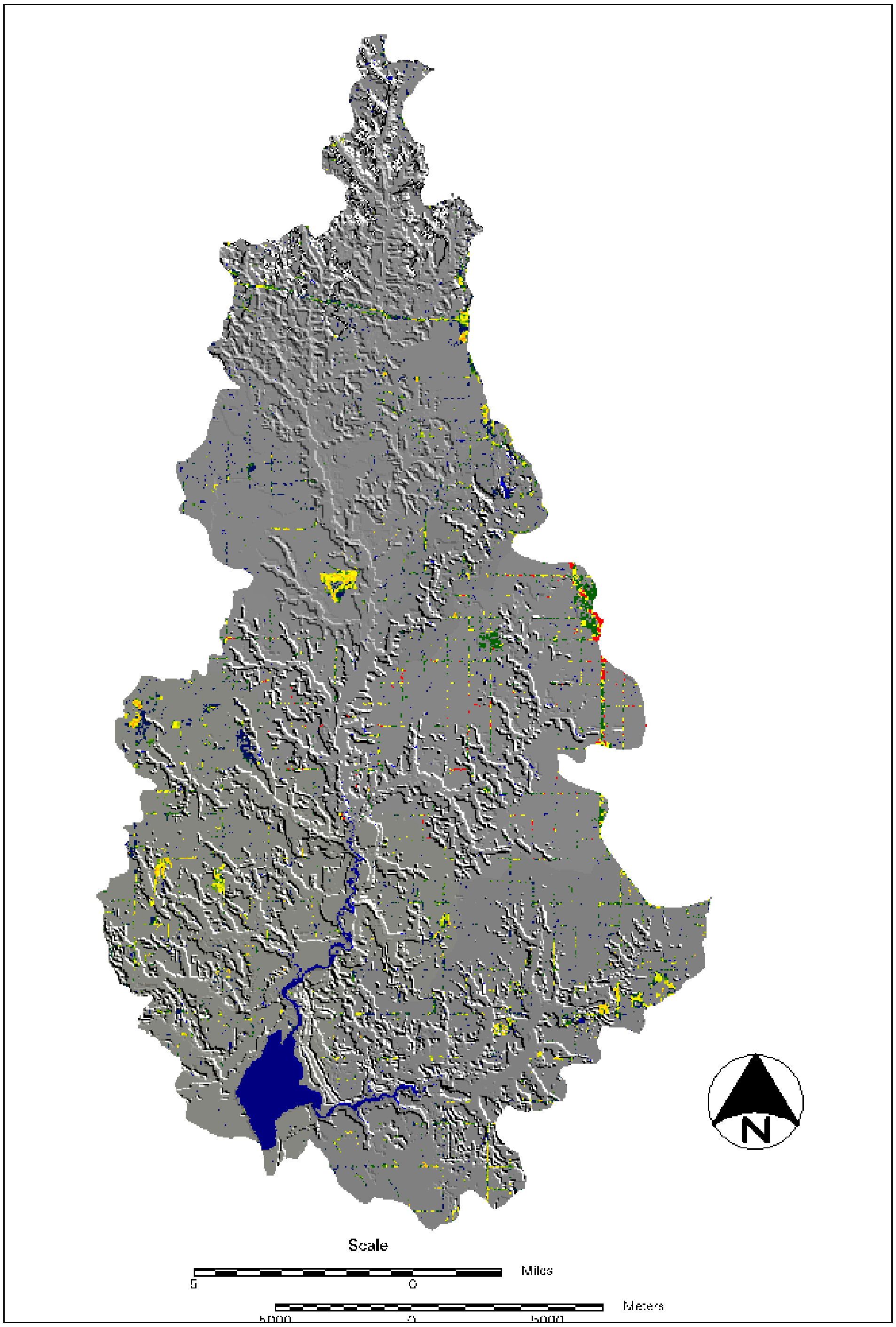


Figure 4-5
2008 Thematic Mapper Data

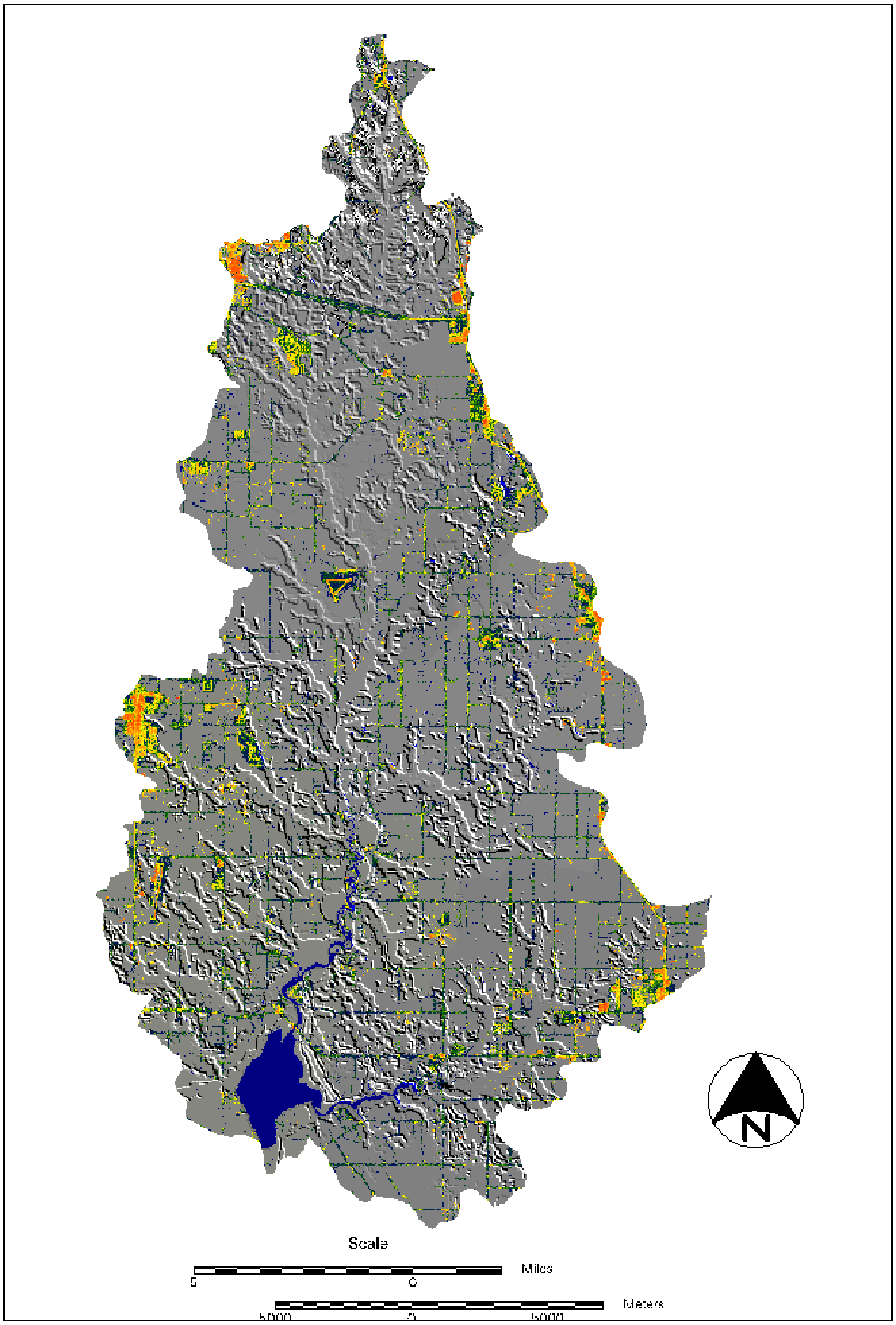
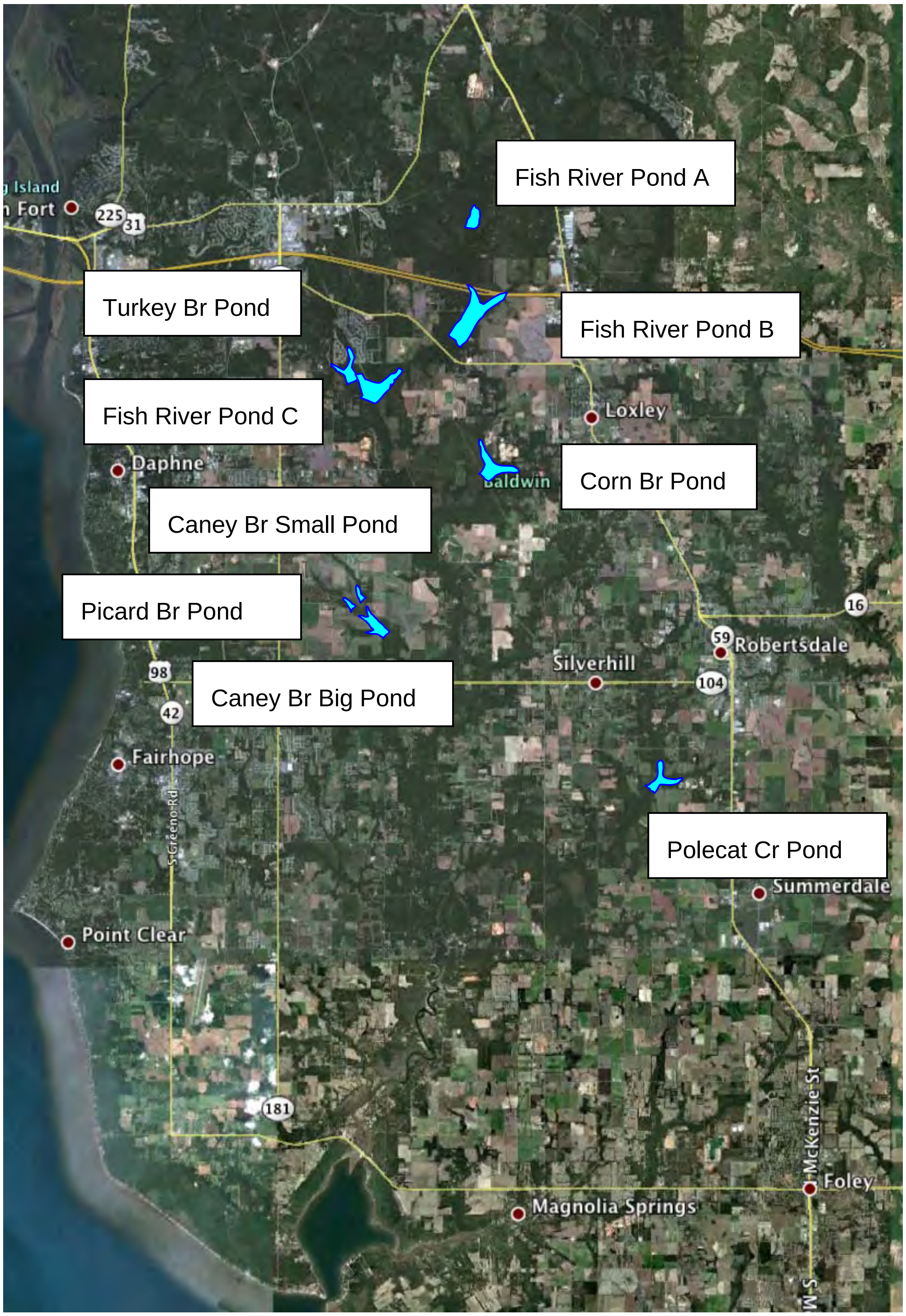


Figure 4-6
Aerial Photograph indicating Pond Locations



4.2. Magnolia River Analysis

The same procedure performed for the Fish River model was used for the Magnolia River model. After the model was calibrated to the T.S. Lee event, a 100-year 24-hour storm with a Type III distribution was used for scenario modeling. The model was run with the calibrated parameters and the discharges were examined at HWY 98 and just above Weeks Bay. There is not any gage information found in *Magnitude and Frequency of Floods in Alabama, 2003 USGS Scientific Investigations Report 2007–5204*; however there is information on the USGS website. The plot in Figure 4-7 indicates there was a peak discharge value of 14,800 cfs on April 6, 2005. According to a publication in 2007 by the Baldwin County Commission – Planning and Zoning Department entitled *Exploring the Baldwin County Flood Zoning Plan and the Benefits of Flood Hazard Mitigation*, "… six to eight inches of rain fell in just 12 hours on April 6, 2005 causing numerous streets to flood and several bridges to be closed. This was part of a larger rain, when 10 to 20 inches of rain fell over eight consecutive days." According to TP 40, 8 inches of rain in 12 hours is a 10-year storm event. However with the addition of the previous rain the soil had been saturated. Depending on the antecedent moisture conditions and rainfall intensity, a 10-year precipitation can possibly produce a discharge upwards of a 25-year to 100-year event. The calibrated model 100-year 24-hour discharge at HWY 98 is 14,680 cfs and just above Weeks Bay is 18,490 cfs.

As with Fish River, different scenarios were performed to see how the watershed reacted to various changes within the basin. The scenarios included development at the headwaters of the watershed, development towards the middle of the basin, and development along Magnolia River from Magnolia Springs to Weeks Bay (Figure 4-8).

The next set of objectives included analyzing possible areas for regional detention. The areas analyzed were on Magnolia River just above CR 65, Magnolia River between HWY 98 and CR 65, and just upstream of CR 24 on a tributary to Magnolia River (Figure 4-9).

Figure 4-7
Magnolia River USGS Gauge – Peak Discharge

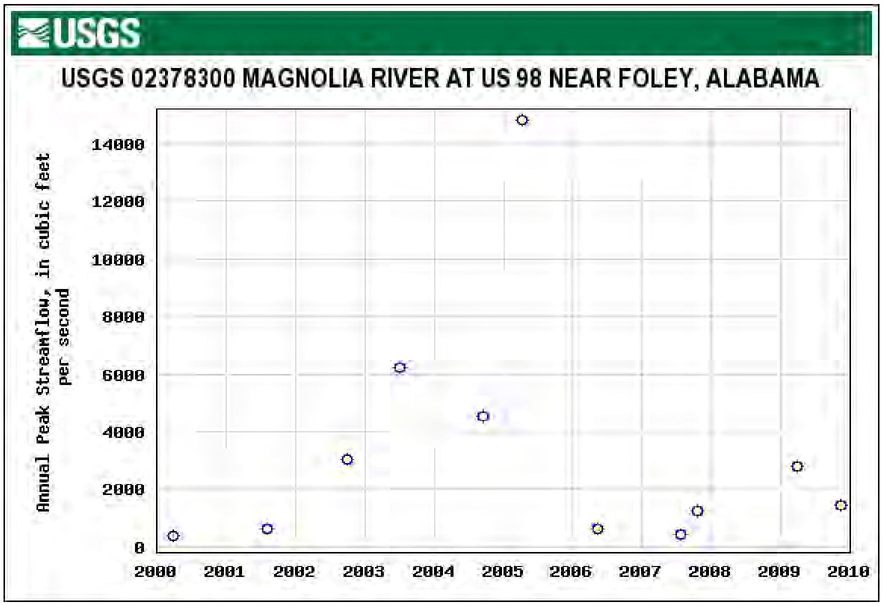


Figure 4-8
Magnolia River Watershed – Developed Areas

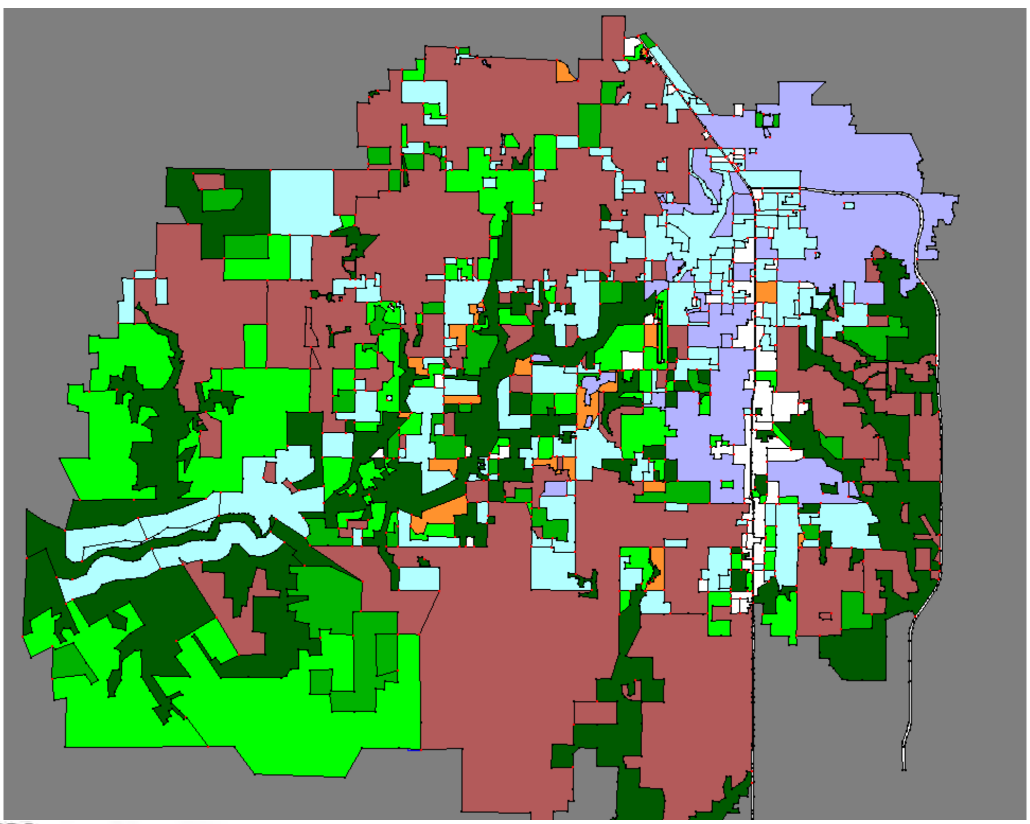
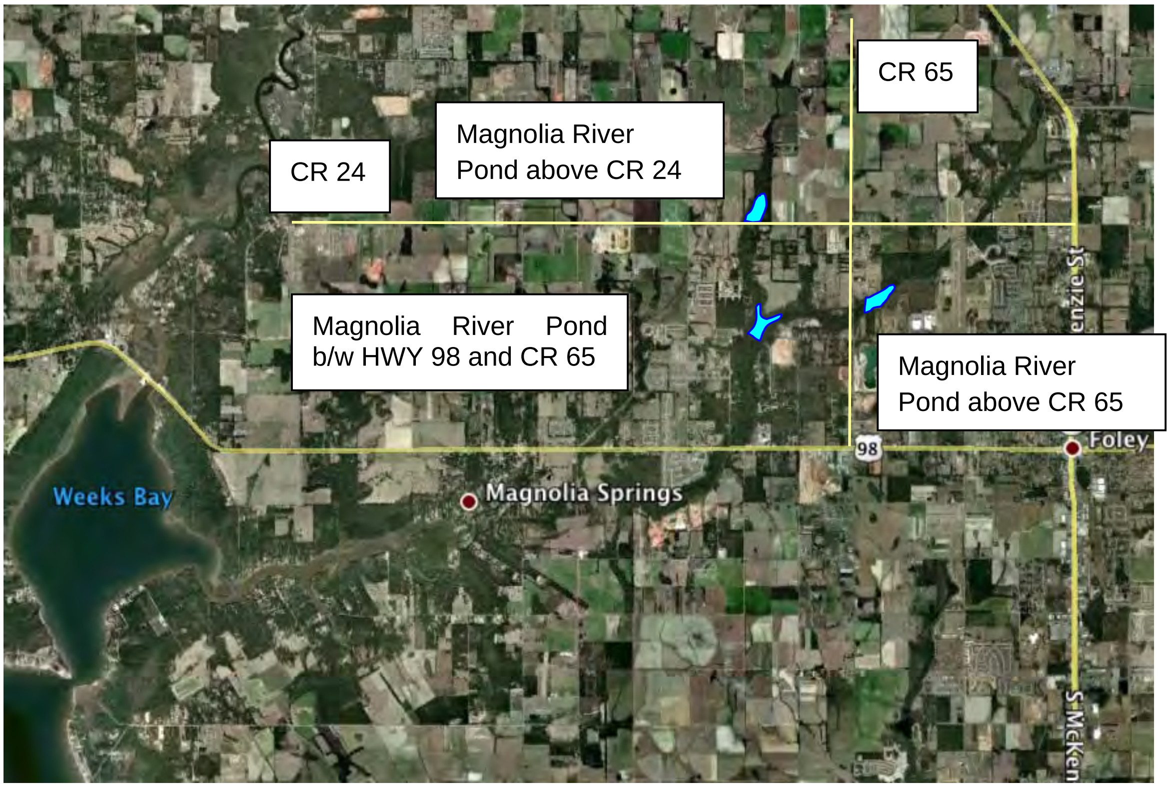


Figure 4-9
Aerial Photograph Indicating Pond Locations



5. Results and Conclusions

5.1. Results

Results from the multiple analyses indicate that the development of each municipality would cause a negative impact to Fish River downstream of where the buildout occurred (Figures 5-1 to 5-6). Also the more northward the development occurs in the watershed, the more impact there is. The most sensitive sub-watershed appears to be the Belforest area watershed. Analysis indicates that addition of regional detention in this area will have a negative impact on Fish River. Due to the location of Fairhope near the bottom of the watershed, development without detention would cause peak discharges to occur earlier. The earlier timing of the Fairhope discharges would not increase the overall discharge at the confluence of Cowpen Creek and Fish River. There is however an increase in the discharge on the local streams and on Cowpen Creek leading to Fish River. The scenario of the undetained stretch of development outside of the floodway on Fish River between CR 32 and HWY 98 indicates that this flow will not cause a negative impact to the overall peak discharge on Fish River.

Results from the multiple analyses of the regional detention ponds indicate that the most effective regional pond placement occurs on Corn Branch downstream of Loxley. This placement has the most impact on the discharges along Fish River. Analysis indicates, however, that if the pond was built with the existing conditions there is a stretch of Fish River that would be negatively impacted. This section is downstream of the confluence of Corn Branch and Fish River down to SR 104. As the flow progresses downstream of SR 104 the discharges start to become lower than the existing conditions discharge due to timing and the addition of extra drainage area. In order to offset the section of the river that would be effected with the addition of the Corn Branch pond, another regional pond would need to be installed downstream of the confluence of Turkey Branch and Fish River. This pond can be designed to handle the smaller more frequent storm events. A pond designed on the smaller events will ultimately have a lower mitigation cost as well as dam and outlet structure cost.

Further analysis of the regional ponds with the addition of development indicates that regional ponds by themselves are not sufficient to handle discharge increases along Fish River. Local detention also needs to be employed in select areas of the watershed. These areas include the area north of CR 64, the headwaters of the Belforest area, and the headwaters of Waterhole Branch. Figure 5-11 indicates the approximate boundary for these areas. Any event in these areas that is not detained will cause an increase to the discharges along Fish River. Results for different buildouts, regional pond locations, and local detention are presented in Table 5-1.

Further considerations should be given to the local streams downstream of the undetained developments. Although the discharges on Fish River will not have a negative impact, there will be increased discharge along the local streams. Consideration should be given to local streams to help guard against in-stream erosion. This may be accomplished using local detention on smaller more frequent events. This will help guard against possible stream degradation that could occur with increased runoff.

Results from the Magnolia River watershed reflect that any undetained development extending from Foley will cause a negative impact to Magnolia River downstream of where the buildout occurred. As undetained development progresses downstream toward the mouth the amount of impact is lessened than with headwater development. See Figures 5-7 to 5-10 for hydrograph plots for different development scenarios. Discharge results for three regional pond scenarios are also included in Table 5-2.

Figure 5-1
Fish River Discharges at SR 104

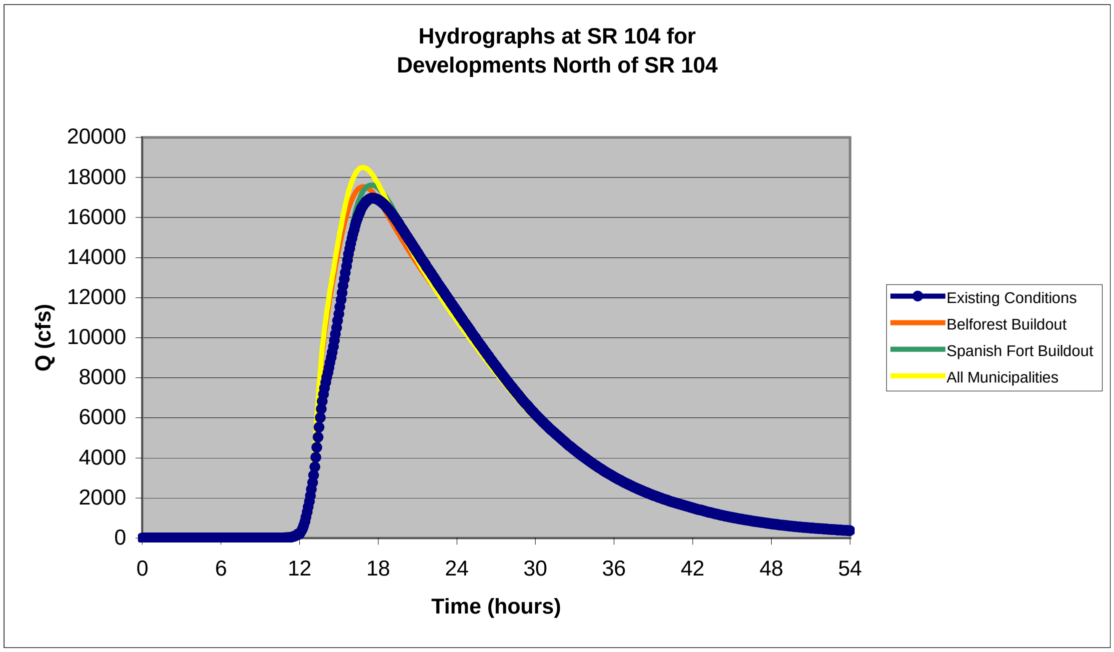


Figure 5-2
Fish River Discharges at SR 104

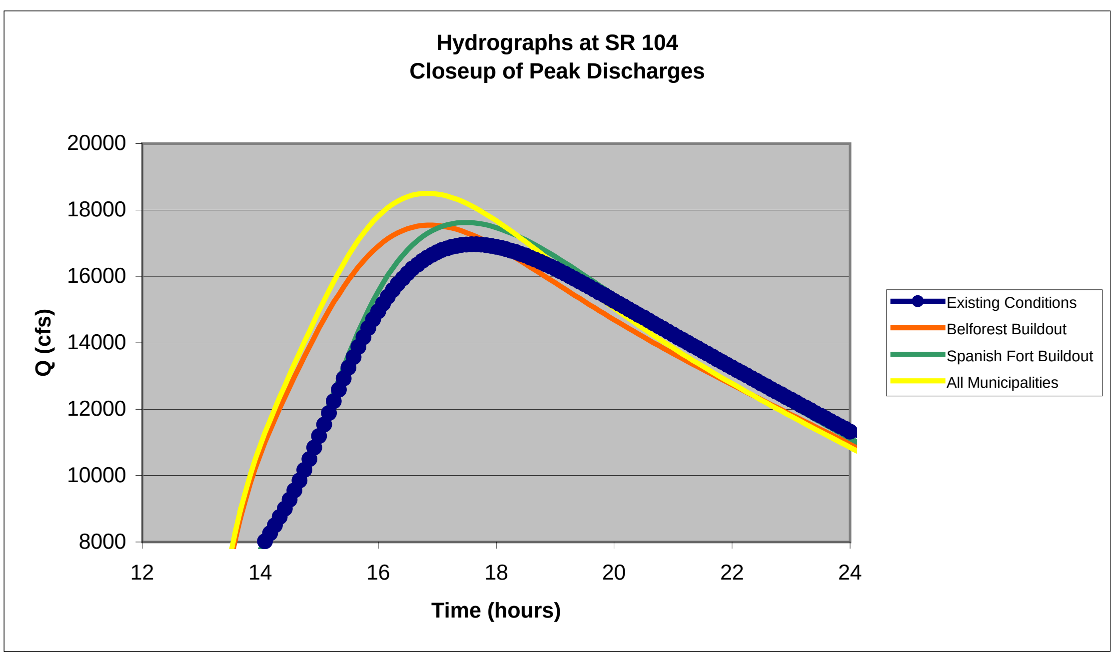


Figure 5-3
Fish River Discharges at CR 48

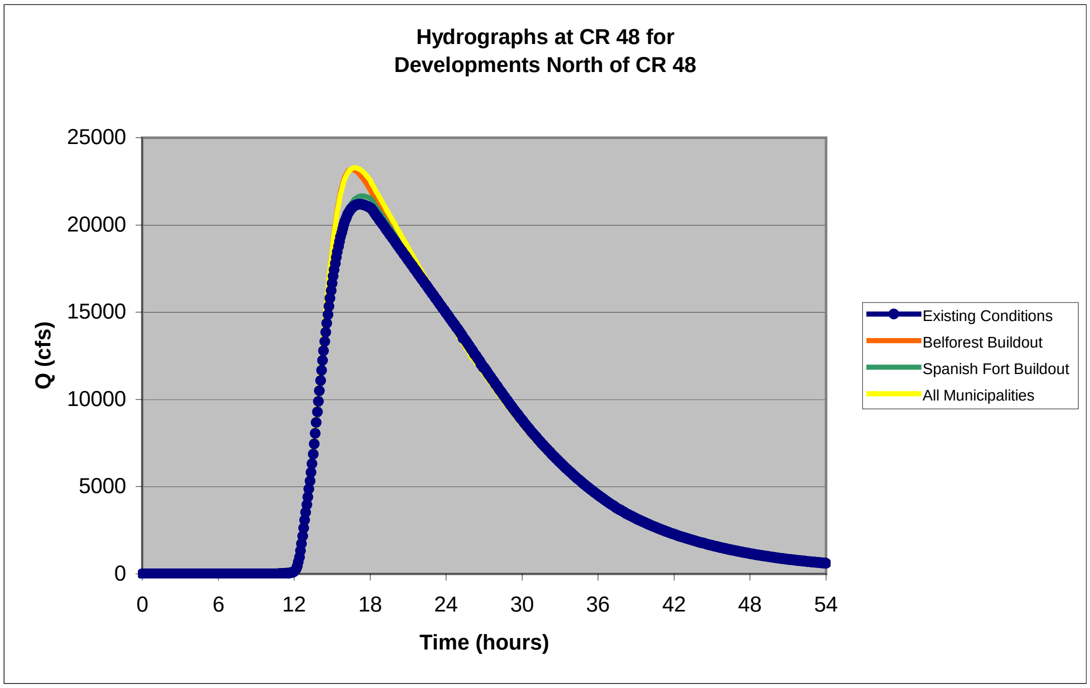


Figure 5-4
Fish River Discharges at CR 48

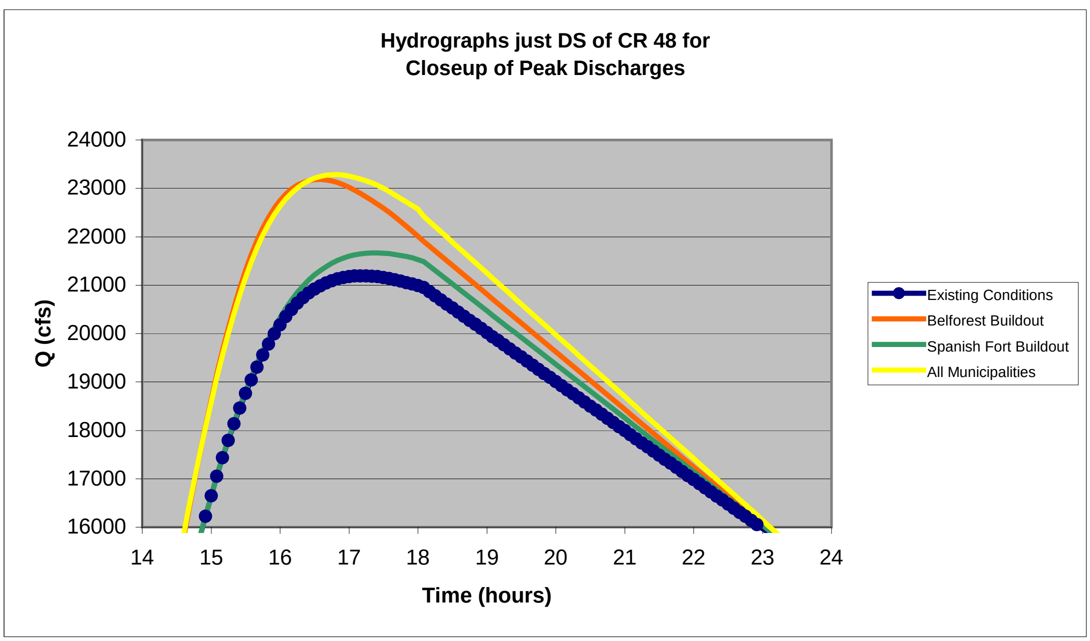


Figure 5-5
Fish River Discharges at Weeks Bay

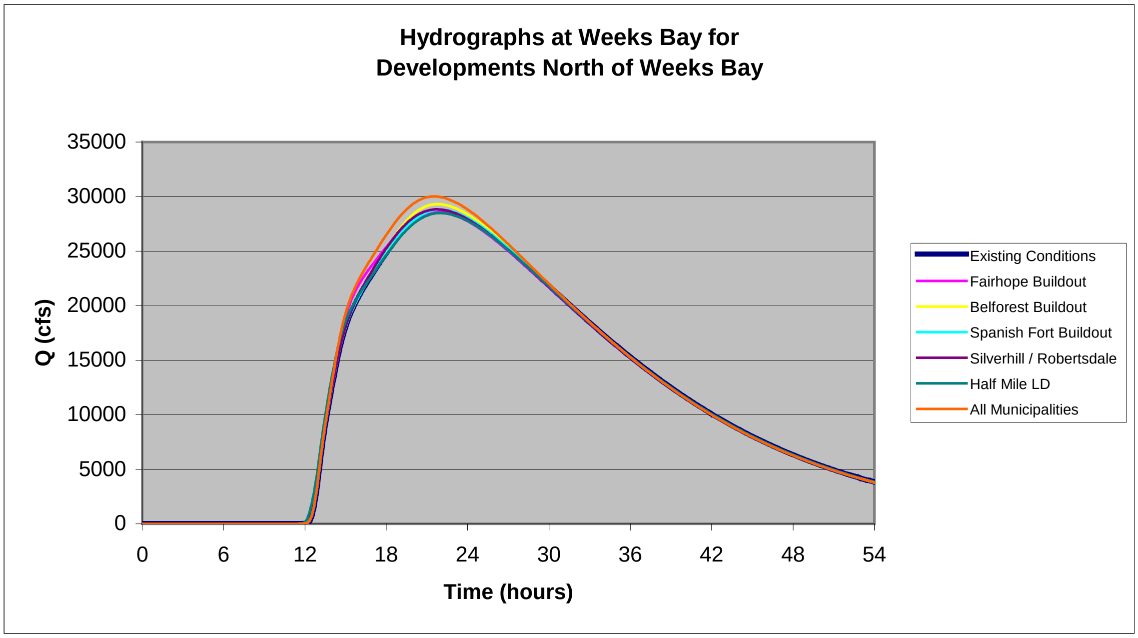


Figure 5-6
Fish River Discharges at Weeks Bay

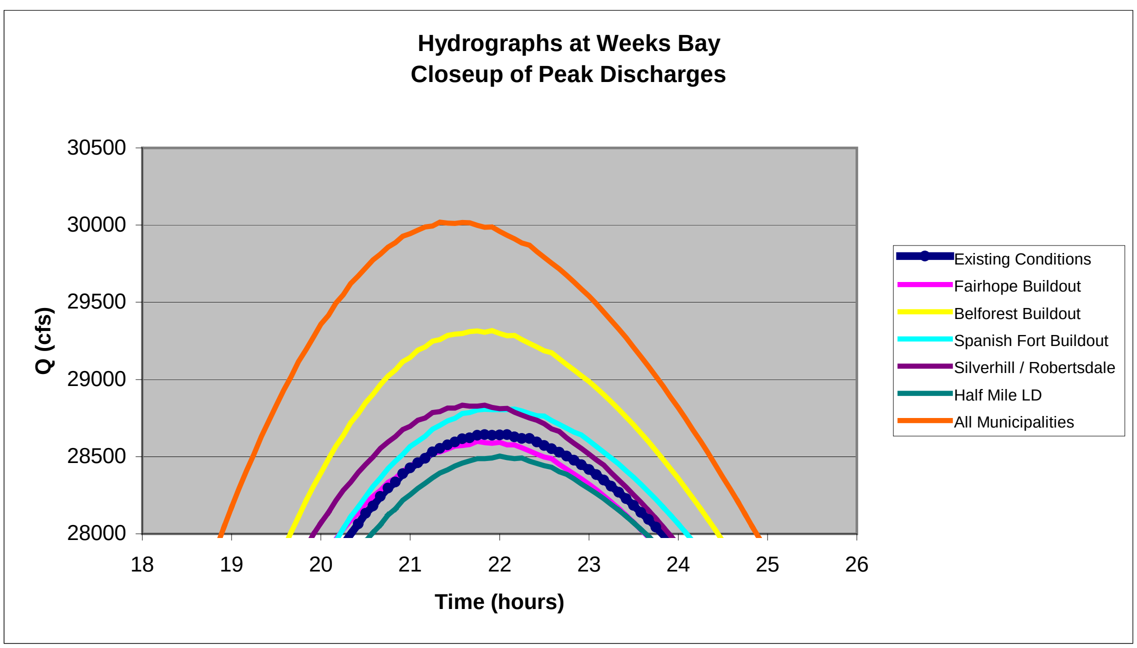


Figure 5-7
Magnolia River Discharges at CR 65

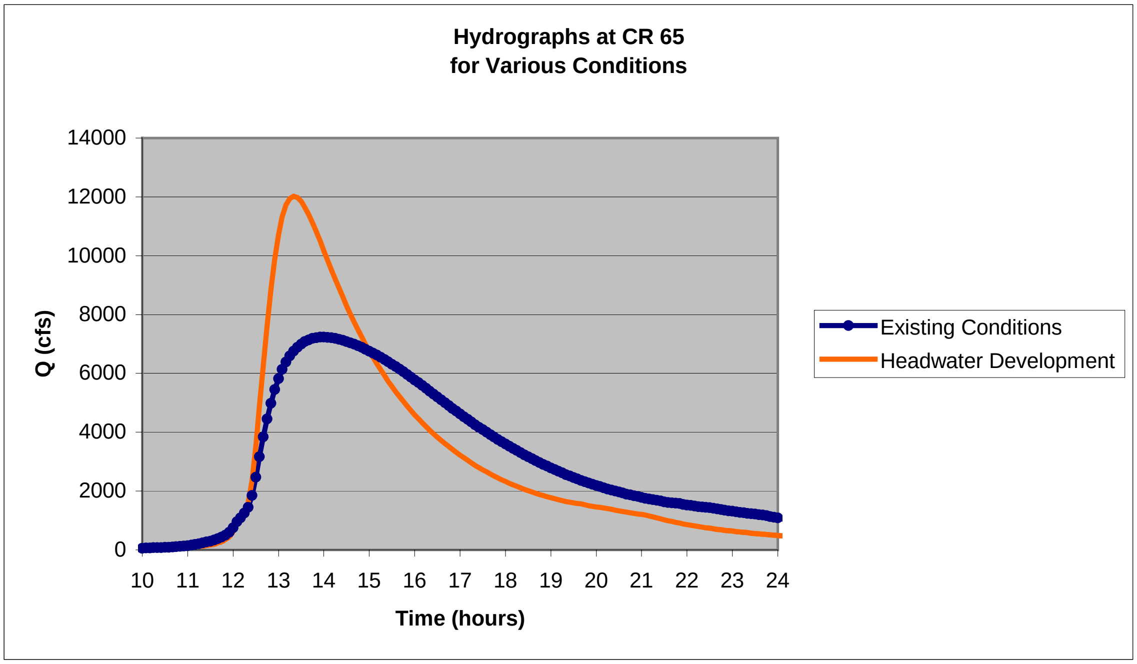


Figure 5-8
Magnolia River Discharges at HWY 98

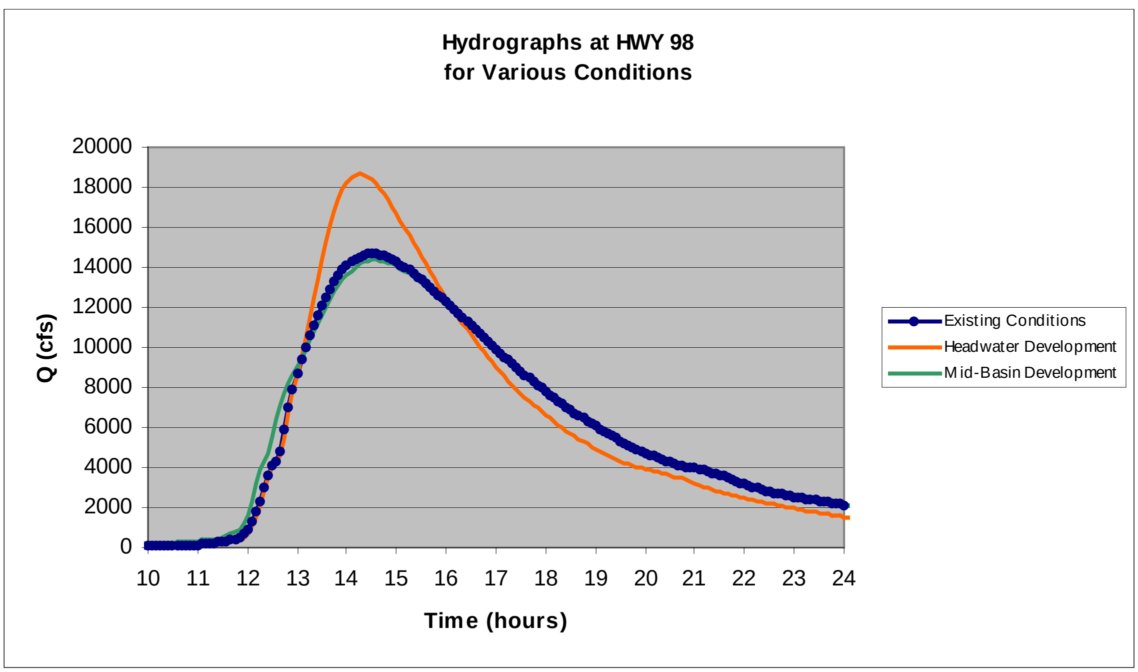


Figure 5-9
Magnolia River Discharges at Weeks Bay

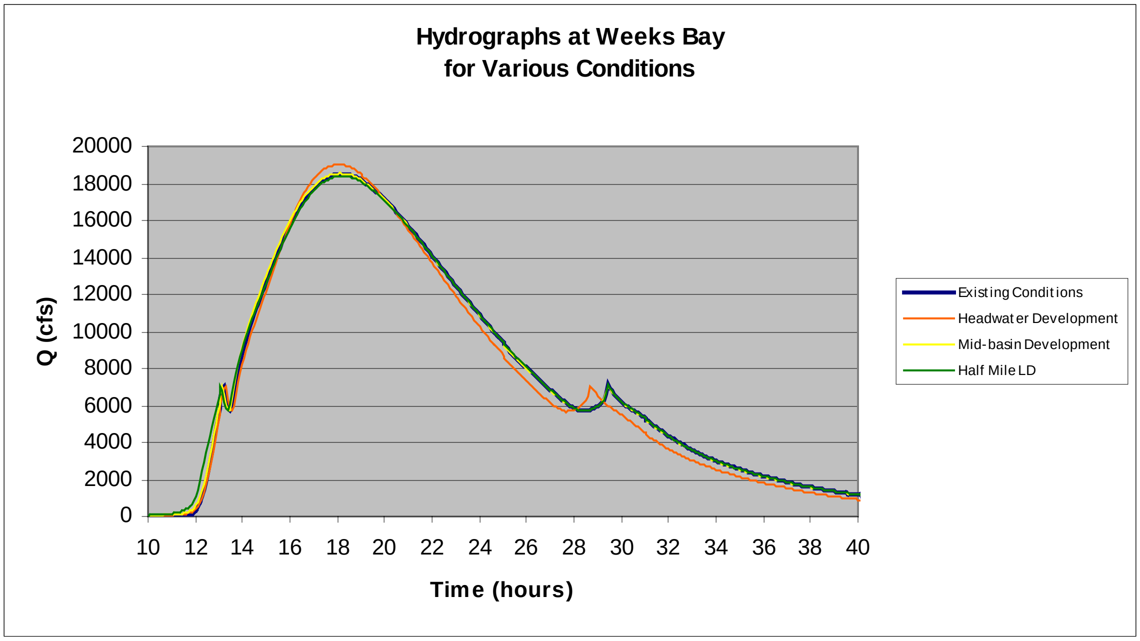


Figure 5-10
Magnolia River Discharges at Weeks Bay

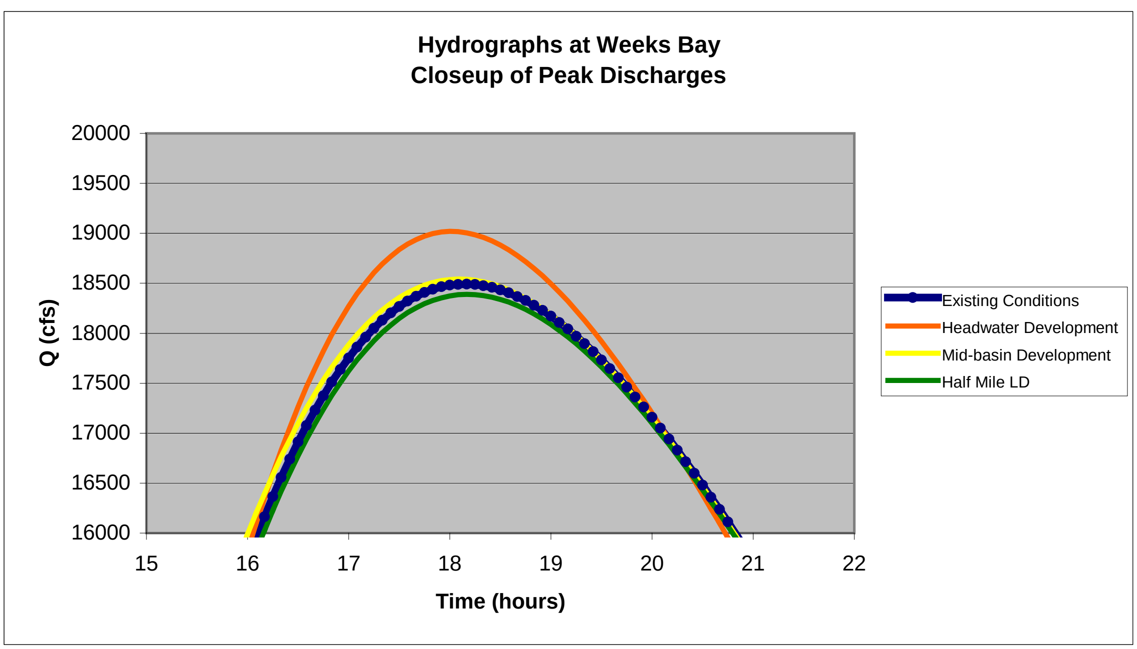


Table 5-1
Fish River Watershed Summary of Discharges

SCENARIO		SR 104	D.S. of CR 48	HWY 98
Existing Conditions		16,960	21,190	28,640
F+B+S/R+SpFt Developed		18,240	23,280	29,620
F+B+S/R+SpFt Developed – Add Fish River Pond B		18,140	23,270	29,540
F+B+S/R+SpFt Developed – Add Corn Branch Pond		17,650	22,100	29,320
F+B+S/R+SpFt Developed – Add Caney Branch Pond		18,500	22,430	29,110
F+B+S/R Developed, SpFt All Local Detention Add Turkey Branch Pond		16,440	22,590	29,220
F+B+S/R+L Developed F+B Headwater Detention SpFt All Local Detention		17,050	22,060	29,000
F+B+S/R+L Developed F+B Headwater Detention SpFt All Local Detention Add Corn Br Pond		16,690	20,880	28,700

F = Fairhope Area B = Belforest Area S/R = Silverhill/Robertsdale Area SpFt = Spanish Fort
L = Area along Fish River below CR 32 and above HWY 98

Table 5-2
Magnolia River Watershed Summary of Discharges

SCENARIO		CR 65	HWY 98	Weeks Bay
Existing Conditions		7,230	14,680	18,490
Existing Conditions – Add Pond above CR 65		7,000	14,510	18,440
Existing Conditions – Add Pond b/w HWY 98 & CR 65		7,230	14,160	17,920
Existing Conditions – Add Pond above CR 24		7,230	14,230	18,180

5.2. Conclusions

The Fish River watershed is a large and complex drainage system. Based on the results, it has been determined that the development of the more northern areas, the Belforest and Spanish Fort areas, have a greater impact to the discharges on Fish River than for the Fairhope and Silverhill/Robertsdale areas. The most sensitive basin is the Belforest sub-watershed that is located in the upper to middle portion of the basin.

Results also indicate that the most effective areas for regional ponds are on Corn Branch below Loxley and on Fish River below the confluence with Turkey Branch (Corn Branch Pond and Fish River Pond C). A regional pond on Caney Branch below the confluence with Picard Branch would help reduce peak discharge increases from Belforest, however the timing of the routed hydrograph would have a negative impact to the Fish River discharges.

It has been determined that development within a half mile outside of the floodway below CR 32 can be performed without any detention. 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.

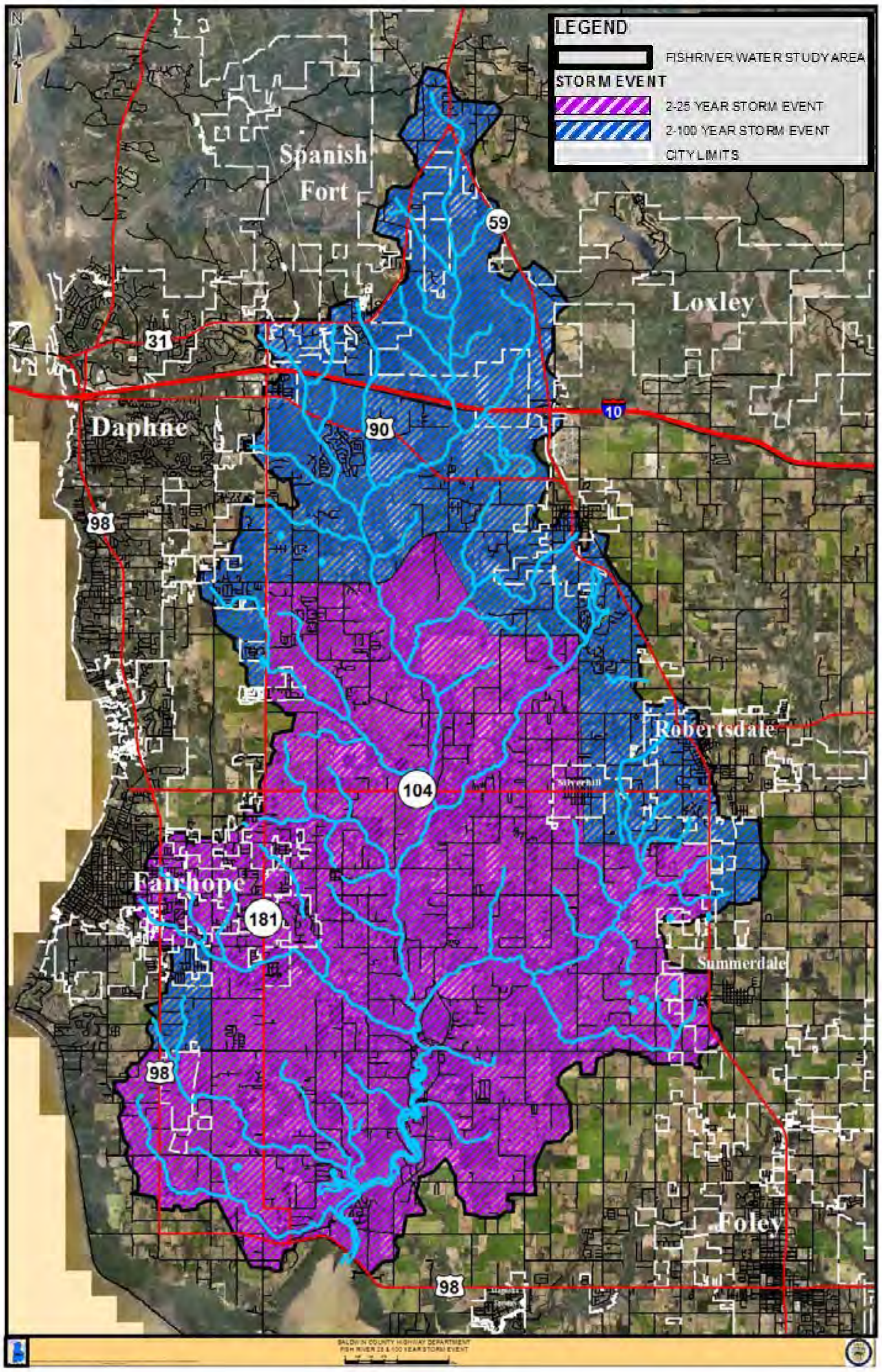
Based upon a conservative scenario in which all municipalities have been built out and development has occurred within a half mile of the floodway downstream the following items would be needed in order to have post development match pre development discharges on Fish River. The regional pond on Corn Branch would need to be designed and installed to detain the 100-year event. Fish River Pond C would need to be installed to offset the stretch of Fish River that is impacted by the installation of the Corn Branch pond. This pond only needs to be designed on the lower bank forming events. All flood events, including the 100-year, must be detained locally for the properties located basically above CR 64 (Figure 5-11). All flood events would need to also be detained in the headwaters of the Belforest area above any current development. Also all flood events would need to be detained in the headwaters of Waterhole Branch. This is just one solution to a very conservative scenario. These measures may not be essential initially, but should be based on how the actual development occurs in the watershed. The calibrated GSSHA model can therefore be used as a dynamic management tool in which to analyze future developments. Outside analysis at a smaller sub-basin level can also be performed and reintroduced into the model to determine possible impacts.

The Magnolia River watershed lacks the size of the Fish River watershed but is still very complex. Development already occurs at the uppermost portion of the drainage basin. As seen in the results section, location of development in the headwaters increases discharges along the main stream. However development 0.5 miles outside of the floodway from Magnolia Springs to Weeks Bay does not indicate an increase in discharge along Magnolia River. As mentioned above, analysis must be performed to ensure undetained properties do not cause increased flooding on adjacent property owners.

The three regional ponds analyzed at different locations appear to have minimal impact to discharges for the existing conditions. Due to surrounding subdivisions and properties and the concern of increased flooding on property owners, the allowable dam height is somewhat restricted. These lower dams do not allow for enough storage volume to be obtained for significant routing of peak discharges. These ponds would therefore be ineffective for detaining any future developments.

As mentioned in the Fish River conclusions, actual development within the Magnolia River can vary from the analyzed scenarios presented. The calibrated GSSHA model can be used as a dynamic management tool in which to analyze future developments within the Magnolia River basin also. Outside analysis at a smaller sub-basin level can also be performed and reintroduced into the model to determine possible impacts.

Figure 5-11
Areas Requiring All Event Detention



CONSTRUCTED WETLANDS

According to ADEM's 303(d) list dated April 2010, the Fish River has been designated as impaired due to pathogens and metals (mercury). The proposed regional detention facilities can assist in improving water quality by incorporating a constructed wetland into the design. Properly constructed and maintained, a constructed wetland can reduce the impacts of pathogens and metals on the Fish River. To achieve measurable water quality benefits from nonpoint source reduction efforts, it is usually necessary to apply BMPs across a substantial portion of a watershed. These ponds in conjunction with other BMPs (to be developed in the future) can play a significant role in minimizing pollutant loadings and restoring Fish River back to its water use designation.

The size of the proposed Fish River Pond C is 77 acres and would extend north up both branches of the confluence at Fish River (Figure 6-1). The size of the proposed Corn Branch Pond is 65 acres and would extend northeast toward Loxley (Figure 6-1).

Sampled data from 2003 was obtained from Alabama Water Watch for a location on Corn Branch. The data suggests that during a heavy rain event there was a significant concentration of pathogens detected. Current literature Jou et al. (2008) shows that a constructed wetland can remove approximately 43% BOD, 64% suspended solids, and 11% ammonia nitrogen. Therefore, a constructed wetland is a very viable BMP that can be used to restore a creek that has been polluted by organic discharges from animal husbandry activities in the watershed back to its intended water use classification.

Figure 6-1
Location of Proposed Ponds in Fish River Watershed

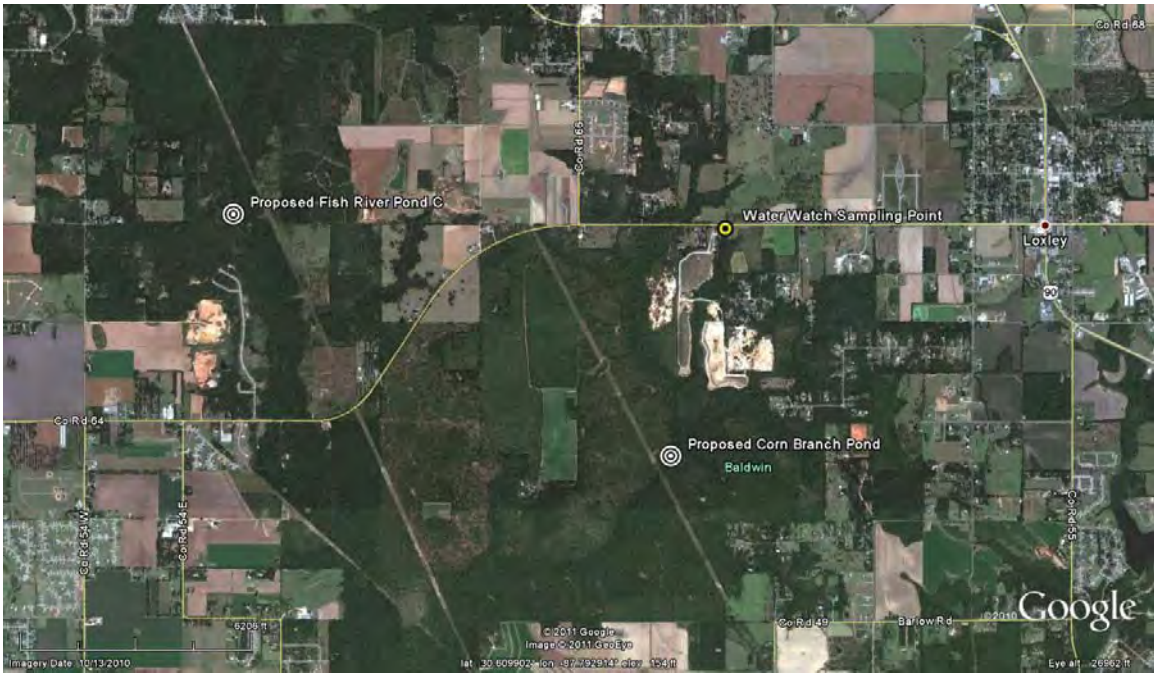


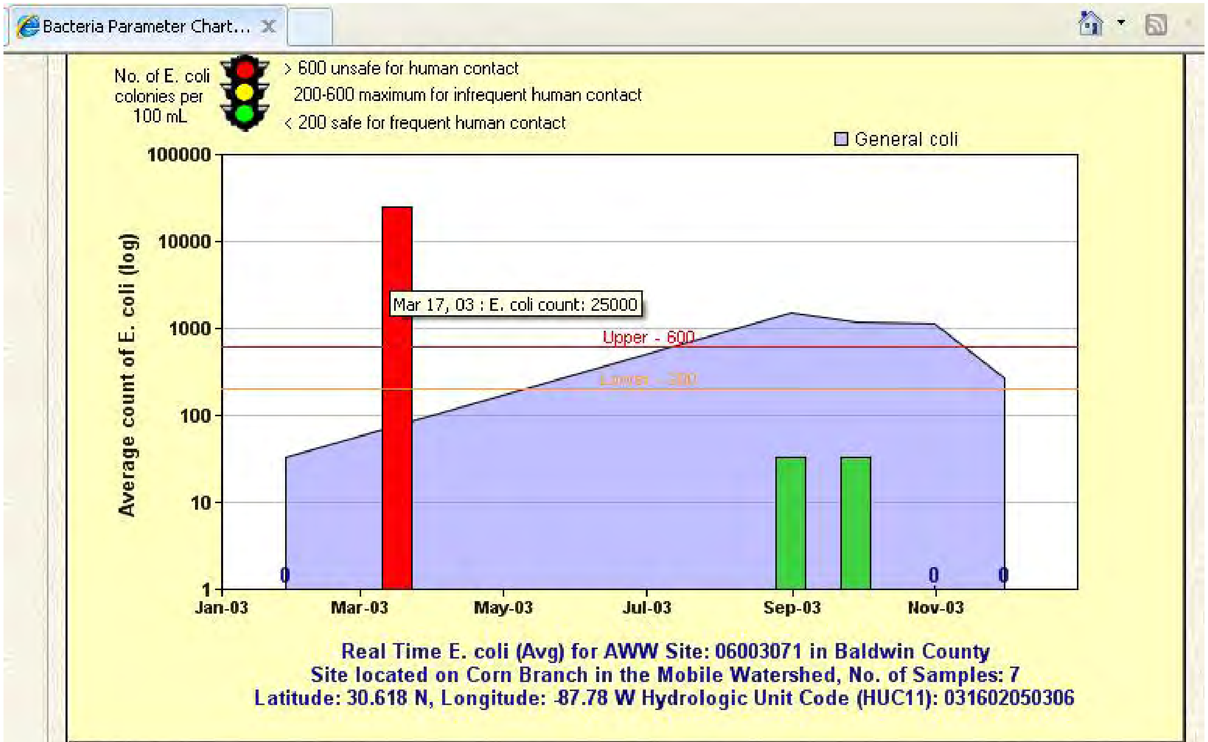
Figure 6-2
Sampled Data on Corn Branch

Sample Date	Access	Tides	Air Temp	Water Temp	pH	DO1	DO2	Hard Drops	Alk Drops	Turb 1	Turb 2	Secchi	Comments
18-Mar-02	1	99	25	21	5.5	1.8	1.4	3	8	3	-	-	very slow flow, a great deal of algea (new site)
1-Apr-02	1	99	24	20	6	0.4	0.4	3	8	4	-	-	turbid, trashy, slow flow. Minimum color change upon MgSO4 and AlkPotI azide addition in DO test.
13-May-02	1	99	29	24	6.5	0.6	0.6	6	20	1	-	-	water thick with macroinverts: daphnids, etc. no visable flow
23-May-02	1	99	22	17	6.5	0.6	0.6	10	28	3	-	-	took sample downstream of culvert. No flow upstream of culvert
12-Jun-02	1	99	32	24	6.5	2	2	11	31	3	-	-	sampled downstream of culvert, no flow through culvert, greeted by 3ft cottonmouth
29-Jun-02	1	99	32	25	5.5	1	1.2	4	6	3	-	-	NA
15-Jul-02	1	99	28	25	6.5	0.4	0.4	7	20	4	-	-	no flow, sampled downstream of culvect, ponded. No color change upon starch add.
23-Jul-02	1	99	27	25	6.5	0.4	0.4	6	21	5	-	-	no flow, sampled downstream ponded
14-Aug-02	1	99	29	25	6.5	6.4	6.4	7	20	7	-	-	no downstream sampling, D.O. detected.
26-Aug-02	1	99	27	25	6.5	6.4	6.4	8	25	4	-	-	sampling downstream of culvent; ponded; surface layer.
17-Sep-02	1	99	28	25	6.5	0.4	0.4	10	23	2	-	-	ponded, sampled down stream of culvent.
6-Oct-02	1	99	29	26	6.5	1.8	1.8	4	9	3	-	-	flow under culvent.
14-Oct-02	1	99	21	22	6	0.6	0.6	4	11	5	-	-	above normal stage but still little flow. Light rain this am.
8-Nov-02	1	99	19	16	6.5	5.4	5.8	5	7	1	-	-	entered online
18-Dec-02	1	99	19	13	6	2.8	2.4	3	6	2	-	-	Flow under culvert, upstream sample. Entered online.
30-Dec-02	1	99	18	12	6	3.4	3.8	3	5	1	-	-	entered online
15-Jan-03	1	99	6	9	6	1.4	1.8	3	6	1	-	-	entered online
28-Jan-03	1	99	13	11	5.5	1	1.4	3	6	1	-	-	upstream sample
23-Feb-03	1	99	13	14	6	6	6.4	3	5	7	-	-	Heavy rain 48 hr prior to sampling. Flow under culvert, upstream sample.
17-Mar-03	1	99	19	18	6.5	6.8	6.4	2	6	-	-	-	Water so turbid could not see black dot in tube even at 25 ml; no turbidity recorded. Heavy rain night before sampling.
31-Aug-03	1	99	30	26	6	3.8	3.8	3	7	3	-	-	No Comments for this Sampling event
28-Sep-03	1	99	25	24	6	2	2	3	6	3	-	-	No Comments for this Sampling event
31-Oct-03	1	99	24	20	6.5	1.2	1.4	4	5	4	-	-	No Comments for this Sampling event

Figure 6-3
Sampled Data on Corn Branch

Sample Date	Access	Water Temp	Samp Vol	Incub Temnp	Inc Time	Inc Per	Ecoli 1	Ecoli 2	Ecoli 3	Gcoli 1	Gcoli 2	Gcoli 3	Ice	Method	Comments
18-Mar-02	99	21	1	37		40	0	0	1	39	25	6	-	2	-Old blue green were: 0, 0, 0
23 May 2002	99	17	1	37		40	5	3	4	10	9	4	-	2	-Old blue green were: 0, 1, 0
29 Jun 2002	99	25	1	37		40	1	1	3	250	250	250	-	2	Ecoli/100ml = 0; 0; 0;-Old blue green were: 0, 0, 0
23 Jul 2002	99	25	1	37		43	0	1	1	45	38	38	-	2	culvent, sampled downstream, ponded.-
26 Aug 2002	99	25	1	37		42	0	1	0	49	49	46	-	2	Old blue green were: 0, 0, 0
06 Oct 2002	99	26	1	37		40	1	0	0	22	20	17	-	2	-Old blue green were: 0, 0, 0
30 Dec 2002	1	12	1	35		48	0	0	0	1	2	1	1	0	unusual white colonies: 50-100 per plate.
28 Jan 2003	1	11	2	36	13:30	48	0	0	0	0	0	2	1	1	NA
17 Mar 2003	1	18	1	36	14:00	48	250	250	250	-	-	-	1	1	E. coli. Heavy rains night before sampling.
31 Aug 2003	1	26	1	36		48	0	0	1	9	22	14	2	2	Description:,at CR 64 upstrm of culvert
28 Sep 2003	1	24	1	37		48	0	1	0	12	15	9	2	2	Description:,at CR 64 upstrm of culvert
31 Oct 2003	1	24	1	37		46	0	0	0	14	9	11	2	2	Description:,at CR 64 upstrm of culvert
30 Nov 2003	1	12	2	36		41	0	0	0	4	5	7	2	2	Description:,at CR 64 upstrm of culvert :Altered

Figure 6-4
E. coli Data for Corn Branch



Sample Date	Air (°C)	Water (°C)	Vol (mL)	Incub (°C)	Incub (hrs)	E. coli (Rep1)	E. coli (Rep2)	E. coli (Rep3)	Gencoli (Rep1)	Gencoli (Rep2)	Gencoli (Rep3)	Monitors
28 Jan 2003		11.0	2	36.0	48.0	0	0	0	0	0	2	Mike Shelton
17 Mar 2003		18.0	1	36.0	48.0	250	250	250				Mike Shelton
31 Aug 2003		26.0	1	36.0	48.0	0	0	1	9	22	14	Mike Shelton
28 Sep 2003		24.0	1	37.0	48.0	0	1	0	12	15	9	Mike Shelton
31 Oct 2003		24.0	1	37.0	46.0	0	0	0	14	9	11	Mike Shelton
30 Nov 2003		12.0	2	36.0	41.0	0	0	0	4	5	7	Mike Shelton

Chart Bacteria for the Year: 2003

Note that a "0" indicates that a monitor took a sample but reported "0" counts. A null indicates that no sample was taken.

7. References

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